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State of email security implementations in Finnish municipalities and joint municipal authorities in 2021

Research on current DNS implementations and organizations' publicly available information

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Description

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Abstract

Finnish municipalities and joint municipal authorities form the administrative structure for local and regional governance in Finland. Municipal organizations represent the largest part of public sector authorities measured by the number of organizations and employees. Therefore, amongst national authorities, municipal organizations also have the broadest Intenet presence and footprint regarding various technical implementations and possible vulnerabilities or risks. One of the most used Internet services is email and one of the most common abuses of email is domain related forgery. Previous studies from 2019-2020 conclude general consensus regarding safe implementation for email. Public sector has significantly lower safe implementation rates than others in the .fi zone or their foreign counterparts. Deeper understanding regarding lack of safe implementations in municipal organizations was needed to better address this deficiency. Simple and efficient instructions on how to deploy nationally recommended best practice guidelines were needed for situation improvement.

The study was executed as a documentary analysis, researching published statistical information regarding municipalities and joint municipal authorities combined and compared to the actual email related configurations of DNS records present in the domains of these municipal organizations. The implementations of SPF and DMARC, along with DNSSEC, HINFO and other technical controls were classified based on definitions in industry standard RFC documents. Criteria for evaluation was set to gain information about possible variations between organizations based on organizational type, field of authority, regional location, size and lingual status. Organizations' dependencies on other organizations and third parties were also examined.

The general status of email related DNS security implementations in municipalities and joint municipal authorities in spring 2021 was clarified. As municipal organizations prepare for the upcoming reform of health, social and emergency services and the transformation to new welfare regions as responsible authorities, paying attention to the status and security related to these technical solutions is ever more current. Large cities around the country were found the most significant in nation wide resilience. The overall status was found to be inadequate, confirming the findings in previous studies. Educational authorities and Swedish lingual minorities were found to have more comprehensive implementation rates than other groups, although still under recommendations. Migrating to cloud-based email services was found to have positive effect on implementing secure configurations. Securing all non-email domains was found to be a significant measure easily applicable. Recommendations were drafted on how municipalities should follow the given guidelines and common best practices regarding email related security and safety.

Keywords/tags (subjects)

Community, town, city, region, Finland, RFC, DNS, DNSSEC, SPF, DKIM, DMARC, statistics, recommendation

Miscellaneous (Confidential information)

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Kuvailulehti

Matti Turunen

Sähköpostin turvallisuusasetukset Suomen kunnissa ja kuntayhtymissä 2021
- Tutkimus käytössä olevien DNS-määritysten tilasta ja julkisesti saatavista organisaatioiden tiedoista

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Verkkojulkaisulupa myönnetty: Kyllä
Julkaisun kieli: englanti

Tiivistelmä

Suomessa kunnat ja kuntayhtymät muodostavat paikallisen ja alueellisen julkisen hallinnon rakenteet. Kuntaorganisaatiot muodostavat suurimman osuuden julkisesta hallinnosta organisaatioiden tai henkilöstön määrällä mitattuna. Tämän johdosta kuntaorganisaatioilla on myös julkishallinnon laajin kattavuus ja jalanjälki erilaisisten teknisten ratkaisujen sekä niihin liittyvien mahdollisten haavoittuvuuksien ja riskien osalta. Yksi käytetyimmistä internetpalveluista on sähköposti, ja yksi yleisimmistä väärinkäytöistä kohdistuu sähköpostiväärennöksiin. Aiemmat selvitykset vuosilta 2019–2020 osoittavat päätelmissään yleisesti hyväksytyt turvallisten sähköpostiasetusten määritelmät ja asetukset. Selvitysten mukaan julkishallinnossa on turvallisia menetelmiä hyödynnetty merkittävästi vähemmän kuin muilla toimialoilla tai vastaavissa ulkomaisissa organisaatioissa. Tarvittiin syvällisempää ymmärrystä siitä, miksi asetukset ovat kuntaorganisaatiossa puuttelisia ja miten nykytilaa voisi parantaa. Yksinkertaisia ja tehokkaita ohjeita, kuinka ottaa käyttöön kansallisesti suositellut parhaat käytännöt tilanteen parantamiseksi.

Tutkimus perustui dokumentaariseen analyysiin ja kvalitatiiviseen tutkimusmenetelmään, jossa tarkasteltiin kunnista ja kuntayhtymistä julkisesti saatavilla olevaa tilastollista tietoa verrattuna tosiasiallisiin teknisiin sähköpostiin liittyviin DNS-nimipalveluiden julkisiin asetuksiin. SPF ja DMARC sekä DNSSEC ja HINFO ynnä muut tekniset asetuskontrollit luokiteltiin toimialan RFC-standardien dokumentaation mukaisesti. Vertailun kriteerit määriteltiin niin, että kyetään selvittämään eroavaisuuksia organisaatiossa niiden tyypin, hallinnonalan, alueellisen sijainnin, koon sekä kielisyyden perusteella. Myös organisaatioiden riippuvuuksia muista organisaatioista ja kolmansista osapuolista tarkasteltiin.

Yleinen tilanne sähköpostiin liittyvien DNS-asetusten tietoturvallisuuden osalta kunnissa ja kuntayhtymissä selvitettiin kevään 2021 tilanteessa. Kuntaorganisaatioiden valmistautuessa tulevaan sosiaali-, terveys- ja pelastuspalveluiden reformiin ja muutokseen kohti uusia hyvinvointialueita vastuuviranomaisina, huomion kiinnittäminen näidän teknisten ratkaisujen tilaan ja turvallisuuteen on erityisen ajankohtaista. Suurimpien kaupunkien maan laajuisesti todettiin olevan merkityksellisimpiä kansallisen sietokyvyn kannalta. Yleisesti tilanne suojausten osalta todettiin olevan riittämätön, mikä vahvisti aiempien tutkimusten tuloksia. Koulutus- ja sivistystoimen viranomaisorganisaatioiden sekä ruotsin kieltä ensisijaisesti käyttävien vähemmistöjen todettiin omaavan kattavammat suojatoimet muihin ryhmiin verrattuna, vaikkakin silti alittavan suositukset. Siirtyminen pilvipalveluihin sähköpostin osalta havaittiin vaikuttavan positiivisesti turvallisten asetusten käyttöönottoon. Kaikkien sellaisten verkkotunnusten suojaaminen, joita ei käytetä eikä ole tarkoitettukaan sähköpostikäyttöön, havaittiin olevan merkittävä parannus, joka on helposti saavutettavissa laajasti. Suositukset laadittiin siitä, kuinka kuntien tulisi noudattaa ja toteuttaa annettuja ohjeistuksia ja parhaita käytäntöjä sähköpostipalveluiden tietoturvallisuuden ja suojaamisen parantamiseksi.

Avainsanat (asiasanat)

Kunta, kaupunki, Suomi, RFC, DNS, DNSSEC, SPF, DKIM, DMARC, tilasto, suositus

Muut tiedot (salassapidettävät liitteet)

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Acronyms

BIND	Berkeley Internet Name Daemon, an open source software that implements the DNS protocols for the Internet
CURL	Client URL Request Library, a tool for getting or sending data using URL syntax
DKIM	DomainKeys Identified Mail
DMARC	Domain Message Authentication Reporting
DNS	Domain Name System
DNSKEY	Resource records where DNSSEC cryptography public keys are stored
DNSSEC	Domain Name System Security Extensions
HINFO	Host Information record of host-specific data that can be used by application protocols
IETF	Internet Engineering Task Force
ISP	Internet Service Provider
MDA	Mail Delivery Agent
MHS	Mail Handling Service
MTA	Mail Transfer Agent
MUA	Mail User Agent
NCSC	National Cyber Security Centre (NCSC-FI, National Cyber Security Centre – Finland)
NUTS	Nomenclature of Territorial Units for Statistics
O365	Microsoft Office 365 (O365/M365) is a Software as a Service (SaaS) solution that includes Microsoft Office and other services, such as email
RFC	Request for Comments, a proposed standard
RR	Resource Record
RRSIG	Cryptographic signature record
RRset	DNS resource record set
SMTP	Simple Mail Transfer Protocol
SPF	Sender Policy Framework
(cc)TLD	(country code) Top Level Domain, such as .fi or .ax
TLS	Transport Layer Security, formerly known as Secure Sockets Layer (SSL)

1 Introduction

Email remains as one of the most used communication methods in organizations and our society in general. The number of messages and the importance of email is high and obvious. As new digital communication mechanisms arise and gain popularity, email is being used as a means for official communication. Email is also one of the primary means of communication for Finnish municipalities, towns and cities as well as for joint municipal authorities, regional councils, health care districts, in-house companies and other organizations of communities' own or have interest in. Communities and their interest organizations are also required by legislation to maintain and offer public email address for official use at their registry office, as well as easy communication to their officials. No signs of decrease regarding the usage of email are in sight.

Email is used for a significant amount communication regarding business relations and other critical communication. As such, criminals use email-based attacks as one of the preferred methods of attacks. Impersonation leading to financial fraud, credential compromise and malicious document delivery are prime examples of email attack types. In order to combat these phenomena, several sources define proper implementation of domain protection to be one of the basic aspects for building and maintaining efficient cybersecurity defences (Kontinen 2020).

Recent system intrusions consist of more complex attacks, typically involving numerous steps. 70% of these attacks involve malware, usually the ransomware variety. Hacking appears in 40% of attacks and most often it consists of the use of stolen credentials or brute force attacks. 23% of the malware was sent by email and 30% directly installed by the actor. This highlights the importance of having a robust defense to cover the major entry paths for malware. Business email compromises / email account compromises (BECs/EACs), and other data breach incidents trend more towards victimizing organizations and less on targeting a single individual. As social attacks continue to compromise people, we begin to see the domination of phishing emails and websites delivering malware used for fraud or espionage. Social engineering incidents have a social action, mostly delivered by email. Breaches are moving toward social and webapp vectors and becoming more server-based, such as gathering credentials and using them against cloud-based email systems. BECs were the second most common form of social engineering (Verizon 2021).

The commissioner for this study was Kuntien Tiera Oy (Tiera). Tiera is an in-house company, owned by 355 Finnish communities and joint municipal authorities. Tiera is also a Finnish social enterprise. As a nationwide company, owned by municipal organizations, Tiera offers high quality productized ICT services and digital solutions for its owner-customers and their residents nationally. The delivered services cover most of the population in Finland, over 4.4 Million residents in the network of communities. Tiera develops its services to municipalities, towns, cities and regions together with its owner-customers and public and private organizations in a network of partners. The company is a trusted advisor, whose operations are based on unique municipal and regional knowledge as well as understanding its owner-customers operational needs regarding various ICT-solutions. Aiming to produce direct effective benefits by helping municipalities in developing their operations (Kuntien Tiera Oy 2021).

Tiera's national outsourcing services mission and purpose is to support and enhance its owner-customers basic IT-infrastructure and digitalization. A key factor in achieving that is the continuous development of information security and privacy aspects as well as instructing and applying necessary security controls (Skog 2020). These services also cover a variety of email related customer specific technical solutions and national Tiera Office (Tiera Toimisto) products delivering email and secured email to communities. As a social enterprise, Tiera promotes the study, research and development regarding municipalities as well as the whole Finnish society.

2 Research scope and methods

2.1 Scope of research

During 2019 NCSC-FI established an internal project where various aspects of network presence of certain parties is mapped out. As email is probably one of the most common electronical communication methods within in the Finnish society, the technologies related to securing email communications and fighting forgeries were chosen as the primary research target (Kontinen 2020). Ville Kontinen wrote his Master's thesis about this subject at JAMK University of Applied Sciences, and it was published in November 2020. In his work he studied and researched available email security solutions and the implementation of technical DNS security methods in use in Finland. His study was carried out at a longer period of time, collecting information about .fi TLDs records. The study included information about the whole TLD name space, as well as particularly targeting the public sector of Finland, divided into four different parts: Ministries, Governmental agencies, Cities and Municipalities. As a statement for further studies, he stated that by using similar methods other target groups can easily be defined and inspected, including domains from other TLDs, different sectors etc.

This research is a continuum for the aforementioned thesis. The focus was on the DNS implementations of Finnish municipalities, regional councils, health care districts and other joint municipal authorities. The targeted organizations were Finnish municipalities, including larger cities, smaller towns and all the other (smaller) communities and the public organizations owned entirely by communities, including joint municipal authorities. The outcome of Kontinens work was planned to be used for influencing the email security settings level in the municipalities, but that has not yet been accomplished despite of all good intentions. This study and conducted research aims to help in that mission. The scope coverage is "domains used by Finnish municipalities and joint municipal authorities" and this also covers other domains outside the .fi TLD, including .ax domains used in organizations in Åland and the domains using .com or .net TLD which organizations announce officially they are using for email communication.

There were 309 communities and 139 joint municipal authorities in the beginning of 2021 in the scope of the research. 132 of the joint municipal authorities have domains registered in use, so in total of 441 organizations and 5,364 domains were studied.

The information studied was collected from a single point of time, gathered with queries to various database-registries containing this information base. There were no continuous measurement or situational awareness timeline that was followed or repeated to discover change or trend; only the onetime collection of data, during March 2021. The goal was to get the necessary registries available for combining them and gaining information about the state of the overall situation of DNS security implementations and other publicly available information about the target group of communities. Then it was possible to analyse the collected dataset for findings and justifiable suggestions and recommendations for improvements.

Out of scope were limited the in-house companies and enterprises owned entirely or partially by communities or joint municipal authorities. Out of scope were also the domains actively used by target organizations, but registered and maintained by a 3rd party partner on behalf of the organization. These include various different service providers, just as Internet service providers (ISPs), advertising agencies or managed (ICT) service providers (MSPs). Out of scope were the domains that are registered to a Holder which is a disband (merged) municipality, except those disband municipalities that are the registered holders of a target organization's active official email domain. In these cases, the disband municipality was included in the study with all the domains registered to its Organization ID. Although these out of scoped entities and domains also represent potentially vulnerable targets regarding municipalities and therefore equally interesting study objectives, these subjects were not covered in this study.

Statistical grouping of municipalities by their relation to areal health care organizations were left out of scope. This could have made more comparison groups for this study, as local authorities provide primary healthcare in Finland. They run 133 health centres, 74 being municipal health centres and the rest belonging to joint municipal authorities. Seven regions have integrated their primary healthcare, social welfare services and specialised medical care under one roof, and the rest are more dispersed. Every local authority is required by law to be a member of a joint municipal authority administering a healt care district (hospital district). There are 20 + 1 health care districts in all, operating in almost but not intairly the same regions as the officials are. These organization bindings were not included in the study as classifications, because these organizations themselves are included. Soon coming health and social services reform and new welfare districts would make this data rapidly obsolete.

The research was carried out in 2021, which is a significant year for the target organizations. Municipal elections were held in the spring and in the summer final decision of the reform of national healthcare from municipalities and health care districts to the new founded national welfare regions was made. These both drive significant changes to municipal organizations and also their ICT-environment and infrastructure. There will be a great number of changes in the ownership and support responsibilities of domain names registration, DNS records and SSL certificates. All these are critical technical functions and components to the operations of these organizations under a large change. This poses a potential threat of misconfigurations or misuse of domains/DNS to the target organizations, by not handling these assets appropriately during these changes in governance structures.

2.2 Study goals and research question

The goals for this research were to:

- Study and report the state of email related DNS configurations and security implementations of Finnish municipalities and joint municipal authorities.
- Find out the volume of registered domains as a potential attack vector and the state of various dns security features implemented in the target organizations.
- Find out and define possible reasons and explanations for the arisen observations regarding successful or unsuccessful implementations.
- Provide the commissioner (Tiera) and its owner-customers concrete information, knowledgebase and arguments for development operations and projects aiming for enhancement of information security

The research question was:

What is the state of email forgery preventing DNS implementations in Finnish municipalities and joint municipal authorities in 2021?

And the more precise researched topics and studied questions were:

- How many of the organization groups primary email domains are protected
    - Using SPF?
    - Using DMARC?
    - Using the combination?
- What about other email domains of organizations?
- What about non-email domains of organizations?
- Is there recognizable differences between organizations in implementing the protective configurations

    - By region? (NUTS1, NUTS2, NUTS3)
    - By statistical classification of municipalities? (urban, densely populated, rural-like)
    - By language?
    - By population?
    - By municipal form (C21 city, town, municipality)?
- Are organizations that have migrated to Microsoft or Googles cloud email services better protected by DNS security implementations?

Additional tests and queries (not reported in comparisons of domains):

- Are there fake domains present for the target domains, where in the domain name the letter “l” is replaced by the letter “i”? (which in capitals is “I”)
- Are there fake domain registrations and/or DNS records present fot the target domains names, but with a different TLD? (*.com/.net/.biz/.org/.info/.fit)
    - Are these fakes registered by the target organizations them selves or by outside 3rd party?

2.3 Document analysis

The applied research method of this study is Analysis of documentary evidence. Document analysis is a qualitative research method, where already existing documents are used as the source of information. The intention is to investigate knowledge currently available and documented in some form in order to gain new information from this analysis to better understand, evaluate and discuss the subject researched. Observations and conclusions can then be applied to develop whatever subject is the researched target. Analysis of documentary evidence can include wide range of sources – almost anything that is stored in written, audio or video format. Any existing set of information can be the source of document analysis, if the needed information wanted for further study can be defined and segregated. The analyzed information can be something inside the document, possible to find and also gather from other similar documents for comparison, or the needed information can be some information about the documents themselves, metadata describing the documents data content itself (Boven 2009).

Document analysis is quite formal and systematic process, often with repeatable steps that apply to all of the documents analysed. Hence the process can be (easily) improved, perfected and automated, especially in data collection phase. Digital formats have made document analysis even

more used and popular, as more and more data are generally available in digital documents or databases and accessible free in the public Internet. For many data sources, gathering data is made faster and more efficient with now common standard Application Interfaces (API). With these APIs, a large amount of data can be queried and retrieved electronically and directly from machine to machine.

Document analysis as a method can be very applicable for targeted and intensive research of a particular phenomenon or an object. It can be used to develop better understanding and discover relevant insight and/or details to the problem researched. As such, it is quite easy to apply to various business needs and daily challenges in organizations, if the researched question(s) can be clearly defined and the data for answering is available in some documented form. It can be applied as a down-to-earth research method in development and still gain results that are certified facts and reliable for knowledge-based decisions. As such document analysis is a useful method for applied research in itself.

Automation is also a key factor in the analysing part of document analysis, as the addressed data sets and amount of information increase. Many types of information can first be automatically processed and parsed into more readable and understandable format. The actual analysis with classifications and conclusions is made easier for people conducting the research. As document analysis is a popular method for qualitative case studies, near the conditions of practice and “real life case examples”, it is also recommended to rely on multiple sources of evidence data – different documents or sets of documents – if possible. In qualitative research it is expected to find and study on at least two or more data sources and seek convergence and corroboration through them for conclusions on the phenomenon under research. This is a way to reduce any impact of possible biases that might be present in a single study, and to avoid suspicion or accusations that the findings are artefacts from a single source studied with a single method to gain a predefined outcome.

First in this study, information about the target organizations was needed, for enabling the targeted collection of information about the existing domain assets of these organizations. Information about these domains is needed to be able gather information about their actual DNS configurations. After collection these different information can be combined and analysed with the

means of statistics for correlations or anomalies. Familiarizing, using and applying Document analysis as a research method also made aware just how easy it was to gather and combine data to a large set of sensitive information at least to some degree of confidentiality. Giving insight on how easy it is for a possible malicious actor to gather the same information for abusive use.

Public records are generally available for these target organizations as they are public authorities. These records (databases) were used as the source of documents. These same records can be applied to basically any other scope of organizations, as the same information is available for any industry. For the source of organizational information and classification, records from the National association of Finnish local and regional Authorities (Kuntaliitto), the Finnish Business Information System © (YTJ) and the Statistic Finland (Tilastokeskus), a national authority for collecting and compiling statistics on various fields of society and economy, were used. For information regarding the domain assets, the database of Finnish domain name register from The Finnish Transport and Communications Agency Traficom (Traficom) was used. Actual technical state of configurations, the public dns records, were retrieved from four different Internet Service Providers (ISP) DNS servers, including three national telecom companies and global Google servers.

2.4 Information gathering

The starting point for this study was to gather the required information and answer the stated research questions using the minimal number of basic tools and methods generally available to everyone free of charge. The tools/methods used were as follows:

The setup

- A basic Windows 10 laptop home computer, used at home office
- Installed basic software: Microsoft Office tools (Word, Excel & PowerPoint in particular), Web-browser (Firefox ESR, Chrome, Edge), PDF reader and printer, Calculator, Notepad++, PowerShell etc.
- Internet-connections from multiple ISPs (Elisa fibre, Elisa 5G, Lounea fibre, Telia 4G)
- cURL -software
- DIG (BIND 9) and nslookup

cURL stands for Client for URLs. It is a command line tool for getting or sending data using URL syntax, that supports DICT, FILE, FTP, FTPS, GOPHER, GOPHERS, HTTP, HTTPS, IMAP, IMAPS, LDAP, LDAPS, MQTT, POP3, POP3S, RTMP, RTMPS, RTSP, SCP, SFTP, SMB, SMBS, SMTP, SMTPS, TELNET

and TFTP of the common Internet protocols. cURL is very useful in performing queries and acquering data from public sources using available APIs.

For Windows cURL can be downloaded with instructions from curl-for-win GitHub repository https://github.com/curl/curl-for-win (cURL project 2021). For use follow the included instructions or at least remember to set the Windows system variable and it is usable:

> from **System Properties** dialog -> **Advanced tab** -> **Environment Variables** dialog -> **System variables** section, under the **Variable column** -> select **Path** and click **Edit** -> type the folder path where cURL utility files were unzipped, followed by "\bin", e.g. *C:\curl-7.75.0_3-win64-mingw\curl-7.75.0-win64-mingw\bin3*

DIG is a command-line tool developed by BIND for DNS nameserver queries. DIG performs DNS lookups and displays the answers that are returned from the name servers that were queried. It is popular for its flexibility, ease of use, clarity of output and more functionality than many other (build in) lookup tools. For Windows it can be downloaded with instructions from BIND Gitlab repository https://gitlab.isc.org/isc-projects/bind9/-/tree/main (Internet Systems Consortium 2021). For use follow the included instructions or at least remember to set the Windows system variable (similar as described above with cURL) and it is usable.

Nslookup is a MS Windows build in command-line tool that displays information to diagnose Domain Name System (DNS) infrastructure. The nslookup tool is available when TCP/IP protocol is installed

Information:

- Information about municipalities is published by the Association of Finnish Municipalities. Including official contact information and covering both, municipalities and joint munipal authorities (Kuntaliitto 2021c).
    - municipalities
    - joint municipal authorities
    - contact information, including:
        - Organizations official email address of its record office (mandatory)
        - Municipality number (only for municipalities)
        - Organization name in Finnish
        - Organization name in Swedish
        - Domicile
    - mergers
    - C21 cities
    - health care districts

    - special care districs
- Organization ID-numbers including information of disband (merged) municipalities is published by the Business Information System © (YTJ in Finnish), a joint service provided together by the Finnish Patent and Registration Office and the Finnish Tax Administration (PRH, Vero 2021)
- Statistics about municipalities are published at the Statistics Finland online service (Tilastokeskus / Statistics Finland 2021).
    - Areal classification by EU NUTS and local sub-region
    - Municipalities supervising AVIs (Regional State Administrative Agency office)
    - Municipalities supervising ELYs (Transport and the Environment centre)
    - Organization types
    - Population
    - Statistical grouping
    - Lingual status
- Domain information is available from the database of Finnish domain name register, provided by The Finnish Transport and Communications Agency Traficom. Register includes information on all registered domains of the .fi TLD.
    - DomainName (including scandic å, ä, ö)
    - Domain
    - TLD (= .fi)
    - FQDN
    - DNSSECInUse
    - DomainHolder
    - HolderOrganizationID (OrganizationId)
    - HolderOrganizationType
    - HolderAddress
    - HolderPostalCode
    - HolderPostalArea
    - DomainGantDate
    - DomainLastValidityDate
    - DomainRegistrar
    - NameServer1, NS2, NS3, NS4, NS5, NS6
- DNS queries to different ISP name servers to gather the actual RRs of all the 5,364 domains gathered as target scope.
    - ANY
        - HINFO
    - MX
    - TXT

Process and activities

The process and activities of this study were conducted using the setup of tools described above and the gathering information from the sources described above, in the order displayed.

The time line used with this study was from February to October 2021. Initial source material and information about the topic, possible data sources and the clarification of research questions were

studied first at February, as well as preparing the setup. Information about the organizations was collected from the sources mentioned by the end of February and the collection of domains based on the target organizations' IDs was conducted on 2 March 2021. During March the information was formalised and stylized for better processing. Scripts for DNS server queries were drafted and tested and the DNS records were gathered using different queries on 14 March 2021, 19 March 2021, 24 March 2021 and 30 March 2021. Some verifying and additional queries were performed also on April and May to clarify noted errors or to rise questions. After the collection of RR data for each domain the data was combined with organizational data gathered previously and started to be analysed. Comparing and analysing the collected dataset was carried out from April to May and continued at October. Final analyses, reporting the findings and conclusions answering the stated research question was done from September to November 2021.

Organizations' information was gathered from the sources using web browsers and manually copying it to a Microsoft Excel spreadsheet. Updating previously collected information with new on every step. Information in the mentioned sources is mostly published on lists, presented as tables in HTM websites or published directly in .csv format. Data collection, all though manual, was mainly strait forward.

Domain information was retrieved by using Finnish Domain Name Register overseen by Traficom. Traficom publishes a WHOIS service online (https://www.traficom.fi/en/communications/fi-domains/whois-shows-public-information-domain-name), which can be used to retrieve information from its database or from other registries, based on the queried domain. The service includes the top-level domains of countries (ccTLD) and the (old) generic top-level domains (gTLD). New gTLDs are not included and only domain of legal person holders is available. Traficom has also implemented a technical API, OData service, for the .fi TLD registry. With this interface, information about domains registered to organizations can be retrieved. Private individuals' information is not published in the OData service either. The service can be used on any platform supporting OData protocol, for example, directly in Microsoft Excel. Registries information can be applied in its users' own services. The usage of the information must comply with Finnish legislation (Viestintävirasto (Traficom) / Fi-verkkotunnukset 2017). Instructions on more information about the OData interface is available at https://www.traficom.fi/en/news/open-data?toggle=Fi-domain%20names.

Organizations .fi domains were retrieved from the OData interface at 2 March 2021, using cURL get-command based on organizations' ID number. This was scripted with PowerShell to a simple loop of commands that has the IDs as variables listed in a TXT file and results stored in XML files per organization. An example of cURL-command is shown in Figure 1, where it would query domains information from an organization of ID "1234567-8" (note the codec of special characters needed in Windows and that the organization ID is in the local Finnish form, not the international VAT). Organization's XML files are then imported to Microsoft Excel where they were combined with the organizational data and spreadsheets rows increased from 441 organization rows to 5,364 domain rows, with every row (domain) including also the organization information with the domain information.

```
curl -G "https://<server>/<service>/Domains?$filter=OrganizationId%20eq%20%271234567-8%27" > c:\fi_domains\1234567-8.xml
```

Figure 1. cURL GET command retrievin domain information of defined organization

Originally in the research plan it was the intention to make an official data request to Traficom about the same data of the listed organizations for comparison check. But after discussion this was discarded as unnecessary, for the data would be collected similarly from the same database and would be exactly same. Information regarding the domains under other TLDs then .fi were gathered manually, using WHOIS service of Traficom and MXToolBox inc. These included the primary email domains of organizations from Åland (.ax) and few organizations using a gTLD domain (.com/.net), as there was OData service for queries known for these TLDs.

Based on the collected domains the actual DNS name server queries for the RRs were run using DIG. Queries were conducted from four different name servers; 8.8.8.8 (Google), resolver1.elisa.fi (Elisa), ns.lounea.fi (Lounea) and ns.inet.fi (Telia) using different Internet connections in use from different ISPs, because the usual function of ISP name servers is to allow requests only from within their own network. Googles 8.8.8.8 was queried from all available connections and results compared but no differences were discovered. This was scripted with PowerShell to a simple loop of commands that has the domains as variables listed in a TXT file and results stored in TXT files per domain. An example of DIG command is shown in Figure 2, where it would query RRs from a domain "somemunicipality.fi". Separate queries for different type RRs were run and stored for each

domain from each of the name servers. Queries were run for ANY, MX, TXT and _dmarc TXT using DIG (legacy SPF was also queried but no RRs found). HINFO was searched separately based on ANY responces. Some verifications and test were carried out using also nslookup and MXToolBox and added manually to Microsoft Excel dataset.

```
dig @resolver1.elisa.fi _dmarc.somemunicipality.fi txt > C:\records\elisa\txt\dmarc\somemunicipality.txt
```

Figure 2. DIG query command retrieving DMARC TXT RRs from Elisa's name server

The collected answer files were collected to their own separate folders for actual inspection of configurations of RRs. This was done using PowerShell to search inside the files in a particular folder. PowerShell is a cross-platform task automation solution made up of a command-line shell, a scripting language, and a configuration management framework. PowerShell runs on Windows, Linux, and macOS (Microsoft 2021). Based on the search results, the files listed in the search output were copied to a second folder where the next, more precise, search was conducted. An example of PowerShell command is shown in Figure 3, where the first command is applied to the folder containing the answer files of TXT query. Then the files from the search result were copied separate and the second search was run to get the actual RRs' results looked for. DNS responses and their corresponding assigned values are based on Kontinen's Assigned value table (Kontinen 2020, 17), with few additions and adjustments. Assigned values are presented in Table 1.

First search to find SPF RR's in TXT query files:

```
PS C:\records\elisa\txt> Get-ChildItem -recurse | Select-String -pattern "v=spf1" | group path | select name
```

Second search to find SPF softfail in the files selected in previous search:

```
PS C:\records\elisa\txt\spf> Get-ChildItem -recurse | Select-String -pattern "~all" | group path | select name
```

Figure 3. Powershell gueries to find domain with SPF softfail configured

Table 1. Assigned values

Assigned value	Information
DNSSECInUse true	Based on information retrieved from Traficom Odata or verified from MXToolBox
DNSSECInUse false	Based on information retrieved from Traficom Odata or verified from MXToolBox
MXInUse false	IN MX response containing "SERVFAIL" (name server failure on reguest) OR IN MX response containing "NXDOMAIN" (name requested does not exist) OR IN MX response containing "SOA" (name exist, but no records of requested type = NODATA) OR IN MX response containing " \. " (No Service MX RR, note the spaces around and \ -escape for period)
MXInUse true	IN MX response not the above
Is1stEmail true	The official email-domain of organization, used in organizations registry office email-address Based on information retrieved from Kuntaliitto (or YTJ or organization website if not availeble)
Is1stEmail true	All other domains except the official email domain
SPFRecord hardfail	IN TXT response containing "v=spf1" and "-all"
SPFRecord softfail	IN TXT response containing "v=spf1" and "~all"
SPFRecord nostance	IN TXT response containing "v=spf1" and none of the above
SPFRecord false	IN TXT response none of the above
DMARCRecord test	IN TXT response to _dmarc.domain.tld containing "v=DMARC1;" and "p=none"
DMARCRecord quarantine	IN TXT response to _dmarc.domain.tld containing "v=DMARC1;" and "p=quarantine"
DMARCRecord reject	IN TXT response to _dmarc.domain.tld containing "v=DMARC1;" and "p=reject"
DMARCRecord unknown	IN TXT response to _dmarc.domain.tld containing "DMARC" but syntax invalid
DMARCRecord false	IN TXT response to _dmarc.domain.tld none of the above
HINFO true	IN ANY response containing "HINFO*"
HINFO false	IN ANY response not the above
MSArureValidation true	IN TXT response containing "MS=ms*"
MSAzureValidation false	IN TXT response not the above
MSOutlook true	IN MX response containing "*outlook.com" OR IN TXT response containing "*outlook.com"
MSOutlook false	IN MX response not the above AND IN TXT response not the above
MSCloudPresentInDNS true	MSArureValidation is true OR MSOutlook is true
MSCloudPresentInDNS false	MSArureValidation is false AND MSOutlook is false

In his study Kontinen researches several different Governmental authorities' and generally acknowledged and known parties' guidelines, instruction sets and policies (Kontinen 2020, 19) and presents the content for the NCSC-FI guidelines (Kontinen 2020, 40). Based on these, the following criteria for a secure deployment of SPF and DMARC are stated to be met:

1. A synthetically valid SPF record has been published with explicit "all" parameter for all possible domains.
2. The "all" parameter must be set to either SoftFail or HardFail state.
3. A synthetically valid DMARC record has been published for all possible domains.
4. For domains without valid MX records DMARC policy must be set to reject.
5. For domains with MX records the policy must be set to either quarantine or reject.

These parameters are then used as a baseline of the following combinations that satisfy the requirements:

- SPF -hardfail + DMARC -quarantine
- SPF -hardfail + DMARC -reject
- SPF -softfail + DMARC -quarantine
- SPF -softfail + DMARC rc-reject

In this study, domains are considered to meet a secure deployment criterion within the target groups are based on this baseline and Kontinen's Secure deployment criteria table (Kontinen 2020,

55), with few additions and adjustments applied for this study target. Secure deployment criteria are presented in Table 2. These criteria were then observed and evaluated against domain and organizational classification described earlier, with the use of Microsoft Excel and its' Pivot functions.

Table 2. Secure deployment criteria of email related DNS RR configurations

Domains	Criteria
Primary email domains (Is1stemail true)	SPF -hardfail + DMARC -quarantine SPF -hardfail + DMARC -reject SPF -softfail + DMARC -quarantine SPF -softfail + DMARC -reject
Email domains (MXInUse true)	SPF -hardfail + DMARC -quarantine SPF -hardfail + DMARC -reject SPF -softfail + DMARC -quarantine SPF -softfail + DMARC -reject
Non email domains (MXInUse false)	SPF -hardfail + DMARC -quarantine SPF -hardfail + DMARC -reject SPF -softfail + DMARC -quarantine SPF -softfail + DMARC -reject

3 Municipalities and municipal landscape in Finland

3.1 Cities, towns and other municipalities

Finland has 309 municipalities at the beginning of 2021, spread across the country as seen in Figure 4. Most of them are small, more than half have less than 6,000 residents. These small municipalities cover about half of the Finnish land, but only for ~15% of the population and for ~10% of all jobs. The smallest municipalities have less than 200 residents, but all municipalities have the same legal obligations of arranging public services in their area. Nine biggest cities have a population over 100,000. The largest city is the country's capital Helsinki with a population of ~656,000 (2020). Followed in order by Espoo, Tampere, Vantaa, Oulu, Turku, Jyväskylä, Lahti and Kuopio. These cities account for ~1% of Finland's area, but for ~30% of the whole population and for as much as ~40% of all jobs. Finnish municipalities and joint municipal authorities employ ~429,000 persons (2019), approximately 20% of Finland's whole workforce (Kuntaliitto 2021a).

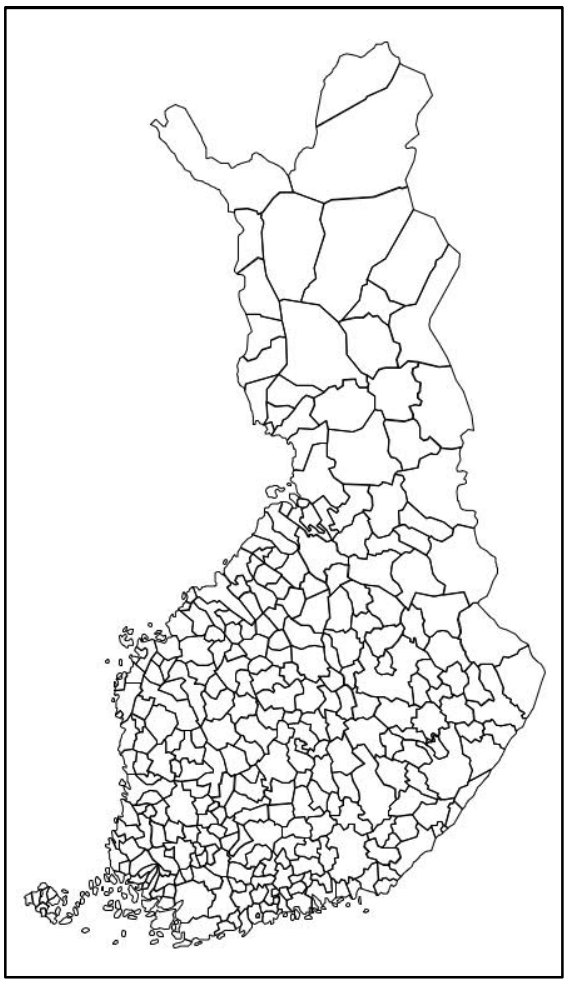

Figure 4. Finnish Municipalities
(©Tilastokeskus 2021)

The number of Finnish municipalities is decreasing by municipal mergers, mainly due to urbanization and descendent population in the rural-like areas, and following financial difficulties of arranging mandatory services in those areas. From the beginning of Finnish independence at 1917 the number on municipalities has gone down from 532 (38 towns, 4 boroughs and 490 municipalities) till current day 2021 to 309 (107 towns and 202 municipalitites). The development is shown in Figure 5. The peak of 603 in the ammount of municipalitites has been at 1942-1944. Especially fast decrease has been during the twenty-first century, with more mergers expected to be seen in the future as well (Kuntaliitto 2021b).

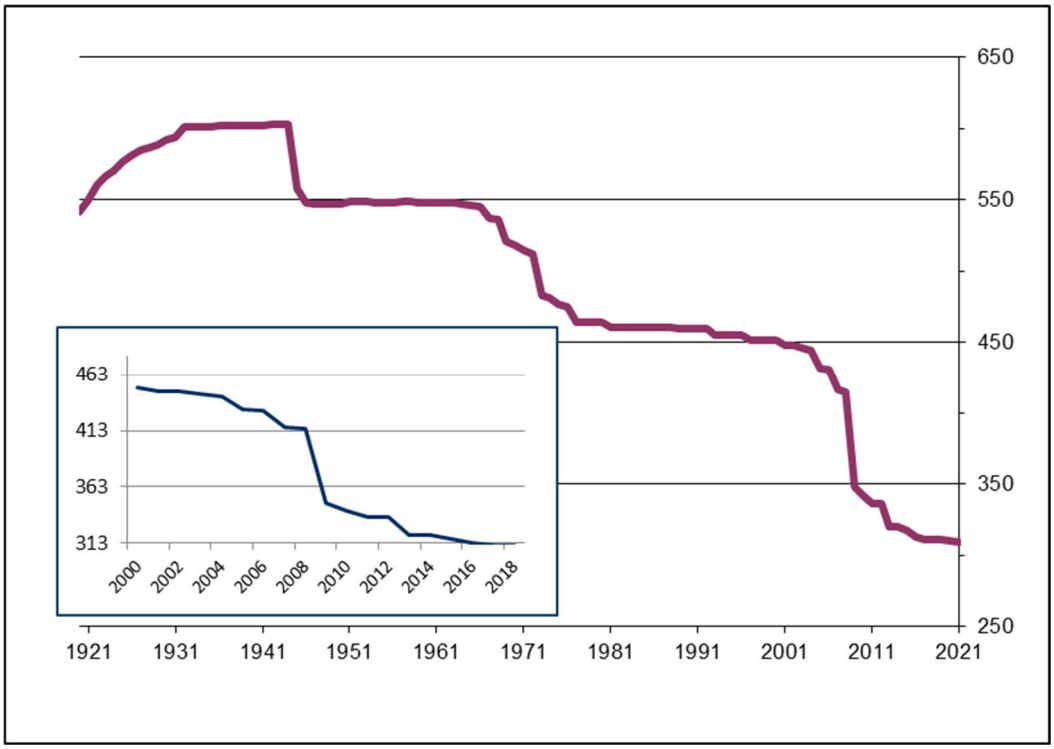

Figure 5. Ammount of municipalities between 1917-2021

Finnish municipalities have strong self-government and broad responsibility for the provision of basic public services to their residents. Self-government is based on local democracy and decision-making and the right to levy taxes. Administration is organized quite freely. Every municipality must have a municipal council, a local executive and an auditing committee for auditing municipal administration and finance.

The municipal council expresses the will of the local residents. It is responsible for activities and finances and exercises the municipality's power of decision. The council has a strategic leadership

role and determines long-term objectives and goals. The local executive is responsible for administration and financial management. It prepares and implements the council's decisions and oversees their legality. Municipalities may also set up other decision-making bodies, for example committees to operate under the local executive or standing committees for managing functions of a permanent nature. The responsibilities of the committees may include social and health care services, education, urban planning, the environment, and cultural and leisure services, E.g. a school management board, an equality commission or a personnel sub-committee (Kuntaliitto 2021a).

3.2 Joint municipal authorities and other organizations

The municipality and its subsidiaries together constitute a local authority corporation, in which the municipality exercises control. The corporation may also include entities in which a subsidiary exercises control. Entities in a local authority corporation may be in-house (limited liability) companies, associations, foundations or joint municipal authorities. The corporation management consists of the local executive, the chief executive or mayor, decision-making bodies, local government officers and elected officials. Corporation's management are responsible for overseeing the operation and for arranging supervision (Kuntaliitto 2021a).

Many of these municipal subsidiaries have been appointed some or several critical responsibilities and even official public authority by arrangement agreements from their owners, in order to organise different fields of activity in the owner's responsibilities by legislation. Industries where municipalities have responsibilities, but often arrange operations outside the main municipality, include operating in critical sectors described in the NIS directive. Such as water supply, energy, transport or health care. Other common operations are education, social work, housing, food supply, cleaning and waste disposal. All these operative organizations are eligible for their funds and expenses as they are under the public sector. They are all bound by the Act on Public Procurement and Concession Contracts for their business transactions and purchases. Depending on the branch of industry, special regulation is also often obligatory.

Joint municipal authorities are a very common way of organising operations in municipalities. As the name suggests, joint municipal authorities are established by two or more municipalities together to organise authority. Joint municipal authorities are also stated as authority officials by

law to the obligations that the founding municipalities agree and transfer to them. Regional counsils and health care districts are joint municipal authorities, governed by separate law. Municipalities in their regions are obligated to join, own and arrange authority of legislated responsibilities as well as operations thru these organizations. Out of the 139 joint municipal authorities in total, mandatory participation is required fot the 19 regional councils and 20 + 1 health care districts. There are also several voluntary joint municipal authorities, especially in education, basic health care and social services.

Other municipal corporation organizations include in-house (limited liability) companies, associations and foundations for specific purposes. In some cases, smaller communities organise arrangement of their obligations by mutual contracts from bigger host-communities with available resources.

In this study 132 joint municipal authorities were included in the researched dataset, as some of the 139 registered had just ended their operation or merged to another and few smaller operate with Internet presens of them selves, but are using the web-services and domains of their main owners.

3.3 Regions

Finland has 19 regions, as shown in Figure 6. Regions are similar to counties or provinces in other countries. 18 of them are on mainland Finland and the autonomous province of Åland Islands that lays off the southwest coast. Åland is both a region and a municipality in terms responsibilities and has a special status among regions. All regions have regional councils, which are regions statutory joint municipal authorities. Every municipality must be, by legislation, a member and an owner in the regional council of their location. Regional councils are organized as joint municipal authorities like other co-operation organizations of municipalities often are (Kuntaliitto 2021a).

The newly founded welfare regions are based on the current Regions, with some adjustments at Uusimaa and the exception of the city of Helsinki. There are 21 welfare regions and city of Helsinki which will carry responsibility of health care, social work and emergency services from the beginning of 2023.

Finnish areas are divided in to different groupings by using the Nomenclature of Territorial Units for Statistics (NUTS). NUTS is a standard created by EU for statistical purposes of countries. It is used in the EU member states for locating areas. For each EU member country, a hierarchy of three NUTS levels is established by Eurostat in agreement with each member state; the subdivisions in some levels do not necessarily correspond to administrative divisions within the country (Eurostat 2021).

Regions in Finland represent the NUTS 3 classification. Other, larger areas are NUTS 2 and NUTS 1 and smaller areal divisions are presented by subregions. Regions used for classification in this study are presented and identified in more detail in Appendix1. Classifications are listed Table 3.

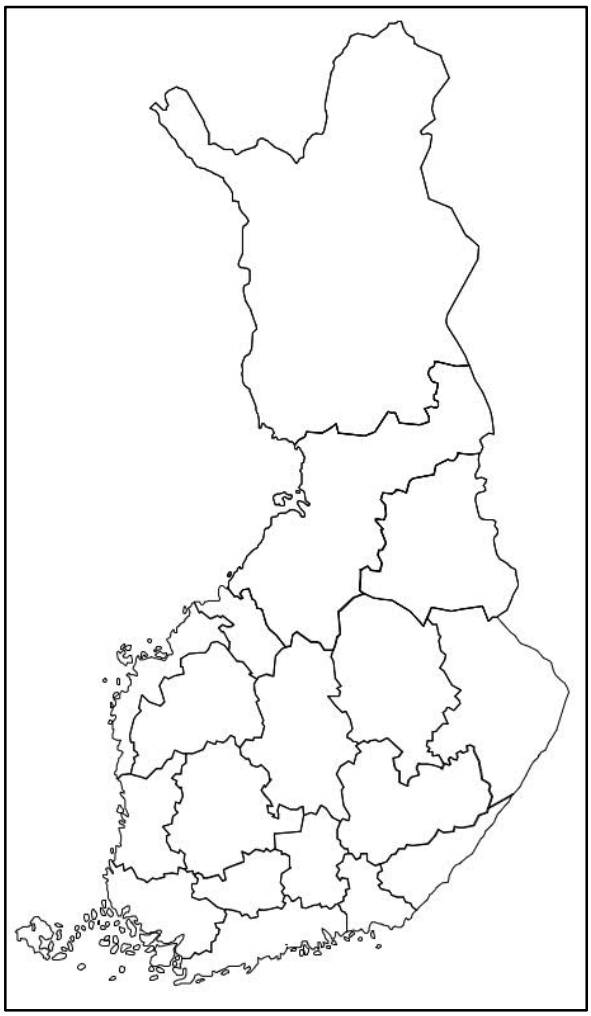

Figure 6. Finnish Regions 2021
(©Tilastokeskus 2021)

Table 3. Areal classification in Finland

Classification	**Description**	**Finnish description**
NUTS 1	Mainland or Åland	Manner-Suomi tai Ahvenanmaa
NUTS 2	Creater area	Suuralue
NUTS 3	Region	Maakunta
--	Subregion	Seutukunta

3.4 Classification of organizations

Classification used to divide the studied domains to different statistical comparison groups was to use the domains owner(/user) municipalities and joint municipal authorities geographical location based on the Eurostat's EU NUTS standard (Eurostat 2021). This 3-level category of areas (**NUTS 1, NUTS 2, NUTS 3**) was comprehended with a local, and since EU a bit outdated, regional category of smaller area **sub-region**. These geographical areas were used in comparison by location with all organizations. Other classifications were also identified and used, as described below.

107 municipalities use the naming **Town**, which municipalities are intitled to declare themselves. At his research Kontinen refers to cities, but in this study the use of "Town" provides a more acqurate description, because many of our towns are quite small (smallest being only 1,246 residents), the domain registry of Traficom knows the term "Town" as an organization type and "City" is more descriptive term for the biggest C21 cities. The rest 202 municipalities use the naming **Municipality**. This was used as the type of organization by adding a classification used by Statistics Finland grouping municipalities by their size in population. Allthough some variation perceptible, this grouping is often conducted with seven groups of population density; under 2 000, 2 001 – 5 000, 5 001 – 10 000, 10 001 – 20 000, 20 001 – 40 000, 40 001 – 100 000 and over 100 001 residents. Giving a total of 2x7 = 14 groups of municipalities for comparison. Joint municipal authorities were grouped for comparison by their function; **regional council**, **health care district**, **educational authority**, **social- and/or health authority** and **other authority**. 19 groups in total.

By statistics 58 Towns are classified as **Urban** (citylike). 64 municipalities are classified as **Densely populated**, which includes rest of the Towns and some other municipalities. 187 municipalities are

classified as **rural-like**. This was used as a statistical grouping, where all **joint municipal authorities** formed one individual comparison group.

C21 is a co-operation network amongst the 21 largest cities in Finland. Not an official statistical classification criterion, but a useful measure of difference between the biggest growing areal central cities in comparison to the somewhat diminishing smaller communities of the country side. The cities included in C21 are: Helsinki, Espoo, Tampere, Vantaa, Oulu, Turku, Jyväskylä, Lahti, Kuopio, Kouvola, Pori, Joensuu, Lappeenranta, Hämeenlinna, Vaasa, Rovaniemi, Seinäjoki, Mikkeli, Kotka, Salo and Porvoo. All other municipalities are **non-C21** as a comparison group.

Finland is bilingual. The national languages of Finland are Finnish and Swedish. 49% of Finnish municipalities are either bilingual or Swedish-speaking. The number of residents in bilingual municipalities totals 1.75 million, which is just over 1/3 of Finland's total population of 5.5 million. 16 are **Swedish-speaking** municipalities, ~5.2% of municipalities (23 of all organizations, and ~5.1%), all located on the Åland Islands. 15 are **bilingual with Swedish as primary**, ~4.9% (21 of all, ~4.7%), mainly located in the south and west coast. 18 are **bilingual with Finnish as primary**, ~5.8% (35 of all, ~7.8%), more scattered around western and southern Finland. The rest 260 are **Finnish-speaking**, ~84.1% (370 of all, ~82.4%), all over mainland Finland.

One used classification regarding municipal organizations are statistical grouping by the supervising governmental authorities' officials of municipalities; the Regional State Administrative Agency (**AVI** offices) and the Centre for Economic Development, Transport and the Environment (**ELY** centres). Both of these organizations are responsible for supervision and guidance of all the target organizations and both of them are organised to regional operative units of national government, with local authority. But their organizational structure by regional offices coverage is not entirely similar to the official regions of Finland, and their regional offices also have some nationwide responsibilities and specialities.

As mentioned before in chapter 2.1, the relation of target organizations relation to health care organizations in targets region was left out of scope for this study. But one aspect in that entity was included, because it is a direct statistical grouping of the studied organizations. Not a statistical grouping of targets based on their relation to some of the other targets in the scope. This is

whether the organization is a **special care district** or a **non-special care district**. Special care districts are for organizing help and social services for disabled people. Finland is divided in to 16 special care districts, stated by the government. Additionally, there is a separate nationwide special care district for Swedish-speaking residents and in Åland a separate joint municipality authority as a special care district.

The whole Domain classification model, including per domain organizational classification is displayed in Appendix 2.

4 DNS-security techniques regarding e-mail communication

4.1 Technical operation of DNS and SMTP

Domain Name System (DNS) is the naming system of the Internet. It was defined in 1987 by RFC 1035 (also known as STD 13) to provide a mechanism for naming resources in a way that the names are usable in different hosts, networks, protocol families, internets, and administrative organizations. It translates names into IP address numbers and vice versa. DNS uses resource records (RRs), are stored at DNS server's database as text records for query. User programs interact with DNS through resolvers, usually host operating system components. Format of user queries and user responses is specific to the host and its operating system or running program initiating the query. The resolver may have to make several different queries to several different name servers to answer a particular user query (Network Working Group, P. Mockapetris 1987).

Fully-qualified domain names (FQDNs) are the hierarchy of DNS. FQDN of a domain determines the status and the location of the domain in the domain name system. It specifies the domains level and includes information of the top-level domain (TLD) and the root zone. DNS root zone is maintained by Internet Assigned Numbers Authority (IANA) and most of the top-level domains are delegated to specific organizations by the Internet Governance Forum (IGF). This multinational arrangement guarantees that no government, enterprise or person runs the Internet or its core services. Finnish Transport and Communication Agency (Traficom) is responsibile for management of the Finnish national TLD .fi, and the Government of Åland is responsibile for management of the TLD .ax.

Simple Mail Transfer Protocol (SMTP) is the current standard for Internet email traffic. It is a defined protocol, described in the RFC 5321, for reliable and efficient email transfer. SMTP needs only an ordered data stream channel and no particular transmission subsystem is used. SMTP is mainly transported over TCP. "SMTP mail relaying" is protocols capability to transport Email across different networks as shown in Figure 7. Using SMTP, a process can transfer Email to another process on the same network or to some other network via a relay or gateway accessible to both networks. SMTP Email message may pass through a number of intermediate relays or gateway hosts on its path from sender to the intended recipient.

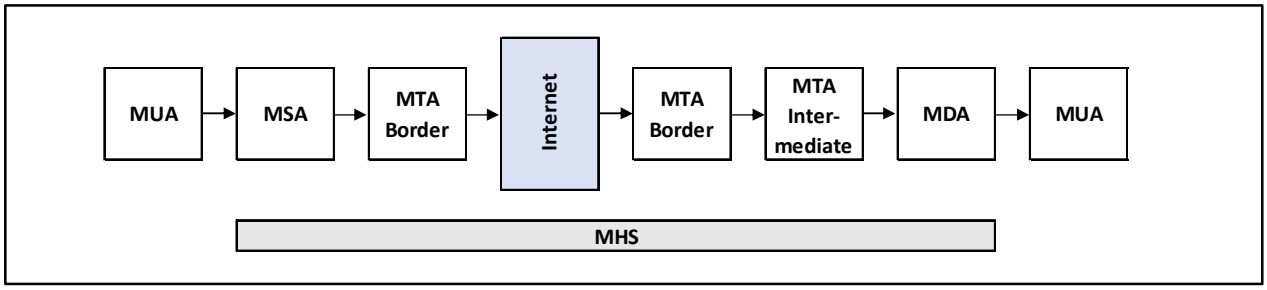

Figure 7. Email transmission

Email is a highly distributed service, with many actors in different roles, as shown in Table 4. Email has its user environment, with applications and user interfaces, in the Mail User Agents (MUA) and the transmission environment in the form of Mail Handling Service (MHS). MHS is a chain of Mail Transfer Agents (MTA) delivering Emails. SMTP is only used in the MHS, for communication between Email servers. A different protocol is used to get the email message from the server to the recipient. First system that receives the Email from the sending MUA in the MHS is called the Mail Submission Agent (MSA), and the last that delivers the Email to the receiving MUA is called the Mail Delivery Agent (MDA). Both, the outbound MSA and the inbound MDA, are Email Mediators. Email Mediators take delivery of a message, make changes to it according to its service and configuration, and then reposts it for further delivery (Network Working Group, J. Klensin 2008).

Table 4. Roles in email transmission

Roles and role-types in email transmission		
	User	Sources of messages. Users can be people, organizations, or processes
	Authors	responsible for creating the message, its contents, and its list of Recipient addresses.
	Recipients	consumer of the delivered message
	Return Handlers	"Bounce Handler", is a special form of Recipient tasked with servicing notifications generated by the MHS as it transfers or delivers the message. These notices about failures or completions are sent to an address that is specified by the Originator. This Return Handling address (Return Address) might have no visible characteristics in common with the address of the Author or Originator
	Mediators	receives, aggregates, reformulates, and redistributes messages among Authors and Recipients who are the principals in protracted exchanges. Preserves the original Author's information in the message it reformulates but is permitted to make meaningful changes to the message content or envelope. The MHS sees a new message, but Users receive a message that they interpret as being from, or at least initiated by, the Author of the original message
	Message Handling Service (MHS)	performs a single end-to-end transfer on behalf of the Author to reach the Recipient. MHS Actors generate, modify, or look at only transfer data, rather than the entire message
	Originator	ensures that a message conforms to both Internet Mail standards and local operational policies, is therefor valid for posting and submits it to a Relay
	Relay	MHS-level routing and transmitting or retransmitting the message to its Recipients. Relay adds trace information, but does not modify the envelope information or the message content semantics
	Gateway	a hybrid of User and Relay that connects heterogeneous mail services. Its purpose is to emulate a Relay. Operates as a User when it needs to modify message content
	Receiver	performs final delivery or sends the message to an alternate address. It can also perform filtering and other policy enforcement immediately before or after delivery.
	ADministrative Management Domain (ADMD)	determined by independence of administrative decision-making and defined boundaries that distinguish different portions of the Internet Mail service. Enterprise Service Providers, Internet Service Providers (ISP) and Mail Service Providers are exaples of ADMDs
	Edge	Independent transfer services in networks at the edge of the open Internet email service.
	Consumer	a type of Edge service, common for web-based email access.
	Transit	Mail Service Providers (MSPs) that offer value-added capabilities for Edge ADMDs, such as aggregation and filtering.

(Internet Engineering Task Force (IETF), D. Crocker. 2009)

Email consists of two parts, the “envelope” and the “message”, as shown in Figure 8. Envelope is the information that is exchanged between email servers using SMTP. It is described in the RFC 5321 and has the recipient address for the message to be delivered to, and the Return address of the sender. If undeliverable, the email will be returned to the Return address at the envelope. Addresses on the envelope are used by the MTAs for routing and relying messages. Each MTA communicates to the next one using SMTP, and on every hop the received envelope is discarded and a new one is assigned in its place.

The message itself has a header and a body. Both described in the RFC 5322. Header holds information of the email, like Sender address as shown in client applications, recipient(s), timestamps and the subject. Header can also contain other technical information such as styling, spam check results and the path the email was relayed through. Headers are usually hidden from email client applications by default, but most are able to view them if needed. The actual content of the message is known as the body of the email. it may contain plain text, styled HTML content and file attachments.

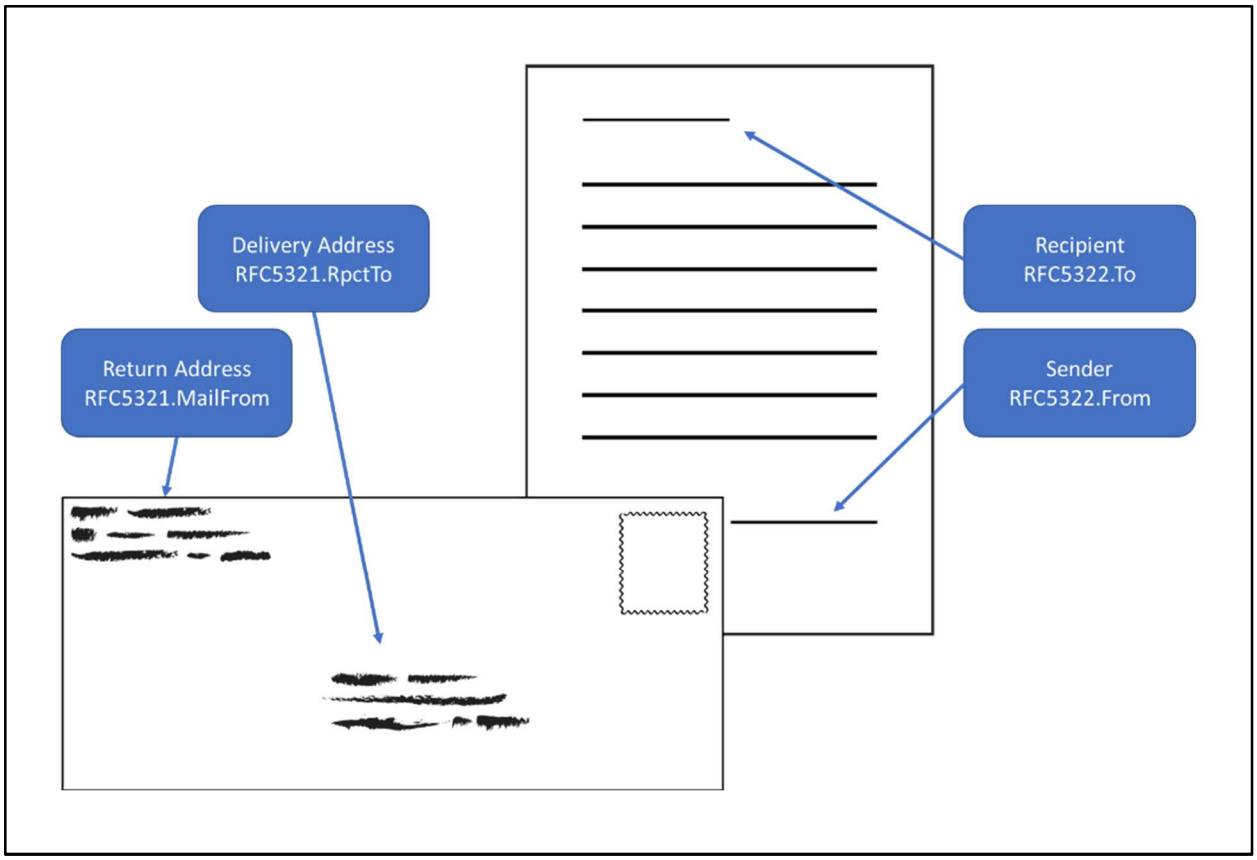

Figure 8. Usage of different SMTP Addresses
(retell: Mailhardener 2019)

An email contains several different addresses, that are set by the sender as shown in Table 5. These addresses may be completely different and even from various different domains. Addresses are also called by many different names which may confuse even professionals, and the presence of various possibilities for these different addresses poses a threat for misuse (Mailhardener 2019). Message envelope is never actually seen by the real recipients, because it is part of the message transmission processes between MTAs, not an actual part of the message. Most information is just copied from the envelope to the header, debending on the settings of the MTA's.

Table 5. Email Addresses used in SMTP-protocol

Email addresses	SMTP Command / Name	Standard term	Used in
The sender	From	RFC5322.From	Email header
The recipient	To	RFC5322.To	Email header
The reply address (optional)	Reply-To	RFC5322.ReplyTo	Email header
Return address	MAIL FROM	RFC5321.MailFrom *	SMTP envelope
Delivery address	RCPT TO	RFC5321.RcptTo	SMTP envelope
The Return path address	(depends on MTA)	RFC5322.ReturnPath	Email header

* When SMTP was defined in 1982 by RFC5321, it was simply called the 'from' address.
The name was never formally defined, and as a result it's referred to by several different names, such as:
- MAIL FROM
- RFC5321.FROM
- 5321-FROM
- return address
- bounce address
- envelope from
- envelope sender
- From_
- Errors-to
- reverse-path

All these terms are used to describe the sender address on the SMTP envelope, the RFC5321.MailFrom (return address).

4.2 Mail Security and Spoofing addresses

SMTP Email is by design insecure in a way that it is easy for almost anyone to create messages that will trick recipients into believing that they came from somewhere else. Constructing Email messages so that the spoofed behavior of it cannot be easily detected, is quite simple. Common knowledge of Internet Email increases and so does knowledge that SMTP Email can not be authenticated or checked for integrity at the transport level. Fairly casual users/MUAs are able to "negotiate" directly with receiving and relaying MDAs or MTAs, and direct their behavior. Depending on

the sender's system configuration, Email can be altered against RFC guidelines and general recommendations, to allow misusage. Typically, a message will have the original rfc5322.From header field and other information originating from the MUA, unless the Mediator, usually the MSA or in some cases the MDA, make changes intentionally, or a malicious MTA on the route changes them. For example, the alternating of the envelope Return address, the RFC5321.MailFrom. Depending on the receiver's DNS and system configurations, this altering can or cannot be detectable or allowed for delivery to receivers (Network Working Group, J. Klensin 2008).

Spoofing cannot be altogether avoided and denied by the organization itself, if an outsider is faking Emails and spoofing Emails with the organizations name. But the organization can protect itself by applying tight security settings to its own implementation of MX records and requiring it is inbound MTA or Email spam-filter to also require Sender Verification for all the SMTP addresses used. This gives the organization good protection against Email forgery. Falsifying the message information so that an expert would not detect it, is significantly more difficult when protective measures are in place. But not impossible to an outsider who knows the possibilities and weaknesses of SMTP Email and is determined to use them against the organization.

Efforts to make it more difficult for users to set the envelope return address (RFC5321.MailFrom) and the header "From" (RFC5322.From) fields to point to valid addresses other than their own are largely misguided. This frustrates legitimate applications, Mediator MDAs and MSAs, in which Email is sent by one user on behalf of another and where error replies or all replies should be intentionally directed to another address. These types of services are commonly News-letter, invitation, registration or Mailing-list services for messaging to large number of recipients at the same time. Systems that provide ability to alter these header fields on a per-message basis, should establish a primary and permanent mailbox address, so that Sender header fields within the message data can be handled accordingly (Network Working Group, J. Klensin 2008).

Consequently, SMTP Email remains inherently weaker than end-to-end communication that uses digitally signed messages, and does not depend on the integrity of the transport layer. True Email security can only be achieved by end-to-end methods involving the message bodies. For example,

the use digital signatures introduced by RFC1847 and Pretty Good Privacy (PGP) by RFC4880 or Secure/Multipurpose Internet Mail Extensions (S/MIME) by RFC3851 (Network Working Group, J. Klensin 2008).

Currently the used Email authentication methods are:

- SMTP Service Extension for Authentication (AUTH)
- Sender Policy Framework (SPF)
- DomainKeys Identified Mail Signatures (DKIM)
- Domain-based Message Authentication, Reporting, and Conformance (DMARC)
- Reverse IP address name validation (IPREV)
- Require-Recipient-Valid-Since Header Field and SMTP Service Extension (RRVS)
- S/MIME Signature Verification (SMIME-REG)
- Vouch By Reference (VBR)

(Internet Engineering Task Force (IETF), M. Kucherawy 2019).

Improvement on the current situation is provided by different optional configurations and protocol extensions that provide authentication. However, they only authenticate one MTA to another through the whole chain of MTA relays and servers and there is no authenticating of users or machines. Despite these imperfections, different methods include quite affective measures to deal with potential Email threats and forgery.

Email security cannot be achieved by a single solution or by one security application. Securing email involves incremental additions to basic subsystems, with each technology adapted to a particular task. Various solutions use DNS protocol for specific security functions like domain authentication, content encryption and message originator authentication. Solutions can be implemented discretely or in aggregate, based on determined needs. Deploying protocols and technologies that improve the trustworthiness of email for both the email sender and receiver, reduce the risk of spoofed email being used as an attack vector and reduce the risk of email contents being disclosed to unauthorized parties (National Institute of Standards and Technology 2019).

4.3 Sender Policy Framework (SPF)

Sender Policy Framework (SPF) determines if the sending server is allowed to send email for the domain name in the RFC5321.MailFrom address (envelope). SPF-compliant domains publish SPF

RRs that can be used to make both positive (source is authorized) and negative (source is not authorized) determinations to evaluate an SPF policy against an arriving email transaction. These RRs authorize the use of the relevant domain names in the "HELO" and "MAIL FROM" identities by the MTAs. Also known as RFC5321.HELO/.EHLO RFC5321.MailFrom identities. Receiving MTA can perform a series of SPF checks for each email it receives. SPF tests the authorization of a client host to allow email with a given identity.

If publishing SPF RR for email receivers to make negative authorization determinations, it is necessary to publish a RR that ends with "-all", or redirect to other records that do. Else no determination of authorization can be made. If no hosts are authorized to use their DNS domain names in the “HELO” or “MAIL FROM” identities during SMTP sessions, SPF RR that state “-all” should be published for those domain names that are neither used in the domain part of email addresses or not expected to originate email at all (Internet Engineering Task Force (IETF), S. Kitterman 2014).

SPF RR tells the receiving email server that if a message comes from <domain>, but not from specified IP addresses, the receiving server should apply the enforcement rule to the message. The enforcement rule is one of these options:

- **Hard fail**. Message marked with 'hard fail' in the message envelope and receiving server's configured spam policy for this type of message is followed.
- **Soft fail**. Message marked with 'soft fail' in the message envelope and typically receiving email servers are configured to deliver these messages anyway, possibly tagged as “spam”. Most end users do not see this mark.
- **Neutral**. Do nothing, no markin in the message envelope. Reserved for testing purposes and should be rarely used.

SPF TXT RR has the following definitions:

<domain> <TTL> IN TXT v=spf1 [<ip4>|<ip6>:<IP address>] [include:<domain name>] <enforcement rule>

- v=spf1 — Mandatory. Defines the TXT RR as an SPF TXT record
- ip4 or ip6 — Indicates whether IP version 4 addresses or IP version 6 addresses are used
- IP address — IP address that is added to the SPF TXT record. Usually, the IP address of the outbound mail server for the organization. List of multiple outbound mail servers is possible.
- domain name — Domain added as a legitimate sender

- Enforcement rules:
  - -all hard fail. List all known authorized IP addresses for a domain and use the –all (hard fail) qualifier
  - ~all soft fail. If a complete list of authorized IP addresses is not known for sure, then use the ~all (soft fail) qualifier
  - ?all Indicates neutral (nostance). Used for testing. not recommend for live deployment.

(Microsoft 2019)

If a domain does not have an SPF TXT RR, some receiving email servers might reject emails directly. This is because the receiving servers cannot validate wether an email comes from an authorized server or not. Although SPF is designed to help prevent spoofing, there are spoofing techniques that SPF cannot protect against. In order to protect against these, you should also configure DKIM and DMARC (Microsoft 2016).

4.4 DomainKeys Identified Mail Signatures (DKIM)

DomainKeys Identified Mail Signatures (DKIM) defines a domain-level digital signature authentication framework for email. DKIM uses public-key cryptography, with DNS as the key server technology (RFC 4871). This permits verification of the organization and the integrity of the message contents, validating outbound email sent from a domain. DKIM also enables a mechanism that permits potential email signers to publish information about their email signing practices, allowing receivers to make additional assessments about messages. Cryptographic signatures are added to outpound emails and these signatures must match the RFC5322.From (header) address in domains DNS RR. Authentication aims to prove that the contents of an email are not tampered with. DKIM is designed for the global control of "spam" and "phishing". Every MSA is a candidate for signing outbound emails using DKIM, and every MDA is a candidate for doing DKIM verification for inbound emails. (Network Working Group 2009)

DKIM authorizes a domain to associate, sign, its name to an email message using cryptographic authentication. Email systems that receive these emails can use this digital signature to help verify whether incoming email is legitimate for this domain. Private key encrypts the header in a domain's outgoing email. Public key is published in the domain's DNS RR, and receiving servers can

use the public key key to decode the signature confirmin the email is really coming from that domain and not someone spoofing it. SPF adds information to a message envelope but DKIM encrypts a signature within the message header. When an email is forwarded, portions of its envelope can be stripped away by the forwarding server but the digital signature stays with the email message, because it is part of the email header. Therefore, DKIM works even when a message is forwarded and reduces false positive spam reporting. Because DKIM relies on public key cryptography to authenticate and not just IP addresses, it is considered a much stronger form of authentication than SPF (Microsoft 2019).

Unlike SPF or DMARC, DKIM RRs are not published in a specific manner, including the relevant settings defined by RFCs. The cryptographic signature is added in a message and the public key is published in a specific RR in a specific location in DNS, as described by Kontinen in his study (Kontinen 2020, p.10). Therefore, DKIM implementation usage rates and configuration models cannot be searched in the same way as SPF or DMARC, by querieng domains general DNS answers. This is why analysing of DKIM is not included in this study.

4.5 Domain-based Message Authentication, Reporting and Conformance (DMARC)

Domain-based Message Authentication, Reporting and Conformance (DMARC) checks that the RFC5321.MailFrom and RFC5322.From addresses match. DMARC is a way for email sending organizations to express domain-level policies and preferences for validation, disposition, and reporting, that receiving organizations can use to improve their email handling processes. SPF and DKIM provide domain-level authentication and enable receivers to detect email authorized to use the sender's domain name. DMARC is a mechanism for using and combining these existing authentication and policy advertisement technologies to enable message-stream feedback and enforcement of policies against unauthenticated email. DMARC aims to allow domain Holders (owners) to verify their authentication deployment, minimize implementation complexity and impact on delivery of legitimate emails for both parties involved, inform about preferred handling of authentication failures for a domain and be usable at Internet scale. It enables domain Holder and email receivers a way to collaborate about domain policies stated by the Holder and provides a method of feedback to monitor authentication and possible threats (M. Kucherawy, Ed., E. Zwicky, Ed., Yahoo! 2015).

The basic DMARC function is:

- Domain Holder publishes a SPF-policy and/or configures and publishes DKIM signing about a domain
- Domain Holder publishes a DMARC-policy about a domain in DNS TXT RR.
- Author generates an email and hands the message to domain designated MSA mail submission service
- MSA submission service passes relevant details to the DKIM signing module and generates a DKIM signature to be applied
- MSA submission service relays the now-signed email to its designated MTA transport service for routing to its intended recipients
- Email may pass through other MTA relays but eventually arrives at recipient's MTA transport service
- Recipient MDA delivery service conducts SPF and DKIM authentication checks by passing this information to their designated modules for performing queries to the Authors domain's DNS
- The results of these are passed to the DMARC module along with the Author's domain. DMARC module attempts to retrieve a policy from the DNS for that domain. If none is found, it determines the Organizational Domain and repeats the attempt to retrieve a policy from the DNS
- If a policy is found, it is combined with the Author's domain and the SPF and DKIM results if present. DMARC compares the RFC5322.From address in the email to the SPF and DKIM results, and the DMARC policy in DNS
    - this produces a DMARC policy result, "pass" or "fail"
    - can cause one of two kinds of reports to be generated depending on the policy published
- Receivers are able to use these results for determination of how the email should be handled according to the policy set by the domains Holder
    - Recipients MDA transport service either delivers the message or takes other local policy action based on the DMARC result
- When requested Receivers Recipient transport service collects data from the email delivery session and sends reports to the Holder about email claiming to be from their domain (defined RUA and/or RUF-address in the DMARC RR)

(M. Kucherawy, Ed., E. Zwicky, Ed., Yahoo! 2015)

DMARC TXT RRs validate the origin of email messages by verifying the IP address of an email's author against the alleged owner of the sending domain. The stated policy is one of these options:

- **None**. A monitoring-mode record, published in order to find out how much email is lost by publishing a more restrictive DMARC policy.
- **Quarantine**. Asking DMARC receivers to put messages from a domain that fail the DMARC checks into the local equivalent of a spam folder instead of receivers' inboxes.
- **Reject**. Asking DMARC receivers not to accept messages that fail the DMARC checks.

DMARC TXT RR has the following definitions:

_dmarc.<domain> <TTL> IN TXT "v=DMARC1; p=<policy>; sp=<spolicy>; ruf=mailto:<ruf address>; rua=mailto:<rua address>; fo=<fo>; adkim=<adkim>; pct=<1-100>"

- domain — Domain intended to be protected
- TTL — desired Time-To-Live value. Units used for TTL are either hours, minutes or seconds, depending on the registrar for the domain
- v=dmarc1 — Mandatory. Defines the TXT RR as an DMARC TXT record
- policy:
  - p=none
  - p=quarantine
  - p=reject
- spolicy — same as policy, but for hierarchical subdomains
- ruf address — Email address where forensic DMARC reports are sent. RUF reports are copies of emails that are reported as not DMARC compliant and as such, possible privacy issues should be highly consider before implementing
- rua address — Email address where aggregate DMARC reports are sent
- fo — DMARC Failure reporting Options (fo): fo=0 / fo=1 /fo=d / fo=s. Can be conjucted with colons, for example “fo= 1:d:s”
  - fo=0 — Generate DMARC report if all mechanisms (SPF and DKIM) fail to produce a “pass” result (default value)
  - fo=1 — Generate DMARC report if any mechanism produces something other than a “pass” result
  - fo=d — Generate DKIM report if the email had a signature that failed evaluation, regardless of its alignment
  - fo=s — Generate an SPF failure report if the message failed SPF evaluation, regardless of its alignment
- adkim — Optional adkim tag refers to the alignment mode for the DKIM protocol. Value is set as either “r” (relaxed) or “s” (strict). Alignment is successful when emails root domain of the DKIM signing domain matches the headers RFC5322.From domain
  - adkim=r — DKIM domain and the RFC5322.From domain are an exact match or a parent/subdomain match, allowing any subdomain + parent domain pair to generate a “pass” result. Either the DKIM domain or the RFC5322.From domain can be the parent or the subdomain.
  - adkim=s — DKIM domain and the RFC5322.From domain must exactly match. No subdomain + parent domain pair is allowed
- 1-100 (pct %) — Optional value in the range of values 1-100, indicitang on which percentage should the stated policy be enforced. 100 being the default if no pct tag is included, meaning 100% of emails should be handled by the stated policy

DMARC is hierarchical. Therefore, a policy published for a domain will apply to its subdomains, unless a different policy is explicitly defined for a subdomain. This is useful as organizations are able

to specify a smaller number of high-level DMARC policies for wider coverage. Attention should be paid if configuring explicit subdomain DMARC policies, where subdomains are not intended to inherit the top-level domain's DMARC RR configuration. Wildcard-type policy for DMARC can be used by adding the sp=reject value, when subdomains are not email domains and no messages is supposed to be sent (Microsoft 2021).

4.6 Announcement for no email service available

Only resolvable FQDNs are permitted when domain names are used in SMTP email traffic. Just names that can be resolved to MX RRs or address RRs (i.e., A or AAAA) are allowed. As are those CNAME RRs whose targets can be resolved, in turn, to MX or address RRs. Local nicknames or unqualified names MUST NOT be used. Mail exchange binding uses the domain part of an email address to determine where the email should be delivered. Domain suffix in the message's recipient address is used as a domain name to locate type MX RRs in DNS. RRs list the hosts accepting email for that domain, together with preference values which rank the hosts according to an order specified by the domain's administrator (Network Working Group, J. Klensin 2008).

The receiving servers address is determined through DNS queries, first by looking for an MX RR and then for an A/AAAA record as a fallback. This means that the A/AAAA RR is taken to be an email server address even when that address does not accept receiving email at all. No service MX RR, called "Null MX", is used to announce that a domain accepts no email, without having to provide a mail server for that purpose. When a domain's DNS service advertises a single MX RR with an RDATA section consisting of preference number 0 and a zero-length label "." as the mail exchange domain, it states that no mail exchanger for that domain exists. Since "." is not a valid host name, a null MX record cannot be confused with an ordinary MX record. The use of "." as a pseudo-hostname meaning no service available is modeled on the SRV RR (RFC 2782) where it has a similar meaning (Internet Engineering Task Force (IETF) 2015).

Non-email domains or domains that are just parked and completely unused need to be protected against email spoofing by creating the necessary DNS records. Absence of MX RR does not state if a domain is meant to receive email or not, so Null MX responses is used as a method to publish

the lack of expected infrastructure to receive messages. Configuring a Null MX response is an improved method to advertise when a domain is not expected to receive messages. Null MX RR must be the only MX record for the particular domain.

Recommended MX RR for non-email domains:

```
Preference: 0 (zero)
Hostname: . (period)
```

(Canadian Centre for Cyber Security 2021)

SPF can be used to authorize outbound senders and for non-email domains SPF should be configured to reject messages sent from any IP address. SPF RR should be created as a wildcard TXT entry, so that it will be returned in response to TXT queries for the root domain or any sub-domains under this parent, or for every subdomain individually.

Recommended SPF RR for non-email domains:

```
v=spf1 -all
```

(Canadian Centre for Cyber Security 2021)

DMARC for non-email domains should be configured to reject all messages that fail SPF and DKIM. This will include all messages when DMARC is combined with the previous SPF RR above. DMARC protocol specifies that the record at the organizational domain level should be used if a DMARC RR for a specific sub-domain is not separately found, so DMARC RR does not need to be created as a wildcard.

Recommended DMARC RR for non-email domains:

```
v=DMARC1; p=reject; sp=reject; pct=100; rua=mailto:<rua address>
```

(Canadian Centre for Cyber Security 2021)

4.7 HINFO and limitation of ANY queries

DNS implementations commonly use the keyword "ANY" to refer type code 255, defined to be "*" (RFC 1035). This ANY query refers to a DNS meta-query with QTYPE=ANY and ANY response is a response to such a query. ANY is expected to return all RRsets for a particular domain queried. ANY queries can be used to exploit the amplification potential of DNS servers and resolvers using

spoofed source addresses and UDP transport and to mine authoritative-only DNS servers for zone data.

Ability to return small responses to such queries and reduce potential for information leaks, makes DNS servers less attractive targets as amplifiers or information sources. A mechanism for an authoritative DNS server to state conventional ANY queries are not supported for a domain QNAME, is introduced in RFC 8482; Providing Minimal-Sized Responses to DNS Queries That Have QTYPE=ANY. DNS responder can return a synthesized HINFO resource record, a single HINFO RR returned with the CPU field of the HINFO RDATA set to "RFC8482" and the OS field of the HINFO RDATA set to the null string to minimize the size of the response (Internet Engineering Task Force (IETF) 2019).

DNS servers provide dynamic answers to questions. For example, depending on how a CNAME is configured, DNS may return the CNAME, fetch the real answer from the target of the CNAME (CNAME Flattening), or provide addresses as answers. DNSSEC implementation signs answers on-the-fly, so returning an ANY answer with many different types of DNS RRs requires signing them all. Answer to an ANY query needs to compute all of the possible combinations of RRs just to know what to return. Answering ANY queries with all the records using DNSSEC has serious computational and response time issues and therefore high costs as well.DNSSEC is one main cause of large answers used for DDoS attacks, due to attackers using ANY queries to maximize the amplification factor and DNS servers not configured to suppress ANY. Attempts to use DNS system as a source of reflection for amplification attacks can be mitigated by deprecation of ANY answers, and not returning larger than needed answers at all. With the same time enabling more secure singned answers and less information about domain Holders assets given out to potentionally malicious queries (The Cloudflare Blog, Ólafur Guðmundsson 2016).

4.8 Domain Name System Security Extensions (DNSSEC)

Domain Name System Security Extensions (DNSSEC) is a method of data origin authentication and integrity for the DNS System. DNSSEC is descibed in a family of RFC-documents, including core DNSSEC documents (RFC 4033, RFC 4034, and RFC 4035), NSEC3 specification (RFC 5155), NSEC3 and SHA-2 (RFC 4509 and RFC 5702) and Clarifications and Implementation Notes (RFC 6840). DNSSEC includes a collection of RRs that defines the public key (DNSKEY), delegation signer (DS),

resource record digital signature (RRSIG), and authenticated denial of existence, next secure (NSEC/NSEC3) (Internet Engineering Task Force (IETF), S. Weiler, D. Blacka 2013).

DNSSEC RRs purposes are:

- RRSIG contains a cryptographic signature
- DNSKEY contains a public signing key
- DS contains the hash of a DNSKEY record
- NSEC and NSEC3 for explicit denial-of-existence of a DNS record
- CDNSKEY and CDS for a child zone requesting updates to DS record(s) in the parent zone.

Email MTAs use DNS to route messages. This means that email delivery is vulnerable to security issues in the DNS infrastructure. Attackers can exploit vulnerabilities in DNS, because by desing it does not check for any credentials before accepting an answer. Email supposed to be sent recipients servers have a risk of routing instead through rogue mail servers. To address this vulnerability DNSSEC can be applied. It provides authentication of DNS records and as such adds a layer of trust on top of DNS. When a DNS resolver is looking for “subdomain”.”domain”.fi, the name servers of .fi ccTLD help the resolver to verify the records returned for “domain”, and “domain” helps to verify the records returned for “subdomain”. Root DNS name servers verify .fi ccTLD and information published by the root is verified by a security procedure, including the Root Signing Ceremony (Cloudflare 2021).

Hijacking email using relay through another email server is one DNS related vulnerability. By poisoning DNS caches so that they can inject their own mail server into the delivery path, emails might get delivered, but it is unknown whether they were modified before delivery or simply logged and monitored. Email is transmitted asynchronously, so the author and recipient are not likely to notice anything out of the ordinary. If the email is not entirely cryptographically protected, intermediate servers can read, modify and even add malicious content to it. Opportunistic TLS encryption between mail servers does not help, because it only ensures the confidentiality of messages in transit, not at the intermediate. DNSSEC is designed to prevent this type of attack by signing DNS RRs with DNSSEC and cryptographic signature added including MX records. Inbound emails will not be hijacked due to DNS poisoning, assuming the sender is performing DNSSEC validation on the DNS resolver that the sending email server uses (Internet Society, Dan York 2014).

4.9 Other techniques preventing email forgery

In addition to authenticating the sender of a message, the message contents can be authenticated with digital signatures. Signed emails protect especially against targeted phishing attacks, as users who expect signed messages are more likely to be suspicious if they receive unsigned messages. Because Security in Multi-Purpose Internet Mail Extensions (**S/MIME**) uses existing PKI infrastucture, it is the recommended format for digitally signing messages. S/MIME messages that are signed with a valid digital signature will automatically validate Because support for S/MIME is present in modern mail clients. Only a single certificate is required for signing mail and software for verifying S/MIME signatures is already commonly in use. This is particularly useful for messages that are designed to be read but not replied to, for example status reports, alerts and announcements to distribution lists. For S/MIME digitally signed messages, a S/MIME certificate where the sender matches the message-From: address is used to sign the messages. Message is first composed and then the mail client software uses both the S/MIME certificate and the private S/MIME key pair to generate the digital signature. Signatures contain both the signature and the signing certificate, allowing recipients to verify the signed message without having to fetch the certificate from a remote server. Certificate is validated using PKI. Receiver of the signed S/MIME message uses the sender's public key from the sender's attached X.509 certificate and validates the digital signature. Receiver should also check to see if the senders certificate has a valid PKIX chain back to a root certificate the receiver trusts to further authenticate the sender. Reason for not using S/MIME signing of organizational email has been the lack of attention to the issue (National Institute of Standards and Technology 2019).

SMTP MTA Strict Transport Security (**MTA-STS**) is a method to declare the ability to receive Transport Layer Security (TLS) secure SMTP connections and to specify if sending SMTP servers should refuse to deliver to MX hosts that do not offer TLS with a trusted server certificate. STARTTLS extension (RFC 3207) enables clients and hosts to use of a TLS channel for encrypted SMTP mail transmission. This opportunistic encryption protocol provides mitigation against passive man-in-the-middle attacks, but if the STARTLS response or other parts of the SMTP session can be deleted or the SMTP session redericted by DNS poisoning or otherwise overwriting the resolved MX record for the delivery domain, downgrade or interception attacks pose a risk.

MTA-STS defines a mechanism for recipient domains to publish policies, a combination of DNS TXT RR and HTTPS available policy-file from the domain. Policy specifies if MTAs sending email to this domain can expect PKIX-authenticated TLS support and what should a conforming client do with messages if TLS cannot be successfully negotiated. MTA-STS rely on certification authorities (CAs) and per- domain policies deployed. MTA-STS policies are distributed via HTTPS from a well-known public path within the Policy Domain, full URL beeing https://mta-sts.[domain.fi]/.well-known/mta-sts.txt. TXT RRs additionally contains a policy "id" field for email sending MTAs to check if a cached policy is still current without performing a new HTTPS request. This id is a string of 1 to 32 alphanumeric characters and needs to be updated every time there is a change to the policy file (Internet Engineering Task Force (IETF) 2018).

Example of a basic MTA-STS TXT RR and TLS reporting RR:

```
_mta-sts.<domain> <TTL> IN TXT "v=STSv1; id=xxxxxxxxxxxxxxx;"
_smtp._tls.<domain> <TTL> IN TXT “v=TLSRPTv1; rua=mailto:<rua address>”
```

Example of a basic mta-sts.txt policy-file, for the domain [domain.fi]:

```
version: STSv1
mode: testing
mx: mail.[domain.fi]
mx: *.[domain.fi]
mx: mail2.[domain.fi]
max_age: 604800
```

DNS-Based Authentication of a Named Entities (**DANE**) is also designed to upgrade unauthenticated encryption or plaintext transmission into authenticated, downgrade-resistant encrypted transmission (RFC 7672). As MTA-STS implements transport security for domains when deploying DNSSEC is impractical or otherwise not wanted, DANE uses DNSSEC for authentication and DNSSEC is reguired in order to deploy DANE. MTA-STS is also designed not to interfere with DANE deployments when they are both used and configurations overlap each other. MTA-STS Policy validation is not intended to override a failing DANE validation (Internet Engineering Task Force (IETF) 2018).

DANE implements DNSSEC infrastructure for signing and storing TLS keys and certificates. DNSSEC provides a similar model as Certification Authorities" (CAs), where trusted keys are used to sign information for untrusted keys. CAs protect their secret keys extremely intensely, while supplying

public keys to TLS clients. DNSSEC provides three significant improvements in regards of email usage. Keys are tied to Internet protocols friendly DNS-names, not arbitrary identifying strings. Signed keys are accessible with a DNS-query using standard DNSSEC protocol, enabling easy and efficient distribution of signed keys for any domain. Most important, the keys associated with a domain name can only be signed by a key associated with the parent of that domain name. For example, keys for [domain.fi] are signed by keys for [.fi] and keys for [.fi] are signed by the DNS root. Compromise of a key only affects the comprimized organizations own subdomains and prevents any untrustworthy signer affecting others. DNS RR named TLSA is defined to associate a TLS server certificate or public key with the domain name where the RR is configured, forming a TLSA certificate association (Internet Engineering Task Force (IETF) 2012).

Example of a basic TLSA RR:

```
_<port>._<protocol>.<host>  <TTL>  IN  TLSA  0 0 0 00000000000000000000000
```

Any computer connecting a website that uses DANE to publish certificate information in DNS can verify that the DNS server responding is the correct one and that any responses from that server has not been altered, which means that the IP address provided for whichever service requested is most likely correct. Also, information related to the certificate received through DNS can be validated and then compared to the certificate presented by the website. If the certificate does not match, the browser should abort the connection process and determine the website is insecure or fraudulent. DANE is not limited to HTTPS and any service that use TLS certificates could use DANE, such as email and Instant Messaging. There are still very few applications that have built in support for DANE out of the box and users have to rely on third-party extensions (Rikard Sandelin 2017).

Both MTA-STS and DANE are rather new email security techniques and common usage in implementations has not yet been achieved. As wide spread threats are being exploited and new rising vulnerabilities emerge, interest in deploying either or both are also coming into sight. Both Microsoft and Google, with several other cloud-based email service providers, have announced their development and support for MTA-STS and DANE during 2020 and 2021.

5 Statistics and analysis

5.1 State of email security implementations in Finnish municipalities

5.1.1 General status of municipal email security

In total there were 5,364 domains registered to municipalities and joint municipal authorities at the time of this studies information gathering at 2 march 2021. 3433 (64.00%) of these domains had email services configured according to DNS MX RRs and 437 (8.15%) were used as the primary official email domain of an authority. 3,840 (71.59%) were registered to municipalities, with 2,532 (65.94%) configured to email usage and 309 (8.05%) used as primary email domains. 1,524 (28.41%) domains were registered to joint municipal authorities, with 901 (58.43%) configured to email usage and 128 (8.30%) used as primary email domains. Worth noticing is where every municipality has an official email address, not all joint municipal authorities do. Out of 139 joint municipal authorities, just 128 have an official email address and a related domain. 11 of them use an email domain held by one of their owner-municipalities or do not announce an official email at all.

The overall situation of applying email security configurations in municipalities is deficient. In mainland Finland 71.38% of all domains do not have a SPF policy in place and 94.23% do not have a DMARC policy in place. The situation is slightly better with domains in email usage (MXInUse true) and even better regarding the primary email addresses (Is1stEmail true), especially with SPF implementation as in mainland 93.72% and in Åland 82.61% of these domains have an SPF policy in place, and with around half of these stating SPF hardfail. Overall SPF and DMARC implementations are shown in Table 6. All of the primary email domains are correctly configured as email intended domains and have the appropriate MX RRs in place (MXInUse true), wich was verified by the searches conducted in the study.

Table 6. SPF and DMARC policy implementation percentages

FQDN		SPF				DMARC				
	domains	false	hardfail	nostance	softfail	false	none	quarantine	reject	unknown
Ahvenanmaa										
All domains	26	19,23 %	46,15 %	11,54 %	23,08 %	92,31 %	7,69 %	0,00 %	0,00 %	0,00 %
MXInUse true	26	19,23 %	46,15 %	11,54 %	23,08 %	92,31 %	7,69 %	0,00 %	0,00 %	0,00 %
Is1stEmail true	23	17,39 %	47,83 %	8,70 %	26,09 %	91,30 %	8,70 %	0,00 %	0,00 %	0,00 %
Manner-Suomi										
All domains	5338	71,38 %	11,20 %	2,59 %	14,84 %	94,23 %	5,17 %	0,36 %	0,22 %	0,02 %
MXInUse true	3407	57,73 %	16,58 %	3,73 %	21,95 %	91,49 %	7,81 %	0,50 %	0,18 %	0,03 %
Is1stEmail true	414	6,28 %	56,52 %	8,45 %	28,74 %	80,68 %	17,63 %	1,21 %	0,48 %	0,00 %
Total	**5364**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**

The implementation rates of DMARC are quite small, specifically with secure quarantine and reject policies. This unfortunately means that configurations considered secure as seen in Table 5, will be even more of a minority when comparing different classifications later on. That is why the secure email DNS configurations, with combination of well aligned SPF and DMARC together, were analysed and documented in Appendixes 3, 5 and 6. But also the configurations of SPF RRs were taken into a closer look separately, to find more accurate differences in comparisons and analyses between organizations state of maturity.

DNSSEC is also experiencing a lack of popularity, as only 204 domains, 3.80% of all target domains have DNSSEC implemented. The state is somewhat better with the primary email domains, probably because the primary email domain is often the main, most used, domain of the organization. Although the penetration rate is overall small, municipalities have relatively implemented DNSSEC much more than joint municipal authorities. DNSSEC coverage is shown in Table 7. Small number of DNSSEC coverage makes it an impractical addition to include in the comparison of security implementations in different study objectives chosen. Therefore, DNSSEC will not be combined to SPF and DMARC implementations discussed later, but will be observed separately.

Table 7. Usage of DNSSEC in municipalities and joint municipal authorities

	All organizations			Municipalities			Joint municipal authorities		
FQDN	**All domains**	**MXInUse true**	**Is1stEmail true**	**All domains**	**MXInUse true**	**Is1stEmail true**	**All domains**	**MXInUse true**	**Is1stEmail true**
DNSSEC									
no %	96,18 %	96,50 %	94,28 %	95,23 %	96,01 %	94,17 %	98,56 %	97,89 %	94,53 %
yes %	3,80 %	3,47 %	5,49 %	4,77 %	3,99 %	5,83 %	1,38 %	2,00 %	4,69 %
yes domains	204	119	24	183	101	18	21	18	6

As the usage of DNSSEC is so low, the implementations of DANE as an email securing method, remains a possibility for the few that have DNSSEC in place. For the small number of possible organizations using DANE, further investigation of DANE was not included in the comparison of DNS settings in municipal organizations. In comparison to Swedish .se domains implementation rates of 49% or 686,471 out of 1,406,335 DNSSEC signed domains in 2017 and only less than 0.1% of these domains using DANE, with HTTPS as the most common usage and email following second (Sandelin 2017). Expectation of DANE implementations in the 3.80% of DNSSEC signed domains of Finnish municipal organizations is marginal.

MTA-STA records were searched for on the TXT RRs with a search string of “v=STSv1;”, but no records in any of the DNS answer files were found. So, it can be stated that MTA-STA is not used for securing email in Finnish municipalities or joint municipal authorities at the time of this studies data collection.

5.1.2 Differences by region

Evaluating differences of domain implementations in municipalities and joint municipal authorities by their area, it can be seen that domains are divided into the organizations quite even by region. Especially in mainland Finland the number of domains in every NUTS 2 (greater) area is around the same. Differences are seen in the NUTS 3 areas, as the more densely populated, larger regions probably have more and bigger organizations with more domains. Uusimaa as the location of the capitol Helsinki and other big cities stands out as a region, but not as a NUTS 2 greater area. The division of domain by region is shown in Table 8.

Table 8. Municipal domains registered in different areas

	All organizations			Municipalities			Joint municipal authorities		
Region (NUTS 2 & NUTS 3)	All domains	MXInUsetrue	Is1stEmail	Domains	MXInUsetrue	Is1stEmail	Domains	MXInUsetrue	Is1stEmail
Ahvenanmaa	**26**	**26**	**23**	**18**	**18**	**16**	**8**	**8**	**7**
Ahvenanmaa	**26**	**26**	**23**	**18**	**18**	**16**	**8**	**8**	**7**
Ahvenanmaa	26	26	23	18	18	16	8	8	7
Manner-Suomi	**5338**	**3407**	**414**	**3822**	**2514**	**293**	**1516**	**893**	**121**
Etelä-Suomi	**1084**	**595**	**89**	**858**	**458**	**63**	**226**	**137**	**26**
Etelä-Karjala	112	66	12	89	55	9	23	11	3
Kanta-Häme	130	97	16	98	69	11	32	28	5
Kymenlaakso	141	74	9	122	59	6	19	15	3
Päijät-Häme	141	99	14	99	70	10	42	29	4
Varsinais-Suomi	560	259	38	450	205	27	110	54	11
Helsinki-Uusimaa	**1434**	**788**	**42**	**917**	**563**	**26**	**517**	**225**	**16**
Uusimaa	1434	788	42	917	563	26	517	225	16
Länsi-Suomi	**1409**	**973**	**126**	**1078**	**754**	**93**	**331**	**219**	**33**
Etelä-Pohjanmaa	230	181	28	186	146	18	44	35	10
Keski-Suomi	218	175	27	169	142	22	49	33	5
Pirkanmaa	428	241	28	360	206	23	68	35	5
Pohjanmaa	335	235	22	188	137	14	147	98	8
Satakunta	198	141	21	175	123	16	23	18	5
Pohjois- ja Itä-Suomi	**1411**	**1051**	**157**	**969**	**739**	**111**	**442**	**312**	**46**
Etelä-Savo	170	138	19	135	107	12	35	31	7
Kainuu	95	76	11	76	63	8	19	13	3
Keski-Pohjanmaa	99	60	12	50	36	8	49	24	4
Lappi	254	164	31	180	119	21	74	45	10
Pohjois-Karjala	193	183	16	87	83	13	106	100	3
Pohjois-Pohjanmaa	375	299	42	280	227	30	95	72	12
Pohjois-Savo	225	131	26	161	104	19	64	27	7
Domains in total:	**5364**	**3433**	**437**	**3840**	**2532**	**309**	**1524**	**901**	**128**

As there was no OData interface known available for querying registered domains for the known Organizations (IDs) under the .ax ccTLD, the gathered domains from organizations located in Åland were limited to the domains the organizations publish as their primary domains. Therefore, the

comparison in the domain statistics can be reliably conducted only for the primary email domains (Is1stEmail true).

Secure DNS configurations for email in municipal organizations by region are shown in Appendix 3. From all domains studied only 0.48% fulfil secure deployment criteria of email related DNS RR configurations. None of the .ax fulfils these requirements. Regarding email domains the number is 0.58% and for non-email domains 0.31%. For primary email domains 1.60% can be considered secure in configurations. Protections for primary email domains are there for three times better than email domains, and five times better than non-email domains. In Uusimaa finds the most secure configuration combinations, with 12 secured domains. Other regions with secured domains are Pohjanmaa (4), Pohjois-Pohjanmaa (4), Etelä-Savo (2) and Päijät-Häme, Varsinais-Suomi, Pirkanmaa, Pohjois-Savo (1).

When looking at just the most common used email security implementation, the SPF, differences are revealed. Division of SPF implementations in regions is shown in Figure 9 and for comparison in NUTS 2 greater areas in Figure 10. Division of primary email domains SPF implementations in regions is shown in Figure 11. It is clear that Uusimaa is the region that has the most email domains and by far most email domains not secured by SPF at all. Still It should be remembered that Uusimaa is both a NUTS2 and a NUTS3 area, where as other regions are just NUTS 3 as seen in Figures 9 and 11. Out of all the 5,364 domains, 71.12% (3,815) have no SPF RRs and totally lack implemented SPF policy. 11.37% (610) have SPF hardfail, 14.88% (798) softfail and 2.63% (141) nostance. Out of 3,433 email domains 57.44% (1,972) have no SPF policy. 16.81% (577) have SPF hardfail, 21.96% (754) softfail and 3.79% (130) nostance. But out 437 primary email domains only 6.86% (30) have no SPF policy. 56.06% (245) have SPF hardfail, 28.60% (125) Have SPF softfail and 8.47% (37) have nostance. Overall most of the municipal domains do not have a valid SPF RR configured at all. But for the domains used in emails, the implementation rate gets better and for the domains used as primary email domains the situation improves even more. SPF actually covers the majority, 84.67% (370), of primary email domains in scope, with either hardfail 56.06% (245) or softfail 28.60% (125).

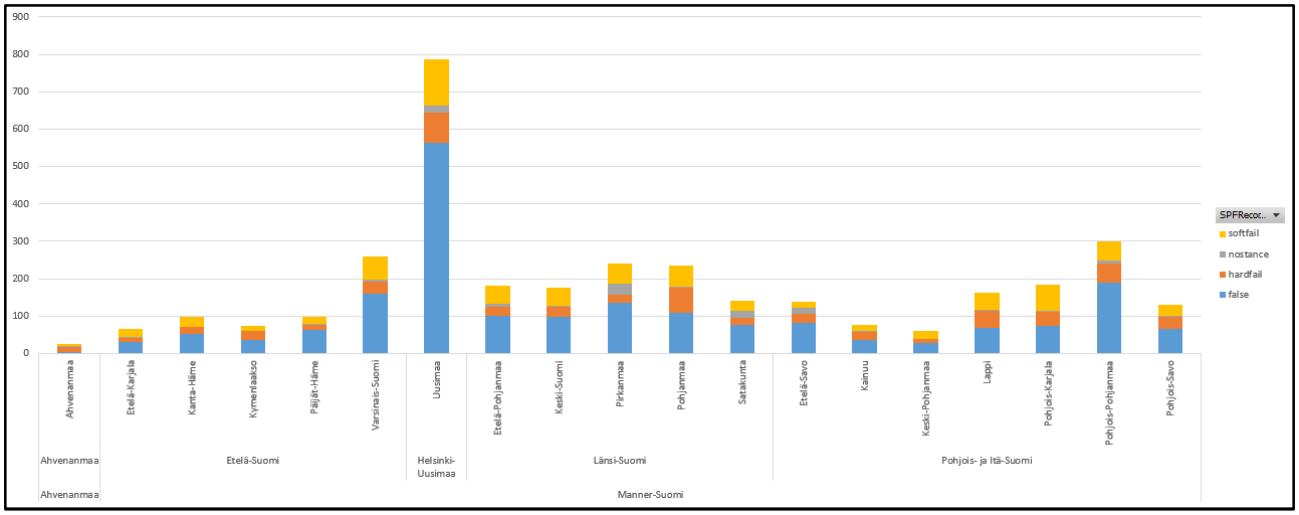

Figure 9. Email domains SPF implementations in regions (NUTS 3)

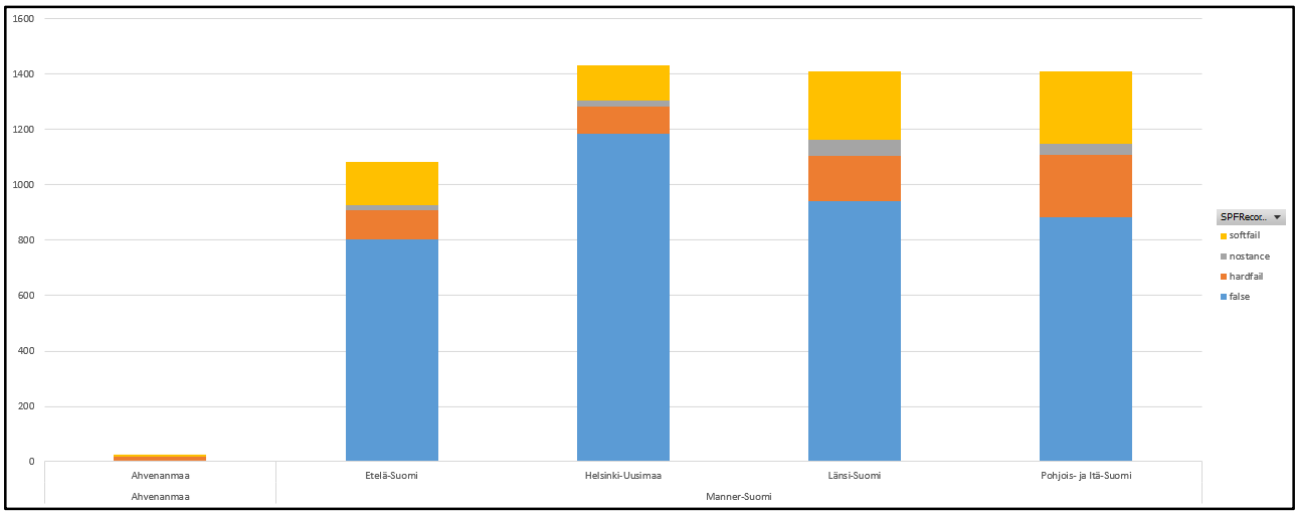

Figure 10. All domains SPF implementations in greater areas (NUTS 2)

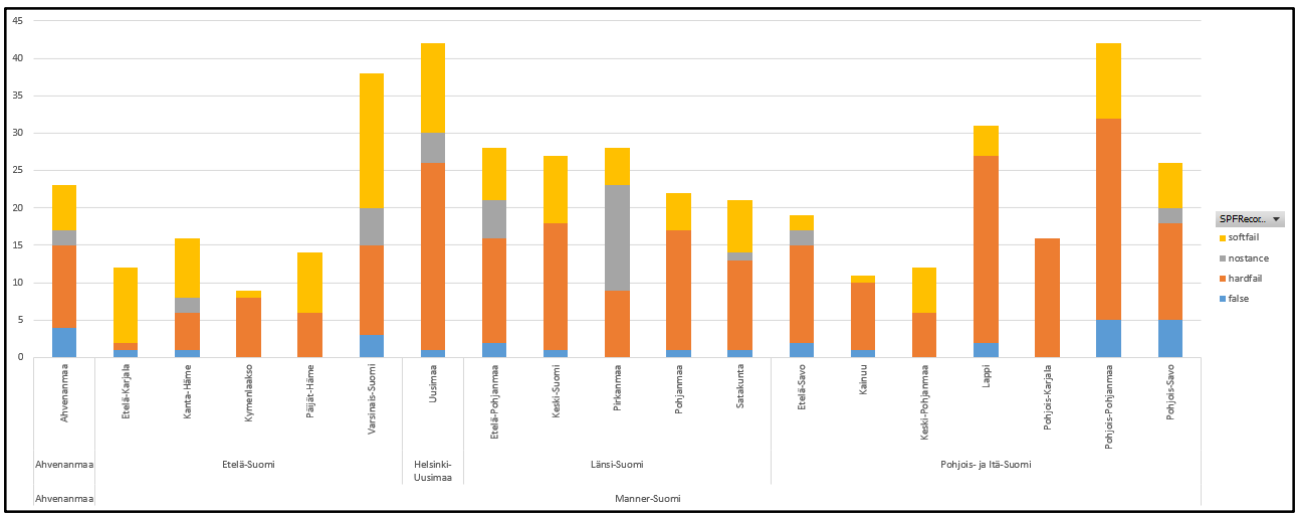

Figure 11. Primary email domains SPF implementations in regions

Looking in to the location of municipal organizations that have applied DNS configurations considered secure for email, no actual concentration or areas of better deployment rates can be observed. The location of organizations with secure deployments by their place of domicile is shown in Figure 12. Keeping in mind that defined secure configurations can only be found at 13 different organizations (2.95%), 9 of them municipalities (2.91%) and 4 joint municipal authorities (3.03%). Domains where secure configurations are applied present only a very small percentage of these organizations overall number of domains in use.

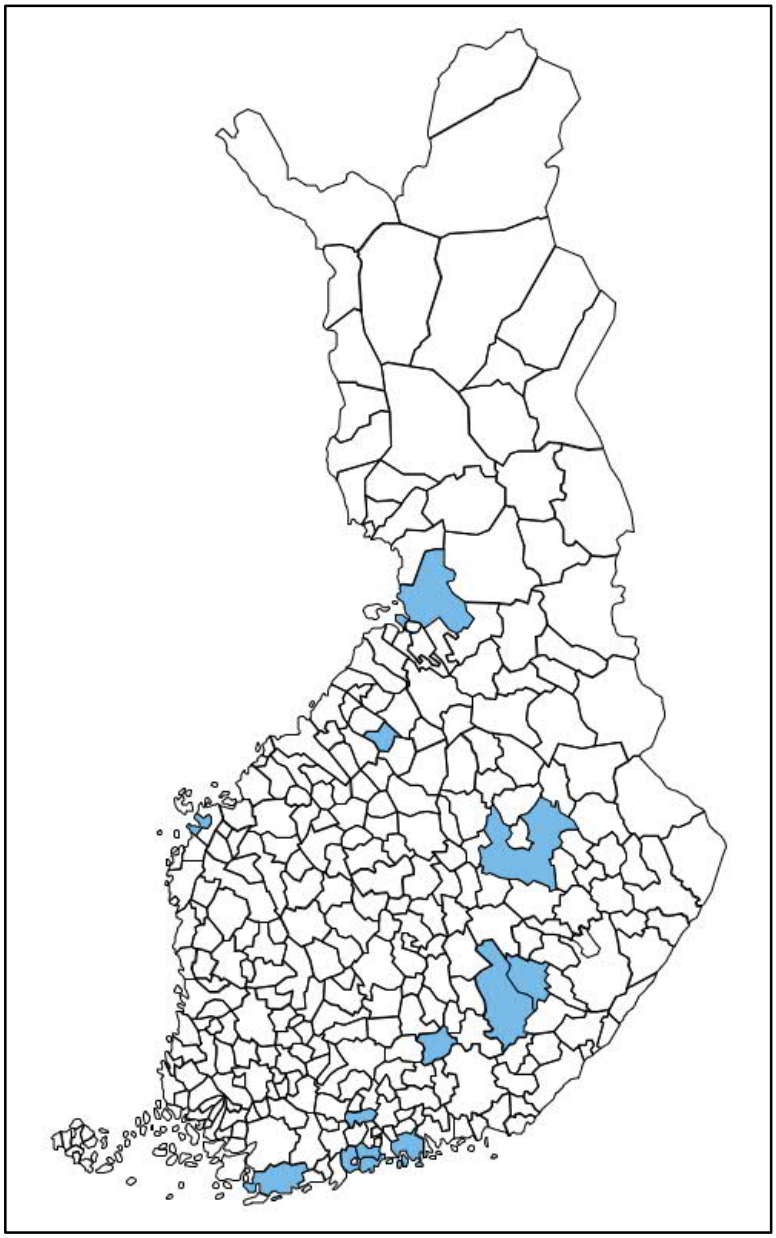

Figure 12. Location of organizations that meet a secure deployment criterion (©Tilastokeskus 2021)

The answer to the research question, is there recognizable differences between organizations' protective DNS configurations based on organizations' location, is no.

SPF as a protective measure for email has been implemented by organizations in all regions, and majority of regions follow the best practises of SPF hardfail regarding their primary email domains, followed by the adoption of also protective SPF softfail. One region stands out having all primary email domains configured with hardfail (Pohjois-Karjala), and only one has the majority of domains with nostance, leaving protective configurations incomplete (Pirkanmaa).

5.1.3 Difference by organization type

Looking into the differences of municipalities and joint municipal authority's usage, deployment and configurations by organization type is multidimensional. There is more than one way of gategorizing these organizations and these gategories both complement and overlap each other. For example, both towns and other municipalities are included in every statistical gategory of municipalities based on population. Declaring oneself to a town does not necessarily mean a big municipality could not be rural-like, or if a municipality is rural-like it does not mean it could not have large number of residents in a densely populated "city-like" center. Some organization types like the special care districts include a variety of various organizations. Some are cities, some are healt care districs and some are joint municipal authorities founded for that particular purpose.

Domains and their volumes in municipal organizations classified by organization type are listed in Appendix 4. Analyzing this data about domains we can observe the different nature of these organizations recarding their cyber presence. There are 5,364 domains in total for 441 organizations, which gives ~12.16 domains per organization in average by arithmetic mean. But if looked at the diffenrenses of volumes also by median number of domains in population-based groups and organization types, there can be seen very different ways of domain usage and registration policy among organizations. Average and median numbers of domains are shown in Figure 13. The biggest C21 Cities and other large towns have the most domains and there for most of the deployment's security in their responsibility. Health care districts are also among the big organizations that have a large national importance of public sector DNS configurations safety, but they are also organizations that have the most variation betveen average and mediun and there for the most difference in the ammount of registered domains between different organizations. Few bigger

health care districs have a lot of domains as the others are more equal. There are only six bigger organizations, which have registered more than 100 individual domains. Two of these organizations have registered more than 300 domains. One of these organizations is a health care district and the rest five are C21 cities. In total these top registers represent 1.36% of municipal organizations but their 1,310 domains represent 24.42% of all domains. More than half of all domains, 2,697, are in the possession of 35 biggest registrant organizations, showing that 7.94% of organizations are responsible for the security of 50.28% of domains.

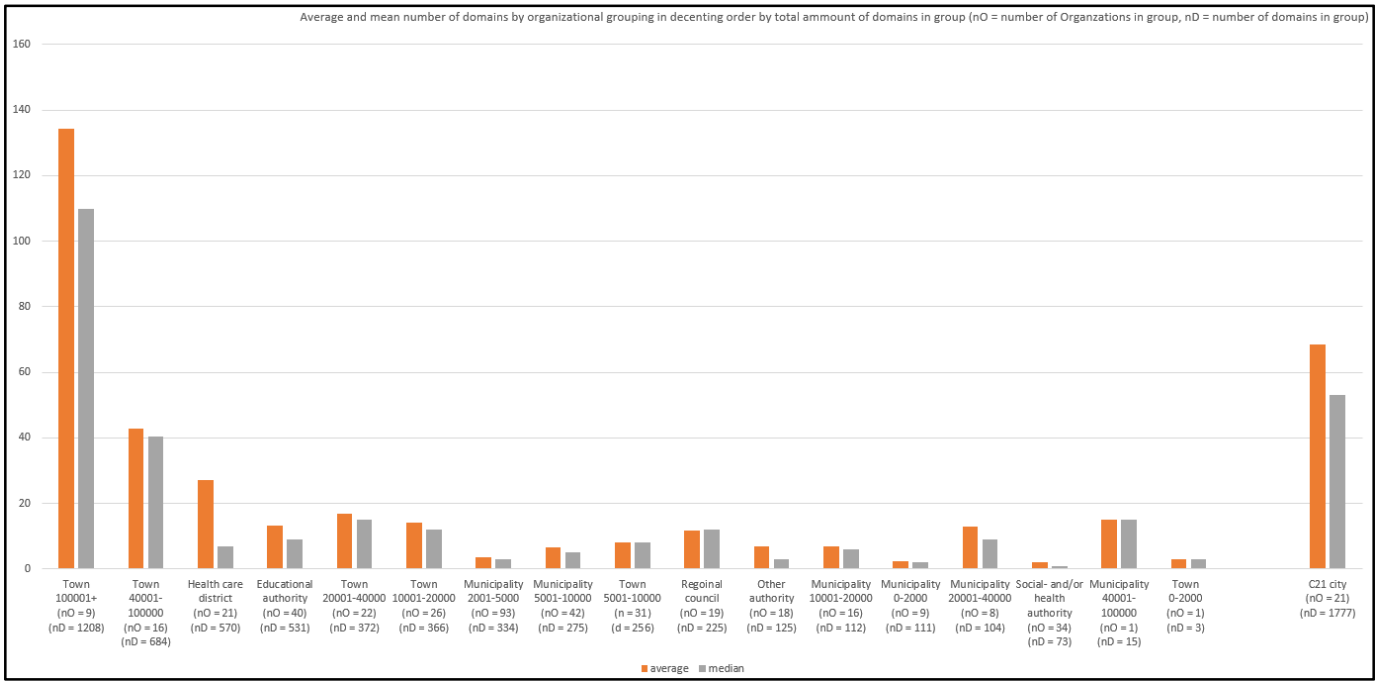

Figure 13. Average and median number of domains in organization groups

Looking into the state of email security by using DNS controls, the small number of actual deployments raise as the primary concern. In all of the target arganizations domains, only 0.48% are configured according to one of the criteria secure as shown in Figure 14. More detailed statistic of secure DNS configurations for email (Table 2) in municipal organizations by organization type is shown in Appendix 5.

	All target organizations		Towns		Other municipalities		Urban		Densely populated		Rural-like		C21 cities	
Criteria	count	%	count	%	count	%	count	%	count	%	count	%	count	%
MXInUse true + SPF -hardfail + DMARC -quarantine	8	0,23 %	4	0,22 %	1	0,15 %	4	0,28 %	1	0,22 %	0	0,00 %	3	0,27 %
MXInUse true + SPF -hardfail + DMARC -reject	2	0,06 %	1	0,05 %	0	0,00 %	1	0,07 %	0	0,00 %	0	0,00 %	1	0,09 %
MXInUse true + SPF -softfail + DMARC -quarantine	8	0,23 %	2	0,11 %	0	0,00 %	0	0,00 %	2	0,44 %	0	0,00 %	0	0,00 %
MXInUse true + SPF -softfail + DMARC -reject	2	0,06 %	1	0,11 %	1	0,15 %	1	0,07 %	0	0,00 %	1	0,16 %	1	0,09 %
MXInUse false + SPF -hardfail + DMARC -quarantine	1	0,05 %	1	0,10 %	0	0,00 %	1	0,11 %	0	0,00 %	0	0,00 %	1	0,15 %
MXInUse false + SPF -hardfail + DMARC -reject	5	0,26 %	4	0,38 %	1	0,38 %	4	0,44 %	0	0,00 %	1	0,52 %	2	0,29 %
MXInUse false + SPF -softfail + DMARC -quarantine	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
MXInUse false + SPF -softfail + DMARC -reject	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Total	**26**	**0,48 %**	**13**	**0,45 %**	**3**	**0,32 %**	**11**	**0,47 %**	**3**	**0,45 %**	**2**	**0,24 %**	**8**	**0,45 %**
n = Mxtrue	3433		1844		688		1448		454		630		1095	
n = Mxfalse	1931		1045		263		**911**		206		191		682	
n = all	5364		2889		951		**2359**		660		821		1777	

	Joint municipal authorities (all)		Educational authorities		Regional counsils		Health care districts		Social and/or health authorities		Other authorities		Special care districts	
Criteria	count	%	count	%	count	%	count	%	count	%	count	%	count	%
MXInUse true + SPF -hardfail + DMARC -quarantine	3	0,33 %	3	0,77 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
MXInUse true + SPF -hardfail + DMARC -reject	1	0,11 %	0	0,00 %	0	0,00 %	0	0,00 %	1	0,79 %	0	0,00 %	0	0,00 %
MXInUse true + SPF -softfail + DMARC -quarantine	6	0,67 %	4	2,78 %	0	0,00 %	2	1,12 %	0	0,00 %	0	0,00 %	0	0,00 %
MXInUse true + SPF -softfail + DMARC -reject	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
MXInUse false + SPF -hardfail + DMARC -quarantine	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
MXInUse false + SPF -hardfail + DMARC -reject	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	1	0,61 %
MXInUse false + SPF -softfail + DMARC -quarantine	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
MXInUse false + SPF -softfail + DMARC -reject	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Total	**10**	**0,66 %**	**7**	**1,32 %**	**0**	**0,00 %**	**2**	**0,44 %**	**1**	**0,52 %**	**0**	**0,00 %**	**1**	**0,19 %**
n = Mxtrue	901		388		128		179		126		80		357	
n = Mxfalse	623		144		97		272		65		45		163	
n = all	1524		532		225		451		191		125		520	

Figure 14. Secure DNS configurations deployment in municipal organizations by type

Rural-like municipalities have deployed less secure DNS configurations than densely populated or urban municipalities suggestive to the ammount of domains registered to them. This can be observed from the difference of 0.24% of rural-like municipalities compared to 0.45% in densely populates and 0.47% urban as well as the difference between 0.45% in towns compared to 0.32% in other municipalities. Educational authorities stand out with 1.32% as the only statistical group having a secure deployment rate over one percent. Regional counsil and other authorities have no secure deployments. The overall status of DNS configurations regarding email security are unfortunately remarkably low.

Comparing the SPF configurations regarding organization type, it can be seen again that the majority of all domains is registered to the largest towns. It is also evident no securing SPF configurations have been deployed for most of the domains configured with email service (MX) in Finnish municipals, as seen in Figure 15. In case of primary email domains, the deployment rate of SPF is significantly better, as seen in Figure 16. SFP Hardfail is the most used configuration for primary email services. Softfail as the second most used, nostance and false (no configuration) are minority. Still there are only three groups, two of them very small in ammount of organizations, that have on SPF hardfail or softfail. In most groups false or nostand is present in some of target domains.

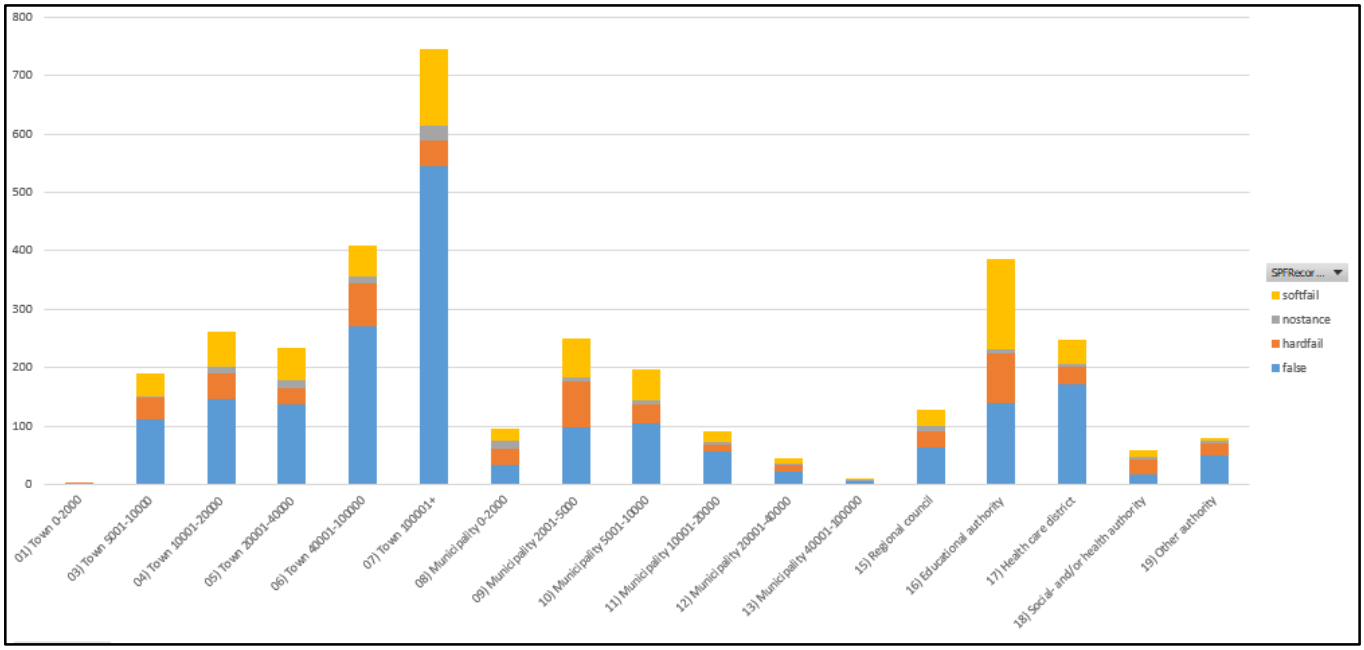

Figure 15. Email domains SPF implementations by organization type

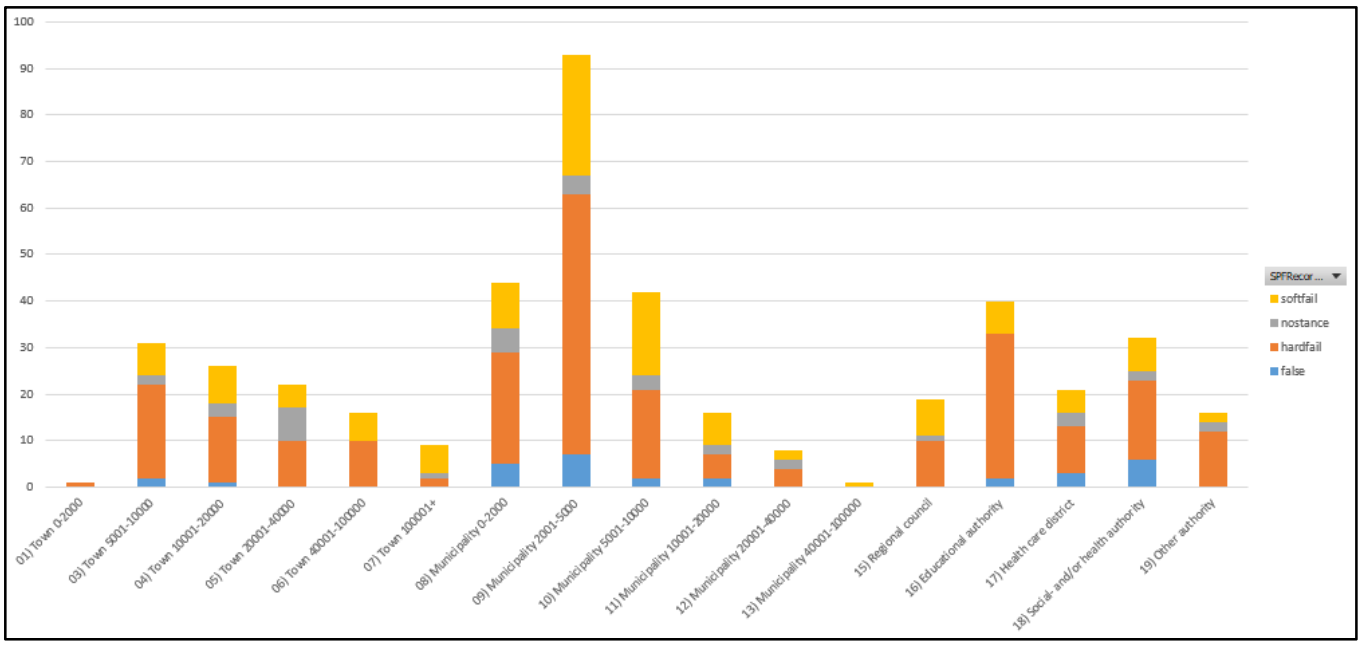

Figure 16. Primary email domains SPF implementations by organization type

The answer to the study question, Is there recognizable differences between organizations protective DNS configurations based on organizations statistical classification, is yes. In average, larger cities are found more mature than smaller municipalities. Also, educational authorities have an advantage regarding DNS security implementations including both SPF and DMARC.

5.1.4 Difference by language

Based on previous information about the state of DNS security deployments regarding email in other countries, it was known that these preventive configurations were more commonly used than in Finland. Kontinen describes statistics related to other nations deployments in his work, in chapter 3 (Kontinen 2020). Based on this information a presumption theory was made for study that using secure deployments might be more common in the bi-langual municipalities in the south and west coast for Finland.

As no secure configurations were discovered conserning the Swedish-speaking municipalities located at Åland, these were not included in the comparison. But a comparison between the other lingual groups was conducted by the following:

- organizations located at bilingual municipality with Swedish as primary
  - 152 of 3,407 MX domains, ~4.46%
- organizations located at bilingual municipality with Finnish as primary
  - 928 of 3,407 MX domains, ~27.24%
- organizations located at Finnish speaking municipalities
  - 2,327 0f 3,407 MX domains, ~68.30%

This analysis was conducted including all organizations in the lingual groups, depending of the language of the domicile of the organization, including both municipalities and joint municipal authorities. Secure implementations by lingual group is shown in Table 9.

Table 9. Secure DNS configurations in all email domains by lingual group

Municipal organizations by language					SPF -hardfail + DMARC -quarantine		SPF -hardfail + DMARC -reject		SPF -softfail + DMARC -quarantine		SPF -softfail + DMARC -reject		All together	
Secure DNS configuration for email	all domains		MX n	%										
Lingual groups	5338	100,00 %	3407	63,83 %	8	0,23 %	2	0,06 %	8	0,23 %	2	0,06 %	20	0,59 %
Finnish speaking	3363	63,00 %	2327	69,19 %	7	0,30 %	1	0,04 %	0	0,00 %	1	0,04 %	9	0,39 %
bilingual with Finnish as primary	1767	33,10 %	928	52,52 %	1	0,11 %	1	0,11 %	6	0,65 %	1	0,11 %	9	0,97 %
bilingual with Swedish as primary	208	3,90 %	152	73,08 %	0	0,00 %	0	0,00 %	2	1,32 %	0	0,00 %	2	1,32 %

Comparing different lingual groups for their relative percentage of secure DNS configurations in all email domains, Bilingual with Swedish as primary language has clearly the most secure configurations with 1.32% coverage and well above the overall 0.48% coverage of all domains and 0.59%

coverage of email domains. Bilingual with Finnish as primary has 0.97% and Finnish Speaking only 0.39%, which is well under the average.

Looking into SPF configurations between different lingual groups, relative to each groups' total amount of domains, differences are not so obvious as with only secure domains. Regarding all email domains, bilingual with Swedish as primary language is still most secure configured, with least of false and nostance deployments. But bilingual with Finnish as primary language has the most of false deployments and less hardfail or softfail configurations than Finnish speaking. SPF configurations status for email domains is shown in Figure 17. When comparing SPF usage in the primary email domains the order is the same as with the configurations considered secure, combining SPF and DMARC. Bilingual with Swedish as primary has 90.48% of primary email domains protected with either SPF hardfail (66.67%) or softfail (23.81%), where as bilingual with Finnish as primary has 88.57% (62.86% & 25.71%) and Finnish speaking has 84.64% (55.31% & 29.33%). SPF configurations status for primary email domains is shown in Figure 18.

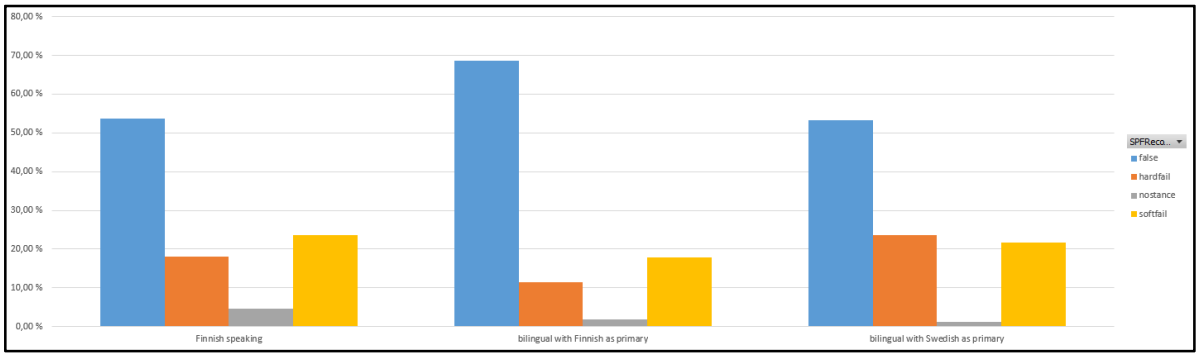

Figure 17. Email domains SPF implementations by lingual groups

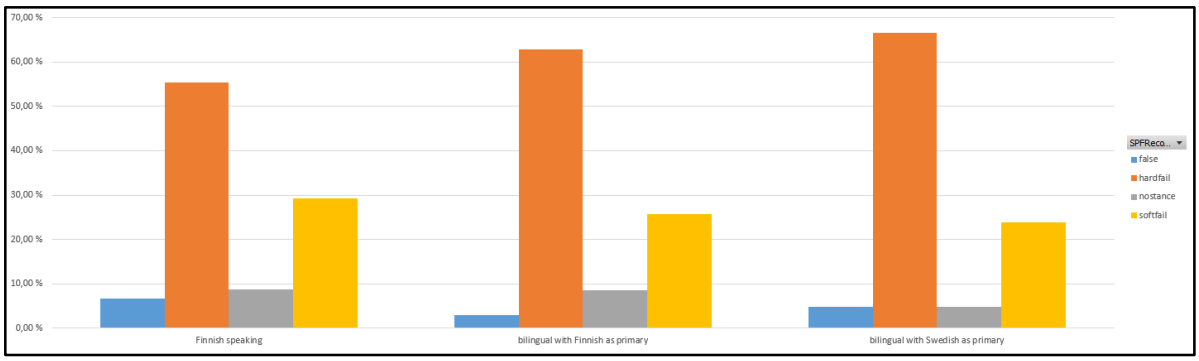

Figure 18. Primary email domains SPF implementations by lingual groups

The answer to the research question, Is there recognizable differences between organizations DNS configurations based on organizations language, is yes. Organizations in bilingual municipalities have deployed more secure configurations for protection of their emails.

5.2 Difference between on-premise and cloud-based email

One of current trends regarding business email is the transformation towards cloud services. This also applies to municipal organizations in Finland. As Skog describes in his work, a common case of migration is from a legacy email system to a cloud service and the renewal of organizations email system to a modern and functional email solution that enables employees' other cloud-based services, tools and storage (Skog 2019, chapter 5.1). Tiera's "Tiera Toimisto" ("Tiera Office") is a service including Microsofts O365/M365 solutions for productivity and lisencing, including Microsofts O365 cloud services for email and collaboration, along with other services like desktop applications or encrypted email.

To study the affect of this trend and these types of services, one research question was stated "Is there recognizable differences between organizations DNS configurations based on the usage of Microsoft's or Google's cloud email services?". By the used serach method there are 308 domains that have Google verification or other presense in ANY, MX and TXT RRs. 142 are present in MX RRs, indicating that the domains email service is at Google. Microsoft is present in 763 domains, including 747 email domains with 594 of these email domains configured to use Microsoft (Outlook.com) as their mail server. As Microsoft is the more popular service provider for municipal email domains, further analysis was conducted for Microsoft MX RR domains in comparison to the defined secure DNS deployments. Usage of Microsoft's email service in those domains considered secure is shown in Figure 19 and in more detail in Appendix 6.

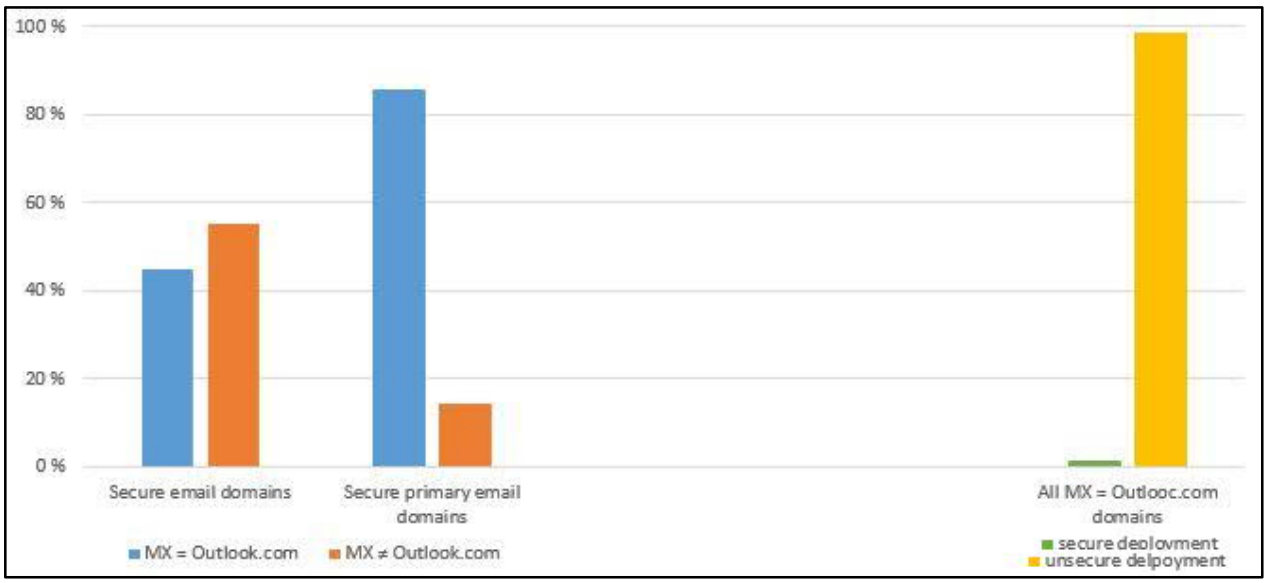

Figure 19. Secure DNS configurations in relation to Microsoft O365

Microsoft is the email service provider in 45% of the secure email domains and in 85.71% of the secure primary email domains. This concludes that deployment of DNS configurations is definedly more likely to be secure when the organization is using cloud email services from Microsoft. On the other hand, only 1.52% of domains using Microsoft as an email service provider has DNS configurations that are considerd secure. That is almost three times as likely as the overall situation, but a low percentage nevertheless.

As stated earlier, SPF is the most common security configurations applied to DNS regarding email security. Analysing SPF deployments for all email domains configured to use Outlook.com, SPF softfail is the most used actual configuration with 22.23%, followed by hardfail 5.35% and nostance 4.19%. But 68.12% are false with no SPF record at all, indicating that these might not actually even be domains intended for email, just domains where the MX is directed to the same MTA as the actual email domains of the organization. With primary email domains the SPF hardfail configuration is clearly most used with 71.55%, followed by softfail 20.20% and nostance only 1.85%. No records (false) is present with 6.40% of domains. SPF configurations in relation to Microsoft O365 is shown in Figure 20.

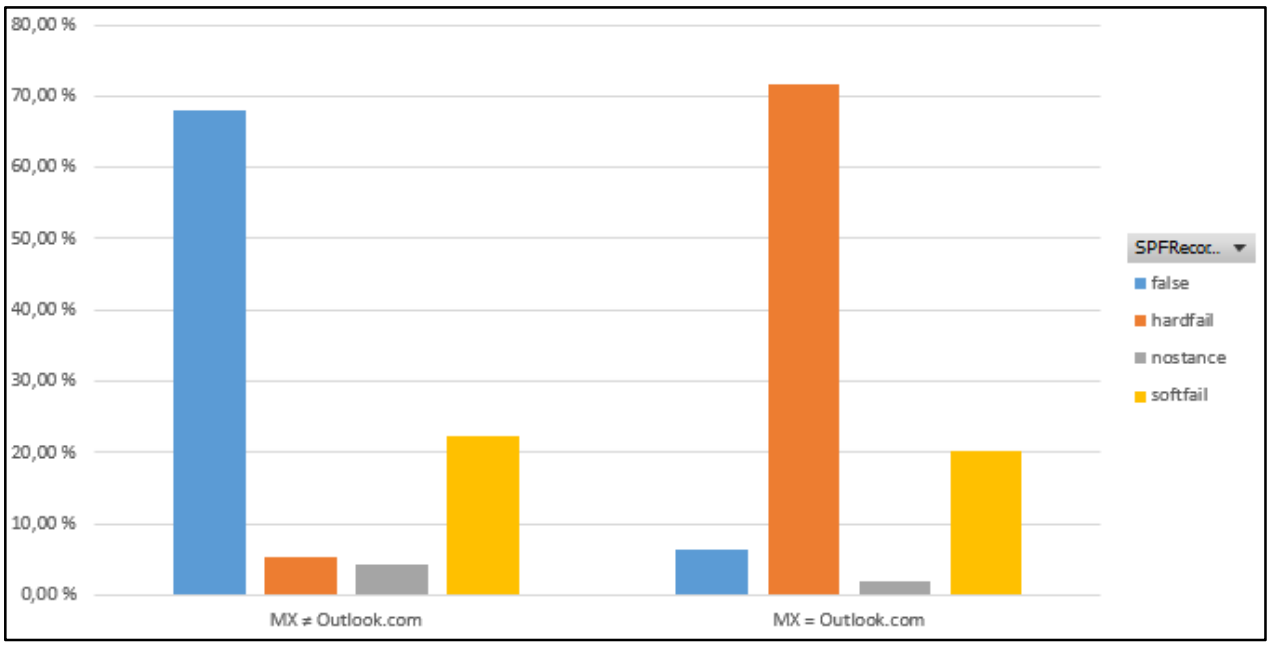

Figure 20. Email domains SPF configurations in relation to Microsoft O365

Current situation indicates that organizations paying overall attention to cyber security have implemented these controls during their cloud transformation and migration into cloud-based services in the past recent years. All organizations have not paid attention to secure configurations during their migration and others are still using more traditional email systems with propably little or no attention to DNS configurations for a long time.

Notice in this comparison should be given to the method of searching the Microsoft's and Google's email services in DNS server's answers. This was conducted using keywords "Outlook.com" and "Google" in MX RRs. Not taking in consideration the few noticed execptions where the actual MX RR is a CNAME reference to another FQDN, often the primary email domain of the organization, that has the actual MX RR with organizations mail server configuration. This means that some of the domains in this comparison may have been classified non-Microsoft (or non-Google) domains and that the volume of actual domains configured to use Microsoft O365 might be even higher than presented here.

The answer to the research question, is there recognizable differences between organizations DNS configurations based on organizations usage of cloud-based email service, is yes. It is evident that secure configurations are applied significantly more when using cloud services. SPF is the most

common control applied in municipal organizations in Finland using Microsoft O365. Applying secure DNS configurations is still not for granted even if cloud-based email is used and organizations should pay more attention in their DNS configrations even if using cloud instead of on-premise or ASP/ISP solutions.

5.3 Other analyses and subjects of interest regarding this study

Other analyses related to the scope and the research questions of this research were conducted for the discovery of organization related domains that could be used for forgery, phishing or misleading users. As exaples of these possibilities, the following tests were chosen:

Forgery by replasing letter "L" with letter "I" (lowercase "l" with uppercase "I")
Testing was carried out by replasing every "l"-letter in the 5,364 FQDN -domains with an "i" letter. This concluded in 2,755 domain name forgery possibilities (2,755 domains have at least one letter "L" in them). Noticing that not all possibilities were included, regarding the domains that have more than one "L"-letter, as they were all replased and not by every possible combination between "L" and "I" letters included, which would have given even a larger group of possibilities.

There were 19 domains discovered active with a possible letterchange-forgery. 5 domains were registered to private persons and were in their personal use. 11 were registered to different companies or societies. Mainly after their own organization name and used in their normal business use, but including 2 domains registered by an international business and more or less just parked. 1 domain was already so close by its name, it was in the possession of the same holder organization but in other use. 2 domains, both variations of primary email domains, were registered by a Finnish municipal organization in the use of forgery prevention and staff security training, 1 by a mid-sized town and 1 by an educational authority. Leaving 2,736 domains available for registration for the quickest and the possibility of the 16 domains found to end up as a treat factors for both the public authority or the private party holder, if they would be targeted indirectly to gain an attack vector against the authority.

The answer to the research question, are there fake domains present for the target domains, where in the domain name the letter 'l' is replaced by the letter 'I', is no. No malicious fake do-

mains were regognized. Two domains were registered in a way what can be concluded as a protective measure by the organization. The broad possibility of domain forgery by name-like registration is acknowledged as a risk, because the number of domains is large to begin with and registration of all possible combinations is not sensible.

Forgery by using the domain name with an alternative TLD

Testing was carried out by replasing the .fi TLD to all of the 5,364 FQDN domains, with TLDs including .com, .net, .biz, .org, .info and .fit. These include the most common used gTLDs and the gTLD .fit as it is very close to Finnish ccTLD .fi. Tested group of domain names ended up as a list of 32,184 possible domain names. The few .com and .net domains actually actively used by target organizations primary domain were not included in this test. 3,270 registered domains with alternative TLD were found to match the names of study target domains. 1,317 .com (24.55% of possibilities), 750 .net (13.98%), 160 .biz (2.98%), 579 .org (10.79%), 394 .info (7.35%) and 42 .fit (0.78%) domains. 44 XN domains were present with alternative TLD, including scandic characters in the domain name.

Total of 1,506 different domains found match with the study target domain names, giving the average of 2.17 alternative TLD registrations for a matching domain name. As some names were present with only one alternative TLD, others had several or all of these combinations registered. Registration includes both non-email and email domains as well as some of the primary email domains of the organizations. No deeper investigation regarding the registrars or holders for these domains were conducted and no analyses on these domains DNS records was performed with the methods used for the target domains.

The answer to the research question, are there fake domain registrations and/or DNS records present for the target domains names, but with a different TLD, is no. No fake domains could be regognized for sure by this superficial method. Yet it can be concluded that some domain name variations are registered by the municipal organizations (or partners), either as a protective measure or for actual business use. Some domains are most likely registered by a completely outsider party, for an unclear purpose.

Usage of common subdomains in municipal organizations, such as edu."municipality".fi

One tested method for harvesting organizational information about municipal organizations and authorities was the usage of common and widely spread subdomains. Testing was carried out by selecting the 437 primary email domains of the organizations and adding a subdomain edu. -prefix to them. DNS RRs were queried for ANY, A, TXT and MX records. 267 domains, 61.10%, were found to have noerror response and therefore were configured in dns for active use. 240 (89.89%) of these domains are used by municipalities, 18 (6.74%) by educational authorities and the rest 9 by other municipal authorities. 247 (92.51%) of these active edu-domains have MX RRs present and are configured for email usage, mainly intended for educational purposes suchs as pupils and teachers' emails.

Microsofts O365 is used as the email service provider in 123 (49.80%) edu email domains and Google in 91 (36.84%), rest beein directed to another MTA. SFP RR is present in 193 (78.18%) of email domains, with 144 (74.61%) hardfail and 49 (25.39%) softfail. SPF usage in the edu-subdomains is much higher than in email domains in general and there are no incomplete configurations present and most RRs stating hardfail with the rest at least softfail. Microsofts cloud service is authirized as sender in 138 RRs and Googles service in 113 RRs, with 61 RRs stating both of these cloud service providers are authorized. Only 2 SPF RRs point to other email servers and one is a statement of denying all email trafic.

DMARC was found in 16 domains, with policies set as 4 quarantine, 3 reject, 8 none and one unknown (misconfiguration). The 7 effective DMARC policies configured in edu-domains are also present in DNS configurations considered secure. Secure implementations covering just 2.83% of all edu email domains, percentage is still significantly better than it is in organizations primary email domains (1.60%). Status of secure implementations and especially SPF indicates that email security implementations regarding educational environments are applied when organizations migrate edu email services to cloud environments.

Usage of common domains and subdomains of 3rd parties

One important aspect of information technology services and their implementations in municipalities and joint municipal authorities is the wide spread usage of similar or same ICT-solutions, services and service providers. Many of these private information technology companies offer their

solutions to several municipalities provided by their own standard methods and implementations. Transformation towards the cloud has led to a situation where many if not most of these common services are provided as online SaaS or cloud solutions to asignificant part of Finnish municipalities. When ICT-services are used online from a MSPs owned and controlled service, the security implementations are also transferred to this 3rd party. SaaS and cloud services always rely on domain names and DNS configurations also, so the possible threats and vulnerabilities ably to these as well. Even on a bigger national scale, as more municipal organizations are coming more and more dependent on the security of configurations in these services.

To gain some perspective and view in this matter, two different type of services from two larger MSPs were chosen to be tested regarding the DNS configurations of email security. This possible real-life threat vector of email forgery could stand out quite effective, as these commonly used domains of trusted MSP-partners are usually considered safe and trustsworthy by recipients conducting normal daily interactions with these services and their providers. The chosen services were educational governance system Wilma by Visma software and a customer service system Kulutus-web for water supply, district heating and gas by CGI.

Wilma is hosted by Visma AS (Norway) in a domain called inschool.fi, registered in the holding of the company. The basic implementation is a SaaS environment for each customer, located in a sub-domain named “organization”.inschool.fi. As municipalities and joint municipal authorities are known and its common knowledge that many of them use Wilma for their educational services, it was in the study goal of this research to analyse and compare the implementation of DNS security controls in this service, related to the email security of Finnish municipalities. A query listing the possible organizations using Wilma-service was conducted combining the names of the organizations to the domain inschool.fi and then making DNS queries for ANY, A, MX and TXT records.

The status of the parent domain inschool.fi was that DNSSEC has not been implemented and HINFO/RFC 8482 was not in use, MX was present and SPF was configured with hardfail, but no DMARC RRs were present. Regarding the sub-domains of municipalities, there were 262 domains present and available according to responses from DNS-queries regarding these municipal organizations in target. 2 of these sub-domains were implemented with HINFO/RFC 8482, both of them in Cloudflares DNS service. The rest of these Wilma-domains basicly have only an A RR pointing to

the server hosting the individual Wilma-service. No MX RRs or TXT RRs including SPF were observed. As email uses A records as fallback if no MX is present and SPF does not inherit from parent domain do a child sub-domain and no DMARC was present at the domains, it can be stated that the possibility of email forgery of every one of these subdomains is easily possible at the time of DNS records retrieval in March 2021.

Kulutus-web.com is hosted by CGI and mainly used by the general public as consumer-customers of municipal organizations. Where municipal organzation's staff uses other aplications, only linked to the web-service kulutus-web. The basic implementation is a SaaS environment for each customer, located in a separate directory under the main domain. For example kulutus-web.com/"somemunicipality"/vesi/Suomi/index.asp, where "vesi" stands for water supply and can be also heat or gas depending on the service. Kulutus-web.com DNS records were retrived and analyzed to have MX RRs and a DMARC policy with p=none and RUA and RUF addresses stated. No DNSSEC, SPF policy nor HINFO/RFC 8482 configuration were in use. When no sub-domain architecture is used the implementations for DNS configurations regarding security are only needed to aply in the one main domain. With Kulutus-web service also, it can be stated that the configurations do not fullfill the stated requirements for secure configuration of DNS regarding email security and should be addressed as many municipalities are dependent and possibly affected by this depency.

These were just two superficial examples of widely used services, common in most of our municipalities all over Finland. A quick test regarding these possible vulnerabilities on email security, that could affect a large number of our public authorities, if abused before this issue is addressed. Allthough a larger group of MSPs or SaaS- or cloud-solutions were not included in this study, it can be stated that the lack of these controls lies in the ICT-solution supply chains as well. Assumably not just in these two exapmles observed, but as a "normal" state amongst many services. Adopting groving numbers of private vendors online-solutions into municipalities and elsewhere in the public sector without mandatory technical security reguirements and legistlation enforcement, is a continuously increasing risk for abuse or forgery sooner or later. On the other hand – when required or willing – MSPs and SaaS-vendors have the possibility to easily and quickly apply controls that emidiatly affect and protect a large portion of municipalities nation wide.

6 Key findings

6.1 state of email forgery preventing DNS implementations

In conclusion of the analyses conducted in the study, it can be stated that the controls available for preventing email forgery by applying technical DNS implementations are not commonly and efficiently used in Finnish municipal organizations. This answers the research question “What is the state of email forgery preventing DNS implementations in Finnish municipalities and joint municipal authorities in 2021?”.

Recognizable differences between organizations based on location are not present. Difference between organizations statistical classification reveal that larger cities are found more mature in regards of security controls than smaller municipalities. Also, that educational authorities have an advantage to other organizations regarding DNS security implementations, including both SPF and DMARC. Bilingual municipalities have deployed more secure configurations for protection of their email domains than Finnish speaking municipalities. Secure DNS configurations are also applied significantly more when organizations are using cloud-based email services.

6.2 Information available publicly

It is noteworthy, how unbelievably easy it was to find information about public authorities and about possible technical vulnerabilities related to them. This collection of organizational data was gathered as described in section 2.4. It became evident that with basic Internet search and some familiarization to municipalities web-pages and mandatory financial statements, the structures and subsidiaries of municipal corporations are available for anyone. If one can obtain this much information about these organizations this quickly in their spare time, it should be assumed that this information, and much more, is most certainly also in the possession of others. Possibly actors that might want to build readiness or directly affect the cyber resiliance of a selected organization among these authorities or in the Finnish society in general. Email, and especially the lack of its security controls, is an ideal means for that objective.

6.3 General findings and statistics

No statements as non-email domains:

MX RRs were searched from the DNS name server's responses as described earlier, and the difference between an email domain and a non-email domain was defined based on these results. For non-email domains there was also another verification, in which the domains that had a valid MX RR were searched for an explicit non-email domain RR with the MX domain set to plain "." (period). None of these records were found, so this states that none of the target domains for non-email usage, is actually configured to announce that "no email exchange is available". As A and AAAA RRs function as a fallback of MX, this should be included in the configuration baseline of all non-email domains DNS.

Usage of other TLDs:

One municipality was found using a .com TLD domain as well as one joint municipal authority was found using a .com and one using a .net TLD domains for their primary email (and primary website) domains. These Generic top-level domains (gTLD) domains are maintained by the Internet Assigned Numbers Authority (IANA) and originally intended for commercial entities business use (.com) and for network infrastructures (.net), but despite their original specification, are now open to use unrestricted. Other gTLDs, .biz, .org, .info, .edu, or .gov are not seen used by the Finnish municipal organizations as primary domains, although some originally intended usage might fit municipalities needs.

No systematic approach or pattern of domain registration regarding possible look-a-like domains, using other TLDs or naming variants, was observed in use regarding the .fi domains of municipal organizations. Few domains were registered as a protective measure and for staff training and various for possible protection against unwanted malicious registration or for possible future needs.

Minor usage of HINFO (RFC 8482):

HINFO RR is found in the records of 37 organizations, 29 municipalities with 69 domains and 8 joint municipal authorities with 10 domains. These represents only 9.39% on all municipalities and 6.06% of joint municipal authorities in this study. HINFO is used only in 1.47% of all domains, 1.80% of domains registered to municipalities and 0.66% of domains registered to joint municipal authorities. Only 39.24% (31/79) of domains that are configured to use HINFO are email domains

and only 10.13% (8/79) are primary email domains. Overall just 0.90% (31/3433) of all email domains and 1.87% of all primary email domains are configured to use HINFO and limit the information in answers to DNS queries for these domains. Noteworthy is that just 13 domains (16.46%) of these 79 domains using HINFO, have their DNS servers hosted by seven different MSPs and that the rest 66 domains (83.54%) DNS servers are hosted by Cloudflare. Cloudflare is noticed as a service provider with a true commitment in applying RFC 8482 guidelines and limiting unnecessary broad answers and exposure of DNS configurations information for their customers. Due to multi-provider usage of target organizations, there are various domain registrars for every domain holder. This shows also in the limiting of ANY requests, as organizations only have some of their DNS services configured according to RFC 8482, depending on the registrar of these particular domains.

No significate usage of other DNS security techniques:
For the domains that had DNSSEC enabled, no search for TLSA RRs was conducted. So, no final statement of weather DANE is used in some organization or not used at all, can be disclosed. What can be stated for sure based on the other findings, is that DANE is not widely used or a popular security technique amongst municipalities if in use at all.

MTA-STS RRs was searched for in TXT records and no RRs were found in any queries in the DNS answer files. It can be stated that MTA-STS is not applied in municipalities.

6.4 Integrity of registries

Total of 43 domains that were registered to a different organization as Holder, then the actual organization using that domain. 37 of these were domains had MXInUse true, so they are configured for email domain usage. 19 of these have Is1stEmail true, so they are used as primary email domains in an organization that is actually not the intended Holder of that domain. 18 of these domains are used by municipalities, which includes 16 email domains and 10 of them primary email domains.

Most of these mis-registered Holders information is due to municipalities mergers, were the Holder organizationID has been left unchanged during organizational changes and the ID in the registry is actually a retired non-existent organizations ID. Others are due to a host municipality

arrangement where one municipality, with dedicated ICT-resources, takes care of registration (and ICT in general) on behalf of others in the same region. Some domains are also registered to in-house companies OrganizationIDs as Holders, taking operative responsibility on behalf of their owners. But 4 domains have an individual person registered as the Holder organization instead of an actual organization, OrganizationaID still being correct. These flaws in registration information presents a possible vulnerability to the using organization, as they are dependent of these domains operatively, especially with the primary email domains, but might not have actual ownership or control to their key domain assets if needed rapidly.

Traficoms registry of the .fi TLD also has other issues in its integrity. The 5,336 domains studied are registered to organizations by the Organization types of “Company” (1 082, 20.28%), “Foundation” (2, 0.04%), “Government” (4, 0.07%), “Organization” (6, 0.11%), “Public community” (1 002, 18.78%) and “Town” (2 817, 52.79%). Most of the organizations have their domains registered to more than one Organization type category, with no consistency observed. No requirements, recommendations or guidelines were found to address the right, most accurate, information Municipal organizations should use when they register .fi or other domans. There is no method or process of verifying authority when .fi domains are registered to municipal organizations OrganizationID’s and every registered Domain Registrar can introduce or update registry information freely. There is also no continuous verification on the status of the OrganizationID’s status in the national Finnish Business Information System (YTJ) registry and changes in municipal organizations structures are not updated in the .fi registry.

Most of the organizations also have their domains divided to many different Registrars, assumably due to historical reasons and the purpose of these domains in relation to the registration prosesses used. This indicates that no real mandatory processes of procurement, maintenance or lifecycle is in in place in municipal organizations and responsibility, entitlement or ownership and authority of domain names as essential assets are not clear and understood.

6.5 Maturity of organizations

Observed from the overall lack of precision and to some degree of disorder in the registries as well the DNS configurations, it can be determined that a clear and unambiguous specification and guidance is missing from most organizations, regarding of how the public Internet domains should be

treated as valuable and operations critical assets. Who is allowed to acquire a domain for the organizations use and with what grounds? Who is the owner of a domain asset and which function of the organization is responsible to which action regarding that asset? What are the baseline registration information the organization determines to be used in the domains registered to its holding? What are the baselines and minimum configurations and settings to be applied for the organization's domains? How are these assets continuously monitored and annually reported for follow-up on integrity and security? All important aspects to be addressed in the Finnish municipal organizations widely.

Maturity regarding the actual DNS configurations security is unfortunately relatively poor. Dispite the small total number of deployments considered secure, it is evident that the larger organizations have greater volume of domains registered. This gives them both control and responsibility to implement secure configurations to a much larger portion of domains, compared to the other smaller organizations. Therefore, although every organization and domain counts, these large cities are the most significant organizations in regards of securing the municipal emails in Finland as a nation. Bigger, urban-like, municipalities and large municipal authorities are also expected to have more know-how and resources to secure their assets. As smaller ones are equally important, they need and should rely on their network of partners for secure deployments.

Municipalities dependencies on 3rd party security is also something to take notice of. The few examples of private systems depended by municipalities tested in this study, show that the same possible vulnerabilities and risks face municipalities also from their trusted service providers and partners. But no mandatory or agreement-based requirements or technical verification methods are in place at this moment.

Transformation to cloud services regarding email, especially from the large global providers Microsoft and Google, have made an improvement in the overall email security situation. As the transformation is still ongoing, further improvement is expected. But the impact has been rather small and focused mainly on the primary email domains and SPF as a technical control. Lack of systematic configuration of controls to non-email domains DNS implementations preventing their misusage, indicates that organizations domains and email traffic is not observed as a whole. But

rather than cloud migrations are conducted to the primary domains in daily focus and the rest are more or less forgotten and not paid attention to.

7 Suggested improvements

7.1 National approach with appropriate resource, regulation and yearly audits

Municipalities and joint municipal authorities form a significant part of Finnish public governance. This should be more in focus from national cyber security point of view as well, alongside government authorities. Attleast not disregarded nor unresourced. The reform of national healt care arrangement and establishing new welfare regions does not change these needs or significantly reduce the number of organizations or domains involved, but gives a good opportunity to re-arrange responsibilities related to the matter on a national scale.

Traficoms registry of .fi domains could be developed by integrations and automation, to gather basic information about public organizations, or maybe even for all organizations, from other registries maintained by other national authorities. For example, Organization information could be updated based on the Finnish Business Information System (YTJ). Including official contact information for organizations as well as the state of activity. Processes for authoritation of domain registration or change and the retirement of a domain Holder could be implemented, attleast when a public authority is in question.

National guidelines and enforcements should be stated and passed out to municipal organizations to address their domain assets and DNS security. Necessary funding for the required resource of implementations needs to be appointed for this particular use along with any enforcements. Actual technical change and operations recarding secure configurations and roll-outs of controls will not take place correctly and systematically if not funded properly equally on a national level. Lack of both regulatory demands and resources responsible can be stated from the current situation. These resources need to be (used) in the organizations responsible for the domains, for the centralized control of assets and related decisions are inline with the actual technical execution of security controls.

Enforcement of using the national ccTLD .fi for all public authorities, including municipalities and joint municipal authorities, should cover at least the primary email domain used by these organizations. As the gTLDs present in this study are maintained by IANA, there is no obvious threat of misuse or complications regarding the TLD-level. But to keep in mind that society needs also to be

prepared for exceptional circumstances, the domains used for governance should be overseen and if necessary controlled by responsible national authorities, not 3rd parties.

Municipal organizations them selves should conduct a more thorough investigation regarding their own domain assets. Investigate the possible fraud naming or TLD variations of their own domains, especially for domains used for email traffic. Follow up should be continuous and performed attleast annually to keep up situational awareness regarding organizations online presens.

As a national fallback solution, a commonly used email messaging solutions could be a preferred solution for municipalities and other authorities, for circumstances where their own normal messaging is not available. Usage of example national Suomi.fi -services with “municipality”.suomi.fi sub-domains as a “backup-platform” for all authorities’ should be investigated. Modelling how the email relay would be arranged and how messaging used between the organizations own and the national “backup system”, attleast regarding the official emails of authorities record offices.

7.2 Best practices and guidelines

One goal for this study was to form easy to use, understandable but still technical enough, guidelines for municipalities and municipal organization to use for their own management and administration of domains and email related security controls preventing email forgeries. These recommendations are published in Appendix 7 in English and Appendix 8 in Finnish. Every municipality and joint municipal authority are encouraged to implement DNS configurations considered secure.

First step is to take control of all the domain assets of the organization and create processes and instructions on handeling them. Second is the need to classify the domains to those where no email messaging should even take place and those that are meant for email messaging. From the email domains, it is essential to also regognize the most important domains, used as primary email domains that needs to be the most protected “crown jewels”.

Next the domains should be protected against email fraud, for example according to instruction in Appendix 7, and in more technical detail as described in referenced Implemetation Guidance: Email domain Protection by Canadian Centre for Cyber Security and NIST Special Publication 800-177 Trustworthy Email.

Finally, a process with efficient process-documentation for change management regarding both the registry information of organization and its domains and the technical configuration of domains DNS records need to be put into place. Annual, or otherwise continuous, review and audit methods need to be adopted as part of the organization's ICT and asset management.

7.3 Easy implementations with high impact

Verifying organization's registered information and simultaniously collecting up-to-date documentation can be executed as a one-time project, which will effectively result in a much better situation regarding these key assets. Observe the needed changes to registries and configurations inside the organization or with a trusted partner. First make plan of needed changes and then move on to implementing it. After this initial effort for correction of registry informations and DNS security configurations, make a schedule for annual review and enhancements. Deploying this kind of practice to municipal organizations will have an efficient affect nation-wide.

Non-email domains shoud be implemented with secure configurations as described earlier. Special attention during domain assets evaluation should be applied in wether a domain is needed for email communication or not. Assessing the high volume of 3,433 domains, 64% of all domains in the target group, being configured as email domains, but with no "Null MX" implementations present in the email domains, it is possible to conclude that some percentage of email domains (MX present) are actually not used for email at all, rather just having an outdated or misconfigured DNS settings. Properly checked and evaluated for real email needs, the ratio between email and non-email domains might actually be the other way around. Easy to implement configurations for all the actual municipal non-email domains would have a huge national impact on security and resilience against possible email frauds and followed up BECs against Finnish municipal authorities.

Precise implementation of DNS security features when implementing changes to organizations email-service is recommended. Every upgrade and migration are great opportunities to enhance the security of the organization by simply conducting the right secure configurations instead of insufficient ones. When having the right knowledge and information, the implementation of secure DNS records takes just as much time and effort as any other implementation for a service such as email to work and annual costs of DNS records are exactly the same regardless of their inner quality.

8 Conclusion

8.1 Reliability of findings

Regarding the study methods used, information collected and analyses performed based on publicly available statistics and previously conducted research, the findings in this project can be considered reliable. Giving an overall trustworthy understanding of the situation regarding email related security and ability of resilience against email frauds in Finnish municipal organizations. The findigs can be used as basis for future research or continuous monitoring of the subject.

As the research was conducted based on information gathered at a particular point in time and involves a great deal of DNS configurations which by nature are always changing, the results of this study should not be taken as a simple unambigious thruth of municipal email security. But rather as a baseline and starting point for national and organizational development and improvement.

Due to the small number in implementations of security tecniques such as DNSSEC and DMARC, a certain interpretation of differences between regional and organizational situations is needed. As with some simple changes to certain organizations or certain configurations, the overall status of these statistics could change dramaticly and rapidly. The stated findigs in this study still ably to the historical development of these security controls and current situation and on-going trends of implementations at 2021.

8.2 Discussion and evaluation

Main interest of this study and its analyses was to further deepen the knowledge of email related mitigation methods used in the target scope of municipal organizations and serve the intrests of Tiera and its owner-customers, as well as Traficom from a national point of view. overall this intentention was achieved and the stated research questions answered according to exceptations.

The use of Document analysis stands out as a very applicable method, as there are already existing databases for information about the study objective to be used as source documents. Usage of mixed methods was considered also, to possibly richen the collected information with specialist

interviews or questioners. Very early in the data collection phase, the amount of data to be processed and that the actual results and answers looked for, were answered by the outcoming results of the analysis. So, the outcomes of this research as something useful and new information, might be of interest to further study with some quantitative methods.

Another way of looking at the possibilities of information gained and methods used in this study, is to evaluate the usability of these findings in a wider national approach. What information can be easily obtained? From which sources this can be collected from? And what are the possible threat factors of revealed from this information, for example regarding a planned targeted attack to a specific organization? From this point of view furher development in the scope of this particular subject should be in the interest of national cyber security regarding organizations in critical industries. One way in investigating the state and situation awareness of actual real-world implementations currently in place. Another in greating a test and possible scenario environment for investigating the consiquences and mitigation methods for example in the national RGCE-environment, where real-like registries used in this study could be simulated and applied.

In his study, Skog describes the process and benefits for email systems migration to a more modern cloud service, with more enhanced messagin and collaboration features, as part of a municipal ICT-outsourcing project (chapter 5.1, page 18). Very little notice is taken into implementing and documenting the safety and security features of email during this change. This study adds to that knowledge about the ICT-outsourcing planning and production, with specified needs and deficiencies regarding DNS and email security aspects. Following the guidelines presented in this study and its source documents referenced, email migrations and implementations can be carried out more secure.

8.3 Ethical review

This study was conducted following the Degree regulations and Ethical Principles for JAMK University of Applied Sciences. All information gathered, processed and analysed were gained from public sources generally available online. Therefore, no study permissions were necessary for the research and otherwise work was carried out according to the needs and instructions of the commissioner. No copyrights were violated as they are presented as is required. The original sources of information are quoted and authors are referenced according to JAMK Thesis reporting

template 2021. Tools, services and software used in this study were either open source or licensed for personal and study purposes and communication services were applied according to regulations and service providers' terms of use. No personal information of individuals under GDPR regulation were intended to be gathered and analysed, but because of certain isolated contact information in the public national registries, some personal information related to certain organizations were included in the studied dataset. This collected information will be permanently removed after the acceptance of this study.

Findings made during this study regarding the integrity of .fi national registry and DNS configurations regarding private vendors were reported to CERT-FI and the responsible parties during November 2021, prior of the acceptance and publication of this study. These organizations were given the possibility and time to react on the findings if they choose to do so. Some of these findings, although not critical, could be considered as vulnerabilities or security configurations weaknesses that might be exploited after publishing. The whole gathered and combined dataset is not published because of its potential confidence and the fact that due to constant change in TLD registry and DNS configurations it would be already outdated in individual detail. Queries and questions about the data can be addressed to the author.

If and when promoted and then adopted by the target organizations, the outcomes and recommendations of this study could result in a significant improvement in email security and resilience against email fraud in Finnish municipalities and other organizations.

8.4 Further studies and development

Continuous improvement of all cyber related commodity is the key to better situational awareness. Therefore, improving national registries integrity by automation of monitoring, gathering and reporting available information from different sources combined and on-going development of quality of registry-services is essential.

One, easy to automate, possibility is gathering of the basic organizational data regarding municipalities. Or whatever other industry or type of Finnish organizations selected as a target scope. As the Business Information System (YTJ) offers a free to use online tool for information checks from

a web site, it is quite manual to use and repeating searches for updating information are not applicable. A solution for this part would be the usage of some API for the same database of information, as it is available from several different providers as a service. More information about the use of direct access to the data is available https://www.ytj.fi/en/index/opendata.html. This is something that could be investigated by for example MSPs, such as Tiera, regarding their customers or by Traficom for maintaining the -fi TLD-registry. When the possibility for easy access to organizations information about their domain assets is available and up to date, it is easier to focus on the actual technologigal solutions when the scope is clear. Security of technical solutions and safety of implementations and deployments used by municipal organizations or others are another thing to develop and automate. A possible solution for better and more secure DNS configurations could also be automation of the actual DNS RR configurations. Where the records would not manually updated, but scripted with predetermined “best practise” configurations, and choise of purpose and use of a particular domain, that would specify for example if the domain is intended for email usage or not, and add the necessary lines of protection against mail forgery automatically.

Other specific areas of potential further studies in the municipal scope are the usage of DNSSEC and DANE TLSA applying the methods presented by Rikard Sandelin (Rikard Sandelin 2017) to implement DANE for services like email and HTTPS. Or the configuration of DKIM in a selected organization or scope of organizations, covering primary email domains or all email domains. Studying DKIM would require a different kind of setup and controlled access to legimit massage-samples sent from all legit sources for these domains. These samples might even useful to combine with RUA reports information regarding these domains. Or the usage of SPF Macros as described in the RFC 7208 section 7.2, providing information about emails being sent using the specific domain. Research about these methods would given more indebth understanding of the comprehensiveness and effectiveness of email spoofing mitigations in addition to situational awareness of protective measures in place.

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Appendices

Appendix 1. Community classification

			NUTS1 -jako	NUTS 2 -jako	NUTS 3 -jako	Kuntamuoto 2018			
Kunta-numero	Nimi	Y-tunnus	Manner-Suomi ja Ahvenanmaa	NUTS2 = suuralue	Maakunnan nimi	Kuntamuoto	Väestö 2019	Tilastollinen ryhmitys	Kielisuhde 2021
020	Akaa	2050864-5	Manner-Suomi	Länsi-Suomi	Pirkanmaa	Kaupunki	16475	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
005	Alajärvi	0177619-3	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Kaupunki	9562	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
009	Alavieska	0184674-5	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Muu kunta	2519	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
010	Alavus	0177736-4	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Kaupunki	11468	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
016	Asikkala	0145208-4	Manner-Suomi	Etelä-Suomi	Päijät-Häme	Muu kunta	8083	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
018	Askola	9000162-0	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Muu kunta	4943	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
019	Aura	0132103-3	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Muu kunta	3941	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
035	Brändö	0204999-1	Ahvenanmaa	Ahvenanmaa	Ahvenanmaa	Muu kunta	445	3 Maaseutumaiset kunnat	2 Yksikielinen ruotsinkielinen kunta
043	Eckerö	0144682-1	Ahvenanmaa	Ahvenanmaa	Ahvenanmaa	Muu kunta	952	3 Maaseutumaiset kunnat	2 Yksikielinen ruotsinkielinen kunta
046	Enonkoski	0163687-9	Manner-Suomi	Pohjois- ja Itä-Suomi	Etelä-Savo	Muu kunta	1361	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
047	Enontekiö	0190662-1	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Muu kunta	1838	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
049	Espoo	0101263-6	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Kaupunki	289731	1 Kaupunkimaiset kunnat	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
050	Eura	0132239-4	Manner-Suomi	Länsi-Suomi	Satakunta	Muu kunta	11632	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
051	Eurajoki	0132322-3	Manner-Suomi	Länsi-Suomi	Satakunta	Muu kunta	9402	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
052	Evijärvi	0177804-1	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Muu kunta	2425	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
060	Finström	0205003-6	Ahvenanmaa	Ahvenanmaa	Ahvenanmaa	Muu kunta	2593	3 Maaseutumaiset kunnat	2 Yksikielinen ruotsinkielinen kunta
061	Forssa	0145626-1	Manner-Suomi	Etelä-Suomi	Kanta-Häme	Kaupunki	16901	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta

062	Föglö	0282394-0	Ahvenanmaa	Ahvenanmaa	Ahvenanmaa	Muu kunta	531	3 Maaseutumaiset kunnat	2 Yksikielinen ruotsinkielinen kunta
065	Geta	0205012-4	Ahvenanmaa	Ahvenanmaa	Ahvenanmaa	Muu kunta	496	3 Maaseutumaiset kunnat	2 Yksikielinen ruotsinkielinen kunta
069	Haapajärvi	0209756-3	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Kaupunki	7010	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
071	Haapavesi	0184872-4	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Kaupunki	6758	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
072	Hailuoto	0184918-8	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Muu kunta	959	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
074	Halsua	0177826-0	Manner-Suomi	Pohjois- ja Itä-Suomi	Keski-Pohjanmaa	Muu kunta	1127	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
075	Hamina	0242496-6	Manner-Suomi	Etelä-Suomi	Kymenlaakso	Kaupunki	20111	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
076	Hammarland	0205014-0	Ahvenanmaa	Ahvenanmaa	Ahvenanmaa	Muu kunta	1583	3 Maaseutumaiset kunnat	2 Yksikielinen ruotsinkielinen kunta
077	Hankasalmi	0174035-0	Manner-Suomi	Länsi-Suomi	Keski-Suomi	Muu kunta	4875	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
078	Hanko	0103166-9	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Kaupunki	8199	1 Kaupunkimaiset kunnat	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
079	Harjavalta	0132585-1	Manner-Suomi	Länsi-Suomi	Satakunta	Kaupunki	6931	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
081	Hartola	0163734-5	Manner-Suomi	Etelä-Suomi	Päijät-Häme	Muu kunta	2697	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
082	Hattula	0145801-3	Manner-Suomi	Etelä-Suomi	Kanta-Häme	Muu kunta	9422	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
086	Hausjärvi	0145997-2	Manner-Suomi	Etelä-Suomi	Kanta-Häme	Muu kunta	8260	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
111	Heinola	1068892-9	Manner-Suomi	Etelä-Suomi	Päijät-Häme	Kaupunki	18667	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
090	Heinävesi	0164308-3	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Karjala	Muu kunta	3254	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
091	Helsinki	0201256-6	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Kaupunki	653835	1 Kaupunkimaiset kunnat	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
097	Hirvensalmi	0164384-1	Manner-Suomi	Pohjois- ja Itä-Suomi	Etelä-Savo	Muu kunta	2136	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
098	Hollola	0146248-5	Manner-Suomi	Etelä-Suomi	Päijät-Häme	Muu kunta	23410	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
102	Huittinen	0203762-4	Manner-Suomi	Länsi-Suomi	Satakunta	Kaupunki	10044	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
103	Humppila	0146456-0	Manner-Suomi	Etelä-Suomi	Kanta-Häme	Muu kunta	2184	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
105	Hyrynsalmi	0185075-2	Manner-Suomi	Pohjois- ja Itä-Suomi	Kainuu	Muu kunta	2271	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
106	Hyvinkää	0125866-0	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Kaupunki	46470	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
108	Hämeenkyrö	0132947-3	Manner-Suomi	Länsi-Suomi	Pirkanmaa	Muu kunta	10404	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
109	Hämeenlinna	0146921-4	Manner-Suomi	Etelä-Suomi	Kanta-Häme	Kaupunki	67633	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta

139	Ii	2054621-1	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Muu kunta	9844	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
140	Iisalmi	9086071-6	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Savo	Kaupunki	21368	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
142	Iitti	0158766-7	Manner-Suomi	Etelä-Suomi	Päijät-Häme	Muu kunta	6711	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
143	Ikaalinen	0203797-4	Manner-Suomi	Länsi-Suomi	Pirkanmaa	Kaupunki	6942	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
145	Ilmajoki	0178008-8	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Muu kunta	12269	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
146	Ilomantsi	0167589-4	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Karjala	Muu kunta	4857	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
153	Imatra	0159216-7	Manner-Suomi	Etelä-Suomi	Etelä-Karjala	Kaupunki	26508	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
148	Inari	0190758-7	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Muu kunta	6907	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
149	Inkoo	0126293-4	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Muu kunta	5386	3 Maaseutumaiset kunnat	3 Kaksikielinen kunta, jossa enemmistön kieli on ruotsi
151	Isojoki	0178071-5	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Muu kunta	1951	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
152	Isokyrö	0178131-2	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Muu kunta	4522	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
165	Janakkala	0147510-4	Manner-Suomi	Etelä-Suomi	Kanta-Häme	Muu kunta	16413	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
167	Joensuu	0242746-2	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Karjala	Kaupunki	76850	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
169	Jokioinen	0147645-7	Manner-Suomi	Etelä-Suomi	Kanta-Häme	Muu kunta	5133	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
170	Jomala	0205023-9	Ahvenanmaa	Ahvenanmaa	Ahvenanmaa	Muu kunta	5233	3 Maaseutumaiset kunnat	2 Yksikielinen ruotsinkielinen kunta
171	Joroinen	0207112-8	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Savo	Muu kunta	4767	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
172	Joutsa	0174108-9	Manner-Suomi	Länsi-Suomi	Keski-Suomi	Muu kunta	4377	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
176	Juuka	0168654-2	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Karjala	Muu kunta	4606	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
177	Juupajoki	0147705-4	Manner-Suomi	Länsi-Suomi	Pirkanmaa	Muu kunta	1844	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
178	Juva	0164551-3	Manner-Suomi	Pohjois- ja Itä-Suomi	Etelä-Savo	Muu kunta	6116	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
179	Jyväskylä	0174666-4	Manner-Suomi	Länsi-Suomi	Keski-Suomi	Kaupunki	142400	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
181	Jämijärvi	0133127-4	Manner-Suomi	Länsi-Suomi	Satakunta	Muu kunta	1739	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
182	Jämsä	0175622-1	Manner-Suomi	Länsi-Suomi	Keski-Suomi	Kaupunki	20182	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
186	Järvenpää	0126541-4	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Kaupunki	43711	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
202	Kaarina	0133226-9	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Kaupunki	33937	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta

204	Kaavi	0170664-6	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Savo	Muu kunta	2893	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
205	Kajaani	0214958-9	Manner-Suomi	Pohjois- ja Itä-Suomi	Kainuu	Kaupunki	36709	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
208	Kalajoki	0185924-7	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Kaupunki	12373	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
211	Kangasala	1923299-5	Manner-Suomi	Länsi-Suomi	Pirkanmaa	Kaupunki	31868	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
213	Kangasniemi	0164690-3	Manner-Suomi	Pohjois- ja Itä-Suomi	Etelä-Savo	Muu kunta	5356	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
214	Kankaanpää	0133596-1	Manner-Suomi	Länsi-Suomi	Satakunta	Kaupunki	12906	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
216	Kannonkoski	0175798-8	Manner-Suomi	Länsi-Suomi	Keski-Suomi	Muu kunta	1339	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
217	Kannus	0178455-6	Manner-Suomi	Pohjois- ja Itä-Suomi	Keski-Pohjanmaa	Kaupunki	5464	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
218	Karijoki	0178498-6	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Muu kunta	1245	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
224	Karkkila	0127046-7	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Kaupunki	8714	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
226	Karstula	9094917-1	Manner-Suomi	Länsi-Suomi	Keski-Suomi	Muu kunta	3949	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
230	Karvia	0133735-0	Manner-Suomi	Länsi-Suomi	Satakunta	Muu kunta	2342	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
231	Kaskinen	0208787-5	Manner-Suomi	Länsi-Suomi	Pohjanmaa	Kaupunki	1246	1 Kaupunkimaiset kunnat	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
232	Kauhajoki	0178718-3	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Kaupunki	13184	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
233	Kauhava	0208852-8	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Kaupunki	15726	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
235	Kauniainen	0203026-2	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Kaupunki	9797	1 Kaupunkimaiset kunnat	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
236	Kaustinen	0178981-6	Manner-Suomi	Pohjois- ja Itä-Suomi	Keski-Pohjanmaa	Muu kunta	4261	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
239	Keitele	0170773-7	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Savo	Muu kunta	2202	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
240	Kemi	0210427-6	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Kaupunki	20707	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
320	Kemijärvi	0191717-9	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Kaupunki	7274	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
241	Keminmaa	0210469-8	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Muu kunta	8079	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
322	Kemiönsaari	0133833-7	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Muu kunta	6640	3 Maaseutumaiset kunnat	3 Kaksikielinen kunta, jossa enemmistön kieli on ruotsi
244	Kempele	0186002-9	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Muu kunta	18355	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
245	Kerava	0127485-5	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Kaupunki	36756	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
249	Keuruu	0208388-2	Manner-Suomi	Länsi-Suomi	Keski-Suomi	Kaupunki	9605	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta

250	Kihniö	0133862-8	Manner-Suomi	Länsi-Suomi	Pirkanmaa	Muu kunta	1865	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
256	Kinnula	0242816-6	Manner-Suomi	Länsi-Suomi	Keski-Suomi	Muu kunta	1620	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
257	Kirkkonummi	0203107-0	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Muu kunta	39586	1 Kaupunkimaiset kunnat	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
260	Kitee	0168900-6	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Karjala	Kaupunki	10136	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
261	Kittilä	0191406-6	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Muu kunta	6453	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
263	Kiuruvesi	0170843-0	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Savo	Kaupunki	7998	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
265	Kivijärvi	0176150-6	Manner-Suomi	Länsi-Suomi	Keski-Suomi	Muu kunta	1096	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
271	Kokemäki	0203925-9	Manner-Suomi	Länsi-Suomi	Satakunta	Kaupunki	7103	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
272	Kokkola	0179377-8	Manner-Suomi	Pohjois- ja Itä-Suomi	Keski-Pohjanmaa	Kaupunki	47681	1 Kaupunkimaiset kunnat	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
273	Kolari	0191528-8	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Muu kunta	3846	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
275	Konnevesi	0176227-7	Manner-Suomi	Länsi-Suomi	Keski-Suomi	Muu kunta	2627	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
276	Kontiolahti	0169048-8	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Karjala	Muu kunta	14821	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
280	Korsnäs	0179699-5	Manner-Suomi	Länsi-Suomi	Pohjanmaa	Muu kunta	2077	3 Maaseutumaiset kunnat	3 Kaksikielinen kunta, jossa enemmistön kieli on ruotsi
284	Koski Tl	0213007-9	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Muu kunta	2308	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
285	Kotka	0160225-7	Manner-Suomi	Etelä-Suomi	Kymenlaakso	Kaupunki	52126	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
286	Kouvola	0161075-9	Manner-Suomi	Etelä-Suomi	Kymenlaakso	Kaupunki	82113	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
287	Kristiinankaupunki	0216509-5	Manner-Suomi	Länsi-Suomi	Pohjanmaa	Kaupunki	6486	3 Maaseutumaiset kunnat	3 Kaksikielinen kunta, jossa enemmistön kieli on ruotsi
288	Kruunupyy	0180065-9	Manner-Suomi	Länsi-Suomi	Pohjanmaa	Muu kunta	6428	3 Maaseutumaiset kunnat	3 Kaksikielinen kunta, jossa enemmistön kieli on ruotsi
290	Kuhmo	0186204-0	Manner-Suomi	Pohjois- ja Itä-Suomi	Kainuu	Kaupunki	8190	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
291	Kuhmoinen	0176357-9	Manner-Suomi	Länsi-Suomi	Pirkanmaa	Muu kunta	2206	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
295	Kumlinge	0205030-0	Ahvenanmaa	Ahvenanmaa	Ahvenanmaa	Muu kunta	314	3 Maaseutumaiset kunnat	2 Yksikielinen ruotsinkielinen kunta
297	Kuopio	0171450-7	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Savo	Kaupunki	119282	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
300	Kuortane	0180117-6	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Muu kunta	3551	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
301	Kurikka	0209046-8	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Kaupunki	20678	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
304	Kustavi	0134349-4	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Muu kunta	949	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta

305	Kuusamo	0186418-5	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Kaupunki	15134	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
312	Kyyjärvi	0176410-9	Manner-Suomi	Länsi-Suomi	Keski-Suomi	Muu kunta	1313	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
316	Kärkölä	0148268-9	Manner-Suomi	Etelä-Suomi	Päijät-Häme	Muu kunta	4368	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
317	Kärsämäki	0186511-0	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Muu kunta	2576	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
318	Kökar	0205032-7	Ahvenanmaa	Ahvenanmaa	Ahvenanmaa	Muu kunta	232	3 Maaseutumaiset kunnat	2 Yksikielinen ruotsinkielinen kunta
398	Lahti	0149669-3	Manner-Suomi	Etelä-Suomi	Päijät-Häme	Kaupunki	119823	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
399	Laihia	0180451-0	Manner-Suomi	Länsi-Suomi	Pohjanmaa	Muu kunta	8017	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
400	Laitila	0134480-9	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Kaupunki	8588	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
407	Lapinjärvi	0203135-3	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Muu kunta	2606	3 Maaseutumaiset kunnat	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
402	Lapinlahti	0172127-2	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Savo	Muu kunta	9485	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
403	Lappajärvi	0180516-9	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Muu kunta	2996	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
405	Lappeenranta	0162193-3	Manner-Suomi	Etelä-Suomi	Etelä-Karjala	Kaupunki	72634	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
408	Lapua	0209113-7	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Kaupunki	14278	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
410	Laukaa	0176478-2	Manner-Suomi	Länsi-Suomi	Keski-Suomi	Muu kunta	18903	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
416	Lemi	0162576-6	Manner-Suomi	Etelä-Suomi	Etelä-Karjala	Muu kunta	2971	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
417	Lemland	0205034-3	Ahvenanmaa	Ahvenanmaa	Ahvenanmaa	Muu kunta	2053	3 Maaseutumaiset kunnat	2 Yksikielinen ruotsinkielinen kunta
418	Lempäälä	0150783-1	Manner-Suomi	Länsi-Suomi	Pirkanmaa	Muu kunta	23523	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
420	Leppävirta	0172231-2	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Savo	Muu kunta	9454	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
421	Lestijärvi	0180774-6	Manner-Suomi	Pohjois- ja Itä-Suomi	Keski-Pohjanmaa	Muu kunta	719	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
422	Lieksa	0169321-6	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Karjala	Kaupunki	10884	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
423	Lieto	0134698-6	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Muu kunta	19994	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
425	Liminka	0186553-2	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Muu kunta	10191	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
426	Liperi	0169583-6	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Karjala	Muu kunta	12084	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
444	Lohja	1068322-0	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Kaupunki	45965	1 Kaupunkimaiset kunnat	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
430	Loimaa	1927453-8	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Kaupunki	15875	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta

433	Loppi	0150919-1	Manner-Suomi	Etelä-Suomi	Kanta-Häme	Muu kunta	7828	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
434	Loviisa	0203263-9	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Kaupunki	14772	2 Taajaan asutut kunnat	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
435	Luhanka	0176592-9	Manner-Suomi	Länsi-Suomi	Keski-Suomi	Muu kunta	690	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
436	Lumijoki	0186580-7	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Muu kunta	2020	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
438	Lumparland	0205038-6	Ahvenanmaa	Ahvenanmaa	Ahvenanmaa	Muu kunta	366	3 Maaseutumaiset kunnat	2 Yksikielinen ruotsinkielinen kunta
440	Luoto	0180857-0	Manner-Suomi	Länsi-Suomi	Pohjanmaa	Muu kunta	5417	3 Maaseutumaiset kunnat	3 Kaksikielinen kunta, jossa enemmistön kieli on ruotsi
441	Luumäki	0162631-2	Manner-Suomi	Etelä-Suomi	Etelä-Karjala	Muu kunta	4636	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
475	Maalahti	0180948-5	Manner-Suomi	Länsi-Suomi	Pohjanmaa	Muu kunta	5475	3 Maaseutumaiset kunnat	3 Kaksikielinen kunta, jossa enemmistön kieli on ruotsi
478	Maarianhamina	0205071-4	Ahvenanmaa	Ahvenanmaa	Ahvenanmaa	Kaupunki	11679	1 Kaupunkimaiset kunnat	2 Yksikielinen ruotsinkielinen kunta
480	Marttila	0135086-2	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Muu kunta	2013	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
481	Masku	0204064-7	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Muu kunta	9534	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
483	Merijärvi	0186588-2	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Muu kunta	1089	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
484	Merikarvia	0135202-4	Manner-Suomi	Länsi-Suomi	Satakunta	Muu kunta	3067	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
489	Miehikkälä	0162675-0	Manner-Suomi	Etelä-Suomi	Kymenlaakso	Muu kunta	1857	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
491	Mikkeli	0165116-3	Manner-Suomi	Pohjois- ja Itä-Suomi	Etelä-Savo	Kaupunki	53134	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
494	Muhos	0186646-3	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Muu kunta	8908	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
495	Multia	0208471-1	Manner-Suomi	Länsi-Suomi	Keski-Suomi	Muu kunta	1566	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
498	Muonio	0191824-3	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Muu kunta	2308	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
499	Mustasaari	0181101-6	Manner-Suomi	Länsi-Suomi	Pohjanmaa	Muu kunta	19448	2 Taajaan asutut kunnat	3 Kaksikielinen kunta, jossa enemmistön kieli on ruotsi
500	Muurame	0176699-9	Manner-Suomi	Länsi-Suomi	Keski-Suomi	Muu kunta	10164	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
503	Mynämäki	2048364-4	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Muu kunta	7654	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
504	Myrskylä	0203282-3	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Muu kunta	1882	3 Maaseutumaiset kunnat	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
505	Mäntsälä	0129261-5	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Muu kunta	20721	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
508	Mänttä-Vilppula	0157867-2	Manner-Suomi	Länsi-Suomi	Pirkanmaa	Kaupunki	9855	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
507	Mäntyharju	0165761-0	Manner-Suomi	Pohjois- ja Itä-Suomi	Etelä-Savo	Muu kunta	5791	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta

529	Naantali	0135457-2	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Kaupunki	19314	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
531	Nakkila	0135662-3	Manner-Suomi	Länsi-Suomi	Satakunta	Muu kunta	5329	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
535	Nivala	0186757-0	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Kaupunki	10639	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
536	Nokia	0205717-4	Manner-Suomi	Länsi-Suomi	Pirkanmaa	Kaupunki	33929	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
538	Nousiainen	0135821-5	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Muu kunta	4715	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
541	Nurmes	0207669-0	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Karjala	Kaupunki	9552	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
543	Nurmijärvi	9014643-2	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Muu kunta	42993	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
545	Närpiö	0181367-9	Manner-Suomi	Länsi-Suomi	Pohjanmaa	Kaupunki	9479	3 Maaseutumaiset kunnat	3 Kaksikielinen kunta, jossa enemmistön kieli on ruotsi
560	Orimattila	0129920-0	Manner-Suomi	Etelä-Suomi	Päijät-Häme	Kaupunki	16003	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
561	Oripää	0135869-6	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Muu kunta	1329	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
562	Orivesi	0151789-6	Manner-Suomi	Länsi-Suomi	Pirkanmaa	Kaupunki	9158	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
563	Oulainen	0186852-2	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Kaupunki	7288	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
564	Oulu	0187690-1	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Kaupunki	205489	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
309	Outokumpu	0207604-1	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Karjala	Kaupunki	6688	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
576	Padasjoki	0151924-2	Manner-Suomi	Etelä-Suomi	Päijät-Häme	Muu kunta	2896	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
577	Paimio	0136169-2	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Kaupunki	10850	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
578	Paltamo	0188808-0	Manner-Suomi	Pohjois- ja Itä-Suomi	Kainuu	Muu kunta	3273	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
445	Parainen	0136082-5	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Kaupunki	15132	2 Taajaan asutut kunnat	3 Kaksikielinen kunta, jossa enemmistön kieli on ruotsi
580	Parikkala	1913642-6	Manner-Suomi	Etelä-Suomi	Etelä-Karjala	Muu kunta	4734	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
581	Parkano	0136311-0	Manner-Suomi	Länsi-Suomi	Pirkanmaa	Kaupunki	6404	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
599	Pedersören kunta	0198517-1	Manner-Suomi	Länsi-Suomi	Pohjanmaa	Muu kunta	11081	3 Maaseutumaiset kunnat	3 Kaksikielinen kunta, jossa enemmistön kieli on ruotsi
583	Pelkosenniemi	0191866-5	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Muu kunta	939	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
854	Pello	0193729-2	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Muu kunta	3373	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
584	Perho	0181464-7	Manner-Suomi	Pohjois- ja Itä-Suomi	Keski-Pohjanmaa	Muu kunta	2759	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
588	Pertunmaa	0165867-2	Manner-Suomi	Pohjois- ja Itä-Suomi	Etelä-Savo	Muu kunta	1690	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta

592	Petäjävesi	0176769-2	Manner-Suomi	Länsi-Suomi	Keski-Suomi	Muu kunta	3841	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
593	Pieksämäki	2048903-4	Manner-Suomi	Pohjois- ja Itä-Suomi	Etelä-Savo	Kaupunki	17682	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
595	Pielavesi	0172446-5	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Savo	Muu kunta	4391	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
598	Pietarsaari	0209242-0	Manner-Suomi	Länsi-Suomi	Pohjanmaa	Kaupunki	19208	1 Kaupunkimaiset kunnat	3 Kaksikielinen kunta, jossa enemmistön kieli on ruotsi
601	Pihtipudas	0243027-4	Manner-Suomi	Länsi-Suomi	Keski-Suomi	Muu kunta	4032	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
604	Pirkkala	0152084-1	Manner-Suomi	Länsi-Suomi	Pirkanmaa	Muu kunta	19623	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
607	Polvijärvi	0169823-6	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Karjala	Muu kunta	4246	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
608	Pomarkku	0136610-0	Manner-Suomi	Länsi-Suomi	Satakunta	Muu kunta	2089	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
609	Pori	0137323-9	Manner-Suomi	Länsi-Suomi	Satakunta	Kaupunki	83934	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
611	Pornainen	0130095-3	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Muu kunta	5035	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
638	Porvoo	1061512-1	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Kaupunki	50380	1 Kaupunkimaiset kunnat	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
614	Posio	0191908-6	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Muu kunta	3183	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
615	Pudasjärvi	0188962-2	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Kaupunki	7873	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
616	Pukkila	0130729-0	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Muu kunta	1860	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
619	Punkalaidun	0138037-5	Manner-Suomi	Länsi-Suomi	Pirkanmaa	Muu kunta	2828	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
620	Puolanka	0189081-8	Manner-Suomi	Pohjois- ja Itä-Suomi	Kainuu	Muu kunta	2528	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
623	Puumala	0166400-1	Manner-Suomi	Pohjois- ja Itä-Suomi	Etelä-Savo	Muu kunta	2151	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
624	Pyhtää	0162798-0	Manner-Suomi	Etelä-Suomi	Kymenlaakso	Muu kunta	5140	3 Maaseutumaiset kunnat	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
625	Pyhäjoki	0189127-1	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Muu kunta	3077	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
626	Pyhäjärvi	0210261-7	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Kaupunki	5131	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
630	Pyhäntä	0189226-6	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Muu kunta	1578	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
631	Pyhäranta	0204403-1	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Muu kunta	2004	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
635	Pälkäne	2050961-3	Manner-Suomi	Länsi-Suomi	Pirkanmaa	Muu kunta	6435	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
636	Pöytyä	1929519-5	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Muu kunta	8276	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
678	Raahe	1791817-6	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Kaupunki	24679	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta

710	Raasepori	0131297-0	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Kaupunki	27536	2 Taajaan asutut kunnat	3 Kaksikielinen kunta, jossa enemmistön kieli on ruotsi
680	Raisio	0204428-5	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Kaupunki	24056	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
681	Rantasalmi	0166507-1	Manner-Suomi	Pohjois- ja Itä-Suomi	Etelä-Savo	Muu kunta	3431	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
683	Ranua	0191974-8	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Muu kunta	3783	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
684	Rauma	0138780-9	Manner-Suomi	Länsi-Suomi	Satakunta	Kaupunki	39205	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
686	Rautalampi	0172586-3	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Savo	Muu kunta	3121	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
687	Rautavaara	0172646-0	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Savo	Muu kunta	1602	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
689	Rautjärvi	0206951-1	Manner-Suomi	Etelä-Suomi	Etelä-Karjala	Muu kunta	3226	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
691	Reisjärvi	0189548-3	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Muu kunta	2718	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
694	Riihimäki	0152563-4	Manner-Suomi	Etelä-Suomi	Kanta-Häme	Kaupunki	28793	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
697	Ristijärvi	0189576-6	Manner-Suomi	Pohjois- ja Itä-Suomi	Kainuu	Muu kunta	1272	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
698	Rovaniemi	1978283-1	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Kaupunki	63042	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
700	Ruokolahti	0163013-5	Manner-Suomi	Etelä-Suomi	Etelä-Karjala	Muu kunta	4994	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
702	Ruovesi	0152842-1	Manner-Suomi	Länsi-Suomi	Pirkanmaa	Muu kunta	4283	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
704	Rusko	0204524-5	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Muu kunta	6327	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
707	Rääkkylä	0169967-7	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Karjala	Muu kunta	2126	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
729	Saarijärvi	0176975-1	Manner-Suomi	Länsi-Suomi	Keski-Suomi	Kaupunki	9309	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
732	Salla	0192936-4	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Muu kunta	3400	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
734	Salo	0139533-1	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Kaupunki	51833	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
736	Saltvik	0205119-4	Ahvenanmaa	Ahvenanmaa	Ahvenanmaa	Muu kunta	1849	3 Maaseutumaiset kunnat	2 Yksikielinen ruotsinkielinen kunta
790	Sastamala	0144411-3	Manner-Suomi	Länsi-Suomi	Pirkanmaa	Kaupunki	24277	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
738	Sauvo	9038213-6	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Muu kunta	2945	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
739	Savitaipale	0163109-0	Manner-Suomi	Etelä-Suomi	Etelä-Karjala	Muu kunta	3383	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
740	Savonlinna	0166906-4	Manner-Suomi	Pohjois- ja Itä-Suomi	Etelä-Savo	Kaupunki	32974	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
742	Savukoski	0210704-7	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Muu kunta	1005	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta

743	Seinäjoki	1928736-3	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Kaupunki	63781	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
746	Sievi	0189615-2	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Muu kunta	4910	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
747	Siikainen	0139842-8	Manner-Suomi	Länsi-Suomi	Satakunta	Muu kunta	1437	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
748	Siikajoki	2047359-3	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Muu kunta	5145	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
791	Siikalatva	0189019-9	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Muu kunta	5231	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
749	Siilinjärvi	0172718-0	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Savo	Muu kunta	21423	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
751	Simo	0193015-4	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Muu kunta	2988	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
753	Sipoo	0203533-8	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Muu kunta	21170	2 Taajaan asutut kunnat	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
755	Siuntio	0131156-4	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Muu kunta	6145	3 Maaseutumaiset kunnat	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
758	Sodankylä	0193169-1	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Muu kunta	8303	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
759	Soini	0182637-3	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Muu kunta	2052	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
761	Somero	0153082-0	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Kaupunki	8711	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
762	Sonkajärvi	9090160-2	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Savo	Muu kunta	3897	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
765	Sotkamo	0189766-5	Manner-Suomi	Pohjois- ja Itä-Suomi	Kainuu	Muu kunta	10336	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
766	Sottunga	0205121-5	Ahvenanmaa	Ahvenanmaa	Ahvenanmaa	Muu kunta	88	3 Maaseutumaiset kunnat	2 Yksikielinen ruotsinkielinen kunta
768	Sulkava	0167265-0	Manner-Suomi	Pohjois- ja Itä-Suomi	Etelä-Savo	Muu kunta	2492	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
771	Sund	0205125-8	Ahvenanmaa	Ahvenanmaa	Ahvenanmaa	Muu kunta	1023	3 Maaseutumaiset kunnat	2 Yksikielinen ruotsinkielinen kunta
777	Suomussalmi	0189925-7	Manner-Suomi	Pohjois- ja Itä-Suomi	Kainuu	Muu kunta	7727	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
778	Suonenjoki	0208061-4	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Savo	Kaupunki	7064	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
781	Sysmä	0167352-2	Manner-Suomi	Etelä-Suomi	Päijät-Häme	Muu kunta	3657	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
783	Säkylä	0139937-5	Manner-Suomi	Länsi-Suomi	Satakunta	Muu kunta	6721	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
831	Taipalsaari	0163320-5	Manner-Suomi	Etelä-Suomi	Etelä-Karjala	Muu kunta	4671	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
832	Taivalkoski	0190100-3	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Muu kunta	3976	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
833	Taivassalo	0139991-4	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Muu kunta	1639	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
834	Tammela	0153179-4	Manner-Suomi	Etelä-Suomi	Kanta-Häme	Muu kunta	6015	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta

837	Tampere	0211675-2	Manner-Suomi	Länsi-Suomi	Pirkanmaa	Kaupunki	238140	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
844	Tervo	0173081-4	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Savo	Muu kunta	1520	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
845	Tervola	0193249-1	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Muu kunta	3001	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
846	Teuva	0182734-1	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Muu kunta	5076	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
848	Tohmajärvi	1919717-3	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Karjala	Muu kunta	4361	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
849	Toholampi	0182779-8	Manner-Suomi	Pohjois- ja Itä-Suomi	Keski-Pohjanmaa	Muu kunta	3033	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
850	Toivakka	0177201-0	Manner-Suomi	Länsi-Suomi	Keski-Suomi	Muu kunta	2388	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
851	Tornio	0193524-6	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Kaupunki	21602	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
853	Turku	0204819-8	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Kaupunki	192962	1 Kaupunkimaiset kunnat	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
857	Tuusniemi	0173128-6	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Savo	Muu kunta	2477	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
858	Tuusula	0131661-3	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Muu kunta	38599	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
859	Tyrnävä	0190140-9	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Muu kunta	6637	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
886	Ulvila	0204910-7	Manner-Suomi	Länsi-Suomi	Satakunta	Kaupunki	12871	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
887	Urjala	0157323-0	Manner-Suomi	Länsi-Suomi	Pirkanmaa	Muu kunta	4688	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
889	Utajärvi	0190224-1	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Muu kunta	2676	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
890	Utsjoki	9129466-4	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Muu kunta	1212	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
892	Uurainen	0177224-8	Manner-Suomi	Länsi-Suomi	Keski-Suomi	Muu kunta	3681	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
893	Uusikaarlepyy	0183077-8	Manner-Suomi	Länsi-Suomi	Pohjanmaa	Kaupunki	7464	3 Maaseutumaiset kunnat	3 Kaksikielinen kunta, jossa enemmistön kieli on ruotsi
895	Uusikaupunki	0144036-6	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Kaupunki	15522	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
785	Vaala	0190027-0	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Muu kunta	2792	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
905	Vaasa	0209602-6	Manner-Suomi	Länsi-Suomi	Pohjanmaa	Kaupunki	67636	1 Kaupunkimaiset kunnat	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
908	Valkeakoski	0157568-2	Manner-Suomi	Länsi-Suomi	Pirkanmaa	Kaupunki	20972	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
092	Vantaa	0124610-9	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Kaupunki	233775	1 Kaupunkimaiset kunnat	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
915	Varkaus	0173416-1	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Savo	Kaupunki	20466	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
918	Vehmaa	0144561-8	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Muu kunta	2293	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta

921	Vesanto	0173787-2	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Savo	Muu kunta	2014	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
922	Vesilahti	0157711-9	Manner-Suomi	Länsi-Suomi	Pirkanmaa	Muu kunta	4355	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
924	Veteli	0184278-7	Manner-Suomi	Pohjois- ja Itä-Suomi	Keski-Pohjanmaa	Muu kunta	3114	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
925	Vieremä	0173835-7	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Savo	Muu kunta	3579	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
927	Vihti	0131905-6	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Muu kunta	29158	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
931	Viitasaari	0208573-0	Manner-Suomi	Länsi-Suomi	Keski-Suomi	Kaupunki	6176	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
934	Vimpeli	0184318-1	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Muu kunta	2827	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
935	Virolahti	0207033-6	Manner-Suomi	Etelä-Suomi	Kymenlaakso	Muu kunta	3109	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
936	Virrat	0206333-9	Manner-Suomi	Länsi-Suomi	Pirkanmaa	Kaupunki	6544	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
941	Vårdö	0205126-6	Ahvenanmaa	Ahvenanmaa	Ahvenanmaa	Muu kunta	447	3 Maaseutumaiset kunnat	2 Yksikielinen ruotsinkielinen kunta
946	Vöyri	2050514-5	Manner-Suomi	Länsi-Suomi	Pohjanmaa	Muu kunta	6461	3 Maaseutumaiset kunnat	3 Kaksikielinen kunta, jossa enemmistön kieli on ruotsi
976	Ylitornio	0210826-9	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Muu kunta	3918	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
977	Ylivieska	0190557-3	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Kaupunki	15255	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
980	Ylöjärvi	0158221-7	Manner-Suomi	Länsi-Suomi	Pirkanmaa	Kaupunki	33254	1 Kaupunkimaiset kunnat	0 Yksikielinen suomenkielinen kunta
981	Ypäjä	0158301-7	Manner-Suomi	Etelä-Suomi	Kanta-Häme	Muu kunta	2343	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
989	Ähtäri	0184622-7	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Kaupunki	5616	3 Maaseutumaiset kunnat	0 Yksikielinen suomenkielinen kunta
992	Äänekoski	2045520-5	Manner-Suomi	Länsi-Suomi	Keski-Suomi	Kaupunki	18765	2 Taajaan asutut kunnat	0 Yksikielinen suomenkielinen kunta
	Helsingin ja Uudenmaan Sairaanhoitopiirin kuntayhtymä	1567535-0	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Sairaanhoitopiiri	0	4 Kuntayhtymät	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
	Etelä-Karjalan sosiaali- ja terveydenhuollon kuntayhtymä	0725937-3	Manner-Suomi	Etelä-Suomi	Etelä-Karjala	Sairaanhoitopiiri	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Kanta-Hämeen Sairaanhoitopiirin kuntayhtymä	0818235-5	Manner-Suomi	Etelä-Suomi	Kanta-Häme	Sairaanhoitopiiri	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Länsi-Pohjan sosiaali- ja terveyspalvelujen ja sairaanhoitopiirin kuntayhtymä	0828618-9	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Sairaanhoitopiiri	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Keski-Suomen Sairaanhoitopiirin kuntayhtymä	0215978-7	Manner-Suomi	Länsi-Suomi	Keski-Suomi	Sairaanhoitopiiri	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Pohjois-Savon Sairaanhoitopiirin kuntayhtymä	0171495-3	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Savo	Sairaanhoitopiiri	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta

	Lapin Sairaanhoitopiirin kuntayhtymä	0819616-7	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Sairaanhoitopiiri	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Etelä-Savon sosiaali- ja terveyspalvelujen kuntayhtymä	0825508-3	Manner-Suomi	Pohjois- ja Itä-Suomi	Etelä-Savo	Sairaanhoitopiiri	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Satakunnan Sairaanhoitopiirin kuntayhtymä	0825915-6	Manner-Suomi	Länsi-Suomi	Satakunta	Sairaanhoitopiiri	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Itä-Savon Sairaanhoitopiirin kuntayhtymä	0215925-0	Manner-Suomi	Pohjois- ja Itä-Suomi	Etelä-Savo	Sairaanhoitopiiri	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Etelä-Pohjanmaan Sairaanhoitopiirin kuntayhtymä	0243096-0	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Sairaanhoitopiiri	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Pirkanmaan Sairaanhoitopiirin kuntayhtymä	0826597-8	Manner-Suomi	Länsi-Suomi	Pirkanmaa	Sairaanhoitopiiri	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Varsinais-Suomen Sairaanhoitopiirin kuntayhtymä	0828255-9	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Sairaanhoitopiiri	0	4 Kuntayhtymät	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
	Vasa Sjukvårdsdistrikt Samkommun-Vaasan Sairaanhoitopiirin kuntayhtymä	0349388-3	Manner-Suomi	Länsi-Suomi	Pohjanmaa	Sairaanhoitopiiri	0	4 Kuntayhtymät	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
	Kymenlaakson sosiaali- ja terveyspalvelujen kuntayhtymä	0725901-5	Manner-Suomi	Etelä-Suomi	Kymenlaakso	Sairaanhoitopiiri	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Keski-Pohjanmaan sosiaali- ja terveyspalvelukuntayhtymä	0216462-3	Manner-Suomi	Pohjois- ja Itä-Suomi	Keski-Pohjanmaa	Sairaanhoitopiiri	0	4 Kuntayhtymät	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
	Pohjois-Pohjanmaan Sairaanhoitopiirin kuntayhtymä	0679480-9	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Sairaanhoitopiiri	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Päijät-Hämeen hyvinvointikuntayhtymä	0215606-8	Manner-Suomi	Etelä-Suomi	Päijät-Häme	Sairaanhoitopiiri	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Kolpeneen Palvelukeskuksen kuntayhtymä	0210574-6	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Kårkulla samkommun	0204197-3	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Sote-kuntayhtymä	0	4 Kuntayhtymät	3 Kaksikielinen kunta, jossa enemmistön kieli on ruotsi
	Varsinais-Suomen Erityishuoltopiirin kuntayhtymä	0136167-6	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Eskoon Sosiaalipalvelujen kuntayhtymä	0283116-6	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Eteva kuntayhtymä	0203300-9	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Vaalijalan kuntayhtymä	0207327-0	Manner-Suomi	Pohjois- ja Itä-Suomi	Etelä-Savo	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Kommunernas socialtjänst k.f.	0954883-0	Ahvenanmaa	Ahvenanmaa	Ahvenanmaa	Sote-kuntayhtymä	0	4 Kuntayhtymät	2 Yksikielinen ruotsinkielinen kunta
	Kokemäen ja Kiikoisten kuntayhtymä Ilola	0134199-0	Manner-Suomi	Länsi-Suomi	Satakunta	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Oasen boende- och vårdcenter k.f.	0205018-3	Ahvenanmaa	Ahvenanmaa	Ahvenanmaa	Sote-kuntayhtymä	0	4 Kuntayhtymät	2 Yksikielinen ruotsinkielinen kunta
	Varsinais-Suomen Lastensuojelukuntayhtymä	0783597-5	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta

Itä-Suomen Päihdehuollon kuntayhtymä	0207252-6	Manner-Suomi	Pohjois- ja Itä-Suomi	Etelä-Savo	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Uudenmaan Päihdehuollon kuntayhtymä	0125920-9	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Kainuun Jätehuollon kuntayhtymä	1744356-1	Manner-Suomi	Pohjois- ja Itä-Suomi	Kainuu	Muu kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Lapin Jätehuolto kuntayhtymä	2008197-9	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Muu kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
SASKY koulutuskuntayhtymä	0204964-1	Manner-Suomi	Länsi-Suomi	Pirkanmaa	Koulu-tuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Jyväskylän Koulutuskuntayhtymä	0208201-1	Manner-Suomi	Länsi-Suomi	Keski-Suomi	Koulu-tuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Keski-Pohjanmaan Koulu-tusyhtymä	0208916-8	Manner-Suomi	Pohjois- ja Itä-Suomi	Keski-Pohjanmaa	Koulu-tuskuntayhtymä	0	4 Kuntayhtymät	1 Kaksikielinen kunta, jossa en-emmistön kieli on suomi
Keski-Uudenmaan koulu-tuskuntayhtymä	0213834-5	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Koulu-tuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Satakunnan koulutuskuntayhtymä	0203929-1	Manner-Suomi	Länsi-Suomi	Satakunta	Koulu-tuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Luksia, Länsi-Uudenmaan koulu-tuskuntayhtymä	0203167-9	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Koulu-tuskuntayhtymä	0	4 Kuntayhtymät	1 Kaksikielinen kunta, jossa en-emmistön kieli on suomi
Lounais-Suomen koulu-tuskuntayhtymä	0204023-3	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Koulu-tuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Lounais-Hämeen koulu-tuskuntayhtymä	0626288-8	Manner-Suomi	Etelä-Suomi	Kanta-Häme	Koulu-tuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Pohjois-Karjalan Koulu-tuskuntayhtymä	0212371-7	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Karjala	Koulu-tuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Itä-Uudenmaan Koulu-tuskuntayhtymä	0210838-1	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Koulu-tuskuntayhtymä	0	4 Kuntayhtymät	1 Kaksikielinen kunta, jossa en-emmistön kieli on suomi
Raahen Koulutuskuntayhtymä	0210287-9	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Koulu-tuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Raision Seudun Koulu-tuskuntayhtymä	0204427-7	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Koulu-tuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Salon Seudun Koulu-tuskuntayhtymä	0139545-4	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Koulu-tuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Itä-Savon koulutuskuntayhtymä	0207390-8	Manner-Suomi	Pohjois- ja Itä-Suomi	Etelä-Savo	Koulu-tuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Valkeakosken seudun koulu-tuskuntayhtymä	0206289-7	Manner-Suomi	Länsi-Suomi	Pirkanmaa	Koulu-tuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Ylä-Savon koulutuskuntayhtymä	0214765-5	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Savo	Koulu-tuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Optima samkommun	0796234-1	Manner-Suomi	Länsi-Suomi	Pohjanmaa	Koulu-tuskuntayhtymä	0	4 Kuntayhtymät	3 Kaksikielinen kunta, jossa en-emmistön kieli on ruotsi
Äänekosken Ammatillisen Koulu-tuksen kuntayhtymä	0208589-6	Manner-Suomi	Länsi-Suomi	Keski-Suomi	Koulu-tuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta

Samkommunen för Yrkesutbildning i Östra Nyland	0214081-6	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Koulutuskuntayhtymä	0	4 Kuntayhtymät	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
Koulutuskuntayhtymä Tavastia	0205303-4	Manner-Suomi	Etelä-Suomi	Kanta-Häme	Koulutuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Espoon seudun koulutuskuntayhtymä Omnia	0502454-6	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Koulutuskuntayhtymä	0	4 Kuntayhtymät	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
Rovaniemen Koulutuskuntayhtymä	0973110-9	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Koulutuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Suupohjan Koulutuskuntayhtymä	0973712-1	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Koulutuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Koulutuskuntayhtymä OSAO	0992445-3	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Koulutuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Koulutuskeskus Salpaus -kuntayhtymä	0993644-6	Manner-Suomi	Etelä-Suomi	Päijät-Häme	Koulutuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Seinäjoen koulutuskuntayhtymä	1007629-5	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Koulutuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Etelä-Savon kampuskiinteistöt kuntayhtymä	1013321-0	Manner-Suomi	Pohjois- ja Itä-Suomi	Etelä-Savo	Koulutuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Etelä-Karjalan Koulutuskuntayhtymä	1027740-9	Manner-Suomi	Etelä-Suomi	Etelä-Karjala	Koulutuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Peimarin koulutuskuntayhtymä	0823246-3	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Koulutuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Järviseudun Koulutuskuntayhtymä	1807931-9	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Koulutuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Savon Koulutuskuntayhtymä	1852679-9	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Savo	Koulutuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Kotkan-Haminan seudun koulutuskuntayhtymä	1958694-5	Manner-Suomi	Etelä-Suomi	Kymenlaakso	Koulutuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Kemi-Tornionlaakson koulutuskuntayhtymä Lappia	2109309-0	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Koulutuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Jokilaaksojen koulutuskuntayhtymä	0210010-1	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Koulutuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Pohjois-Suomen laboratoriokeskuksen liikelaitoskuntayhtymä	2483868-4	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Kainuun sosiaali- ja terveydenhuollon kuntayhtymä	2496986-0	Manner-Suomi	Pohjois- ja Itä-Suomi	Kainuu	Sairaanhoitopiiri	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Kainuun liitto	2496992-4	Manner-Suomi	Pohjois- ja Itä-Suomi	Kainuu	Maakuntaliitto	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Järviseudun sähkövoiman kuntayhtymä	0218977-5	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Muu kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Korpelan Voima kuntayhtymä	0178464-4	Manner-Suomi	Pohjois- ja Itä-Suomi	Keski-Pohjanmaa	Muu kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
Vatajankosken Sähkön kuntayhtymä	0133625-1	Manner-Suomi	Länsi-Suomi	Satakunta	Muu kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta

	Kuntayhtymä Raision-Naantalin Vesilaitos	0204419-7	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Muu kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Keski-Uudenmaan vesi kuntayhtymä	0131665-6	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Muu kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Hollolan-Lahden vesilaitos kuntayhtymä	0217865-4	Manner-Suomi	Etelä-Suomi	Päijät-Häme	Muu kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	HSY Helsingin seudun ympäristöpalvelut -kuntayhtymä	2274241-9	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Muu kuntayhtymä	0	4 Kuntayhtymät	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
	Pirkanmaan liitto	0828308-4	Manner-Suomi	Länsi-Suomi	Pirkanmaa	Maakuntaliitto	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Uudenmaan liitto - Nylands förbund	0201296-1	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Maakuntaliitto	0	4 Kuntayhtymät	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
	Satakuntaliitto	0830322-5	Manner-Suomi	Länsi-Suomi	Satakunta	Maakuntaliitto	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Lapin liitto	0937073-7	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Maakuntaliitto	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Varsinais-Suomen liitto - Egentliga Finlands förbund	0922305-9	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Maakuntaliitto	0	4 Kuntayhtymät	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
	Etelä-Karjalan liitto	0869462-5	Manner-Suomi	Etelä-Suomi	Etelä-Karjala	Maakuntaliitto	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Hämeen Maakuntaliitto, kuntayhtymä	0826048-0	Manner-Suomi	Etelä-Suomi	Kanta-Häme	Maakuntaliitto	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Päijät-Hämeen liitto	0215610-5	Manner-Suomi	Etelä-Suomi	Päijät-Häme	Maakuntaliitto	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Keski-Suomen liitto	0830155-3	Manner-Suomi	Länsi-Suomi	Keski-Suomi	Maakuntaliitto	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Keski-Pohjanmaan liitto - Förbundet för Mellersta Österbotten kuntayhtymä	0959806-1	Manner-Suomi	Pohjois- ja Itä-Suomi	Keski-Pohjanmaa	Maakuntaliitto	0	4 Kuntayhtymät	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
	Etelä-Pohjanmaan liitto kuntayhtymä	0955281-3	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Maakuntaliitto	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Österbottens förbund - Pohjanmaan liitto kuntayhtymä	0970063-6	Manner-Suomi	Länsi-Suomi	Pohjanmaa	Maakuntaliitto	0	4 Kuntayhtymät	1 Kaksikielinen kunta, jossa enemmistön kieli on suomi
	Kymenlaakson liitto	0206714-5	Manner-Suomi	Etelä-Suomi	Kymenlaakso	Maakuntaliitto	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Suupohjan Elinkeinotoimen kuntayhtymä	1078732-9	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Muu kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Pohjois-Pohjanmaan liitto	0922484-4	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Maakuntaliitto	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Pohjois-Karjalan maakuntaliitto	0927140-5	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Karjala	Maakuntaliitto	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Pohjois-Savon Liitto-Maakuntayhtymä	0827616-7	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Savo	Maakuntaliitto	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta

	Etelä-Savon Maakuntaliitto	0215839-7	Manner-Suomi	Pohjois- ja Itä-Suomi	Etelä-Savo	Maakuntaliitto	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Oulunkaaren kuntayhtymä	1006538-5	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Muu kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Ålands Kommunförbund	1449974-6	Ahvenanmaa	Ahvenanmaa	Ahvenanmaa	Maakuntaliitto	0	4 Kuntayhtymät	2 Yksikielinen ruotsinkielinen kunta
	Tampereen kaupunkiseudun kuntayhtymä	2014682-4	Manner-Suomi	Länsi-Suomi	Pirkanmaa	Muu kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Jokilaaksojen Musiikkiopiston kuntayhtymä	0210007-2	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Koulu-tuskuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Kommunalförbundet för Södra Ålands Högstadiedistrikt	0205024-7	Ahvenanmaa	Ahvenanmaa	Ahvenanmaa	Koulu-tuskuntayhtymä	0	4 Kuntayhtymät	2 Yksikielinen ruotsinkielinen kunta
	Västra Nylands Folkhögskola	0203394-9	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Koulu-tuskuntayhtymä	0	4 Kuntayhtymät	3 Kaksikielinen kunta, jossa en-emmistön kieli on ruotsi
	Norra Ålands Högstadiedistrikt	0216345-2	Ahvenanmaa	Ahvenanmaa	Ahvenanmaa	Koulu-tuskuntayhtymä	0	4 Kuntayhtymät	2 Yksikielinen ruotsinkielinen kunta
	Keski-Uudenmaan vesiensuojelun liikelaitoskuntayhtymä	0202691-7	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Muu kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Kvarnen samkommun	0209021-4	Manner-Suomi	Länsi-Suomi	Pohjanmaa	Koulu-tuskuntayhtymä	0	4 Kuntayhtymät	3 Kaksikielinen kunta, jossa en-emmistön kieli on ruotsi
	Svenska Österbottens förbund för Utbildning och Kultur	0988182-8	Manner-Suomi	Länsi-Suomi	Pohjanmaa	Koulu-tuskuntayhtymä	0	4 Kuntayhtymät	1 Kaksikielinen kunta, jossa en-emmistön kieli on suomi
	Haapaveden-Siikalatvan seudun kuntayhtymä	1059660-2	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Muu kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Itä-Lapin kuntayhtymä	1044651-6	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Muu kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Vaasanseudun Areenat Kuntayhtymä - Vasaregionens Arenor Samkommun	1025565-6	Manner-Suomi	Länsi-Suomi	Pohjanmaa	Muu kuntayhtymä	0	4 Kuntayhtymät	1 Kaksikielinen kunta, jossa en-emmistön kieli on suomi
	Pohjois-Lapin Alueyhteistyön kuntayhtymä	1510651-0	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Muu kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Helsingin seudun liikenne -kuntayhtymä	2274586-3	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Muu kuntayhtymä	0	4 Kuntayhtymät	1 Kaksikielinen kunta, jossa en-emmistön kieli on suomi
	Keski-Savon Jätehuolto liikelai-toskuntayhtymä	2367681-2	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Savo	Muu kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Ounastähti Kehit-tämiskuntayhtymä	1828127-7	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Muu kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Keski-Satakunnan terveydenhu-ollon kuntayhtymä	0203738-4	Manner-Suomi	Länsi-Suomi	Satakunta	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Malmska fastigheter sk - Malmin kiinteistöt ky	0209271-1	Manner-Suomi	Länsi-Suomi	Pohjanmaa	Muu kuntayhtymä	0	4 Kuntayhtymät	3 Kaksikielinen kunta, jossa en-emmistön kieli on ruotsi
	Forssan seudun hyvinvointi-kuntayhtymä (FSHKY)	0214295-0	Manner-Suomi	Etelä-Suomi	Kanta-Häme	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta

	NuVa-kuntayhtymä	0207667-4	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Karjala	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Orimattilan seudun terveydenhuollon kiinteistökuntayhtymä	0203361-5	Manner-Suomi	Etelä-Suomi	Päijät-Häme	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Paimion-Sauvon Kansanterveys kuntayhtymä	0204213-2	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Pelkosenniemen-Savukosken Kansanterveystyön kuntayhtymä	0210526-0	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Pöytyän Kansanterveystyön kuntayhtymä	0204411-1	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	SoTe kuntayhtymä	0208521-2	Manner-Suomi	Länsi-Suomi	Keski-Suomi	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Sisä-Savon Terveydenhuollon kuntayhtymä	0214913-2	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Savo	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Riihimäen Seudun Terveyskeskuksen kuntayhtymä	0205809-7	Manner-Suomi	Etelä-Suomi	Kanta-Häme	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Raahen seudun hyvinvointikuntayhtymä	0210286-0	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Kuusiokuntien sosiaali -ja terveyskuntayhtymä	1983230-9	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Kuntayhtymä Kaksineuvoinen	2071277-7	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Kommunalförbundet för Ålands Miljöservice	1752847-7	Ahvenanmaa	Ahvenanmaa	Ahvenanmaa	Sote-kuntayhtymä	0	4 Kuntayhtymät	2 Yksikielinen ruotsinkielinen kunta
	Itä-Suomen laboratoriokeskuksen liikelaitoskuntayhtymä (ISLAB)	2126106-6	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Savo	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Peruspalvelukuntayhtymä Kallio	2125690-2	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Perusturvakuntayhtymä Karviainen	2187280-1	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Suupohjan peruspalveluliikelaitoskuntayhtymä	2204227-9	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	JIK-peruspalveluliikelaitoskuntayhtymä	2220682-7	Manner-Suomi	Länsi-Suomi	Etelä-Pohjanmaa	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Pohjois-Satakunnan peruspalvelukuntayhtymä	2205488-6	Manner-Suomi	Länsi-Suomi	Satakunta	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Kust-Österbottens samkommun för social- och primärhälsovård	2223170-7	Manner-Suomi	Länsi-Suomi	Pohjanmaa	Sote-kuntayhtymä	0	4 Kuntayhtymät	3 Kaksikielinen kunta, jossa enemmistön kieli on ruotsi
	Peruspalvelukuntayhtymä Selänne	2265415-2	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Pohjanmaa	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Meri-Lapin kuntapalvelut liikelaitoskuntayhtymä	2264173-0	Manner-Suomi	Pohjois- ja Itä-Suomi	Lappi	Muu kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Ylä-Savon SOTE kuntayhtymä	2265875-1	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Savo	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Perusturvakuntayhtymä Akseli	2338872-2	Manner-Suomi	Etelä-Suomi	Varsinais-Suomi	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta

	Pohjois-Karjalan sosiaali- ja terveyspalvelujen kuntayhtymä	2732095-2	Manner-Suomi	Pohjois- ja Itä-Suomi	Pohjois-Karjala	Sairaanhoitopiiri	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Keski-Uudenmaan sote-kuntayhtymä	2844969-4	Manner-Suomi	Helsinki-Uusimaa	Uusimaa	Sote-kuntayhtymä	0	4 Kuntayhtymät	0 Yksikielinen suomenkielinen kunta
	Ålands Hälso- och Sjukvård (Ahvenanmaan maakunta ja sen virastot)	1907542-4	Ahvenanmaa	Ahvenanmaa	Ahvenanmaa	Sairaanhoitopiiri	0	4 Kuntayhtymät	2 Yksikielinen ruotsinkielinen kunta

Appendix 2. Domain classification model

For Every domain, of the 5,364 domains studied, the following information was used for classification and analyse:

- ID-number (for index purpose)
  - < number >
- Municipality number (only for municipalities)
  - < number >
- Organization name
  - < name >
- Organization name in Swedish
  - < name >
- Domicile
  - < name >
- OrganizationId (Y-tunnus)
  - < ID-number >
- Organizations official email address (record office)
  - < Organizations primary email domain FQDN >
- NUTS 1 < choice >
  - Manner-Suomi (Mainland Finland)
  - Ahvenanmaa (Åland)
- NUTS 2 < choice >
  - Ahvenanmaa [Ahvenanmaa]
  - Etelä-Suomi [Manner-Suomi]
  - Helsinki-Uusimaa [Manner-Suomi]
  - Länsi-Suomi [Manner-Suomi]
  - Pohjois- ja Itä-Suomi [Manner-Suomi]
- NUTS 3 (region) < choice >
  - Ahvenanmaa [Ahvenanmaa]
  - Etelä-Karjala [Etelä-Suomi]
  - Etelä-Pohjanmaa [Länsi-Suomi]
  - Etelä-Savo [Pohjois- ja Itä-Suomi]
  - Kainuu [Pohjois- ja Itä-Suomi]
  - Kanta-Häme [Etelä-Suomi]
  - Keski-Pohjanmaa [Pohjois- ja Itä-Suomi]
  - Keski-Suomi [Länsi-Suomi]
  - Kymenlaakso [Etelä-Suomi]
  - Lappi [Pohjois- ja Itä-Suomi]
  - Pirkanmaa [Länsi-Suomi]
  - Pohjanmaa [Länsi-Suomi]
  - Pohjois-Karjala [Pohjois- ja Itä-Suomi]
  - Pohjois-Pohjanmaa [Pohjois- ja Itä-Suomi]
  - Pohjois-Savo [Pohjois- ja Itä-Suomi]
  - Päijät-Häme [Etelä-Suomi]
  - Satakunta [Länsi-Suomi]
  - Uusimaa [Helsinki-Uusimaa]
  - Varsinais-Suomi [Etelä-Suomi]
- Sub-region < choice >
  - Mariehamns stads ekonomiska region [Ahvenanmaa]
  - Ålands landsbygd [Ahvenanmaa]
  - Ålands skärgård [Ahvenanmaa]
  - Imatran seutukunta [Etelä-Karjala]
  - Lappeenrannan seutukunta [Etelä-Karjala]
  - Järviseudun seutukunta [Etelä-Pohjanmaa]
  - Kuusiokuntien seutukunta [Etelä-Pohjanmaa]
  - Seinäjoen seutukunta [Etelä-Pohjanmaa]
  - Suupohjan seutukunta [Etelä-Pohjanmaa]
  - Vaasan seutukunta [Etelä-Pohjanmaa]
  - Mikkelin seutukunta [Etelä-Savo]
  - Pieksämäen seutukunta [Etelä-Savo]
  - Savonlinnan seutukunta [Etelä-Savo]
  - Kajaanin seutukunta [Kainuu]
  - Kehys-Kainuun seutukunta [Kainuu]
  - Forssan seutukunta [Kanta-Häme]
  - Hämeenlinnan seutukunta [Kanta-Häme]
  - Riihimäen seutukunta [Kanta-Häme]
  - Kaustisen seutukunta [Keski-Pohjanmaa]
  - Kokkolan seutukunta [Keski-Pohjanmaa]
  - Joutsan seutukunta [Keski-Suomi]

    - Jyväskylän seutukunta [Keski-Suomi]
    - Jämsän seutukunta [Keski-Suomi]
    - Keuruun seutukunta [Keski-Suomi]
    - Saarijärven-Viitasaaren seutukunta [Keski-Suomi]
    - Äänekosken seutukunta [Keski-Suomi]
    - Kotkan-Haminan seutukunta [Kymenlaakso]
    - Kouvolan seutukunta [Kymenlaakso]
    - Itä-Lapin seutukunta [Lappi]
    - Kemi-Tornion seutukunta [Lappi]
    - Pohjois-Lapin seutukunta [Lappi]
    - Rovaniemen seutukunta [Lappi]
    - Torniolaakson seutukunta [Lappi]
    - Tunturi-Lapin seutukunta [Lappi]
    - Etelä-Pirkanmaan seutukunta [Pirkanmaa]
    - Lounais-Pirkanmaan seutukunta [Pirkanmaa]
    - Luoteis-Pirkanmaan seutukunta [Pirkanmaa]
    - Tampereen seutukunta [Pirkanmaa]
    - Ylä-Pirkanmaan seutukunta [Pirkanmaa]
    - Jakobstadsregionen [Pohjanmaa]
    - Sydösterbottenin seutukunta [Pohjanmaa]
    - Vaasan seutukunta [Pohjanmaa]
    - Joensuun seutukunta [Pohjois-Karjala]
    - Keski-Karjalan seutukunta [Pohjois-Karjala]
    - Pielisen Karjalan seutukunta [Pohjois-Karjala]
    - Haapaveden-Siikalatvan seutukunta [Pohjois-Pohjanmaa]
    - Koillismaan seutukunta [Pohjois-Pohjanmaa]
    - Nivala-Haapajärven seutukunta [Pohjois-Pohjanmaa]
    - Oulun seutukunta [Pohjois-Pohjanmaa]
    - Oulunkaaren seutukunta [Pohjois-Pohjanmaa]
    - Raahen seutukunta [Pohjois-Pohjanmaa]
    - Ylivieskan seutukunta [Pohjois-Pohjanmaa]
    - Koillis-Savon seutukunta [Pohjois-Savo]
    - Kuopion seutukunta [Pohjois-Savo]
    - Sisä-Savon seutukunta [Pohjois-Savo]
    - Varkauden seutukunta [Pohjois-Savo]
    - Ylä-Savon seutukunta [Pohjois-Savo]
    - Lahden seutukunta [Päijät-Häme]
    - Pohjois-Satakunnan seutukunta [Satakunta]
    - Porin seutukunta [Satakunta]
    - Rauman seutukunta [Satakunta]
    - Helsingin seutukunta [Uusimaa]
    - Loviisan seutukunta [Uusimaa]
    - Porvoon seutukunta [Uusimaa]
    - Raaseporin seutukunta [Uusimaa]
    - Loimaan seutukunta [Varsinais-Suomi]
    - Salon seutukunta [Varsinais-Suomi]
    - Turun seutukunta [Varsinais-Suomi]
    - Vakka-Suomen seutukunta [Varsinais-Suomi]
    - Åboland-Turunmaan seutukunta [Varsinais-Suomi]
- AVI < choice >
    - Ahvenanmaan valtionvirasto
    - Etelä-Suomen AVI
    - Itä-Suomen AVI
    - Lapin AVI
    - Lounais-Suomen AVI
    - Länsi- ja Sisä-Suomen AVI
    - Pohjois-Suomen AVI
- ELY < choice >
    - Ahvenanmaa
    - Etelä-Pohjanmaan ELY-keskus
    - Etelä-Savon ELY-keskus
    - Hämeen ELY-keskus
    - Kaakkois-Suomen ELY-keskus
    - Kainuun ELY-keskus
    - Keski-Suomen ELY-keskus
    - Lapin ELY-keskus
    - Pirkanmaan ELY-keskus
    - Pohjanmaan ELY-keskus
    - Pohjois-Karjalan ELY-keskus
    - Pohjois-Pohjanmaan ELY-keskus
    - Pohjois-Savon ELY-keskus
    - Satakunnan ELY-keskus
    - Uudenmaan ELY-keskus

    - Varsinais-Suomen ELY-keskus
- Population of residents
    - < number >
- Statistical grouping < choice >
    - Kaupunkimaiset kunnat (Urban municipalities (city))
    - Taajaan asutut kunnat (Densly populated municipalities)
    - Maaseutumaiset kunnat (Rural-like municipalities)
    - Kuntayhtymät (Joint municipal authorities)
- Lingual status < choice >
    - Yksikielinen suomenkielinen kunta (Finnish-speaking)
    - Kaksikielinen kunta, jossa enemmistön kieli on suomi (Bilingual with Finnish as primary)
    - Yksikielinen ruotsinkielinen kunta (Swedish-speaking)
    - Kaksikielinen kunta, jossa enemmistön kieli on ruotsi (Bilingual with Swedish as primary)
- Organization type groups < choice >
    - Kaupunki (Town) 0 – 2 000
    - Kaupunki (Town) 2 001 – 5 000
    - Kaupunki (Town) 5 001 – 10 000
    - Kaupunki (Town) 10 001 – 20 000
    - Kaupunki (Town) 20 001 – 40 000
    - Kaupunki (Town) 40 001 – 100 000
    - Kaupunki (Town) 100 001 -
    - Municipality (Kunta) 0 – 2 000
    - Municipality (Kunta) 2 001 – 5 000
    - Municipality (Kunta) 5 001 – 10 000
    - Municipality (Kunta) 10 001 – 20 000
    - Municipality (Kunta) 20 001 – 40 000
    - Municipality (Kunta) 40 001 – 100 000
    - Municipality (Kunta) 100 001 -
    - Koulutuskuntayhtymä (Educational joint municipal authority)
    - Maakuntaliitto (Regional council)
    - Sairaanhoitopiiri (Health care district)
    - Sote-kuntayhtymä (Basic health care and social services joint municipal authority)
    - Muu kuntayhtymä (Other joint municipal authority)
- C21 City < choice >
    - True
    - False
- Special care district < choice >
    - True
    - False
- DomainName (including scandig å, ä, ö)
    - < name >
- Domain
    - < name >
- TLD
    - < TLD >
- FQDN
    - < FQDN >
- DNSSECInUse < choice >
    - True
    - False
- MXInUse < choice >
    - True
    - False
- Is1stEmail (Organizations official email address) < choice >
    - True
    - False
- SPFrecord < choice >
    - False
    - Hardfail
    - Softfail
    - Nostance
- DMARCrecord < choice >
    - False
    - Test
    - Quarantine
    - Reject
    - Unknown
- HINFO < choice >
    - True
    - False
- MSArureValidation < choice >
    - True
    - False

- MSOutlook < choice >
  - True
  - False
- MSCloudPresentInDNS (if MSArureValidation is True OR MSOutlook is True = True, else false) < choice >
  - True
  - False
- DomainHolder
  - < Organization name of the registered holder >
- HolderOrganizationID
  - < Organization ID-number of the registered holder >
- HolderOrganizationType < choice >
  - Company
  - Government
  - Public community
  - Town
  - N/A (record empty)
- HolderAddress
  - < address >
- HolderPostalCode
  - < postal code number >
- HolderPostalArea
  - < postal area >
- DomainGantDate
  - < date >
- DomainLastValidityDate
  - < date >
- DomainRegistrar
  - < name >
- NameServer1
  - < server FQDN >
- NameServer2
  - < server FQDN >
- NameServer3
  - < server FQDN >
- NameServer4
  - < server FQDN >
- NameServer5
  - < server FQDN >
- NameServer6
  - < server FQDN >

Appendix 3. Secure DNS configurations for email by region

Municipalities and joint municipal authorities by region

Secure DNS configuration for email					SPF -hardfail + DMARC -quarantine		SPF -hardfail + DMARC -reject		SPF -softfail + DMARC -quarantine		SPF -softfail + DMARC -reject		SPF -hardfail + DMARC -quarantine		SPF -hardfail + DMARC -reject		SPF -softfail + DMARC -quarantine		SPF -softfail + DMARC -reject		SPF -hardfail + DMARC -quarantine		SPF -hardfail + DMARC -reject		SPF -softfail + DMARC -quarantine		SPF -softfail + DMARC -reject	
			n	%									n	%									n	%						
Ahvenanmaa	26	0,48 %	26	100,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	23	88,46 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Ahvenanmaa	26	0,48 %	26	100,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	23	88,46 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Ahvenanmaa	26	0,48 %	26	100,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	23	88,46 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Manner-Suomi	5338	99,52 %	3407	63,83 %	8	0,23 %	2	0,06 %	8	0,23 %	2	0,06 %	1931	36,17 %	1	0,05 %	5	0,26 %	0	0,00 %	0	0,00 %	413	7,74 %	3	0,73 %	2	0,48 %	2	0,48 %	0	0,00 %
Etelä-Suomi	1084	20,21 %	595	54,89 %	1	0,17 %	0	0,00 %	0	0,00 %	0	0,00 %	489	45,11 %	0	0,00 %	1	0,20 %	0	0,00 %	0	0,00 %	89	8,21 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Etelä-Karjala	112	2,09 %	66	58,93 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	46	41,07 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	12	10,71 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Kanta-Häme	130	2,42 %	97	74,62 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	33	25,38 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	16	12,31 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Kymenlaakso	141	2,63 %	74	52,48 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	67	47,52 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	9	6,38 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Päijät-Häme	141	2,63 %	99	70,21 %	**1**	**1,01 %**	0	0,00 %	0	0,00 %	0	0,00 %	42	29,79 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	14	9,93 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Varsinais-Suomi	560	10,44 %	259	46,25 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	301	53,75 %	0	0,00 %	1	0,33 %	0	0,00 %	0	0,00 %	38	6,79 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Helsinki-Uusimaa	1434	26,73 %	788	54,95 %	1	0,13 %	2	0,25 %	4	0,51 %	1	0,13 %	646	45,05 %	1	0,15 %	3	0,46 %	0	0,00 %	0	0,00 %	42	2,93 %	1	2,38 %	2	4,76 %	2	4,76 %	0	0,00 %
Uusimaa	1434	26,73 %	788	54,95 %	**1**	**0,13 %**	2	**0,25 %**	4	**0,51 %**	1	**0,13 %**	646	45,05 %	1	0,15 %	3	0,46 %	0	0,00 %	0	0,00 %	42	2,93 %	1	2,38 %	2	4,76 %	2	4,76 %	0	0,00 %
Länsi-Suomi	1409	26,27 %	973	69,06 %	0	0,00 %	0	0,00 %	4	0,41 %	0	0,00 %	436	30,94 %	0	0,00 %	1	0,23 %	0	0,00 %	0	0,00 %	125	8,87 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Etelä-Pohjanmaa	230	4,29 %	181	78,70 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	49	21,30 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	27	11,74 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Keski-Suomi	218	4,06 %	175	80,28 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	43	19,72 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	27	12,39 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Pirkanmaa	428	7,98 %	241	56,31 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	187	43,69 %	0	0,00 %	1	0,53 %	0	0,00 %	0	0,00 %	28	6,54 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Pohjanmaa	335	6,25 %	235	70,15 %	0	0,00 %	0	0,00 %	**4**	**1,70 %**	0	0,00 %	100	29,85 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	22	6,57 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Satakunta	198	3,69 %	141	71,21 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	57	28,79 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	21	10,61 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Pohjois- ja Itä-Suomi	1411	26,30 %	1051	74,49 %	6	0,57 %	0	0,00 %	0	0,00 %	1	0,10 %	360	25,51 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	157	11,13 %	2	1,27 %	0	0,00 %	0	0,00 %	0	0,00 %
Etelä-Savo	170	3,17 %	138	81,18 %	**1**	**0,72 %**	0	0,00 %	0	0,00 %	1	**0,72 %**	32	18,82 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	19	11,18 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Kainuu	95	1,77 %	76	80,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	19	20,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	11	11,58 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Keski-Pohjanmaa	99	1,85 %	60	60,61 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	39	39,39 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	12	12,12 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Lappi	254	4,74 %	164	64,57 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	90	35,43 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	31	12,20 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Pohjois-Karjala	193	3,60 %	183	94,82 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	10	5,18 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	16	8,29 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Pohjois-Pohjanmaa	375	6,99 %	299	79,73 %	**4**	**1,34 %**	0	0,00 %	0	0,00 %	0	0,00 %	76	20,27 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	42	11,20 %	2	4,76 %	0	0,00 %	0	0,00 %	0	0,00 %
Pohjois-Savo	225	4,19 %	131	58,22 %	**1**	**0,76 %**	0	0,00 %	0	0,00 %	0	0,00 %	94	41,78 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	26	11,56 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
All together	5364	100,00 %	3433	64,00 %	**8**	**0,23 %**	**2**	**0,06 %**	**8**	**0,23 %**	**2**	**0,06 %**	1931	36,00 %	**1**	**0,05 %**	**5**	**0,26 %**	**0**	**0,00 %**	**0**	**0,00 %**	436	8,13 %	**3**	**0,69 %**	**2**	**0,46 %**	**2**	**0,46 %**	**0**	**0,00 %**
	All domains (0,48% secure)		**MXInUse true** Domains considered secure 20/3433 = 0,58%										**MXInUse false** Domains considered secure 6/1931 = 0,31%										**Is1stEmail** Domains considered secure 7/436 = 1,60%							

Appendix 4. Domains in municipal organizations by organization type

Organization type	FQDNs						
Urban municipalities	**All domains**		**MXInUse true**		**Is1stEmail true**		
Town 0-2000	3	0,06 %	3	0,09 %	1	0,23 %	
~~Town 2001-5000~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	
Town 5001-10000	28	0,52 %	17	0,50 %	3	0,69 %	
Town 10001-20000	49	0,91 %	37	1,08 %	3	0,69 %	
Town 20001-40000	290	5,41 %	190	5,53 %	18	4,12 %	
Town 40001-100000	684	12,75 %	409	11,91 %	16	3,66 %	
Town 100001+	1208	22,52 %	746	21,73 %	9	2,06 %	
~~Municipality 0-2000~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	
~~Municipality 2001-5000~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	
~~Municipality 5001-10000~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	
Municipality 10001-20000	21	0,39 %	14	0,41 %	3	0,69 %	
Municipality 20001-40000	61	1,14 %	23	0,67 %	4	0,92 %	
Municipality 40001-100000	15	0,28 %	9	0,26 %	1	0,23 %	
~~Municipality 100000+~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	
Domains	**2359**	**43,98 %**	**1448**	**42,18 %**	**58**	**13,27 %**	
Densely populated municipalities	**All domains**		**MXInUse true**		**Is1stEmail true**		
~~Town 0-2000~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	
~~Town 2001-5000~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	
Town 5001-10000	93	1,73 %	69	2,01 %	14	3,20 %	
Town 10001-20000	311	5,80 %	219	6,38 %	22	5,03 %	
Town 20001-40000	82	1,53 %	44	1,28 %	4	0,92 %	
~~Town 40001-100000~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	
~~Town 100001+~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	
~~Municipality 0-2000~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	
~~Municipality 2001-5000~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	
Municipality 5001-10000	51	0,95 %	34	0,99 %	9	2,06 %	
Municipality 10001-20000	80	1,49 %	66	1,92 %	11	2,52 %	
Municipality 20001-40000	43	0,80 %	22	0,64 %	4	0,92 %	
~~Municipality 40001-100000~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	
~~Municipality 100000+~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	
Domains	**660**	**12,30 %**	**454**	**13,22 %**	**64**	**14,65 %**	
Rural-like municipalities	**All domains**		**MXInUse true**		**Is1stEmail true**		
~~Town 0-2000~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	
~~Town 2001-5000~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	
Town 5001-10000	135	2,52 %	104	3,03 %	14	3,20 %	
Town 10001-20000	6	0,11 %	6	0,17 %	1	0,23 %	
~~Town 20001-40000~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	
~~Town 40001-100000~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	
~~Town 100001+~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	
Municipality 0-2000	111	2,07 %	96	2,80 %	44	10,07 %	
Municipality 2001-5000	334	6,23 %	250	7,28 %	93	21,28 %	
Municipality 5001-10000	224	4,18 %	163	4,75 %	33	7,55 %	
Municipality 10001-20000	11	0,21 %	11	0,32 %	2	0,46 %	
~~Municipality 20001-40000~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	
~~Municipality 40001-100000~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	
~~Municipality 100000+~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	~~0~~	~~0,00 %~~	
Domains	**821**	**15,31 %**	**630**	**18,35 %**	**187**	**42,79 %**	
Joint municipal authorities	**All domains**		**MXInUse true**		**Is1stEmail true**		
Educational authority	531	9,90 %	387	11,27 %	40	9,15 %	
Regional council	225	4,19 %	128	3,73 %	19	4,35 %	
Health care district	570	10,63 %	248	7,22 %	**21**	4,81 %	
Social- and/or health authority	73	1,36 %	58	1,69 %	**32**	7,32 %	
Other authority	125	2,33 %	80	2,33 %	**16**	3,66 %	
Domains	**1524**	**28,41 %**	**901**	**26,25 %**	**128**	**29,29 %**	
All together	**5364**	**100,00 %**	**3433**	**64,00 %**	**437**	**8,15 %**	of all domains
						12,73 %	of MX domains

Appendix 5. Secure DNS configurations for email by organization type

Municipal organizations by type					SPF -hardfail + DMARC -quarantine		SPF -hardfail + DMARC -reject		SPF -softfail + DMARC -quarantine		SPF -softfail + DMARC -reject			SPF -hardfail + DMARC -quarantine		SPF -hardfail + DMARC -reject		SPF -softfail + DMARC -quarantine		SPF -softfail + DMARC -reject			SPF -hardfail + DMARC -quarantine		SPF -hardfail + DMARC -reject		SPF -softfail + DMARC -quarantine		SPF -softfail + DMARC -reject	
Secure DNS configuration for email			n	%									n	%									n	%						
Municipalities by population	3840	71,59 %	2532	47,20 %	5	0,20 %	1	0,04 %	2	0,08 %	2	0,08 %	1308	34,06 %	1	0,08 %	5	0,38 %	0	0,00 %	0	0,00 %	309	8,05 %	2	0,65 %	1	0,32 %	1	0,32 %	0	0,00 %
Town 0-2000	3	0,06 %	3	0,06 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	1	33,33 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Town 2000-5000	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Town 5001-10000	256	4,77 %	190	3,54 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	66	25,78 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	31	12,11 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Town 10001-20000	366	6,82 %	262	4,88 %	**1**	**0,38 %**	0	0,00 %	0	0,00 %	0	0,00 %	104	28,42 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	26	7,10 %	**1**	**3,85 %**	0	0,00 %	0	0,00 %	0	0,00 %
Town 20001-40000	372	6,94 %	234	4,36 %	0	0,00 %	0	0,00 %	**2**	**0,85 %**	0	0,00 %	138	37,10 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	22	5,91 %	0	0,00 %	0	0,00 %	**1**	**4,55 %**	0	0,00 %
Town 40001-100000	684	12,75 %	409	7,62 %	**1**	**0,24 %**	**1**	**0,24 %**	0	0,00 %	0	0,00 %	275	40,20 %	0	0,00 %	**2**	**0,73 %**	0	0,00 %	0	0,00 %	16	2,34 %	0	0,00 %	**1**	**6,25 %**	0	0,00 %	0	0,00 %
Town 100001+	1208	22,52 %	746	13,91 %	**2**	**0,27 %**	0	0,00 %	0	0,00 %	**1**	**0,13 %**	462	38,25 %	**1**	**0,22 %**	**2**	**0,43 %**	0	0,00 %	0	0,00 %	9	0,75 %	**1**	**11,11 %**	0	0,00 %	0	0,00 %	0	0,00 %
Municipality 0-2000	111	2,07 %	96	1,79 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	15	13,51 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	44	39,64 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Municipality 2001-5000	334	6,23 %	250	4,66 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	84	25,15 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	93	27,84 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Municipality 5001-10000	275	5,13 %	197	3,67 %	0	0,00 %	0	0,00 %	0	0,00 %	**1**	**0,51 %**	78	28,36 %	0	0,00 %	**1**	**1,28 %**	0	0,00 %	0	0,00 %	42	15,27 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Municipality 10001-20000	112	2,09 %	91	1,70 %	**1**	**1,10 %**	0	0,00 %	0	0,00 %	0	0,00 %	21	18,75 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	16	14,29 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Municipality 20001-40000	104	1,94 %	45	0,84 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	59	56,73 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	8	7,69 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Municipality 40001-100000	15	0,28 %	9	0,17 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	6	40,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	1	6,67 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Municipality 100000+	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Joint municipal authorities	1524	28,41 %	901	16,80 %	3	0,33 %	1	0,11 %	6	0,67 %	0	0,00 %	623	40,88 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	128	8,40 %	1	0,78 %	1	0,78 %	1	0,78 %	0	0,00 %
Educational authority	531	9,90 %	387	7,21 %	**3**	**0,78 %**	0	0,00 %	**4**	**1,03 %**	0	0,00 %	144	27,12 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	40	7,53 %	**1**	**2,50 %**	0	0,00 %	0	0,00 %	0	0,00 %
Regional council	225	4,19 %	128	2,39 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	97	43,11 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	19	8,44 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Health care district	570	10,63 %	248	4,62 %	**0**	0,00 %	0	0,00 %	**2**	**0,81 %**	0	0,00 %	322	56,49 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	21	3,68 %	0	0,00 %	0	0,00 %	**1**	**4,76 %**	0	0,00 %
Social- and/or health authorit	73	1,36 %	58	1,08 %	0	0,00 %	**1**	**1,72 %**	0	0,00 %	0	0,00 %	15	20,55 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	32	43,84 %	0	0,00 %	**1**	**3,13 %**	0	0,00 %	0	0,00 %
other authority	125	2,33 %	80	1,49 %	**0**	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	45	36,00 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	16	12,80 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
All together	**5364**	**100,00 %**	**3433**	**64,00 %**	**8**	**0,23 %**	**2**	**0,06 %**	**8**	**0,23 %**	**2**	**0,06 %**	**1931**	**36,00 %**	**1**	**0,05 %**	**5**	**0,26 %**	**0**	**0,00 %**	**0**	**0,00 %**	**437**	**8,15 %**	**3**	**0,69 %**	**2**	**0,46 %**	**2**	**0,46 %**	**0**	**0,00 %**
Statictical classification	5364	100,00 %	3433	64,00 %	8	0,23 %	2	0,06 %	8	0,23 %	2	0,06 %	1931	36,00 %	1	0,05 %	5	0,26 %	0	0,00 %	0	0,00 %	437	8,15 %	3	0,69 %	2	0,46 %	2	0,46 %	0	0,00 %
Urban (citylike)	2359	43,98 %	1448	61,38 %	**4**	**0,28 %**	1	0,07 %	0	0,00 %	**1**	**0,07 %**	911	38,62 %	**1**	**0,11 %**	**4**	**0,44 %**	0	0,00 %	0	0,00 %	58	2,46 %	**1**	**1,72 %**	**1**	**1,72 %**	0	0,00 %	0	0,00 %
Densely populated	660	12,30 %	454	68,79 %	**1**	**0,22 %**	0	0,00 %	**2**	**0,44 %**	0	0,00 %	206	31,21 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	64	9,70 %	**1**	**1,56 %**	0	0,00 %	**1**	**1,56 %**	0	0,00 %
Rural-like munnicipalities	821	15,31 %	630	76,74 %	0	0,00 %	0	0,00 %	0	0,00 %	**1**	**0,16 %**	191	23,26 %	0	0,00 %	**1**	**0,52 %**	0	0,00 %	0	0,00 %	187	22,78 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
Joint municipal authorities	1524	28,41 %	901	59,12 %	**3**	**0,33 %**	**1**	**0,11 %**	**6**	**0,67 %**	0	0,00 %	623	40,88 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	128	8,40 %	**1**	**0,78 %**	**1**	**0,78 %**	**1**	**0,78 %**	0	0,00 %
All together	**5364**	**100,00 %**	**3433**	**64,00 %**	**8**	**0,23 %**	**2**	**0,06 %**	**8**	**0,23 %**	**2**	**0,06 %**	**1931**	**36,00 %**	**1**	**0,05 %**	**5**	**0,26 %**	**0**	**0,00 %**	**0**	**0,00 %**	**437**	**8,15 %**	**3**	**0,69 %**	**2**	**0,46 %**	**2**	**0,46 %**	**0**	**0,00 %**
C21 cities	1777	33,13 %	1095	61,62 %	**3**	**0,27 %**	**1**	**0,09 %**	0	0,00 %	**1**	**0,09 %**	682	38,38 %	**1**	**0,15 %**	**2**	**0,29 %**	0	0,00 %	0	0,00 %	21	1,18 %	**1**	**4,76 %**	**1**	**4,76 %**	**1**	**4,76 %**	0	0,00 %
Special care districs	520	6,99 %	357	68,65 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %	163	31,35 %	0	0,00 %	**1**	**0,61 %**	0	0,00 %	0	0,00 %	42	8,08 %	0	0,00 %	0	0,00 %	0	0,00 %	0	0,00 %
	All domains (0,48% secure)		**MXInUse true Domains considered secure 20/3433 = 0,58%**										**MXInUse false Domains considered secure 6/1931 = 0,31%**										**Is1stEmail Domains considered secure 7/436 = 1,60%**									

Appendix 6. Secure DNS configurations for email using Microsoft O365

Secure DNS configurations in relation to Microsoft O365

							SPF -hardfail + DMARC -quarantine			SPF -hardfail + DMARC -reject			SPF -softfail + DMARC -quarantine			SPF -softfail + DMARC -reject		
Secure DNS configuration for email	nA	nMS	%	nA	nMS	%												
Municipalities by population	2532	402	15,88 %	10	3	30,00 %	5	2	40,00 %	1	1	100,00 %	2	0	0,00 %	2	0	0,00 %
Town 0-2000	3	1	33,33 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %
Town 2000-5000	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %
Town 5001-10000	190	32	16,84 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %
Town 10001-20000	262	41	15,65 %	1	1	0,00 %	**1**	**1**	**100,00 %**	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %
Town 20001-40000	234	39	16,67 %	2	0	0,00 %	0	0	0,00 %	0	0	0,00 %	**2**	**0**	**0,00 %**	0	0	0,00 %
Town 40001-100000	409	69	16,87 %	2	1	50,00 %	**1**	**0**	**0,00 %**	**1**	**1**	**100,00 %**	0	0	0,00 %	0	0	0,00 %
Town 100001+	746	39	5,23 %	3	1	33,33 %	**2**	**1**	**50,00 %**	0	0	0,00 %	0	0	0,00 %	**1**	**0**	**0,00 %**
Municipality 0-2000	96	29	30,21 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %
Municipality 2001-5000	250	84	33,60 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %
Municipality 5001-10000	197	47	23,86 %	1	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	**1**	**0**	**0,00 %**
Municipality 10001-20000	91	12	13,19 %	1	0	0,00 %	**1**	**0**	**0,00 %**	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %
Municipality 20001-40000	45	8	17,78 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %
Municipality 40001-100000	9	1	11,11 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %
Municipality 100000+	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %
Joint municipal authorities	901	192	21,31 %	10	6	60,00 %	3	3	100,00 %	1	1	100,00 %	6	2	33,33 %	0	0	0,00 %
Educational authority	387	86	22,22 %	7	3	42,86 %	**3**	**3**	**100,00 %**	0	0	0,00 %	**4**	**0**	**0,00 %**	0	0	0,00 %
Regional council	128	33	25,78 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %
Health care district	248	28	11,29 %	2	2	0,00 %	**0**	**0**	0,00 %	0	0	0,00 %	**2**	**2**	**100,00 %**	0	0	0,00 %
Social- and/or health authority	58	25	43,10 %	1	1	0,00 %	0	0	0,00 %	**1**	**1**	**100,00 %**	0	0	0,00 %	0	0	0,00 %
other authority	80	20	25,00 %	0	0	0,00 %	**0**	**0**	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %
All together	**3433**	**594**	**17,30 %**	**20**	**9**	**45,00 %**	**8**	**5**	**62,50 %**	**2**	**2**	**100,00 %**	**8**	**2**	**25,00 %**	**2**	**0**	**0,00 %**

				SPF -hardfail + DMARC -quarantine			SPF -hardfail + DMARC -reject			SPF -softfail + DMARC -quarantine			SPF -softfail + DMARC -reject		
Secure DNS configuration for email	nA	nMS	%												
Municipalities by population	4	3	75,00 %	2	2	100,00 %	1	1	100,00 %	1	0	0,00 %	0	0	0,00 %
Town 0-2000	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %
Town 2000-5000	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %
Town 5001-10000	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %
Town 10001-20000	1	1	100,00 %	**1**	**1**	**100,00 %**	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %
Town 20001-40000	1	0	0,00 %	0	0	0,00 %	0	0	0,00 %	**1**	0	**0,00 %**	0	0	0,00 %
Town 40001-100000	1	1	100,00 %	0	0	0,00 %	**1**	**1**	**100,00 %**	0	0	0,00 %	0	0	0,00 %
Town 100001+	1	1	100,00 %	**1**	**1**	**100,00 %**	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %
Municipality 0-2000	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %
Municipality 2001-5000	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %
Municipality 5001-10000	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %
Municipality 10001-20000	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %
Municipality 20001-40000	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %
Municipality 40001-100000	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %
Municipality 100000+	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %
Joint municipal authorities	3	3	100,00 %	1	1	100,00 %	1	1	100,00 %	1	1	33,33 %	0	0	0,00 %
Educational authority	1	1	100,00 %	**1**	**1**	**100,00 %**	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %
Regional council	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %
Health care district	1	1	100,00 %	0	0	0,00 %	0	0	0,00 %	**1**	**1**	**100,00 %**	0	0	0,00 %
Social- and/or health authority	1	1	100,00 %	0	0	0,00 %	**1**	**1**	**100,00 %**	0	0	0,00 %	0	0	0,00 %
other authority	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %	0	0	0,00 %
All together	**7**	**6**	**85,71 %**	**3**	**3**	**100,00 %**	**2**	**2**	**100,00 %**	**2**	**1**	**50,00 %**	**0**	**0**	**0,00 %**

Email domains
0,58% of all email domains are secure. 17,30% use Microsoft

Secure email domains (MXInUse true)
Domains considered secure using Microsoft email service 9/20 = 45%

Secure primary email domains (Is1stEmail)
Domains considered secure using Microsoft email service 6/7 = 85,71%

Appendix 7. Recommendations for email security in municipalities

1. **VERIFY THAT RESPONSIBILITIES FOR ORGANIZATIONS DOMAIN ARE CLEAR AND UNIVOCAL**
    - Domain -registrations and management of DNS -services are a centralized responsibility
        - Organization has an accountable party for domain management
        - Registration and changes of domains are only carried out by the accountable party
        - DNS -configurations are centralized only to the accountable party or a named partner
    - Domain -registrations are reviewed annually and detected flaws are corrected
        - Review of registered domains is part of the accountable party's annual review plan
        - Domain registrations are valid and organizations information in registries is correct
    - DNS resource records are reviewed annually and detected flaws are corrected
        - Resource records in DNS are adequate, secure and safe
2. **VERIFY THAT DOMAIN REGISTRATION AND PURSUE IS ALIGNED AND INSTRUCTED**
    - Every domain has a justifiable purpose of use and an owner/subscriber
        - Domains are classified to web-pages, online services and email services (one or more)
        - Party in need of a domain defines the purpose of use as the owner
        - Organization preferres the use of sub-domains ("child"), parented by current domains
            - New domains are only exceptionally registered when truly justifiable
        - Organization intentionally aims to avoin domains registered by 3rd parties (providers)
        - When 3rd parties are holders, domains security requirements are enforced by agreements
    - Domains are part of organizations ICT -assets and they are documented up to date
        - It is possible to examine domains in asset by purpose and implemented configurations
3. **VERIFY THAT ORGANIZATIONS DNS -SERVICE DOES NOT REPLY TO BROAD ANY -REGUESTS**
    - DNS -service is configured to reply according to RFC 8482 specifications (HINFO)
4. **VERIFY THAT DNSSEC IS IMPLEMENTED TO ALL OF ORGANIZATIONS IMPORTANT DOMAIN ASSETS**
5. **VERIFY THAT NON-EMAIL DOMAINS HAVE CONFIGURATIONS CONSIDERED SECURE**
    - All domains that are not meant for email usage prevent unauthorised sending of email
    - DNS resource records include configurations that prevent receiving of email:
        - <domain> 0 MX . (TTL=0, value=NULL/period, if A/AAAA published)
        - <domain> TXT "v=spf1 -all"
        - *._domainkey.<domain> TXT "v=DKIM1; p="
        - _dmarc.<domain> TXT "v=DMARC1; p=reject; pct=100; rua=mailto:<rua address>"
        - *._report._dmarc.<domain> TXT "v=DMARC1"
6. **VERIFY THAT DOMAINS MEANT FOR EMAIL USAGE HAVE CONFIGURATIONS CONSIDERED SECURE**
    - Mail Excgane servers are configured accordingly in MX records
    - Email is only sent from chosen authorized sources that are valid
        - 3rd party have been taken into consideration (mailing services, newsletters)
        - Email sending peripheral devices (multi function printers etc.) and various alert-messages
    - SPF is implemented in use
        - In principle using hardfail, if justifiable purpose softfail is possible
    - DKIM is implemented in use
    - DMARC is implemented in use
        - Email address for falsification RUA-raports is defined in use (possible RUF)
        - Implementation in stages; first none, then quarantine, final reject
7. **VERIFY ATTLEAST THE PRIMARY EMAIL-DOMAINS ARE SECURED BY ALL OF THESE BEST PRACTICES**
8. **VERIFY THAT THE RECEIVING EMAIL SERVICE REJECTS SPAM BASED ON SENDERS DNS SETTINGS**
9. **VERIFY THAT CERTIFICATES RELATED TO DOMAINS ARE ALSO SECURE AND SAFE**
    - Certificates are also a responsibility of the accountable party responsible for domains
    - Certificates are handled, reviewed and documented with similar processes as domains
    - Type and technical implementation of certificates correlate to the purpose of usage
        - Adequate way of organization confirmation for certificates is defined by usage
        - Adequate safety and quality of technical security of certificates is defined by usage
10. **VERIFY THAT DEVELOPMENT OF EMAIL RELATED SECURITY IMPLEMENTATIONS IS CONTINOUS**
    - Secure the usage of email by implementing 2FA/MFA, Geoblock and denial of legacy protocols
    - When these recommendations are in place, move to deploying MTA-STS, DANE and other controls
    - Ensure that users have annual security awareness training and know about these controls in place

Appendix 8. Suositukset kuntien sähköpostin suojaamiseksi (Finnish)

1. **VARMISTA ETTÄ ORGANISAATION VERKKOTUNNUKSILLE ON SELKEÄT VASTUUT**
    - Verkkotunnus-rekisteröinnit ja DNS-nimipalveluiden hallinta on vastuutettu ja keskitetty
        - Organisaatiossa on nimetty vastuutaho verkkotunnusten hallintaan
        - Verkkotunnusten hankinta ja muutokset tapahtuvat vain vastuutahon toimesta
        - DNS-nimipalvelut on keskitytty organisaatiossa tai valitulle sopimuskumppanille
    - Verkkotunnusten rekisteröinnit katselmoidaan vähintään vuosittain ja virheet korjataan
        - Verkkotunnus-rekisteröintien tarkastus on kirjattuna vastuutahon vuosikellossa
        - rekisteröinnit ovat voimassa ja organisaation tiedot rekisterissä ovat oikein
    - DNS-nimipalveluiden tietueet katselmoidaan vähintään vuosittain ja virheet korjataan
        - DNS-nimipalveluissa olevat asetukset ovat tarkoituksenmukaiset ja turvalliset
2. **VARMISTA ETTÄ ORGANISAATION VERKKOTUNNUSTEN HANKINTA ON LINJATTU JA OHJEISTETTU**
    - Jokaisella verkkotunnuksella on perusteltu käyttötarkoitus sekä omistaja/tilaaja
        - Verkkotunnukset on luokiteltu www-sivustoihin, verkkopalveluihin ja sähköpostiin
        - Verkkotunnusta tarvitseva taho määrittelee omistajana käyttötarpeen
        - Organisaatiossa suositaan jo käytössä olevien verkkotunnusten ali-verkkotunnuksia
            - Erillinen (uusi) verkkotunnus rekisteröidään ainoastaan perustellusti
        - Organisaatiossa vältetään palveluntarjoajien omistamia verkkotunnuksia
        - 3.-osapuolen omistamien verkkotunnusten tietoturvavaatimukset edellytetään sopimuksilla
    - Verkkotunnukset ovat osa organisaation ICT-omaisuutta ja dokumentointi on ajan tasalla
        - Verkkotunnukset ovat tarkasteltavissa käyttötarkoituksen ja asetusten perusteella
3. **VARMISTA ETTÄ ORGANISAATION DNS-NIMIPALVELUISSA EI VASTATA LAAJOIHIN TIETUEKYSELYIHIN**
    - DNS-nimipalvelu vastaa laajoihin ANY-kyselyihin RFC 8482 mukaisesti (HINFO)
4. **VARMISTA ETTÄ ORGANISAATION TÄRKEÄT VERKKOTUNNUKSET SUOJATAAN DNSSEC-TEKNIIKALLA**
5. **VARMISTA ETTÄ VERKKOTUNNUKSET JOITA EI OLE TARKOITETTU SÄHKÖPOSTILLE SUOJATAAN**
    - Kaikki domain-nimet joista sähköpostia ei ole tarkoitus lähettää, estävät sen
    - Verkkotunnusten DNS-tietueet sisältävät sähköpostin kieltävät määritykset:
        - <domain> 0 MX . (TTL=0, arvo=NULL/piste, jos A/AAAA julkaistu)
        - <domain> TXT “v=spf1 -all”
        - *._domainkey.<domain> TXT "v=DKIM1; p="
        - _dmarc.<domain> TXT “v=DMARC1; p=reject; pct=100; rua=mailto:<rua address>"
        - *._report._dmarc.<domain> TXT "v=DMARC1"
6. **VARMISTA ETTÄ SÄHKÖPOSTILLE TARKOITETUT VERKKOTUNNUKSET SUOJATAAN**
    - Sähköpostipalvelimet on määritelty halutusti MX-tietueissa
    - Sähköpostia ei lähetetä kuin valituista tunnetuista lähteistä
        - Huomioidaan 3.-osapuolten palvelut (sähköpostiviestintä, uutiskirjeet)
        - Huomioidaan lähettävät laitteet (kopiokoneet) ja erilaiset hälytysviestit
    - SPF on määritelty käyttöön
        - Lähtökohtaisesti hardfail, perustellusti mahdollinen softfail
    - DKIM on määritelty käyttöön
    - DMARC on määritelty käyttöön
        - Sähköpostiosoite väärinkäytön RUA-raportoinnille on määritelty (mahdollinen RUF)
        - Etene vaiheittain; ensin none, sitten quarantine, lopuksi reject
7. **VARMISTA VÄHINTÄÄN TÄRKEIMPIEN SÄHKÖPOSTI-VERKKOTUNNUKSIEN SUOJAUS SUOSITELLUSTI**
8. **VARMISTA ETTÄ SAAPUVA SÄHKÖPOSTI TORJUU ROSKAPOSTIA DNS-MÄÄRITYSTEN MUKAISESTI**
9. **VARMISTA ETTÄ MYÖS VERKKOTUNNUKSIIN LIITTYVÄT VARMENTEET OVAT TURVALLISIA**
    - Varmenteet ovat organisaation verkkotunnuksista vastaavan tahon vastuulla
    - Varmenteet käsitellään, katselmoidaan ja dokumentoidaan verkkotunnuksia vastaavasti
    - Varmenteiden tyyppi ja tekninen toteutustapa vastaavat kutakin käyttötarkoitusta
        - Riittävä organisaation vahvistaminen varmenteen luonnissa on määritelty käytön mukaan
        - Riittävän suojattu ja laadukas tekninen toteutus varmenteille on määritelty käytön mukaan
10. **VARMISTA ETTÄ SÄHKÖPOSTIIN LIITTYVIEN TIETOTURVA-ASETUSTEN KEHITTÄMINEN ON JATKUVAA**
    - Suojaa sähköpostin käyttöä toteuttamalla 2FA/MFA, Geoblock ja vanhentuneiden protokollien estot
    - Kun suositukset ovat käytössä, etene toteuttamaan MTA-STS, DANE ja muita suojauksia
    - Huolehdi käyttäjien säännöllisestä tietoturvakoulutuksesta ja informoi näiden suojausten käytöstä