Implementation of Bluetooth based timing solution

Case small sports events

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Abstract

Commercial RFID timing systems used in large sports events are expensive. Buying a timing system or hiring a timing service provider is not affordable for small events that often use the manual timing method for timekeeping. Manual timing has a high risk of human and systematic error. A fully automatic timing solution is needed for small events to add reliability and reduce the support and timing costs.

The case study research examined the currently available timing methods and described implementing a smartphone-based Bluetooth timing system targeted to small events. The Bluetooth timing system that can be used with a self-service portal is presented. The self-service portal allows the event organizer to create a new event easily and use the Bluetooth-based timing system. The Bluetooth-based timing system's reliability and precision needed to be analyzed to be used as a timing method of an event.

The Bluetooth timing was tested using a smartphone for every kilometer of marathon and half marathon distances of Helsinki City Running Day 2020, with 336 test users enrolled to use a personal smartphone as a timing device. The times recorded by the Bluetooth timing system were compared with the official RFID recorded times to research the precision. The count of the individual participants was compared with all the timing locations to study the reliability. Finally, the self-service portal was integrated into the online entry system to the online entry platform to enable new event creation.

The field test results showed that the reliability of the Bluetooth timing system was good; even the unexcepted hardware issues caused a significant loss of the active timing devices. The recorded time sessions were evaluated with the same principle as the RFID-based systems and the best RSSI values. Because most participants had recorded several timing sessions for each timing point, a combined method is presented to add precision.

The self-service portal streamlines an event created by removing manual work from the service provider. The Bluetooth-based timing system proved to be reliable and easy to set up. The precision using only one device is not suitable for recording the official finish times, but it is ideal for a split point. Further development is needed to inspect the precision of several devices at a timing point and test the Bluetooth wristbands' accuracy.

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Tiivistelmä

Suurten urheilutapahtumien ajanottoon käytetään yleisesti kaupallisia RFID-ajanottojärjestelmiä. Ajanottojärjestelmät ovat kalliita, joten pienillä tapahtumilla ei ole varaa hankkia omaa ajanottojärjestelmää tai käyttää ajanottopalveluntarjoajaa. Usein näissä tapahtumissa päädytään käyttämään manuaalista ajanottoa, joka luotettavasta RFID-ajanotosta poiketen on altis systemaattisille sekä inhimillisille virheille. Pienet urheilutapahtumat tarvitsevat edullisen ajanottojärjestelmän, jonka avulla lisätään luotettavuutta sekä vähennetään tuki- ja ajanottokuluja.

Tapaustutkimuksessa tarkasteltiin yleisesti käytettyjä ajanottojärjestelmiä älypuhelin-pohjaisen Bluetooth-ajanottoratkaisun toteuttamista varten ja tutkittiin kehitetyn järjestelmän tarkkuutta ja luotettavuutta väliaikapistekäytössä. Bluetooth-ajanoton mahdollistamiseksi toteutettiin itsepalvelusivusto, jossa tapahtuman järjestäjä voi luoda ja hallita tapahtumiaan ja käyttää Bluetooth-ajanottojärjestelmää.

Älypuhelinpohjaista Bluetooth-ajanottoa testattiin Helsinki City Running Day -tapahtumassa asentamalla ajanottolaite maratonin ja puolimaratonin jokaiselle kilometrille. Testiin osallistui 336 juoksijaa käyttäen omaa puhelintaan ajanottolaitteena. Ajanoton luotettavuutta tarkasteltiin vertaamalla kunkin aikapisteen tallennettujen yksittäisten seurantakoodien määriä. Ajanoton tarkkuutta tarkasteltiin vertaamalle Bluetooth-järjestelmän ja virallisten RFID-järjestelmän aikaeroa. Tutkimuksen aikana itsepalvelusivusto integroitiin ilmoittautumisjärjestelmään uusien tapahtumien luomista varten.

Tutkimuksessa järjestelmän käyttöönotto todettiin helpoksi ja luotettavuus hyväksi, vaikka laitteisto-ongelmien takia osa ajanottolaitteista ei ollut käytössä. Tarkkuutta testattiin käyttäen samaa menetelmää kuin RFID-ajanotossa sekä käyttäen aikaa, jolla on paras signaalin voimakkuusarvo (RSSI). Paras tarkkuus saavutettiin yhdistämällä menetelmät, koska useat osallistujat saivat ajanottopisteiltä enemmän kuin yhden ajan.

Itsepalvelusivusto yksinkertaisti tapahtuman luomisprosessia vähentämällä palveluntarjoajan manuaalisen työn määrää. Bluetooth-ajanottojärjestelmä osoittautui tapaustutkimuksessa luotettavaksi ja helpoksi asentaa sekä käyttää. Tarkkuus käytettäessä yhtä Bluetooth-ajanottolaitetta ei kuitenkaan sovellu virallisen maaliajan tallentamiseen, mutta järjestelmä soveltuu erinomaisesti käytettäväksi väliaikapisteillä. Lisätutkimusta siis tarvitaan tarkkuuden parantamiseksi käyttäen useampaa ajanottolaitetta ajanottopisteellä sekä Bluetooth-rannekkeiden tarkkuuden testaamiseen RFID-ajanottojärjestelmää vastaan.

Avainsanat (asiasanat)

liikuntatapahtumat, urheilutulokset, Bluetooth, ajanottolaitteet

Muut tiedot (salassa pidettävät liitteet)

n/a

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Acronyms

API	Application Programming interface
AWS	Amazon Web Services
BLE	Bluetooth Low Energy
EPC	Electronic Product Code
GPDR	General Data Protection Regulation
GPS	Global Positioning System
HCRD	Helsinki City Running Day
IAAF	International Association of Athletics Federations
JSON	JavaScript Object Notation
LF	Low Frequency
MAC	Media Access Control
NTP	Network Time Protocol
REST	Representational State Transfer
RFID	Radio-frequency identification
RSSI	Received Signal Strength Indicator
SMS	Short Message Services
UHF	Ultra-High Frequency
UUID	Universally Unique IDentifier
VAT	Value Added Tax

1 Introduction

1.1 Background

Different kinds of running events are popular nowadays. These running events are usually organized by various sports clubs, sports associations, and commercial companies. The organizers use different kind of timing systems in their events. This thesis will concentrate on the events having the time measured using Radio Frequency Identification (RFID) transponder-based solutions.

Wyld (2008) presents the ways how the RFID technology can be used on sports events. The RFID-based timing system was used the first time in the Berlin marathon in 1994 (MYLAPS Sports Timing, 2019). After the first presentation, the automatic RFID chip-based timing has become a standard for all major street running events. The first timing system called ChampionChip is a low frequency (LF) RFID system, and it is based on re-usable transponder attached to shoelaces.

The Ultra High Frequency (UHF) RFID timing systems were introduced soon after the EPC Gen. 2 air interface protocol (EPCglobal Inc, 2007). UHF RFID systems quickly replaced the low-frequency systems because the price of the timing transponder is as low as € 0.1 (AtlasRFIDstore, n.d).

Both the LF and the UHF systems used special readers and antennas, which makes the hardware cost high. Active RFID transponders are used in elite and high-speed sports events like cycling and triathlon. Active transponders are actively sending data and are powered by an internal battery. The data sending is triggered by a low-frequency ground loop antenna.

Because of the high investment cost of the timing systems, a way to create a cost-effective timing system has been researched. A low-cost timing system can be built using Arduino based IoT board (Chockchai, 2018). He presents how to build a full timing system with an antenna, transponder and reader and successfully tested it in sports field.

A cost-effective LF RFID solution can be built by using cheap components (Satitsuksanoh et al., 2017). He made a test system using an RFID card reader and wrist bands, and because of a short reading distance of LF RFID products they used a touch plate to record the times.

The timing system is a critical part of the event result service, but it needs to connect to an entry database typically created by the online entry system. The collected times need to be processed to results and shared with the participants (Chokchai 2018; Satitsuksanoh et al., 2017). To be able to provide fast results and ranking is essential today.

Ultimate Sport Service has provided online entry and timing services for large sports events in Denmark, Norway, and Finland with more than 500 participants. During the last five years, the number of events has grown, but at the same time, the average count of the event participants has decreased. The decrease in the participant count has increased the price of the timing service per entrant. The cost of the event timing is divided into three main categories: the materials produced, transportation of both staff, and equipment and used working time. A simple event with a start and a finish time typically needs one to three trained operators and three to five timing systems.

1.2 Objectives

Most of the small-size events use manual timing that exposes the timing for human errors and affects precision. The automatic transponder-based timing has not been available for small-size events because of the high price of the timing devices. A new method of timing is needed to work without a need for these commercial timing devices. The objective is to implement an automatic Bluetooth-based timing system for small events that cannot use traditional timing systems because of the high base cost of timing.

The currently available timing systems are analyzed to review how the Bluetooth technology can be used. In addition to the timing system, a self-service portal is needed for the event organizers to manage and create the event configurations.

This thesis will present a new timing system concept based on Bluetooth Low Energy (BLE) technology and use an Apple iPhone smartphone as a timing device to read the times and can use a smartphone or a BLE wristband as a timing transponder. The test case of the Bluetooth timing system is introduced, and the reliability and precision of the collected Bluetooth timing data are analyzed. The system's reliability is analyzed by comparing and counting the number of the received times for each of the tracked runners during the running event.

The precision of the Bluetooth timing is tested by comparing the official time recorded by the RFID timing system and the Bluetooth timing data collected using smartphones and the RaceConnect application acting as a transponder.

The self-service portal is introduced for small events' organizers. The portal allows easy event creation and management. The portal is connecting smartphones and wearable Bluetooth wrist bands to use Bluetooth-based timing. The self-service portal is implemented to the existing online entry platform and result service platform.

1.3 Research methods

Runeson et al. (2012) defines the case study method as follows:

> *The term "case study" is used for a broad range of studies in software engineering. There is a need to clarify and unify the understanding of what is meant by a case study, and how a good case study is conducted and reported. There exist several guidelines in other fields of research, but we see a need for guidelines, tailored to the field of software engineering, which we provide in this book.*

Case study method is based on five major steps: case study design, preparation of data collection, collecting evidence, analyzing of the collected data, and reporting (Runeson et al., 2012).

Research questions set in the case study design define the expected results of case study. This thesis is looking for answers to these questions:

1. How to implement simple Bluetooth based timing system without need for special timing devices?
2. How accurately will the Bluetooth timing compare to the RFID timing?
3. How to implement the self-service portal to the existing entry and results platforms?

The data used in this thesis is metrics data collected from the developed Bluetooth timing system and the official RFID timing system used in Helsinki City Running Day on 3 October 2020 (Finnish Athletics Federation, n.d.). The data for Bluetooth is gathered for each of the kilometers in the half marathon and the marathon. The official systems are used for only each of the 10-kilometer split times. This thesis will only use the split times 10km and 20 km for the half marathon distance. The test data is recorded only using runners' personal smartphones because Bluetooth wristbands were still in the design phase during the test. Only one Bluetooth device is used at every split point to gather the to simplify the test results.

The gathered data is analyzed using quantitative data analysis. The data analysis focuses on two objectives: investigating the precision of timing against the official RFID times and the reliability of the Bluetooth timing systems.

The reliability of the Bluetooth timing systems is investigated by comparing the number of recorded tracking ids on each timing location. The tracking ids are unique to the runner. The easiness of the system setup is observed by installing the devices for each kilometer of the marathon.

The precision of the Bluetooth timing system is investigated by comparing the difference between the recorded Bluetooth time and the official time received from the RFID timing system. The comparison is made using two methods: a first session recorded and the best Received Signal Strength Indicator (RSSI) value. The first seen method is usually used in RFID-based timing systems and takes the best RSSI value in the first recorded session. The timing system can have multiple saved sessions for the same tracking id. The lowest RSSI method takes the session having the best RSSI value.

1.4 Research ethics

The employment agreement of the author with Ultimate Sport Service recommends protecting business secrets and the technical data used during the research. Any of the protected material is not published in this work.

The event organizer Finnish Athletics Federation owns the participant data of the test event, which is protected by the General Data Protection Regulation (GDPR) regulations. The metrics data used in this work does not contain material protected by the GDPR regulations. The results data of the event are public. The data was only collected from the test users who had given manual permission to record the tracking data and activated the RaceConnect application during the event. The participant and timing data have been connected by using an 8-digit personal tracking code that is only used by the entry and timing systems. To prevent the recording of any other Bluetooth devices, the smartphones using the RaceStation application tracked only the beacons having an event-specific Universally Unique IDentifier (UUID) code added to the payload. The research work is based on the collected Bluetooth timing data and the official results recorded for the event. All the used data is handled anonymously and does not violate the test users' GDPR regulations or any personal rights.

The RaceConnect brand name and the RaceConnect and the RaceStation application are developed and owned by Ultimate Sport Service ApS. This thesis does not violate any agreements between the author and Ultimate Sport Service ApS, and it is written followed by JAMK ethical principles (JAMK, 2018) and JAMK project reporting instructions (Stevens & Crawford, 2020).

2 Event timing and data management in the sport events

Chapter 2 describes the RFID based timing devices and data management the event timing companies are using today. In running there are two methods for timing an event: Hand timing and timing by transponder system (International Association of Athletics Federations, 2014). Event timing means time measurement from the start point to the finish point. The different sports have their own rules for the time measurement.

2.1 Manual timing

Manual timing is based on hand-held stopwatch or a stopwatch with a printer. Both methods record just times, and the participant needs to be connected manually to the time. The risk of error is high if there are several finishers finishing simultaneously. By experience human interaction makes the risk of systematic errors higher during finishing peaks.

2.2 RFID based timing solutions

2.2.1 Passive Low Frequency RFID transponders

A passive RFID transponder is cheap to use because it does not have a power supply (Chawla & Ha, 2007). The transponder is activated by an electromagnetic field, created by the RFID reader. After powering up, the transponder transmits data back to the reader.

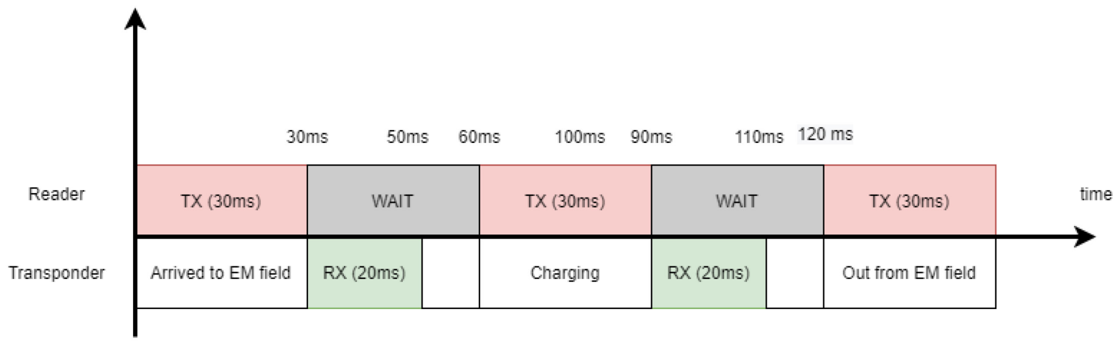

Figure 1 ChampionChip reading cycle

The ChampionChip system operates in low frequency (LF) mode using the frequency of 134 kHz. Figure 1 shows the RFID reader's synchronization cycle, starting with 30 milliseconds charge, when the device is creating an electromagnetic field. The next 20 milliseconds is a wait time when the transponder is transmitting data back. The transmitting power of the reader is 1,000 times stronger than the transponder, which means all the devices in close area need to be synchronized.

The downside in the low frequency passive transponders is a high risk of electromagnetic interference and short reading range.

2.2.2 Passive UHF transponders

The Ultra-High Frequency (UHF) systems are using the frequency ranging from 865 to 868 MHz for timing purpose in Europe and from 902 to 928 MHz in North America (European Telecommunications Standards Institute, 2020; Lenehan, 2021). Most of the systems are based on EPC Gen 2 Air Interface protocol (EPCglobal Inc, 2017). UHF RFID readers use four multiplexed channels, which gives a maximum read rate of 300 transponders per second.

The field testing has shown that the maximum reading range for transponder can be 40 meters with a patch antenna. This needs to be taken care of when setting up the system to avoid unwanted missed reads. To record the time, the timing system uses a gating time. The gating time is the time system that waits after first read of transponder to determine the highest RSSI value of the transponder, which is the moment the transponder is nearest to the antenna. Experience has shown that the system is reliable, and most of the missed transponder reads are based on human errors such as a misplaced transponder, or a runner has blocked a transponder accidentally.

Figure 2 shows a typical setup of an RFID timing system with ground antennas installed inside rubber mats. In critical timing points such as the start and the finish, the two separate sets of the timing lines and readers are used to prevent the loss of times. Also patch antennas can be used for backup or read from overhead.

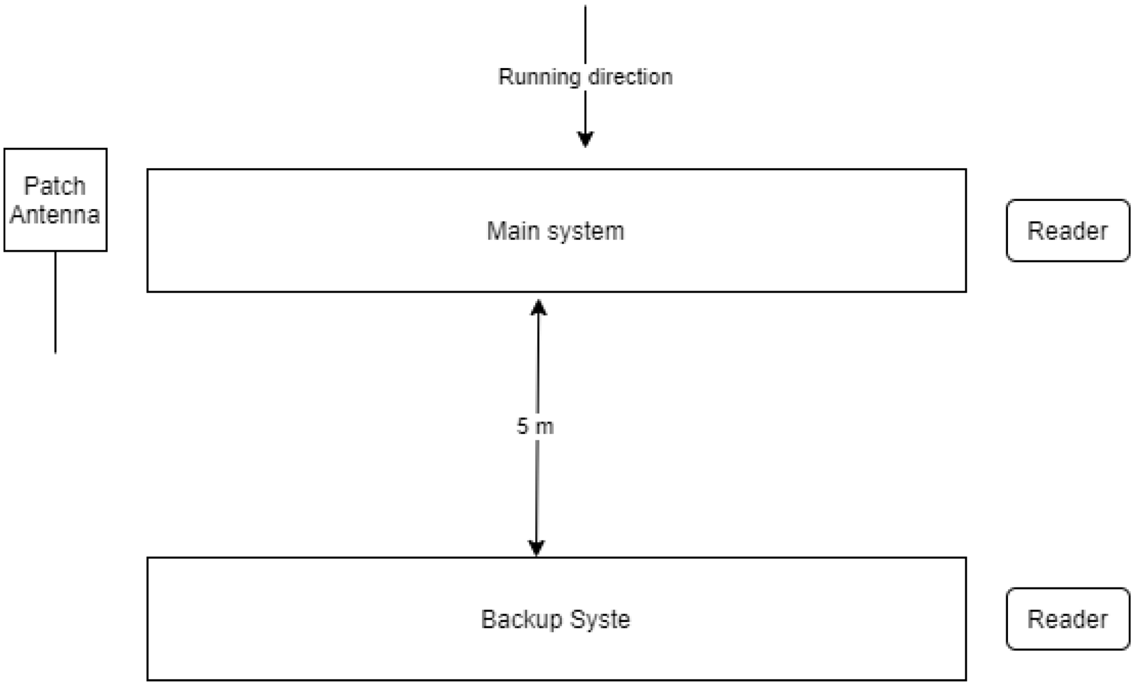

Figure 2 RFID timing system

2.2.3 Active transponders

Active transponders have an internal battery; hence, they do not need a magnetic field to power the transponder (RaceResult AG, n.d.). Figure 3 shows RaceResult active transponders working principle. A wire loop is connected to the active timing point, and the decoder is constantly transmitting the activation beacon using a frequency of 125 kHz. When transponders arrive inside the loop, it starts 2-way communication with the reader using a frequency of 2.4 GHz. The transponder has been recorded by the decoder at least 50 times to record reliable time. The precision of the system can be modified by altering the loop width and the power of the activation signal. The standard width of the loop ranges from 50 to 60 centimeters. The precision of the timing system increases when the width decreases.

The active timing system provides high precision and reliability because the activation loop and the transponder are transmitting using different channels. The downside of this system is that the transponders have a high unit price, and the internal battery is not changeable.

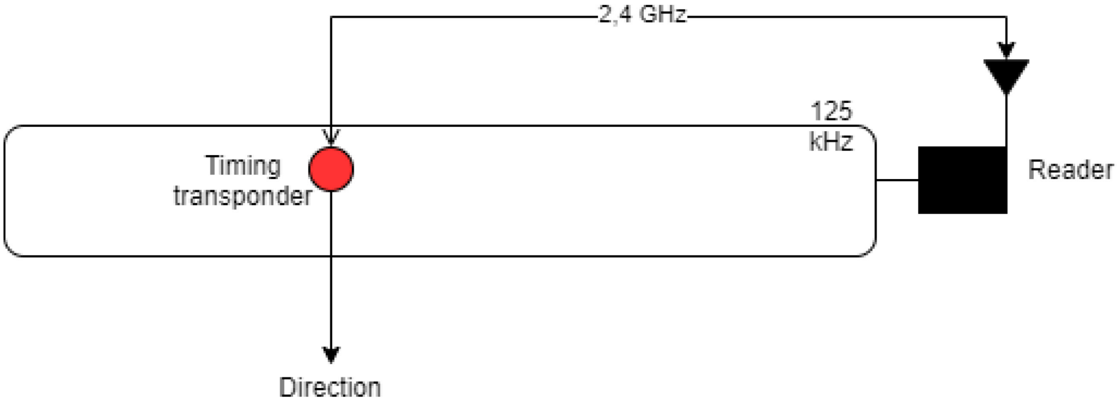

Figure 3 Active Timing System

2.2.4 Bluetooth based timing

Bluetooth technology is not widely used for timing yet. A Bluetooth Low Energy (BLE) technology can be used to build a timing system (Sun et al. ,2019). Their system based on tracking the RSSI level of the transmission and their experiments gave the reliability of 100 % and they reported that timing error was under 156 msec for each participant. The system uses active battery powered Bluetooth transponders and receivers installed on ground. The Bluetooth transponder will broadcast id beacon every 20 msec allowing the 0.1 second timing resolution.

Bluetooth has been used for tracking participants in the 2017 Barcelona Marathon (Perez-Diaz-de-Cerio et al., 2018). They used the BLE advertising method with a custom-made runner sensor. In their research, they found that Bluetooth Low Energy can use a supplementary system for RFID timing and add extra data such as blood pressure information to the sent data packets. They see the interrupted scannable undirected advertisement method implementation increases the reliability of the system. With this method, the Bluetooth device stops sending the advertisement packets after the reading device has sent the acknowledge packet to the device. By using this approach, they could reach the 100% reading rate of the used sensors.

2.3 Publishing of competition results

The timing system measures timing data, and to be able to produce the results that data need to be processed in the results service platform. The platform connects the transponder to the participant data and provides the rules how to the rankings are made. Figure 4 explains the workflow for the results system. The results service application connects to the entry database and timing data from the timing system.

Each of the competition distances have their own configuration for the timing points. The timing point rules determine, how the timing data collected from each timing locations are used. These rules set for example the minimum and maximum times the location is used, lap gap time and counts. The finish time and the intermediate times are calculated based on these rules.

When the times are calculated, the results are synchronized to the online database, pushed to the mobile application, and sent to the participant using SMS.

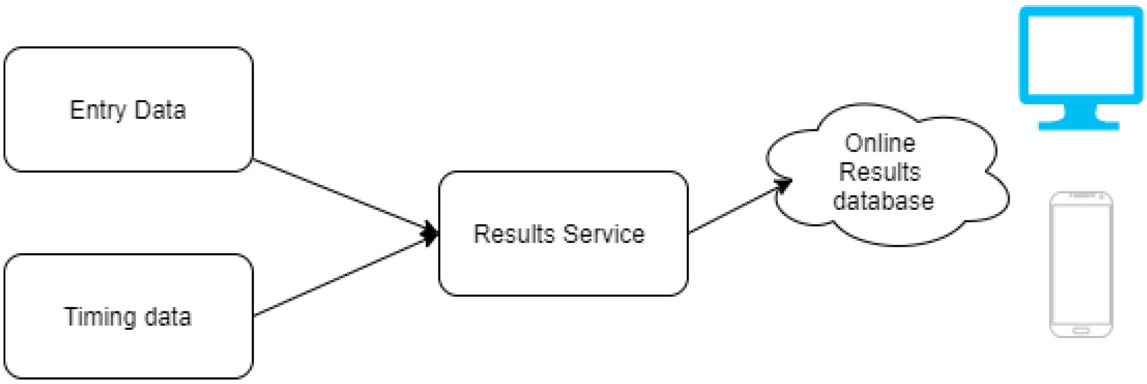

Figure 4 Results workflow

2.4 Online entry system

The main purpose of the online entry system is to collect all needed information from the participant and the entry fees during the registration. The Online entry system provides interfaces for the entrant and the event organizer to manage the entrant data.

Most events have one or more-sub event usually divided into different distances. Each distance has entry fees, which typically rise periodically to create an entry fee ladder. Figure 5 shows an example of the entry fee ladder based on time span with the start date and the end date.

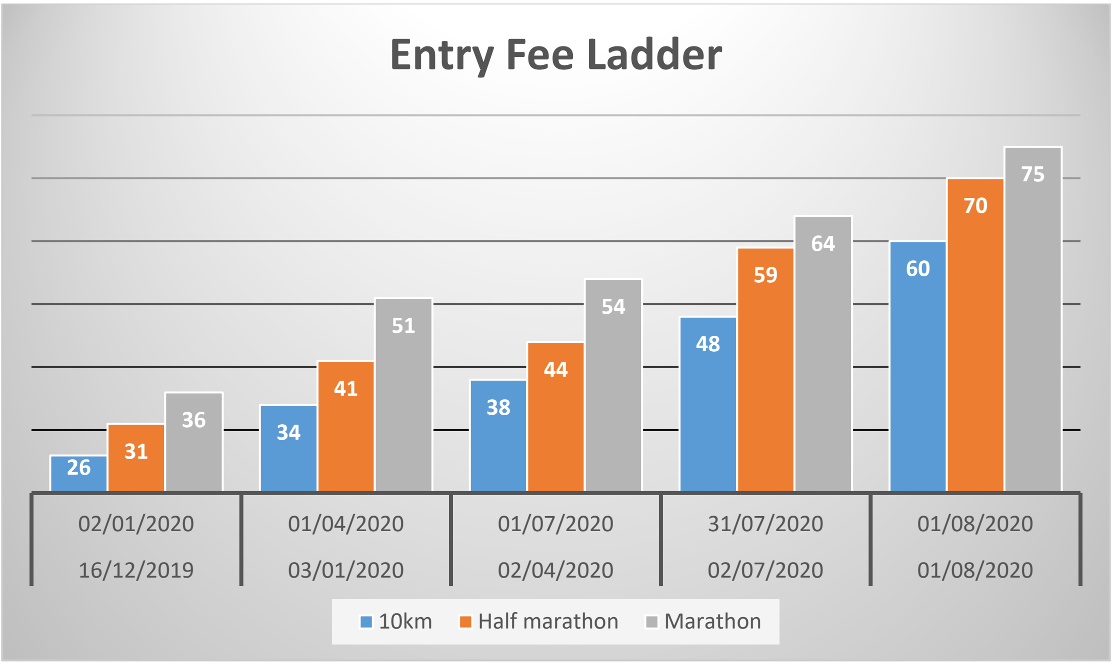

Figure 5 Example of entry fee ladder

The experience with the online entry system has shown that the entry fee ladders are typically used as a marketing strategy. The first entry fees are usually affordable after the previous event date. These prices, usually called as early bird prices are often valid only less than one week, and their main purpose is to offer a low price for the runners who enrolled in the past event.

The entry fee increase is used for the email campaigns to offer a notice of a forthcoming price increase for the event marketing register. The marketing of an upcoming online entry fee increase is clearly seen in the online entry amounts. Figure 6 demonstrates the online entry behavior by a date before and after the online entry fee price had been increased on 2 July.

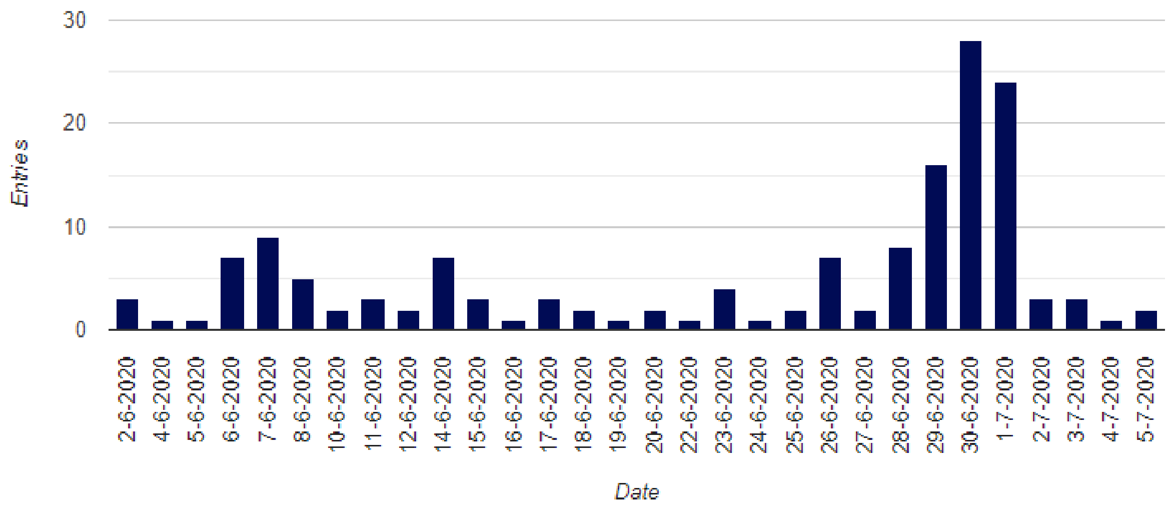

Figure 6 Online entries by date

The online entry system can also be used for marketing and communication. The experiment has shown that the good planning of the entry system also keeps data clean and formatted, which makes it easier to handle. The system makes it easy to comply with the GPDR policies.

2.5 Event timing and results service system

2.5.1 Structure of the event timing system

The timing and results service system connects several systems together. The system connections are shown in Figure 7. The event timing generally consists of three main parts: the time collection, the time and the results calculation, and the results publication. The three parts can be run on the same server when the event timing is done in offline mode, or each of the parts can be run on different servers. Usually, several time collection systems can be used on large-scale events, even using another timing system connected to the same time and the results calculation system.

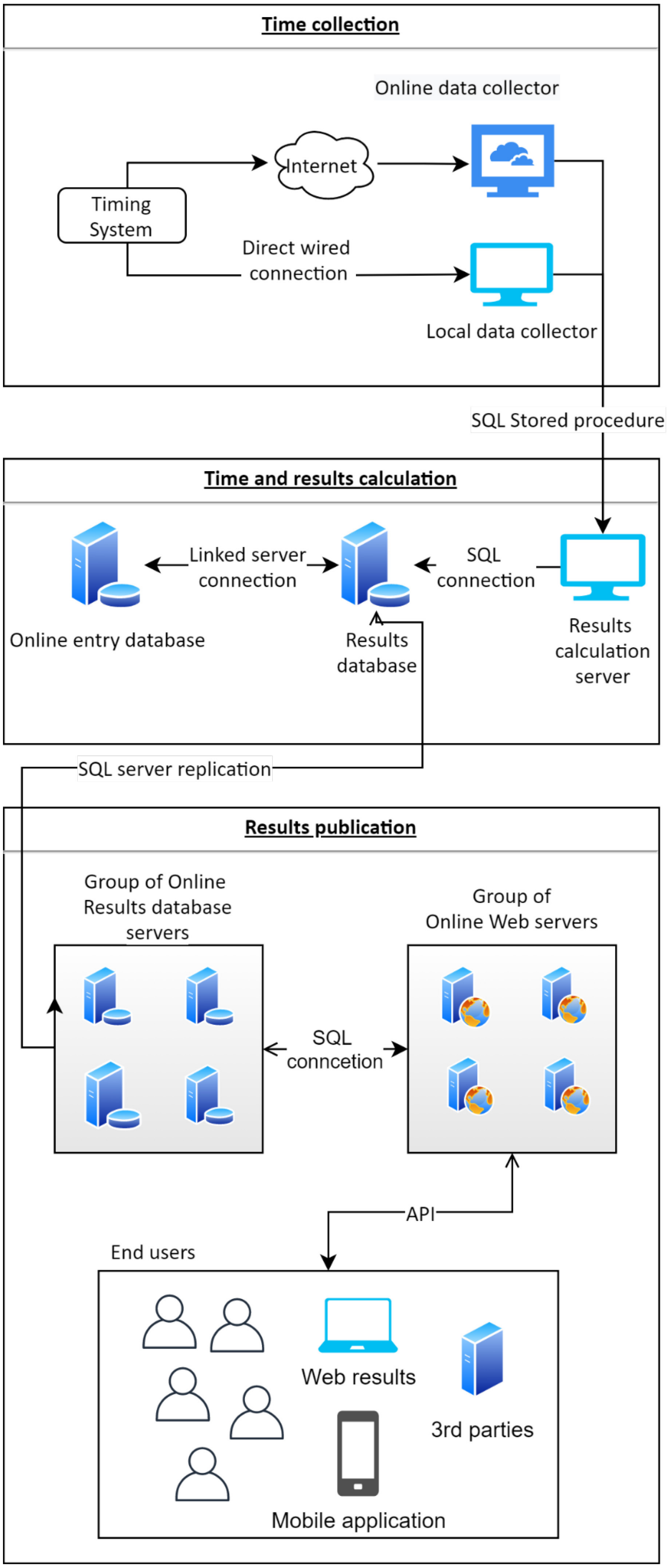

Figure 7 Components of the event timing system

The time collection includes the used timing system and the needed network infrastructure and software to get the recorded time and the transponder code to calculate the result. The timing system can be locally connected to the results calculation server or remotely connected without a physical connection to the results calculation system. The time information is exported to the results calculated using a direct SQL connection by calling a stored procedure. The data collector can also provide a user interface to remotely manage the timing devices and see the connection and device status.

The time and the results calculation are responsible for collecting the raw timing data and using it calculating the results based on the predefined calculating rules. The timing and the results calculation system can be set up locally on the event site or a virtual server hosted online. Depending on the size of the event the results database and the timing server can be running on different computers, but usually, they are located on the same computer.

The results publication contains the servers needed to deliver results to the end users and third-party systems. The results publication part is located on the cloud service, and the amount of the required servers are scaled by the total amount of the events and participants processed during the day. The online database servers and the results calculation server are using the Microsoft SQL server (Microsoft, n.d.) replication to transfer data. The results calculation database acts as a publisher and can serve the needed number of online database servers who act as a subscriber. Only the data needed for the event results are replicated, and all the results calculations are made in the results database server.

2.5.2 Timing system and data collector

The timing system is responsible for record the raw timing data containing the time stamp and the identity specifying id linked to the time. In a chip-based timing system, this is a transponder code and a bib number in the manual timing. The timing system sends the data to the data collector, which then deliver the data to the results calculation server.

The data collector is an application that the timing system manufacturer provides. Some of the timing systems also offer an open data protocol to create an own collector software. The data collector and the timing system can connect by a direct serial cable connection or by network connection. The network connection can use an Ethernet or a socket-based connection on a local network or using an Internet connection by the mobile network. The data collector receives the raw timing data from the devices and maps the device to the preset timing location. The primary purpose of the data collector is to forward the location-mapped timing data to the results server and give an overview of the status of the timing devices and an interface for remote configuration.

2.5.3 Time processing and calculations

The results calculation server calculates the event results using the raw timing data and predefined rules set for event distances. The entrant data is retrieved directly from the online entry system, using an external API or from the manual entrant list. The results of the calculation are based on the distance and the timing location-based rules.

Each distance has a start and a finish timing location with the optional split timing points. The raw timing data from the data collector and the entrant data are mapped by a transponder id or a race number. The location-based mapping is used to calculate the results for each location in the entrant’s distance. The calculation also takes in additional rules. The minimum and the maximum time values filter out the raw data before and after the set values. The time calculation method can be defined as the first time, the last time, always or laps. The selected method defines how the data is used for the result calculation. The first and the last time methods will look the first or the last time for the split, and if processing time is earlier or after the already checked result, the result will be updated. The always method does not look like the earlier set result; it updates the result every time a new time has been recorded. The lap method is used when the timing location is passed several times during the event. In the lap mode, the amount of the laps and the gap time separating the laps is set, and each of the laps is mapped to its own results.

After the time calculation, a raw time is written to the results, and the ranking rules are used to calculate the positions based on the distance, gender, and age category if the distance has the age categories defined. The results database is actively replicated to the one or many online results database servers, depending on the size of the event.

2.5.4 Results publication

The online web results servers offer a web interface for the event results using the online result database servers. These servers also provide an API for mobile phone applications and third-party use such as broadcast graphic providers.

The results publication servers are divided into the database servers and web servers. The database servers and web servers are running in virtual servers behind the load balancers. Depending on the size of the event and amount of the events ongoing, the count of the database and the web servers are scaled to match the estimated loads.

3 Development of a system for small events

This chapter describes a plan for the develop the bluetooth based timing system and the self service portal to allow an event organizer to set up the event and activate timing to the event in a simple and affortable way.

3.1 Development of the Bluetooth timing system

First, a way to build a Bluetooth timing system using a smartphone as a timing system and a smartphone or Bluetooth bracelet as a transponder is described. The second part defines a plan to build a self-service portal that integrates to the online entry system and gives its users access to build their own entry portal and event timing configuration automatically.

The previous studies indicate that a Bluetooth timing system (Sun et al., 2019) and a low-cost RFID timing system (Chockchai, 2018) need special hardware for their setup. Perez-Diaz-de-Cerio et al. (2018) presented a timing system to locate the runner during the 2017 Barcelona Marathon. Their research-based use a smartphone application to read the passing runners having a small custom-made BLE beacon device. Their research base is to collect extra information from a runner.

The goal for Ultimate Sport Service is to create a timing system, which does not need any special hardware for timing. The timing system should be working in an Apple iOS or Android smartphone and not need any external hardware to allow anyone to use it anytime.

3.1.1 System components

The Bluetooth timing system has three basic elements shown in Figure 8.

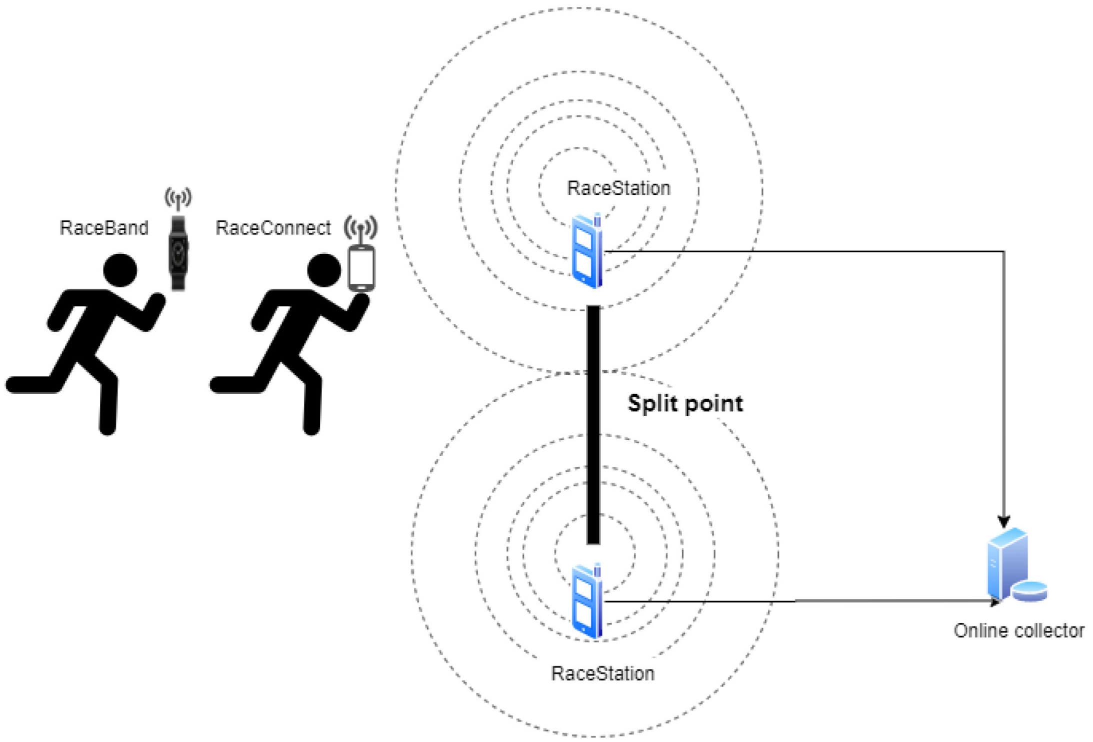

Figure 8 Bluetooth timing system

The runners are using a smartphone application RaceConnect, or a custom-made BLE wristband as a timing transponder. One or two smartphones with the RaceStation application work as a timing device. They receive a tracking beacon from the RaceConnect application or the wristband and then deliver it to the online collector for time processing.

3.1.2 RaceConnect and RaceStation applications

The Bluetooth timing system is based on Bluetooth Low Energy BLE (Bluetooth SIG, Inc, 2019) and advertising mechanism. The UUID is set for each of the events, and it is used to identify the advertisement packets. The RaceConnect application is a client application used by the runner. It broadcasts the event UUID, the hashed device serial code and the runner's personal tracking id.

The RaceStation application works as a Bluetooth server listening the broadcasted advertisements near the device. When a broadcast is detected, it instantly connects to the client device emitting RaceConnect application and starts a new session to record the beacons from the RaceConnect application. For each of the received advertisement beacon, the time stamp, and the Received Signal Strength Indicator (RSSI) value is stored for time calculation. This happens until the session is closed by the time limit or the emitting device is outside of the receive range. The race connect application will record all the reads from the session and send them to the online collector which is handling the time calculations.

3.1.3 Bluetooth smart band

An alternative for the smartphone and the RaceConnect application, a Bluetooth smart band is made especially for timing-purpose. This technology is based on Nordic nRF52832 Bluetooth platform (Nordic Semiconductor, n.d.). The band is based on MOKOSmart W2 wristband (MOKOSmart W2 wearable bracelet Beacon, 2021) shown in Figure 9. The firmware of the band is custom-made, which allows it to be configured using RaceConnect and Race Station applications. The configurable parameters are shown in Table 1.

Figure 9 RFID wrist band

Table 1 Bluetooth band configuration parameters

Parameter	Definition	Range
UUID	Unique service identifier	Unique for each event
PID	Unique serial number	7 alpha numeric characters
TX power	Transmitting power	10-100%
Interval	Advertising interval	20ms - 1000ms

The parameters are the same for the RaceConnect application and set by the event configuration of the online entry system, and they are not accessible by the end-users.

3.1.4 Online collector and time calculation

The online collector is responsible for receiving the times from the RaceStation Application, time calculation and transferring the calculated times to the results service system. The connection between the RaceStation application and online data collector is made using the REST API. The REST API is used for three message types: Status, Time, and Wave.

The status message contains the status information from the RaceStation application. The content of the status information is shown in Table 2.

Table 2 RaceStation Status message

Parameter	Description
GPS coordinate	Location of the device
Battery level	Percentage battery level
State	Scanning/Stopped
Total Sessions	Total session recorded
Uploaded sessions	Count of uploaded sessions
Pending sessions	Sessions not uploaded yet
Sessions having error	Sessions having an error

Each of the RaceStation devices saves the current location, battery level and state for remote observation as well as the count of recorded sessions.

The wave messages are used to set the start time for individual start wave. This is used in the mass start events to set the common start time for a group.

The time message transfers the session timing data from the RaceStation application to the timing system. The data contains location id, Tracker id, which is unique for each participant, Device type and Media Access Control (MAC) address as shown in Table 3. The difference between the Android and Apple iOS devices is the Android device sends out the real MAC address of the device. The Apple iOS device are always using a random MAC address in the broadcast. The Android device is shown in the type of one and the Apple iOS device is shown in the type of two.

Table 3 Session Data

ID	Location	Tracker ID	Type	Device MAC address
77069	1	4NA19C	2	B3DEF361-210B-80D9-4FEE-D68E86C88EDD
77070	1	4NA19C	2	3F35B65F-2570-58F2-4B42-C20155B102F9
77071	1	4NA19B	1	5E-67-F5-96-A9-1D
77072	1	4NA19B	1	5E-67-F5-96-A9-1D

Each of these sessions have one or more recorded times with the RSSI value received from the RaceConnect application or the Bluetooth timing band. Table 4 represents the received capture of one session.

The session time calculation is based on finding the smallest RSSI value indicating the best connection, which relates the closest possible distance between the runner and the timing device. In Table 4 the smallest RSSI value is -41 for the record id of 2427508. A new session is created when a connection between the Bluetooth timing device and the RaceStation application closes.

Table 4 Recorded times in the session

ID	Session ID	Epoch time stamp	RSSI
2427527	77069	1609350382912	-50
2427528	77069	1609350383321	-50
2427529	77069	1609350383458	-50
2427530	77069	1609350383866	-48
2427531	77069	1609350383996	-48
2427511	77069	1609350377300	-46
2427510	77069	1609350377159	-42
2427509	77069	1609350376745	-44
2427508	77069	1609350376464	-41
2427507	77069	1609350376201	-46
2427506	77069	1609350375929	-44
2427505	77069	1609350375798	-45
2427504	77069	1609350375665	-54
2427503	77069	1609350375530	-70
2427502	77069	1609350375396	-48
2427501	77069	1609350375265	-47
2427500	77069	1609350375126	-50
2427499	77069	1609350374594	-51

3.2 Implementing self-service portal

The self-service portal gives event organizers the possibility to setup the event online entry and basic configuration without remote assistance from Ultimate Sport Service. The experience with large events has shown that set up of a fully customized online enrollment form usually takes at least one working day for configuration and acceptance. To allow a self-service to work the form needs to be more standardized and simplified to avoid the need of the extra support time. The self-service will be built over the existing entry platform to allow an easy use of the payment channels, marketing and discount tools already existing in the current system.

The portal will be built using the Laravel Nova admin platform (https://nova.laravel.com). The portal will be running in Amazon AWS (Amazon Web Services, n.d.).

The portal needs to collect all the necessary details for the event owner and the events created. The details needed to collect for each of the events are shown in Figure 10.

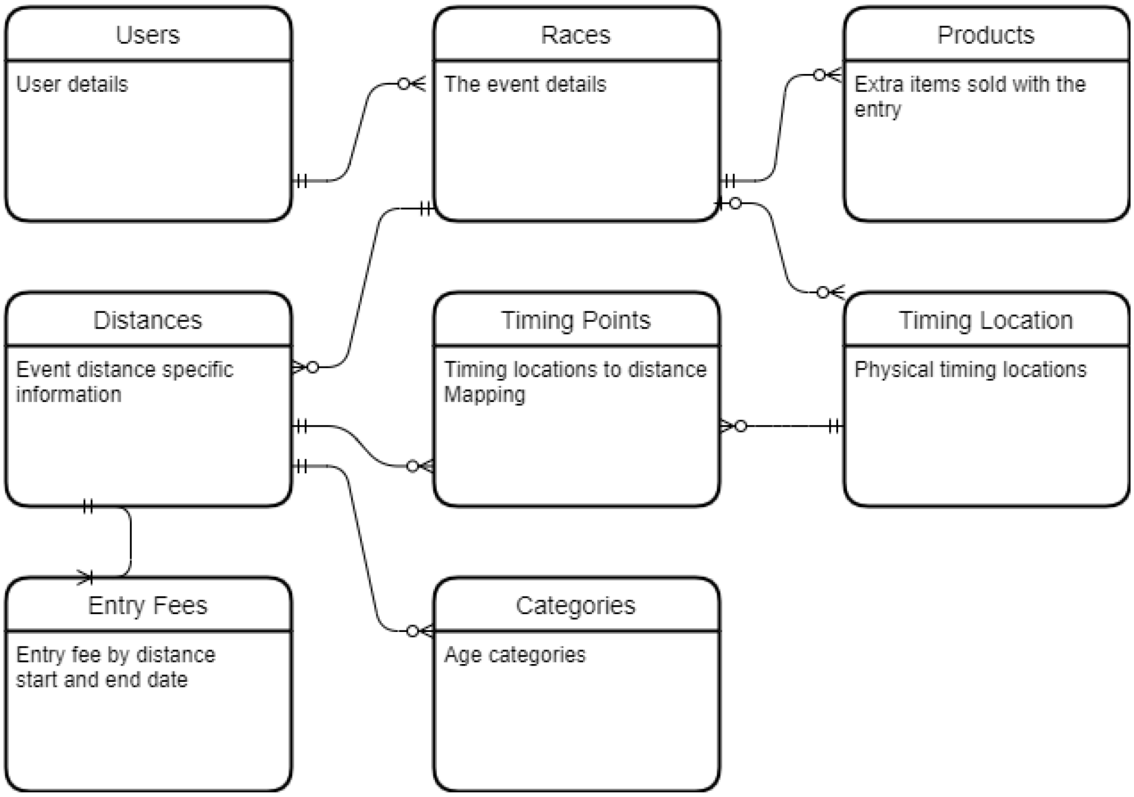

Figure 10 Structure of the Self-Service Portal

The event organizer needs to be registered before starting to use the self-service portal. For the event organizer the contact information, financial information and the status is stored in the Users database table. The users need to be verified by Ultimate Sport Service before they can start to publish new online entry forms.

All the event specific data is stored into the races table. Race data is divided to event description data, location data and layout data. Event data contains the name of the event, the description, the Value Added Tax (VAT) level for entry fees and the contact information. The location data includes event address details and the race start and the end times. The layout data contains the header and footer image and the layout template to be used for the entry form.

Products are extra items or services sold by the event organizer. These are separated from the distances because the VAT levels can be different from the event distances.

The timing locations are physical locations for the timing systems in the race. These locations are used to login to the RaceStation application.

Each of the race has one or more distances. The distance can be used for separating the timing of the different distances as well as the timing of the sub events. In most of the marathon events a shorter distance as half marathon and 10 km are also organized. Distance contains name, start time and description with bib allocation range and age range requirements. Each of the distance has collection of entry fees, timing points and categories.

The entry fees create an entry fee ladder for the distance. Each of the entry fees under the distance is defining the price for the entry with the start date and the end date.

The timing points are used to map the race timing location to the specific split point for the distance. The timing point sets the rules for the time calculation. The type of the timing point can be first seen time, last seen time, or laps. The first seen time will always use the smallest received time in the field and it is usually used for the split times and the finish time. The last seen time will always use the last received timestamp and it is usually used for the start time. In the laps mode the same timing point is used to record several laps with a set lap count. Each of the time points also support setting of the minimum and maximum times for the split point. This can be used to filter out the times outside the active race time.

The categories are used for dividing the results by the age groups. Each of the distances can have their own category setup based on the age range and the gender of the participant.

3.3 Implementing portal to existing platform

To make event creation automatic the self-service platform needs to be integrated to the current environment. The current production environment contains the online entry system and the results service platform. Both need to be modified to allow automatic event creation and publishing.

3.3.1 Online entry system

The current online entry system handles all the needed functions to set up the online entry database. The existing system is built to separate each of the new entry databases to its own database table and keep the data logically separated. The online entry system contains many extra features which are not needed for a small event. A new data structure is implemented to the online entry system to enable the addition of small events.

In this structure, all the self-service portal events are stored in a standardized database structure. The standard database structure will make it possible to use automation when creating the new entry form. This structure will have the information shown in Table 5.

Table 5 Online Entry Fields

FieldId	**Description**
EventId	ID of the event
Id	Record Id
DistanceId	Distance Id
FirstName	First Name
LastName	Last Name
Nationality	Mation code in ISO3 format
Gender	Male, Female, Other
DateOfBirth	Used for age category calculation
Club	Club shown in results list
Email	Email
CellPhone	Cellphone
Bib	Allocated bib number

With these fields also the timestamp, status, and transaction details are saved to this table. After the entry is saved, the bib number is assigned using the predefined bib number range. The bib numbers will be given in the entry order starting from the smallest available number. In case there are no free bib numbers left, the system should not accept more entrants.

The new structure will be implemented to the whole entry process shown in Figure 11.

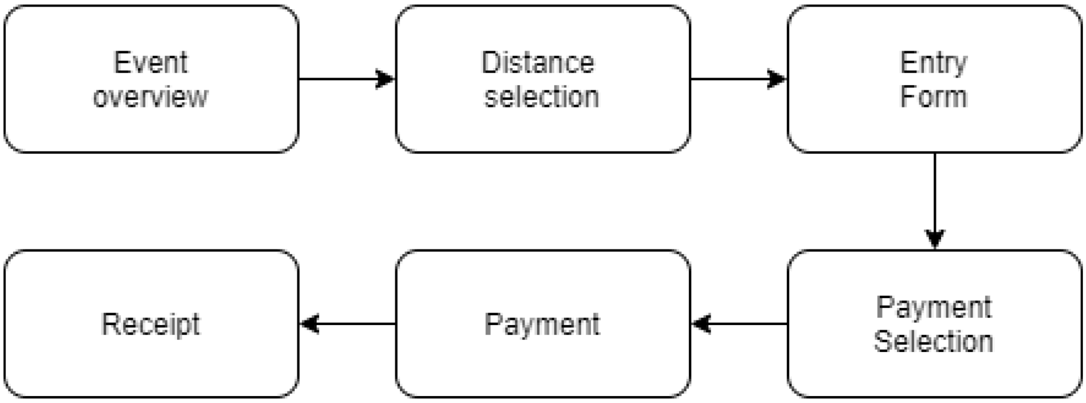

Figure 11 Online entry process

An online entry starts from the distance selection and ends by sending a confirmation email to the customer. In the event overview, the basic race information the user has entered the self-service portal is shown with links to the start list and entry profile login. The distance selection phase lists all available distances having an active entry fee available and the list of the products. When the user selects a distance or a product, the entry form for filling the data is shown. The form is validated after filling, and if all the fields pass the validation, the user is entering the payment selection phase. Regarding the location of the event, the available payment options are listed. After a successful payment using the selected payment method, the entrant will receive a confirmation email and receipt of the payment.

The integration between the online entry system and the self-service portal is made using a Laravel in-build API and a gateway service and the mapping API inside the online entry system. The connections between the systems are shown in Figure 12.

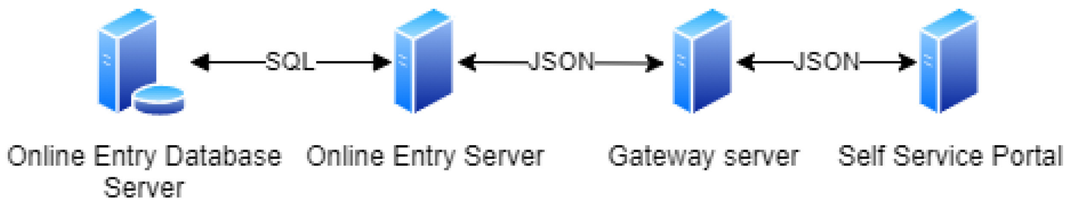

Figure 12 Connection between the Self-service portal and online entry system

The online entry system is not directly connected to the self-service portal because the gateway server provides extra protection and manipulates data to fit in the online entry system format. The new event for online enrolment starts with the self-service portal user, who is publishing the event using the race details view inside the self-service portal. This action will go to the Gateway server, which will request the event creation from the online entry system. If the user is verified by the online entry system and the obligatory data is filled into the event, The Online entry system launches a request to the gateway to fetch all the race data.

The self-service portal produces a JavaScript Object Notation (JSON) object containing the whole event data in one message and sends it to the gateway server, validating the request to match the online entry system request. The gateway server will connect to the entry system using a JSON package containing the event details shown in the calculated security checksum to verify the source if the details match. The example of the self-service portal data is shown in Appendix 1.

The online entry system will create a new event if the race id is not previously found in any of the events or if it is found, the data is updated. The database structure in the self-service portal and the online entry system is different, which causes a need to map the data between the systems. The online entry system uses a Microsoft SQL Server for the database (Microsoft, n.d.) and the self-service portal uses Laravel Vapor for the database (https://vapor.laravel.com). The data mapping needed between the tables is shown in Table 6.

Table 6 Mapping of database tables

Self-service portal	**Online Entry System**
Users	Users table
Races	Events
Distances	Distances, EntryFees, StartGroups, Bibs, Categories, TimingPoints
Products	Products
TimingLocations	TimingLocations
Translations	Translations
Configurations	Clients

The user, configuration, and product data will be imported to the administration database. Ultimate Sport service will use this database to accept the new organizers to the system and set the location-based parameters as the accepted payment channels. The races are also set into their own database, and after data validation by Ultimate Sport service, they can be published and open for online entry.

3.3.2 Results platform

The results platform is currently based on the results database and the results server. The current results database server has a dedicated database for each event. One database model for all the small events will be introduced and integrated into the existing APIs. One database model is possible because the self-service portal makes the entry data homogenous compared to the custom professional events.

4 Research results

4.1 Implementing the self-service portal

The self-service portal is made using the Laravel Nova Admin template (https://nova.laravel.com), based on Laravel Framework (Laravel, n.d.). The service is hosted in Amazon AWS Lambda (AWS Lambda, n.d.) using Laravel Vapor (https://vapor.laravel.com). Laravel Vapor is used to enable the self-service portal to be serverless and scaled automatically.

The self-service portal allows users to log in or create a new user id on its landing page shown in Figure 13. The self-service portal has two user types: standard users and administrators. The administrators have system-wide access to all the users and events. The standard user can access the events created by the account used.

Figure 13 Self-service portal landing page

By logging in to the system, the user can create a new race or manage the already created races. Because many sports events are recurring periodically, the system allows easy creation to duplicate one of the existing event configurations to a new race. The experience of handling the online entry forms for several years has shown that most times only the event date, a banner image, entry fee steps dates and prices are changing.

A new event creation starts when the user inputs all the needed parameters to the form shown in Figure 14. The basic event configuration includes the name of the event dates, description, and contact information shown on the front page of the online entry system.

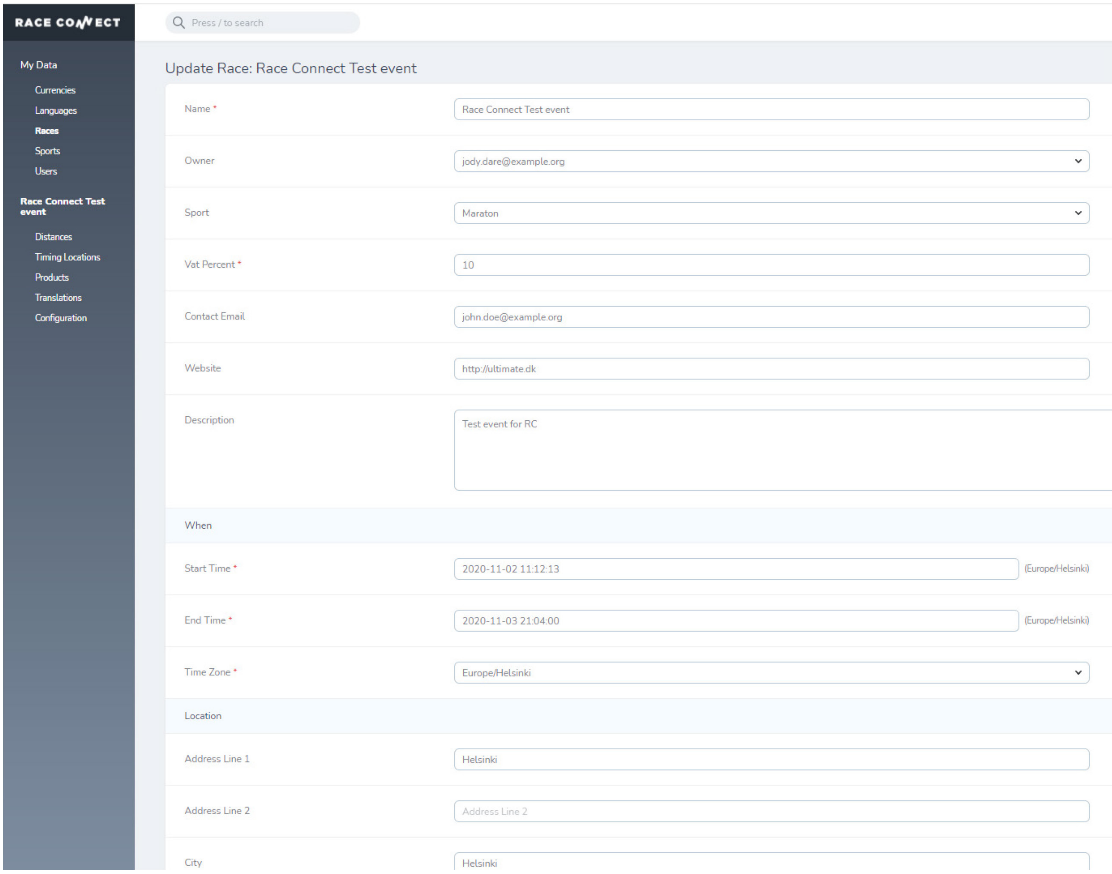

Figure 14 Event Basic Configuration

After the user has completed the basic configuration, the self-service portal will show a race overall menu. The menu shows the race details entered and gives a traffic light indicator for the race status shown in Figure 15. There are two categories of indicators: online registration and timing. The online registration checks the basic configuration, and the distances are set, and all the distances have at least one entry fee step set. The timing checks will ensure that the timing locations have been inputted and the timing points connecting the timing location and a distance have been set for all the distances.

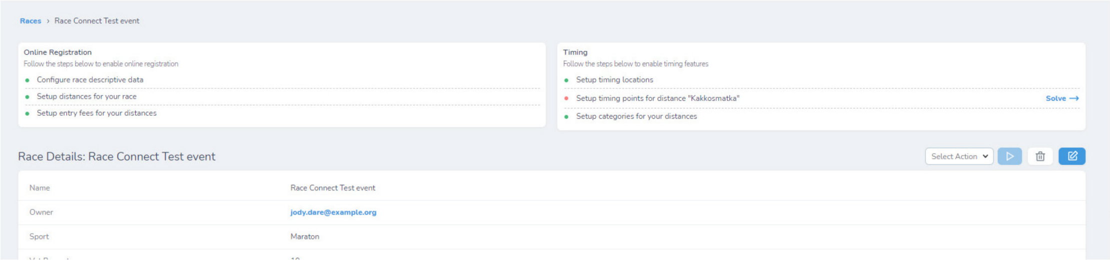

Figure 15 Race overview

Once all the setup is completed, the self-service portal will send the configuration to the online enrollment system using a REST API. This API converts and fills all the needed fields to the form used in the online entry system and creates an online entry form based on the configuration sent. If the online entry form of the event is already made, only the new settings are changed by the API to prevent any deletion by user mistake.

I did not implement the results service system and the self-service portal in the scope of this thesis because the results service system is made to use only one online entry form for one results service event. The self-service portal uses an approach to have one online entry form for all the owner user's events. To add this new approach means the results service system needs to be adjusted to the new one entry form approach.

4.2 Timing using a Bluetooth beacon

4.2.1 Setup of the timing devices

The Bluetooth timing was tested in Helsinki City Running Day on 3 October 2020 (Finnish Athletics Federation, n.d.). The test was made by measuring the Bluetooth split times in every kilometer mark in marathon (42.195 km) and half marathon (21.0975 km) distances. The marathon has 42 split points described in Table 7.

Table 7 Helsinki City Marathon Bluetooth timing points

Distance	GPS Coordinates	Lap	RFID Timing System
1 km	60.177533,24.931734	1	
2 km	60.170964,24.931970	1	
3 km	60.163547,24.922310	1	
4 km	60.159518,24.932310	1	
5 km	60.155328,24.944981	1	
6 km	60.160925,24.956991	1	
7 km	60.154360,24.958086	1	
8 km	60.154243,24.942060	1	
9 km	60.161291,24.929481	1	
10 km	60.161991,24.919640	1	Yes
11 km	60.161380,24.902805	1	
12 km	60.162071,24.896618	1	
13 km	60.164957,24.882302	1	
14 km	60.163653,24.867501	1	
15 km	60.169914,24.860540	1	
16 km	60.176479,24.853207	1	
17 km	60.184377,24.857187	1	
18 km	60.187809,24.874066	1	
19 km	60.194008,24.884162	1	
20 km	60.199498,24.891731	1	Yes
21 km	60.197268,24.903066	1	
22 km	60.196302,24.920484	1	
23 km	60.191776,24.929207	1	
24 km	60.185558,24.933912	1	
25 km	60.177426,24.932031	2	
26 km	60.170964,24.931970	2	
27 km	60.163250,24.922395	2	
28 km	60.160826,24.906882	2	
29 km	60.162718,24.901017	2	
30 km	60.164317,24.885303	2	
31 km	60.163021,24.869852	2	
32 km	60.168369,24.859491	2	
33 km	60.175123,24.853810	2	
34 km	60.182883,24.855226	2	
35 km	60.187272,24.870680	2	
36 km	60.192669,24.882587	2	
37 km	60.197338,24.891522	2	
38 km	60.200310,24.892302	2	
39 km	60.196788,24.915013	2	
40 km	60.191056,24.925485	2	
41 km	60.188004,24.934612	2	
42 km	60.186688,24.928534	2	

To measure the precision of the Bluetooth timing, there are 4 RFID Timing systems used for split times 10 km, 20 km, 30 km, and 40 km. The half marathon has a different route and the Bluetooth split points for half marathon are shown in Table 8. The RFID timing systems was used for timing points 10 km and 20 km.

Table 8 Helsinki City Run Half marathon Bluetooth timing points

Distance	**GPS Coordinates**	**RFID Timing system**
1 km	60.177533,24.931734	
2 km	60.170875,24.931723	
3 km	60.163250,24.922395	
4 km	60.160893,24.906678	
5 km	60.162607,24.900580	
6 km	60.164335,24.885150	
7 km	60.162988,24.869690	
8 km	60.168420,24.859512	
9 km	60.175161,24.853727	
10 km	60.182883,24.855226	Yes
11 km	60.187272,24.870680	
12 km	60.192669,24.882587	
13 km	60.187573,24.893228	
14 km	60.189799,24.900105	
15 km	60.193038,24.890123	
16 km	60.200310,24.892302	
17 km	60.197233,24.898968	
18 km	60.196859,24.916712	
19 km	60.190644,24.927219	
20 km	60.187348,24.934888	Yes
21 km	60.186250,24.926962	

The timing point setup was made using 37 Apple iPhone 6s (Apple Inc., 2021) smartphones installed inside a small Pelican 1040 Micro Case (Pelican Products Inc, n.d.).

The phones are using SimpleMDM (https://simplemdm.com) for central management. The management system is needed to keep track of the device locations and keep the phone’s software updated. The application RaceStation is set to the device to act as a timing system. Each of the timing locations has a log-in username based on the kilometer mask, such as 1 km split point has username 1.

The cases shown in Figure 16 have a modified foam insert and a high-power magnet installed to the backside of the box. The magnet is used to attach the pelican case with a timing box to a lamp post, as shown in Figure 17. The installation height is around 2 meters from the ground to minimize the blind spots when several runners pass the timing location.

Figure 16 The Pelican 1040 smartphone case

Figure 17 Installation of a Bluetooth timing point

Because we have only 37 timing devices, some are reconfigured and moved during the marathon event. Figure 18 shows the results management system view with the half marathon timing points on Google map. It shows that the marathon timing points 1 km, 2 km, and 3 km were almost in the exact location as timing points 25 km, 26 km, and 27 km. The crew moved those devices as soon as the last person had passed them. Split points from 4 km to 9 km are also not used for the second lap, and they were used for split points 27 km and 28 km.

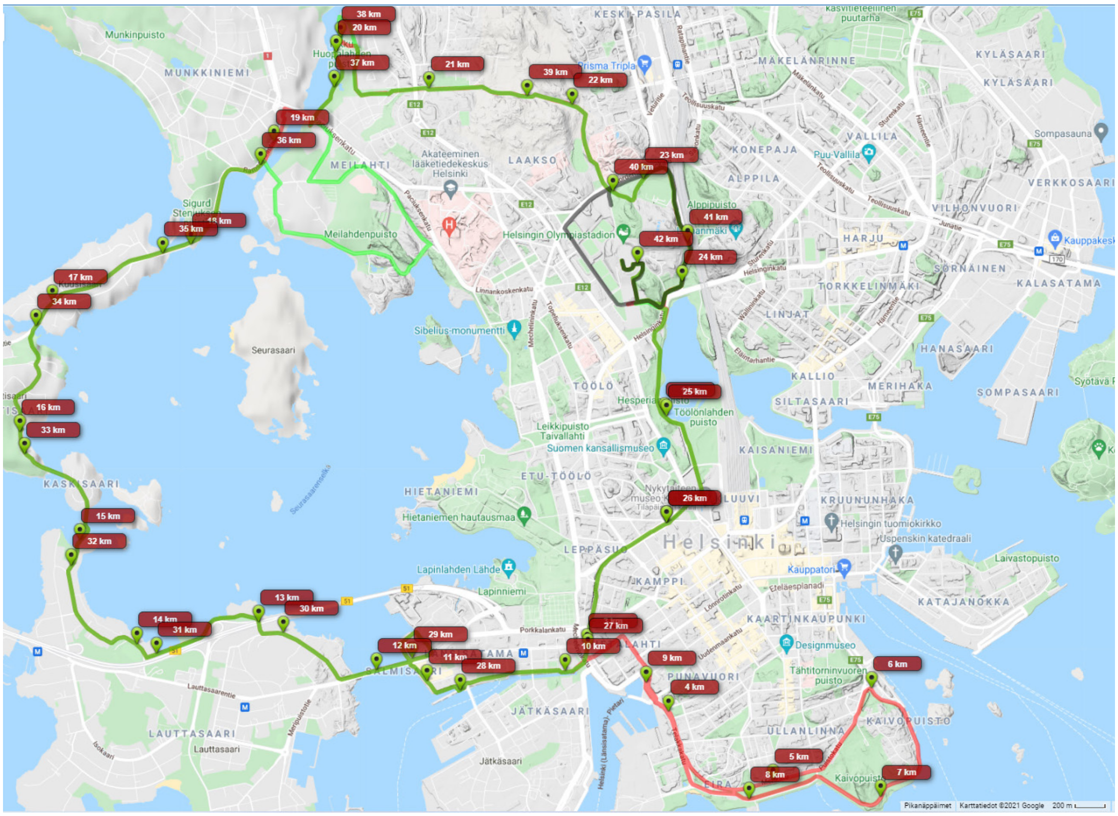

Figure 18 Marathon timing points on the map

The systems were installed by a 2-person team moving on the racetrack by car first to set the half marathon route. The half marathon started at 11:00. The setup was started two hours before the official start time. The installation crew followed the last runner, and after they had passed, the team moved the devices ready for the Marathon’s first lap, which started at 14:30. The team was following the last runner to reset the locations prepared for the second lap of the marathon and finally disassembled the devices following the last runners.

4.2.2 Bluetooth test user coverage

To enable Bluetooth timing, the user needs to use the RaceConnect application with a personal unique Tracking ID. The RaceConnect application is available for Apple iOS and Android mobile devices. The personal tracking id was delivered to the participants using the online entry system email function. The message contained the instructions on how to download and enable the timing shown in Appendix 2.

This email was sent to all the participants participating in Helsinki City Marathon and Helsinki City Run Half Marathon. Statistics of the usage is shown in Table 9. Based on the collected data, the 9.8 percent of the marathon runners and 4.8 percent of the half marathon runners used Bluetooth timing. The difference between the participation count and the sent emails was high because of the covid-19 pandemic. The participants had been given an option to transfer their entry for the following year.

Table 9 Participant statistics and RaceConnect users

Distance	Email sent	Started	Finished	Bluetooth timing users
Helsinki City Marathon	1865	1411	1367	138
Helsinki City Run	6041	3384	3371	225

4.2.3 The collected Bluetooth test data

The RaceStation devices captured a total of 14,278 sessions from the participant RaceConnect application during the day. The detailed session counts by the split points are shown in Table 10. It shows the amount of the sessions for both the distances and the count of the recorded sessions for each of the kilometer. The client static shows that 201 users used an iPhone, and 163 users were using an Android phone.

The results in Table 10 show that some split points had bad results or did not record any results at all. The split points 30 km and 40km needed to be left out of the test because of the lack of the devices. The split points in kilometers 18, 22, 27, 30, 31, 33, 37, 38, and 42 were affected by the Apple iPhone proximity sensor.

Table 10 Sessions by the split point

Split point	Count of sessions	Recorded times	Runners
1	320	305	211
2	755	723	323
3	646	622	315
4	452	427	208
5	580	571	192
6	717	693	321
7	525	488	110
8	347	328	108
9	598	567	114
10	450	441	209
11	498	476	111
12	1053	1019	321
13	419	415	113
14	352	339	208
15	561	541	208
16	442	432	112
17	512	493	110
19	106	102	46
20	464	454	228
21	3013	2828	305
23	23	19	17
24	487	479	116
25	456	437	125
26	564	521	118
28	241	234	111
29	790	752	112
32	432	418	111
34	536	522	110
35	363	358	109
36	539	521	110
37	27	22	14
39	304	296	109
41	76	71	7

We found out the proximity sensor was causing some of the devices to lock the screen automatically. The locked mode prevents the RaceStation app to scan the nearby Bluetooth devices because of the restriction in Apple Bluetooth stack.

This behavior was found out a day before the event during the field tests using the Pelican cases. The only quick fix we could find was on Apple Discussions

(ProustGiulio, 2021) to tape the sensor with black tape, which worked for most of the devices. The split point 1, 4, and 8 had only been working during the half marathon and split points in kilometers 7, 9, 11, 13, 16, and 17 during the marathon.

The split points 17, 19, and 37 had been shut down in early phase of the event because of battery had drained empty.

By observing the session counts, some of the timing points have a higher total count of the sessions than others. The count of sessions for the split point 21 km is high because the device was installed to the Olympic stadium 98 meters before the finish line close to the seating area for competitors. The system had logged high as 91 sessions for one tracking id for one hour. The high count of sessions for split point 12 km was caused because it was online for both laps of the marathon. The split point 29 km had recorded each runners several times. The obvious reason for a multiple read is caused by the race route is making a loop shown in Figure 19.

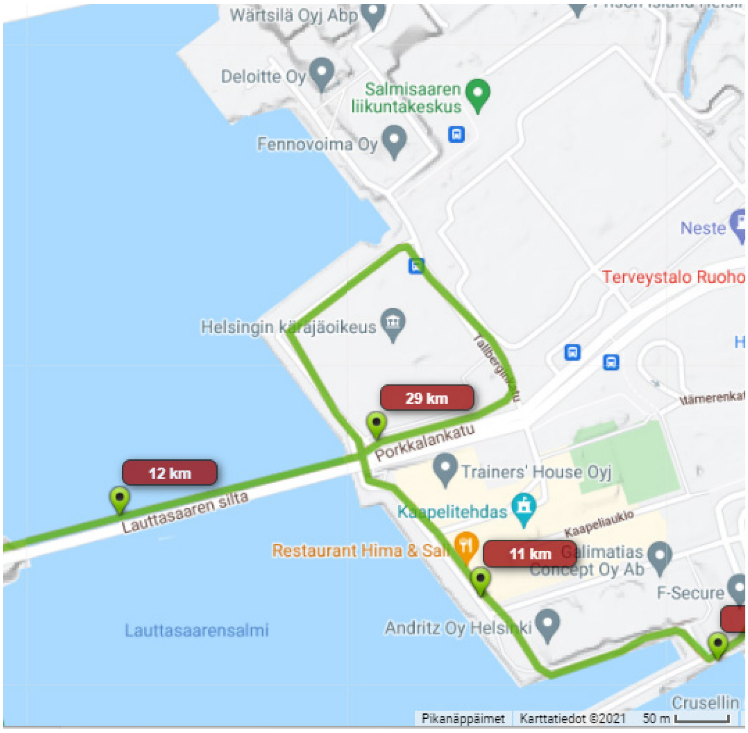

Figure 19 Timing Point 29 km

5 Discussion

5.1 Implementing a simple Bluetooth timing system

5.1.1 System Setup process

Implementing the Bluetooth timing system, which is affordable and straightforward to use, was one of the primary objectives of this thesis. The used test was a scenario with a timing system to record time for each kilometer of the marathon: the half marathon tests the system's precision against the RFID timing system.

The Bluetooth timing system setup was handled by two operators who had not ever used the system before. The team drove and followed the race route and installed the timing devices one by one. While moving to the following location, the second member of the team set the configuration ready for the next split point.

The RFID timing systems were installed at the same time with a crew of four operators using two vans and an extra car. For the marathon, they installed four RFID timing systems, and for the half marathon, they installed two RFID timing systems. The installation of a standard RFID split time system with a four-meter-wide ground antenna and two patch antennas takes around ten minutes. The Bluetooth timing system installation takes only a few seconds to put the device to pole using a magnet or a zip tie.

The field test has shown the RaceStation application is easy to use and does not need special user instruction. The Bluetooth timing system setup process requires only filling in three parameters to the RaceStation application: the id of the event, a pin code, and the id of the location.

To set up a RFID timing system, the operator needs to know how to place the antennas, connect the cables and start the device. When comparing the setup time, the Bluetooth-based timing system is simple to install and does not need any physical antennas or additional devices. The physical dimension of the system is small compared to the RFID timing system. The RFID system with four Mylaps Modular Mats (MYLAPS Sports Timing, 2021) has total weight of 60 kg.

5.1.2 Observations made during the system setup

By looking at the data recorded by the marathon split point 21 km seen in Figure 19, several runners were detected the first time when they run near the timing system before they went around the block. The smartphones' Bluetooth uses an omnidirectional antenna, which emits signals around the device. The field of the Bluetooth signal is around the device, and the RaceConnect users are read in every direction around the device.

The marathon split point 12 km has a high rate of detections. It was set up in the middle of a bridge with a long line of sight to detect the mobile devices using RaceConnect client.

In their study (Perez-Diaz.de-Cerio et al., 2018) measured the reading distance of the BLE device depending on the transmission power and the speed of the sensor. They measured that the coverage of the BLE transmission can vary from two meters to 400 meters. The static sensor has more than two times longer coverage against a sensor moving at velocity of 25 km/h. They found out the acute setting for the precision is to control the transmission power of the runner's BLE device.

Sun et al. (2019) used the BLE devices with a custom-made ground antenna. They find out that by lowering the transmission power they can have the timing resolution of 0.1 seconds with three-meter coverage.

The field test unveils the importance of setup planning. The RFID timing devices use a polarized directional ground antenna, which makes it easy to control the coverage area of the device. Because modifying the transmission power is not possible during the test, I noticed the only way to alter the coverage of the Bluetooth split point device is to alter the installation height of the system. By lowering the installation height, the surrounding trees and other objects seem to have an effect on the signal coverage. The optimal installation of the Bluetooth device would be a narrow path where the race route is not going close to the split point again.

The iPhones' proximity sensor caused problems during the test by suspending the RaceStation timing application in 10 devices. The issue was found during the test and had a significant impact. The main test idea was to provide a split time for each kilometer and provide extra service for the test users. The reason to find the problem so late was that we got the specially made cases just before the event and had no previous tests using the cases. All the previous small case tests were made by using the iPhones without a case, and this behavior did not happen. The cases are just needed to prevent a device from being stolen or damaged by weather. All the timing devices except the ones in RFID timing systems have a timing crew member to observe the system's functionality. To find a fix for the issue a more investigation is needed.

The long event day caused some of the devices to shut down because smartphones ran out of battery. We found three main reasons why the batteries ran out. Some of the used smartphones have been used for several years, which has lowered the battery's maximum capacity. The over-taped proximity sensor caused some iPhones to change the display's brightness leaving some devices to use maximum brightness settings, which shortened the battery life. Charging 37 devices to full capacity overnight was not possible in the working area allocated for the timing crew, leaving some of the device batteries partially charged. An external power supply can extend the battery time for the long race day. A power bank can be installed into the Pelican case to extend the battery life. The installation process of the systems can be adjusted, so the system is set up just before the first runner is approaching. For the charging of multiple smartphones, a centralized charging station is required for replacing the individual power adapters.

5.2 Precision of the implemented Bluetooth timing system

This thesis investigates the half marathon session data recorded from 10 km and 20 km split points. The long event day affects the marathon split times, and both locations, 10 km, and 20 km, have not got enough session data stored to measure the precision, and because the split points 30 km and 40 km did not have the Bluetooth device, it was not possible to compare the precision with the official times.

The Bluetooth timing devices recorded 225 individual tracking ids for the half marathon. The average count of the recorded split time per tracking id is 11 of 21 split times. As mentioned earlier, the problem with the proximity sensor and the battery drainage of devices, the split times for kilometers 7, 8, 9, 13, 16, 17, 18, and 19 were not working or were recorded only a couple of sessions. The total amounts of the recorded half marathon split times for 13 working split times are shown in Table 11. The finish times are recorded only by the official RFID timing system. One of the participants did not finish the race, and the total number of individual tracking ids is 224. The finishers are recorded by the official RFID timing system.

Table 11 Half marathon split times

Split time	**Recorded times**	**Hit percentage**	**Missed**
1	211	93.8	14
2	211	93.8	14
3	203	90.2	22
4	207	92.0	18
5	192	85.3	33
6	211	93.8	14
10	209	92.9	16
12	210	93.3	15
14	208	92.4	17
15	208	92.4	17
19	46	20.4	179
20	211	93.8	14
21	177	78.7	48
Finishers	224	99.6	0

The data used to create Table 11 is found in Appendix 3. The collected data shows the time of the first session recorded. The most missed split times are random, and 12 of 225 runners have only recorded 1 or 2 split times. By removing these 12 tracking ids from the test count, the reliability to read the tracking ids from the RaceConnect application of the 10 km Bluetooth timing point is 98.1% and, 20 km is 99.1 % of the RaceConnect application users.

The reliability of the Bluetooth timing points is good, and the collected session data is used to measure the precision of the Bluetooth timing system against the official times recorded by the RFID timing system. The target precision used to measure the system is one second, which is the official measurement precision for the long street runs (International Association of Athletics Federations, 2014). The test was made with the standard Bluetooth BLE advertisements and using preset transmission power in the RaceConnect application. Perez-Diaz-de-Cerio et al. (2018) presented an interrupted scannable undirected advertisement method, which set the BLE device to stop transmitting for a given time allowing more devices to interact with the Bluetooth timing device. This approach would be possible to avoid reading misses when a large group is passing the split point.

The standard method of timing a split time using the RFID system is to use the first seen time record. The RFID system uses ground antennas to have a read distance from three to five meters around the edges of a timing mat. The passing time is calculated by collecting the reads of the RFID tag until the gating time closes. The gating time is the time used for collecting the RFID tag reads starting from the first time the RFID tag is seen. Typical gating time for a finish line and split points is three seconds and for the start systems, it is one second. The RFID timing device then finds the read with the best RSSI value to determine the shortest distance to the timing device. Figure 20 shows the result when the same method is used to the Bluetooth times for split times 10km and 20km. The difference in seconds has been calculated by subtracting the Bluetooth first seen time from the official RFID time.

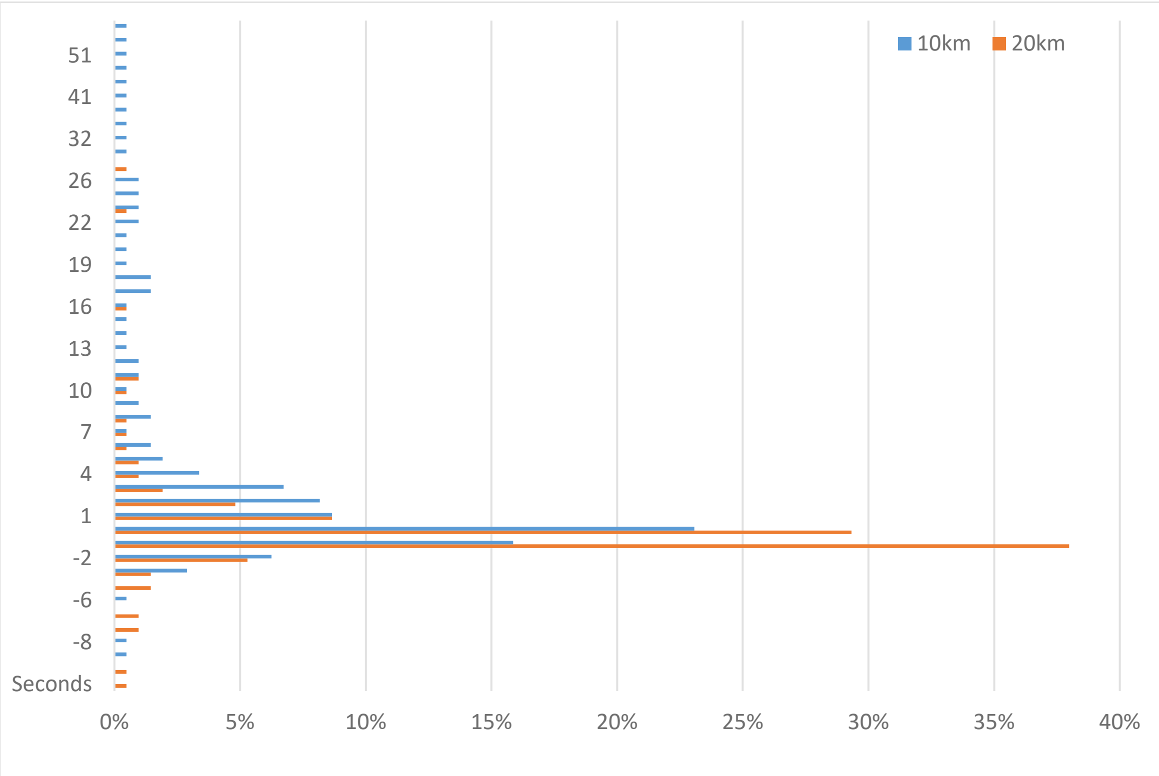

Figure 20 Difference of times using method first time seen method

Figure 20 shows the difference between the Bluetooth and the RFID times recorded for the 10 km split point. The 75.5 percent of the times are found in a range of five seconds before or after the official split time. For the 20 km split point the 92.8 percent have a five-second difference from the official RFID time. The collected data also shows that most of the times recorded by the Bluetooth timing device match or are ahead of the official times recorded by the RFID timing system. Only five percent of all readings are later than two seconds from the actual time. The two-second difference could be affected because the devices RFID and Bluetooth are not synchronized together.

The RFID timing devices are manually synchronized to have the same time together before the event. Even the synchronization time is fetched using Online Time Protocol (NTP) from an online time server. The computer clock is used to set the time of the RFID boxes using a TCP Connection. The Bluetooth timing devices use the Apple iPhone’s system time synchronized by GPS.

By looking at the count of recorded sessions for the 10 km split point, the average session count for a single tracking id is 1.9, having an average difference of 15.9 seconds. The 20 km split point has an average of 1.5 sessions for a tracking id. The 123 of the sessions were unique and had an average time difference of 12.4 seconds. The count of the sessions and the time difference from the first and the last seen times are collected in Table 12. The 10 km split point has recorded more than one session for 67 percent of all tracking ids. The 20 km split point has only recorded more than one session for 41 percent of the tracking ids. Table 12 shows that the difference from the first and last seen times increases if the tracking id has more than two recorded sessions.

Table 12 Session counts and the average difference of the first and last

Sessions	**Count 10 km**	**Average of difference 10 km in seconds**	**Count 20 km**	**Average of difference 20 km in seconds**
1	67	0.00	123	0.00
2	99	14.10	62	22.65
3	34	40.97	21	46.57
4	7	63.14	4	70.00
5	1	90.00		

As noticed during the system setup, the higher session count means the runner has been in the range of the timing device for a long time, the approaching speed has been slow, or the split point has broad coverage. The surroundings of the split points 10km and 20 km are shown in Figure 21. The 10 km split point was installed to the bridge and had an open line of sight. The 20 km split point was installed into a road bend having a bedrock wall and trees next to it.

Figure 21 Surroundings of the split points (Google Maps)

5.3 Methods to increase the precision

Table 12 illustrates that the data collected by using the first time received from the split point is not always the correct one. Perez-Diaz-de-Cerio et al. (2018) have proved the coverage area of a Bluetooth BLE device can be as much as 400 meters. Table 12 shows the tracking ids having more than one stored session with a high average difference between the recoded minimum and maximum session times. The RSSI value should be used to find the session with the best signal strength.

The signal strength should be best when Figure 22 shows the difference between the official time and the time recorded by the Bluetooth timing system with the best RSSI value recorded. By this method, 93.2 percent of the 5 km split times are in the five-second range from the official time. The 20 km split time has 95.7 % coverage for this duration.

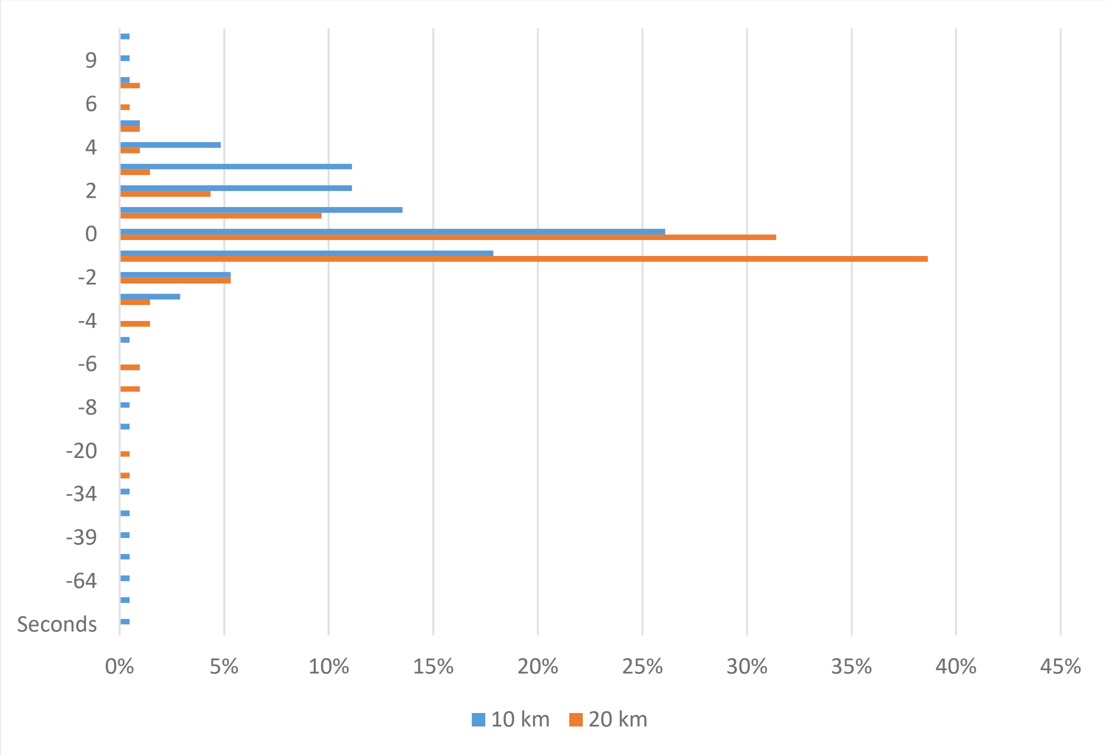

Figure 22 Time difference when using smallest RSSI value

The collected data shows there are now more hits for 10 km, where the Bluetooth time is greater than the time recorded by the RFID timing system. The average RSSI value for the times inside the ten-second marginal is -69 dBm. The collected values in Table 13 show that the precision depends on the signal level of the session. The lower the RSSI value goes, the higher the difference will rise. All the sessions having an RSSI value lower than -100 are recorded before crossing the timing point.

Table 13 Times having more than 30 second difference in 10 km Split point

Tracker Id	**Bluetooth time**	**Official time**	**Difference (s)**	**RSSI**
H6APTD	12:32:48	12:32:59	11	-75
YN3TXH	12:31:20	12:30:48	-31	-100
5GFH1R	11:51:01	11:50:26	-34	-101
LDD7FG	12:31:26	12:30:49	-37	-102
MLG5CQ	12:40:01	12:39:21	-39	-100
QCQY16	12:43:45	12:42:58	-47	-101
ZYS596	12:40:45	12:39:40	-64	-100
HG2DDH	13:07:48	12:06:30	-78	-101

Figure 23 shows the time difference distribution between the RFID timing system and the Bluetooth timing system in each of the RSSI levels. The minimum and maximum lines showing the precision under the RSSI value of -67 are close to the average difference and have a precision of two seconds. The RSSI level is insufficient to determine the system's precision because when RSSI is lower than -67, the possibility of random error rises.

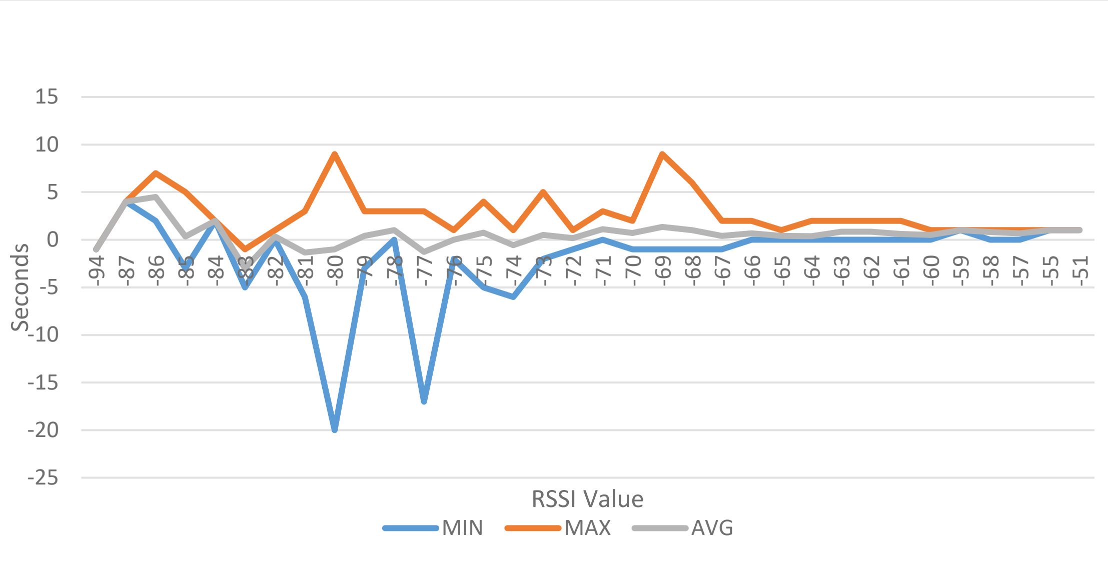

Figure 23 The time differences in 20 km on different RSSI values

By using the minimum seen time, the precision of the low RSSI values can be increased. Table 14 shows the result when using a first seen method instead of the best RSSI value for sample data shown in Table 13. In most cases, the time difference between the first recorded time is close to the official time for the 10 km split point.

Table 14 Comparing times with highest RSSI value

Tracker Id	**Bluetooth time**	**Official time**	**Difference (s)**	**RSSI**	**Bluetooth min time**	**Difference (s)**
H6APTD	12:32:48	12:32:59	11	-75	12:32:48	11
YN3TXH	12:31:20	12:30:48	-31	-100	12:30:21	27
5GFH1R	11:51:01	11:50:26	-34	-101	11:50:26	0
LDD7FG	12:31:26	12:30:49	-37	-102	12:30:48	1
MLG5CQ	12:40:01	12:39:21	-39	-100	12:39:23	-2
QCQY16	12:43:45	12:42:58	-47	-101	12:42:59	-1
ZYS596	12:40:45	12:39:40	-64	-100	12:39:39	1
HG2DDH	13:07:48	13:06:30	-78	-101	13:06:18	-78

The collected session data shows that the best timing precision is gathered by using both the minimum RSSI value and the minimum time recorded value. The data shows that the best precision is gained by using the minimum RSSI value method when the RSSI value is less than -90 dBm, and the first time seen method for RSSI value is -90 dBm or higher. By using this same method for session data of the 20 km split point, 96.1 percent for the recorded Bluetooth times are in five-second difference from the official time.

The study results show that the Bluetooth timing system with one device is suitable for recording a split time. The precision is not enough to be used on the finish line system to record an official time because it is not good enough to detect the order of two participants finishing close to each other. An auxiliary timing system is still required for these cases, such as manual timing and writing down the finishing order. In addition to manual timing, the Bluetooth timing system adds much more reliability to record all the participants because the same system records the time and the bib number. In the manual timing method, these are often handled by a different operator. The experience has shown that some of those lists miss one bib number or finish time, causing several times to be misplaced.

The achieved accuracy is good when comparing the difference of the RFID and Bluetooth timing working principles. The RFID-based systems use directed antennas installed on the ground or a directed activation field. These fields activate the timing transponder to emit its information only when the transponder is inside this field. The Bluetooth beacon continuously emits the advertisement packets, making it hard to determine the actual moment when the participant is on the timing line. It was shown in the test data that a person had two sessions with the same RSSI level. The time difference for these two sessions was even 58 seconds for tracker id YN3TXH shown in Table 14. These sessions had a high contrast compared to the official time from -31 seconds to 27 seconds. When taking an average from these values, the time difference between the official and the averaged time is -2 seconds. Both sessions had a low RSSI value of -100 dBm, which means the low RSSI values should also be taken looked if there is a long period between two sessions. This method cannot always be used because of a lack of knowing the direction of the detection. The

Bluetooth timing device does not know if the runner has stopped near the timing point.

5.4 Self-service portal

The self-service portal is designed and implemented during this thesis to the acceptance environment. It has proved to be an easy interface to set up all the needed information for a new event compared to the previous way, which was to open a new online entry by the service provider. Earlier the customer has filled an Excel sheet for the required parameters. The experience has shown, the Excel sheet was often missing some of the needed parameters. The missing information has increased the need for support time during the entry form setup. The setup process for the online entry system has been made by manually copying the received fields on the Excel sheet.

How the self-service portal guides a user to fill in all needed information and the homogenized fields for all the events makes automatic event creation and updating possible and will have a high impact on the time required for the event setup. The customer can also make a change online, which lowers the need for external support.

The self-service portal set up in this thesis can create an event in the online entry system used for the large events. The online entry system still needs additional work to create user-based extra configurations, which hold the settlement details and the user-related payment gateway settings depending on the country of the event, the user choice, and the used currency. The user acceptance mechanism is also needed to ensure the user is trusted and can start collecting online payments using the payment gateways registered for Ultimate Sport Service.

The current online entry system and the self-service portal have differences in their data structures. The current online entry system is heavy and has too many configuration options for small events. Even the event can be automatically created to the current online entry system, and all the data need to be converted between two different database systems. Every update to the self-service portal requires the system to check all the field values from the online entry system against the self-service portal to run the update, delete or create command. These data conversions add the need for support time during the system development and maintenance. More research is needed to investigate how the online entry system could be directly integrated into the self-service portal. By combining the online entry process with the self-service portal, data conversion is not needed. However, the small events usually use only one entry fee level and a static set of the entry fields. They might only take in entries typed in manually on the onsite event office, which makes the online entry system un-needed.

The results service part was not included in the self-service portal during this work. The current online entry system has plenty of functions, which are not needed in small-size events. In the results service system, each event has its database replicated to the online server. The small-size events have a homogenized database structure, making it possible to use one central database for all of these events. Research is needed for integrating a light version of the results service directly into the self-service portal to have an entirely separated system.

6 Conclusions

This thesis introduces the concept of a Bluetooth timing setup for small events using a smartphone-based timing system that can use a runner’s smartphone or an affordable custom Bluetooth wristband as a timing device. The self-service portal is introduced for automating the system creation and configuration and it offers an easy interface for race organizer.

Against the earlier studies of inexpensive passive RFID Timing systems introduced by (Satitsuksanoh et al., 2017; Chockchai et al., 2018), and the study Bluetooth timing made by (Sun et al., 2019) and (Perez-Diaz-de-Cerio et al., 2018), the tested timing system setup based only on smartphones. With this approach, no special equipment is needed for the event timing, which makes it easy for anyone to start timing using the hardware they already have.

The setup of the timing system needs to be fast and straightforward and can be performed by anyone without training. This study has introduced a system that can be set up only in a few seconds, making the setup process simple; the device needs to mount to a metal pole or a traffic sign using the in-build magnet on the Pelican case. The case study shows that the timing point's location requires inspection in advance because the long-range of the Bluetooth receiving field can cause false readings.

The test data collected have shown, the precision of the Bluetooth timing is suitable for using it as a split point, having a precision of around one second. More research is needed to investigate the precision of the finish line setup with more than one timing device because the precision of one system is not enough to record the official finish time. With the current Bluetooth system, the finish line system should have a manual backup to record the times and order of the finishers.

The self-service portal enables a simple and easy timing setup without any support from the service provider. The best implementation of the self-service portal still needs to be investigated further. The online entry and the result service components should be directly integrated into the self-service portal to have a cost-effective solution.

7 Further development

Bluetooth timing system

The Bluetooth timing test was performed by using only the runners’ cellphones as a timing beacon. It was seen during the test that several devices were only recorded one or two times. By investigating the data and the physical locations of the Bluetooth timing devices, the result shows that some of the runners might have had their phone in the back bag or running belt behind the body, and others have used an armband or pocket to store the phone. To have optimal and controlled timing results, all the participants should wear the identical timing device in the same way in the same body location. In the RFID timing, the passive RFID chip is glued behind the chest bib number, and for the triathlons, the active timing chip is attached to the participant’s ankle with a neoprene band.

The beacon wristband would homogenize the timing for participants for Bluetooth timing. A new field test should be arranged to test the precision of the Bluetooth wristband against the RFID timing system and the RaceConnect Application.

The most significant issue of the field test was the Bluetooth timing devices that did not record times. More research is needed to fix the proximity sensor locking problem. Reliability and precision should be tested using a pair of timing devices installed on both sides of the track to prevent total data loss if one device stops working. With two devices, the precision should also increase, and the maximum throughput of the timing system rises because a second device doubles the amount of concurrent BLE sessions.

Duplicating the timing devices will make the timing more reliable and result in higher precision. It would not add much setup time, and it would cut the shutdown risk to half. Adding a second device makes concurrent session count higher, which helps if the split point is wide.

The need for an easy-to-use user interface to monitor the Bluetooth timing devices is needed. The timing systems were observed only by the data in the database, making it hard to watch the system's overall state. The missing kilometer split times were fixed during the test using the RaceConnect GPS tracking function to calculate the elapsed distance.

The technology in the tested Bluetooth timing system is based on the Bluetooth BLE version 5.1. The following Bluetooth BLE version 5.2. (Bluetooth SIG, Inc., 2019) has introduced two new direction-finding methods: Angle of arrival and Angle of departure. With these methods, a Bluetooth receiver can detect the direction of a moving device. The detection is made by using a radio switcher and antenna array. The distance and the location calculation are made by calculating the radio signal phase shift between two or more antennas. Using the angle of arrival makes it possible to determine the moment when the runner is directly over the timing location.

Self-Service portal

The currently used online entry system and the results service systems are highly customizable, including a high number of features that the small-size event rarely uses. The self-service portal needs more research work for integrating the online entry system and the results service system directly into it.

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Appendices

Appendix 1. An example of JSON data provided by self-service portal

{
"data": {
"id": 41,
"owner_id": 12,
"sport_id": 1,
"name": "Race Connect Test event",
"description": "first test event for RC",
"contact_email": "john@smith.com",
"website": "http://website.org",
"local_start_time": "2020-11-02T07:12:13.000000Z",
"local_end_time": "2020-11-03T17:04:00.000000Z",
"timezone": "Europe/Helsinki",
"address_line_1": "Mannerheimintie 1",
"city": "Helsinki",
"state": null,
"postal_code": "00100",
"country_code": "FI",
"currency_code": "EUR",
"tracker_code": "A",
"vat_percent": 10,
"published_at": null,
"created_at": "2020-12-02T11:19:32.000000Z",
"updated_at": "2020-12-11T13:51:08.000000Z",
"deleted_at": null,
"distances": [{
"id": 1,
"race_id": 41,
"sort_order": 1,
"name": "10 km",
"short_name": null,
"description": "10 km running",
"local_start_time": "2020-11-03T09:12:13.000000Z",

"min_age": 10,
"max_age": 99,
"age_calculation": "end_of_year",
"start_bib": 1,
"end_bib": 212,
"created_at": "2020-12-02T11:19:32.000000Z",
"updated_at": "2020-12-14T06:36:54.000000Z",
"deleted_at": null,
"categories": [{
  "id": 1,
  "distance_id": 1,
  "name": "M50",
  "short_name": "M",
  "gender": "m",
  "min_age": 0,
  "max_age": 99,
  "created_at": "2020-12-02T11:19:32.000000Z",
  "updated_at": "2020-12-02T11:19:32.000000Z",
  "deleted_at": null
 },
 {
  "id": 12,
  "distance_id": 1,
  "name": "N yleinen",
  "short_name": "N",
  "gender": "f",
  "min_age": 0,
  "max_age": 20,
  "created_at": "2020-12-08T12:44:12.000000Z",
  "updated_at": "2020-12-08T12:44:12.000000Z",
  "deleted_at": null
 }
],
"entry_fees": [{
  "id": 1,
  "distance_id": 1,

"name": "Early bird",
"short_name": null,
"local_start_time": "2020-12-08T00:00:00.000000Z",
"local_end_time": "2020-12-10T00:00:00.000000Z",
"currency_code": "EUR",
"created_at": "2020-12-08T12:49:55.000000Z",
"updated_at": "2020-12-11T13:11:49.000000Z",
"deleted_at": null
},
{
"id": 2,
"distance_id": 1,
"name": "Basic",
"short_name": null,
"local_start_time": "2020-12-11T00:00:00.000000Z",
"local_end_time": "2020-12-31T00:00:00.000000Z",
"currency_code": "EUR",
"created_at": "2020-12-08T12:49:55.000000Z",
"updated_at": "2020-12-11T13:11:49.000000Z",
"deleted_at": null
}
],
"timing_points": [{
"id": 1,
"distance_id": 1,
"timing_location_id": 100,
"name": "Ennakko",
"meters": 9900,
"type": "finish",
"laps": 0,
"min_time": null,
"max_time": null,
"created_at": "2020-12-02T11:19:32.000000Z",
"updated_at": "2020-12-02T11:19:32.000000Z",
"deleted_at": null
},

{
"id": 2,
"distance_id": 1,
"timing_location_id": 101,
"name": "Maali",
"meters": 10000,
"type": "finish",
"laps": 0,
"min_time": "16:00:00",
"max_time": "20:00:00",
"created_at": "2020-12-08T13:03:47.000000Z",
"updated_at": "2020-12-08T13:03:56.000000Z",
"deleted_at": null
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]
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"translations": [],
"configurations": [],
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"name": "PREFINISH",
"pin_code": "24567",
"created_at": "2020-12-02T11:19:32.000000Z",
"updated_at": "2020-12-02T11:19:32.000000Z",
"deleted_at": null,
"timing_points": [{
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"timing_location_id": 100,
"name": "Ennakko",
"meters": 9900,
"type": "finish",
"laps": 0,
"min_time": null,

"max_time": null,
"created_at": "2020-12-02T11:19:32.000000Z",
"updated_at": "2020-12-02T11:19:32.000000Z",
"deleted_at": null
}]
},
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"updated_at": "2020-12-02T11:19:32.000000Z",
"deleted_at": null,
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"distance_id": 1,
"timing_location_id": 101,
"name": "Maali",
"meters": 10000,
"type": "finish",
"laps": 0,
"min_time": "16:00:00",
"max_time": "20:00:00",
"created_at": "2020-12-08T13:03:47.000000Z",
"updated_at": "2020-12-08T13:03:56.000000Z",
"deleted_at": null
}]
}
],
"owner": {
"id": 12,
"email": "john.doe@who.com",
"email_verified_at": true,
"first_name": "John",
"last_name": "Doe",

"organization": "Company X",
"address_line_1": "Mannerheimintie 1",
"address_line_2": null,
"city": "Helsinki",
"state": null,
"postal_code": "00100",
"bank_bic": "NDEAFIHH",
"bank_iban": "FI123456798",
"currency_code": "EUR",
"country_code": "FI",
"timezone": "Europe/Helsinki",
"onreg_id": null,
"approved_at": null,
"created_at": "2020-06-02T10:47:41.000000Z",
"updated_at": "2020-12-08T12:52:22.000000Z",
"deleted_at": null
}
}
}

Appendix 2. Customer email for Bluetooth and GPS tracking

Helsinki City Running Day — Ultimate Sport Service

John Doe
Race number: 1234
Distance: 42,195 km
Marathon 2 // 14:40 WHITE / Valkoinen

The day for Helsinki City Running Day is approaching and we wish you a good race. Before the race we would like you to remind you of our online results and tracking services available to you and your followers and friends on race day.

Last week we sent you the registration card which you can find here. Please familiarize yourself with the event area maps here and find all the important info, course maps and elevation profiles here.

LIVE results on the internet
All results are updated LIVE during the event on this link. Your online certificate can also be downloaded from here once you have finished.

LIVE results on the UltimateLIVE app
All results are available and updated LIVE during the event in the UltimateLIVE smart phone app. The app can be downloaded for iPhone, Android and Windows Phone in App Store, Google Play and Windows Store - or directly from the link http://app.ultimate.dk

LIVE GPS-tracking and extra intermediate timing points
Helsinki City Running Day offers LIVE GPS-tracking and extra intermediate timing points for all runners who wishes to share their position and expected arrival time at the finish with their friends and followers - via the new **RaceConnect** app.

If you run with the **RaceConnect** app (minimum iOS12+ or Android 5+ users), you can use your smart phone for LIVE GPS-tracking and extra intermediate timing points.

This is how you do:

- Download the **RaceConnect** app for iPhone (via App Store) or Android (via Google Play)
- Login with your Tracker-ID: **H123456**
  (this is a personal ID, please keep it secure)
- Click "**Connect Tracker**" before you start your race
  (advised to do 2-3 minutes before you start)

RaceConnect works in background mode, so you can easily put your device to standby mode to save battery power. The app is optimized for minimum 12 hours battery life time on a fully charged smart phone.

Good luck for your race!

Best regards,

Helsinki City Runnig Day team

During the event on 1st - 3rd of October our customer service servises only at the Olympic Stadium race office. We are able to read the emails on the following week.

Ultimate Sport Service

Appendix 3. Bluetooth data recorded for Half Marathon

Tracking ID	RC01	RC02	RC03	RC04	RC05	RC06	RC10	10 km	RC12	RC14	RC15	RC19	RC20	20 km	RC21
16H6CA	11:05:40	11:10:42	11:15:30	11:20:35	11:22:24	11:29:33	11:49:45	11:49:50	11:59:34	12:09:11	12:14:34	12:34:14	12:39:01	12:39:03	12:43:36
1AQQDD	11:15:15	11:20:27	11:25:33	11:30:30	11:32:47	11:40:39	12:00:36	12:00:40	12:10:38	12:20:44		12:44:24	12:49:05	12:49:09	
1D7134	11:35:51	11:41:41		11:53:31	11:56:09	12:05:26	12:29:13	12:29:17	12:41:04	12:53:10	12:59:01		13:30:48	13:30:49	13:36:59
1GDNBS	11:16:22	11:21:59	11:27:24	11:33:03	11:35:48	11:45:12	12:09:32	12:09:34	12:21:54	12:34:52	12:41:37		13:15:35	13:15:33	
1S6SHA	11:47:26	11:53:49	12:00:44	12:07:01		12:19:44	12:44:39	12:44:41	12:56:03	13:08:51	13:14:50		13:44:05	13:44:05	
1T1K5D	11:15:17	11:20:20	11:25:15					12:00:44						12:53:37	13:31:40
1TRHFF	11:36:01	11:41:54	11:47:30	11:53:18	11:55:53	12:04:55	12:28:35	12:28:39	12:40:07	12:52:25	12:58:13		13:29:02	13:29:04	13:26:05
1ZTMQ1	11:38:37	11:46:17	11:53:26	12:01:18	12:04:38	12:15:41	12:46:45	12:46:47	13:02:07	13:18:02	13:25:45		14:05:16	14:05:18	14:12:16
225LLF	11:06:02	11:11:09	11:16:00	11:20:52	11:23:04	11:31:03		11:50:40	12:00:25	12:10:27	12:15:10	12:35:31	12:40:25	12:40:25	12:45:24
2BGAB6	11:48:08	11:55:37	12:03:00			12:24:40	12:53:19	12:53:24	13:07:13	13:20:44	13:27:25		14:01:12	14:01:14	14:08:34
2LGTSM	11:16:36		11:27:38	11:33:07	11:35:36	11:44:22		12:06:59	12:18:14	12:29:31	12:35:00		13:03:58	13:03:58	13:09:42
2TMTDG	11:17:30	11:23:14	11:28:54	11:34:19	11:36:51	11:45:44	12:08:16	12:08:19	12:19:50	12:31:23	12:37:11		13:09:04	13:09:05	
2ZYHS8	11:16:57	11:22:54	11:28:53	11:34:59	11:37:34	11:47:05	12:11:50	12:11:50	12:23:29	12:35:35	12:41:47		13:11:30	13:11:31	13:16:13
317PT5								11:53:44						12:46:50	12:27:06
35HQ85	11:45:41	11:50:49	11:57:16	12:02:53	12:05:34	12:15:00	12:39:58	12:39:50	12:52:51	13:06:36	13:13:10		13:47:49	13:47:42	
3EPNX4	11:48:36	11:56:14	12:03:45	12:11:10		12:25:47	12:53:47	12:53:46	13:06:30	13:19:55	13:26:26		14:00:50	14:00:48	14:07:32
3HZ7Y6	11:15:10	11:20:12	11:25:04	11:30:06	11:32:19	11:40:14	12:00:25	12:00:23	12:10:21	12:20:14	12:24:48	12:44:25	12:49:11	12:49:12	
3NPS8F	11:15:50	11:21:08	11:26:15	11:31:20	11:33:37	11:41:45	12:01:57	12:02:04	12:11:49	12:21:43	12:26:31	12:45:37	12:50:14	12:50:16	12:54:56
3P4EZ4	11:15:16	11:20:10	11:25:15	11:30:05	11:32:20	11:40:13	12:00:34	12:00:35						12:50:51	
3PR2MS	11:36:28	11:42:03	11:47:24	11:53:29	11:55:44	12:03:36	12:23:25	12:23:23	12:33:02	12:42:48	12:47:34		13:12:14	13:12:14	13:29:45
42ZLNT	11:48:25	11:55:52	12:03:16	12:10:28		12:24:48	12:53:49	12:53:55	13:07:57	13:22:57	13:30:12		14:07:57	14:07:56	14:00:44
4A3PP8	11:05:54	11:10:57	11:15:53	11:20:47	11:23:01	11:30:52	11:51:26	11:51:28	12:01:42	12:12:25	12:17:33	12:39:12	12:44:39	12:44:41	12:49:55
4FNKLD	11:37:10							12:33:09						13:35:09	
4HBZXL	11:46:06	11:51:51	11:57:14	12:02:29	12:04:42	12:13:52	12:37:44	12:37:44	12:49:57	13:02:53	13:09:14		13:43:21	13:43:20	13:49:47
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4TA7B8	11:46:38	11:52:03	11:59:06	12:06:14	12:08:14	12:19:02	12:46:57	12:47:11	13:00:23	13:14:45	13:21:28		13:57:02	13:57:04	14:03:58
57Q9Z8	11:36:34	11:42:44	14:08:23	11:54:57	11:57:36	12:06:42	12:31:52	12:31:54	12:43:39	12:56:02	13:02:09		13:31:51	13:31:52	13:37:40
5DTLSC	11:05:29	11:10:30	11:15:17	11:20:02	11:22:15	11:29:41	11:49:07	11:49:10	11:58:49	12:08:25	12:13:11	12:32:48	12:37:18	12:37:19	12:41:58
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5GFH1R	11:05:50	11:10:58	11:15:51	11:20:49	11:23:08	11:30:52	11:50:26	11:50:26	12:00:02	12:09:38	12:14:19	12:34:11	12:39:08	12:39:07	12:44:01
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63AK52	11:37:38	11:45:09						12:45:06						13:57:53	
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85X253	11:48:47	11:56:43	12:04:27	12:11:48		12:27:08	12:57:00	12:57:02	13:11:37	13:26:32	13:33:33		14:10:14	14:10:17	14:17:36
8ASPYL	11:16:16	11:21:58	11:27:39	11:33:15	11:35:48	11:45:03	12:09:22	12:09:22	12:21:11	12:34:31	12:40:44		13:14:38	13:14:39	13:21:29
8NSLNH	11:47:08	11:52:50	11:59:05	12:05:08	12:07:52	12:17:17	12:41:10	12:41:21	12:52:59	13:05:58	13:11:58		13:45:21	13:45:25	
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8S9RAM								12:07:35						13:02:49	13:02:49
975EZB	11:26:32	11:32:18	11:37:43	11:43:14	11:45:37	11:54:37	12:18:30	12:18:33	12:30:31	12:43:29	12:49:50		13:24:21	13:24:25	13:31:02
9FMKT6	11:26:44	11:32:51	11:38:37	11:44:17	11:46:51	11:55:40	12:17:20	12:17:21	12:28:12	12:38:59	12:44:14		13:10:34	13:10:33	13:15:32
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9P1BA7	11:16:19	11:21:49	11:27:01	11:32:15	11:34:40	11:43:01	12:04:40	12:04:38	12:14:39	12:26:02	12:31:05	12:52:06	12:57:02	12:57:03	13:02:16
9PD1CK	11:36:50	11:42:38	11:48:22	11:54:01	11:56:36	12:05:42	12:28:53	12:28:52	12:40:04	12:51:48	12:57:29		13:25:41	13:25:41	13:31:11
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9YNPTT	11:26:26	11:31:58	11:37:36	11:42:36	11:44:57	11:53:02	12:12:56	12:12:55	12:22:52	12:32:59	12:37:55		13:02:43	13:02:43	13:08:33
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