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Jahangir Saqlain

IoT and 5G history evolution and its architecture their compatibility and future.

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The purpose of this thesis is to study the concept of Internet of things IoT and 5G, their historical background and their architecture through the history have its concept by the time it evolved and now it's taking the shape of connecting devices by using 5G when it will be fully implemented. Evolution of networks from 1G to 5G is also discussed and how faster data requires faster networks. So 5G is the future and it will revolutionize the IoT concept in practice.

Next for any network or connected system the security is the big challenge as in IoT the massive number of devices will connect and communicate for that the challenge of security can be solved at layered level and in 5G that challenge is solved by security assurance and standardizations. The cloud security is done by isolation and slicing, and radio access network been secure by encryption. In year 2020-25 when the implementation of the IoT with 5G will be functional that will have same impact as mobile phone launched.

This thesis gives understanding and opportunities for business in IoT and 5G applications which are huge from Smart city to smart home vehicular wearables and many more. The topic is very much popular IoT requires network for gathering data and transmitting data, so both are interlinked with the future. We want as customer and user faster data and in future the appliances and demand growing exponentially. There are huge business opportunities for both these concepts and applications.

In Conclusion my thesis by studying IoT and 5G gives us direction research and development. That thesis paper will help upcoming thesis writers about IoT and 5G. Future is coming, and future belongs to IoT with 5G enabled network.

Keyword	IoT,5G, Smart Home, Smart City, Vehicular, healthcare, Sports and leisure

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Abbreviations:

1G:	**First Generation**
2G,3G,4G,5G:	**Second, Third,Fourth,Fifth Generation**
AES:	**Advanced Encryption Standard**
AMPS:	**Advanced Mobile Phone Systems**
AMQP:	**Advanced Messaging Queuing Protocol**
API:	**Application Programming Interface**
BLE:	**Bluetooth Low Energy**
CCN:	**Content Centric Network**
CDMA:	**Code Division Multiple Access**
CRC:	**Cyclic Redundancy Check**
CoAP:	**Constrained Application Protocol**
DDoS:	**Disturbed Denial of Service**
DoS:	**Denial of Service**
EOT:	**Extranet of Things**
FDMA:	**Frequency Division Multiplexing Access**
GPS:	**Global Positioning System**
GSM:	**Global System for Mobile**
HDFS:	**Hadoop File System**
HTML:	**Hypertext Markup Language**
HTTP:	**Hypertext Transport Protocol**
ICT:	**Information and Communication Technology**
IEEE:	**Institute of Electrical and Electronics Engineers**
IMSI:	**International Mobile Subscriber Identifier**
IoT:	**Internet of Things**
IP:	**Internet Protocol**
IPv6:	**Internet of Protocol version 6**
JMS:	**Java Message Service**
ITU:	**International Telecommunication Union**
LPWAN:	**Low Power Wide Area Network**
LTE:	**Long Term Evolution**
MAN:	**Metropolitan Area Network**
MQTT:	**Message Queuing Telemetry Transport**
NB-IoT:	**Narrow Band Internet of Things**
NFC:	**Near Filed Communication**
NMT:	**Nordic Mobile Systems**
OSI:	**Open System Interconnection**
PAN:	**Personal Area Network**
PNF:	**Physical Network Function**
RAN:	**Radio Access Network**
RFID:	**Radio Frequency Identification**
SDN:	**Software Defined Network**
TCP:	**Transmission Control Protocol**
UDP:	**User Datagram Protocol**
UMTS:	**Universal Mobile Telecommunication System**
URI:	**Uniform Resource Identifier**
WAP2:	**Wi-fi Protected Access 2**
WebOS:	**Web Operating System**
VNF:	**Virtual Network Function**
XMPP:	**Extensible Messaging and Presence Protocol**
M2M:	**Machine to Machine**
MAC:	**Media Access Control**

1 Introduction

The Internet of things is the future of the modern world. The Internet of things (Internet of every-thing, ubiquitous internet, ubiquitous computing) or in short IoT often term used in which things communicate with each other things like devices and sensors those are connected to the internet are communicating each other via different protocols at each layer of IoT. With the passage of time the IoT and its definition becoming more and more clear. Things that we can imagine few years ago like smart home, digital assistant, smart cars or self-driving cars, trucks etc, are now becoming reality. Day by day the shape and products of IoT is becoming clearer and new frontier for business and research are appearing. I will explain that concept in a following example that clears the IoT idea to reality.

Consider you wake up in the morning and getting ready for office, school, university and a sleep tracking band records your sleeping hours and then uploaded them to any of the cloud services. According to the time the coffee maker and microwave received data from the cloud services and understood that you got up and starts preparing breakfast for you. When you get up according to your movement lights turned on by sensors and when you go out from your room or house light automatically switch off by using same data. When you are coming to kitchen light will turn on and coffee is ready as well when you move out lights and coffee machine will switch off. When you leave the house your expected desire to clean the house by IoT it's been done like Robot Vacuum cleaner will clean the floor and tidy up the rooms. We are surrounded by the sensors and smart devices only logically way forward is to make them communicate with each other. Electronic sensors almost available so easily and cheaply they can measure different quantities like Temperature, Pressure and Humidity. There are many sensors those can measure temperature humidity and other measurements. Those sensors quite easily and then put the data on the given cloud services. There are an estimated 50 billion devices will be connected to the internet by 2020 which is enormous number as compared to today [14].With such an enormous impact on our life and business no one knows completely about the internet of things surely. Almost all the big companies have already allocated projects that are related to IoT.

Nowadays most of the utilities are becoming cheaper and easily available that is the plus point towards embedded devices and internet of things future. The cost of electronic components and utilities expands a new arena of research and development towards connecting devices and communicating with each other. There is always a tentativeness

from companies as well as from customers about internet of things products and services. Why? Because new concepts and its applications always take time to settle and IoT is also the same its architecture is becoming more clearer day by day and its opportunities becoming more visible. So, by witnessing the possibilities now companies started acting towards that concept. The fields mainly that IoT will cover are home automation energy as well as transportation (Self driving cars and busses etc.), education and healthcare and many more.

The purpose of this thesis is to present IoT concept and its history its interactions with devices and mainly its possibility to use 5G (Fifth Generation) faster data communication. Internet of things and 5G both are very new concepts so will define and explain its concept and their interactions. The term 5G means 5th generation of telecommunication before that it was 4G,3G,2G,1G all are still in used for different applications. Like for 1G the voice calls and for 2G short messaging and browsing with voice calls in 3G video conferencing and mobile Television with GPS was the applications that are still in use. For 4Gthe have high speed applications with mobile TV and wearable devices [15].4G LTE and LTE Advanced LTE it is most recent in which more data capacity for richer content it connects faster it connects in real time. The upcoming chapters will be discussed in detail about term IoT its history and its definition and 5G will be defined and presented the concept. This thesis helps others about the IoT concept and its opportunities by doing business and 5G interactions.

The purpose of thesis is to study IoT because IoT is hot topic nowadays and when comes to big data everybody wants faster data and faster devices communications. The progress in 5G is also very hot topic and it is still developing and shaping its way towards future. When we see potential of IoT and 5G just see the number of subscriber to understand the opportunity of business [16]:

	2016	2022
Worldwide Smartphone Subscription	3.9 Billion	6.8 Billion
Worldwide Broadband Subscription	4.4 Billion	8.3 Billion
Worldwide LTE Subscription	1.9 Billion	5 Billion
Worldwide Mobile Subscription	7.5 Billion	9 Billion
Worldwide Data Traffic	8.8 EB	71 EB
Worldwide Data Traffic/Smartphone	2.1 GB	12 GB

But one thing is certain 5G will be more faster more effective only problem it costs so much money. The other big concern in IoT is the security. When the devices start to communicate making sure security is the big challenge that is solved by layer security. There is still more progress going on security management cycle. There are some

innovative ways of millimeter wavelength that are being used in 5G. The discovery of new spectrum helps us to understand the 5G and its core concept about doing business in IoT driven world. My thesis will outline the IoT concept and 5G from introduction to application. My thesis on IoT and 5G gives clear view about IoT its concept its architecture and its protocols with different layers and security challenges. In my thesis about 5G is also written in order of evolution to its architecture and its security challenges and prospects in this field. The market of IoT will reach up to $457 billion globally by 2020 [17].The numbers like $457 billion that's huge money for business and for future business opportunities in almost all walks of life. So, the revolution of IoT is coming and it will reach to its full potential when 5G fully implemented. The references are indicated in the numbers below with each section and with each figures and tables.

2 Internet of things(IoT) history and Overview

In this chapter I am introducing general concept of IoT from historical background to until know. I will describe how it was developed and how it became so popular. I will introduce future possibilities and key concerns about IoT.

2.1 IoT history

What is internet of things from the 1832 we can see the different milestones of Electronics and telecommunication.

I would like to recall the history of telecommunication and internet from the article History of IoT, that was written on Postcapes (2016), lists following milestones [18]:

- 1832: An electromagnetic telegraph was created by Baron Schilling from Russia
- 1844: Samuel Morse sends first Morse code public message
- 1926: Nikola Tesla to Colliers magazine:
- "*When wireless*[1] *is perfectly applied the whole earth will be converted into a huge brain, which in fact it is, all things being particles of a real and rhythmic whole.....and the instruments through which we shall be able to do this will be amazingly simple compared with our present telephone. A man will be able to carry one in his vest pocket.*"

[1] * not the 802.11 version

- 1964: Marshall McLuhan “....by means of electric media, we set up a dynamic by which all previous technologies -- including cities -- will be translated into information systems”
- 1969: ARPANET developed
- 1974: TCP/IP started
- 1989: Tim Berners-Lee proposes World Wide Web
- 1990: Toaster was created by John Romkey
- 1991: First web page
- 1995: First e-commerce service started (Amazon, Echo Bay or eBay).
- 1998: Google incorporated
- 1998: Mark Weiser: "*Ubiquitous computing is roughly the opposite of virtual reality*," Weiser wrote "*Where virtual reality puts people inside a computer-generated world, ubiquitous computing forces the computer to live out here in the world with people*."
- 1999: The internet of things not precisely exact but the concept was introduced. The Auto-ID Centre Kevin Ashton described Internet of things “*I could be wrong ,but I am fairly sure the phrase “Internet of Things” started life as the title of a presentation I made at Proctor & Gamble (P&G) in 1999.Linking the new idea of RFID in P&G’s supply chain to the then-red-hot topic of the Internet was more than just a good way to get executive attention. It summed up an important insight which is still often misunderstood.*”
- 2000 to 2004: The term internet of things or connected word that was remained in Guardian and other Scientific American magazines. There were some discussions about in near future devices that will automatically connect and works independently with very less instructions. When RFID developed on massive scale then the concept of IoT is becoming more and more clear.
- 2005: Then in 2005 after earlier terms appeared in Guardian and other scientific publications the term starts to gain more popularity so the ITU (International Telecommunication Union) and the first report is published: "A new dimension has been added to the world of information and communication technologies (ICTs): from anytime, anyplace connectivity for anyone, we will now have connectivity for anything. Connections will multiply and create an entirely new dynamic network of networks – an Internet of Things".
- 2006-2008: European Union recognized the Internet of things term in a conference that was held IPSO alliance (members are: Ericsson, Google, Cisco, SAP, Sun, Fujitsu and Bosch, Intel) opened for study to promote the IP network of smart object and to empower IoT. (IPSO alliance.)
- 2011: IPv6 was launched

- 2011: today Europe shows their keen interest in Internet of things and supports with ICT-FP7 Work Programme, IoT-A and its digital future directives. China funds continuously for the development and research in the field of IoT and its Global standards initiative started. China funds institution so to get more innovative results from new minds. The UK government invests £5m in the research and development of IoT in the country.

After 2011 the big companies like Cisco, Ericsson, IBM produces large educational and marketing intuitive on IoT or other related terms. We can divide internet of things into many stages I have drawn a figure that illustrated the timeline and development of internet of things. It's clear that development of IoT is not very fast but it's taking its pace and always the first step is difficult next steps becomes easy. So, we can define latest situation it will increases number of devices that interact not only with the users but also with each other M2M machine to machine. I have drawn a figure 1 that will show us the internet stages and its development over the years that figure gives us brief period when then web and internet of things evolved and remaining theoretical part I have described above.

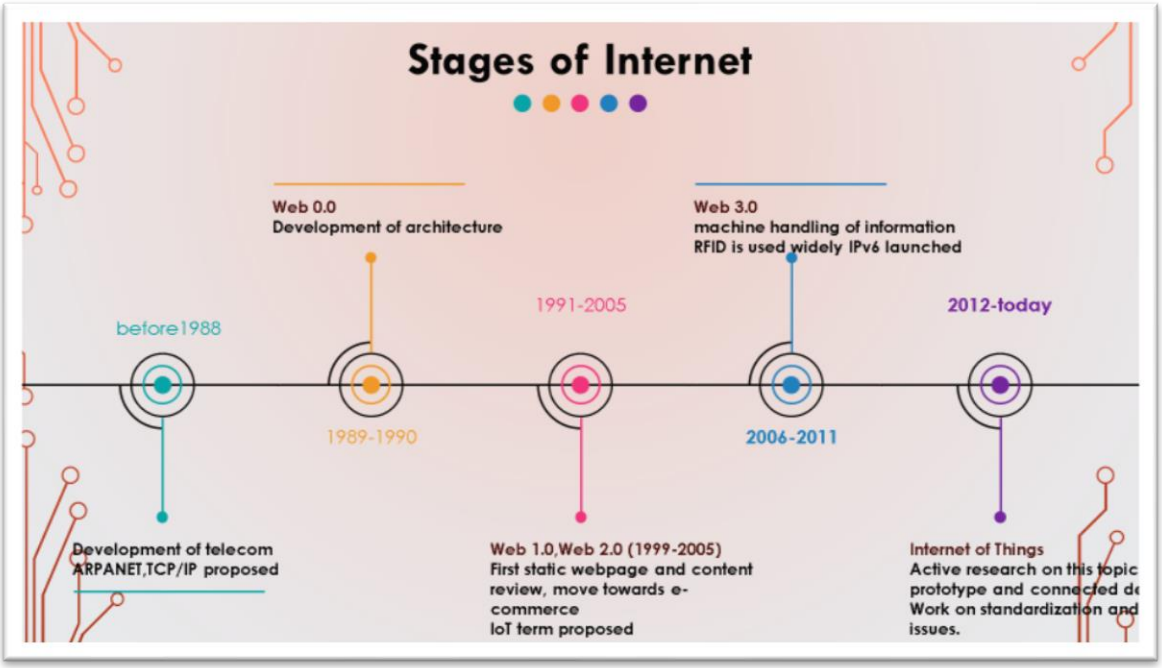

Figure 1. Stages of Internet development.

The history of the internet will be concluded as I have inserted a graph from google trends the term internet of things and it's gaining popularity.

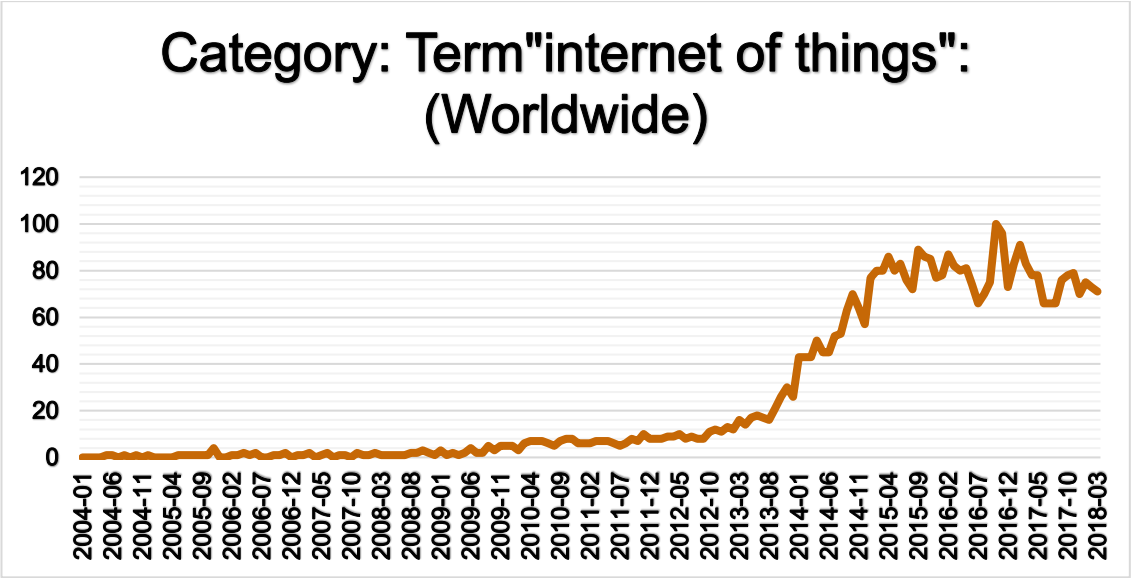

Figure 2. Google data made by excel about the term Internet of things worldwide [1].

The time span is indicated from 2004 to 2018.So the IoT is coming with huge possibilities and challenges for the business and all aspects of the life. The popularity is marked between 0 to 120 where value of 60 means half as popular. Today the google trends IoT popularity worldwide is around 80% so it is very popular and its becoming more popular as the concept is coming to reality. The top five countries that is are more interested are South Korea, St. Helena, Japan, Singapore, Taiwan, Finland is at 21st place as of today about IoT term popularity search on Google [1].

2.2 Evolution of web

The evolution of web came from different phases that I have drawn in the figure 3 through the history in which we can see the Web development from 1989 to 2012. The Web 1.0 that was first implementation and it lasted from 1989 to 2005. In 1991 [19] Tim Berners-Lee created first website that had introduced the Web as “read only” Web. Basically, it provides very little interaction in which the user or consumers can exchange the information together. But the concept of web came by this implementation that have changed the internet altogether. That web is Web 1.0 was first world wide web which (www) was static, and the purpose was to deliver content only on the page like read only option. The user interaction was very minimal its characteristics are written below [20]:

Technologies and protocols was introduced like HTTP, HTML, URI.

Content was only read only

Static web pages and language was Hypertext Mark-up Language

It was available online at all time.

The initial world wide web pages are static and then by the time and technological evolution things starts to form unique features and functionality. Since first webpage to “Web 2.0” there is a long way we come forward. Now we are doing shopping e commerce and other things on internet like social networking and online banking is the result of “Web 2.0”. The evolution of the internet is continuous and the need for faster web and its services raised drastically. In future devices and things will be connected to each other as I have written previously about the internet of things. For devices and things to communicate with each other they need new web technology and new protocols that can be used for communication with the devices. The new world of devices and things is called world of internet of things. The “Web 3.0” will have many features of web and how people interact with the web. The “Web 3.0”is basically for things and their interactions with things and devices to communicate with each other and decide real time. Before the 1988 the development was going on to make communication possible via networks so for that reason the development of telecommunication ARPNET/TCP, IP protocols was introduced the following years 1988-1990 “Web 0.0” was introduced by using static development architecture started. In the years 1991-1998 “Web 1.0” was developed for displaying static pages and content along with a minor side of ecommerce started. Since the first webpage to its evolution the need and demand for getting more and more services and its fast and efficient response was needed. So, by witnessing that demand the from 1999-2005“Web 2.0” is launched with more information and more services for e-commerce and other aspects of the internet. Internet is nowadays used for many services like information retrieval, video streaming, online shopping and online banking and social networking is all been done via internet. These all aspects of internet and its services are using “Web 2.0”. I am listing Web 2.0 characteristics below [20]:

Technology Centric

Business Centric

User Centric

The evolution of the internet is continuously growing and the concepts of things communication with each other requires new web, so the next phase is “Web 3.0”. The concepts of things communicating with each other is called internet of things known as IoT. Web 3.0 term is first coined by John Markoff in the New York Times he suggested that web 3.0 means third generation of the web in 2006.Web 3.0 can also be called “executable web” so the idea of the web 3.0 is it defines the structure data and link them to more effectively so that it can be discoverable and the integration and automation becomes much easier for reuse across various application. Web 3.0 able to improve the data management and mobile internet that simulate the creativity and innovation. The

collaboration on social web is also new web 3.0.I have listed web 3.0 characteristics that are as below [21]:

Open Source Software Platform

The world-wide database

Web Personalization

Resource Pooling

Intelligent Web

So as the figure 3 below describes very clearly that Web 3-time span was from 2006 to 2011.The next development of the web is for Web 4 where more smarter and intelligence web is on its way to impact on our every field of life.

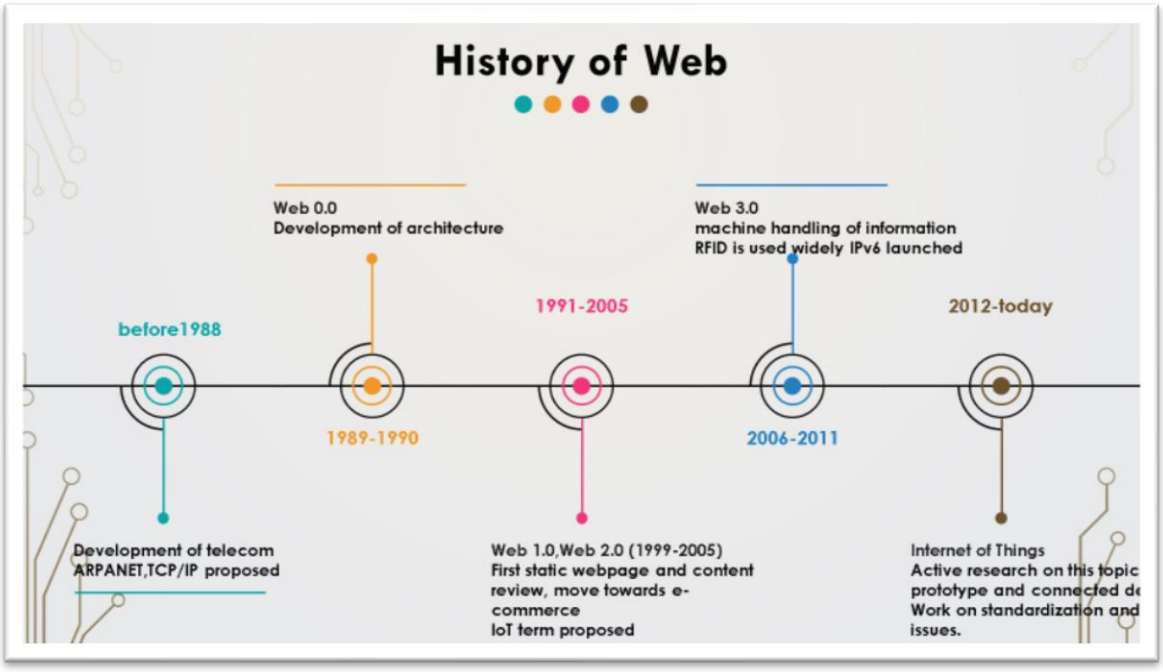

Figure 3 History of Web.

The web 4.0 is the future I have wrote about Web 1.0, Web 2.0 and Web 3.0 now the future is Web 4.0. In simple word we can say Web 4.0 is Mobile Web [22]. The figure 3 above in the form of timeline illustrates the future of Web 4.0 in 2018-2020. Web 4.0 will be Ultra-Intelligent Electronic Agent in which the symbiotic web and Ubiquitous web included. The interaction between human to machines was motive behind symbiotic web. The web 4.0 is powerful as our brain the telecommunication progress and advancement in nanotechnology interface that is using web 4.0. In Web 4.0 the WebOS is middleware in which the start function and operating system works. The WebOS will be parallel to the human brain and it has high intelligent interactions.

3 Internet of things Definition

There are many definitions of the internet of things shortly that is IoT. I will use most of the time IoT in the thesis paper in next chapters. When I have wrote the history of internet of things in previous section there are some definitions like Nikola Tesla at a conceptual level and Kevin Ashton. The new definitions are written below that was taken from Postcapes [18].

The simplest definition is Internet of things is way to connect computers sensors actuators through internet protocols.

[23]

Minimalist:

"A minimalist approach towards a definition may include nothing more than things, the Internet and a connection in between. Things are any identifiable physical object independent of the technology that is used for identification or providing status information of the objects and its surroundings. Internet in this case refers to everything that goes beyond an extranet, thus requiring access to information for more than a small group of people or businesses." [23]

"the future Internet of Things links uniquely identifiable things to their virtual representations in the Internet containing or linking to additional information on their identity, status, location or any other business, social or privately relevant information at a financial or non-financial pay-off that exceeds the efforts of information provisioning and offers information access to non-predefined participants. The provided accurate and appropriate information may be accessed in the right quantity and condition, at the right time and place at the right price. The Internet of Things is not synonymous with ubiquitous / pervasive computing, the Internet Protocol (IP), communication technology, embedded devices, its applications, the Internet of People or the Intranet / Extranet of Things, yet it combines aspects and technologies of all of these approaches." [23]

There are still many more IoT definition but my definition and concept of internet of things is “Internet of things name is self-explanatory internet for connected things with people, and machine to machine that interaction with real and virtual objects from all walks of life. Internet of things is a powerful concept that combines analogue and digital networks due to that people interactions with things will change by the time. Internet of things is not only way to connect devices rather it combines real and virtual worlds where communication is performed where everything controlled by the devices and users. So,

in future the environment becomes smarter the events become systematic, so we can say that internet of things is next step towards artificial intelligence."

I have defined internet of things in easiest way possible the first definition is very simple second definition is more detailed that took from book of internet of things. The last one I have defined myself after so much material on internet of things. In IoT there are things like with tiny sensors and robotic arms they all have some basic characteristics for IoT infrastructure:

Sensors or devices: Tracking and measurements and monitoring

Connections Direct or indirect connection to end device and virtualization and wireless for long distance and effectiveness.

Processing unit Analyzation process and then makes decisions on given data

Energy efficiency Challenge is energy efficient IoT devices should be and when don't using will remain in sleeping mode.

Economic efficiency Cost effective more devices more cost and more data so with 5G making it more economical.

Quality and Reliability follow ISO standards like for Smart home, Smart Agriculture, Smart City, vehicular, Sports and leisure maintains an excellent quality standard from start to end.

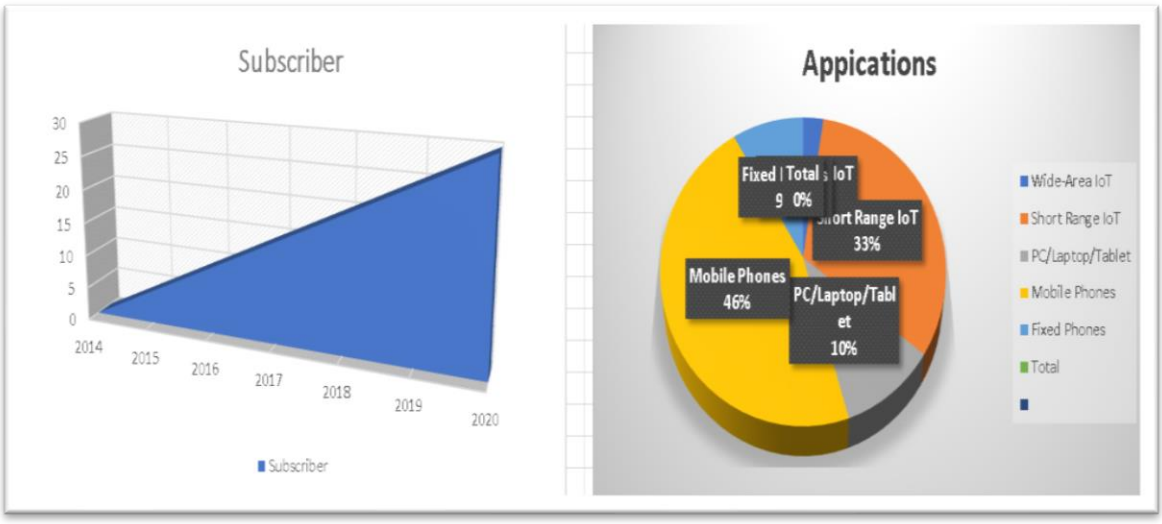

Figure 4 Connected devices [16].

In the figure 4 above the connected devices now around 18 billion and in 2022 it will reach up to 29 billion. The usage and its classification are mentioned in figure above like Wide area IoT will increase from 0.2 to 2.1 percent 30% increase is expected and short-range IoT from 5.2 to 15.5 percent will increase until year 2022 around 20 percent will increase. So, for that sizable chunk of data require faster and connected devices to

capture monitor and smartly decides the data. The potential is huge for business and the prospects are very bright for future of IoT [16].

I have written the big IoT application areas and how it will transform our life from living to working to healthcare and how we travel and spent our time in leisure. All big concept is written below from smart home, smart city, healthcare, vehicular, sports and leisure.

3.1 Smart City

The concept of smart cities is shown in the figure 5 below. That shows the basic concept of the smart cities and their future development towards internet of things. The urbanization of the cities is growing more and more. The estimates by UN says that until 2050 the 66% population of the world will be urbanized [24]. This enormous numbers of urbanization and burden of social services can create a havoc. The strain on the existing system can crumble the infrastructure so due to that there is need for new smart and innovative solutions needed. For this smart solution the IoT Smart City is the best that can suits and adapts with the devices and things starts to communicate with each other. In smart city there can be many small protocols that can gather information then sent to central data unit. So, I am writing some wireless protocols that smart city can be used now there is not unified single protocol for smart city but different applications and their different protocols. 6LoWPAN, AES. BLE, CoAP,

DTLS, HCI Host controller interface, HTTP, IP, MQTT, TCP, UDP. When 5G will be fully implemented then the network will be 5G that will help to communicate with device like M2M, M2H and data collection and analyzation will be done in real time.

Smart City contains six basic interaction those are visible in figure 5. Like Smart Industry, Healthcare or eHealth, Smart Mobility, Smart Building, Smart Education, Smart Government [25]. Smart industry means that the Artificial Intelligence and machine learning will be enabled at manufacturing level so that the machine becomes smarter correct errors and fix the problem by itself and report it to the system. In many companies the warehouse and its machine are fully RFID and Sensor enabled system where they work autonomous like in Valio Oy Haapavesi in 2011 there was experimental forklift was in use to work in warehouse by Rocla Oy. The whole path where automated guided vehicle that was sensors and RFID tags was there that was communicating with automated guided vehicle. The smart city until 2022 some applications like lighting and traffic routes, signals monitoring been done by IoT. When 5G will be enabled then whole services will be connected to single faster network 5G. The cities are more urbanized, and the mobility is becoming problematic so smart mobility can predict the best path and smooth flow of traffic. Smart train and smart parking is also feature of smart mobility that can shows us spaces and travel in real time. Due to this the analytics and decision

making will become more fast and effective for commuters and passengers. The next arena of Smart City is the smart buildings in which the buildings becomes smart it will become more energy efficient that will reduce cost also digitalization can make us safe and can monitor the temperature Humidity etc and devices predicts the best possible temperature energy and digitalize solutions. Smart education transforms our way of studying like eServices and resources for research and development and digitalization will improve more coordination and productivity [25].

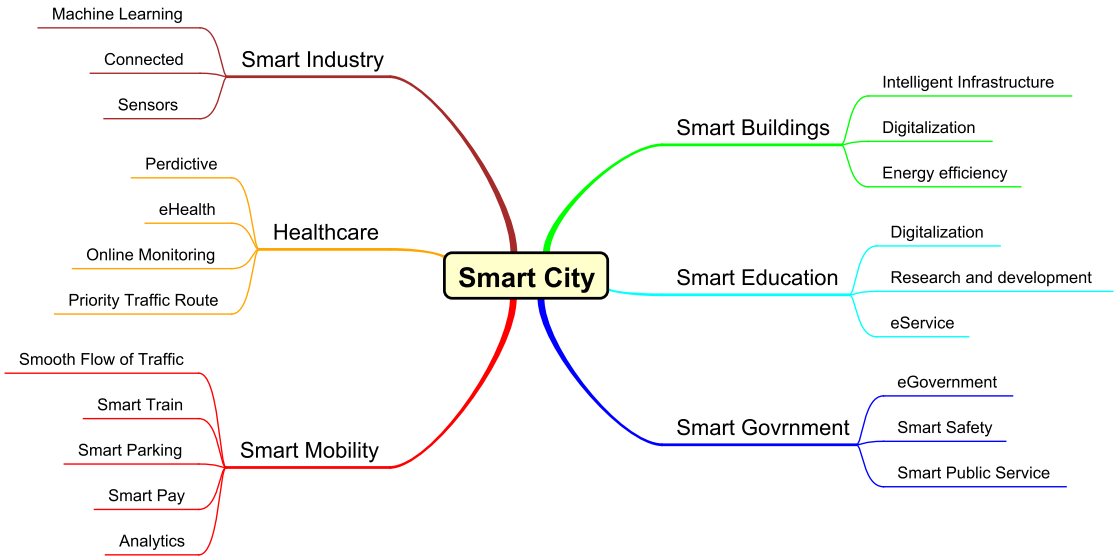

Figure 5. Smart City Concept Mind map [25].

In IoT era the smart home is very important solution for cities where Smart government can enable eServices and smart safety that can improves the public health and ensures safety by notification and connected devices like emergency services calls and monitoring. When comes emergency services the smart mobility picks faster path for emergency services to reach a certain point. Healthcare is also a brilliant application by smart city the monitoring and predictive data enables patient and doc what is the best now and the patient will be monitored by online 24/7.

3.2 Smart home

The smart home concept in IoT is explained earlier in an introductory paragraph. In which at the breakfast how smart kitchen which was IoT enabled can perform different tasks like making coffee to toaster preparing hot water. All these simultaneously tasks performed and controlled by sensors and IoT enable setup in which we use different protocols depending on their requirements. Some are infrared, WIFI, Bluetooth, and Thread, ZigBee. These are basically short distance protocol not WIFI it can increase by the router. The figure 6 about smart home shows many devices that relate to each other and communicated with each other via specific protocol or Wi-Fi. The figure 6 shows us

the smart home applications like lighting when you reach at the door sensors detects your movement and the lights turned on and all the appliances by gathering your data from cloud can make ready food or coffee as per the requirement. When you come out from the room after some time lights will become off again so that is called smart lighting and smart kitchen. Smart home protocols are Infrared, KNX, Bluetooth, thread, Zigbee, Zwave [26]. The other appliances like PC/Television is also connected by Wi-Fi or ether net to smartly surf and select the desired programs. The next thing is water and that can be monitored by IoT smart home application to monitor how much usage and how to make it more efficient usage. Appliances refrigerator automatically sends you text message when mil was near to end or when groceries was ending. In 2020-25 the home appliance like fridge will can order ending items as well. Vacuum cleaner works autonomously when you leave the home or when you are not using it so connected devices revolution is about to happened. Heating is also big cost during the winter thermostat or smart thermostat will check the temperature and then make heat low or high as the temperature goes up or down

Figure 6 Smart home

. The next big worry is security that door is locked or who coming so that all be monitored by security cameras and according to facial recognition door will be open, so the devices will become more secure through data that they collect from the surroundings. How much water we need for our lawn that all be calculated and then you will be aware of weather changes in smart irrigation, so the change is huge, and it will affect everybody especially in developed countries because infrastructure and network is already there. Finland is in a leading role of implementing Smart City Tampere and Smart home already there are many companies of smart homes, in future endless opportunities are coming for customers companies and government [25].

3.3 Vehicular

The most visible form of Internet of things applications are vehicular. In vehicular we can see the self-driving and sensor-oriented cars that are collecting data as well analysing in the real time to make a smart decision. We are expecting in 2020 almost millions of the cars will be on the road. In the figure 7 below, we can see the three components of the internet of the things. The three components are things with networked sensors second component is data stores in the form of text pics and videos, database etc as well.

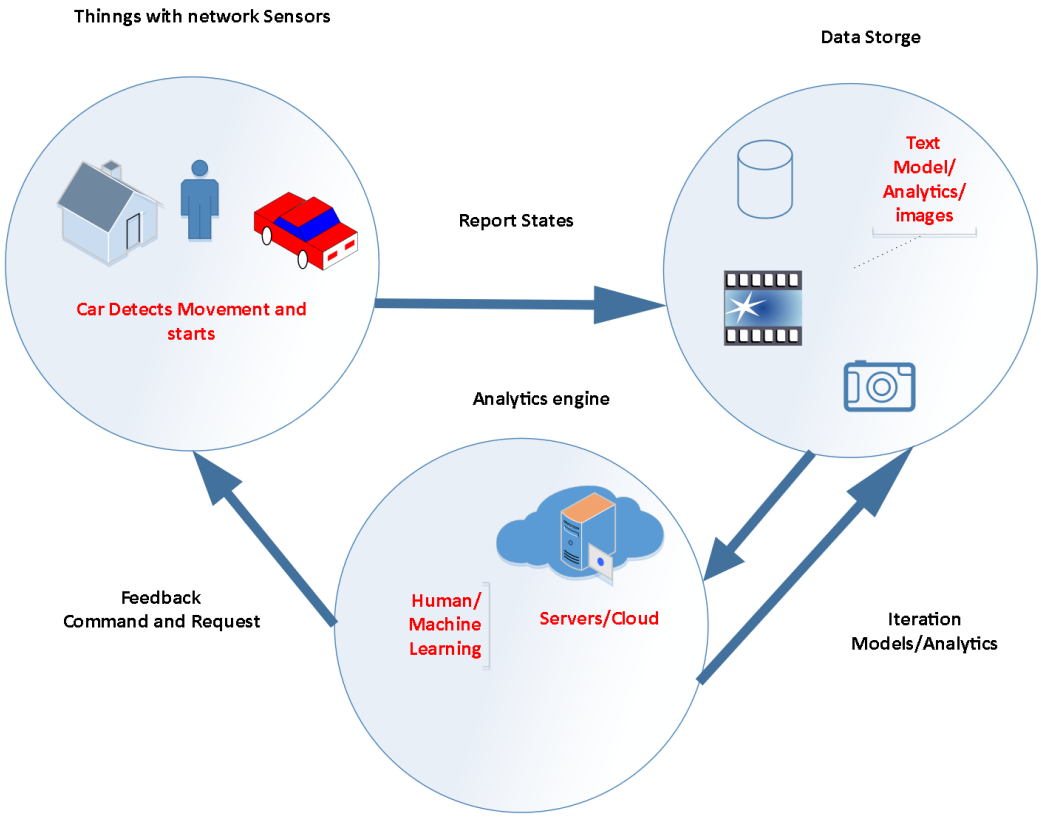

Figure 7 Vehicular

The third component is analytic engines that comprise on human and machine interactions and servers that have stored data. The three-component cycle work as the vehicular moves it collects data from the sensors and then that collected data send to data storage unit. In data storage unit different data is individualize and the analysed decision is make and send to next stage which is analytic engine that iterates according to the requirement and the changes of the sensors data. The collected and refined data that we get at third phase analysed decision and the feedback then sent to vehicles and the sensors for future real time decision and movements.

The field is evolving there are many players but the most famous one is the Tesla motors and their features from autopilot to inside whole interface just like tv screen makes it more user friendly and smart internet of things application [27]. So, in the future the mobility in the city or in the long distance can be done without driver and the smart cars and other vehicles like busses, trams and even trains can go to their journeys smartly. The danger of human error minimized and the figure 7 can shows as the general idea how the smart cars works and perform driving by continuous getting data from machine learning and artificial intelligence like sensors and other devices with changing traffic conditions. In future more and more cars trucks and other transportation means will be changed to smart vehicular an IoT application.

3.4 Healthcare

The internet of things has many applications in healthcare from online monitoring to remote sensing and collecting and analysing data by using internet of things concept.

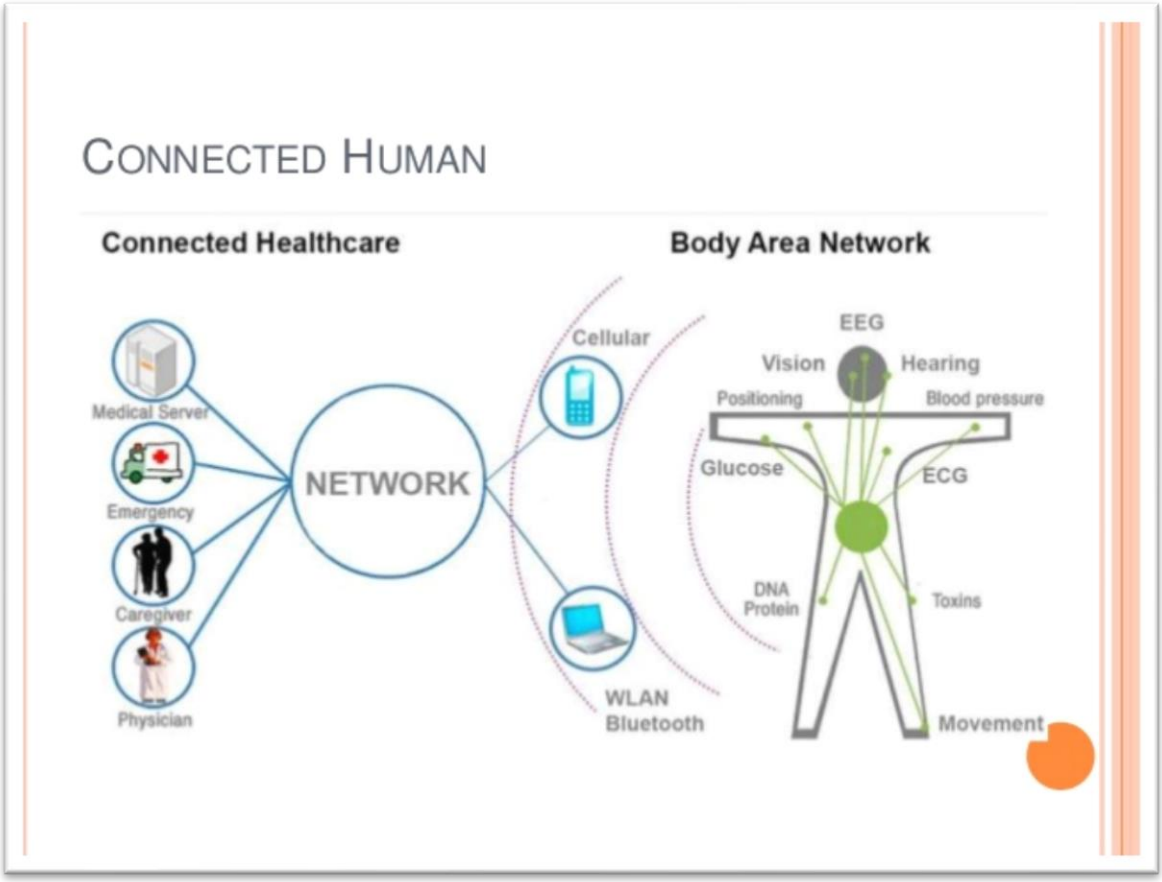

Figure 8. eHealth or Healthcare [2].

The integration of medical instruments and its gather data to the cloud or server makes it easier to accessible and then prescribe the correct medication for the patient. The more

visible application was at Electria Metropolia amk where we have a project name Health Memes a device that can monitor the pulse rate and heart rate and sends data to a WIFI and remotely doctors can monitor the health of the patient [28].

The project was mainly for old people where they are living alone or any other patient where if pulse or heart reading drops calls the emergency services automatically. The health Meme project was funded by Tekes and it took 3 years to complete from start to end [28]. In figure 8 shows the same concept of the healthcare in internet of things like connected healthcare and network that can be 4G LTE or 5G in near future. The end device mobile or laptop can see the Body Area Network that shows us the ECG, Version, Hearing, Blood pressure can be monitored and seen on the end devices. The protocols that are used for low power devices are Bluetooth, BAN (Body Area Network), cellular and WAN in near future when 5G will be fully functional the eHealth will use 5G as a network which will monitor 24/7 predict and suggests the best possible diagnostics and cure. In healthcare the emergency services will be enables with IoT with 5G so that they can find best possible traffic route and best possible medical help on the spot. In Finland the Robotics hand helped during the brain surgery according to Yle news [29] so the partial implementation of IoT is been done it will be more effective with 5G. Now 4G LTE is being used for different prototype projects and tests of healthcare.

3.5 Sports & Leisure

The next big field in which internet of things can impact in sports and leisure. The market is huge in sports and leisure by using internet of things. The wearables and activity monitors can monitor our activity and then they can send data to the cloud by using different protocols like wireless and other light weight protocols. So, the sports and leisure industry will be revolutionizing with the full presence of IoT athletes can train monitor and manage their performance feedback can make them more competitive. The figure 9 below shows us the tracker that are collecting the data then from WIFI or Bluetooth sending that data to cloud the cloud receives that data and stored and act on that data to send for system surveillance. At the same time the data sent to device management as well refine and filters raw data and makes decision on the data and then sent to system management which performs smart decision based on the data. So, this way the activity tracker data cycle completes. The figure 9 basically gives us a general idea that data can comes from Smartphones, activity tracer, smart watch, or tracker that data is then be transmitted to cloud where your previous data and new data by using machine learning predicts and decides best calories and best diet plans.

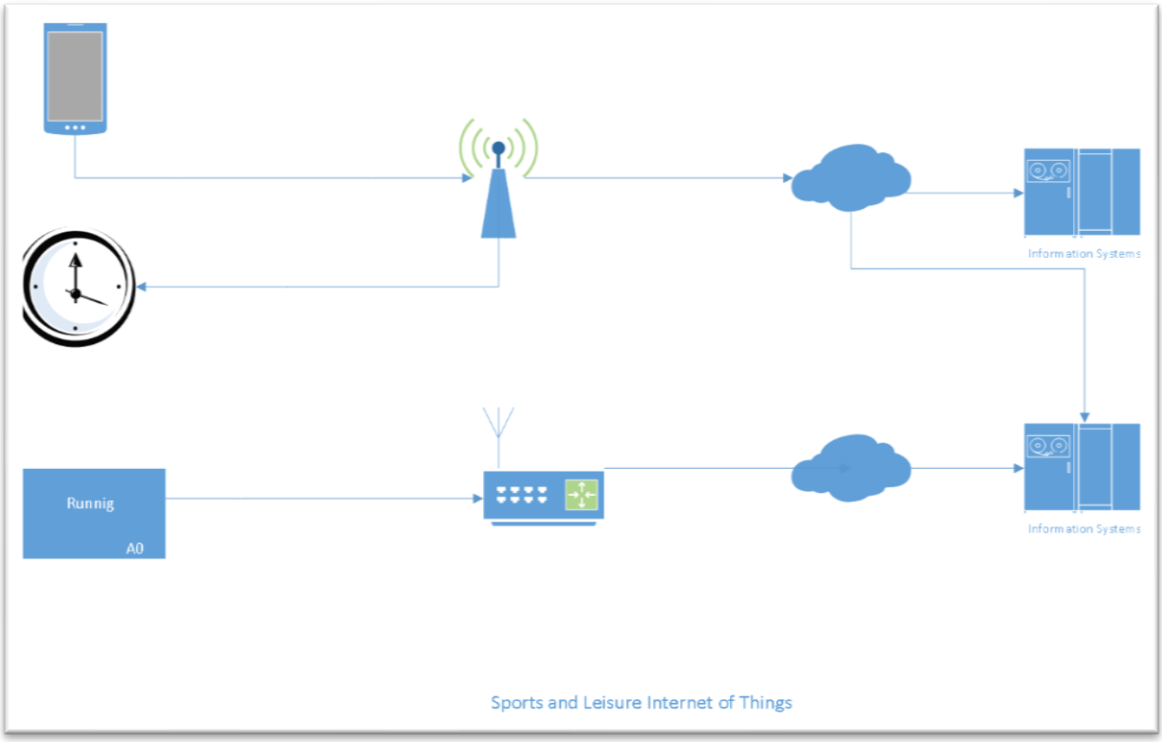

Figure 9. Sports and Wearables.

Many diet applications using the cloud data and then performing the analysis in IoT with 5G that will becomes more accurate and effective. that cloud stored data can also be given to medical Doctors so that they can view your activity and suggests you best exercise. The leisure time at hilly spot where no network coverage at that spot the low power devices and sensors gathers data and when they will have connected to network they will sends that data to your profile. These applications are in use, but the network latency and layered architecture sometime makes them slow IoT and 5G will make them more effective by reducing latency as well machine learning and best analytics results that can change our decisions for better health and enjoyment.

4 Internet of things (IoT) Layers

Internet of things has its own layers as things starts to communicate with each other the communication takes layers network for communication. There are seven layers application and basic four layer below the first layers basically a physical layer like Arduino Raspberry Pi sensors that belongs to devices layer or physical layer. That layer is for collecting data and then transporting it by using protocols so that the raw data can be defined and then analysed. The companies rely that collecting much data is not the all that beneficial rather than analysing that data is becoming more beneficial. So vast

resources are being allocated on the analyzation of the data. The internet of things basic four-layer architecture that is in details below made in which identifies the layers protocols and their functionality. I have made basic four-layer general IoT architecture. I have explained below three layers as I have taken application and data management service as a third layer in which explained the data and its management by analyzation filtering and then storing on various places like locally and on the cloud.

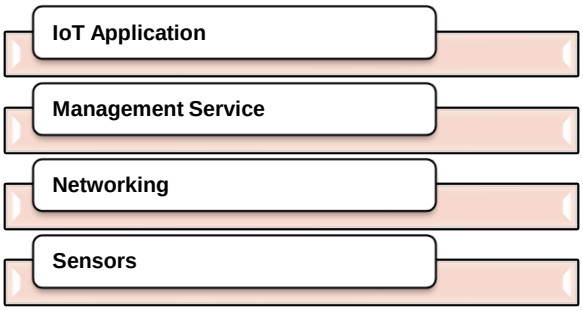

Fig 10. four Layer Architecture of Internet of Things.

Sensing Layer:

Sensing layer that known as the device layer which consists physical objects like tags, sensors, RFID and code readers and radio frequency identification, cameras, GPS or GPS tracker, in simple words all types of sensors and network that contains sensors from M2M (Machine to Machine) communication for its internal and gateways. The main purpose of that layer is to collect data and identification of the objects for gathering information. It depends on the sensors or other device which type of information is collected it will appropriately send to the next layer which is network layer.

Network Layer:

The next layer is the network layer in which the gathered data is been collected from Sensors or first layer then by smart gateways that information comes to this layer. The collected information come from wireless and cable network. So, by using 2G,3G, Bluetooth, infrared depends on the device or 4G LTE and 5G as well been sent to next layer where data is managed. The network or transport layer will include protocols that governs that how the information should be transferred and transmitted to the next layer and how next layer can receive it. The collected data from the devices can be transferred to a long distance for that needs several types of technologies and protocols to make sure that data is transferred smoothly and received without errors. The networking or transport layer handles that data transfer to various places where is can be processed and used for different purposes like analyzation or decisions.

Application Layer:

The third layer of the internet of things is application layer. Third layer basically get data from networking layer like storing and analysing and it will process data that will receive from the transport layer been done. Application layer involves cloud computing, ubiquitous computing, intelligent processing and mega databases. The main aspect in IoT is analyzation of the data so in this layer IoT data is analysed and then custom-made for specific purposes like some for used vehicular or smart home or healthcare it all depends on which data and from which device it came. The gathered data after analyzation made available for all kind of use to process information is then used for different industries to meet their goals in the form of products and services.
I have made one table below that shows four layers in which briefly explains the layers and their components. That will give us the more better understanding for IoT that which layers and which components corresponds to them.

IoT Architecture Layer	**Components**
Application Layer	Environment, Energy, Healthcare, Transportation, People tracking, Surveillance, Supply Chain, Retail
Management Service Layer	Device Modelling, Configuration and Management
Gateway and Network Layer	WAN (GSM, UMTS, 4G, LTE, LTE-A,5G)
Sensors connectivity and Network	Sensors Networks

Table 1. Four layers architecture with components.

I have written about basic layers and its working with the components and different protocols. But the total ecosystem of IoT applications requires application architecture so I have written in detail below the internet of things application architecture.

4.1 Internet of things application Architecture

I have made seven layers application architecture of the internet of things, in which you can see the seven layers that can tells us how the internet of things application takes its application cycle by completing these seven layers steps. So briefly I will explain them at general or basic level I have explained earlier four-layer IoT that can give us little idea about the IoT processes. Briefly IoT application architecture is explained below:
The blocks that are arrange below we can read them from bottom to top.

The first layer as you can see in the figure is the Physical devices and controllers layer that have sensors and electronic devices that can able to connect with things and collects data from those devise around them. The next or second layer in which collected data that comes from sensors or other device like tags, RFID etc that is converted into a format that can be understandable. So, after conversion those sensor devices uses protocols that we need to configure in this layer and refine the data so that will put some limiting point for collecting and storing data on this stage for making smart decisions. The third step is network connectivity, so the device will be connected to the wireless or internet connection. This connectivity can be changed as per the context and demand that are required. The next layer is for security we know the biggest challenge in IoT is the security so in this layer or application abstraction here we can add security on our products. That layer can be changeable depending on domain and application abstraction how you want to implement. The next stage is to use data that is collected and refined then transported through different protocols near or far depending on needs or requirements. Then the smart decision will be made as the gathered data analysed and reported for the actions and events that occurs during the process. At that layer our product and business come into picture like analyzation results and target marketing or user requirements etc. The next layer where we can present our result and take decision, so we can call this layer decision taking layer. Here we can apply machine learning and other big data analytics to control the results aspects and future devices. We can display reporting as we required and our custom logic that takes us smart decisions like sending signal back to sensors or adding more devices to gather correct and appropriate data that we need. The last layer that we saw as a user our user interface that can be made as per the requirements and as per the application like healthcare, telemedicine, vehicular, smart home, smart grid etc [4]. This layer is basically user interface layer where interface can tell the use what to do or user can give command for changing room temperature or humidity etc. I have explained seven-layer internet of things architecture in a very brief way there are some terms that I can explain here like Edge computing : "Its mesh network of micro data centres that process or store critical data locally and push all received data to a central data centre or cloud storage repository, in a footprint of less than 100 square feet," according to research firm IDC [30]. The concept is the IoT devices collects data sometime its massive data then it will send it to the data centres or cloud for processing and sending. The benefit of edge computing that it processes some data locally and that reduces the backhaul traffic to the crucial point. The edge computing and its data normally been done in IoT devices those transfer data to a local device in which local computers storage and network connectivity in small factor included. In internet of things

world, the network is the key when it is connected it works brilliantly but what happened when network is down or slow then edge computing helps in poor connectivity it stores collected data to data bases or storages locally or in a data centres. My definition in simple word of edge computing is it allows data from internet of things devices or sources to be analysed at the edge of the network before that data being sent to cloud or datacentre.

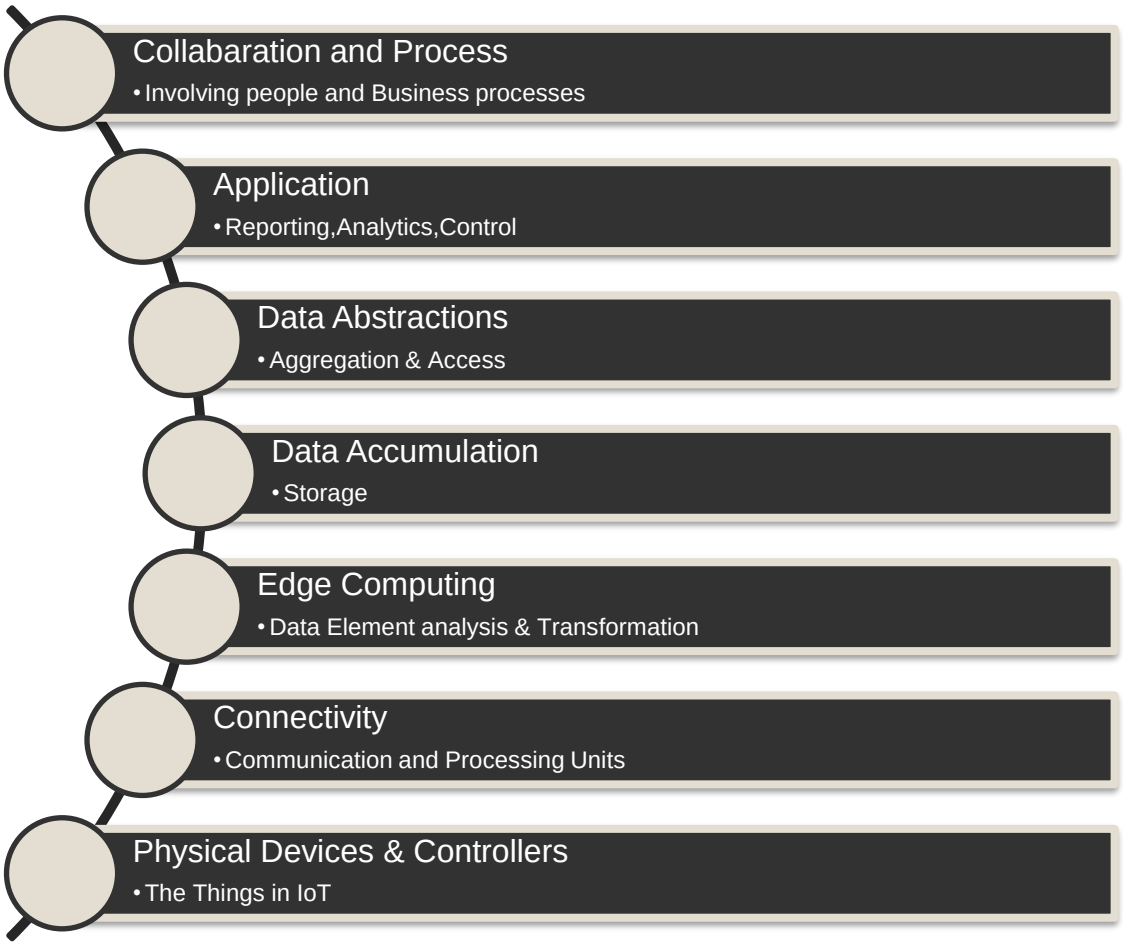

Fig 11. Layer application architecture for Internet of thing [31].

I have written about the application layers of the internet of things that is not the only model for application those blocks can be changed or rearranged as per the need or application requirements.

I have one more architecture picture of internet of things that shows us in Java stack that how the devices and their appropriate protocols interact in an internet of things environment. So, if briefly I can explain the architecture on left side are devise those are collecting data from different source those sources are sensors that is the core part in IoT.

The collected data then transported by using different protocols and it depends on whether needs to send data for long distance or shorter because protocols are different for different ranges. The collected data been checked and refined and then after filtration of the data the analyzation started to analyse which data is necessary and which is not. Normally in IoT architecture each stage is gather and then send data so that data can be for error correction and for monitoring purposes. So, then the fast data moves towards faster gem file and the other data by using different protocols like JMS, MQTT protocols reached to their destinations.

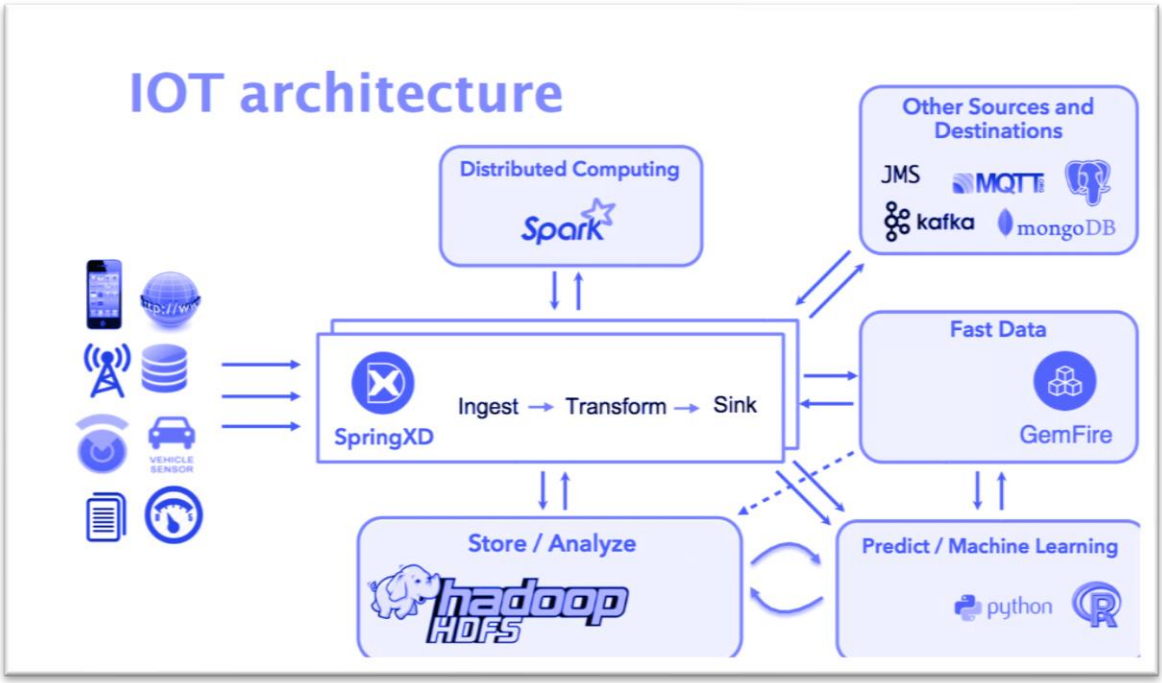

Figure 12. Internet of Things architecture using Java Stack [4].

For storage and analyzation Hadoop HDFS or other machine learning tools are used then from analyzation the data sent to machine learning in that step predictions corrections and other machine learning techniques applied that is in a loop with Hadoop, so they gather correct predict and enhance the capabilities of the system. So very briefly I have explained IoT basic three-layer architecture then to make it simpler I have made table for four-layer architecture. Then I have made seven-layer architecture that can demonstrate us the internet of things application architecture and at last visual representations of the architecture in a real world shows us the complete system of the internet of things. In the next chapter I have written about the internet of things protocols as per their layers and applications.

4.2 Internet of things protocols

I have introduced and wrote about IoT and 5G from beginning to until now. I have discussed IoT so much what it would be in real life as we imagined and listened that term again and again. So, there are IoT big concepts like Smart home and smart city and vehicular, healthcare/Telemedicine/Wearable Applications/Sports & Leisure.
There is below comparison between traditional web and internet of things protocols. The need for new protocols that are used for communicating things are required. So, the traditional technologies are http and TCP for application and transport layer. The IPv4 and IPv6 are the IP address that are used for communicating over the network. So, for Wi-Fi the wireless communication has its own protocol for communication new protocols for communicating of things are MQTT, UDP, IEEE 802.15.4 and things to communicate with each other [12].

TCP/IP	IoT Protocols
Application	HTTP, XMPP, CoAP, MQTT, AMQP
Transport	UDP, TCP
Internet	IPv6,6LoWPAN, RPL
Network access & physical	IEEE 802.15.4 Wi-Fi (802.11 a/b/g/n) Ethernet (802.3), GSM, CDMA, LTE

Table 2 [12]

4.2.1 Network access and Physical layer protocols

The first layer in IoT stack is Network access and physical layer basically sensors or devices layers. This layer protocols are BLE (Bluetooth low energy), Cellular, LPWAN, NFC, RFID, Ethernet, Wi-Fi, ZigBee [12].

Bluetooth Low Energy:

Bluetooth low energy protocol is very famous especially Bluetooth 2.4 GHz for wireless commination. Bluetooth protocol basically was for short range communication like tis not more than 100 meters. When we configure Bluetooth in a star configuration with a single primary device and many secondary devices that will be controlled by Bluetooth. When we see OSI (Open system interconnection) model it works with first two layers like

Physical and MAC or Data link layer. BLE is used in devices which transmits low volume of data bursts and these devices designed like when they are sleep they don't transmit data. Wearables health tracers and other fitness trackers are often use BLE.

ZigBee:

Zigbee just like Bluetooth it also works on 2.4GHz for wireless communication and the spectrum has range up to 100m.Its data rate is lower than BLE Zigbee data rate is 250kbps and BLE data rate is 270kbps.Zigbee is basically mesh protocol and was designed for buildings and obstacles in a near range like controlling lights and Zigbee also used for home automation.

LPWAN Low power wide area network:

LPWAN is designed for low power devices this protocol can also be used for long range wireless communication. So, they are ideal for long range wireless and low power devices. LPWAN includes SigFox, Haystack, LTE-M, NB-IoT (Narrow-Band IoT), LoRa (Low Range Physical Layer).

Cellular:

I have written about LPWAN in LPWAN NB-IoT and the LTE-M these both standards are for low power low cost IoT options that can use the existing cellular network. The new standard in NB-IoT which is for long range communication mainly for indoor devices. NB-IoT and LTE-M both are developed for IoT and they include 2G(GSM) that is legacy technology and that is replaced by CDMA,3G,4G.

NFC Near field communication:

NFC protocol is in use for very small range communication (up to 4 cm). When we hold NFC card or tag to reader it can read but very near normally that is used in payment systems. In IoT NFC can be used for tags as well as smart labels and in asset tracking application at industrial level.

RFID Radio frequency identification:

RFIDs are basically small tags that can identify and stores very small data that can be read by RFID reader typically used in stores for tracking inventory. Their range is less than a meter and RFID tags can becomes active or passive depending on our needs like it can be assisted passive as well. Normally the passive tags like locks and other keys works without batteries as ID passively read by the reader. The active tags are broadcasting identification when the assisted passive tag become active in the presence of RFID reader. RFID uses Dash7 protocol for active communication within IoT long range communication.

Wi-Fi:

The next protocol is WIFI that is standard wireless protocol that is based on IEEE 802.11a/b/g/n in which its specifications 802.11n that offers highest throughput at the cost of higher power consumption. For IoT the only use is 802.11b or g that takes less power. In many IoT enabled applications using Wi-Fi but the current IoT devices range is low due to that power consumption is also lower so the solution will supersede the lower power alternatives by new protocols, but the value and use of the WIFI will be remain prominent in IoT enabled systems and devices.

Ethernet:

Ethernet is basically wired network that is connected by wire and that follows IEEE 802.3 standard. All the IoT devices do not need to be wireless some devices can be wired network so for those devices ethernet would be the best. For example, building automation can be done with ethernet.

4.2.2 Internet layer protocols

In OSI model the layer third that is concerned with routing and identification packets of data. The internet layer protocols are IPv6, RPL,6LoWPAN, briefly explained these protocols below [12]:

IPv6:

The internet layer has its devices identification by its IP address so earlier it was IPv4 address that was 32 bits long but those are used. Now the new IPv6 IP address uses 128 bits which provides trillions of addresses so for IoT we need more devices and more IP addresses. The good thing in IPv6 is it can support legacy IPv4 as well, so the older devices will remain compatible with new one. The IP addresses are private and public address in practice the not all IoT enabled devices need public addresses some of them needed private as well, so they can use internally private address and then when they want to send or receive data they can use public IP addresses.

6LoWPAN:

IPv6 Low power wireless personal area network protocol allows 6LoPWAN to use over 802.15.4 for wireless network. The 6LoWPAN protocol is often used for wireless sensor networks and Thread protocol for home automation on which we can use 6LoWPAN.

RPL:

Internet layers also do routing for routing that protocol is designed for routing in constrained networks such as wireless sensors networks where all the devices are not able to reachable at all the time to the internet. In RPL due to unreachability data lost so RPL compute the best metric for data to be reached to the destination [12].

4.2.3 Application layer protocols and comparison

When collecting all data from all the devices the next phase is to make them communicate with each other. For making communication with each other we need protocols. When devices communicate with each other they use messaging for gather data as well as taking instructions from them. So, most of the protocols are messaging protocols and the evolution is still going on. I have not found one universal protocol that can work easily with all devices. There are other protocols as well at application layer such as, HTTP, XMPP, the possibility of using only one end to end protocol is very less. Because most of the devices don't work on the single protocol. I am writing some protocols below [13]:

MQTT Message Queuing Telemetry Transport

AMQP Advanced Message Queuing protocol

CoAP Constrained Application protocol

MQTT protocol is stands for messaging que telemetry transport protocol that is open standard protocol that is maintained by the OASIS, designed for internet of things communications over TCP. When MQTT was developed its main purpose was to develop device to gateway messaging requirements and does not meet most of the needs for gateways to a datacentre or intra-datacentre connections. The present MQTT 3.11 and MQTT 5.0. Below are some pros and cons of using MQTT [13]:

Merits	Demerits
Message header can be as small as two bytes. This makes it very bandwidth efficient, ideal for spotty coverage or limited networks.	It does not have message support for header fields as TTL(time-to-live), reply To and user properties.
MQTT.SN (sensors network) supports topic ID instead of topic name and UDP, Zigbee, Bluetooth and other wireless protocols (i.e., TCP is not needed)	It does not support message queue support (only the most recent message is stored in a message broker)
Supports the major IoT message patterns: publish/subscribe and request/reply. (supported by a message broker's extension of MQTT now and will be in a later version).	MQTT do not have section for message properties.

Lightweight API requires minimal processing on a device. Good for low battery consumption**.**	

Table 3. Merits and demerits of MQTT [13].

AMQP Advanced Message Queuing protocol

AMQP is open standard protocol that is used for middleware like message-oriented middleware protocol. The AMQP was designed for the replacement of existing protocols that was working for middleware. AMQP is basically binary wire protocol which was made for interoperability. The merits and demerits of AMQP protocols are written in table below:

Merits	**Demerits**
AMQP supports both TCP and UDP	Power, processing and memory requirements for a device are relatively high.
Advanced Messaging queuing protocols support all classes of service.	It required header fields are rather long.
It enables portable encoding of messages.	
It supports for detailed header fields such as TTL, replyTo and user properties.	
AMQP supports for most message exchange patters including publish subscribe request-reply and message queue.	

Table 4. Merits and demerits of AMQP [13].

CoAP Constrained Application protocol

CoAP is stands for constrained application protocol is based on a subset of HTTP methods like REST the merits and demerits of CoAP is written below in the table:

Merits	Demerits
In CoAP communication between device to device in UDP is very fast.	It has same weakness as well as REST except for quality of service levels.
It has the same API verbs and messaging patterns as REST over UDP.	It can only be used within a subnet only.
	It offers confirmable and non-confirmable quality of service.
	It can only be used in a subnet not outside
	It only supports request and reply response.

Table 5. Merits and demerits CoAP [13].

I have written about the protocols for IoT as per the layers, so the protocols guide us how the devices start to communicate with each other and the data send and receive through these protocols. But there are some challenges in IoT networking layer. So, these challenges are described below [12]:

Range:

In IoT at the devices at the first layer normally are very close so they can interact with each other. Due to range and distance some devices can reach near or far depending on the area. The range of the devices can be expanding by Narrow Band IoT which is radio technology standard which is made for wide range of devices and services that will be connecting through cellular telecommunication bands [32].

PAN (Personal Area Network): is short range and its range is in meters normally very close in fitness tracker that is used.

LAN (Local Area Network): is short to medium range in which the distance is hundreds of meters between a home automation and sensors in factory environment.

MAN (Metropolitan Area Network):is long rage (city wide) where distance can be measured in kilometres for example smart parking sensors that are installed in mesh network to get the parking space free or occupied.

WAN (Wide Area Network): Wide area network is protocol in which distance is measured in kilometres like smart agriculture where sensors are installed across the big form and can be monitored by the micro-climate and other measurements depending on the sensors or devices that network owe make.

Bandwidth:

The next challenge is bandwidth in which the amount of data that can be transmitted in specific period can reduce the rate at which data is collected from IoT upstream. There are three factors for bandwidth that are written below:

Data volume that device is generating or collecting

How many devices are on a network

How data is being sent continuous or in bursts normally higher bandwidth for higher periods. Packets of the data should be match up with the networking protocols that is typically transmitted. Data packets speed is not symmetrical like upload and download speeds differs due to many factors absorption, loss of signal interference noise and other like attenuation etc. When full duplex commination is going on at that time data transmission factored in and the wireless and cellular networks are low-bandwidth, so due to that the consideration is whether to use wireless or high-volume application. The amount of data collection and then storage of that data is costly as well it takes so much space so to consider we need all gathered data that we call as raw data or simply we need the filtered and sliced data to meet our requirements. Because gathering so much raw data and then storing it is costly and difficult to manage and takes so much bandwidth. We can minimize the bandwidth by aggregating the data on upstream for that bursting is not suitable for time sensitive or latency sensitive data either. IoT have much possibilities and big market but it will also require more storage that will increase cost and bandwidth.

Power Usage:

There are different challenges in low power IoT application the next important challenge is power usage or energy consumption of the devices that are connected because the amount of the devices will increase so much that our energy requirement also increases. When we transmit data at that time we need power especially for long distance transmission due to its distance. To reduce the cost and energy one way is the devices that have battery life can be put on sleep mode so when they are idle this way the battery will be saved.

Interoperability:

The buzzword nowadays is IoT,5G, Big data if we see IoT in IoT there are many devices at sensor level that measures the data and then transmit or transport to the next layer by using different protocols. There are many devices different protocols the interoperability is a challenge. There is one question Do traditional protocols can fulfil IoT requirements for data or communication? Simple answer no but I cannot answer this question completely because still so much research is going on and hopefully it will fulfil IoT

demands and standardizations. So, the standardization of the IoT struggles to keep up with the rapid pace of technology and its evolution.

Security:

The most discussed and worrying topic in IoT enabled environment that how secure it that system. Often that question arises whenever IoT concept comes in our mind now it's becoming reality in near future the need to implement security at layer level is the way forward because so many devices that can connect to different protocols and gathers so much data too keep them secure there are some measure that are taken at network. There are some general guidelines for networking technologies that implement end to end security that includes encryption and authentication to protect open ports. In IEEE 802.15.4 standards have security model that provides security features like access control message integrity message confidentiality, which are implemented by ZigBee standard. I have written about these below in IoT security [12].

Authentication

Authentication at the device level can be made sure by applying authentication protocols like X.509 for device authentication.

Encryption

To make wireless even more secure the recommend protection from network engineers are Wireless protected access 2 (WPA2) for wireless network encryption. The other ways to encrypt is by adopting Private Pre-Shared (PPSK). The next step is to make sure the privacy and data integrity when devices communicate with each other at that time TLS needs to be adopted or Datagram Transport-Layer Security (DTLS), which is basically based on TLS which was adopted from UDP.

Port protection

Securing port is also next step to make sure that network won't be compromised in any way. So, to protect port protection make sure the port that requires to communicate with upstream needs to be protected from external sources or connection or access. Normally in our CISCO switches best practice for port security is to shut down all unused ports so that nobody can get access on unused ports and protect only used ports with firewalls and Universal Plug and Play (UPnP) disabled on router to protect from vulnerabilities.

5 Evolution of Mobile Technologies (1G,2G,3G,4G,5G)

The evolution from first generation to fifth generation there is a long way from 1G to 5G. There are now 16 Billion users of cellular connections from 1G to 4G and roughly it will

increase 100% more like total connection will be 29 Billion approximately [16] connection from things and devices after 5G. I am attaching a figure 13 below that can clearly shows us increase in subscriber by the network evolution like 1G to 2G and 3G the boom came. When smartphones launched then the need for faster data and low latency network was needed so 4G then 4G LTE introduced with vast number of subscriber. Now revolution is coming because now devices and subscriber will add that number to 29 billion by 2022 [16].

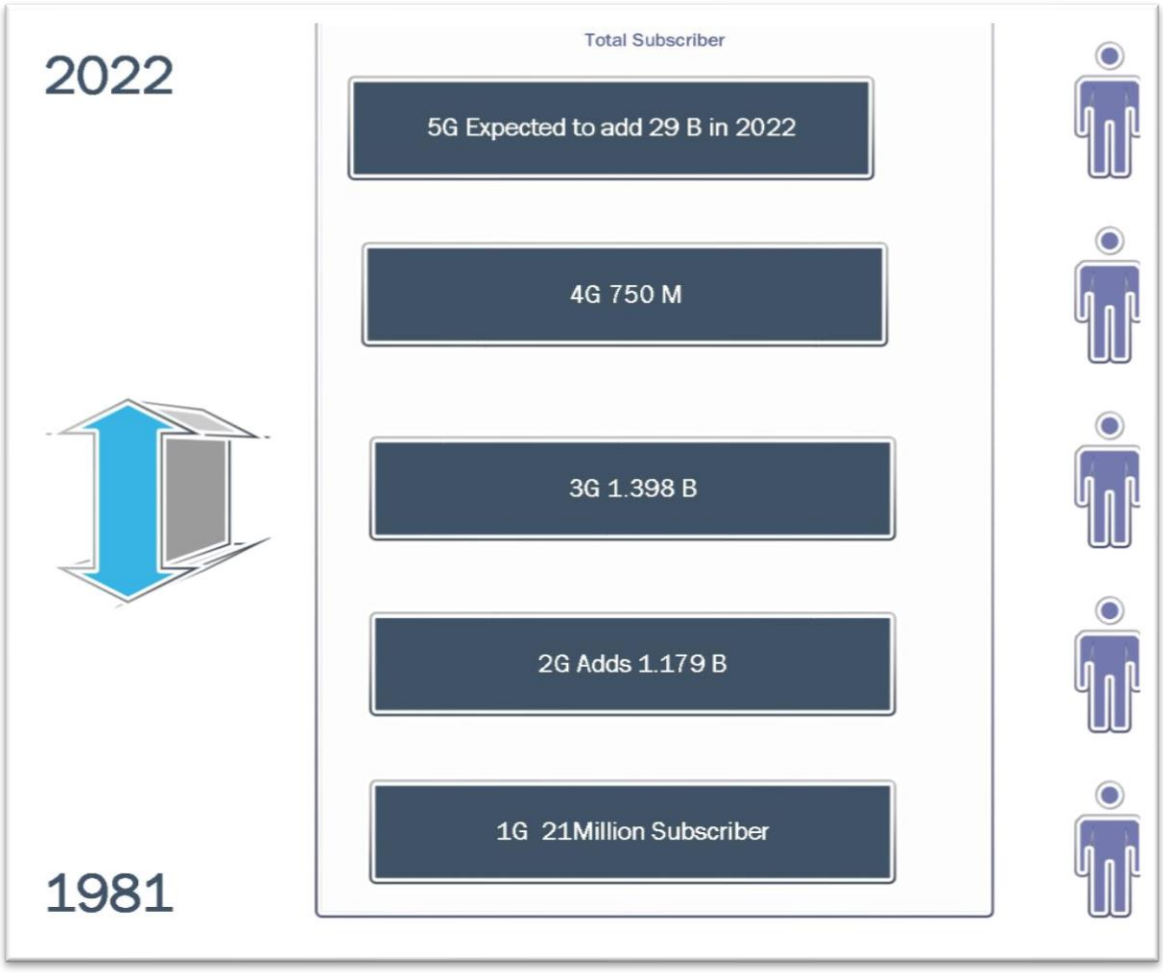

Figure 13. Evolution of Network and subscribers [5].

The figure 13 clearly shows us more subscriber and more demand for fast and agile network connection. Due to that 5G is needed and it will extend almost 1.1 Billion more subscribers by the year 2020.The brief history from 1G to 5G is written below. The 5G have more boom in the field of IoT and the expected market shares is very much high. So many companies and other research institutions are allocating funds and resources. Like NOKIA they have tested 5G as well as Samsung and Ericson and others as well.

Fully functional 5G will be in the year 2020 and the IoT will cover a huge chunk of that technology boom. Now, I will explain very briefly about that evolution in 1981 1G means 1st generation was introduced and that was all analogue 100%. In 1981 the mobile from Motorola was introduced that was a bigger size and was mainly for call and telephony purpose. The technology in 1G was used are analogue and FDMA (Frequency division multiple access), NMT (Nordic Mobile systems), and the switching was AMPS (Advances Mobile phone system). The average speed was 2.4Kbps and it was wireless network communication. Then in 1991 almost 10 years later 2G launched with more services and features like improved coverage and capacity of course voice quality was better than 1G. In 2G network the speed was increased to 64kbps and First digital standards was used like GSM (Global System of Mobile), CDMA (Code Division of Multiple Access), TDMA (Time Division Multiplexing Accessing) 2G the technology was circuit switching was used for voice and packet switching used for data. The new era of mobile technology and its services started in 2003 when 3G was launched the boom came in internet services on a mobile devices and smartphones launched later the 3G services.3G was based on digital voice and separate digital IP and web data email and SMS is also included. The technology was used in 3G was W-CDMA and UMTS the switching was packet with air interference. In 3G the speed was increased to 2000 kbps and the first mobile broadband was introduced as well. Since the first mobile devices launched the desire to make mobile devices more useful and more functionally smarter. Cell phones was used for General Cellular mobile where they use cells for communication. In 2005 when Steve Jobs was presenting the Smartphone that almost changed the smartphone and cell phone forever. Smartphones are just like a wireless computer that can call and works as a computer, but they can still fit in your pocket. So, the demand and portability made smartphone most popular item in today's life. So almost everybody owns a phone or a smartphone.

When the 3G fully functional and the launch of smartphones and the service almost implosion for need to get higher speed internet on a smartphone more and more services and apps require the faster internet so due to this huge demand for faster internet services 4G was launched in 2011 it in use nowadays along with 2G and 3G. The main difference in 4G was it designed primarily for data and it is based on IP based protocol (LTE) for multimedia. In 4G the technology for switching was packet switching. The speed increased to 100,000 kbps. Dawn of new era has just begun the quest to make things communicate is not a new concept, in year 2020 there is estimated 50 billion approximately devices will be connected to the internet. Due to this enormous demand high speed internet and next generation of the transport network is required.5G is the

answer to these questions in year 2020 5G will be fully functional. In Nokia and Samsung, they have tested and got very got results in their labs and real time environment.

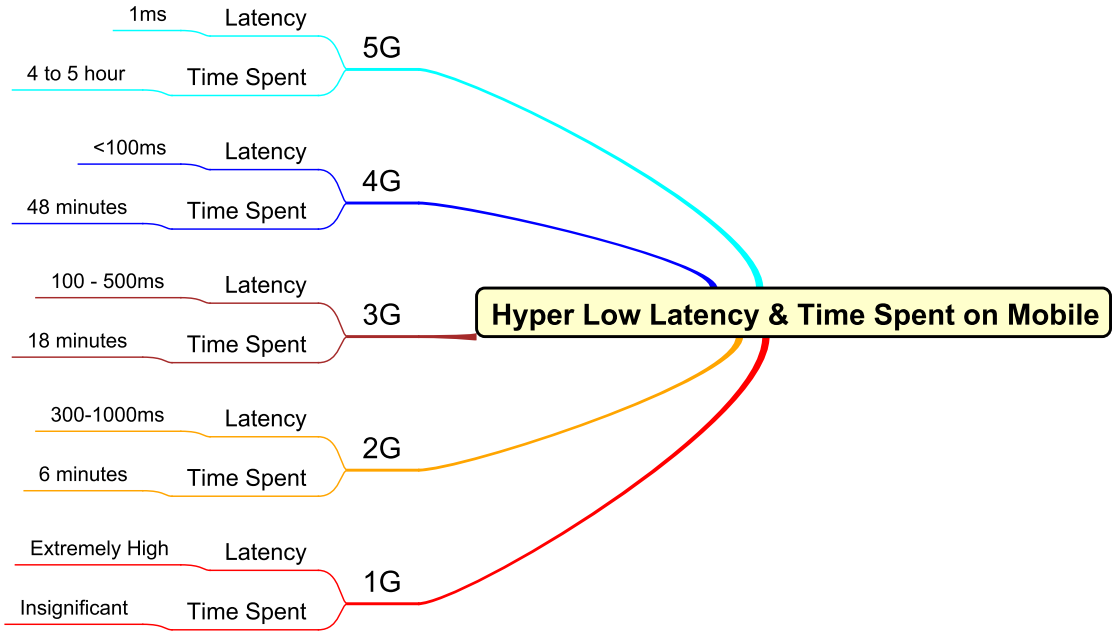

Figure 14. Evolution of key indicators [5].

The 5G technology is a digital voice and data capacity and distinctive feature for IoT (internet of things) and AR (Augmented Reality), VR (Virtual Reality). For IoT smart everything from smart cars to smart cities grids etc and things communicate with each other by using different protocols like CISCO CCN protocol and MQTT protocols for things communication. The technology will be used in 5G network is packet switching. The figure 14 I have drawn shows the evolution of key indicators in every generation. Like hyper mobility as per the time spent is 4 to 5 hours for 5G and below is the less time spent for 4G 48 minutes and then 18 minutes for 3G and for 2G time spent is 6minutes.When we compare user experience for hyper low latency 1G is extremely high then next is 2G 300-1000 ms. The 3G latency less then 2G but still 100-500 ms and current 4G latency is very minimal less than 100 ms. The revolutionary 5G latency is only 1ms.Now you can see the difference between the latency and performance of the internet on your devices.

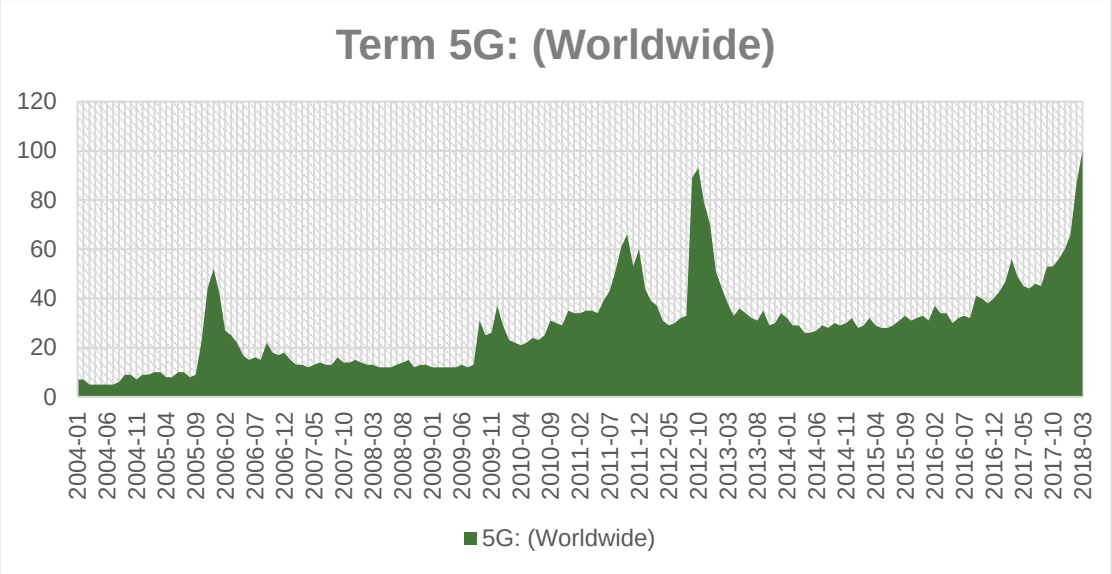

Figure 15. 5G term worldwide data from Google trends [1].

I have drawn the graph for 5G and its popularity worldwide below you can see in the google trends 2018 the world-wide popularity is increasing as the technology is near to arrive but will take time when it becomes fully functional.

5.1 5G Spectrum Bands

There are two types of ranges for 5G bands for lower and early deployments and higher bands for early deployments that are listed below as per the continent [33]:

Lower bands for early deployment[2]

Europe	3400 – 3800 MHz (awarding trial licenses)
China	3300 – 3600 MHz (ongoing trial), 4400 – 4500 MHz, 4800 – 4990 MHz
Japan	3600 – 4200 MHz and 4400-4900 MHz
Korea	3400 – 3700 MHz
USA	3100 – 3550 MHz (and 3700 – 4200 MHz)

Higher Bands for early deployment[3]

USA: 27.5 – 28.35 GHz and 37 – 40 GHz pre-commercial deployments in 2018

[2] 5G Spectrum https://gsacom.com/5g-spectrum-bands/

[3] 5G Spectrum https://gsacom.com/5g-spectrum-bands/

Korea:	26.5 – 29.5 GHz trials in 2018 and commercial deployments in 2019
Japan:	27.5 – 28.28 GHz trials planned from 2017 and potentially commercial deployments in 2020
China:	Focusing on 24.25 – 27.5 GHz and 37 – 43.5 GHz studies
Sweden:	26.5 – 27.5 GHz awarding trial licenses for use in 2018 and onwards
EU:	24.25 – 27.5 GHz for commercial deployments from 2020

5.2 5G and its characteristics

I have written above the evolution from 1G to 5G. The international telecommunication union have classified the 5G services into three categories [34]:

Enhanced mobile broad band, eMBB is aims to meet the demands of the people like digital life style, and it focus on services that have high bandwidth like HD (high Definition), AR (augmented reality), VR (Virtual Reality)

ultra-reliable and low latency communication, uRLLC is basically designed to fulfil industrial demands that is basically digital that will work with latency and legacy technologies.

Massive machine type communication mMTC is to meet the growing demand of further digital societies and it focuses on services that includes high connectivity density like smart city and smart agriculture. I have drawn a figure 16 below that will gives the idea about the core classifications and their categories. The figure 16 is ITM shows us the ecosystem of 5G in which we can see the

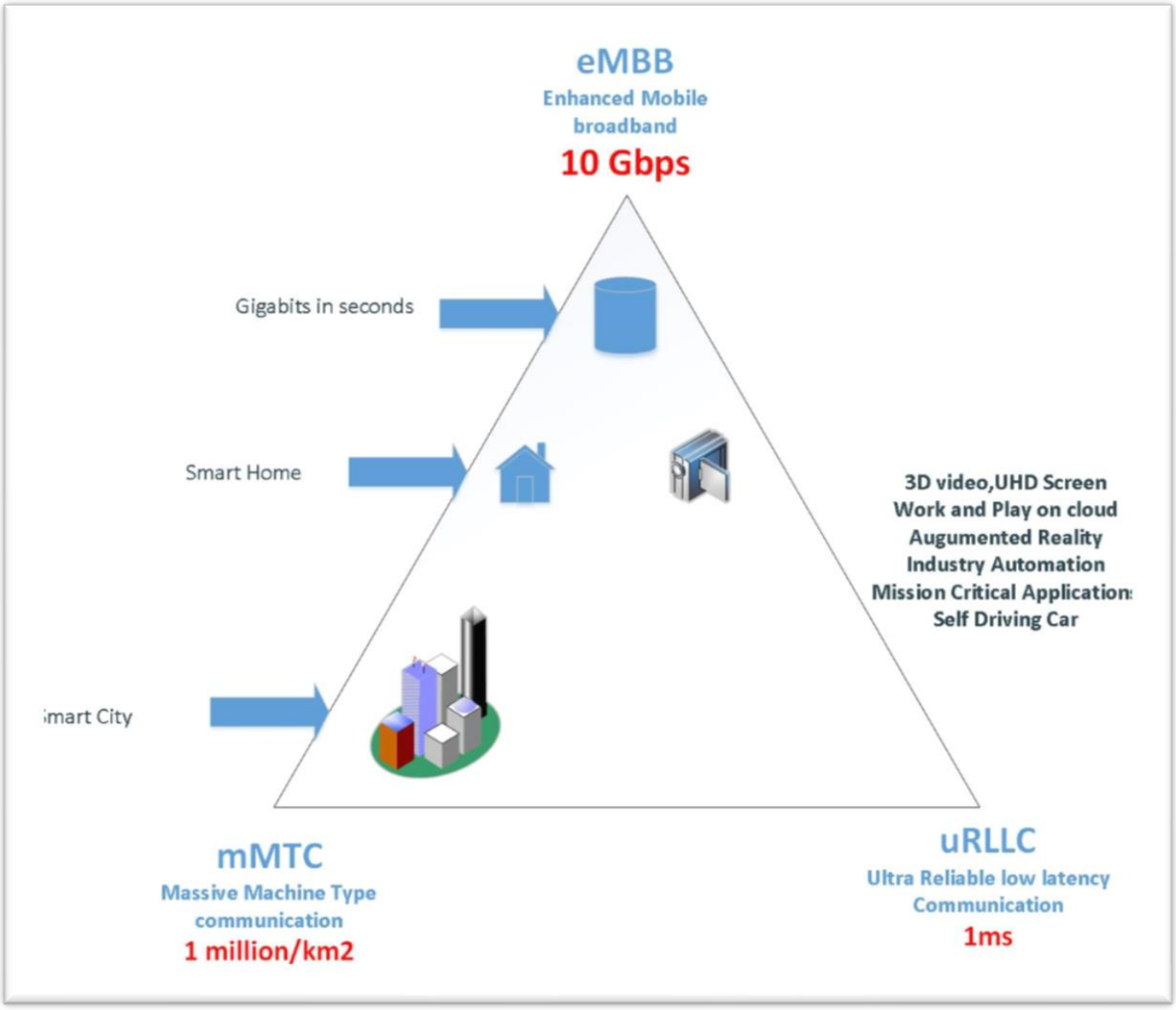

Figure 16. IMT scenarios in 2020 and beyond from ITU [6].

5G digitalization of the personal and society level will transform from healthcare, agriculture, automotive, municipal systems by using above mentioned ecosystem [6].

How the network and technology evolved and how our needs change the overall structure of data and its usage. Day by day the demand is increasing and to meet the growing demand we need faster network that can use higher data at bigger rate. So, all the evolution from 1G to 5G is the result of continuous demand for higher and faster network. So, in the year 2020 the future of the things becomes more visible when things start to communicate with each other. For that aspect a faster network is required 4G LTE is very much faster but still slower than its demand. Due to that need the research on further and faster network is started in Nokia labs have successfully tested the 5G and so in Ericson and in Samsung also have tested 5G.

I have written some core concepts of 5G that can tells us the characteristics in 5G.

5G comprise of five important feature that can be seen below by the process diagram. Nowadays the amount of data people is consuming is huge and it is increasing more and

more. Due to that the current wireless network run into a problem the excessive data consumption will crammed on the same bands of radio-frequency spectrum where mobile providers have always used. What it means in simple words? It means that less bandwidth for everyone that will cause slower service and it will drop more connections. One way to get around that problem is to simply transmit signals on a whole new swath of the spectrum, one that's never been used for mobile service before. That's why providers are experimenting with broadcasting on millimetre waves, which use higher frequencies than the radio waves that have long been used for mobile phones [34].Presently it's not very clear that which technology will lead in 5G but surely some are front runner that are listed below.

There are five main characteristics in 5G that are written below [14]:

- Millimetre Waves
- Small Cells
- Massive MIMO
- Beamforming
- Full Duplex

5.2.1 Millimeter Waves

Millimetre waves are the most discussed characteristic of the 5G. The range in which frequencies between 30 and 300 gigahertz compared to the bands below 6 GHz that were used in mobile devices in the past. The size of the wave is 1 to 10 mm that's why it's called millimetre waves. When we compared between millimetre waves and radio waves that serve today's smartphones that measures tens of centimetres in length. The only operators that are using the satellites and radar are using the millimetre waves in real world applications. In nowadays the operator's cellular providers have begun to use them for sending data for stationary points, like between two base station. That approach for connecting base stations with each other by using millimetre wave is a new way for sending data because their fixed position makes it easier for data sending that approach is completely new. The modern technology and features have its benefits and its drawbacks in millimetre wave the major drawback is the waves cannot pass the buildings or obstacles and they can be absorbed and foliage and rain. Due to that the 5G networks will likely augment the traditional cellular towers with another modern technology called small cells [34].

Figure 17. 5G characteristics.

5.2.2 Small Cells

5G second more important feature is small cells what are these small cells. Small cells are basically miniature base stations that require minimal power to operate and these small base stations can be placed after every 250 meters throughout the cities.

The signal drop is the most problematic aspect so to prevent from signal drop carriers could install thousands of these base stations where network is very dense like cities those base stations acts like a relay team for receiving signals from other base stations and will send data to users at any location. There can be many causes of signal drops like attenuation and densely populated buildings weather and absorption. Traditional cell networks must rely on increasing numbers of base stations for achieving 5G performance will require an even greater infrastructure. For small cells the requirements of antennas are also small than the traditional antennas if they are transmitting tiny milometers waves. The small cells make it easier to stick cells on light poles and atop buildings. The radically different network structure should provide more targeted and efficient use of the spectrum so that more bandwidth and frequency can be used for other services. The advantage of having many stations means that frequencies that one station uses to connect with devices in one area can be reused by another station in a different area to serve another customer [34].

There always drawbacks about small cells as more and more small cells grows in number in 5G it will becomes harder for network to set up in rural areas. The difference between

traditional antennas and 5G base station antenna are more for broadcasting over millimetre waves.

5.2.3 Massive MIMO

The third characteristics of the 5G is the massive MIMO (Multi input multi output). We can see the maximum amount of error-free digital data can be transmitted over a communication channel that can be calculated in below formula by Shannon-Hartley theorem and Shannon-Hartley law [35]:

$C \approx W.n.log_2(1 + SNR)$ Shannon-Hartely Law [5]

$C = Capacity$

$W = Spectrum$

$n = Antenna$

Capacity = Channels *BW* log2(1 + S/N) Shannon-Hartely Theorem

S/N = Signal to noise ratio

At the present the 4G base station have dozens of ports for antennas that handle all the cellular traffic. In all dozens of ports eight are used for transmitter and four for receivers' that completely changes in 5G base station they have almost hundred ports which means that many more antennas can fit on a single array. In 5G that capability means that base station could send and receive signals from many more users at once to increase capacity of mobile networks by a factor of 22 or greater. That technology is called massive MIMO (Multiple input multiple output). MIMO can be described as a wireless system that uses two or more transmitters and receivers to send and receive more data at once. I have described about MIMO in 5G massive MIMO takes this concept this concept to a new level by featuring dozens of antennas on single array. MIMO is already in use in some 4G base stations. The massive MIMO until know is only tested in labs and few field trials. The early tests show that it has set new records for spectrum efficiency which is a measure of how many bits of data can be transmitted to a certain number of users per second. The more crucial factor in 5G is the latency in 5G latency is 1ms.The future of 5G is looks promising and the future of massive MIMO also. The drawback that comes to my mind is by adding so many antennas to handle cellular traffic it will cause interference if those signals cross each other, That is the reason 5G stations must incorporate beamforming [34].

5.2.4 Beamforming

Beamforming is a traffic-signalling system for cellular base stations that identifies the most efficient data-delivery route to a user and it reduces interference for nearby users in the process. Beamforming can be implemented in diverse ways in 5G networks, Beamforming helps massive MIMO arrays that will make more efficient use of spectrum and around them. In telecommunication there is always problem of interference on a network as in 5G the interference also causes problems to overcome this problem beamforming can reduce the interference when it will transmit more information from many more antennas at once. Massive MIMO base stations and its signal processing algorithms plots the best route through the air to transmission for user. That will help to reduce the interference in the transmitted signal. Then they can send individual data packets in many directions and bouncing them from buildings and other objects in a precisely coordinated pattern. The packet's movements and its arrival time can allow many users and antennas by beamforming on a massive MIMO array to exchange much more information at once. As the millimetre waves have problem with absorption and distracting from buildings the beamforming addresses in way that it can help by focusing a signal in a concentrated beam that points only in the direction of a user, rather than broadcasting in many directions at once. This approach will strength the signal chances to arrive and intact and reduce interference for everyone else. When we broadcast over millimetre waves it will boost data rates and beef up spectrum efficiency with massive MIMO wireless engineers are trying to achieve the high throughput and low latency 1ms in 5G through technology called full duplex that will modifies the way antennas deliver and receive data [34].

5.2.5 Full duplex

Full duplex means that data can be transmitted in both directions on a signal carrier at a same time. Now the base stations and cell phones are relied on transceivers that must take turns for transmitting and receiving information over the same frequency or operate on different frequencies if a user wants to send and receive information at a same time by using same frequency. With 5G the transceiver will be able to transmit and receive information at same time by the same frequency. This technology is full duplex in which we can transmit and receive at a same time on a same frequency. Full duplex can make it possible to double the capacity of wireless networks at the most fundamental physical layer [34]. Physical layer in which segmentation of the network is been done by doing radio access network, transport network, core network, and internet. The 5G architecture

is explained in detail below, I have explained the network segments and slicing of the network in the 5G in the next chapter where architecture is discussed in details. Full duplex can easily be understood by human example in which when two people starts conversation at a same time and still understood each other that is called full duplex that conversation on the network or face to face. Full duplex is not a new concept it's been already in use where technology that relies on bulky equipment. To achieve full duplex in our personal devices research should be on designing on a circuit that can route the incoming and outgoing signals, so they don't collide with each other while an antenna is transmitting and receiving data at the same time. That problem normally occurs due to radio waves tendency it travels both forward and backwards on the same frequency a principle that is called reciprocity. Recently experts assembled silicon transistors that act like high speed switches to stop the backwards radio frequency roll of these waves, that will enable us to transmit and receive signals on the same frequency at once. All the new features have its own advantages and its drawbacks the drawback in full duplex is that it also creates ore signal infrastructure through a pesky echo. The more the base station in 5G when it emits signal the power in the signal is so high due to closer device's antenna. So, when we expect an antenna to both speak and listen at a same time it's possible only with protection like eco-cancelling technology. For this and other 5G technologies there is a hope that engineer's will built wireless network that in future smartphones users, VR gamers and IoT enabled cars will rely on every day. The researchers and different companies at present sets very expectations for 5G by giving them very low latency only 1ms and record-breaking data speeds for consumers [34]. With all the expectations and challenges if all those will be solved the 5G will be very much close to use now. The high-speed data and other aspects are coming closer and close in year 2020 it will become more operational. Now different telecom carrier's providers are testing as well as analysing the drawbacks and fixing it for the better and fast data driven future. Nokia, Siemens, AT&T bell labs China mobile already testing different scenarios and it labs so the 5G is coming with faster and quicker things and data.

6 5G Architecture and Security Management

I have written about 5G from its inception to its application but have not discussed about the architecture so below I am writing about the 5G architecture this will elaborate many functionality and helps us to understand the layers and architecture in the 5G era. So, the main aspect of the 5G it provides logically independent network which can slice

different networks in a single network for the diverse requirements. The architecture for this aspect is DC cloud based which can provide different requirements and its applications. The next feature is CloudRAN (Radio Access Network) that will reconstruct the radio access so that multiple network and channel can get the access to the network easily. The internet service provider nowadays faces more pressure about the growing needs of the base station and faster data rates. So, the cost of more and more base stations and the data speed always increase cost for this problem most of the telecom operators wants to slice down the network on a single package so that they can give access to maximum users possible as well for those who are not using the same service that stream can be free for the other users. This aspect is covered in 5G by CloudRAN and independent networks. The future needs more and more access points because things start to communicate and collects data and that data can be used for analyzation and smart decisions. The third feature of the 5G architecture that it can simplifies the core network to implement on demand configuration of network functions through control and user plane separation and component-based functions and unified database management [8]. These all features can enable us to reduce the operating cost for the telecom operators through agile network O&M. The figure 18 below shows us the main architecture that was presented in the European Commission working group in July 2016.The main architecture is divided in four stages like physical infrastructure that includes four segments like Radio Access Network and next is Transport network then core network and the last one is for internet. We can see that these segmentation in 5G makes easier for getting connection and segment users on demand network access to the devices or the internet. These all segment have their own architecture like radio access network have end users like IoT radio, Other Radio,5G Radio that can communicate via base stations and then send data to RAN PNF (Radio Access Network by Physical network function) The PNF (Physical Network function) normally in the premise based where we need them for RAN we use there. The next step where RAN base data goes I to VNF(Virtual Network Function) form VNF by using API the data sent to mobile controller that is software based and from there by sing API the data sent to resource abstraction and virtualization layer then from there to Network slice layer and from network to Software network service chain layer then by API the last layer is service layer which will provide appropriate response for the request and the networks. The main feature in 5G is faster and segmented networks that can save cost and band width for the telecom operators due to that the next segmentation is the transport network layer in which the data that was connected via edge cloud is reached to routers after routing the data from VNF (Virtual Network Functions) that are transferred to the next segment via

router that is connected to the cloud. The SDN controller (Software defined network) SDN basically manages the traffic according to the needs and requirements. Then from SDN controller the data by using API transferred to the next layer until it reaches to the destination. The next segment is core network segment that took its input from previous segment via Transport network VNF and from transport network segment. The core network consists on the data servers and other storage facilities on a cloud these all relate to each other and from their they send data to the SDN controller which will allow traffic to pass or block or apply priority according the needs and requirements. Then the data will transmit to the next layer that is resource abstraction and virtualization layer from them to the networking and slice layer from networking slice layer it reaches to software network service chain layer and at last it reaches at service layer. The last segment in the physical infrastructure layer is internet that receives data from Network controller which controllers the network traffic. The core network segment data via connection reaches to the internet that will uploads or deploy on logical infrastructure and then logical infrastructure in software network service chain layer and lastly at service layer on service orchestration the data will completes it layer cycle. The next phase is the management orchestration that data we receive in network slice layer and software network service chain layer interact with management orchestration in which it can be managed as per the requirement and the traffic will be allowed and managed with this. The below pictures give us a brief concept of the 5G architecture that is mainly will remain same, but the slight changes will come when IoT will be fully enabled on the everyday life and then network utilization and slicing will checked more effectively.

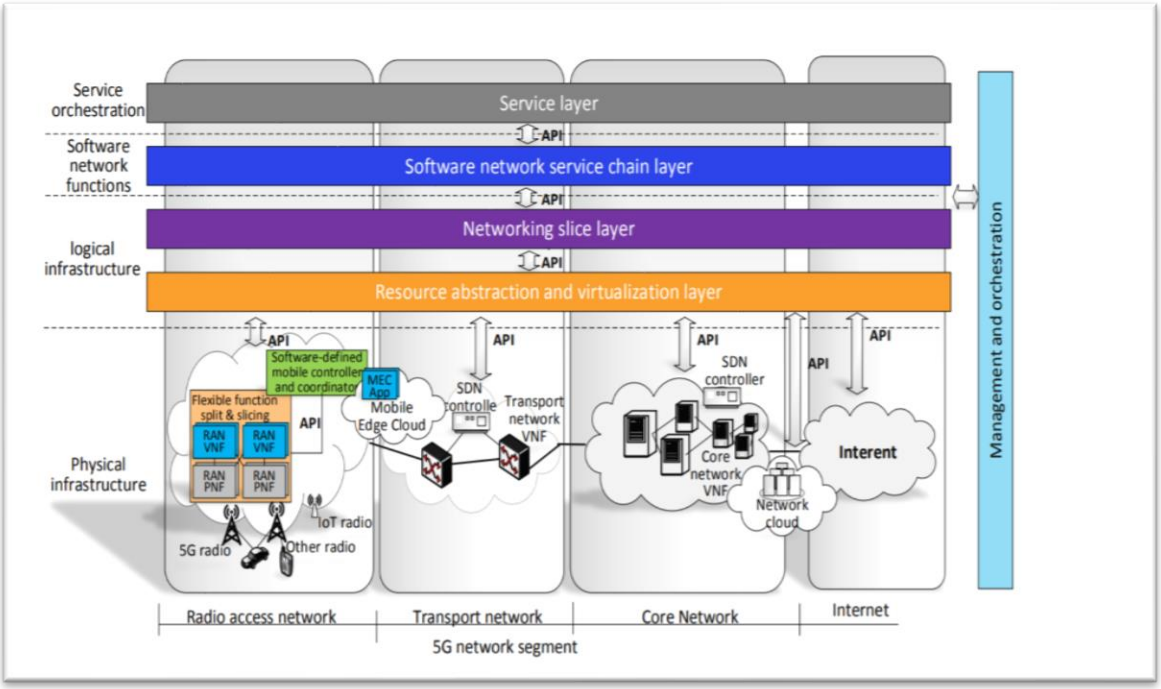

Fig 18. 5G PPP architecture [7]

Since the 5G and IoT both are very new as per implementation point of view though IoT concept is not very new. There is one more picture from Huawei white paper 5G Network Architecture, A prominent level perspective in which the 5G service driven architecture figure 19 is below. I summarise the service driven architecture it shows us the flexibility and diversity in which system requires diverse connection and networks requirements as per the demand of the user or things. The SDN (Software Defined Network) and network functions virtualization of the segments supports the physical infrastructure, and which enables different segments to share and receive information via cloud. The other segment are core and transport network as shown above in the figure 18. Cloud support allows better accessibility for diversified demand for 5G services and it enables E2E, network slicing, and component-based network functions can make faster and easier for access and speed.

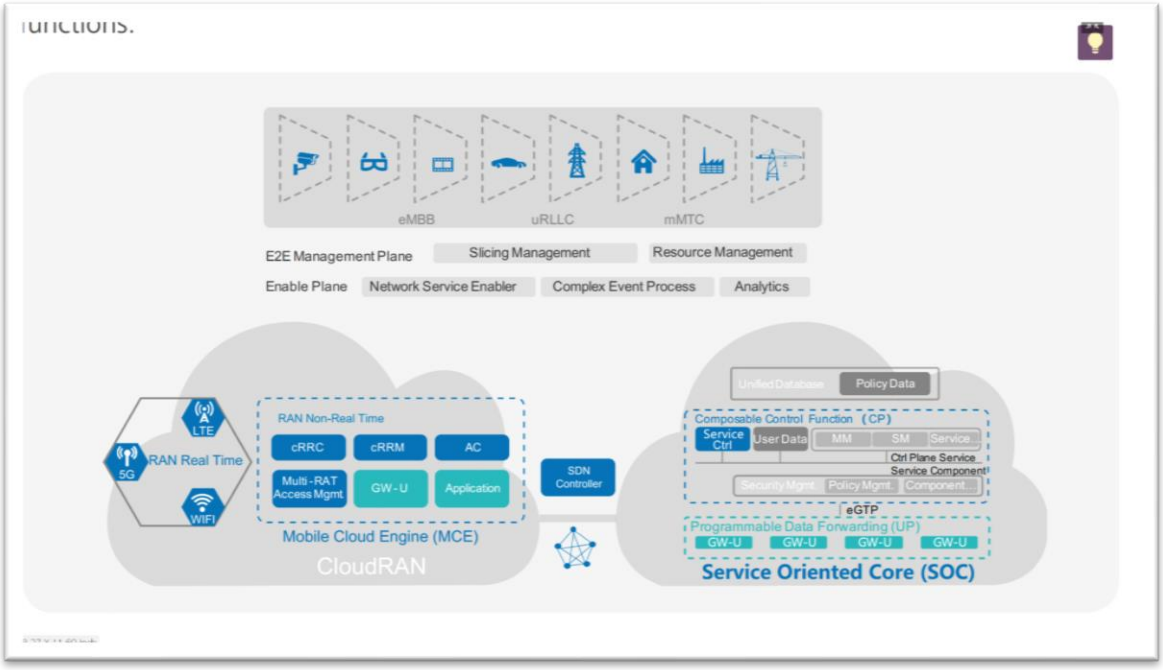

Fig 19. Service Driven Architecture [8].

I have explained CloudRAN (Radio Access Network) earlier but in a summarize way according to this picture that have service driven architecture. The CloudRAN consists of two aspects like on site and mobile cloud engines. The two aspects coordinate with

many services and different standards and operations in different site for RAN in real time. The increasing demand for multiple access for different services requires RAN that non-real time resources. The core network segment implements the network policy control for dynamic policy and its semi-static user, the unified database for core network side stores static data. In 5G the component-based control and programmable users plane allows for network function orchestration to ensure network can choose corresponding users functions or control plane as per the different services requirements. The transportation of the network comprises on SDN (Software defined network) controller that allows and manages the traffic flow according to the user demands. SDN have one more functionality it generates a series of specific data forwarding paths that are based on networks and service needs. The collected data and the segmented data then by API sent to the next layers so to enable the plane abstraction and analysing networks capabilities it needs to implement the network optimization or open network capabilities in the form of API (Application programming Interface). The upper layer of the 5G network architecture implements the E2E automatic slicing and network resource management [8]. I have used below physical infrastructure figure 20 to make it clearer what happen for eMBB, uRLLC, mMTC slicing. The below figure 20 shows us the process from starts to until data is stored or analysed and made decision on that captured or stored data.

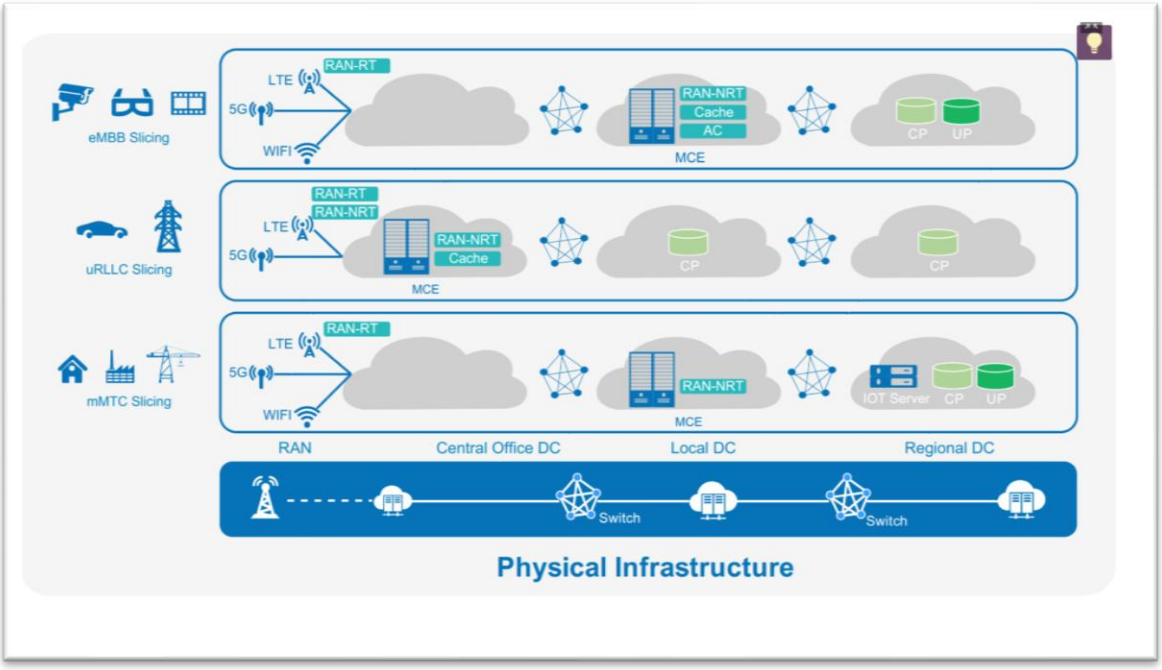

Figure 20. Physical Infrastructure [8].

In 5G the diversified services are the key for that E2E network slicing is a foundation to support diverse services. That slicing is based on NFV and SDN that shows in physical infrastructure of the future network consists of sites and three layers DCs [8]. Normally sites support multiple modes like 5G, LTE, and Wi-fi in the form of macro and micro also Pico base stations for implementation of the RAN in real time. For specific functions and high requirements for computing capability and real time performance and require dedicated hardware. In the layered architecture three layers are for cloud DC that consists of computing and storage sources. The lowest layer is for the central office DC which is nearest in relatively to base stations. The next layer is local DC and the upper layer is regional DC with each layer of arranged DCs connected through transport networks [8].5G requires diversified services and its application and in the diverse requirements network generator corresponding to the network topologies and a series of network functions sets and slices the networks according to the demand. In each network segmentation at the physical infrastructure layer slice or segment derived from a unified physical network infrastructure which reduces the operators network costs. In 5G the network slicing feature creates a logical arrangement that is separated as individual structures that allows heavily customizable service functions and independent O&M [16].

6.1 5G Security Management Cycle

Whenever modern technologies developed the challenges to make them secure is always priority. Nowadays more and more devices and the internet make privacy and confidentiality a biggest challenge. We hear almost every day somewhere some hackers hacked system to deliver its message or got benefits in the form of stealing. So, the data and its confidentiality as well as integrity with availability is the biggest challenge to maintain. I have written about the evolution of 1G to 5G for 25 years earlier when GSM systems was developed and standardized at that time the security functions to protect the system was introduced but the lack of threats in variety and volume makes that system unsustainable. That system was basically analogue system by the time technology evolved and boom in the devices to get connected makes security more challenging. Initially encryption for the radio interference was introduced. The previous systems were radio receivers that was enables eavesdropping on conversations through mobile communication. When initially encryption was used at that time it was touchy issue so due to that aspect modern design was evolved where the encryption strength was moderate. It remains very strong regardless of its contentious, so it grows strongly with the for the economic growth lifetime of GSM at that time. The next big challenge is

risk of fraud like making calls that will be charged to other subscribers that was big problem earlier. To overcome this problem a new tamper-resistant SIM card, adding strong authentication [9] for subscriber so the subscriber can pay what subscriber is using or calling. Lastly the next challenge was to make sure the privacy of the subscriber that have entered the scene in which a mechanism that can assign identifiers to make it harder to track and or identify subscriber. The 3G came and the further enhancement were made for security. Like mutual authentication to alleviate the threat of rogue base stations with moving the encryption deeper into the network and making it site of the art in terms of strength. The demand for higher speed and faster data rate makes the way for the new research like 4G LTE. In 4G LTE standards was set additional security in which the returning of user data encryption to the base station [9]. The key management was introduced to protect against the potential physical-ins to radio base stations. Basically, the security that is offered in the LTE is similar as it was in 3G like strong protection. I have attach picture below in which we can see the 5G elevated level security principle that illustrates us the overall the idea about 5G security. So, the core 5G security topics are [9]:

1. Security assurance
2. Identity management
3. 5G radio network security
4. Flexible and scalable security architecture
5. Energy efficient security
6. Cloud security

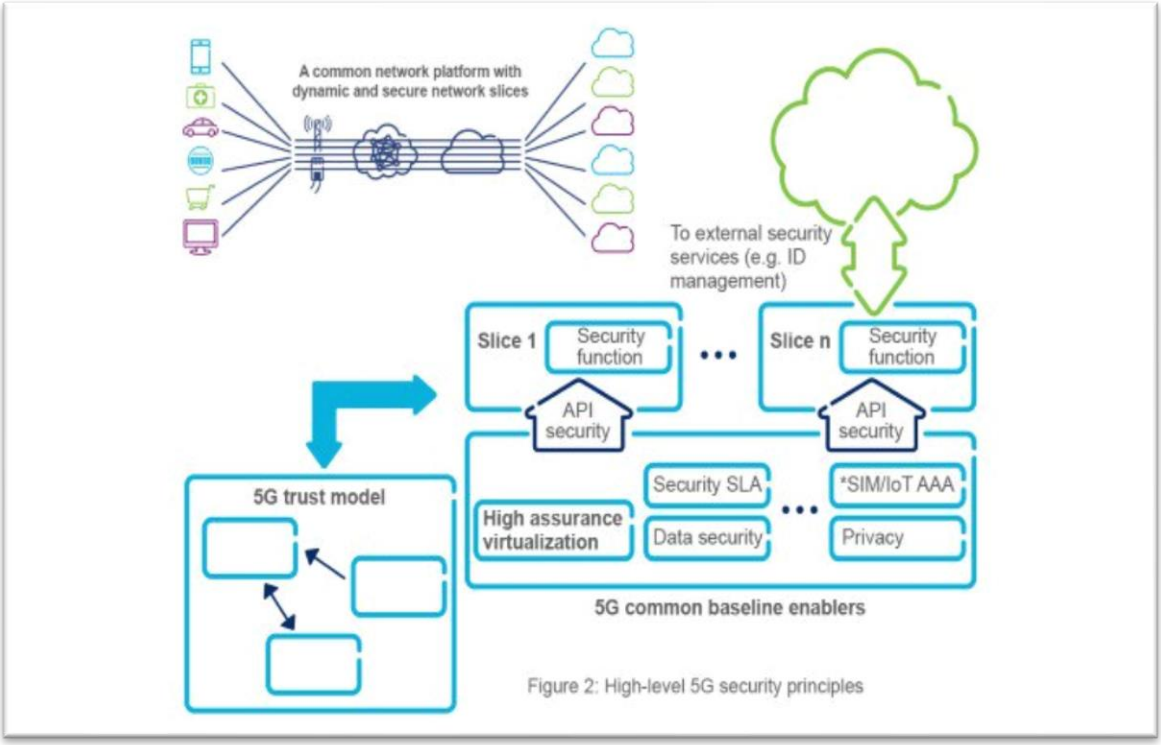

Fig 21, High Level Security Principle [9]

Security assurance:

Security for networks always been the topic on interest as per the evolution from 1G to 4G LTE the ways to make more secure encrypt and cover more and more vulnerabilities takes the priority. In 5G with the promise of faster data and efficient and more reliable these aspects make you think about the security of the 5G. The 3GPP has already gave its observation to extend the need for security specialization at the interface as well node level implementation that has initiated the work that is known as SECAM. It all depends on how much security valued because protecting each node requires skills and money. So, for effective way is to vulnerable nodes or points critically secure. The standard for IT assurance standard product is Common Criteria (ISO 15408). In future the network 5G will becomes general platform for connected societies. We can imagine that when vehicle/road in IoT the safety depends on 5G network so to makes connection more secure the standards that follows ISO 26262 follows road safety. The next sector which covers healthcare and its security follows standard ISO 27799 and in US the HIPAA (Health Insurance Portability and Accountability Act). In 5G the network slicing is introduced to slice the network for different applications and roles to make it more effective. The input or the data comes from various sources and the nature of the data is also different so for that slicing is the best solution. Slicing provides isolated sub

networks that can be optimized for specific types. The one characteristic that could be related to security and safety requirements. The properly implemented high assurance mechanism supports slicing that will possible to confine the impact of security requirement on a single slice. The other ways for network enabled security services that will attract to multiple users groups that include network enforced security policies authentication key management and data security services [9]. The figure 22 below shows us the trust model in 4G and 5G as we can see in 4G the user and network trust each other and the requested service comes with care and have encryption and security enabled system that protects the information.

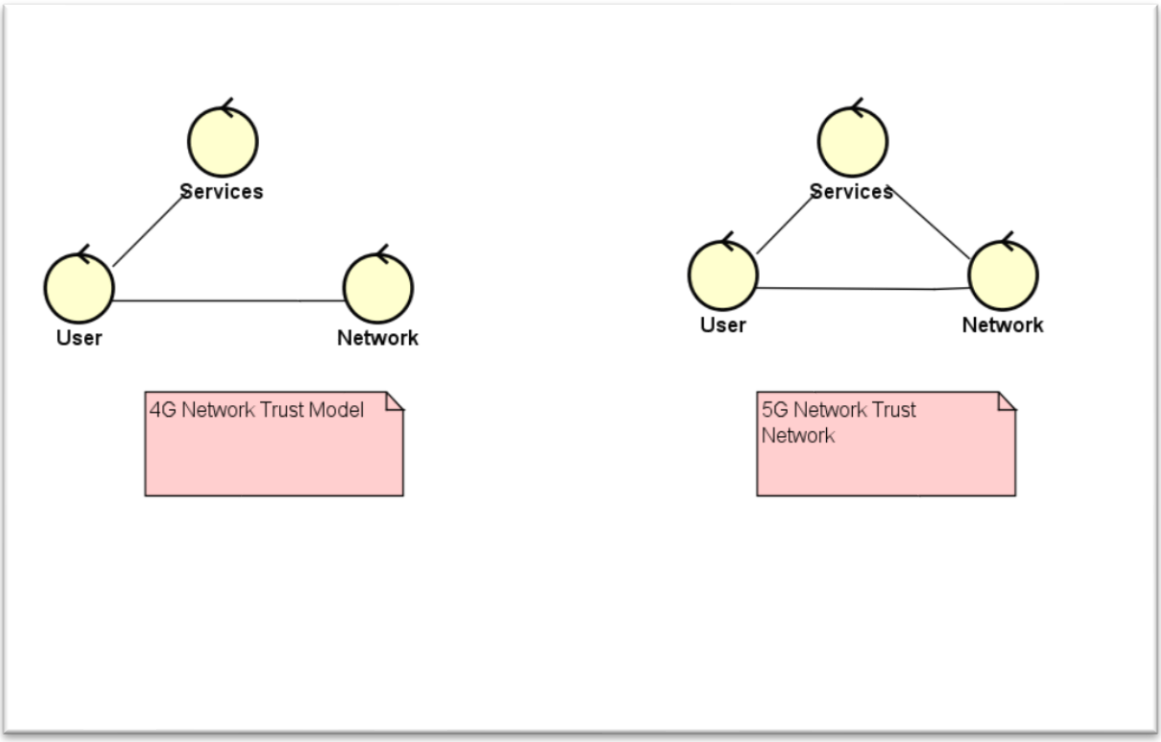

Figure 22. 4G and 5G Trust Model [36].

The 5G trust model can be seen in which user and network be also service that user required or demands. So, in 5G trust model the trust between the user and network both ways as the user encrypt the system and makes cover the vulnerabilities. The service that user demand or needed been trusted in both ways for requesting and receiving [9].

Identity Management in 3G-4G LTE,5G

4G LTE standards those required USIM that stands for Universal subscriber identity module on physical universal integrated circuit cards to network for gaining access. The handling of identity will continue to be an important part of 5G reasons such as prominent level of security and user friendliness. Embedded SIM significantly lowers the level of

development problems that are related to machine-to-machine communication. There is an overall trend to bring your own identity, in 5G ecosystem would generally beneficial for more open identity management architecture that allows for alternatives. To solve this one example is to allow enterprises with an existing secure ID management solution to reuse it for 5G access. In 5G the new concept for network slicing can be enabler for securely allowing different ID management solutions side by side by specific usage to virtual and separate slices of the networks. The danger of IMSI catching [9] when rouge radio network equipment requests from mobile devices to expose their identity now there is no protection method was in 3G-4G. For 5G that aspect needs to be protected from fake IMSI catching rogue devices.

5G radio network security:

The increasing risk in modern technology that provides its users less cost-efficient options to run their devices, the attack resistance of the radio access network should be more spoken consideration in 5G, threat analyzation like denial of from potentially misbehaving devices and enhancing mitigation measures to radio protocol design [9]. Though LTE radio access has nice cryptographic protection from eavesdropping there is no protection against changing the contents or adding injection in user plane traffic. Adding integrity protection for radio access in 5G is a main pillar so in industrial automation the potential benefits seems to investigate.

Flexibility and Scalability in architecture:

When we see the figure 21 of 5G security management sceneries and solutions we can see that with virtualization and more dynamic in 5G tells us the more dynamic and flexible security architecture required. Security of the synchronous system like RAN signalling could be close to user plane.

Cloud Security:

Security is a very hot topic and cloud security is extremely hot topic as well in the list of 5G concerns. We can develop network virtualization that assures the isolation. We can merge same security requirements in a same security infrastructure. We need to build useful ecosystem and create an architecture for only trusted computing tools that can get the access and authentication mechanism. Cloud security needs to provide efficient solutions for cloud-friendly data encryption techniques that encrypt data and save no data loss will occur [9].

6.2 Internet of things Security

The most discussed and worrying aspect about IoT is about its security. The more and more devices start to connect to the internet or other network the volume and

vulnerability increases. The estimated numbers for IoT connected devices are about 50 billion to secure all of them it's a big task. The net phase is the data these devices are collecting needs to be stored safely by volume and its integrity and confidentiality of the user or individual remains maintained. The basic IoT security requirements are data confidentiality, data availability, data integrity. When we implement IoT enabled system If any one of these areas breached the IoT system damaged. So, to protect from any breach IoT four-layer IoT network system needs to fulfil IoT basic security requirement [37].

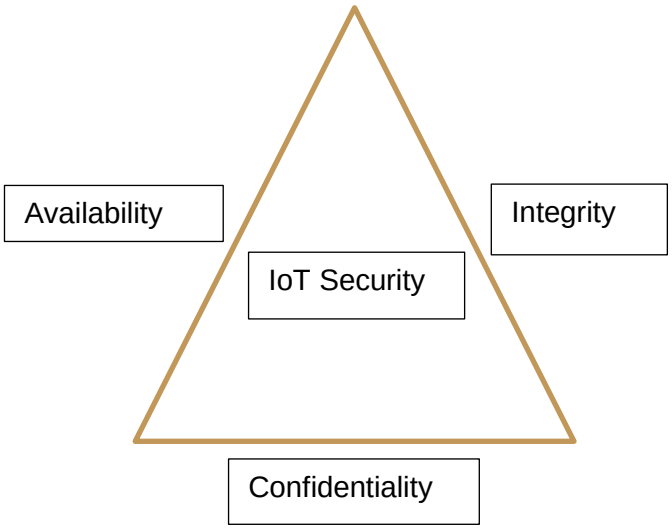

Fig 23. Basic Security Requirement for Internet of things.

Data Integrity:

Data integrity means that it will protect data from online cybercriminals who wants to change or misuse our data during the communication. Data can be affected by power disturbance server crash or power failure etc. To protect the data integrity there is a method called cyclic redundancy check (CRC) at first level. CRC is a simple error detection mechanism to encode the message by adding fixed-length to check values for error detection IoT communication network, so we can make sure the data integrity by checking the check value.

Data Confidentiality:

Data confidentiality means that it can protect the privacy of data or information from unauthorize access. The main sources of data collection are sensors and nodes, data

confidentiality by the sensors and nodes means that collected information cannot be sent to unauthorized party or server. To prevent this aspect of IoT the encrypted data convert into cipher text: thus, unauthorized users cannot access data easily. The other way to prevent unauthorized access by adding two step verifications so that data confidentiality will be maintained. Two step verification means that the user must authenticate and verify that that the user asking for access or data.

Data Availability:

What means by data availability means that whenever users need and want the data is available. In IoT system the security is very important that user can access to the information resources in both normal and disastrous situation. The important thing is the data availability ensures the consequent flowing of the information. To make sure data availability and reliability the internet of things system needs backup and redundant techniques to provide us data and if needed duplication of the data to prevent data loss in system failure or system confliction conditions. To prevent the attacks like Denial of service (DoS) and distributed denial of service (DDoS) that can cause security issues to data router filtering can be used to prevent it from DoS, DDoS attacks.

Security Structure:

When we see the security structure of IoT based devices and system it is restricted to devices that consume low power wireless sensors and battery-operated network devices. Efficient security structure can be implemented by lightweight security design. Since the nodes and sensors are low powered devices so it's much more efficient to use lightweight security structure for IoT devices. The worst-case scenario is the data those devices are collecting maybe got into wrong hands by intruder or hacker to destroy network. So, to avoid this several basic security structures at all level should be needed to protect the entire system.

Threats at Sensor layer:

At the basic and first layer the that can be called as element layer or sensor layers is exposed to different threats like unauthorised access, spoofing, eavesdropping etc.

There are several types of attacks on a sensor layer where attacker wants to **Unauthorizing** access also wants to access the different nodes and sensors to collect the data from the collected network environment. The sensor layer has different devices like RFID, tags, barcode labels and actuators to detect devices for collection of data the lack of authentication services can get access and modify the data even in worst case delete the data without user's knowledge. The other types of attacks are **eavesdropping** the information collected by the wireless components like tags and RFID are easy to attack by reading the monitored interface. Attackers can use data that he collected during

eavesdropping that collected data would be password or personal information like bank etc. So, to avoid that eavesdropping there is need to secure every node of the IoT system. The next type of attack that can happen is **spoofing** attack it means that attackers sends some fake information to the sensors and nodes that pretends that system is failure then it will take control of your system by fake messages.

Security in Application Layer:

I have written about network layer security above in IoT protocols and here I am writing about application layer security. IoT applications gather data with layers at go back and forth so the chances of getting exposed to attacks are higher. Normally the attacks happen like database information stolen or altered unauthorized access theft of user data or fake IMSI catcher for mobiles worms and viruses. So many possibilities to exploit the vulnerabilities so to take care of this layer security access control management and privacy protection is used for improving security.

7 Internet of things (IoT) and 5G Compatibility

What will happen when 5G will be fully functional along with Internet of things enabled systems like smart homes, smart mobile, Smart city, Vehicular, Sports and leisure. All the applications of IoT required faster data and low power so due to that the 5G is best for those scenarios like IoT applications smart home to smart city and vehicular. The main reason for faster data is user average data on average smartphone in 2016 is about 2.1 GB that will be 12GB in 2022 [16].The 5G we can say fifth generation mobile networks will able to transmit data roughly about 10 times faster than 4G LTE according to Ericsson Annual Mobility Report [16]. What change it will bring to our life either higher or lower data firstly higher the data higher the performance we can get information fast we can see our faults earlier and we can fix them quickly.5G of course will revolutionize IoT and IoT concept is not new it was there but the implementation now seems to reality as we have wireless almost covers most part of the world. IoT and 5G though it will take time to roll out fully but many hardware operators or makers and telecom operators and start to test and implement at the lab level. That all happens to decision that was happened in March by 3GPP.What is 3GPP it's an association of telecom that approves initial 5G standardization. It means that adoption of 5G will come within few years. Ericsson project that 5G will reach 15% of the world population by the 2022.The expected usage until 2022 is roughly about 15% of the world will use 5G and IOT enabled devices those required faster data [16]. The figure 24 below is the

Then by the time that number will grows

Figure 24. Copied from European Commission towards 5G [10].

Figure 24 copied from European commission towards 5G shows us what will be 5G in practice. According to Ericsson 5G will be deployed in major metropolitan area, so IoT applications at first will be used for streetlights and traffic lights. Eventually when 5G will be fully functional and covers all the area then the smart city as a bigger concept will be implemented by 5G faster network where things communicate and decide best decision and devices. These applications are smart home and smart agriculture to autonomous cars and robotics at different level. We are moving towards digital society the need for higher data rate and wireless connectivity makes it easier. The faster data transmission means that many devices will be connected to the network that means 5G is the solution for faster data connections that enables IoT [38]. The system which have IoT devices requires faster data so the 5G is best solution for them. Why 5G will be compatible with IoT, Latency in cellular network limits many IoT application at moment many IoT applications are using cellular networks like 4G LTE that will be connected to cloud, but devices in these IoT solutions produces so much data that it's very difficult to process and analyse that data quickly. When data is higher the latency increases due to increase in the latency the delay increases so for that the faster network is needed like 5G. The 4G LTE effectiveness limited due to higher latency. So, the answer to that problem is 5G Why because in 5G the latency is 1ms and in 4G the latency is <100ms.So the difference is obvious that's why for IoT solutions 5G is the best as a latency pint of view. The characteristics of 5G it can transmit data radically fast, so the companies can deploy

much more devices without the fear of an overcrowded network. Overcrowded network causes latency issues that slows the data transfer and the potentially data can be lost. So, the low latency and higher speed gives companies and individuals chance to boost overall connected devices that are deployed now after 5G arrives according to estimates around 22 billion IoT devices will be installed globally by 2022 that number up from previous year that will be roughly 16 billion. The Internet of things (IoT) will revolutionize the business, governments, and customers how they will interact to the world. There is projection that companies like Ericsson, Nokia, Samsung, AT & T, DNA, Sonera or telecom operators will invest $5 trillion on IoT in next five to ten years. The IoT research evolves and now we know more that gathering huge amount of data is not beneficial, but the analyzation of the data is the key to find the target market target solution and fulfil customers demand monitor flows in cities and home and healthcare. The next important thing in IoT is analyzation revolution that revolution includes machine learning and Artificial Intelligence in which smart decision are made and autocorrect the faults and calibrates the devices for better performance. To give the glimpse of future I am just giving some products of IoT with 5G from Qualcomm that was shown in CES 2018.The 5G will be fully functional by Qualcomm in 2019.The Qualcomm wireless earbuds with QC5100 enabled chipset Bluetooth low power design which can be used for more time it consumes less battery [39].That is IoT application when 5G will be fully implemented then everything will be faster and smarter. There are many more prototypes from Qualcomm Nokia and others. The Alexa from Amazon is also IoT application. I have drawn a mind map for future of IoT and its market in different applications areas and which are the more areas where the potential is higher is what aspect. There are three sections like Internet of people and internet of things with IP addresses the third box is internet of things without IP address. There is market that can be seen in the figure 25 below that clearly shows us the potential in internet of people section that is more marketable chunk and there is more money in third section devices at first layer don’t need IP due to its implementations and in second section the profitable section is components and system. The figure 25 below also gives us the opportunity for 5G because its network and every device that is connected to the internet needs network to do its application cycle completed. So, all the mentioned areas will be together changed with IoT and 5G.

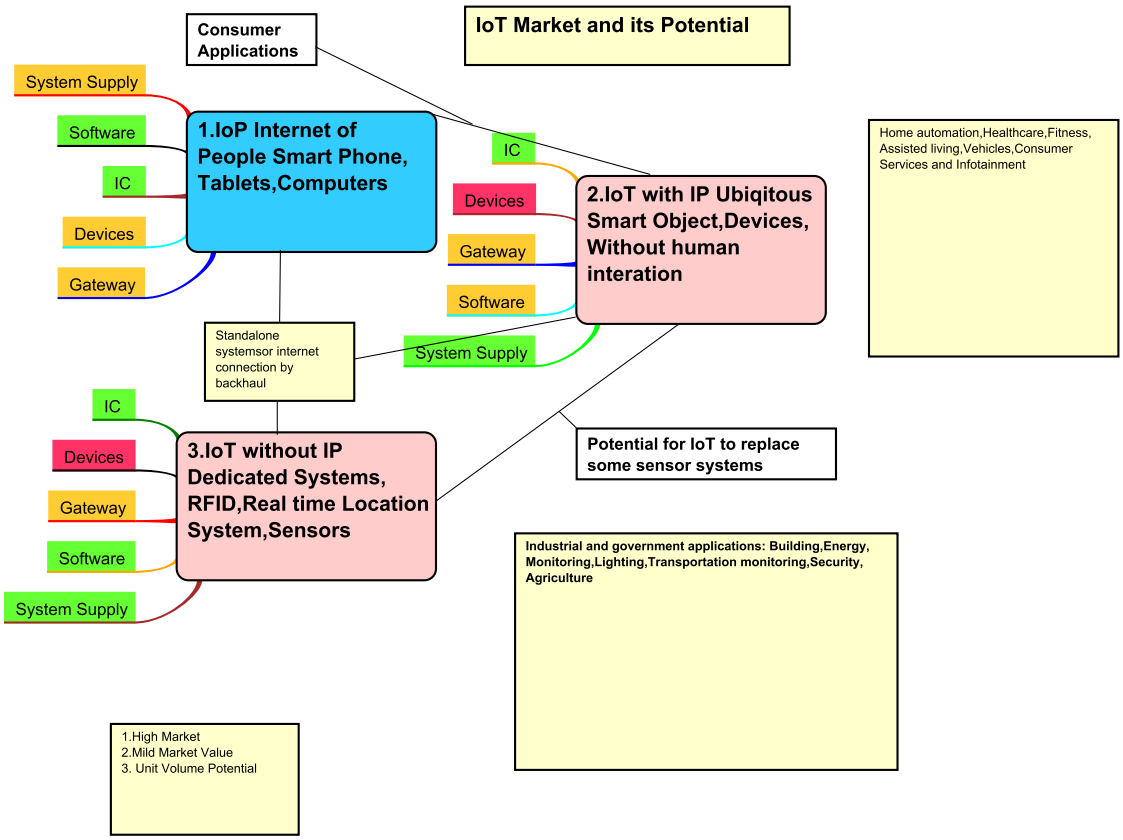

Figure 25. IoT Market Mind map [11]

There is some example of smart cities like Tampere in Finland smart city is initiated and its experiment is going. There is one more city Singapore on 23/03/2018 (IDC,2018) expects that smart city initiative would reach up to $29 billion approximately. According to IDC the spending will reach in 2022 around $ 46 billion. The Australian Telstra on 05/02/2018 opened innovation centre at Southport exchange on Gold Coast where it will test and perform 5G and its impact on the real-world environment. That innovation centre will be able to ensure that the Australia as a first country that have access to 5G (Telstra innovation 5G, 2018). Telstra 5G field trial on a data cell of 26GHz mm Wave and radiofrequency spectrum. During 2018 more trials and more field tests will be done [40].So in the late 2018 some of the companies will launch their 5G services for testing and trails and then gradually it will be implemented. At&T have confirmed that in end of 2018 5G will be commercially available for but did not provide what data and what price it will be available Verizon also said that 5G will available later this year or earlier next year will be available for commercial use but did not mention the pricing. The only information that is from Verizon is fixed wireless 5G speed will be 28GHz using older 5G TF specifications-Mobile have also confirmed that they will launch 5G services in 2019 [41].

8 Conclusion

The internet of things is so diverse that on each chapter and section can be explained to write a book. When I have started to study with IoT and 5G it becomes wider as a topic because both are modern technologies yes concept is not new, but the execution is coming now. I have written my thesis aiming to introduce and then take in the depth the concept of IoT and 5G. I can see the concept and its implantation is in use and will be more soon when in 2020 almost 50 billion devices will be connected then the understanding becomes clearer. So, the modern technologies and topic always have room for more research and more improvement at all level from definition to its implementation. In my introduction I have wrote the Nikola Tesla said about IoT.

Then when things put into perspective I have wrote about the protocols that will be and at presently are in use for internet of things applications. I have written about MQTT, JMS, CoAS, AMQPP, DDS, etc many more their merits and demerits compared in a table. Then next about 5G, I have written about the architecture both layered and structured architecture for internet of things. Then some applications like smart home smart city vehicular sports and leisure. These are big concept of application areas of IoT. Then my thesis comes on network side because all the devices require network to communicate with each other and with internet, so I have written about evolution from 1G to 5G. The purpose was to familiarise the reader about the topic then architecture of 5G its implementations and its security challenges with IoT. The compatibility of IoT and 5G will be brilliant due to its characteristics for interaction from small cells to millimetre waves that can easily reuse frequency and full duplex makes things easier for devices to communicate with each other and mainly with humans as well. The main concern in modern fast and efficient devices is security and the solutions and emphasis are heavily on it normally networks are better secured due to radio encryptions but in IoT when devices increase so much then the security is the challenge its solutions are at every layer that will be secured according to the layers.

The opportunities for IoT and 5G are huge it can transform our life completely the way we do business the way healthcare works, or our transport system works. So, they future is more revolutionary in the aspect of IoT and 5G and for companies and business huge opportunities in all sectors to transform and earn simultaneously. The growth and research for IoT will be continue and it will open more opportunities for the business and

it will makes things easy for monitoring suggesting and forecasting for future. The future IoT and 5G research and business areas with enormous potential are listed below [10]:

- Connected Homes
- E-Health
- Entertainment
- Home Automation
- Security and Surveillance
- Smart Architecture
- Smart Cars
- Smart Grid
- Smart Mobility
- Smart Parking
- Smart Wearables

I have been succeeded to complete my thesis by doing research and number of reading from different sources those sources are web, books, journals, publications, thesis papers and newspapers and also by reading Ericsson, IBM, Nokia, Samsung, Verizon, Huawei educational material about IoT and 5G.The main help also came from my supervisor Dr Tero Nurminen who gave me direction in which way I will continue my research. I have written my result after reading many sources and writing my thesis.

Hence the result of the thesis the explanation of IoT and 5G in detail their concept evolution history and future possibilities and potential market shares. The results tell us what is IoT and 5G how they will change our near future where we can invest in future and what are the challenges for new frontier in the modern technological world.

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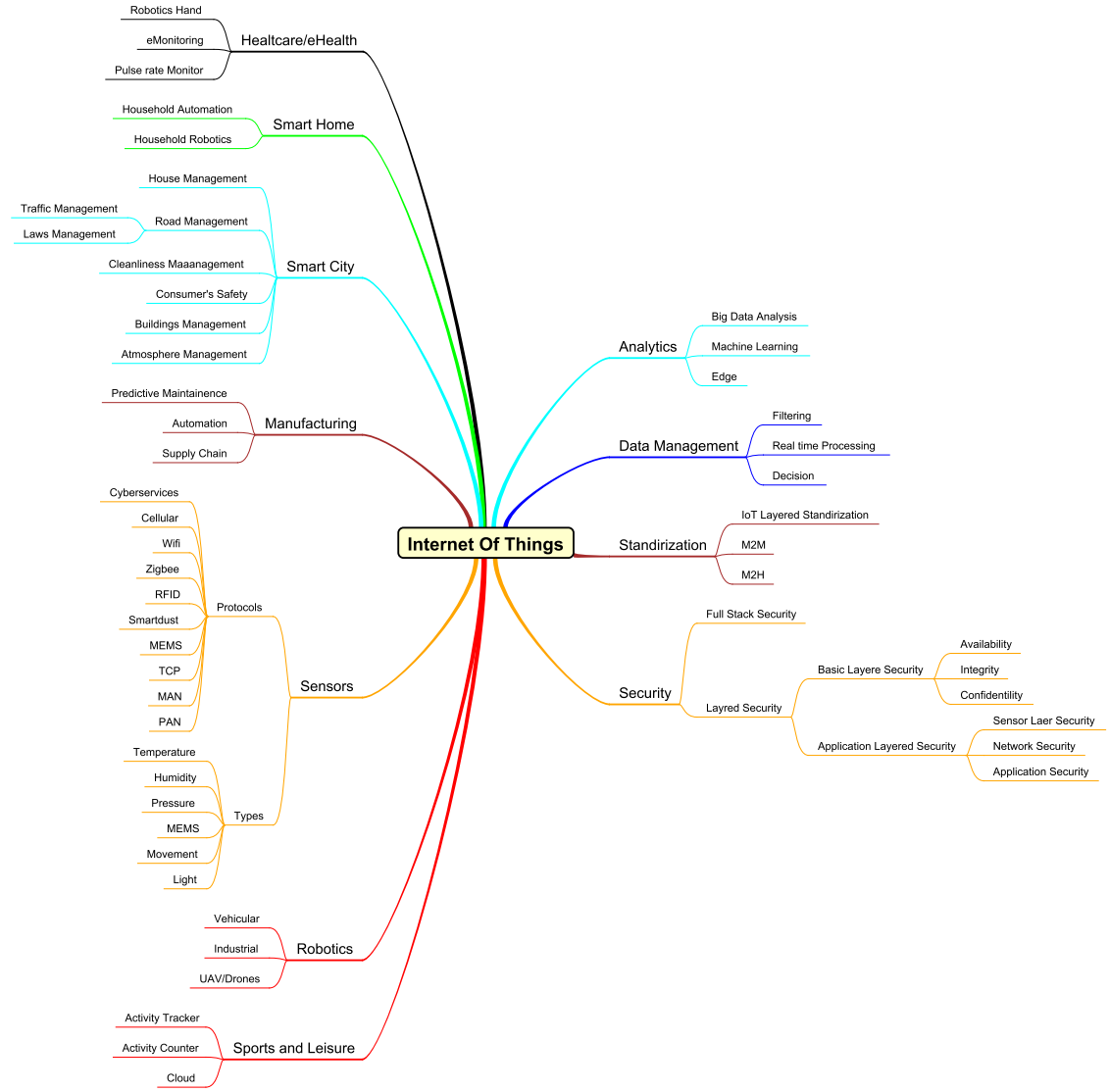
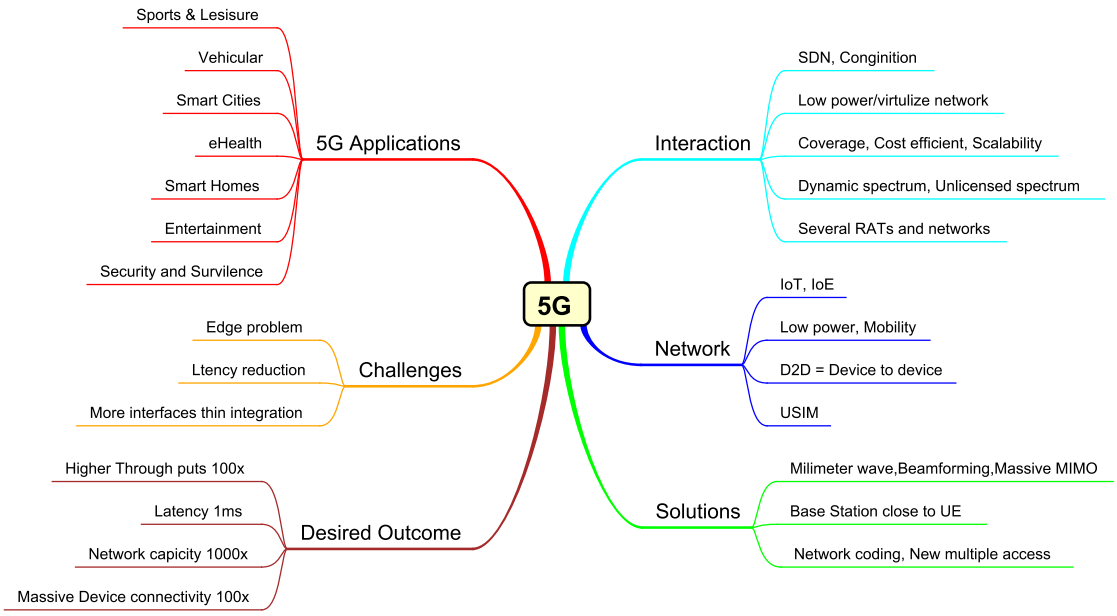
Title of the Appendix

IoT Mind map



Title of the Appendix

5G Mind map and Throughput formula



Throughput = Available spectrum × Cell Density × Spectral efficiency
(By Dr Emil Bjornson)

5G Throughputs = Transmit Time Interval × Component Carrier
= 660.15 × 8 = 5,281 = 5.3 Gbps/UE(User Equipment)