A Project Report on

Analysis of 5G technology and its Smart Bins applications as an enabler to smart cities

Submitted by

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(From University of Alberta)

Under the guidance of

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ABSTRACT

The world is progressing, and new advancements are developed in mobile networks very rapidly. High-speed internet, higher data rates and quality of service are now heavily in demand; people are now constantly on their electronic devices. 5G is the proposed next telecommunications standards beyond the current 4G/IMT-Advanced standards. 5G planning aims at a higher capacity than current 4G, allowing a higher density of mobile broadband users, and supporting device-to-device, ultra reliable, and massive machine communications. Wherein 5G would give benefits to mobile users; it is also helping the cities in the world to become Smart Cities by deploying various technologies and Framework so that the cities can achieve smart urban growth. The smart city combines various aspects of Information and communication technology and IoT in such a way so that the assets of the city are managed properly. One of the applications which smart cities use for their efficient working is Smart Bin solutions. It is the smartest way to manage the waste in the city. It automatically sorts the rubbish in recycling category. A lot of metropolitan cities have deployed the Smart Bin concept. The United Kingdom is the recent country who is going to deploy the SmartBin application.

Acknowledgment

I would first like to thank The Almighty God without whom nothing is possible.

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Chaman Preet Singh

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CHAPTER 1

INTRODUCTION

1.1 HISTORY

In today's world the mobile broadband industry is expanding which has transferred both business world and lives. The demand for High-speed internet, higher data rates and quality of service is increasing day by day. In almost every 10 years a new mobile generation has been launched. In 1982, the first 1G system i.e. Telephone was introduced to the world. Then in 1992, 2G system was introduced and 3G system came in the world in 2001. In 2012, 4G systems with International Mobile Telecommunications-Advanced standard (IMT-Standard) were introduced. All the generations evolved in the world of Mobile technology have brought their own improvements.

- 1G: These were the first mobile phones to be used in the world. The 1G phones had a very low spectral efficiency and security as well. These were based on analog transmission and were used to transmit voice signal.
- 2G: These were based on digital communication and had better efficiency and security then 1G.
- 3G: The fundamental goal of 3G was to provide high-speed data to the users in the world. It allowed data up to 14 Mbps.
- 4G: It almost provided 10 times the data transfer over 3G.
- 5G communications aims to give better capacity, connectivity and coverage than other generations because with the previous generations the main problems were lack of coverage, dropped calls and low performance of cell edges. A new term WWWW which is worldwide wireless web is being associated with 5G where there will be no limitation of wireless network.

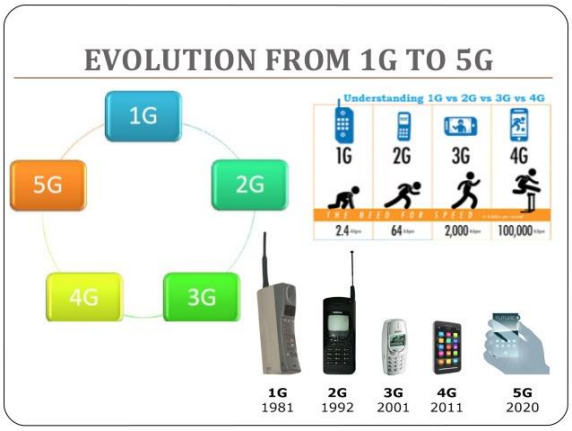

Fig 1: Evolution of 1G to 5G

1.2 EVOLUTION OF 1G:

It is the first generation of the mobile communications. 1G technology was based on analog communication. It was first launched in 1979 in Japan by Nippon Telegraph and Telephone (NTT). It used frequency modulation technique for transmission.

Fig 2: First Commercially Available Cellphone – Motorola

The first Advanced Mobile Phone System using 1G was introduced by Bell Labs in USA in 1983.

1.2.1 Disadvantages of 1G:

- The main drawback of 1G was that it was based on analog communication due to which it suffered a lot of interference problems.
- The voice quality was very poor, unreliable handoff and had security issues as well

1.3 EVOLUTION OF 2G:

It is the Second-generation cellular technology introduced in 1991 which was based on GSM architecture.

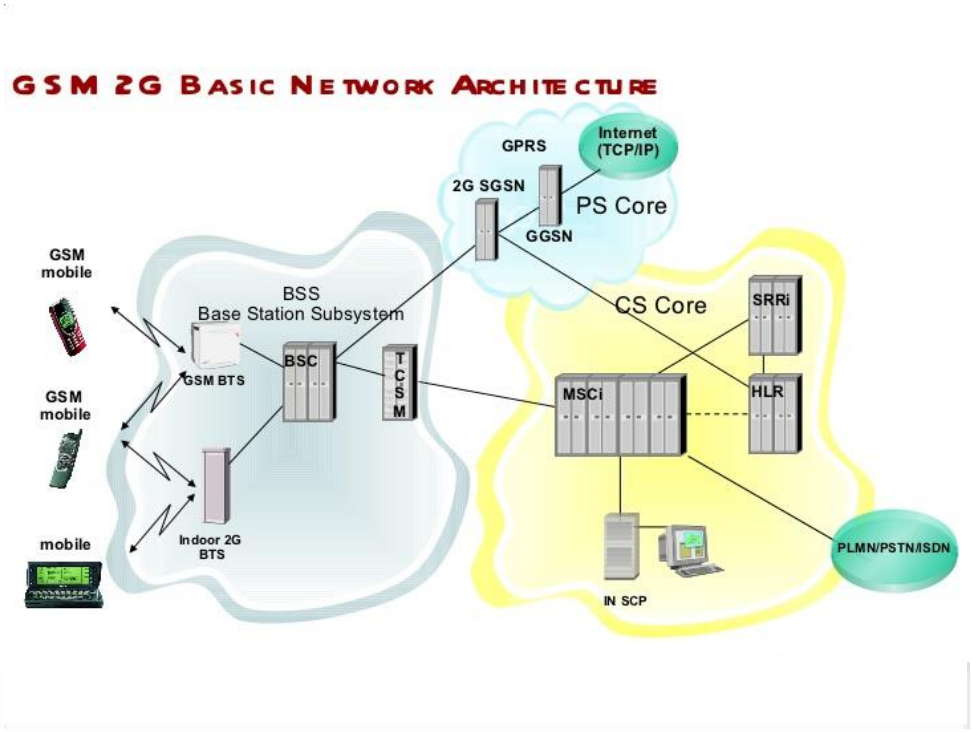

Fig 3: Basic 2G Architecture

The above figure shows the basic 2G architecture based on GSM. It has 4 fundamental areas: Mobile station (MS), Base-station subsystem (BSS), Network and Switching Subsystem (NSS), Operation and Support Subsystem (OSS). All these elements of GSM operate collectively, and the user is not aware of these elements within the system.

1.3.1 Advantages of 2G:

- Digital signals had less battery consumption
- Reduction in noise due to digital coding hence, better voice clarity.
- Better privacy level then 1G

1.3.2 Disadvantages of 2G:

- The main drawback was that the digital signal that was being transmitted by the cell phones was weak to reach the cell towers in some areas.
- The downloading and uploading speeds in 2G were not even that great which was limited to only 236 kbps and with the increase in the distance the signals dropped out and had no reception.

1.4 EVOLUTION OF 3G:

The 3G was introduced in 2001 in Japan by NTT Docomo.

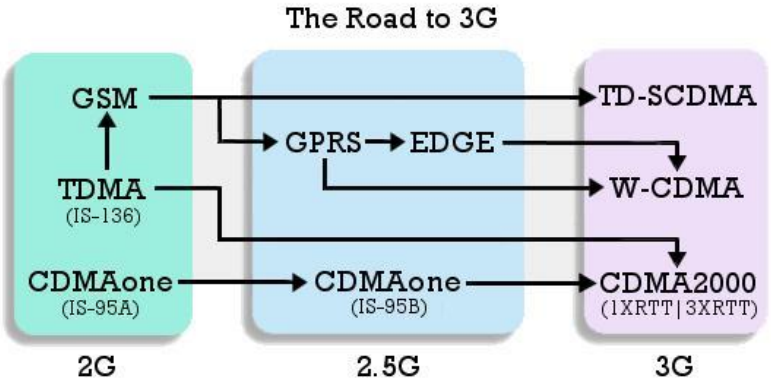

Fig 4: How 3G Works

The 3G technology gave users a sophisticated and better internet and Bluetooth connectivity. It was based on IMT-2000 Technical standards. The above figure shows the standards that comply with IMT-2000/3G which includes EDGE which allows data rates in order of 200 Kbps, W-

CDMA which is most common deployment which is operated on 2100 MHz band, CDMA2000 which provides better voice and data clarity

1.4.1 Advantages of 3G:

- Better reliability, security and bandwidth.
- Applications like video conferencing from one city to another was possible.
- Fast data transfer rates

1.4.2 Disadvantages of 3G:

The main drawback was its high-power consumption and the plans were really high cost.

1.5 Evolution of 4G:

4G technology offers higher speed data rates and lower latency.

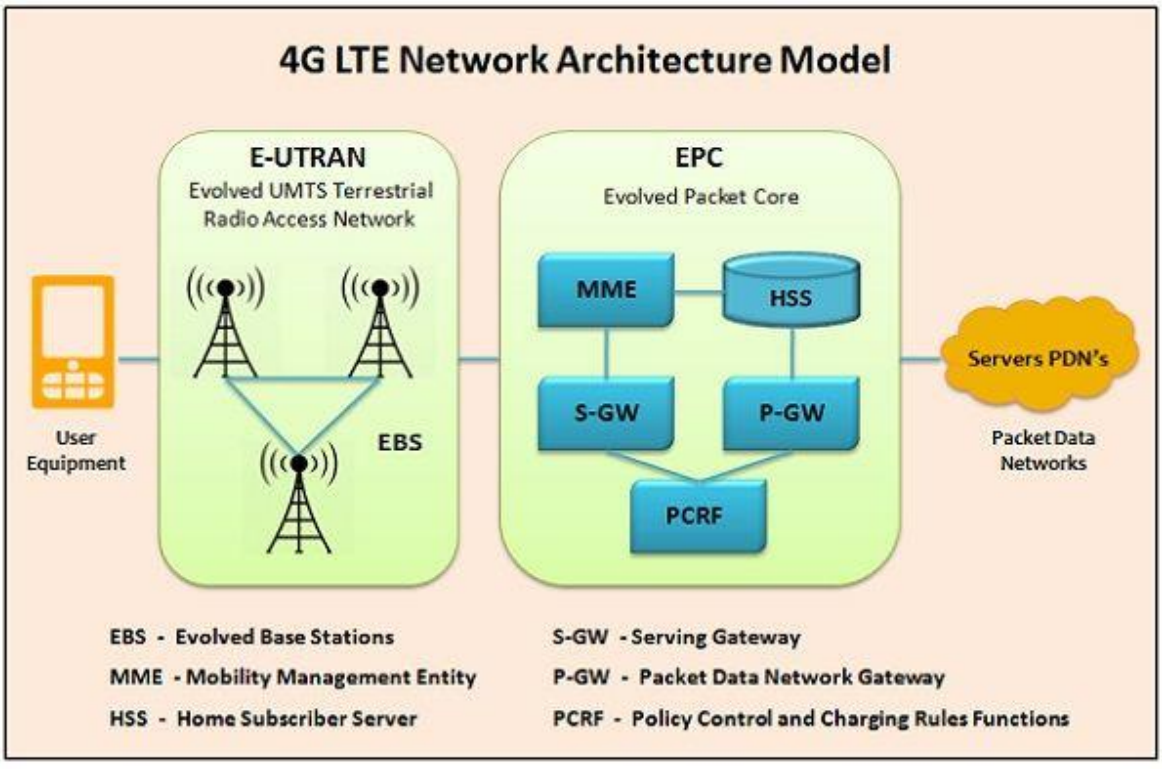

Fig 5: 4G Architecture

The above figure shows the basic 4G architecture which includes:

- User equipment
- E-UTRAN that controls radio communication between user equipment and EPC
- Evolved packet core that communicates with internal and external packet data networks and IP multimedia subsystem.

1.5.1 Advantages of 4G:

- Better connectivity
- Lower latency rates
- Increased user data throughput
- Handoff is done vertically and horizontally both

1.5.2 Problems using 4G

The main drawback was its complex hardware and high cost. 4G is good for data rates but wasn't best for voice services.

CHAPTER 2

5G TECHNOLOGY

2.1 INTRODUCTION

From analog to LTE each mobile technology was brought out to meet the requirements of people. The combination of broadband networks and smartphones has resulted in better internet experience which led to development of app-centric interface today. Mobile broadband has played a key role and brought a lot of benefits from email to social media through music and high-quality video streaming or controlling your home appliances from anywhere thus fundamentally changing the lives of people in the world.

Generation	Primary services	Key differentiator	Weakness (addressed by subsequent generation)
1G	Analogue phone calls	Mobility	Poor spectral efficiency, major security issues
2G	Digital phone calls and messaging	Secure, mass adoption	Limited data rates – difficult to support demand for internet/e-mail
3G	Phone calls, messaging, data	Better internet experience	Real performance failed to match hype, failure of WAP for internet access
3.5G	Phone calls, messaging, broadband data	Broadband internet, applications	Tied to legacy, mobile specific architecture and protocols
4G	All-IP services (including voice, messaging)	Faster broadband internet, lower latency	?

Fig 6: Evolution of technology generation

2.2 CHALLENGES AND REQUIREMENTS

2.2.1 5G KEY REQUIREMENTS:

The objective of 5G networks is to introduce new services which are cost-effective and efficient thus creating an ecosystem for technical and business innovation. 5G networks will provide support in vertical markets such as automation, agriculture, food, healthcare etc. As compared to previous mobile technology networks 5G requires improved network solutions and combination of massive computing and storage infrastructures.

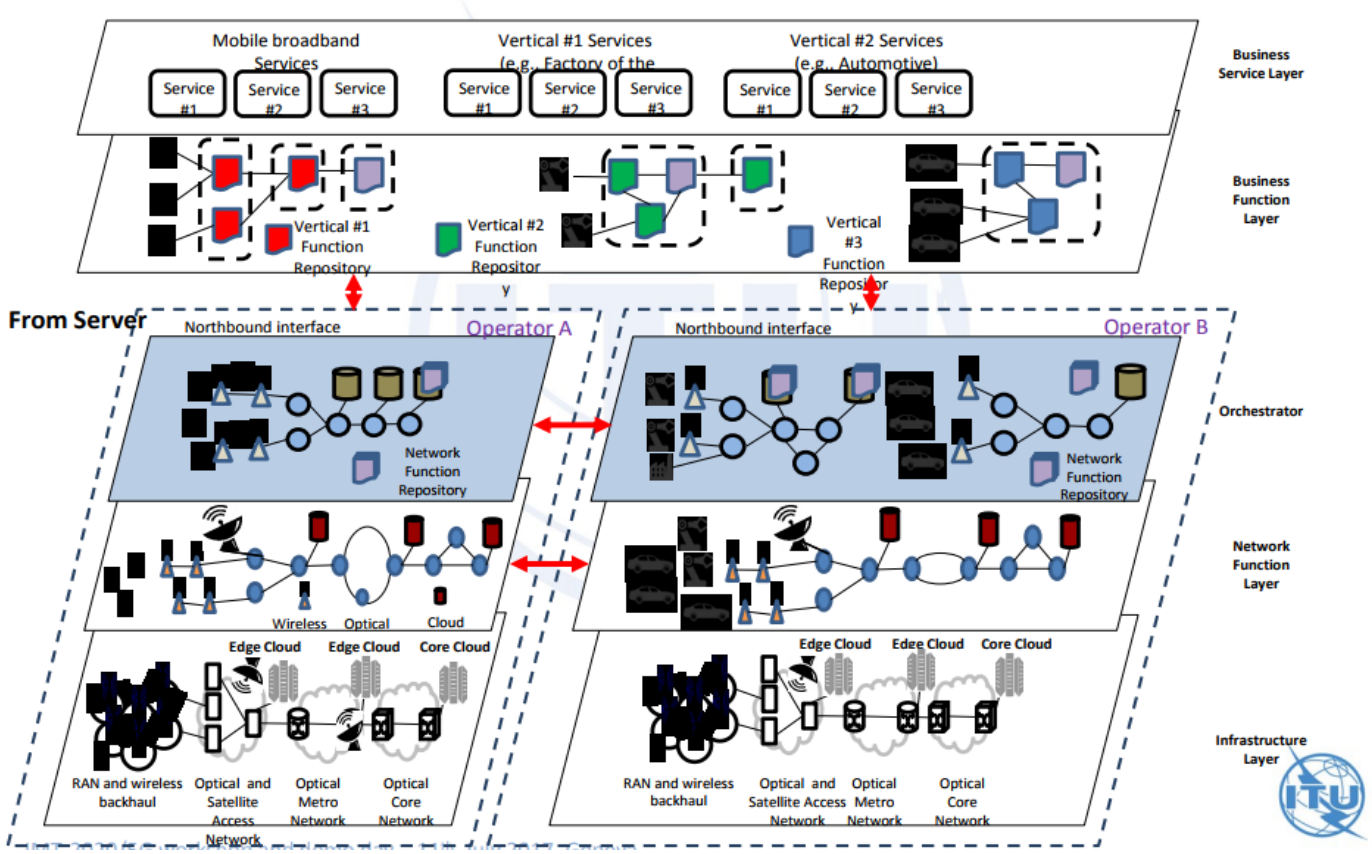

Fig 7: 5G Ecosystem

For achieving such a diverse ecosystem the telecom operators need to deploy Orchestrator functions that will distribute the required computing and network resources. The Network function layer will contain specialized networking and computing functions to meet the key performances of service providers.

The implementation of 5G is inclined to meet the following 3 requirements: -

- Massive Broadband (xMBB) that is inclined to deliver gigabytes of bandwidth
- Massive Machine Type Communication (mMTC) inclined to connect billions of servers and machines
- Critical Machine Type Communication (uMTC) providing high reliability and remote control

In the coming years the demand for mobile technology and communication will increase manifold and 5G will be a great platform that will meet high demand requirements in various industries ranging from IT to automotive, manufacturing industries etc.

2.2.2 5G DESIGN OBJECTIVES:

- In 5G networks, when there is high mobile traffic demand the biggest challenge is the availability of the spectrum. In the densely deployed areas the current spectrum is very crowded therefore for proper working we will require higher frequency and usage of large spectrum bands. That means high spectrum range with diverse range of characteristics will be required for 5G mobile technology.
- The spectrum characteristics will require the ability to support different concurrent network functions. The parameters of these functions will depend on the hardware that is available, different communication links and the topology.
- To achieve high Quality of Service, the 5G technology should also support traffic differentiation. Keeping QoS in consideration 5G will require slicing framework.
- The overall objective is to create a system that is well adaptive to changing conditions of network and the external environment where the network operates.

2.3 5G ARCHITECTURE:

The 5G architecture will emerge to meet a lot of business requirements by implementing cost-efficient network slicing, combining fixed and wireless technologies, communication and computation, supporting various software, by working on end user and operational services. These qualities have number of advantages where one is the high degree of flexibility.

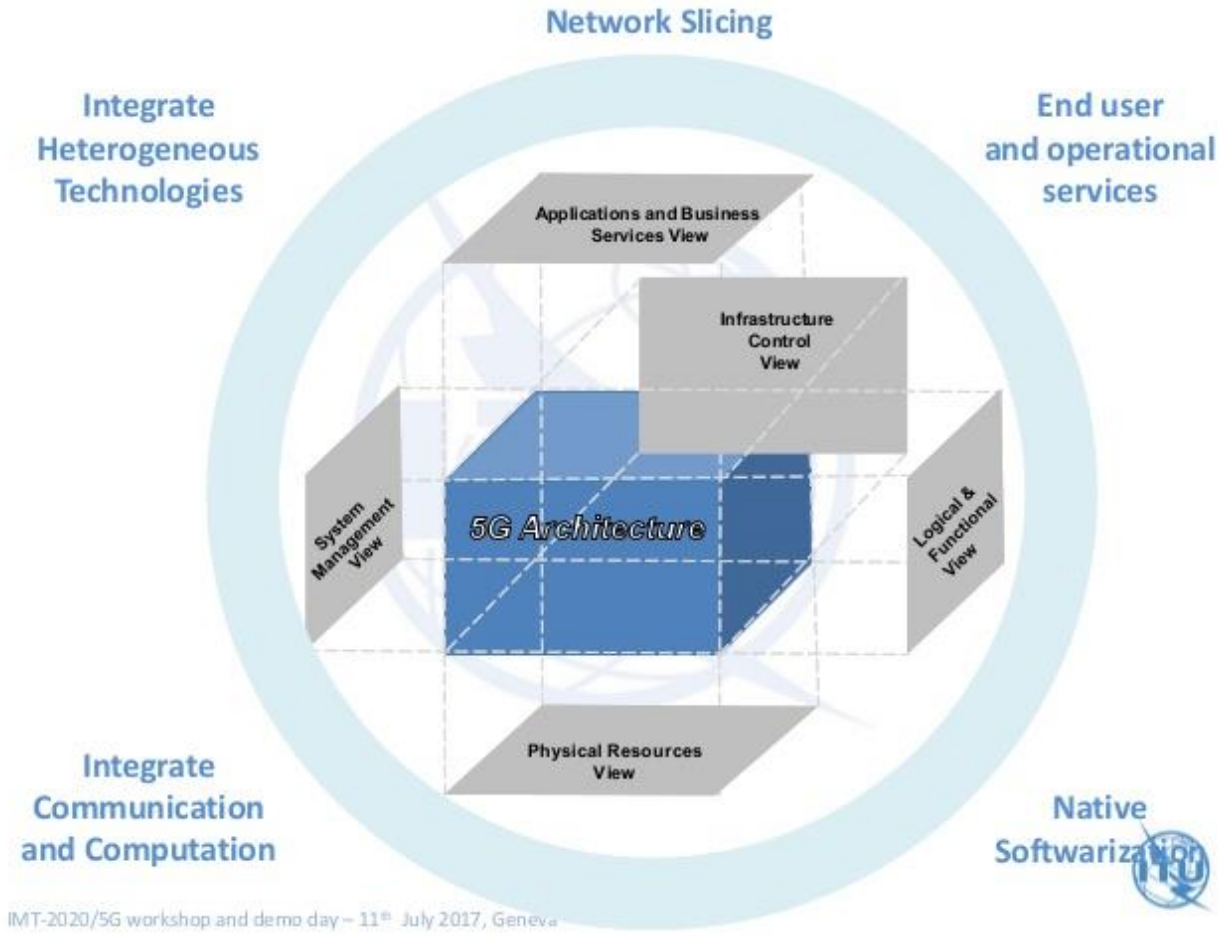

Fig 7: 5G Architecture

With 5G technology coming in use a lot of new requirements will be fulfilled. A cloud native E2E architecture has following features:

- To meet various service requirements an independent network slicing will be deployed on a single network which will support various applications.
- To achieve massive connection of various standards CloudRAN will be used which will reconstruct radio access networks.
- To reduce operating expenses automated network slicing will be implemented.

The use of softwarization and programmability will be crucial enabler for achieving various 5g services. Various functions included by network softwarization are:

1. Network devices
2. Network functions
3. Network slices
4. Network applications
5. Data, control and management planes.

The network programmability will permit deployment of new network and management services that are fast and flexible. The figure below shows the future smart management network.

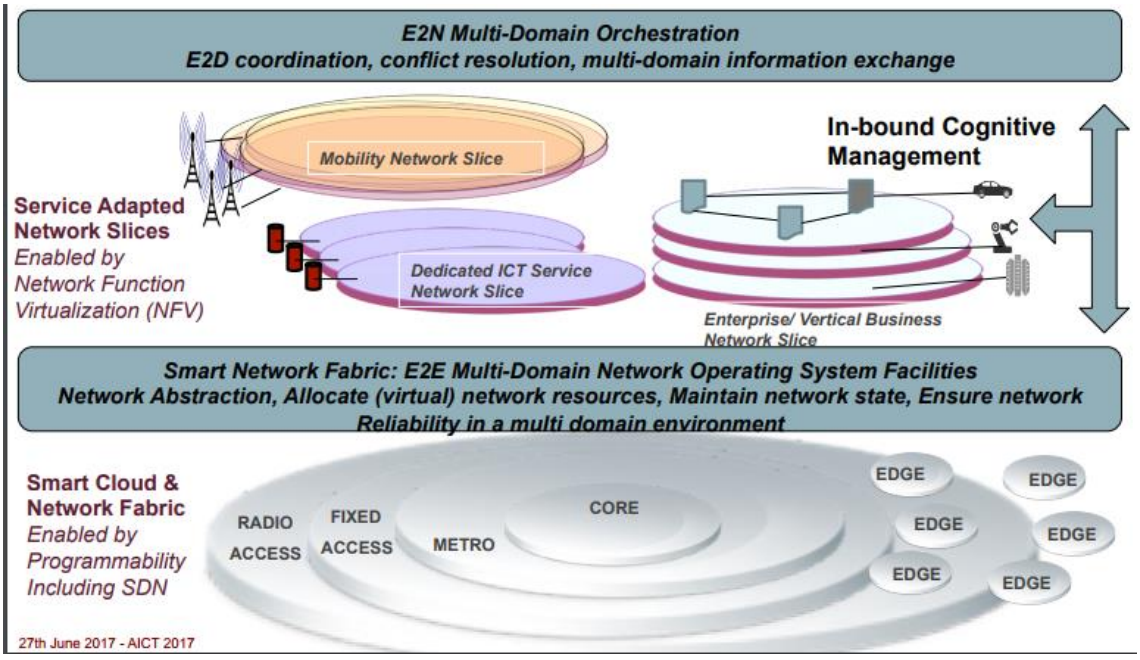

Fig 8: Future Smart Management Network

2.3.1 Service Driven Network Architecture:

The main aim of service driven network architecture is to provide flexible and efficient mobile services. With the support of software defined networking (SDN) and Network functions virtualization (NFV), 5G cloudifies access, transport and core networks.

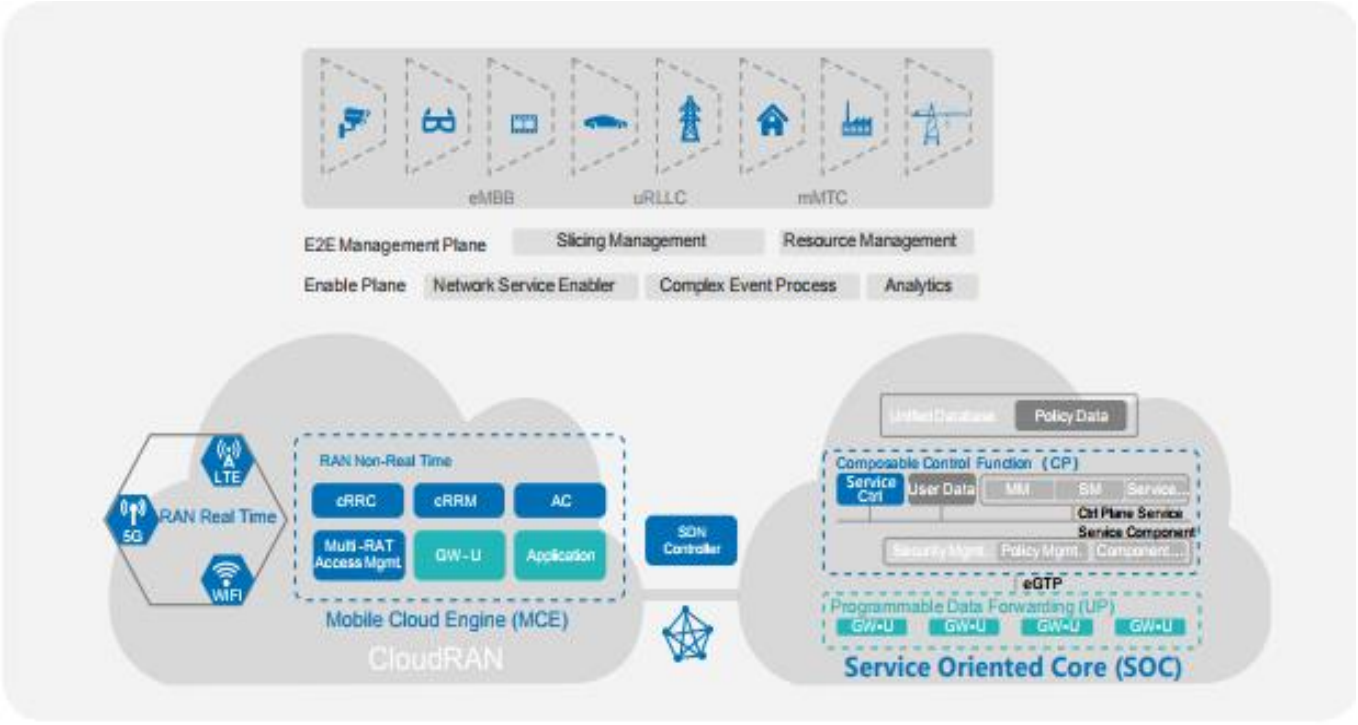

Fig 9: 5G Service Driven Network Architecture

- **CloudRAN** consists of mobile cloud engines and sites. Multiple services are being coordinated by this facility that operates on different standards. To allow on-demand network deployment for RAN non real-time resources, multi-connectivity is introduced.
- Component based control planes and programmable user planes allow planning such that networks can select control planes or user plane functions depending upon different service requirements.
- The transport network consists of software defined network controllers which generate series of data forwarding paths based on the network topology and requirements.

- The enabling plane scrutinizes network capabilities to implement network optimization.
- The top layer of network architecture implements network slicing and network management**.**

2.3.2 End-to-End Network Slicing for Multiple Industries Based on One Physical Infrastructure:

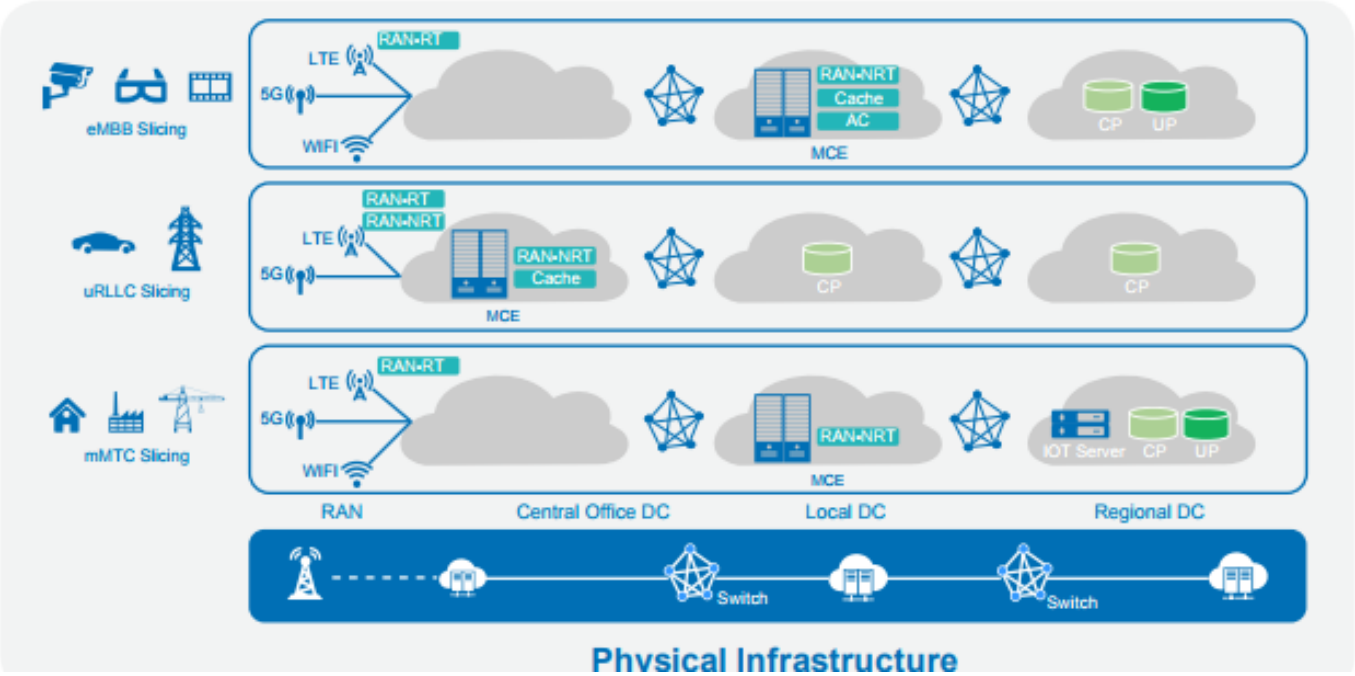

Fig 10: Network Slicing

To support the 5G services, end to end network slicing is introduced as its foundation. It is based on SDN and NFV which consists of sites and 3 layer DC's. Sites supports various modes like Wi-Fi, 5G and LTE in the form of micro, macro, and pico BS to implement real time functions. 3 layers DC's consist of storage and computing resources.

The bottom layer which is near to the base station side is the central office DC, upper layer is connected through transport networks and serves as regional DC.

According to service requirements networks generate topologies and network slices for each service type using NFV on the physical infrastructure. Network slice which is network function sets aims to reduce the construction cost.

In the above figure mMTC, uRLLC and eMBB are independent and are supported on one physical infrastructure. eMBB requires high bandwidth and provide high speed services to users which are near to it.

mMTC slicing has less network data interaction and low signaling interaction due to which mobile cloud engine is deployed in local DC and other functions and application servers are deployed in regional DC, due to which the central office resources are released and operating expenses are reduced.

2.3.3 RECONSTRUCTING THE RAN WITH THE CLOUD:

In the coming years to support full mobile connectivity with all great performances and requirements for users, business services and modern technologies a new architecture will be needed. This network architecture to be unified and working in future run should be able to support diverse technologies such as 3G, 4G, and 5G.

This unification should work well with existing technologies and radio technologies such as Wi-Fi. The network architecture should be able to support different services with different performances based on data rates, connectivity and latency in mobile network.

- In order to implement real time function, component-based functions, flexible coordination and RAN slicing we use cloud RAN architecture. Based on different service requirements cloud RAN can carry out flexible symmetry for RAN real time and non-real time functions.
- The various functions included in RAN real time are network scheduling, power control, link adaptation, modulation, retransmission, coding which require high performance and computing load. Highly specified hardware with proper specification and performances should be used in the deployed sites.

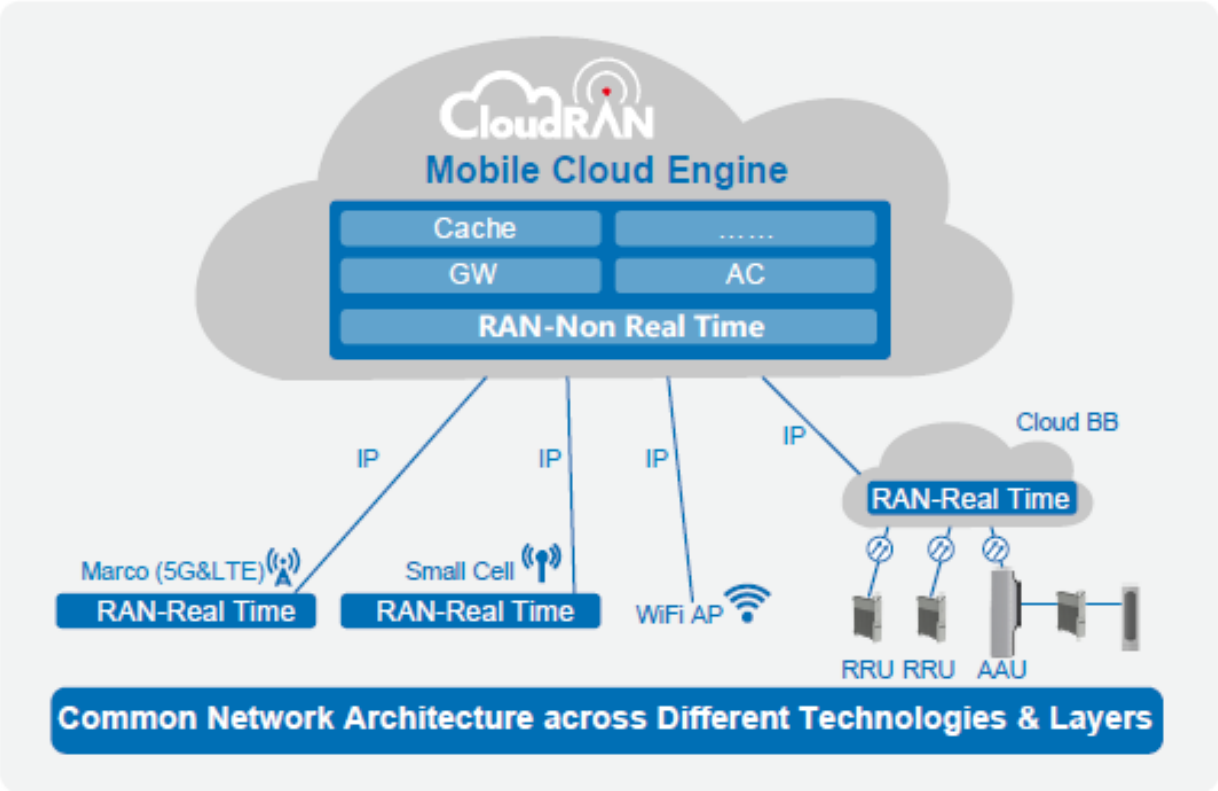

Fig 11: Common Network Architecture with different Technologies

- The functions that are included in RAN non-real time are inter-cell handover, cell selection, reselection, encryption etc. which require minimum performance and latency requirements and are best suited for centralized deployment.
- The ability of the Cloud RAN is to jump from single connectivity to multiple connectivity for multiple users.
- Before the 5G arrives, the cloud architecture should support the existing mobile technologies. With introduction to the new elements, Cloud RAN is assumed to be powerful architecture in the market which will provide virtualization, cloud resourcing, flexible coordination for future needs.
- The biggest improvement in RAN will be providing multiple connectivity to the users and carrying different services with different quality of service on the same network using network slicing.

- CloudRan comprises of real and non-real time functions. The real time functions and placed close to user end for accurate resource management while non-real time functions will be deployed centrally that will take care of complicated management units like time, frequency and spacing.

2.4 ROLE OF SDN AND NFV:

- It is estimated that by 2020 many mobile networks will dominate in the world but there are few challenges as well which include power consumption by devices, data rates, scalability, cost and elasticity etc. To meet the demands of 5G, SDN is introduced which stands for Software Defined Network which will help to provide solution for mobile network problems.

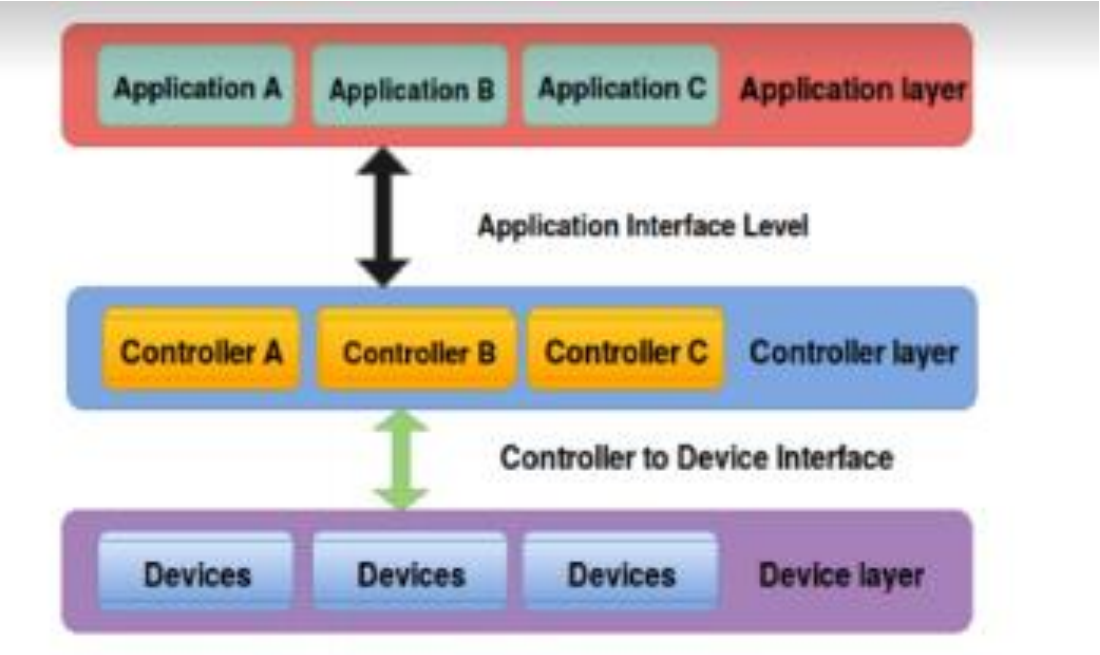

Fig 12: The General concept of SDN architecture model

The figure above shows the general SDN architecture model which is based upon decoupling the data and control layers. The commodity switches are placed in infrastructure layer. Controllers

are present in control layer. Network appliances and applications are deployed in application layer. Firewalls are placed virtually in the application layer and reclaim the NFV.

SDN	NFV
CONTROL	
1. Standardization of the control interfaces 2. Protection of commercial business operating schemes 3. Measures to avoid performance degradation 4. Maintenance of information of the controlling network-big data development	1. Seamless control and provisioning 2. Real time and dynamic provisioning 3. Creation of network granularity policies 4. Maintenance of virtualization information-big data development
RELIABILITY	
1. Seamless connectivity and fast connection recovery 2. Security requirements in EPC and RAN 3. Security and reliability of the transport and data network 4. Equilibrium among performance, security and flexibility	1. High complexity of 5G (technologies, devices, IoT) 2. Seamless and high quality connectivity 3. Virtualization of terminal points 4. Security concerns (same physical medium)
SCALABILITY	
1. Support of technology and device heterogeneity 2. Controller messages with performance and survivability (low packet loss levels) 3. Optimization of flow rules-better network slicing	1. Carrier-grade scalability and robustness 2. Acceleration of implementation 3. Openness and interoperability, global reach and cross-administration
COST EFFICIENCY	
1. Capability to support a pay for service commercial model 2. Replacement of hardware with software applications 3. Deployment and acquisition of commodity switches-Replacement of legacy hardware 4. Shorter time to market and less deployment risks	1. Power consumption reduction 2. Operational efficiency improvement 3. Higher capital costs 4. Higher operational costs (short life-cycle of configuration tools)

Table 1: Challenges and Requirements linked with SDN an NFV.

The table above shows the challenges and requirements lined with SDN and NFV. Following are the existing solutions in SDN cases:

- **OpenRAN:** It presents an approach via virtualization. The four levels of virtualization introduced are application, cloud, spectrum and cooperation. The main idea is that the controllers have proper routing and bandwidth allocation and other flow priorities.
- **NetShare:** The shared resources are managed by NetShare. It helps to separate the entities and utilizes the resources of entities. It brings the reallocation of existing resources of base stations and several entities in a present network. The resource allocation is based on numerous factors like distribution, isolation, network heterogeneity etc.

- **SDCN:** SDCN stands for Software Defined Cellular Network. It helps in efficient resource allocation by segmenting resources like bandwidth, topology, traffic, forwarding tables etc.
- **Cellular SDN:** It focuses on subscriber attributes which includes flexible policies, flexible switch patterns, scalability etc.
- **Wireless SDN:** It helps in analyzing the network infrastructure and also works on various other issues like sharing, SDN, OpenFlow, energy policies etc.

Various applications of SDN include Traffic Engineering, security, Data-Center Networking, mobility support etc.

- To manage, design and deploy network services, **Network Function Virtualization** (NFV) is used. It helps to decouple various network functions which include firewall, intrusion detection, DNS, NAT etc.

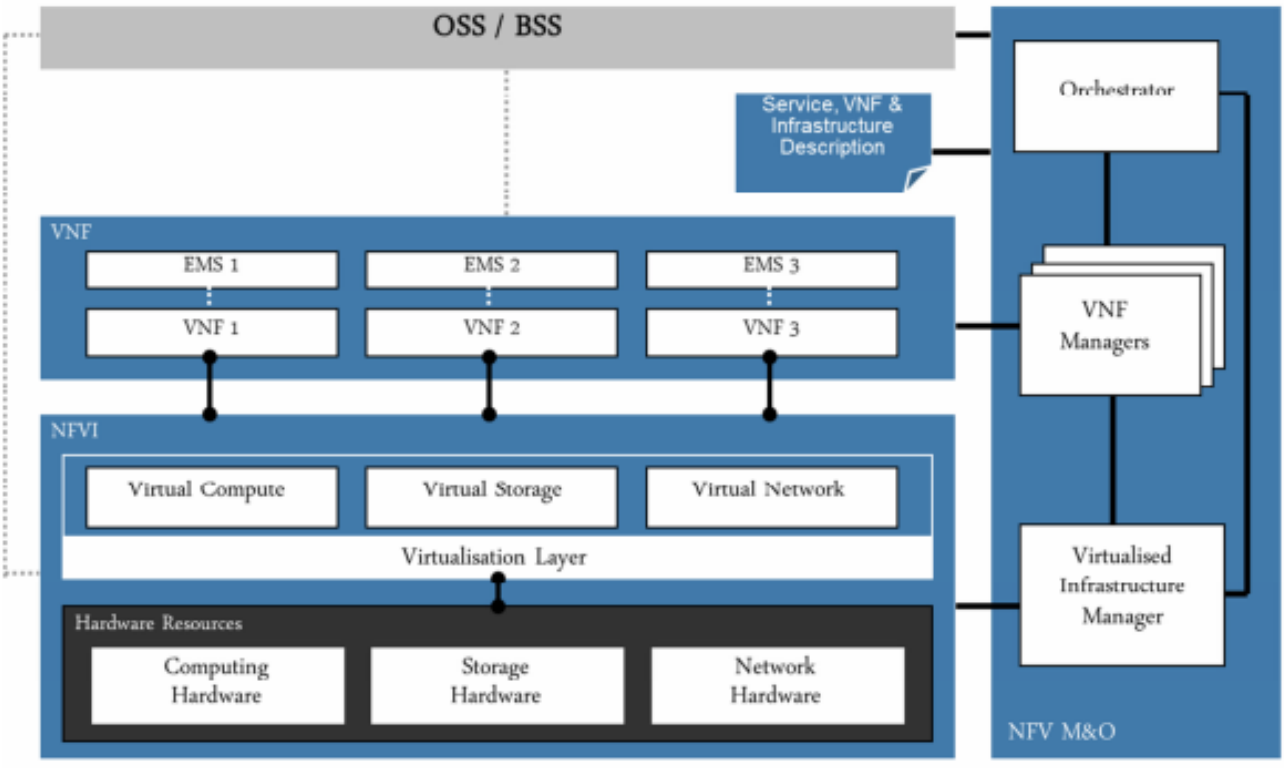

Fig 13: NFV architectural Framework

The main components of NFV architecture framework are:

- **NFVI (Network Functions Virtualisation Infrastructure):** For the execution of Network functions, NFVI provides the virtual resources which includes a software layer for abstraction and virtualization of hardware, accelerator components and Commercial-Off-The-Shelf hardware.
- **Virtualised Network Function (VNF):** It runs over NFVI and is basically a software implementation of a network function. Element Management System is usually accompanied with VNF which helps to understand individual VNF.
- **Management and Orchestration (NFV M&O):** This helps to support infrastructure virtualization and management of VNF's.

2.5 PRIVATE LTE NETWORK:

Private LTE networks have a multi-service capability and designed with machine communications. There are various advantages of using Private LTE networks such as:

- Range/Link Budget: The development and deployment of LTE systems is done using RF equipment's which have higher specifications. LTE systems are designed in such a way that they can operate well under fading channel conditions. To have a significant greater range, category-B small cells and CBRS 3.5 GHz spectrum is used.
- Mobility: It includes intra-network and inter-interwork mobility and is the strength of LTE systems.
- Ecosystem and Interoperability: The 3GPP ecosystem consists of interoperability testing and certification processes because of which many network organizations do deployments with a mixture of suppliers and devices.
- Security: Various security options like SIM based security and also non-sim options can be deployed for security in the cellular networks worldwide.
- Roadmap to 5G: When it comes to development and evolution of 5G, LTE plays a significant role because many wide capabilities are linked with 5G which are well suited for LTE networks. These advanced capabilities include flow based QoS, low-power operation etc.

2.5.1 ARCHITECTURE OF LOCAL-AREA PRIVATE LTE NETWORKS

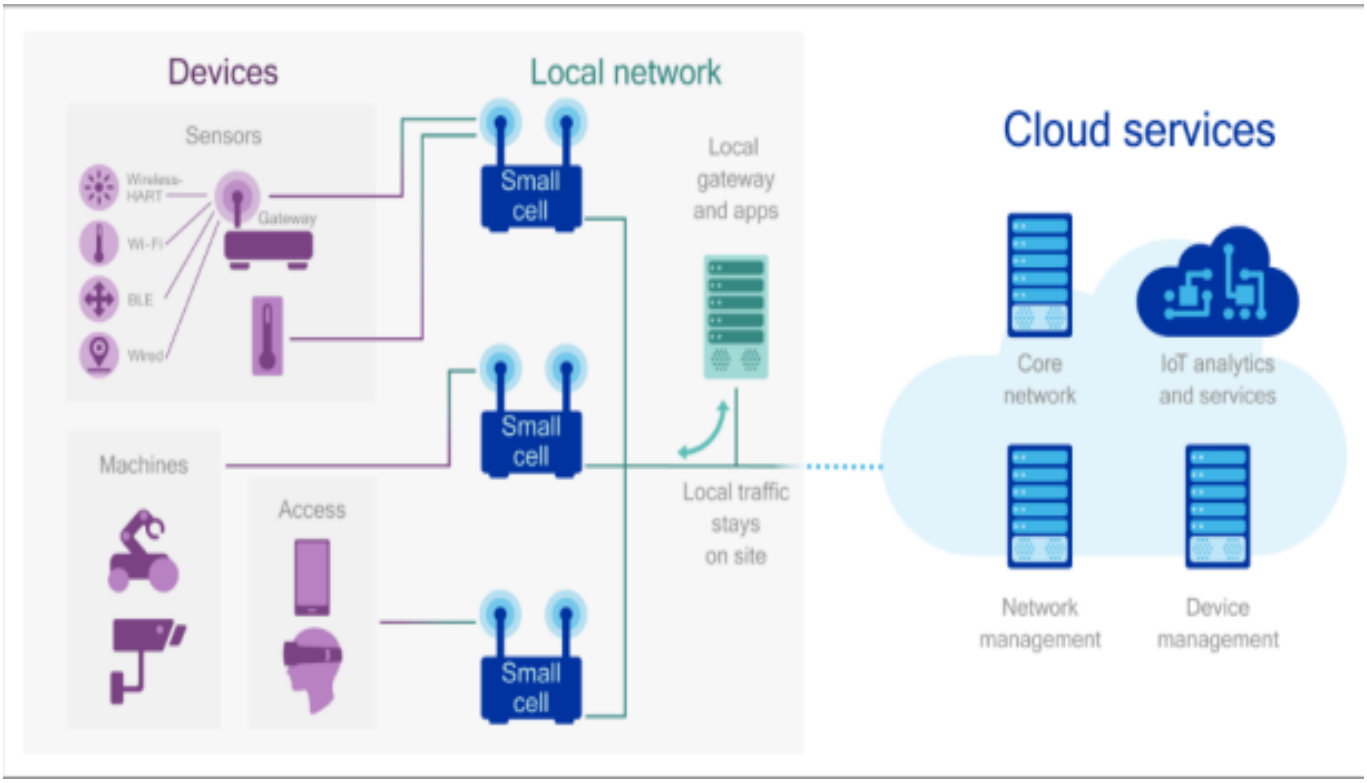

Fig 14: Local Area Private LTE Network Architecture

The architecture consists of radio access, devices and core network. To maintain the traffic in the local site the core box is deployed on the premises and is virtualized as well. Deployment of core box on the premises is very important for several factors like performance, security and service continuity. The technology that is used for standalone LTE operation is Multefire technology which covers system architecture and radio performance and was first released in 2007. Various companies that have deployed private LTE networks are: **Rio Tinto** which was the first large enterprise to deploy private LTE networks, **Ocado Technology** which is largest UK based online grocery retailer, **Enel group** with headquarters in Italy is one of the biggest electricity and power distributor,

2.6 CITIZENS BROADBAND RADIO SERVICE (CBRS)

The policymakers and regulators have been facing a lot of issues in allocating the spectrum resources because of increase in demand of additional mobile broadband capacity. To overcome these, 2 approaches have been used which fall under coordinated shared spectrum (CSS), these are Licenced Shared Access (LSA) and Citizens Broadband Radio Service (CBRS) in United States. The various CBRS functional components are:

- **Spectrum Access Systems:**

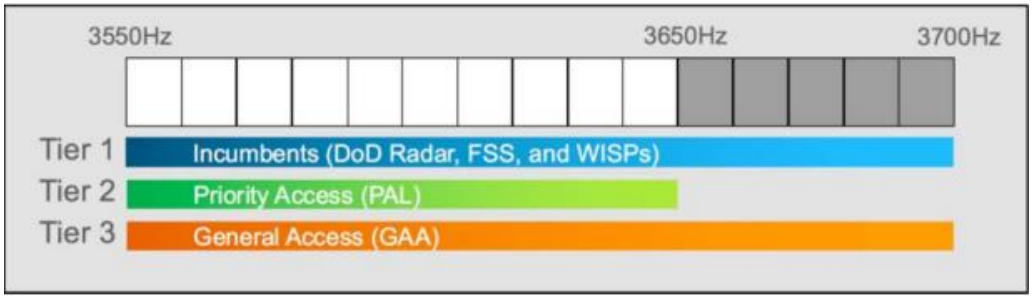

Fig 15: CBRS 3-Tiered Spectrum Sharing Framework

To enable the CBRS 3-tier sharing framework, spectrum access system helps to provide the centralized coordination. The following functions are to be performed before the radio node begin transmitting in CBRS band:

- Various parameters along with location must be registered with SAS
- The desired frequency range and power level must be indicated to gain access grant from SAS
- The frequency range and operating power limit must be indicated to gain access grant from SAS

- **Environmental Sensing Capability:** To protect the radars from any sort of interference from outside, the environmental sensing capability is being deployed at coast side. ESC will help to detect any kind of interference and will also inform SAS which will assign other frequency to the users.

- **Radio Base Stations:** In Citizens broadband radio service, the radio nodes are known as citizens broadband radio service devices. To have proper operation in CBRS band these devices must communicate well with SAS. Whenever a device will lose its connectivity with SAS the operation must be ceased, and this is known as “fail off”.

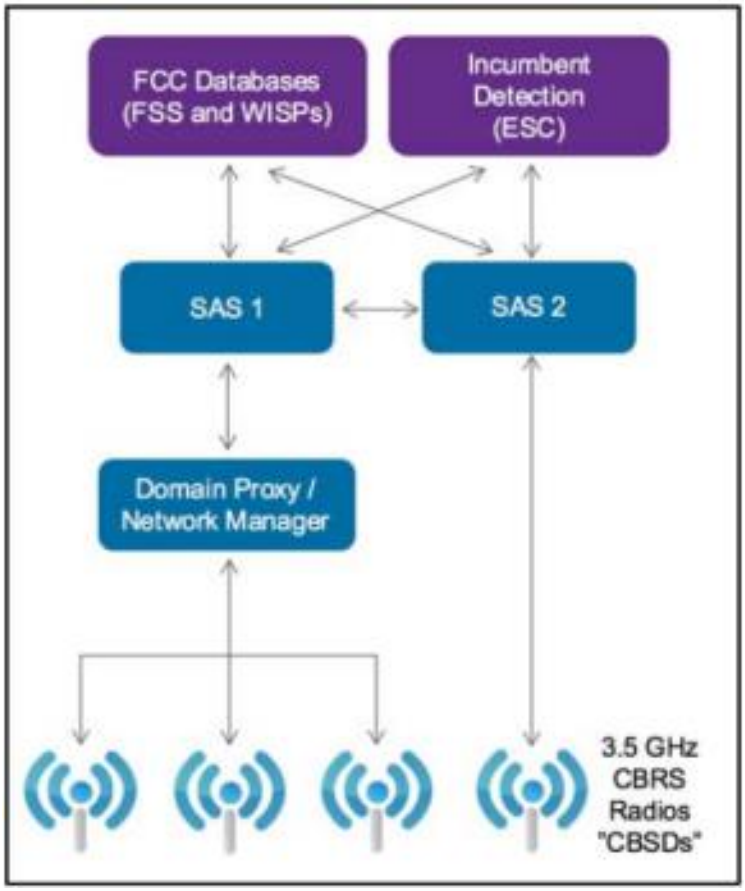

Fig 16: CBRS Functional Components

In July 2016, CBRS alliance was announced that will help to enable LTE based solutions in CBRS band. The Alliance will also focus on promotions in broader market in terms of innovative solutions and technologies.

2.4 RECENT TRENDS AND NEWS FOR 5G:

➢ 2.4.1 Annual Brooklyn 5G summit, April 2017:

- 4th annual Brooklyn summit provides an inside view of contemporary trends and developments in 5G. the agendas discussed were focusing on 5G bringing new technologies such as millimeter waves, massive MIMO, small cells and Beamforming.

- AT&T had updated that last year in their lab in Austin, Texas they tested 5G technology at 4 GHz, 15 GHz, and 28 GHz. They are focusing on achieving fixed wireless services which works between 2 stationary points with air broadband internet service.
- According to Dave Wolter, Assistant vice president of AT&T said that their plan is on expanding fixed wireless services which can serve 10 pilot customers in Austin which will be a combination of residential and small business properties.
- For trial purpose, the company placed a transmitter on top of its building with receiver installed at 250 m away with clear line of sight on client side. The main challenge which came in their way was the windows on client side were double coated which prevented millimeter waves to enter because the windows were energy efficient. Therefore, in order to achieve success AT&T had to switch to windows which were single coated.

- According to Wolter the key frequency for fixed wireless and mobile devices is supposed to be 39 GHz and they had recently achieved straight path communications which has a spectrum holding for 39 and 28 GHz
- **NYU wireless** had their focus this year on Massive MIMO. It works with 4G technology which uses multiple antennas in combination with signal processing to communicate with users on same frequency level at the same time.
- The meaning of massive MIMO was a subject of debate but according to what Fred Vook, an engineer at NOKIA replied that it consists of more than 8 antennas and massive MIMO have over 100.
- **According to Durga** Malladi, senior vice president at Qualcomm declared that MIMO works with 4G and they expect massive MIMO will work well with 5G.

2.5 3GPP and 5G

The 3GPP stands for 3rd Generation Partnership Project. 3GPP basically ties seven telecommunication development associations generally known as Organizational Partners. These groups help generate the specifications that explain the 3GPP development and technologies. The main aim behind the 3GPP was to develop a globally accepted 3G mobile phone specification which is based on GSM specifications. This was the initial scope and was enhanced or advanced later with time. The development on following was included in 3GPP scope,

- GSM including EDGE and GPRS

- UMTS including High Speed Packet Access (HSPA)

- LTE in accordance to 4G standards

- IP Multimedia Subsystem

The 3GPP specification also includes core transport network, radio access, codecs, quality of service and security and therefore it provides complete specifications for systems. Networking using Wi-Fi and non-radio access is also included in the 3GPP specifications.

The seven organizational partners as defined above makes the policy and execute tasks like approving and maintaining 3GPP scope, Creation or terminating specification groups, allocating human and financial resources etc.

In Release 15 of 3GPP the first specifications of 5G will be published that will involve system architecture and Radio Access Network. In the present time the specifications and architecture of 5G that have been there are all based on assumptions that have been around the mobile systems. 3GPP is working on to combine different views and projects that can be brought together in for 5G specifications.

As mentioned previously in the current trends, AT&T began their testing regarding 5G in Austin, Texas in 2016 with proper licensing from US government. They did outdoor testing and field trials so that they can provide wireless connectivity in fixed locations in Austin. The trials that AT&T were having they made sure that they had put up international 5G standards development and accommodate with the standards set by 3GPP.

2.5.1 3GPP Release 15

In June 2016 as per the 3GPP technical specifications group decided to bring a detailed work plan for release 15 which will include various tasks and checkpoints for references and a help for working groups.

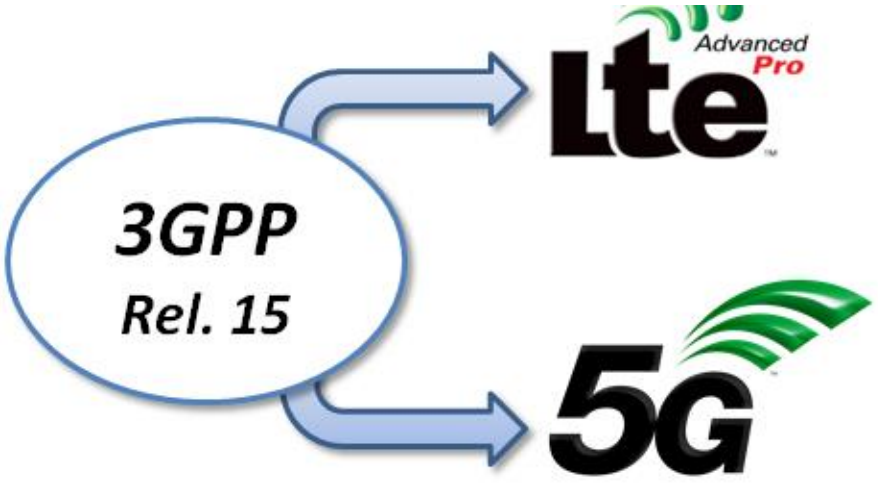

Fig 17: Two phases of 3GPP Rel.15

Rel-15 focuses on phase 1 and Rel-16 will focus on phase 2. Work items for 5G phase 1 are:

- It will include network slicing, Quality of Service framework, access to untrusted 3GPP, migration, roaming etc. The guidelines in Rel-15 will focus towards system architecture and procedures for 5G system
- The first phase for 5G will cover the basic feature for enhanced mobile broadband URLLC with frequency range up to 52.6 GHz. The phase 1 of radio access technology will focus towards non-standalone and standalone connectivity options.
- Various EPC enhancements (Evolved Packet Core) are being worked out to support 5G early deployments where LTE serves as signaling anchor and NR serves as secondary cell. These enhancements will work on extending the range of QOS, controlling access to 5G NR.

CHAPTER 3

5G IN VERTICAL MARKETS AND CITIES

3.1 INTRODUCTION

5G is a key aspect in the future of digital world. The shift from 4G to 5G will bring in new emerging technologies and different approaches to internet that will bring a change in the markets and lives of people. 5G will bring new innovations in various vertical markets such as automation, healthcare, energy sector, food and agriculture, city management, government transportation etc.

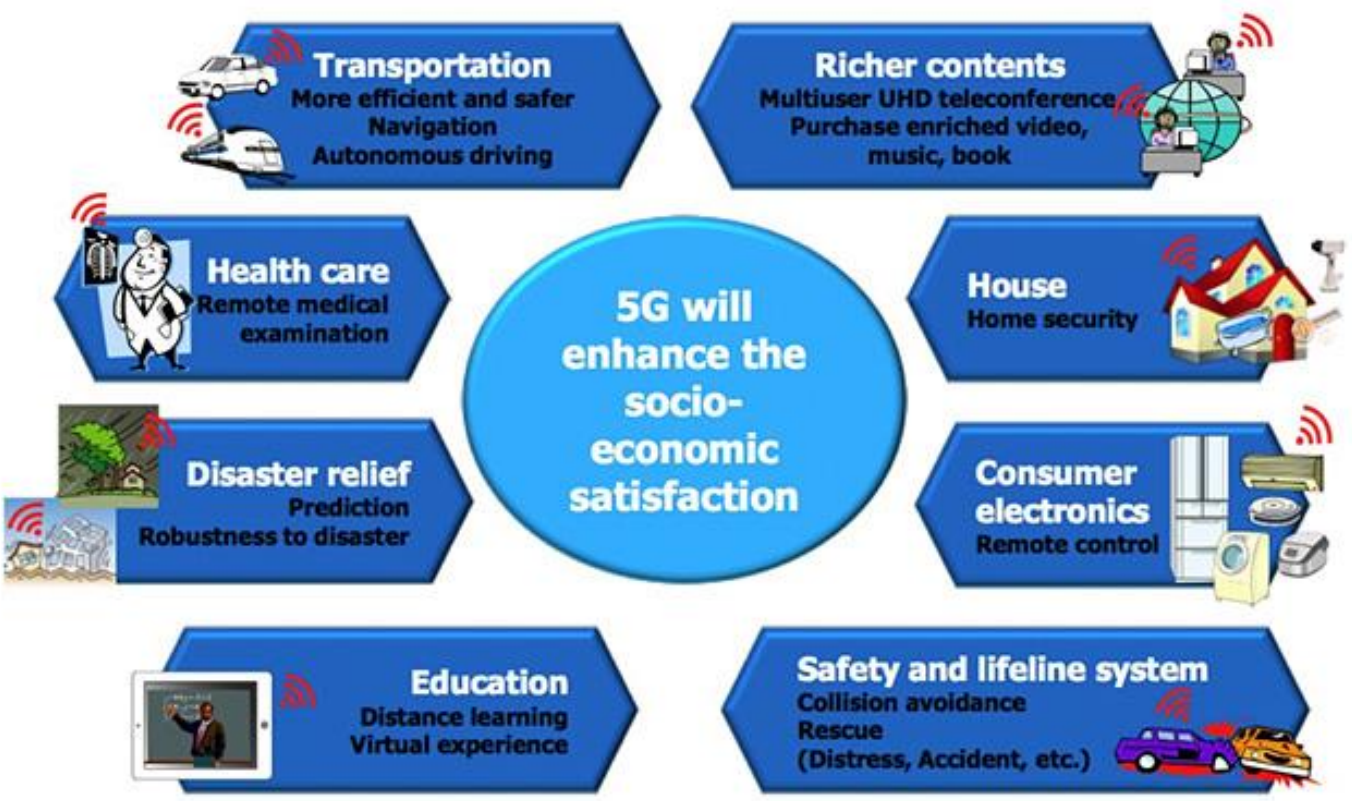

Fig 18: 5G Applications

With various enhancements in QoS, universal availability of communication and cost levels 5G will benefit lot of people and various business markets. By building strong relationships between vendors, operators and verticals 5G will emerge as a great technology which brings new business opportunities.

3.2 5G AND HEALTHCARE

According to World Health Organization e-health is the practice which involves healthcare and health resources by electronic means. It focuses on 3 fundamental areas:

- Providing health professionals and consumers complete health information electronically
- Improving health services through power of IT
- Use of e-commerce and e-business principles in health management systems.

PWC in 2013 generated in their report related to socio-economic impact of m-health which highlighted the benefits of mobile health development in Europe. The report stated that with m-health a total of 99 billion EUR healthcare costs can be saved if it is properly adopted.

- Decentralized trends included m-health delivery at homes, rural areas, clinics, rehabilitation centers, over internet etc. the main aim was to shift the attention to the causes of lifestyle and wellness.

- Trends with social context includes personalized care for people, providing a healthy lifestyle, community services for patients etc.

- Global context shows various countries which can save a lot of money by adopting e-health and m-health. One of them being Africa, where mobile health could save 1 million lives. Reports show that the average distance between a person and a health care center in Africa is 5 miles. The positive results of adopting m-health are shown that with proper information regarding pregnancy and its prevention and awareness has helped a lot of women in Mali, Africa which has helped to reduce perinatal and maternal mortality by 30%

According to the green paper, WHO defines m-health as a platform for providing medical services through mobile phones, or other wireless devices, 5G will play a big role as a catalyst for e-health and m-health. Various advantages would be:

1. Increase in efficiency that will focus towards better healthcare decision making processes.
2. The pharmaceuticals wastage can be reduced
3. The art of Tele-surgery can be enabled safely and in a secure manner
4. Healthcare services can be accessed anytime and anywhere
5. The hospital assets can be tracked easily
6. It will give assorted options to people to choose where and how they can access health care services.

3.2.1 HEALTHCARE APPLICATION AREAS OF INTEREST:

1. **Managing the assets in the hospitals:**
    - Usually in the hospitals the assets like wheelchairs, ECG monitors etc. are scattered at places. The hospitals need to have proper management of these assets. When patients are discharged sometimes the wheelchairs can be accidentally taken away.
    - Proper tagging should be done for the equipment's so that they can be easily tracked down when needed.
    - Hospitals should work on geo-fencing and real-time tracking of assets in order to prevent they unwanted removal
    - To keep track and proper monitoring of pharmaceuticals to prevent harmful drugs being given to patients and to have detection of consumables which are coming closer to expiry dates.

2. **Robotics:** Sometimes the surgery specialists are not available in the area and local surgeon could join remotely to help with certain procedures to carry out the surgery which require expert skills.

- In the future time surgeons can have robots operated from their offices via mobile connections because coming to operation theatre is time consuming and costly for them.
- Junior surgeons can be helped by senior surgeons remotely if the latency was below 200 ms. For the modern operating robot the latency is 180 ms.
- The figure below shows telesurgery with help of robotics

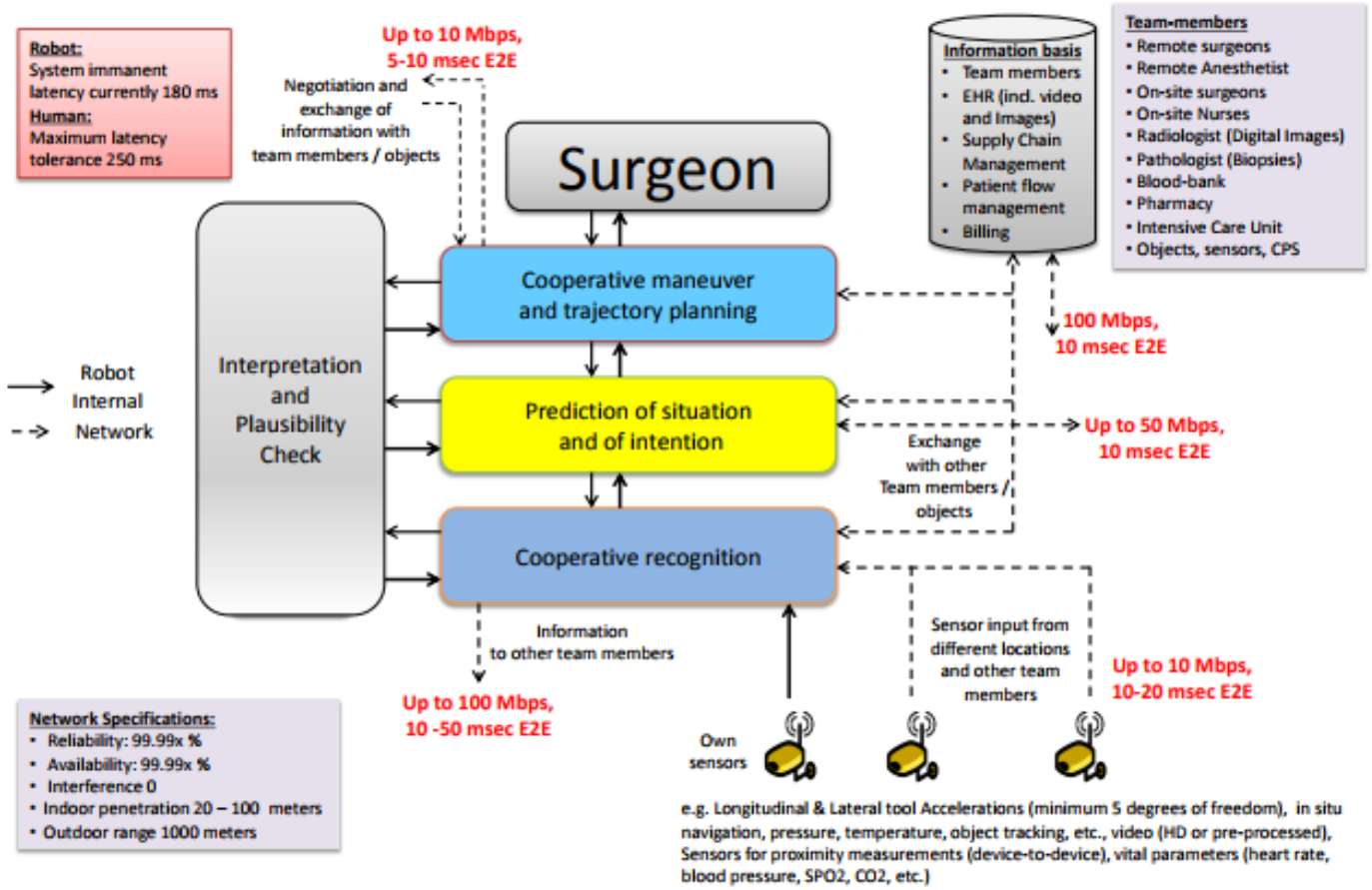

Fig 19: Robotics assisted Tele-Surgery

3. Smarter Medication:

- E-health can play a major role in impacting the health of a patient. For instance, in Europe the rising health issue these days is brain stroke and providing immediate medication via e-health and m-health can increase the chance of recovery. The choice of medicine should not only be based on person's body but other factors should also be considered which include air pollution, temperature etc.

- Smart pharmaceuticals, that is the pharmaceuticals that are connected to the mobile devices can be really helpful for asthma, diabetes etc. this includes proper smart algorithm on mobile phones which can provide complete information regarding care process, more devices are connected per geographical area and use of cyber-physical system as part of health 4.0 strategy.

5G technology will play a key role in healthcare sector for delivering personal healthcare and very effective therapy approaches. Self-determination theory can be used for m-health applications. By combining real-time psychological, physiological and symptomatic data of a person and integrating it with inputs from healthcare professionals, patients can receive an immense help in self-managing their health and health problems.

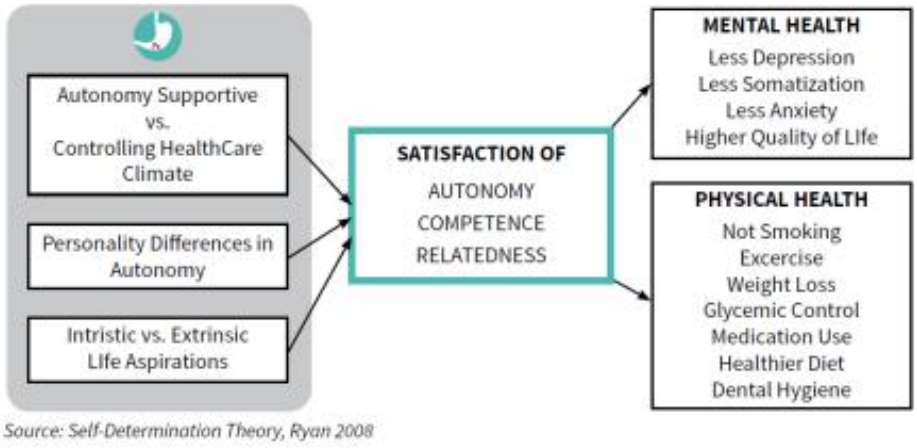

Fig 20: Self Determination Theory

- Autonomy: It gives a chance to patient to use m-health applications anywhere, anytime and at any place. Various algorithms will work with these applications like personal predictive algorithm will help patients to be more independent from clinical services.

- Competence: by proving information regarding diet and behavioral factors such as drinking, smoking via m-health can help a patient to have more knowledge about health and address specific competence levels.
- Relatedness: the patients can grow their network through this and can share information and exchange via third party safely.

3.2.2 TECHNICAL REQUIREMENTS OF 5G:

- To manage the assets, proper positioning of assets is to be done so that it's easy to track those assets. It requires a precision of around 1m in indoor conditions.
- Having multi-radio access technologies with seamless handover
- Managing the mobile assets which include mobile helicopters, which must be connected and have services at a typical flight altitude, which requires to have a mobility >300 km/h
- In case of telesurgery, the connectivity while the surgery should be of great level to avoid any disruptions.
- The latency should be as low in order of 30 ms to cope up with latency of operating robots.
- To have a proper data connection when a patient is talking to a doctor
- To improve energy consumption. The main aim is to have connected devices that are self-sustainable. The target till 2020 is to have devices avoid battery replacement up to 10 years.

3.3 5G AND EDUCATION SYSTEM:

5G mobile technology is working to bring a Networked Society where we can access information anytime and anywhere in the world. With Internet of things it will accommodate connection of many devices simultaneously to improve terminal battery life. With recent developments there has been a high availability of digital resources with proves helpful in classrooms and for learners as well. To improve the quality of education various applications like virtual Reality and augmented reality will play a significant role. With integration of

high speed internet with VR and AR will bring a new experience in tele-teaching, virtual university, virtual classroom, virtual team-working etc. new mobile technology will help students to share and learn new opportunities with minimum interaction with teachers.

Various potential uses of 5G in education system are:

- High speed internet and skillset communication: with high speed internet the delivery of information to students will be effective and useful for them. Tele-teaching and Tele-mentoring will be improved and will provide students new experience for manual training and skill development. With 5G technology new ways of distance learning can be achieved. For proper haptic interaction of our limbs in association with audio and video feedback the response time of service should be low which can be achieved by 5G.
- Virtual Reality: VR will play a key role in improving our education system. It will provide better quality of education. By bringing these services to our daily lives it can prove to be interesting way of learning new things. It will bring new experiences for learning and will enable virtual presence of students. It will need very high bandwidth and very low latency.
- Augmented Reality: with AR right amount of information can be provided to learners which will prove to be helpful for them. With services like mobile cloud classroom and virtual presence new learning ways in education will be enabled. I will also help teachers to have proper information about students and their needs and capabilities. This service will require optimized routing, seamless wide-area coverage, virtual presence, low latency speech and video coding.

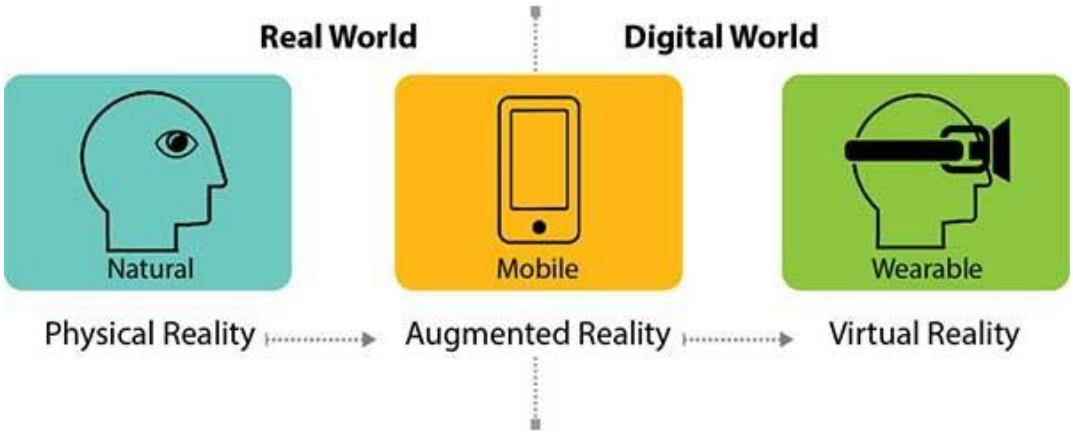

Fig 21: Virtual Reality vs Augmented Reality

- Walled-off classroom: with virtual reality and high-speed internet services the experience of teaching will be improved. The need of physical location can be removed because VR can help share and distribute information anywhere and anytime.
- Students with special needs: VR and AG reality will also benefit student with special needs who can access information and learn new things by sitting at home only. Cloud based robots can assist students with special needs who will help students to interact with education and their peers.
- Smart classroom and Smart campus: IoT applications are proving efficient in various fields in the market and education system if one of them. By automatically logged into classroom with entering there will give them opportunity to remove the administrative burden and focus more on individuals. With enabling real time feedback, students can let the teachers know their area of weakness and what problems they have regarding real-time analysis of their notes.

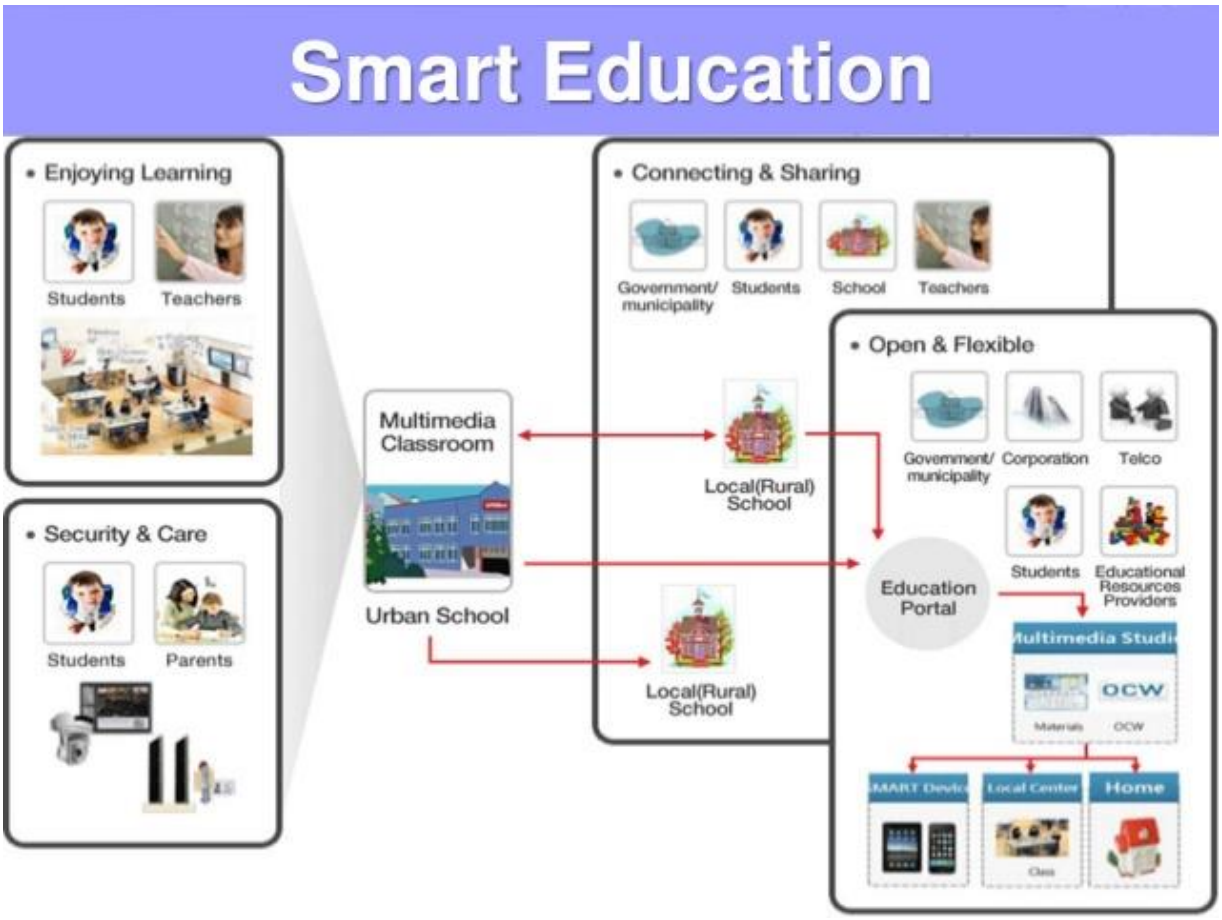

Fig 22: Smart Education System in Thailand

3.3.1 TECHNICAL REQUIREMENTS OF 5G:

- Backhaul Network: one the major requirements are the core network that can accommodate the traffic with required Quality of Service for a particular service. National Research and Education network, NREN is the internet service provider in England. It is a specialized internet service that works with various mobile operators and service providers that supports the needs of education and research communities within a country. In Europe different NREN's are connected through GEANT, that connects 50 million users at 10,000 institutions in Europe. GEANT is regarded as most advanced research network in the world because it provides operating speeds up to 500 Gbps an

offers great geographical coverage. The network slicing in 5G plays key role in achieving different services that have totally independent virtualized networks that provides various levels of latency, reliability, availability and security. To improve the efficiency of core networks techniques like information centric networks and content centric networks can be used.

- Non-3GPP access network: Federation-based Wi-Fi service is provided by NREN's to their community and the service is known as education roaming service. Eduroam which is implemented on federation basis is highly popular network access service in education and research community. It provides seamless internet service to the users whether local or roaming users without having any guest-access account. Currently it is active in 76 countries. According to 3GPP technical requirements the architecture must support new RAT, evolved LTE and non-3GPP access type. In non-3GPP access type, WLAN access and fixed access should be looked upon.

- Cellular coverage in education premises: cellular coverage plays a key role in education system because almost every student uses smartphones and tablets anywhere and anytime to access any information that they need. Many organizations suffer due to poor connectivity that impacts the education system there. Solution to this problem is the NREN's that has a backhaul network that provides high quality and high data rate connectivity in education sector. By deploying Multi-operator core network in which frequency can be shared and also by using common PLMN-ID and aggregated gateway, the problem of cellular coverage can be improved.

- Throughput: usually throughput in the education system is high because most of the users are students. 5G technology is working on to provide 20Gbps data rate in indoor and dense area scenarios.

- Heterogeneity: In order to use all the resources in efficient ways the wireless technologies should be adaptable to changing situations

3.4 5G AND AUTOMATION

In recent a lot of vehicles and being connected to internet and the industry is undergoing a lot of transformation to make lives of people much better. The term Vehicle to everything has been proposed that allows vehicles to exchange information with other vehicles, with roadside infrastructure and with a pedestrian. Various connected vehicles services have been implemented within last 10 years that give information about vehicle crash, breakdown, traffic information etc. Following this a new feature called e-call i.e. emergency call will be added in vehicles that will be connected to mobile networks and to be capable of geo location by means of European Global Navigation Satellite System receivers. The automobile industry sees two developments to happen with association with 5G: automated driving and road safety and traffic efficiency services.

3.4.1 KEY TRANSFORMATIONS HAPPENING IN AUTOMOTIVE INDUSTRY

- **Automated Driving:**
  Six levels with increasing degree of automation have been defined according to US society of automotive engineers and German association of automotive industry. According to the principle automated driving can be made possible with having vehicle to everything communication. In the fully automated driving where vehicles only have onboard sensors and there is no communication from mobile networks is not possible. The figure below shows the scenarios for automated driving until 2025.

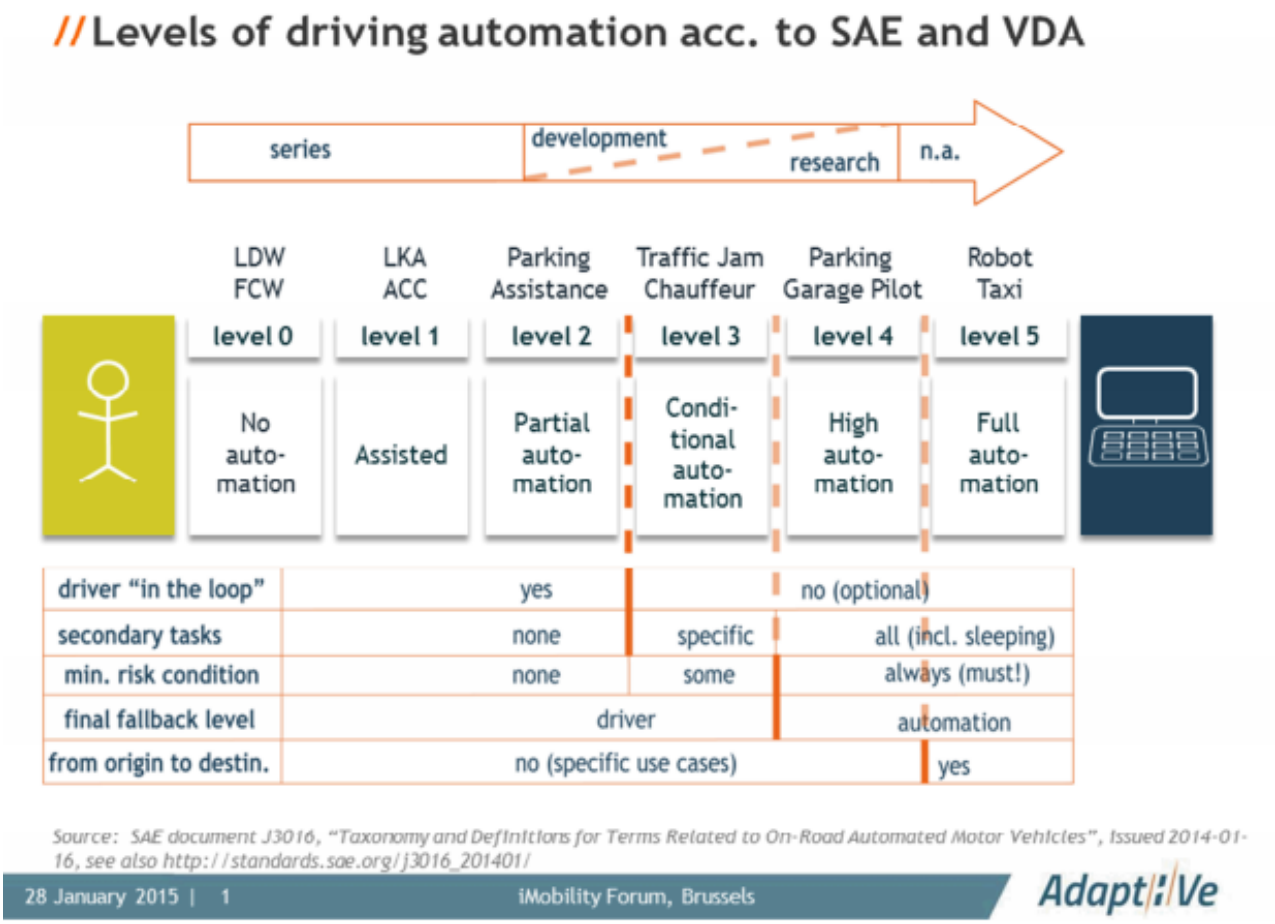

Fig 23: SAE/VDA automation levels

Automated driving can prove really beneficial from vehicle to vehicle and vehicle to infrastructure combined with vehicle to network because vehicle behavior is better adapted when it comes to traffic situation which gives a great customer satisfaction.

- **Digitalization of transport and logistics**: the first meeting of digital transport and logistics forum was held in Brussels in July 2015. The directorate-general for mobility and transport, DG-MOVE introduced 4 content drivers with respect to digitalization of transport: increase in data efficiency of transport logistics chain, decarbonisation, human factor and international aspects. Digital data and logistics will focus on information related to goods, means of transport, authentication etc. internet of things will play a key role in exploiting the data. The development in the

automotive industry needs to be worked keeping future needs of transport and logistics. The vehicles will gather information from their own elements along with other vehicles and roadside units. This data along with E-business will help drivers in daily basis.

- **Intelligent navigation**: navigation system is really helpful for drivers by helping them chose the efficient traffic routes according to real-time information. With help of IoT more efficient data will be collected with combining data from other vehicles and road authorities. More useful data will be available to drivers like point-of-interest which will give information reading nearest hotel, restaurant, parking place etc. in future the navigation systems will combine data by receiving information from extra sensors such as cameras and radars installed on vehicles along with real time information from other vehicles.

3.4.2 TECHNICAL REQUIREMENTS:

A. Key Performance Indicators:

	Use Case	KPIs	Background	Security Requirements
1	**Automated Overtake**	10 ms 10^{-5} 30 cm[1]	On two-way roads, automated overtake maneuvers will require cooperation among vehicles on multiple lanes, to create the necessary gap in time to avoid a collision with an oncoming vehicle. Lateral and longitudinal controllers need updates within their 10 ms cycle time.[2] This is a safety-of-life use case with ultra-high reliability requirements.[3]	Client authentication Authenticity Integrity Confidentiality User privacy (optional)
2	**Cooperative Collision Avoidance**	*Trajectory handshake:* 100 ms 10^{-5} *Status updates:* 10 ms 10^{-3} *Positioning:* 30 cm	In a critical driving situation, trajectories have to be exchanged, rated and agreed upon in order to avoid a collision. This handshake must be completed within 100 ms and shall not fail with a probability higher than 10^{-5}. Upon agreement, during the execution phase, lateral and longitudinal controllers need status updates within their 10 ms cycle time. The status information is used by each vehicle to update its trajectory and inform its controllers (in case of minor deviations from the agreed trajectory) or cancel the maneuver (in case of major deviations). A status message shall be received within 10 ms with a probability of 99.9% (packet loss rate of 10^{-3}).	Mutual authentication Authenticity Integrity Confidentiality

3	**High Density Platooning**	10 ms 10^{-5} 30 cm	The idea behind high-density platooning is that vehicles will be driving very close to each other. Thus, latency and reliability become the KPIs. The control cycles of typical longitudinal controllers are in the range of 10 ms (as above). The platoon must have their own synced timing. Kinematic data needs to reach all participants of the platoon within a single cycle (10 ms) with ultra-high reliability, and, optionally, all participants need to acknowledge that they can provide the necessary control within this cycle.	Mutual authentication Authenticity Integrity Confidentiality User privacy
4	**See-Through**	10 Mbit/s 50 ms	The main KPIs for this use case are channel capacity/data rate and tolerated latency. We assume that view-sharing is usually done one way. It requires a data rate of 10 Mbit/s and a delay of 50 ms (e.g., 720p video @ 30 fps, MJPEG).	Client authentication Authenticity Integrity Confidentiality User privacy (optional)
5	**Vulnerable Road User Discovery**	10 cm	This use case mainly requires highly accurate localization. For vulnerable road users, the positioning error needs to be less than 10 cm (sigma_1) for a 1 m width pedestrian/bike lane. Relative localization must be supported by 5G.	Authenticity Integrity User privacy (VRU)
6	**Bird's Eye View**	40 Mbit/s 50 ms	This setting is similar to the See-Through use case, but with four cameras pointing at an intersection. Consequently, the required data rate reads 4 x 10 Mbit/s and the required latency 50 ms.	Client authentication Authenticity Integrity Confidentiality

Table 2: KPI requirements for Automated Driving.

1. **Automated driving, road safety and traffic efficiency:**

The architecture will depend on 2 different cases:

- High level data transmission: in this the data that is generated from sensor processors like radar will be transmitted to vehicles, infrastructures etc. combined with receiving systems. The data rate requirement for this architecture is 1 Mbits/s

- Low level data transmission: in this the low level data generated from sensors like cameras is transmitted to vehicles, combined with receiving systems. The data rate requirements for this architecture is 10-20 Mbits/s.

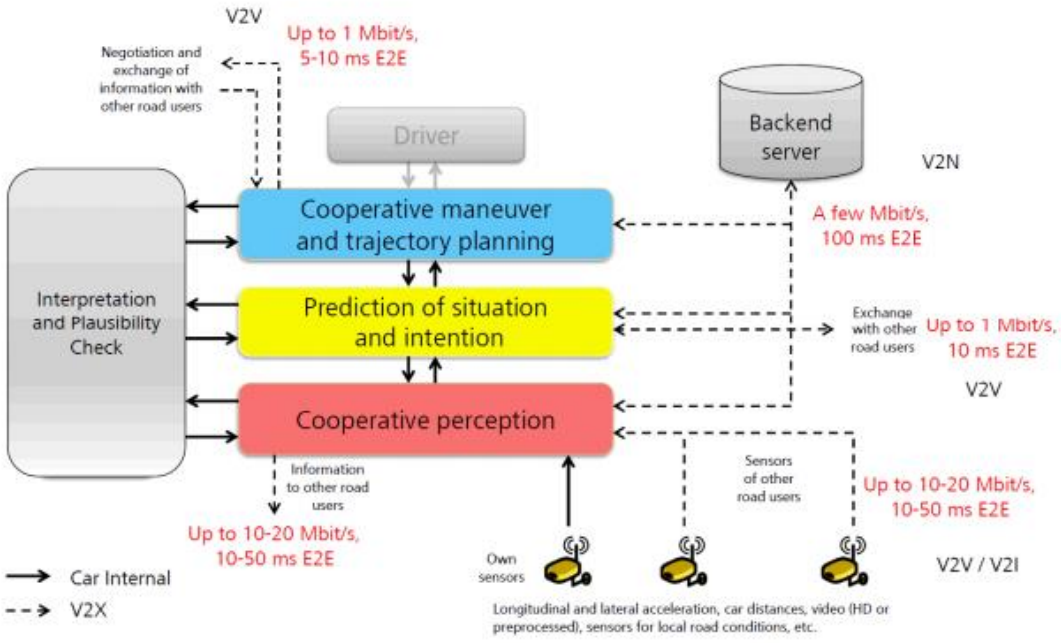

Fig 24: Connectivity demands of future connected vehicles

The figure above shows the connectivity demands of vehicles considering cooperative perception, sharing of data intention and trajectory planning.

2. Digitalization of transport and logistics:

- Remote sensing and control: in order for vehicles to be automatically started or unlocked using remote, security aspects should be kept in mind to avoid hacking and theft of the vehicle. The following requirements should be kept in mind which includes low power consumption, strong security mechanisms, end to end latency, higher penetration through walls etc.
- Remote processing for vehicles: the vehicles to have proper information regarding any change on road conditions or traffic a specific handover mechanism should be used with low latency requirements so that virtual machines are moved from one BS to another very quickly.

CHAPTER 4

INTERNET OF THINGS (IoT)

4.1 INTRODUCTION:

Internet of things is the fastest growing topic in the field of technology today. Basically IoT is the network of physical devices that are embedded with software's, sensors and network connectivity that allows them to connect and share data. The term Internet of things was coined in 1999 by Kevin Ashton of Procter and Gamble.

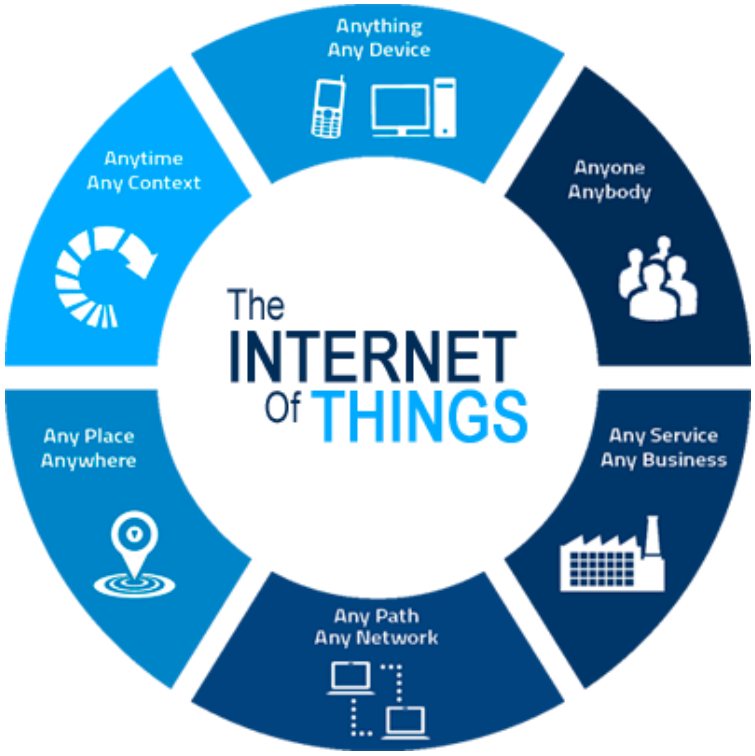

Fig 25: Internet of Things

The IoT implementations have made the lives of consumers efficient. New products like home automation systems, internet friendly appliances, devices providing way to smart homes, which offers more security and energy efficiency, health monitoring devices, network

enabled medical devices etc. have transformed the lives of people. IoT has helped to achieve the status of a city to Smart City by bringing in various services like networked vehicles, intelligent traffic systems, sensors that are embedded in roads and bridges etc. various companies have offered their projections regarding IoT in next 5 to 10 years

- CISCO estimated that by 2019 24 billion objects will be internet connected
- Morgan Stanley estimated that by 2020 75 billion objects will be internet connected
- Huawei estimated 100 million objects to be internet connected by 2025
- McKinsey estimated the impact of IoT on global markets will increase from $3.9 to $11.1 trillion by 2025

IoT plays a key role in various fields like smart cities, smart healthcare, smart education system etc. looking back at the history of IOT, IP was required to connect to various devices other than computers came into use in 1990 where an IP-enabled toaster that could be turned on and off using internet was featured at an internet conference. Since then many other "things" were made IP-enabled like soda machine at university in US. From all the implementations a lot of research and development in this field gave a foundation to Internet of Things.

In common terms basically IoT is new kind in the world where all the devices are connected to the internet network. The 7 IoT characteristics are:

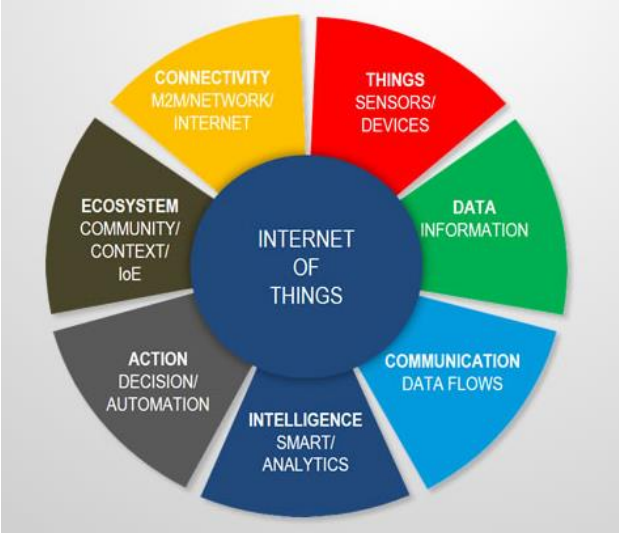

Fig 26: Defining the Internet of Things using 7 characteristics

- Connectivity: The various devices, sensors should be properly connected to the network to have efficient usage
- Things: it includes anything that is designed to be connected. From sensors, to household things etc. these devices contain sensors which are attached to other devices
- Data: it's the key thing for IoT which is first step towards intelligence.
- Communication: various devices are connected to each other so that they can share and exchange data
- Intelligence: it basically refers to the sensing capabilities in IoT devices.
- Action: This is the result of intelligence
- Ecosystem: it is the circle where internet of thing fits in collaboration with technologies, communities, markets, etc.

With increase in internet connected devices, the traffic generation will also increase. According to CISCO the internet traffic will rise from 40% to 70% by 2019 and the machine to machine connections will also see a significant rise from 24% in 2014 to 43% in 2019.

According to analysis of Mckinsey Global Institute, the 9 areas which will see an increase in size in by 2025 due to IoT are:

- Factories, which includes operations management and maintenance: $1.2 to $ 3.7 trillion
- Cities, which includes public health, traffic control resource management: $0.9 to $1.7 trillion
- Human, which includes monitoring and wellness, improving wellness: $0.2 to $1.6 trillion
- Retail: $0.4 to $1.2 trillion
- Outside, which includes logistics, navigation, self-driving vehicles: $0.6 to $0.9 trillion
- Work sites: $0.2 to $0.9 trillion
- Vehicles: $0.2 to $0.7 trillion
- Homes, which includes energy management, security, automation: $0.2 to $0.3 trillion
- Offices: $0.1 to $0.2 trillion

According to the report presented by Mckinsey, the figure below shows the potential applications with respect to IOT.

"Settings" for IoT Applications (Source: McKinsey Global Institute[25])		
Setting	**Description**	**Examples**
Human	Devices attached or inside the human body	Devices (wearables and ingestibles) to monitor and maintain human health and wellness; disease management, increased fitness, higher productivity
Home	Buildings where people live	Home controllers and security systems
Retail Environments	Spaces where consumers engage in commerce	Stores, banks, restaurants, arenas – anywhere consumers consider and buy; self-checkout, in-store offers, inventory optimization
Offices	Spaces where knowledge workers work	Energy management and security in office buildings; improved productivity, including for mobile employees
Factories	Standardized production environments	Places with repetitive work routines, including hospitals and farms; operating efficiencies, optimizing equipment use and inventory
Worksites	Custom production environments	Mining, oil and gas, construction; operating efficiencies, predictive maintenance, health and safety
Vehicles	Systems inside moving vehicles	Vehicles including cars, trucks, ships, aircraft, and trains; condition-based maintenance, usage-based design, pre-sales analytics
Cities	Urban environments	Public spaces and infrastructure in urban settings; adaptive traffic control, smart meters, environmental monitoring, resource management
Outside	Between urban environments (and outside other settings)	Outside uses include railroad tracks, autonomous vehicles (outside urban locations), and flight navigation; real-time routing, connected navigation, shipment tracking

Table 3: Potential Applications of IoT

4.2 INTERNET OF THINGS COMMUNICATION MODELS

It is very important that to have proper operations we need to focus on how IoT devices are connected and communicate. In March 2015, an architectural document was released by the Internet Architecture Board which focused on for communication models used by IoT devices.

- **Device to Device Communication:**

In this model the devices are directly connected to each other and have communication between them directly instead of having an application server as an intermediate.

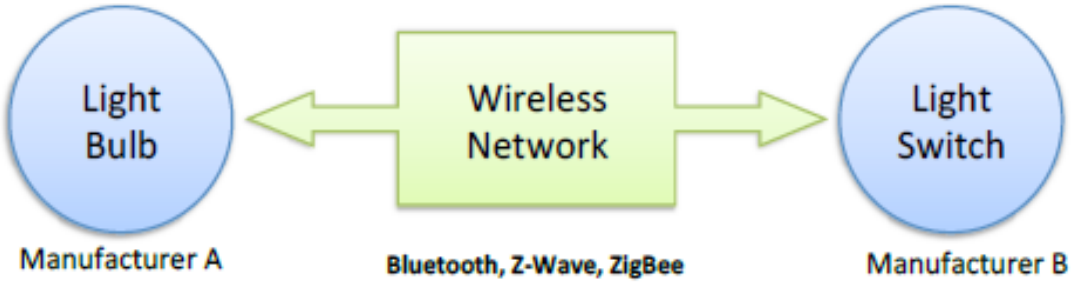

Fig 27: Device to Device Communication Model

In order to have direct to direct communication, these devices use protocols like Bluetooth, ZigBee etc. These models use small packets of information which have low data rate requirements and very commonly used in home automation systems.

- **Device to Cloud Communication:**

These kinds of model have internet cloud service through which IoT devices are connected and communicate with each other. The internet cloud service usually is an application server that helps in data exchange and controlling message traffic.

Fig 28: Device to Cloud Communication

Nest labs learning thermostat and Samsung Smart TV have deployed this kind of model. In case of nest learning thermostat, the data is transmitted to the cloud database through which the energy consumption at home can be analyzed and also this cloud enables the user to have remote access to their thermostat via smartphone.

- **Device to Gateway model:**

These kinds of model use ALG service which is application layer gateway model, which acts as a channel to reach cloud service and provides security and data translation.

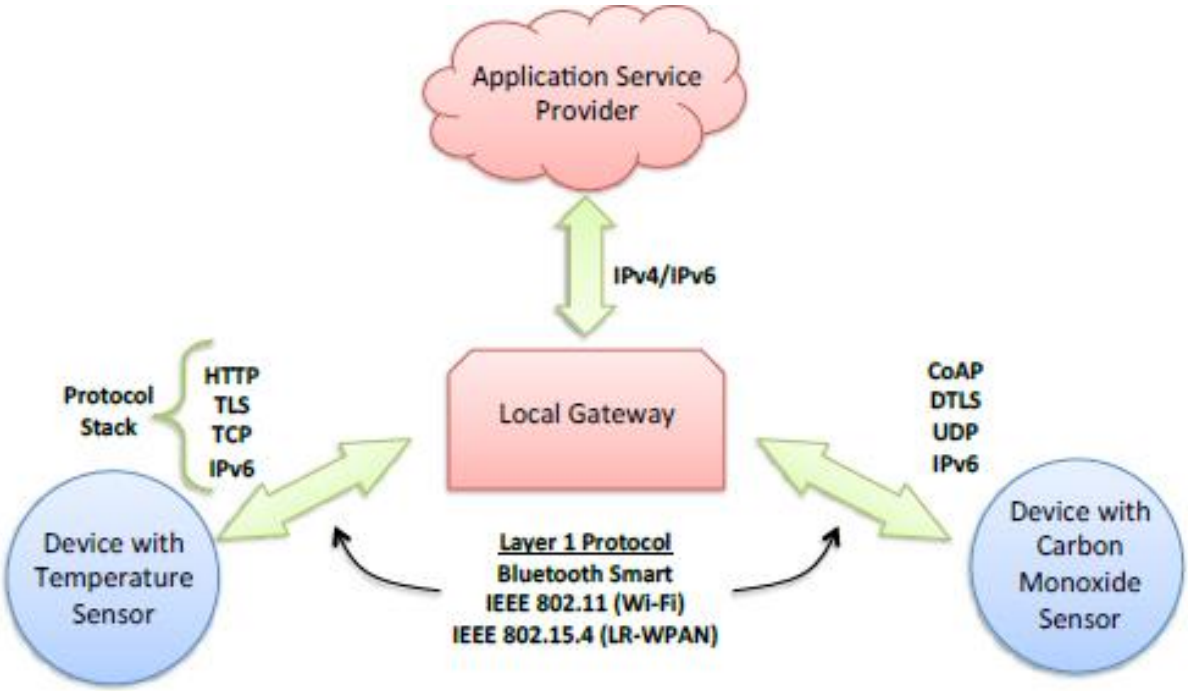

Fig 29: Device to Gateway Model

Usually the smartphones act as the local gateway device which communicate with devices and relay data to the cloud. The common example of this model is SmartThings hub which is stand alone gateway device that uses Zigbee and Z-Wave transceivers which communicate with the devices.

And then further it connects to cloud service known as SmartThings cloud service which allows user to access the devices via smartphone app and an internet connection.

- **Back-End Data-Sharing Model:**

In this the smart object data is exported and analyzed from a cloud service architecture integrating with data from other sources.

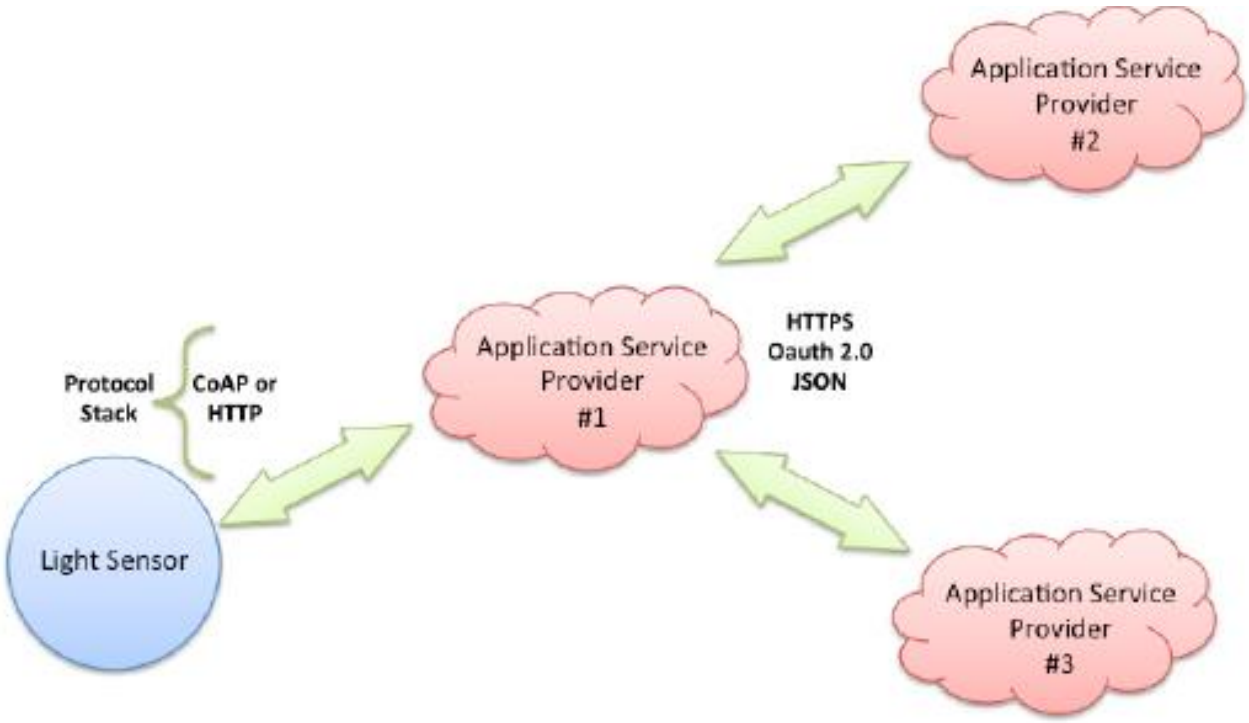

Fig 30: Back End Sharing Model

This provides the users the permission to uploaded sensor data to third parties. This model is basically an extension to the device to cloud model. For example, a corporate user has to analyze and consolidate the energy consumption by all the IoT sensors on the premises, in case of single device to cloud model the data produced by each IoT sensor sits in stand-alone silo.

Having an effective back-end data sharing architecture will help to analyze and access the data in the cloud that is produced by whole spectrum of devices in the premises. Also, this architecture helps the users to move their data when they switch between IoT services.

4.3 ARCHITECTURE OF IoT

4.3.1 **Three and Five-layer architecture:**

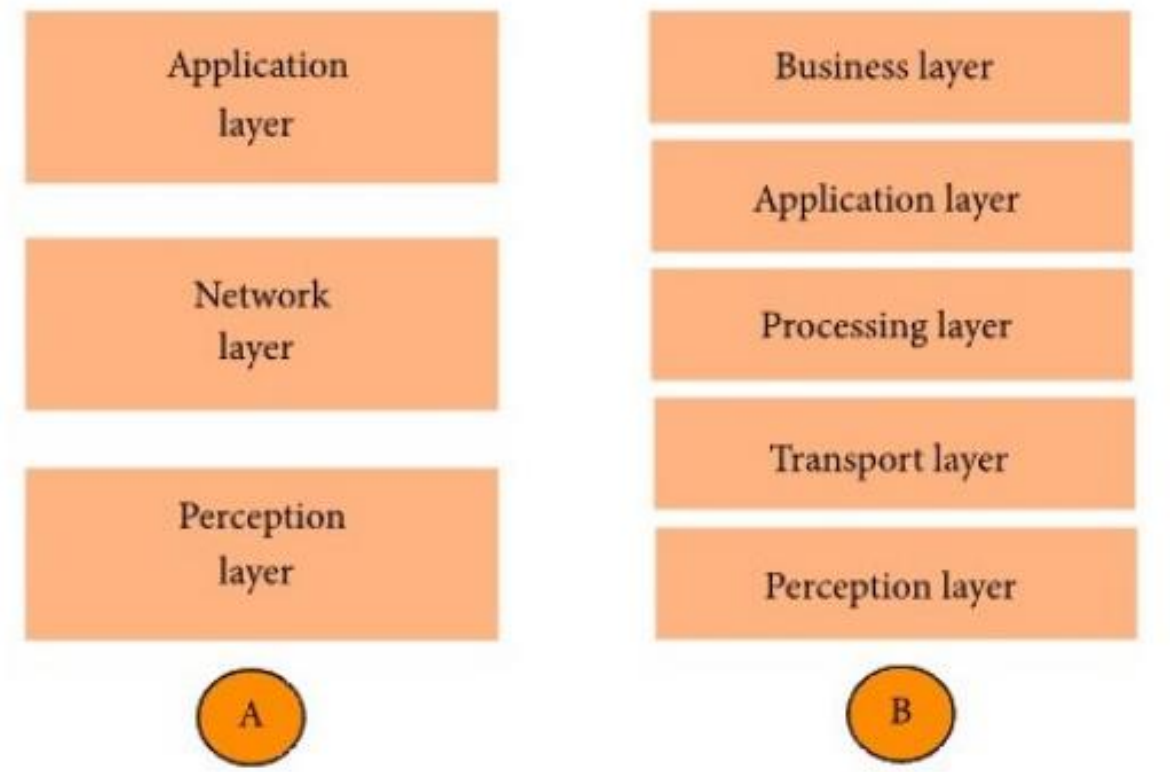

Fig 31: IoT 3 and 5 Layered Architecture

3-layer architecture is of the basic architectures of IoT that was introduced in the initial stages of research. It consists of three layers:

- Perception Layer: it basically senses and gathers the information about the environment with help of sensors. It acts as a physical layer. It is used for identification of smart objects in the environment.
- Network Layer: the function of this layer is to connect to networks devices and servers. The sensor data is transmitted and processed by network layer.
- Application Layer: It deals with the various applications that can be deployed with respect to Internet of things. Example smart homes, smart cities, smart health etc.

To have a better idea about IoT, 5-layered architecture was introduced which focuses on the finer aspects of IoT. The function of perception and application layer is same, but the functions of other 3 layers are:

- Transport Layer: the function is to transport the sensor data from perception layer to processing layer with help of networks such as wireless, 3G, Bluetooth etc.
- Processing Layer: the function of this layer is to analyze and process the data that it has received from transport layer. Various technologies that are employed by processing layer are cloud computing, big data processing modules etc.
- Business Layer: the main function of this layer is to manage the whole IoT system.

4.3.2 Cloud and Fog based Architecture

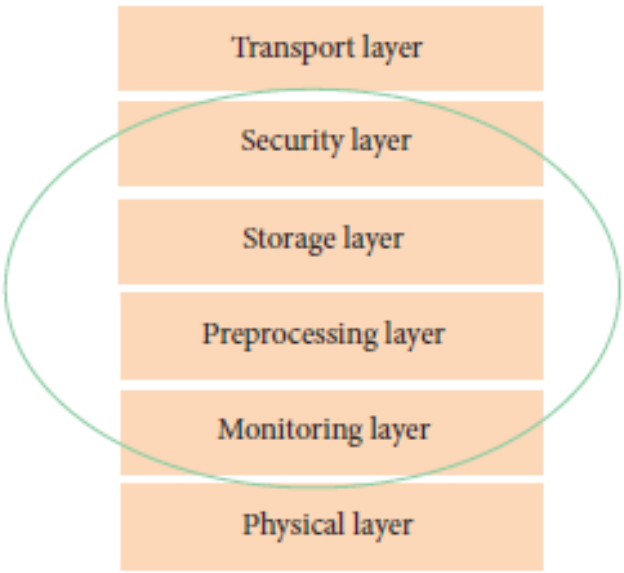

Fig 32: Cloud and Fog based IoT Architecture

In fog architecture the data processing and analyzing is done by sensors and network gateways. Fog architecture is a layered architecture where security, storage, preprocessing and monitoring layers are placed between transport and physical layer.

- The function of monitoring layer is to monitor power, responses and services.
- The function of preprocessing layer is to filter, analyze and process the sensor data
- The function of storage layer is to provide storage functionalities like data replication, data distribution etc.
- The function of security layer is to perform encryption and decryption and also checks for privacy.

Before the data is sent to the cloud, monitoring and preprocessing of data is done at the edge of the network.

4.4 INTERNET OF THINGS (IoT) TAXONOMY

Coming to the architecture of IoT the first component is the perception layer which uses sensors to collect the data. There are various kinds of sensors used today and smartphone is one of them and has a lot of sensors embedded in it for example GPS, camera, light sensor, microphone. Etc. apart from these various sensors are being used to monitor various things like temperature, pressure, humidity, medical parameters of body. Etc.

The next component is the data processing whose function is to filter and summarize data and make it available to the network. The next architectural component is communication where many devices communicate with each other using different protocol standards.

Protocols like radio frequency identification (RFID), and near field communication (NFC) are used for short range low power communication. Protocols like Bluetooth, ZigBee, Wi-Fi are used for medium range communication.

Communications in IoT requires different protocol mechanism that should run effectively on the devices to have an efficient communication with each other.

There are two kinds of software components for IoT:

1. Middleware: It basically creates an idea for the programmer where the hardware details can be hidden. This results in efficient interoperability. The various examples of

middleware services for IoT are OpenIoT, MiddleWhere, Hydra, FiWare and Oracle Fusion Middleware.

2. Applications: it includes various IoT applications like home automation, health and fitness, smart vehicles and transport system, smart cities, smart environment and entertainment etc.

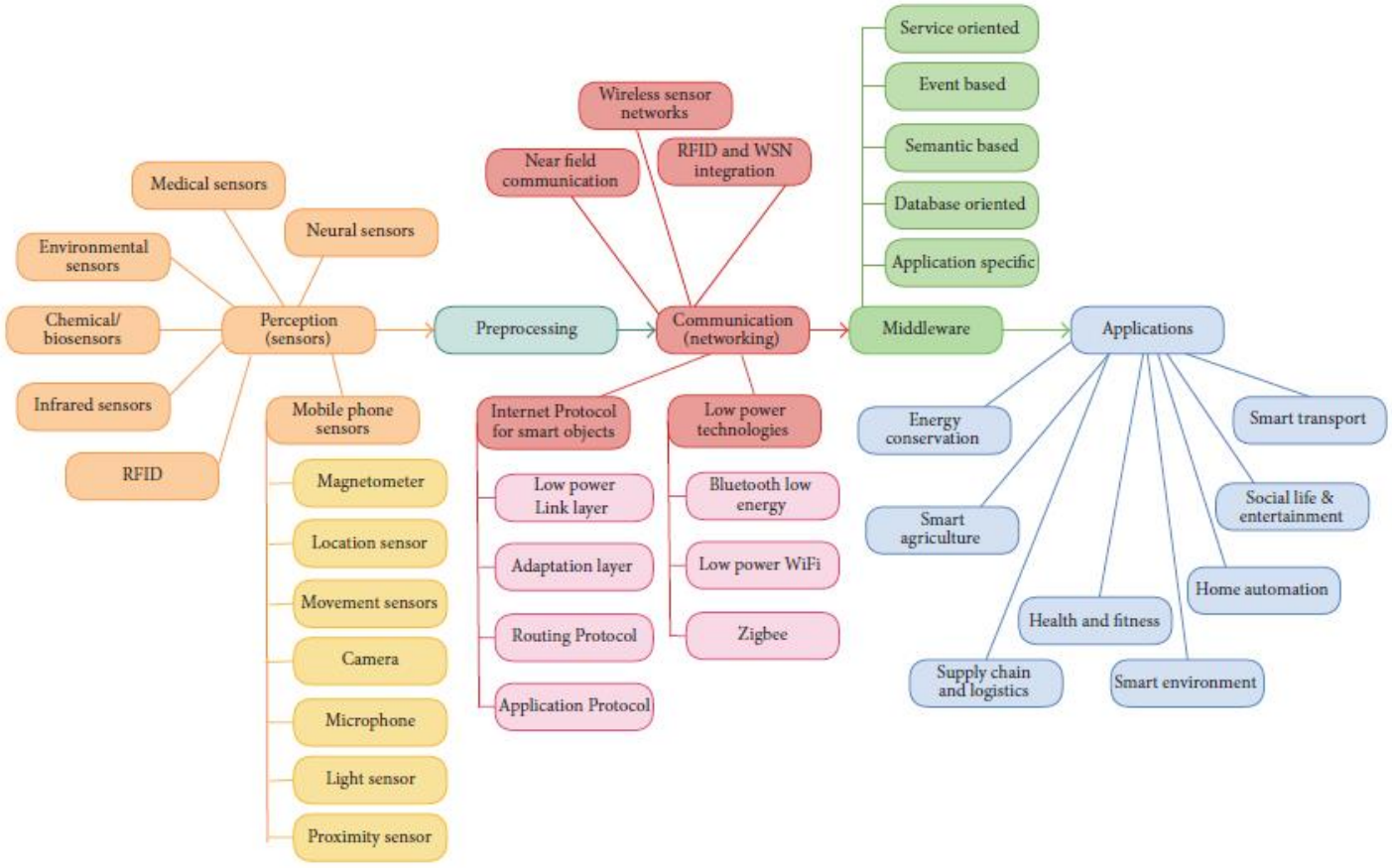

Fig 33: IoT Taxonomy

4.4.1 Sensors and Actuators

Sensors are the basic requirements in the IoT applications because they are responsible for collecting the data from the environment. The various types of sensors used in IoT applications are:

1. Mobile Phone based Sensors: smartphone is a very user-friendly device that itself has a lot of sensors embedded in it. With increase in the popularity and need for smartphones many companies are using them for IoT purposes because of sensors embedded in them. To bring out the meaningful data applications are built on the smartphones that uses sensor data. The diverse types of sensors in a smartphone are:

- Accelerometer sensor that helps to sense the motion and acceleration of a smartphone. Accelerometer can be used to sense physical activities of a user like walking, running with help of data patterns captured by the sensor.
- For capturing audio and visual information microphones and cameras are used which can help to analyze and capture lots of user information like the user's current environment.
- For detecting the location, GPS is widely used in the smartphones. The detection of location is done using trilateration.
- The light sensor in the smartphones can be used to control the lighting system.

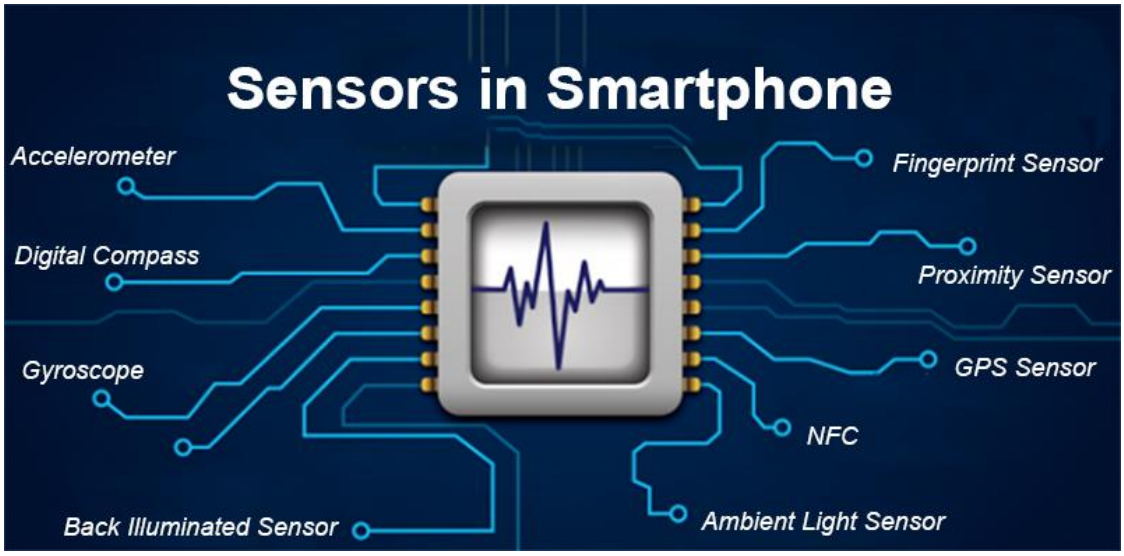

Fig 34: Sensors in Smartphones

2. Medical Sensors: In the healthcare system medical sensors are used to keep the track for person's health and fitness. Many devices are available in the market that are embedded with the sensors that are used for measuring various parameters like blood pressure, body temperature, heart rate and pulse etc.

There are many wearable devices present in the market like smart watches, fitness trackers, wristbands etc. smart watches basically have their connectivity with smartphones and smart sensors.

Another kind of advancement is the monitoring patches that are posted on the skin which are used by patients for few days for monitoring their health parameters.

Fig 35: Smart Watches and Skin Patches

3. Neural Sensors: EEG known as Electroencephalography is used for reading the brain signals. The electric field generated by neurons inside the brain can be measured from outside in terms of frequency. The various types of brain waves are alpha, beta, gamma, theta and delta. These waves can tell us regarding the brain activities. This information can be used in real time for training our brain to stay focused and manage stress etc.,

Fig 36: Neural Sensors

4. Radio frequency Identification: It is used for identification purposes and consists of an RFID tag that consists of data and RFID reader is used to read the data. The two types of RFID technologies are used in the market, near and far. The RFID tags can be attached to a vehicle to determine whether it's an authorized vehicle or not. It can be used for tracking the movement of objects.
5. Actuators: these devices are used for converting electrical energy into useful energy. Examples are speakers, lights, motors etc. In home automation systems actuators can be used for locking and unlocking of doors, switch on/off lights or any other electrical appliances etc. Actuators are of three types: electrical, hydraulic and pneumatic. The most common example in IoT is the digital finger used for switching on/off lights.

4.5 IoT APPLICATIONS

IoT has brought a lot of significant changes to the lives of people by connected them anytime, anywhere and at anyplace. It has played a significant role in various fields of life transforming into smart cities, smart healthcare, smart retail, smart transport system, smart vehicles. Etc. the key factors for building IoT are security, privacy, safety, integrity, trust, dependability, transparency, anonymity and ethics

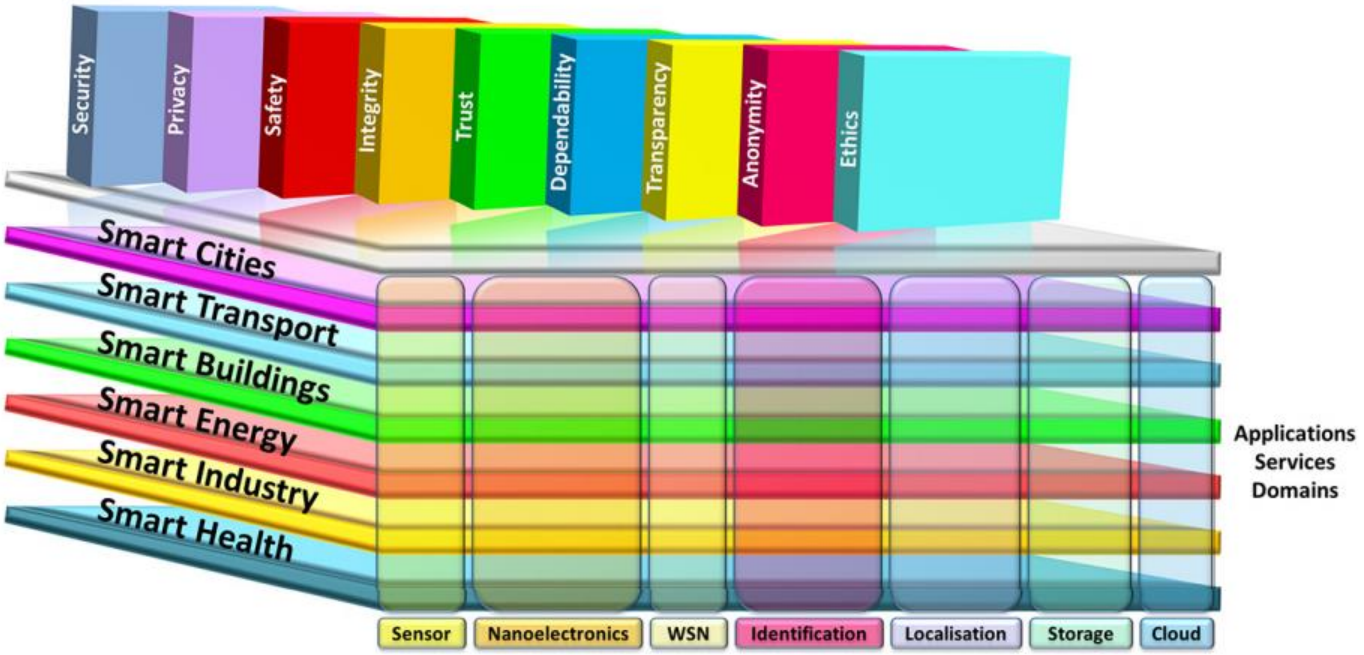

Fig 37: IoT 3D Matrix

The applications of IoT are very diverse and we have them in our daily lives. The different application domains of IoT which are most popular are:

- Smart Cities: it is estimated that by 2020 the cities will have a networked architecture and they will be named as smart cities. By 2025, 60% of the population is expected to live in the urban cities and the urbanization will have a significant impact on the lives and mobility.as per estimation, there will be 30 megacities globally by 2023 with 55% in countries like India, Russia, China and Latin America. Smart cities will enable various smart features like smart economy, smart buildings, smart mobility, smart energy, smart information and technology, smart planning, smart citizen and smart governance.

Fig 38: Smart City Concept

- Smart Health: the today's health market is focused on enabling such devices that are made up of diverse architectures and user friendly as well. IoT is playing a key role in smart health where patients can get help easily anywhere and anytime in the world. These techniques are very beneficial because it improves the quality of care and helps in cost reduction via eliminating the need of caretakers.

  The main aim is to improve the quality of lives of the people by providing right medical support.

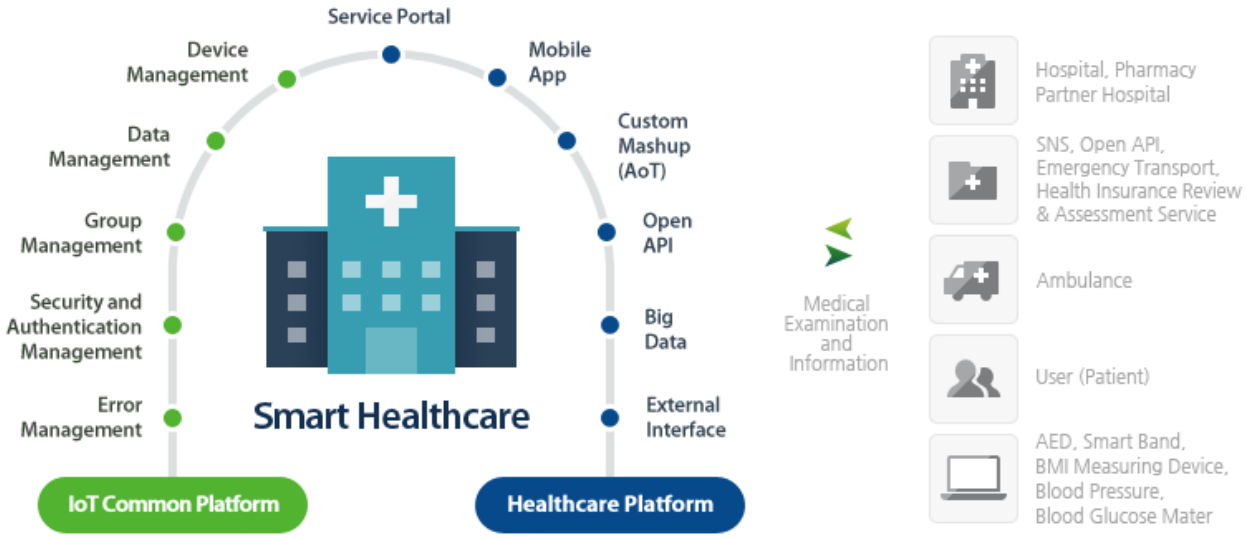

Fig 39: Smart Healthcare System

- Smart Homes: the IoT has played a vital role in building smart homes with sensors and automation system that provides people monitoring and control of their home appliances and system whether they are outside or inside. Smart homes consist of devices that provide security, comfort, energy efficiency and these devices are usually controlled by smartphones.

These days smart homes have controls for windows, doors, security, lighting, temperature etc. Requirements to set up a smart home includes sensors, actuators, controller, compatible appliances, network system and an interface.

Examples of smart home devices for 2017 are Amazon cloud cam, Philips hue white LED, ECOBEE thermostat, August's Smart lock, Wi-Fi video doorbell etc.

Fig 40: Smart Home System

- Smart Retail: the best example for the recent development in digital trends is shopping. Smart retail has made lives of consumers easy by making such applications that are user friendly and they can access information anytime and anywhere in the world.

The developments like online stores, physical stores, social media, and mobile communications have impacted the retail sector in a terrific way. With help of IoT lot of retailers have molded their way of retail to give better customer satisfaction.

Examples of IoT smart retail devices are Asset tracking via RFID, sensors and cameras for security and monitoring, in-store Wi-Fi, digital signage, IoT based payment systems, smart lightning etc.

Fig 41: Smart Retail Ecosystem

- Smart Water Systems: These days it has become really important to manage our water resources because of the increasing demand due to which many cities in the world are deploying meters on water supply lines to keep the record of water usage and wastage. The meters will keep a record of inflowing and outflowing water and will also check if there is any leakage or not.
- Smart transport: various applications are used in transport system to control and manage the traffic in the cities. Traffic conditions can be estimated when vehicles connect to each other through networks, RFID's, GPS, cameras etc. with help of smartphone sensors like accelerometer and GPS traffic congestion can also be predicted. Intelligent parking management system is being used in the cities which uses sensors to detect whether the parking space is available or not.

  Another new application is the smart traffic lights that have sensors and capture and analyze the information regarding traffic congestion in an intersection and will also forward the data to the neighboring traffic light system.

4.6 IoT PROTOCOLS AND STANDARDS

The Protocols that are used in IoT focus on multiple sensors so that can communicate properly and aggregate information before getting to the internet. In the routing layer, protocols are defined to have proper routing for sensors. The session layer protocols are used for enabling the messaging among various elements of ecosystem. Etc.

Session		**MQTT**, **SMQTT**, **CoRE**, **DDS**, **AMQP** , **XMPP**, **CoAP**, …	**Security**	**Management**
Network	**Encapsulation**	**6LowPAN**, **6TiSCH**, **6Lo**, Thread, …	TCG, Oath 2.0, SMACK, SASL, ISASecure, ace, DTLS, Dice, …	**IEEE 1905**, **IEEE 1451**, …
	Routing	**RPL**, **CORPL**, **CARP**, …		
Datalink		WiFi, **Bluetooth Low Energy**, **Z-Wave**, **ZigBee Smart**, **DECT/ULE**, 3G/LTE, NFC, **Weightless**, **HomePlug GP**, **802.11ah**, **802.15.4e**, **G.9959**, **WirelessHART**, **DASH7**, ANT+, **LTE-A**, **LoRaWAN**, …		

Table 4: IoT Protocols

4.6.1 **DATA LINK PROTOCOLS**: It includes various physical and MAC layer protocols.

- **IEEE 802.15.4**: This protocol is widely used and is most common standard for MAC. It defines source address, destination address and how communication should be done between the nodes. Its extension was IEEE 802.15.4e which was introduced in 2008 to support low power consumption. Various features include:
  - Slotframe Structure: this structure deals with scheduling and informing nodes what to do. During the sleep mode, the node saves the power by turning off its radio and will collect all the information and messages that it will forward at next transmission opportunity. After transmitting the data, it waits for the acknowledgment. When the message has to be received, the node will turn on, receive the message and will send an acknowledgment and then it will turn off

its radio and will deliver that data to the upper layer before going back to sleep.

- Synchronization: It is very important that nodes communicate with each other properly and it is made sure by synchronization. Synchronization can be achieved in 2 ways: acknowledge based and frame based synchronization. Acknowledge based is the one where node sends the message and receives the acknowledgment once the message is received and this ensure proper connectivity between them.

- **IEEE 802.11 AH**: this standard is the low energy version of the previous one. It is widely used in laptops, computers, tablets, digital TV's etc. various features include:
  - Synchronization Frame: A station should have complete medium information that allows it to capture the medium and stop packet exchange, then only the station can transmit. If the duration packet is correctly received, then the station will have information otherwise it has to wait a specific amount of time called probe delay.
  - Efficient Bidirectional packet exchange: In bidirectional packet exchange there is uplink and downlink communication between access point and sensor which saves the power. Once is communication is finished, the sensor will go back to sleep.
  - Short MAC Frame: the normal frame as per IEEE 802.1 is 30 bytes which is not suitable for IoT applications, IEEE 802.11ah introduces a short MAC frame which is 12 bytes.

- **WirelessHART**: It is based on time division multiple access and lies on the top of the IEEE 802.15.4 PHY. In order to offer better reliability, it uses advanced encryption to encrypt messages and calculate integrity. The architecture consists of Network manager, gateway to connect wireless devices to wired networks, security manager, routers, adapters etc.

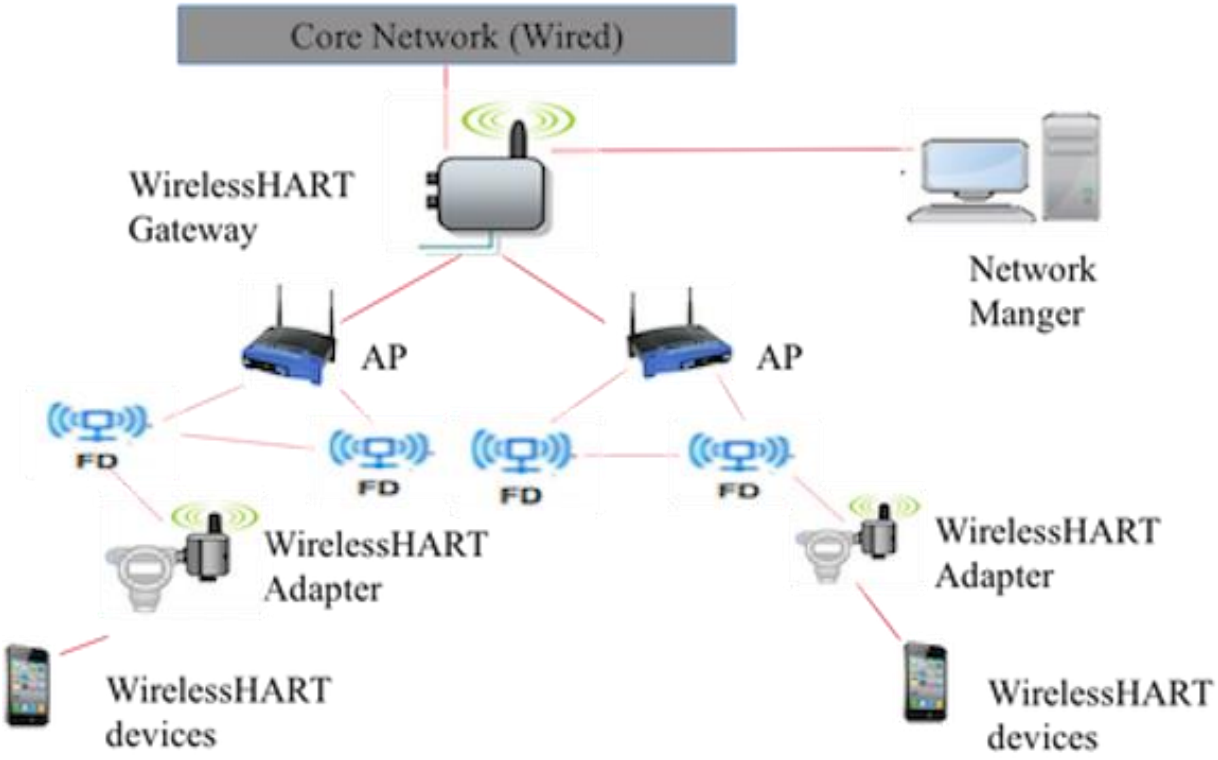

Fig 42: Data Link Protocol

- **Z-Wave**: This protocol is mostly popular in smart home system because of its low power characteristic. It offers 30 m point to point communication and used for applications like light control, energy control, health care control etc. It is based on CSMA/CD for collision detection and ACK for good transmission.

- **Zigbee Smart Energy**: It is used in many IoT applications like smart homes, smart healthcare, remote controls etc. various topologies supported by Zigbee are star, peer to peer or cluster-free. There are 2 stack profiles that are defined by Zigbee standards: Zigbee and Zigbee Pro where both support full mesh networking.

- **DASH7**: It is a wireless communication protocol and is available in Industrial Scientific Medical band. It is used for long range outdoor coverage and supports IpV6

addressing. Its architecture is based on Master/Slave architecture. Various features defined are:

- Filtering: CRC, a 4 bit subnet mask and link quality assessment are used for filtering of frames and processed further.
- Addressing: Two types of addressing used by DASH7 are: unique identifier which is a EUI 64 bit ID and dynamic address identifier which is 16 bit address identified by network administrator.
- Frame Format: The frame is of variable length consisting of maximum 255 bytes which had addressing, subnets, estimated power of transmission etc.

- **LTE-A**: It is used for M2M communications and applications in cellular network.

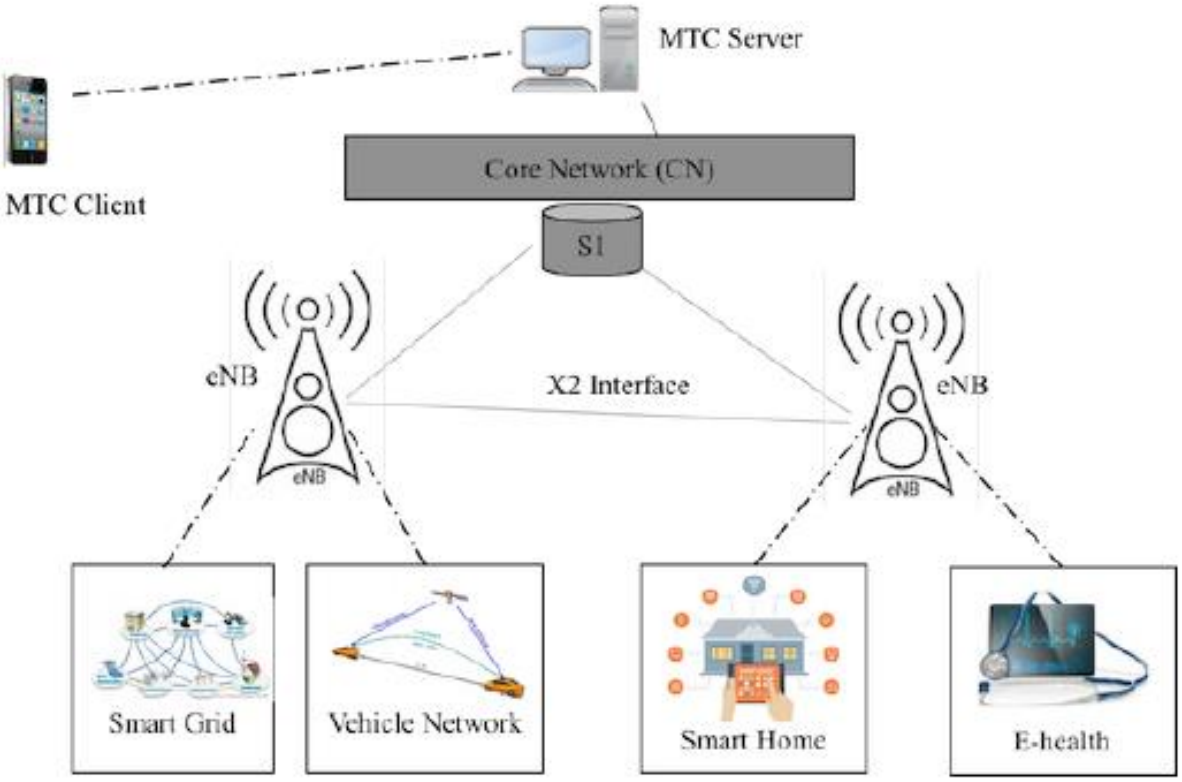

Fig 43: LTE-A Network

It is based on orthogonal frequency multiple access where MAC layer divides frequency into multiple bands so that each one can be used separately. The various components of its architecture are Core network, radio access network, and mobile nodes. The function

of core network is to monitor the mobiles devices and keep a track of their IP's. The function is radio access network is to handle wireless connectivity and establish control and data planes.

- **LoRaWAN**: It offers low power, low cost, security, mobility and bi-directional communication. It is considered to be the new arising wireless technology which is designed for low power WAN networks. . LoRaWAN is based on star topology. The end devices get the messages via gateways which act as a transparent bridge and a central network server is in the backend. The3 types of end devices defined by LoRaWAN are:
    1. Class A: The devices that fall under Class A bidirectional communication between device and gateway. The messages that are sent from device to server are known as uplink messages and can be sent randomly. The two receive windows will be opened at 1sec and 2 secs and if the server doesn't respond to these open windows then it will have to wait until next transmission.
    2. Class B: It is an extension of Class A. These devices add up for scheduled receive windows for messages from server.
    3. Class C: Until the transmission is taking place, the receive windows will be kept open.

4.6.2 NETWORK LAYER ROUTING PROTOCOLS: The network layer is divided into 2 sub layers: routing layer which is responsible for transfer of packets from source to destination and encapsulation layer which forms the packet.

- **RPL:** It is a distance vector protocol that has destination oriented directed acyclic graph which represents only one route from each leaf node to the root in which all the traffic will be routed to. It is defined as routing protocol for low power and lossy networks. It constructs the Destination Oriented Directed Acyclic Graph (DODAG) which consists of only one single route from leaf node to the root in which all the traffic from the node is routed to.
- **CORPL: T**he extension to RPL is known as CORPL which is designed for cognitive networks. It chooses the forwarding path through multiple forwarders and chooses the next best hop to forward the packet after building a coordination with nodes. It builds up

two modifications in DODAG. Each node updates its neighbor by DIO messages regarding any changes and also consists of forwarding sets. With the help of updated information, the neighbor priorities are also updated so that forwarder set can be constructed.

- **CARP:** It stands for channel-Aware Routing Protocol and is designed for communications which are underwater. It has 2 cases: network utilization where HELLO packet is transmitted from sink to all other nodes in the network and data forwarding wherein hop by hop fashion packet is routed from sensor to sink. Due to its lightweight packets it is used in IoT. One of the biggest disadvantage of CARP is that it doesn't reuses previously collected data. The enhancement to CARP is known as E-CARP in which sink node will save all the previous data. The E-CARP will send the ping packets whenever the new data is required which results in reducing the communication overhead.

4.6.3 NETWORK LAYER ENCAPSULATION PROTOCOLS: One of the problems with the IoT applications is that it cannot accommodate IPV6 addresses because they are too long. Therefore, IETF is building mechanisms that can help to accommodate such long addresses. Various mechanisms are**:**

- **6LoWPAN:** It is one of the most commonly used standard which accommodates long addresses in IEEE802.15.4 small packets which cannot exceed 128 bytes. This standard uses four types of headers: No 6LoWAN header (00), Dispatch header (01), Mesh header (02) and Fragmentation header (03). This standard gives specifications which support different topologies, low bandwidth, low power, mobility, long sleep time, low cost. Etc.

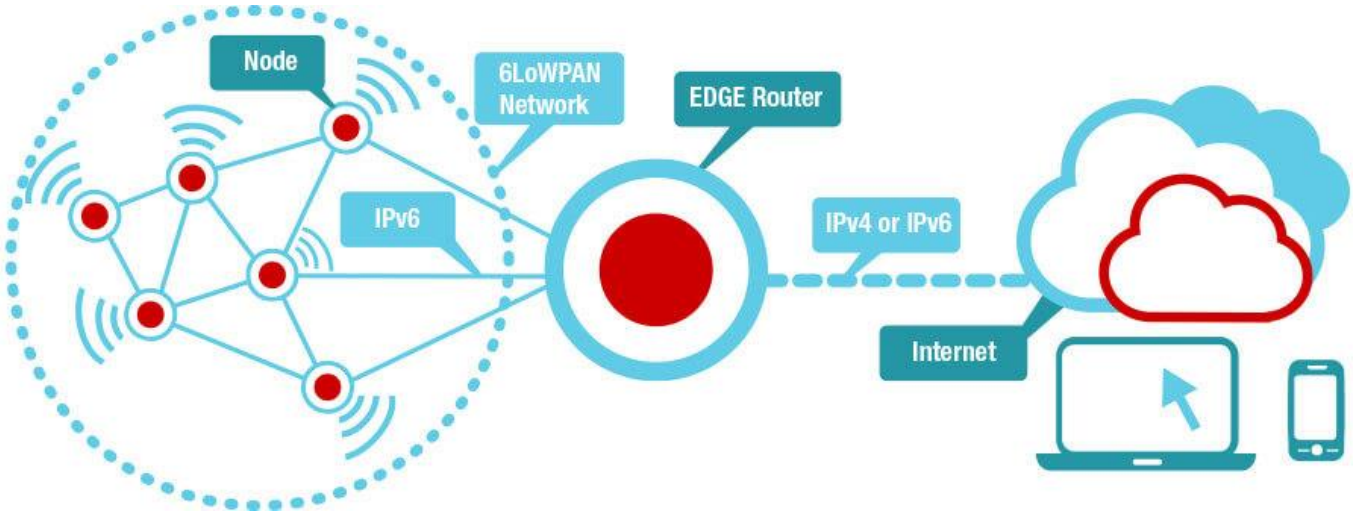

Fig 44: 6LoWPAN

Functions of four types of header are:

(00), frames are discarded if they don't follow 6LOWAN specifications.

(01), it is used for multicasting and used for compressing IPV6 header.

(02), it is used for broadcasting.

(03), this is used to break the IPV6 header so that they can be accommodated in fragments of maximum 128 bytes.

- **6LO**: This standard is used to facilitate the connectivity of IPV6 over restricted node networks. Two 6LO specifications have been defined:
  a. IPV6 over G.9959: It defines a home network identifier which is 32 bits and is assigned by controller and also a host identifier which is 8 bit and allocated for each node.
  b. IPV6 over Bluetooth low energy: The LLC and L2CAP layer provides segmentation and reassembly of large payloads into 27 byte packets.

4.6.4 SESSION LAYER PROTOCOLS: TCP and UDP have been used by various IoT applications and even IP applications for transport. The various session layer protocols defined are:

- **MQTT**: It stands for Message Queue Telemetry Transport and was introduced in 1999 by IBM and was standardized in 2013 by OASIS. On one side it provides embedded connectivity between applications and middleware and on the other side it provides networks and communication.

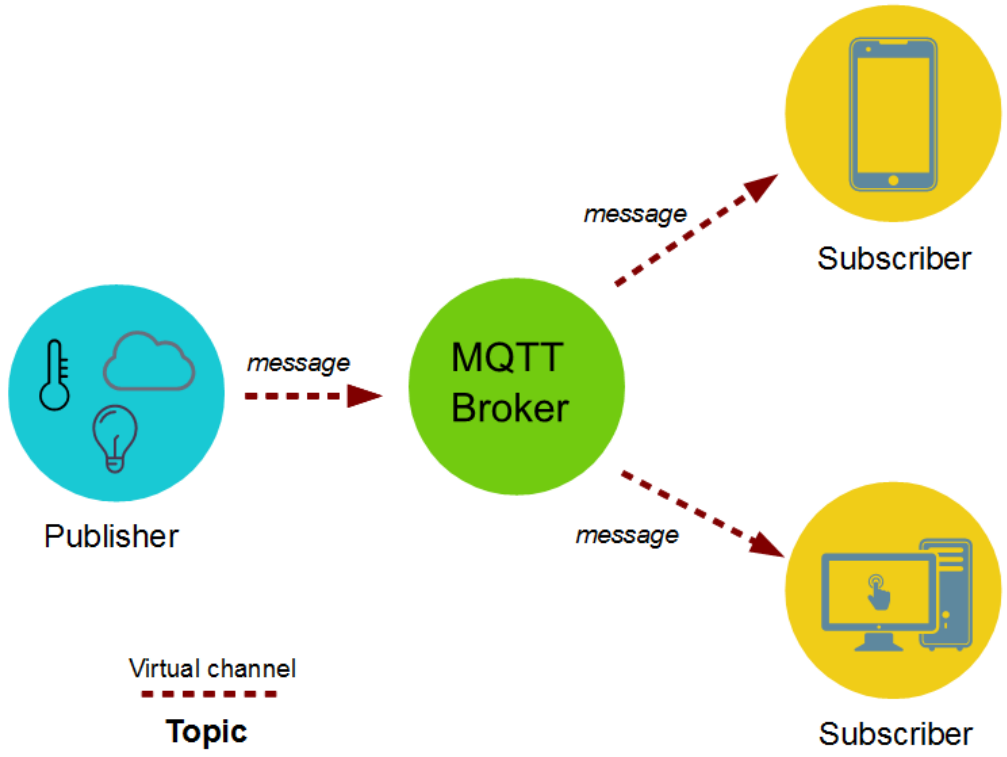

Fig 45: MQTT Protocol

It is based on publish/subscribe architecture. The above figure shows the 3 components of architecture namely publisher, MQTT broker and subscriber. In IoT applications the publisher is the sensor which is lightweight and used to connect to the broker so that it can forward its data and go back to sleep whenever possible. Subscriber is the application that is connected to broker which informs them whenever a new sensory data is available. The MQTT broker will break the sensory data into similar group topics and send them to the subscribers according to their need.

- **SMQTT**: It is the extension of MQTT and uses encryption based on lightweight attribute. This kind of feature has an advantage of broadcast encryption which

will encrypt the message and will be delivered to multiple nodes. It has four main stages:

a. Setup: in this phase the subscribers and publishers register themselves to the broker and in return they are assigned a master secret key.
b. Encryption: when the data is published by publishers it is encrypted at this stage.
c. Publish: when the data is received to broker it is then published and sent to subscribers.
d. Decryption: at this stage the data is decrypted at subscribers.

- **AMPQ:** this protocol stands for Advanced Message Queuing Protocol and was designed for finance industries. It is based on same architecture as MQTT and runs over TCP.

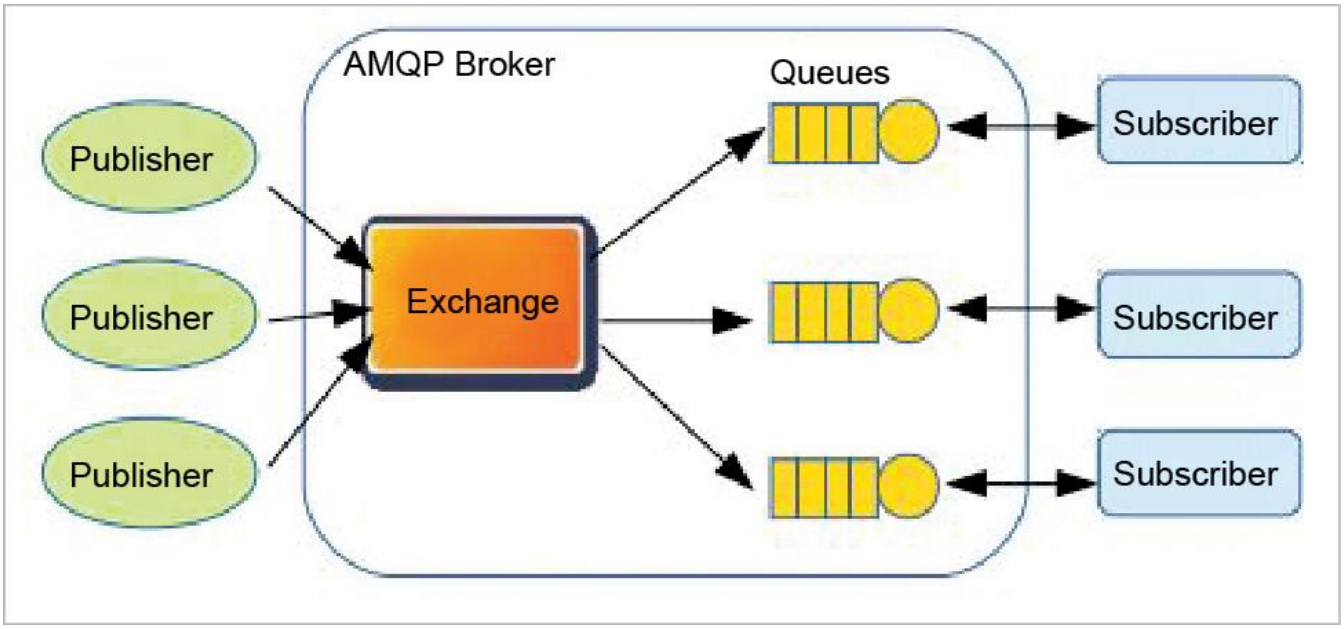

Fig 46: AMPQ Protocol

The main difference between architecture of MQTT and AMPQ is that the broker is divided into 2 categories exchange which receives the publisher messages and forwards to the queues

based on the pre-defined categories. Queues are basically the topics that are broken according to subscribers needs.

- **COAP:** It stands for Constrained Application Protocol. The interface used between HTTP client and server is known as Representational state transfer (REST). COAP helps to provide a RESTful interface which uses low power sensors.

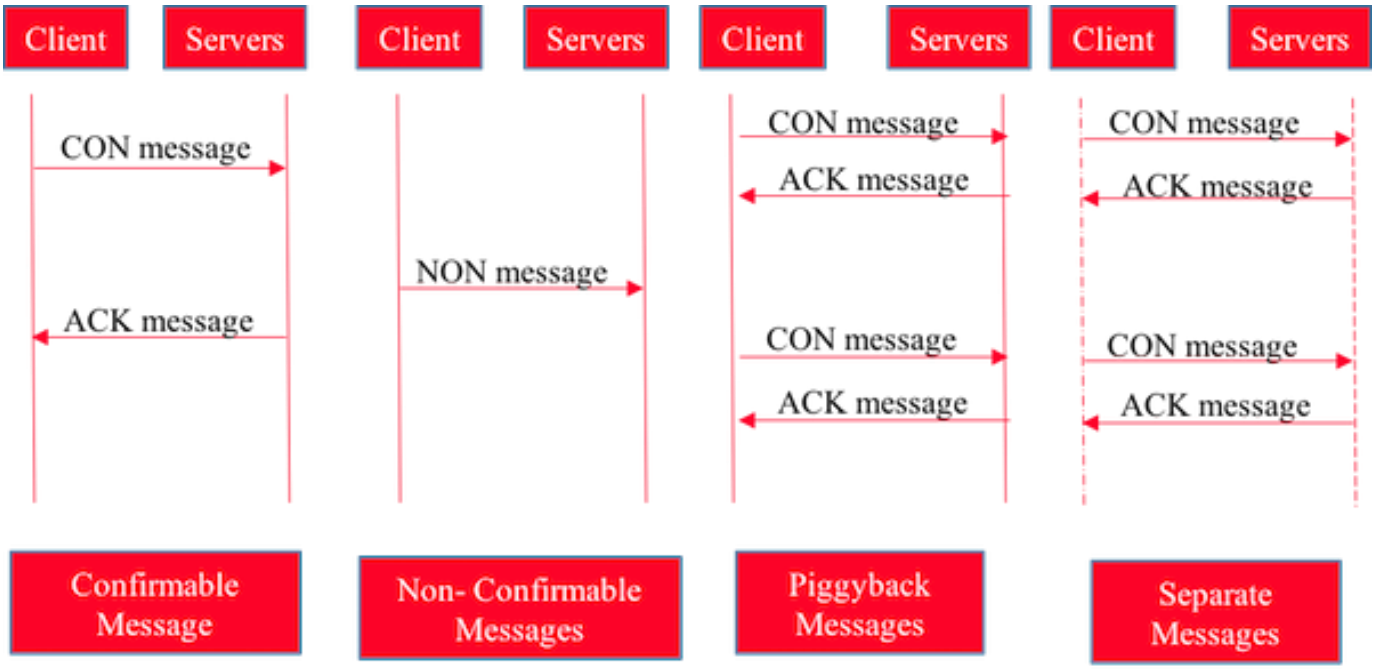

Fig 47: COAP Protocol

To provide reliability, it is built over UDP instead of TCP. The two main sublayers of COAP are:

a. The messaging sublayer: it deals with duplication of messages and reliability
b. Request/response sublayer: it deals with communication.

CoAP has four messaging modes: confirmable and non-confirmable modes represent reliable and unreliable transmissions, piggyback is used for client and server communication while separate mode is used server comes across a message separate from acknowledgment. The request used by CoAP are GET, PUSH, PUT AND DELETE to retrieve, create, update and delete respectively.

- **XMPP:** It stands for extensible messaging and presence protocol which is used for chatting and message exchange applications. It is used in near real-time applications and is highly efficient over internet. However, it does not provide QoS and thus not suitable for M2M communication.

4.6.5 IOT MANAGEMENT PROTOCOLS: There are 2 management protocol standards that are used to provide communication between different data links and play a critical role in IoT applications.

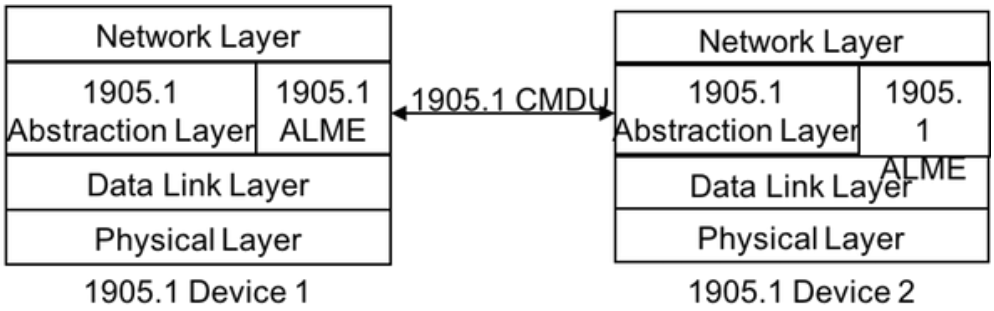

Fig 48: IoT Management Protocols

The 2 standards are: Interconnection of heterogeneous data links and Smart transducer interface. The main function of abstraction layer here is to hide the features of different protocols and exchanges messages known as control message data units. The figure above shows the abstraction layer management entity used in IEEE 1905.1 devices which offers topology exchange, security associations, and topology change notifications. Etc.

Smart transducer interface standard is uses plug and play identification with help of transducer electronic data sheets known is TED's. These data sheets are present in transducers which contains information which is required by measurement system.

4.7 INTERNET OF THINGS CHALLENGES

When applications are developed using internet of things there are a lot of challenges that come in the way to deliver a successful and a smart application for users. The following are some challenges:

- **Mobility:** To work efficiently IOT devices change their IP addresses and network according to the location due to which the routing protocol has to rebuild the DODAG every time when there is a network change which adds a lot of overhead. There can be a possibility that due to mobility there is a change in service provider due to which another layer of complexity is added because of service interruption and changing gateway.
- **Reliability**: The IoT devices and applications should work effectively so that they don't cause any trouble to the users. The devices should be highly reliable and effective in collecting data to avoid any disastrous scenario.
- **Scalability:** In each same network millions of devices are connected to each other and sometimes there is an issue of scalability where the devices are hard to manage on that same network. To prevent scalability IoT devices should be flexible enough to accommodate new services and operations.
- **Management:** Sometimes it is really difficult to manage the devices and keeping record of their failures, performances, configurations, system changes etc. FCAPS, which is Fault, Configuration, Accounting, Performance and Security are the key factors that the providers should always look upon.
- **Availability:** IoT availability comes in two ways, software where service is provided to users anywhere and anytime and hardware, where the devices are easily accessible and are compatible with IoT protocols.
- **Interoperability:** There are enormous number of different platforms in IoT where different devices are connected to each other. Sometimes it is challenging because many devices are protocols need to inter-work together on a large platform. The developers and device manufactures should work together on the interoperability so that the customer can use any specifications on a platform or a hardware.

4.8 LATEST TRENDS IN INTERNET OF THINGS

- **International Data Corporation predicts jump in IoT spending in 2018**

As per the latest reports from IDC spending on IoT will reach $772.5 billion in 2018 which is an increase of 14.6%. The areas that are expected to have substantial portion of spending includes the hardware things like modules, sensors, infrastructure and security. Software and services will also account for total growth of 16.1% and 15.1% respectively. As per the reports of IDC the top 3 industries that will have most of the spending in 2018 are: manufacturing, transportation and utilities.

- **Changes in Cybersecurity – Harvard Business Review**

In 2016 due to breaches there was a loss of nearly $4 billion in the businesses and as per reports it rose to 36% in 2017. Due to large amount of security attacks, in 2018 businesses are expected to invest $93 billion in cyber defense**.** To overcome the security issue our systems should have an intelligent cybersecurity system that works independently without any human supervision. With the help of an intelligent system suspicious traffic behavior can be immediately identified.

- **Italy launches a new wireless network for the internet of things**

In January 2018, Italy's largest communication provider Telecom Italia is working to bring a new wireless network for IoT. Two types of networks are being deployed which are Long Term Evolution for Machine and Narrowband-Internet of Things which will only be used for low power devices. The specifications for these networks were released in 2016 by 3rd Generation Partnership Project and after that almost 21 countries including China, Germany, Spain, Turkey, and USA have deployed these networks. LTE-M provides lower latency in order of 10ms whereas NB-IOT provides high latency of order 10 seconds.

CHAPTER 5

SMARTBIN SOLUTIONS AND INTERNET OF THINGS

5.1 INTRODUCTION

In today's life internet and its applications are playing a significant role. Another advancement with applications of Internet of Things is Smart Bins. In beginning of 1990's waste management collection was introduced in Germany and then later in European countries. At that time green, blue, brown, yellow and gray bins became really popular for collecting waste and over the past few years lot of advancement and improvements have been done in waste collection and recycling.

Reverse Vending Machines were introduced as well in the market which was another big step towards waste management system. Citizens used to bring plastic, glass and cans and used to receive exchange vouchers that they can use in supermarkets.

Fig 49: Reverse Vending Machines

Nowadays a lot of RVM's are being used which are developed by Tomra, RVM systems, Diebold etc. In this modern era which changes to lot of applications and advancement in the market new waste management system have been deployed known as Smart Bins, which are now being used for waste collection.

Smart Bins uses sensors, network protocols like Lora WAN and cloud platform for analyzing, visualization and data collection. Few countries that have deployed Smart Bins are Sweden, which has deployed an automatic vacuum waste collection system that is only applicable to collect only four types of waste: recyclable paper, cardboard, organic waste and general waste. This smart bin system does not collect light bulbs, batteries, lamps, large sheets of cardboard etc.

Republic of Korea uses 3 types of garbage systems: RFID based garbage system, chips and stickers and standard plastic garbage bags. One of the most significant difference between these 3 systems is that in RFID based garbage system accurate discharge weight can be obtained while college the waste.

Type	Pros	Cons
Plastic garbage bags	(i) Convenient discharge (ii) High adaptability in poor environments	(i) Inaccurate measurements (ii) Odor problems (iii) Spoils the beauty of the city
Chips and stickers	(i) Remedies for the shortcomings of plastic garbage bags (ii) Various charge commissioning methods	(i) Inaccurate measurements (ii) Elaborate charge commissioning system required (iii) Inconvenient discharge and bin management
RFID-based garbage collection system	(i) Accurate weight measurement (ii) High impact on food waste reduction	(i) Causes server overload owing to data concentration (ii) Low mobility from a fixed power supply (iii) User inconvenience caused by complex discharge process

Table 5: 3 Types of RFID based Garbage System in Korea

Smart bins are an upcoming IoT based application that will bring a new change in the world and environment as well because waste management is one of the biggest issues in the world these days. It is estimated that by 2030, almost 2/3rd of the world's population will be living in the cities due to which it is important to develop the sustainable solutions for urban life.

Efficient and energy saving waste management system can prove an asset to the society and help in waste management as well which in return will prove beneficial for human health and environment.

5.2 SMARTBINS SOLUTIONS

Smart bins is an emerging application of IoT that helps to collect the waste smartly with help of sensors, network gateways, cloud platforms etc. Several types of smart bin solutions have been proposed till now.

5.2.1 SMART GARBAGE BIN COLLECTION SYSTEM:

RFID based smart bins consists of communication module that is used for communicating with central server, RFID tag module that is used to read data from RFID card, automatic garbage entrance and scale function used to measure the amount of food wastage. The drawback for this kind of system is server overload, because collection bin only communicates with server and doesn't have a communication with other collection bins and due to fixed power supply, RFID based system lacks mobility.

To overcome these issues IoT based SGS system was introduced which is applicable to both internal and external environment. It includes the below mentioned components:

- **Reliability:** Having a reliable communication is a key factor where devices communicate with each other efficiently. The smart garbage bins used in the new SGS system communicate well with each other using wireless mesh network which gives a secure reliability.
- **Mobility:** it is possible that IoT devices have to move depending upon the location and environment. SGS uses battery instead of fixed power that was used in RFID card system. Using the battery in the system helps to secure mobility.
- **User convenience:** Smart garbage system helps to reduce the waiting time for processing the waste food and hence is user friendly and convenient.
- **Energy efficiency:** many of the IoT's rely on infrastructure and require high mobility which causes large amount of energy consumption. To prevent this SGS uses energy efficient techniques which helps to increase the battery lifetimes.
- **Service continuity:** IoT is a large domain where data exchange and services should be used anywhere and anytime. SGS which communicates on basis of wireless mesh network helps the user to process the waste anywhere a bin is available.

5.2.2 SMART GARBAGE SYSTEM ARCHITECTURE

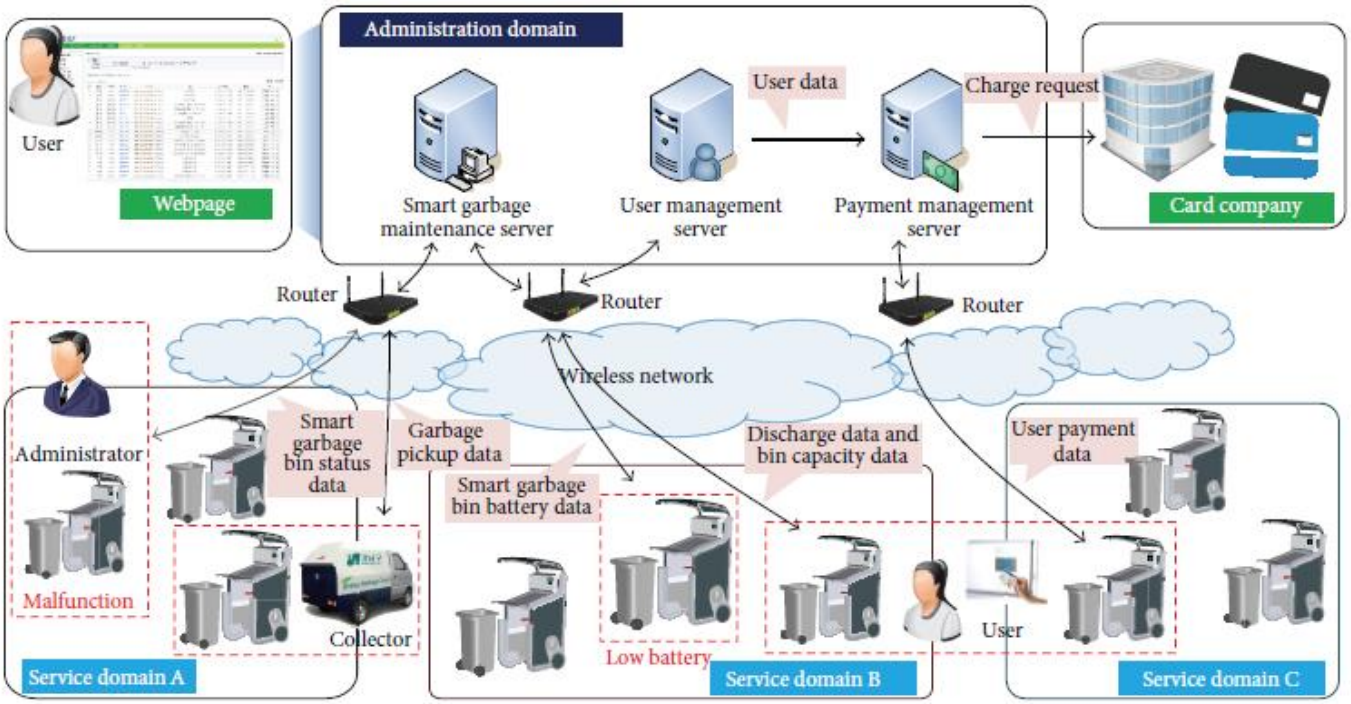

Fig 50: Smart Garbage System Architecture

Smart Garbage system exchange information with other via wireless communication. Their installation is near buildings, houses, apartments etc. and the information gathered is sent through wireless network. The smart garbage system is divided into 2 categories:

- **Administration Domain:** In this domain whatever the information is gathered by smart garbage system, it is analyzed and processed. The information consists of data about residents, payment and the status information which includes information about battery life, memory and any malfunctions if present. To have the proper working 3 types of servers are used.
    - User Management Server: this server helps to gather the information about residents and manages the food waste discharge information. In this server, the information about food waste discharge is classified on basis of resident, their region and bin.

- Payment Management Server: this server helps to process the payment which is based on the weight of waste food and payment is done through user's card company. When the user uses his RFID card to discharge the waste, the personal information is resident is forwarded to charge management server through which a request is made for the payment.
- Smart Garbage Maintenance Server: this server gathers the information about status of smart garbage bins, the amount of waste food a bin has and how much waste a company has collected. In case of a malfunction, a request is made to the administrator to check the problem and residents are made to use the near by bins.

Administration domain gathers all the information and is provided to the residents via web based services where they can check their payment information and amount of food they have thrown.

- **Service domain:** In this domain when a resident comes to throw the waste, they use their RFID card. The bin will open the lid once the RFID card of a resident has touched the RFID reader of smart garbage system and the resident has been authenticated. Once the resident throws away the waste it is then weighed, and the information is sent to the administrative domain.

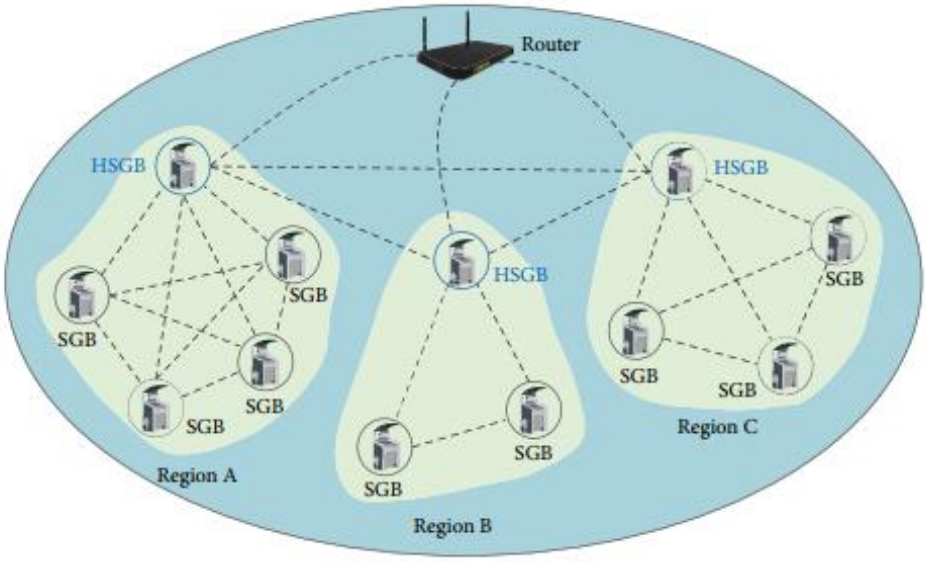

Fig 51: Network topology of Smart Garbage Bins

The above figure shows the network topology of smart garbage system located in service domain. The garbage bins exchange information and have communication through wireless mesh network. The use of HSGB, header smart garbage bin is to manage all other smart bins after analyzing and collecting information from them. The HSGB communicates with other HSGB's through wireless mesh network and exchanges information through this network only.

5.2.3 DISCHARGE PROCESS OF SMART GARBAGE BIN SYSTEM:

In case of simple RFID based garbage system, when a resident comes to throw the waste, they have to touch the RFID card to the bin 2 times because for the first time the bin will does the resident authentication and second touch is for the payment. This causes the delay in whole process because till the time the waste is being weighed the resident has to wait for the payment which causes inconvenience for the residents. In the newer system which is smart garbage bin system, the delay is prevented because the resident has to touch the card only once. Once the resident has been authenticated and the food waste has been weighed, the information about the FRID card will be shown on LCD screen of smart garbage bin system where the information is gathered using previous payment data from the server and the present weight of the waste. If there is no other resident waiting in line to throw the waste, the bin will send the payment data to server with help of router and then server will process the payment on basis of the company card information of a resident. The figure below shows the difference between a RFID based garbage system and newly proposed Smart garbage bin system.

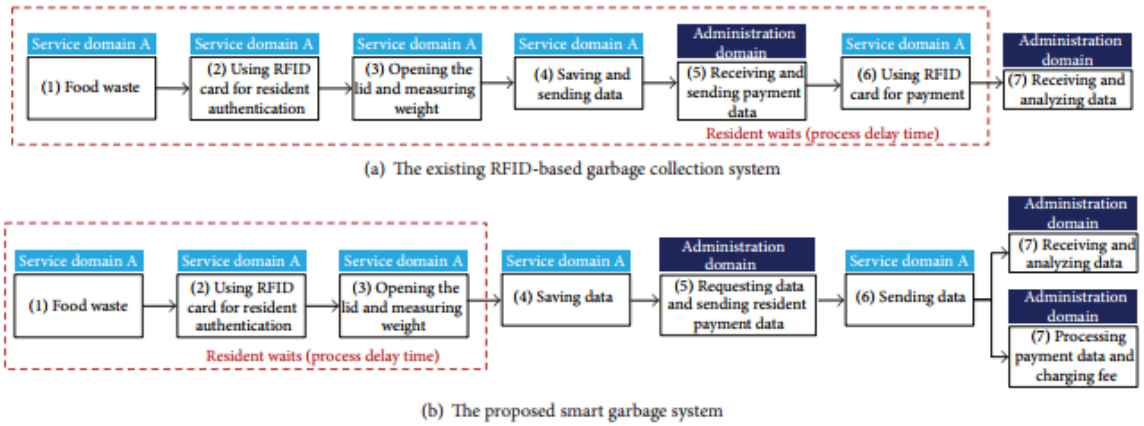

Fig 52: Difference between RFID based bin system and Smart garbage bin system

5.2.4 MIDDLEWARE ARCHITECTURE OF SMART GARBAGE BIN SYSTEM

The middleware service is basically based on the service that is combination of administration domain and service domain. The function of router in the administration domain is to boost the weakness of centralized server when number of smart bins are increased in the location. Therefore, multiple routers are used to avoid any traffic and load. The centralized server in administration server is made up of three modules: service management, charge management and maintenance management module.

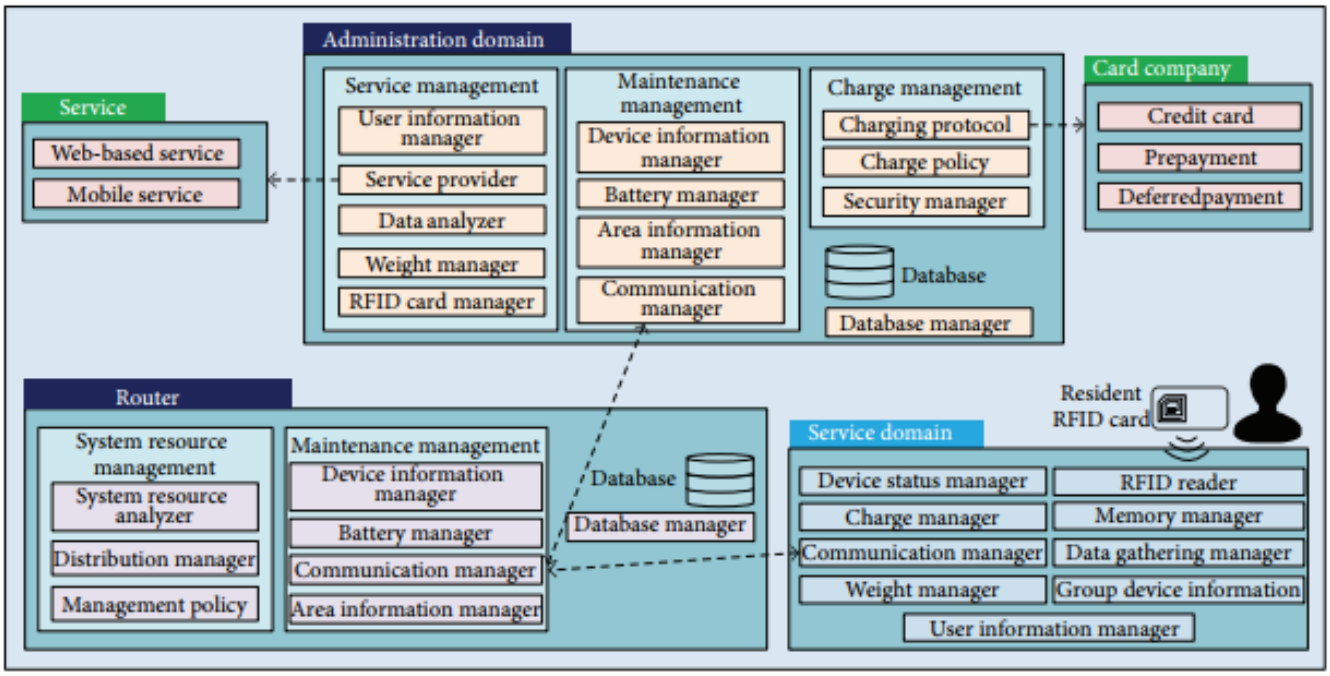

Fig 53: Middleware Architecture of Smart Garbage Bin System

- **Service management module:** It consists of user information and manager that modifies the user information when there is a change, a service provider that helps to provide web-based service, a data analyzer that helps to analyze the compiling statistics information, a weight manager that helps to provide information about the unit price of waste food and lastly RFID card manager that helps to manage the information about RFID card.
- **Maintenance management module:** This module consists of device information manager which helps to gather information about each smart garbage bin, a battery

manager which keeps the track of a battery that is used in the bin, a communication manager which keeps the record and provides information about the communication status and lastly an area manager which keeps and provides information about the area.

- **Charge management module:** It consists of 3 components: a charge protocol which helps to cooperate with an external charge interface, a charge policy component and lastly a security management component that deals with encryption for charge information.

Along with these 3 modules a database and database manager are also used which are used to provide the information to a server or router.

5.3 LATEST TRENDS IN SMARTBIN TECHNOLOGY

5.3.1 Improving EHS performance and cost reduction through Smart Waste Management

It is right that collecting waste from areas can be a tough job when sometimes the bins are overflowing with garbage and they are not emptied on time.

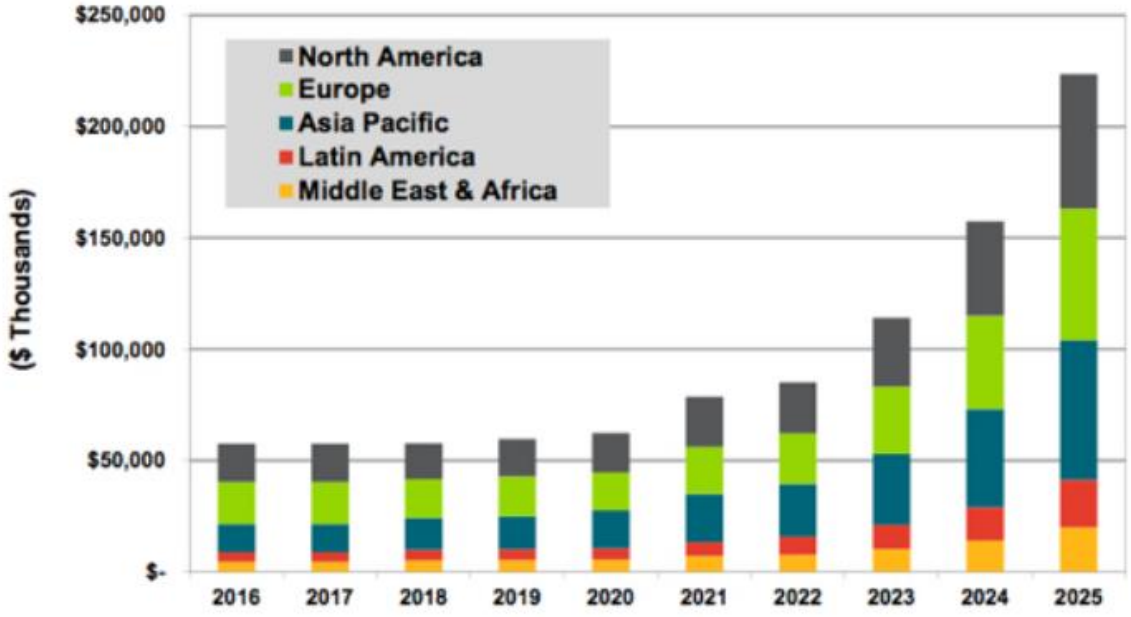

Fig 54: Annual Smart Waste Collection Technology Revenue by Region

The above figure according to Navigant research report shows that the market related to smart waste collection is estimated to grow from $57.6 million to $223.6 million from 2016 to 2025 which accounts to a total growth of 16.3 %. Smart waste management technology will include sensors that will help to provide real time information about the bins and the level of waste in them and alerting people that the bin is full and needs to be emptied now. This technology also uses various software to for collecting data and providing route optimization.

5.3.2 Bigbelly's smart Wi-Fi enabled garbage bins in New York

In 2015, Bigbelly in New York is a waste management company has worked out to bring solar powered smart bins that are Wi-Fi enabled.

Fig 55: Wi-Fi Enabled Smart Bin

First in Manhattan 2 smart bins were first used to act as hotspot in the neighborhood. Those bins provided Wi-Fi at a speed of 50 to 75 Mbps. The effect of having these Wi-Fi enabled smart bins was promising because it helped people that doesn't have Wi-Fi access. These bins also help to collect the data and display information regarding the amount of waste in the bins. Researches and engineers are working their way up so that these solar powered smart bins can be expanded more in the cities.

5.3.3 Bengaluru to introduce smart bins to tackle waste problem in the city

According to 2016 waste management report, Bengaluru which is one the India's biggest metropolitan city generates over 5000 tons of waste. The amount of waste which is collected by BBMP, the administrative body of the city is 30% and the rest is collected by contractors. According to the report presented by Times of India, the BBMP was given a go-ahead by urban development department in 2017 for setting up the smart bins across the city to prevent the waste. The focus is to bring smart bins in 50 locations in the city which will help in waste management with effectively collecting waste on time.

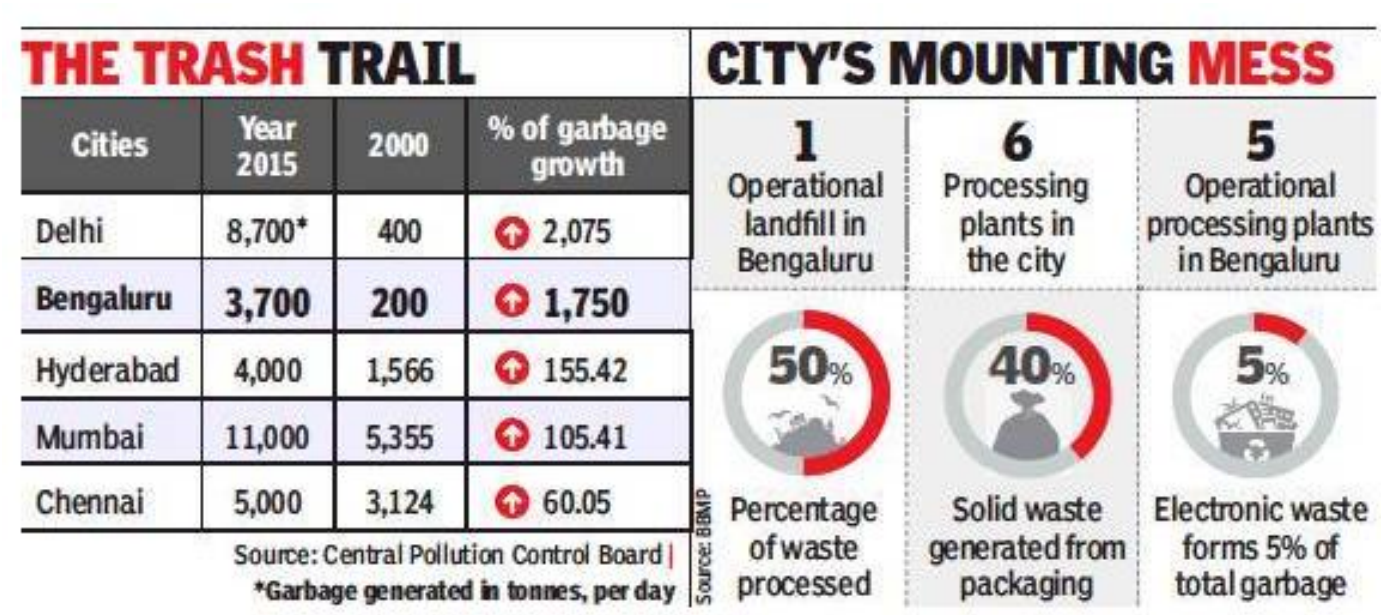

Fig 56: Garbage Generation in tonnes, Per Day

These stations will also have compressors which will help to drain the liquid out to prevent bad odor and weight of garbage. According to a 2017 report by Hindustan times, Bengaluru which the garden city of India is soon becoming the garbage city of India. Smart Bin technology will really help to improve the city's image and help in waste management as well. The state government believes that bringing in the smart bin technology will mark the beginning of a new way for waste collection in the city.

5.3.4 EvoBins to educate consumers regarding waste management

EvoEco is a Seattle based company which was founded in 2015 has implemented a new smart bin known as EvoBin, which aims to educate people regarding waste management.

Fig 57: EvoBins

These bins have integrated scales in them, when the waste is thrown in the bin the scale will start to detect. A responsive message will pop up on the screen once there is a change in the weight. When people have fully discarded their waste, the bin will record the weight and will help to provide immediate feedback as well. When the bins are not in use, then the screen that is present there will constantly show images of waste to be put in the correct bin which will help to educate people regarding sorting their waste correctly. Other companies that are working on this technology are Bin-e whose functioning is based on collaboration of mechanical, electrical, software and artificial intelligence elements. With installation of EvoBin, the company has seen a reduction of 50% in waste contamination and waste diversion has increased by 25%

CHAPTER 6

SMART CITIES

6.1 INTRODUCTION

The urbanization is rapidly increasing globally today. According to the report presented by United Nations, by 2030 world's 60% of total population is going to live in megacities which are mostly in Asia, Africa and Latin America. With increase in urbanization in cities the need for energy, water, sanitation along with other services like education, healthcare, infrastructure is also increasing. To fulfill the needs of people it is very important to use these resources in a smart way and develop cities in Smart Cities.

Many countries are trying their best to fulfill these specific resources needs and deliver them to the people. Few examples of countries having smart city projects are Barcelona, Amsterdam, San Francisco, Shanghai, Beijing etc. and recently a 100 smart cities initiative was also launched in India as well. In 2015, the 18th annual session of United Nations Commission on Science and Technology for Development was held in Geneva and its prime focus was towards Smart cities and Infrastructure. In future time cities and infrastructure are believed to dominate the human development.

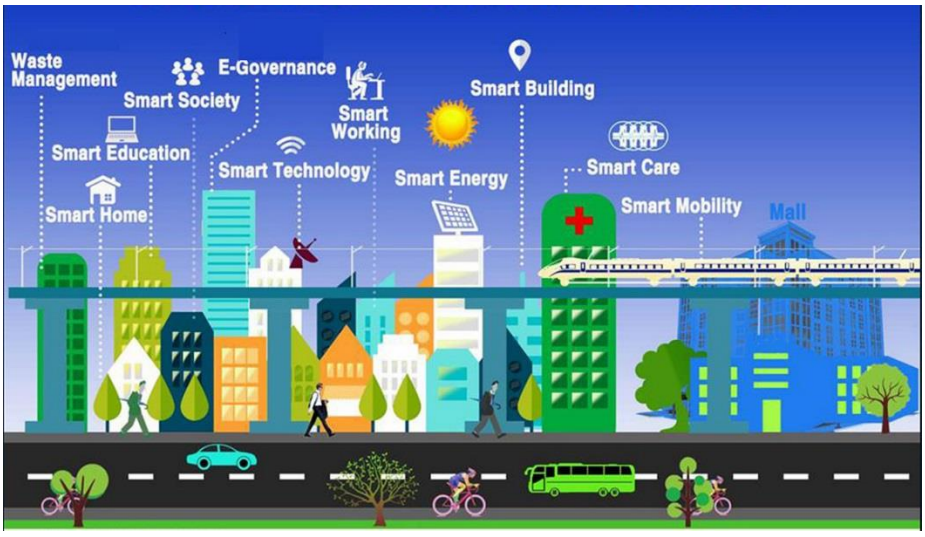

Fig 58: Example of Smart City

Looking at the urbanization trends during 1950's the total percentage of population that lived in rural areas was 65% and urban areas was 35% but till 2050 the percentage of population in urban areas will be 70% and remaining 30% in rural.

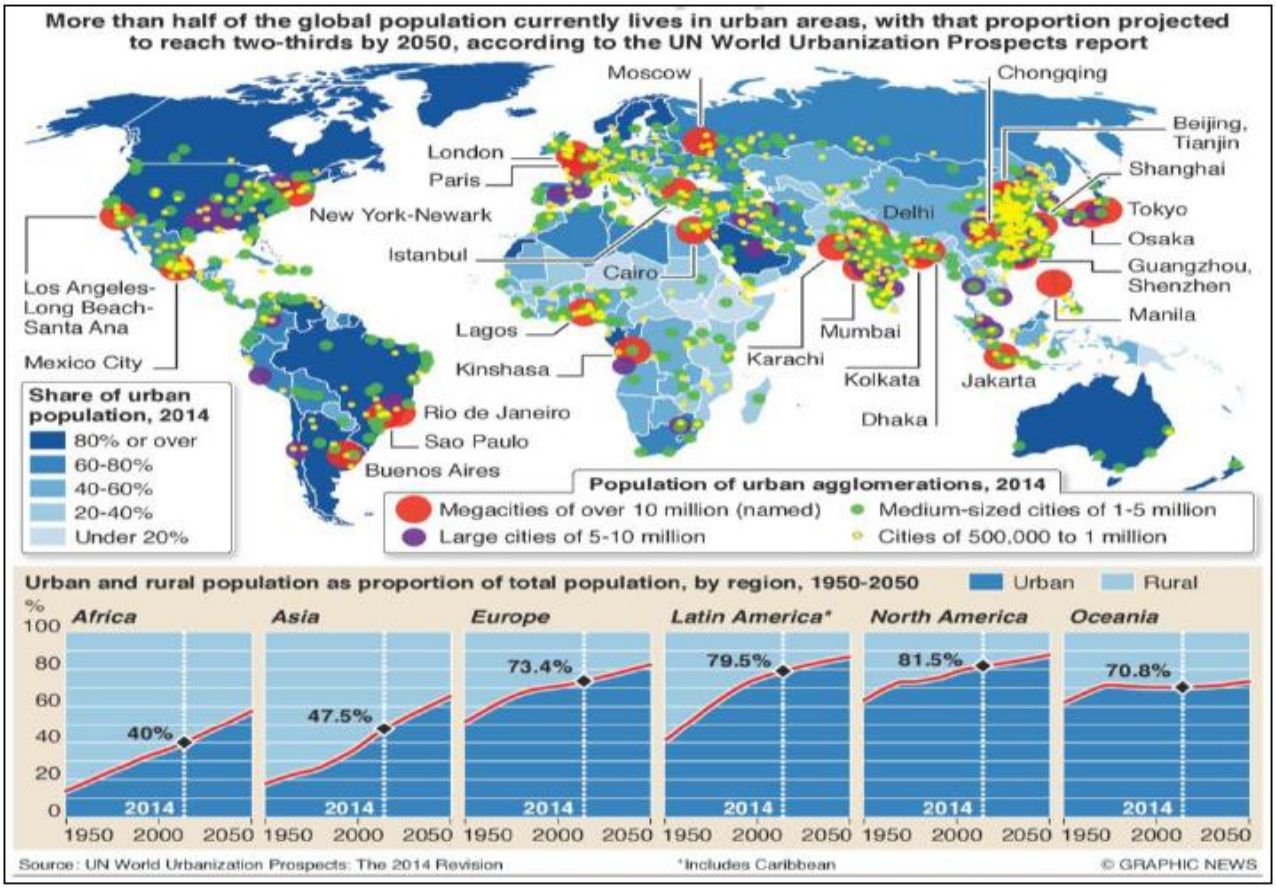

Fig 59: Urbanization Trends across the World

The figure above shows the urbanization trends across the world. In the coming times the countries that have low income are expected to have a massive urban population growth. According to the reports of United Nations Environment Programme and Sustainable urbanization policy brief, the usage of energy by cities is 70% along with increased demands of water, land, infrastructure, food, pollution control, waste management etc. due to these reasons of increased demands, cities are transforming into Smart Cities bringing in new smart applications and infrastructure to fulfill the needs of citizens.

6.2 WHAT IS A SMART CITY?

A smart city is a city that brings in latest information and communication technologies along with other means that helps to improve the quality of life, provides efficient services, and assures that it meets demands of people keeping present and future generation in mind. It helps to manage various components like transport, health, energy, homes and buildings and environment.

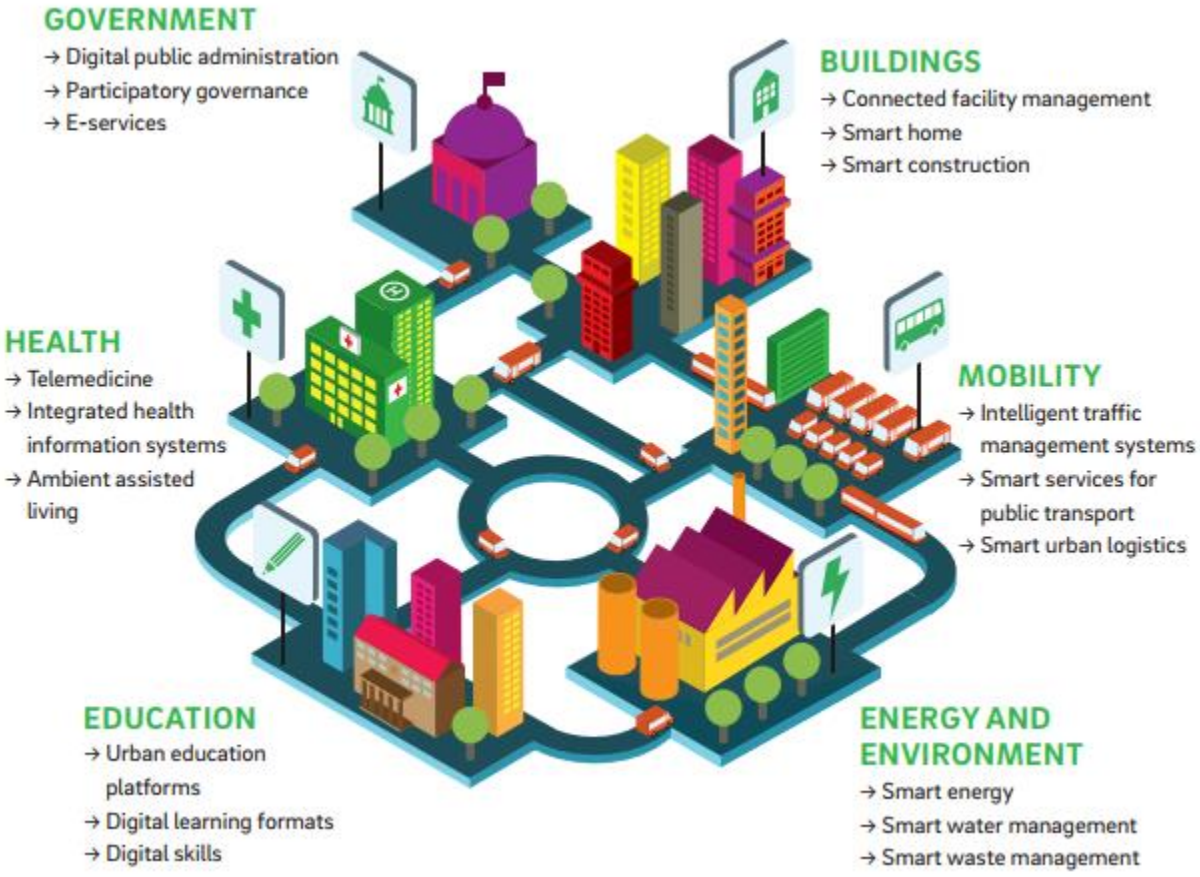

Fig 60: Application Areas of Smart City

The smart city consists of following six components:

- **Smart Economy:** It portrays the concept of innovation and entrepreneurship. It makes sure that there is always a link between domestic economy and global

economy by deploying new and high-end technologies so that the city's competitiveness is always maintained.

- **Smart Mobility:** It deploys various video surveillance and remote detection technologies to monitor the traffic in the city. It also gathers the traffic data, pedestrian flow data in real time and in case of emergencies as well.
- **Smart Environment:** It deploys web based and remote technologies to keep the track of public spaces, grasslands and green belts which further helps to promote the idea of green environment. It focuses on energy conservation and emission reduction and taking care of water bodies to achieve environmental sustainability.

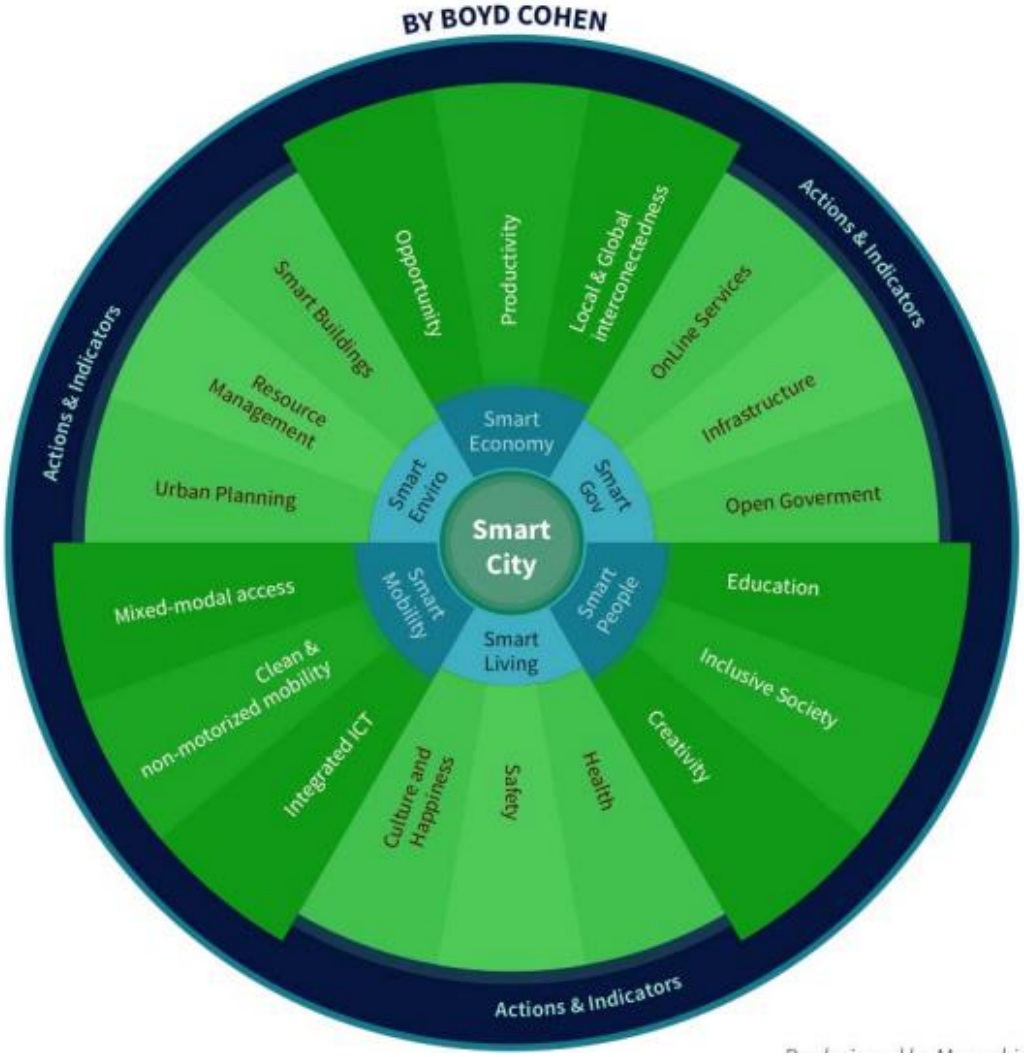

Fig 61: Components of Smart City

- **Smart Citizen:** Citizens are encouraged to participate in public affairs that will educate them towards transforming a city into smart city.
- **Smart Living:** With high-end applications and internet of things, lives of people is made better and standard of living is also improved. Home automation systems are an example of smart living. It also allows people to connect with each other at any point of time and anywhere in the world.
- **Smart Government:** It focuses on the connecting bridge between government and people through public information and services. It aims to increase the government's responsiveness towards the need of people which is addressed on time and efficiently.

6.2.1 MULTI-LEVEL SMART CITY ARCHITECTURE

In the present time we have a lot of wireless technologies and wireless sensor networks that help to provide efficient, intelligent and flexible support for the people to improve their lives.

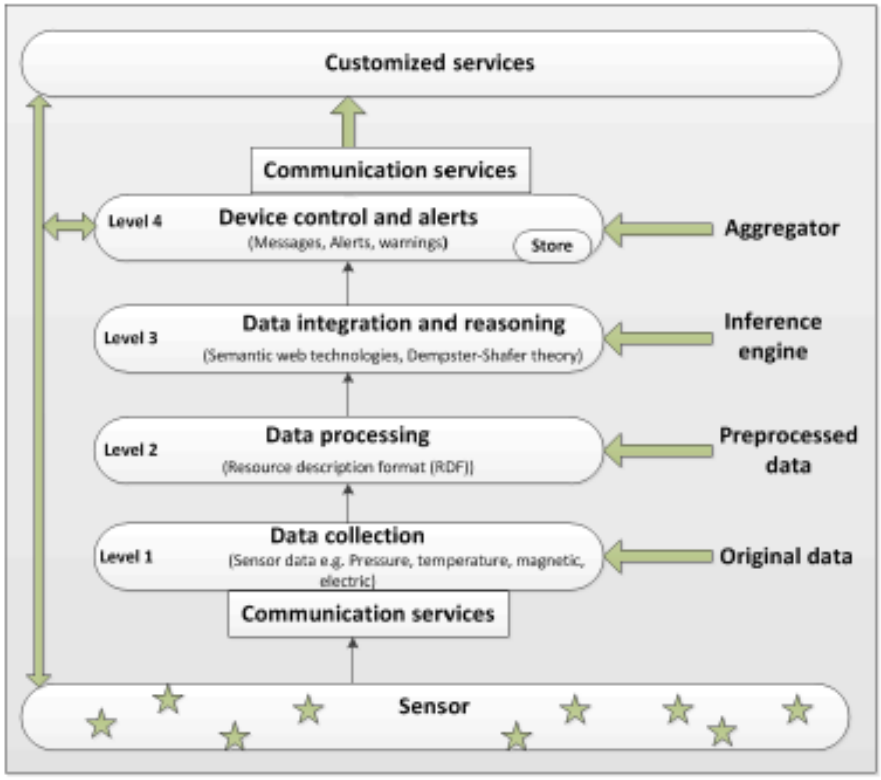

Fig 62: Multilevel Smart City Architecture

- **Level 1 – Data Collection:** In this level sensors will help to collect the raw data which can be further processed. The formats used for collection of data are text messages, database schemas, tweets etc. With the help of web technologies this data is processed which is further processed for converting into common format at level 2
- **Level 2 – Data Processing:** The information gathered with the help of web technologies is converted into familiar format at this level known as Resource Description Framework. RDF is termed to be one of the most common ways to exchange the information on web. RDF data can be used by various software applications for intelligent reasoning operations.
- **Level 3 – Data Integration and Reasoning:** There are 3 types of techniques that are used at this level.
    - Web Ontology Language (OWL): Ontologies are published with help of this language. This is basically a graph that is made using RDF and ontologies.
    - SPARQL: It is basically RDF query language that helps to retrieve and manipulate RDF format data records. Once the data is collected in the RDF format then SPARQL will enable the query and retrieve the data in the same format.
- **Level 4 – Device control and Alerts:** Different web application can use the data delivered from level 3 for various intelligent operating conditions like messaging, alerts, warnings etc.
- **Communication Services:** To achieve a smart city concept, communication plays a key role. The communication services that are being utilized in the present time are.
    - 3G (3^{rd} Generation)
    - LTE (Long term evolution)
    - WI-FI
    - WiMAX (Worldwide Interoperability for Microwave Access)
    - ZigBee
    - Cable Television
    - Satellite Communication

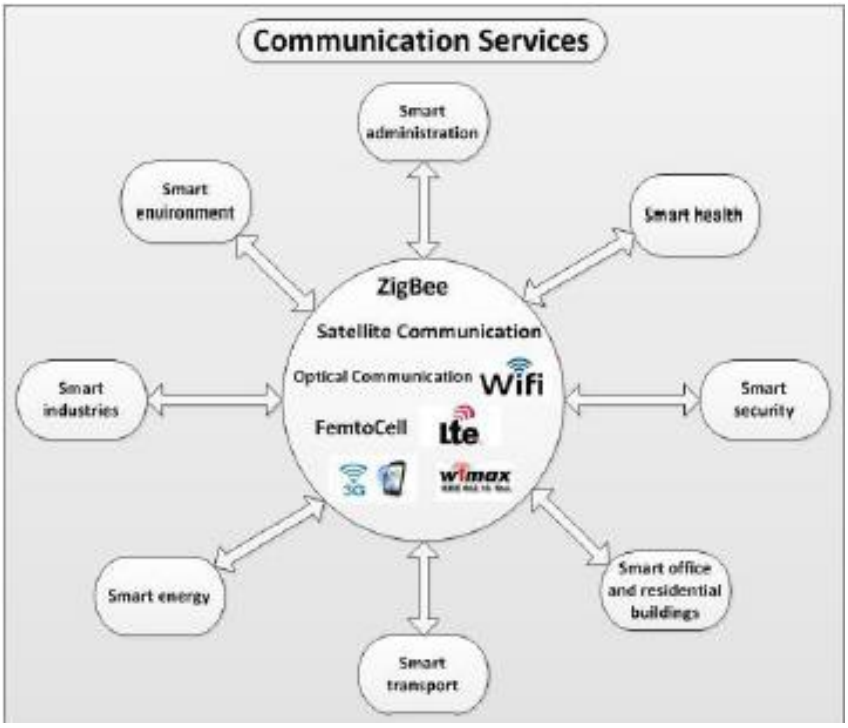

Fig 63: Smart City Communication Services

The main goal is to connect all sensors with Internet of Things to deliver efficient results that helps to make the lives of people comfortable and safe. One of the common examples is the home domain where telephones and PC's are connected through internet. In the government sector by combining cloud and communication services the aim of better governance can be achieved. In the health sector, a patient can access any information related to health and medication from anywhere around the world which helps to achieve smart health system.

- **Customized Services:** The figure shows some of the customized services. In health and vehicle sector to determine the driver's health parameters we can combine data from various sensors. We can measure blood pressure and heart rate and combining it with vehicle status we can determine the real time health condition of a driver. Vehicle status can be monitored using vehicle location, vehicle speed and the traffic flow. In case of smart health a disabled person can access any information regarding his health with help of data collected through sensors, the information can be readily available on patients mobiles which can be accessed anywhere and anytime in the world.

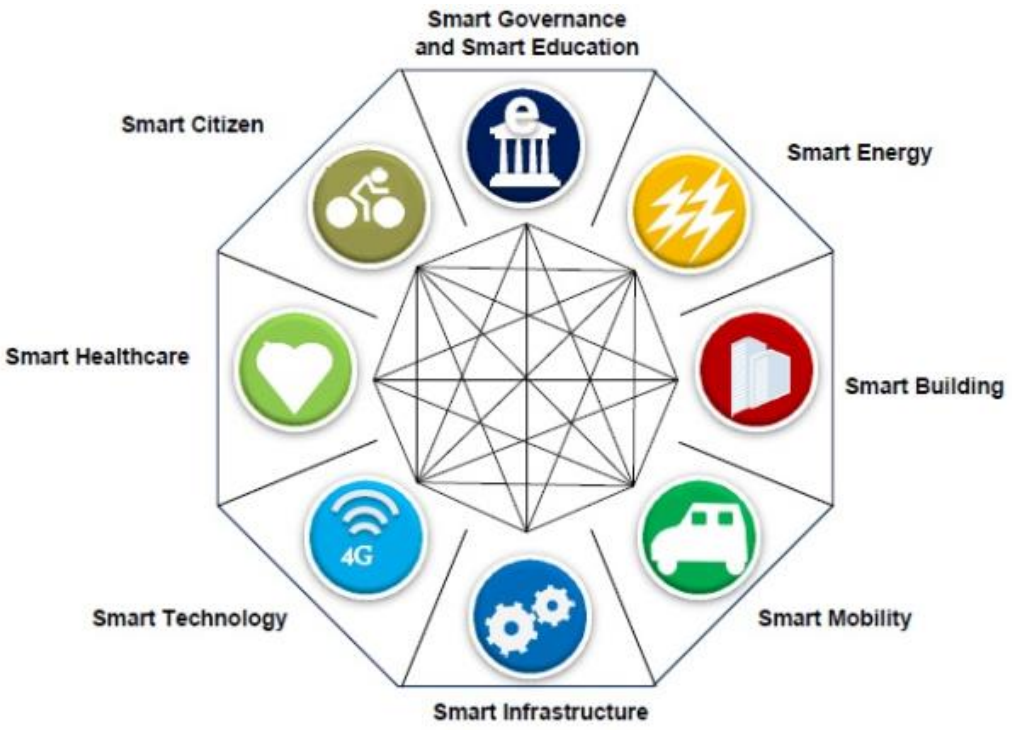

Fig 64: Customized Services

Another example can be of home where combining sensor data we can measure the effects of temperature in our homes which can prove useful for people at home.

6.2.2 THE ROLE OF PRIVATE SECTOR, UNIVERSITIES AND NON-PROFITS

For a city to turn into a Smart City the universities, non-profits, public and private sector along with government entities can prove valuable in shaping a smart city.

- Private Sector: The private sector includes various local business and multinational corporations that work towards bringing up new and innovative technologies in the market. Smart government should make methodologies to engage private sector to strengthen up the shape and quality of a smart city that will provides better services to citizens and will also improve various communities.
- Universities: Universities can be helpful when it comes to a high-quality research. Various communities should collaborate with universities to work on various research

projects and programs that can guide regarding various things like various measurement techniques required for better understanding of systems and improving them, understanding the complex systems and working on new policies for smart city.

- Non-Profits: the non-profit areas in a city are most close to the community's activities. It will prove very useful to bring non-profit areas in defining and implementing a smart city because it helps to keep various inclusive policies and priorities in the part of discussion because non-profits can also provide useful data-sets.

6.2.3 THREE DIMENSIONS OF SMART

Taking an example of Austin, Texas the three dimensions of smart are:

- **Smart Projects:** Smart Integrated Mobility solutions was proposed by the transportation department of Austin

Fig 65: Three Dimensions of Smart

Smart stations include numerous services like retail, health and mobility etc. that are useful for travelers. The Smart transportation will have access to medical, legal and groceries services as well. Connected corridors are basically a connecting bridge between smart stations with new services that includes electric bus transit, transit lanes which results in active transportation and a sensor and beacon rich environment that deploys V2V and V2I technology.

Mobility provides travelers a new integrated that helps them in payment methods. To make sure that this technology works best for everyone, Smart Ambassadors known as the human-driven outreach component will work on educating people and helping them so that the mobility marketplace is used efficiently.

Fig 66: Transportation System in Austin

All these above initiatives work together to give better services like jobs, health, education, food and other areas of need. These programs can work better if advanced technology and infrastructure is used which will include a 2-way open data portal, network of intelligent sensors and urban analytics and policy research platform.

- **Smart Policies:** Let's take an example of Smart Kiosks which is one of the booming technology which works on providing efficient Wi-Fi, search engines, browsing, advertising and social media. Kiosks are useful in areas of high pedestrian traffic and community centers.

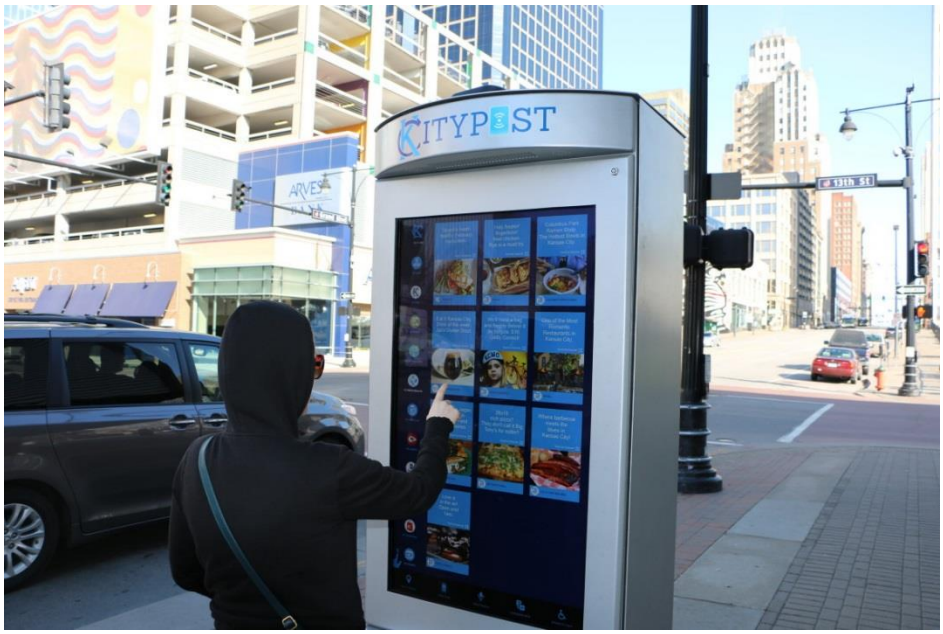

Fig 67: Smart Kiosks

In Austin, these kiosks will be deployed in the areas where the city plans to build the community centers. It will provide the information regarding business, markets, food, city's information, services and activities. In 2016 Kansas City launched 2 kiosks in the city. The Kiosks screen is just like a smartphone that will provide the users regarding nightlife, restaurants, parks and even google maps. According to the chief innovations officer of Kansas City the total cost of deploying the kiosks is $1 million.

- **Smart Language: Assets, Valuations, Cost and Projects:**

It includes 4 basic steps:

- Data as an asset: Asset is basically that can store and generate data which includes sensors and networks. Even cloud storage can be used as an asset.
- Assigning cost to data assets: the cost expression of these assets is done in Dollars per GB storage, Dollars per GB per second of network demand, Dollars per unit of data processing capacity.
- Measurement of value returned from Asset: The values includes less pedestrian causalities at intersections, maintaining local parks, controlling green house gas emission etc. The measurement of values should be done so that the city can monitor and access the returns it is getting.
- Attaching data assets to projects: After analyzing the cost and value of data asset we can attach it with a smart project for further efficient use.

6.3 SMART CITIES FIRST INTERNATIONAL CONFERENCE: SPAIN, JUNE 2016

The first smart cities conference, Smart-CT was held in Spain in June 2016. A lot of innovative ideas were proposed and discussed keeping smart cities in mind.

- **URBEM Smart City Application:** This application helps to integrate various models that operate in various domains like building physics, electrical energy, thermal energy, mobility, sociological behavior modeling etc. By integrating these different models, the stakeholders get an interactive and dynamic visualization. This application is a joint initiative between Wiener Stadtwerke Holding AG which is Vienna's largest and biggest energy and mobility provider, TU Wein and City of Vienna. With the help of this application stakeholders get a dynamic web-based visualization that helps them to explore the city and also know about different evolving projects with predictions up to 2050. This application gives stakeholders a chance to explore the city in various ways

from districts to blocks, individual buildings etc. by looking at results of different domain models they can make changes accordingly by adding and removing layers.

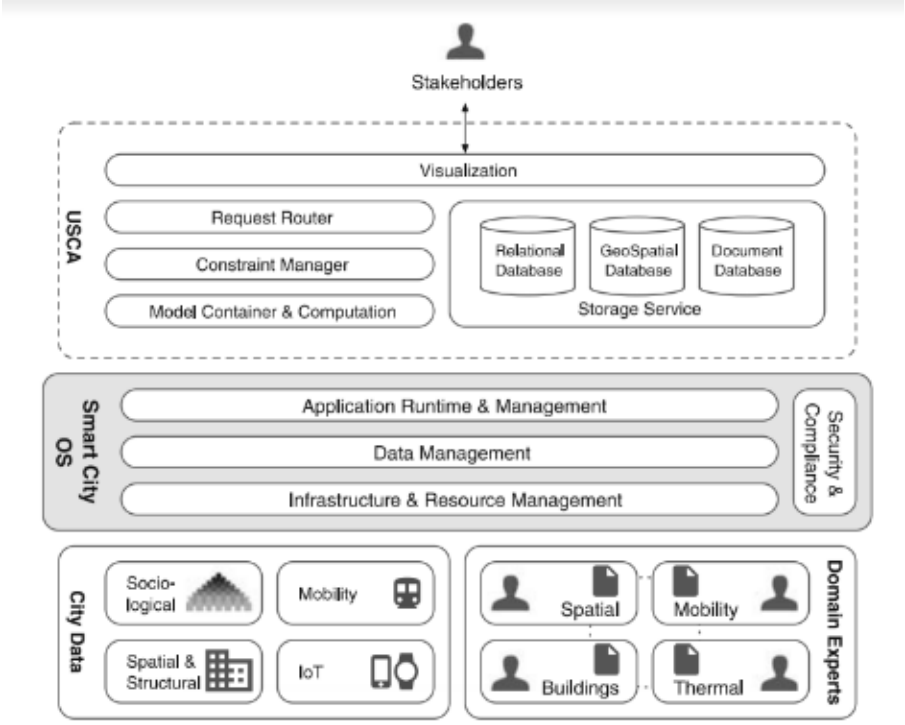

Fig 68: UBREM Model

With the model interactions specific requests are released with are handled by Request Router. As per the request patterns of USCA this router acts as a smart request proxy which scales up and down the necessary infrastructure resources. The request router further forwards the request to constraint manager who is responsible for checking that USCA meets the compliance and privacy requirements. Once it checks that no request violates the privacy and compliance then it forwards the request to model container and computation component. This component verifies that models are executed in a right way and contain all necessary data and information. The components are the main elements of USCA along with storage service which helps to provide integrated view of city to the stakeholders. USCA is basically a cloud based model that works with help of smart city operating system.

- **ICT based reference model for E-Grocery in Smart Cities:** E-commerce has helped to change the businesses all around the world very drastically. It helped to boom various business sectors like retail, clothing, electronics etc. and now grocery, which is still in an early phase of implementation. This project is named as Simulation and Optimization of Urban Logistics (SOUL) which is in collaboration with Telecom Italia. The purpose of E-grocery is to reduce inefficient ways of delivering and picking operations and to pay more attention in terms of serving best food.

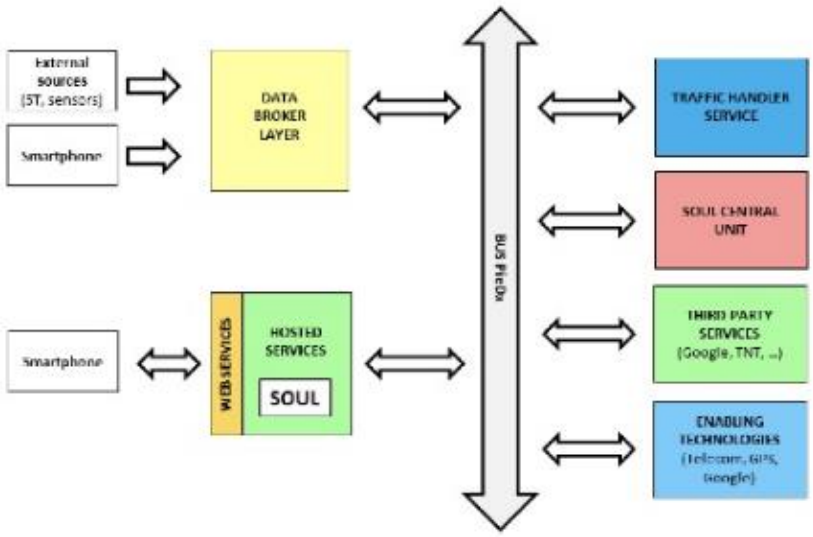

Fig 69: ICT based Reference Model for E-Grocery

Following are the blocks of SOUL architecture:

- Central Unit: The main functionality of CU is to provide traffic management and real-time control of fleet of vehicles.
- Traffic Handler Service: The function of THS is to combine the traffic information together to detect congestion of streets and then the traffic events are communicated to central unit.
- Data Broker Layer: the main functionality is aggregation of data sources through integration rules so that the data is preserved.
- Hosted Services: The function is to provide an interface so that user and service interactions are done in a right way and properly. Supply chain Management Unit can

be the best example for this where it gets orders from users and then forwards them to associated suppliers.

- Third party services: They provide functions like cartography and do not require any hosting system.
- Enabling Technologies: Internal and external technologies play an important role in the decision-making process for example internet, local area networks play a major role in exchanging information between software and hardware modules.
- External Sources: External sources would include sensors that provide information required for traffic which is also available from vehicles. These sensors can be private and public.
- Mobile Devices: mobile devices in SOUL architecture are main source of traffic data because they are directly in touch with real-time situations.

The SOUL architecture overcomes various gaps which include decision making, composition of vehicles, warehouse organization for grocery retailers etc. these gaps are reduced by introducing ICT architecture with integration of e-grocery supply chain with reference to various business models.

6.4 SMART CITIES AND 5G

The 5G definition of smart cities is that a smart city is a city which integrates multiple information, networks and internet of things in a reliable manner so that the city's assets can be managed efficiently. The different types of city's assets are:

- Schools
- Libraries
- Local department's information system
- Transportation
- Hospitals
- Power plants
- Smart homes
- Water supply chains

- Waste management.

Let's look at few examples of 5G enabled smart city use cases:

- **Smart Transportation:** Traffic congestion is becoming a major issue in many urban areas, and it's leading to productivity loss, environmental pollution and degradation of quality of life. 5G will enable real-time collection of massive amounts of data from vehicles, drivers, pedestrians, road sensors and cameras to help streamline traffic flow.

  For example, it can help optimize traffic lights and road usage, direct public transportation to where it is needed most, navigate vehicles to avoid congestion and raise tolls to limit traffic entering a congestion zone.

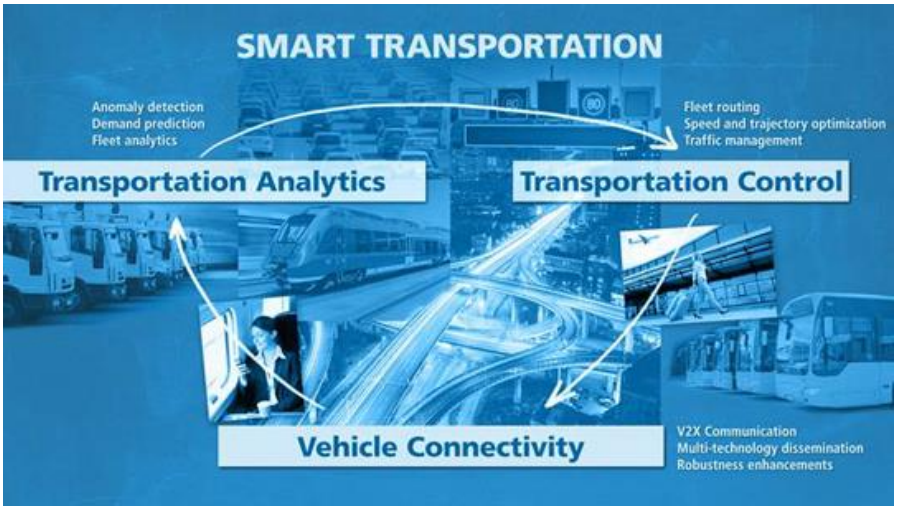

Fig 70: Smart Transportation

- **Smart Building:** Urban buildings are major consumers of energy and resources. Streamlining building operations will lead to increased productivity and energy efficiency.

  For example, 5G-connected sensors/actuators can help optimize building temperature, humidity and lighting based on current activities inside them. They will also enable buildings to detect when hidden pipes and cables need repair, when unauthorized access takes place, when office supplies are running low and even when garbage bins are full.

This information allows building management to take appropriate action in a cost-effective and timely manner.

Fig 71: Smart High-Tech Building

- **Smart Homes:** Home security and automation applications constitute another M2M service area that is expected to grow significantly in the future. Examples include the transmission of home security alarms and home surveillance video data to commercial monitoring stations.

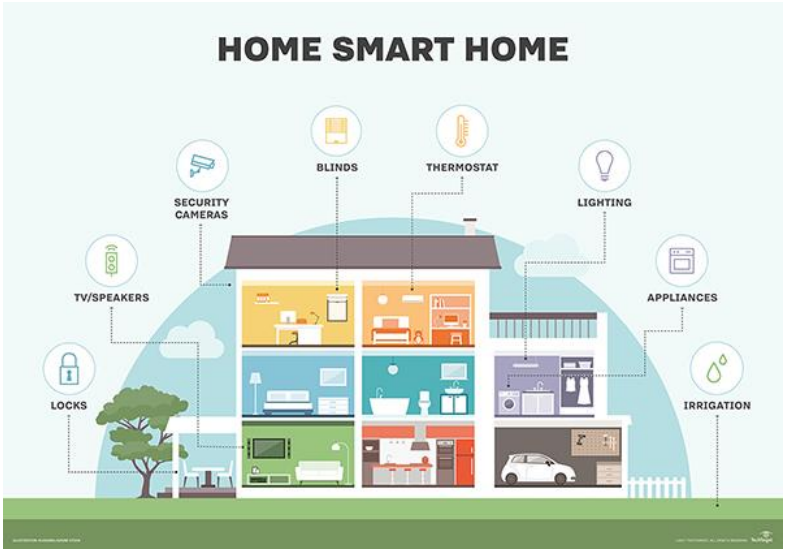

Fig 72: Smart Homes

6.5 TOP 5 SMART CITIES IN THE WORLD

With the advancement in technology these days a lot of cities in the world are adopting innovative ideas which can help to improve the lives of citizens. According to Juniper Research the following are top 5 smart cities in the world.

- **Singapore:** The Republic of Singapore's Prime Minister in 2014 brought an initiative which included sensors and cameras to be deployed which can keep a track of everything in the city from cleanliness to traffic. With its advanced technology and innovation, the city is already able to detect smoking at unauthorized places or garbage being dumped from high rise buildings. In 2014, the city announced its new dynamic 3-D project named Virtual Singapore which helps the city planners to perform virtual tests. Singtel a broadband company was bringing in a dynamic 10-Gbps fiber broadband service that will allow users to download a 2-hour HD movie in just 90 seconds.
- **Barcelona:** The city planners are working hard to bring innovative ideas to reduce the amount of traffic flow by deploying sensors in the city. They are making amendments in their current model which will help to reduce the traffic flow up to 21%. The city has already installed smart streetlights system, smart parking system and deployed sensors to monitor air and noise quality. Sustainable energy is the greatest strength of Barcelona which has helped to deploy smart grid systems, smart meters etc. The city also has an open source software platform which allows planners around the world to have a look into city's projects.
- **London:** London is regarded as one of the tech hubs in the world with great broadband facilities. To help public and citizens London has a smart app built on open data which will automatically detect your location and the person will just have to say the name of destination and the app will show all the routes. London has been investing huge money on smart city projects like 4-billion pound for roads in the city and 200-million pounds for bus network in the city. In 2003 a congestion charge was implemented which informs bus drivers through messages regarding traffic congestion.
- **San Francisco:** This city is regarded as North America's first city to adopt smart city initiative and ranks first in United States in terms of having highest number of LEED-

certified buildings. The city is regarded as a leader in Smart parking initiative which was launched in 2011 by deploying various sensors in parking areas.

- **Oslo:** Oslo is regarded as one of the wealthiest cities in the world which uses information technology to limit the energy consumption and green house gas emission. According to city planners the emission will be slashed by 50% by 2020 by making amendments in transportation grid. With a broader sensing network to a plate recognition technology, Oslo is one of the smart cities in the world.

6.6 CONCLUSION

The concept of Smart Cities is trending a lot these days and the cities are working up hard on bringing up smart plans in the future. Various factors like cost reduction and managing traffic flow can be done using smart technologies in the cities. With High speed, greater reliability and reduced latency, 5G will prove to be a key enabler for turning cities into Smart Cities. 5G will play a major role in various aspects of smart cities including Homes, Automation, Healthcare, Education, Energy etc. Many countries like USA, UK, Singapore, Spain etc. have already implemented the concepts of Smart which include Smart Parking, Smart Street Lights, Smart Traffic Control, Smart Bins etc. and are still working up to bring more innovations in this field which can benefit the citizens of that country respectively. The Commercial availability for 5G is expected to arrive in 2020 and by then it will surely help to transform the Cities into Smart Cities.

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