MINOR PROJECT

Report on Research Project (RP)

Study of Cellular-IoT & Development of a Business Case for Smart Campus

Towards partial fulfillment of requirements for award of EMBA
in Marketing & IT Management

Submitted By:

MILIND SINGHAL
(2K20EMBA24 / EMBA2020000168)

Under the Guidance

Dr. Sonal Thukral

DELHI SCHOOL OF MANAGEMENT

Delhi Technological University Bawana Road

Delhi 110042
EMBA – BATCH 20-22

CONTENTS

CERTIFICATE

This is to certify that research project titled

Study of C-IoT and Development of a Business Case for Smart Campus

Is a bona fide work carried out by Milind Singhal of batch 2020-2022 E-MBA under the guidance of Prof. Dr. Sonal Thukral

Dr. Sonal Thukral

Assistant Professor

DTU

Milind Singhal

2K20EMBA24

EMBA2020000168

DECLARATION

I, **Milind Singhal**, student of **EMBA 2020-22** of Delhi School of Management, Delhi Technological University, Bawana Road, Delhi – 42, hereby declare that the dissertation report

"Study of C-IoT and Development of a Business Case for Smart Campus"

submitted in partial fulfilment of Degree of EMBA is the original work conducted by me.

The information and data given in the report is authentic to the best of my knowledge.

This report is not being submitted to any other University, for award of any other Degree, Diploma or Fellowship.

Place: Delhi **Date: 10:05:2022**

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CHAPTER 1
EXECUTIVE SUMMARY

1.1 Introduction

Cellular technologies are evolving to help connect people and with the ever-increasing demand for and provision of Internet access. During this development cycle, there has been an increase in data speed, a decrease in latency and an improvement in the overall quality of communication that is carried out using the wireless medium. However, mobile networks are not only developing in this direction. There is an increase in aspects of the Internet of Things and machine-to-machine communication. This aspect is not new as such, but is gaining more and more popularity for various existing and new use cases that would enable a better connected world where technology enables such connectivity to improve the overall quality of life, safety and efficiency of various tasks. The concept is popularly known as the Internet of Things (IoT) and covers machine-to-machine (M2M) and machine-to-machine (MTC) communications with device use cases ranging from video surveillance requiring higher data rates to meter monitoring requiring very small, intermittent data capabilities . . The networks used to connect these IoT devices are usually referred to as Low Power Wide Area Networks (LPWAN) due to the nature of the devices that connect to such networks.

The Narrowband IoT (a.k.a. NB-IoT) industry is on the rise. The most unique characteristic of NB-IoT is that it can be deployed over the operators existing network on the existing spectrum bands. One important feature of NB-IoT includes effective and efficient indoor coverage which cannot be matched by any other technology in this industry. It supports connections with massive low-throughput and low-cost devices. Low power consumption and optimized network architecture are some of the additional advantages worth mentioning. It is expected that NB-IoT will soon evolve into a large-scale deployment across various industries and across the world.

The LPWAN market has existed for a decade now. The existing solutions in the market are fragmented and not standardized, hence leading to shortcomings like poor reliability, poor security, high operational and maintenance costs. Furthermore, the new overlay network deployment is not simple and involves lot of complexities. [22]

NB-IoT overcomes the above issues by providing ubiquitous coverage, faster network upgrade, low power consumption, very long battery life, low cost terminal devices, high reliability and high carrier-class network security. The initial investment in the network implementation can be quite substantial and the superimposed costs are very little. In such a scenario, NB-IoT proves to be an ideal solution to the LPWA requirements. Moreover, it enables the communication service providers (CSPs) to enter into this new field.

Traditional applications like smart tracking, smart metering, smart agriculture, smart parking, etc. can be provided by NB-IoT at and ultra-low cost ($5) per module and a extremely high connectivity (100K/cell) and opens up more industry opportunities like smart city, smart health and other low data rate applications yet to be uncovered. [22]

NB-IoT is a new mobile radio access technology specified by the 3GPP in version 13 to address the rapidly expanding market for low power broadband connectivity. To ensure broad coverage and widespread adoption of NB-IoT services, MNOs (Mobile Network Operators) must ensure that devices and end-to-end services from different operators must connect to the NB-IoT systems that have been deployed. Data transfer options and connection modes must be well understood. [23]

Various guidelines are available for the design and deployment of NB-IoT networks. This is done to ensure interoperability and smooth roaming. The GSMA guide contains the functions standardized in 3GPP Release 10-13, regarding the key functions that will be deployed in the coming time. The GSMA provided recommendations based on entry and implementation plans shared by members of the NB-IoT Operator Forum, which plan to roll out NB-IoT networks in more than 40 countries in Europe, the Middle East and Africa, South America and APAC, including Japan, China and South Korea..

Machine type correspondence (MTC) has a trademark which is expansive range of capacities. For instance, CCTV observation cameras need to convey immense measure of uplink (UL) information while being practically fixed. Then again, gadgets for armada following, pet following, and so on have a limited quantity of information while playing out a great deal of handovers. One more class of gadgets has neither of these abilities. Models for these incorporate gadgets for metering including power, gas or water utilization. These are many times standard and needn't bother with a streamlined handover. Non-defer delicate data is typically moved in little

sums as it were. Nonetheless, the quantity of developing MTC gadgets might turn out to be very enormous, even up to a few significant degrees contrasted with the conventional gadgets. In any event, utilizing the current fast organizations would prompt an organization clog, in light of the fact that notwithstanding of their modest quantity of client information, how much flagging is about something very similar. The principal detail of NB-IoT focusses on this class of gadgets.

These gadgets are frequently introduced at places without power supply. Subsequently, they run totally on battery and it could be extravagant to change the battery, since they may just be gotten to via prepared staff. Consequently, the battery lifetime now and again could decide the lifetime of the entire gadget. An enhanced power utilization is in this way fundamental for a legitimate activity. Moreover, the inclusion at these spots is in many cases very terrible. Subsequently, the indoor inclusion must be fundamentally improved, up to 23 dB are viewed as required.

In this research, I have attempted to addresses the specialized potential outcomes of the equipment and programming engineering for terminals in view of LTE Feline M. I have attempted to give examinations that feature the contrasts between LTE Feline M and different classifications. Likewise, I have depicted the potential distinctions in structures among classes and how I can profit from the proposed changes in LTE Feline M. I have moreover tended to the LTE-NB (LTE Restricted Band) proposition that exist in 3GPP and contrasted them and existing advancements. Other contending advancements will likewise be contrasted with the LTE classifications and proposed classifications, featuring upsides and downsides.

1.2 Objective

We at Delhi Technological University (DTU) are trying to develop a theoretical business pilot of a smart campus keeping the DTU Campus as a reference for the research. The main aim of this research is to improve the systems which exist and may also call for a full replacement of the existing system in case of implementing this pilot project. Under this project I plan to cover various domain including – smart classrooms, smart attendance, smart infrastructure including water and electricity management, smart parking, smart monitoring, pet tracking, implementation of AR/VR to improve the classroom experience, flipped classrooms, etc.

With the advancements in technology, there has always been a change in the way the existing system operates. Technological advancements help in better capturing the requirements and data and also helps in taking preventive and corrective actions. The low power wide area (LPWA) technologies have always existed since a decade. However, large scale and wide geographical implementation of these technologies has pushed 3GPP to enable the mobile network operators (MNOs) to enter into the IoT space. With the standardization and wide implementation of cellular-IoT (CIoT) various new business cases can be implemented.

Using the C-IoT technologies which include the underlying network of NB-IoT or LTE-Cat-M, I will try to present a theoretical business pilot. In this research I plan to include the details of the technologies including NB-IoT, LTE-Cat-M and justification why that particular technology should be implemented for the respective business case.

1.3 Conclusion

Using the power of technology and with the growing IoT market in cellular domain, various business challenges can be solved and various new business cases can be implemented. Thus, the intention of implementing this pilot project is expected to lead to betterment in management of the resources, lower the wastage, enhance the learning experience, improve tracking and attendance systems. The underlying technology though explained may not be the soul solution to the project and the respective business case could be implemented using an alternative technology in the same domain. For example, implementation of a smart dustbin and waste management could be carried out using a NB-IoT network as well as LTE-Cat-M network. However, the case demands for the low data rate, stationary or low mobility solution which would call for implementing the NB-IoT network.

CHAPTER 2
LITERATURE SURVEY

2.1 IoT Technologies

Around the world millions of battery powered things are adding up to the mesh of internet in a bid to achieve a smart architecture. These objects include street lights, utility meters (gas and water), pipelines, trash bins, location trackers, environmental sensors, smoke detectors and water hydrants. Getting them connected leads to increase in the operational efficiency of any city or residential space such as an educational campus. Applications such as asset tracking, smart parking, smart lighting and smart building are just few of them which are the leading solutions in the IoT business [9]

Following can be included further in the wide spectrum of IoT services:

1. Water and gas metering
2. Public security
3. Street lighting
4. Smart parking
5. Location tracking
6. Leak detection
7. Disaster precaution
8. Livestock monitoring
9. Environment monitoring
10. Smart energy
11. Waste management
12. Agriculture

However, creating these IoT ecosystems require cross industry collaborations, which demands change in the retro business models and changing the value creation or sometimes altering the same. This cross industry collaboration is known as the open horizontal IoT applications spanning over various industries. [8] The challenges will hence involve developing, adopting and maintaining and effective cross industry technology. The business model hence is based on the service- dominant logic. This means that the firms using it are not the only business entity providing value to the customers but also the collaborators of the entire architecture are the ones constructs the value to the end customers [2]. In larger companies this kind of collaborative innovation could be difficult due to certain inertias. This can be overcome by making user- developer communities [8].

The following table can be referred to understand the user- developer model:

TABLE I : User-Developer Model[8]

Type of business model	Value drivers	Value nodes	Value flows /exchanges	Value extracts	Challenges
IoT service developer	Measuring and benchmarking eco-efficiency (footprint)	Company and their customers (real estate owners), databases, algorithms	Information, service and money exchange	Company developing the service	Developing algorithms, finding partners, getting pilot customers; Who owns the data?
Bottom up models	Tapping into trustworthy information services cost-efficiently	Individuals producing and consuming, possibly a roof organisation	Peer-to-peer information, central database, payments for devices, programming, visualisation work	Individuals co-producing and using the service	Getting fair compensation of work and investments

For these growing business cases and to support the above innovative business models the use of LPWAN technology is considered substantially. LPWA standards have displayed a good start in many countries, displaying active customer scenarios and millions of client devices already in service [9]. LPWAN technologies are designed to operate with minimal power while sending data over wide networks. This technology functions well where data needs to be transferred in small amounts over long distance or deep underground. The key benefits include long range communication, deep penetration indoors and outdoors, long battery life, cost effective connectivity and security of choosing a proven technology with an extensive global footprint. In the implementation of this technology, selecting the right network service provider with the right kind of technical

capabilities will be of prime importance. The key attributes I will need to consider in selecting the right kindof service provider will include network coverage, maturity, Reliability, affordability, and security [4].

Low Power Wide Area Network technologies have an extensive global footprint. With large-scale use proliferating in cities and municipalities across the globe, LPWANs can be found throughout Europe, North America, Asia-Pacific region and are being deployed in emerging markets across South America and Africa. Low Power Wide Area Network is a network category defined by two characteristics. The first characteristic is that the network is low power, which means that the network sensors can operate for many years on small, inexpensive batteries. The second characteristic is that the network covers a wide area, which means that it has an operating range with single transmissions often reaching up to 30 miles, depending on the application. Its narrow-band characteristics make it extremely suitable for virtually all connected devices that require small amounts of data to be transmitted. Low Power Wide Area Networks work well in situations where small amounts of data need to be sent over wide areas by sensors that will be in place for long periods of time and are well suited for easy field programmability and updateability. In fact, many of the products certified by the LoRa Alliance (www.lora-alliance.org), an international non-profit devoted to standardizing LoRa, the leading type of LPWAN technology, are designed to have a battery life of up to 10 years or more, depending on the application. In addition to keeping energy related costs low, these long-lasting batteries are critically important for use cases where sensors are located in hard-to reach areas such as underground or deep within buildings or other structures because they greatly reduce the cost of maintaining the entire system [4].

A significant thought while choosing a LPWAN answer for execution is the possession and business model of the norm. The three significant scale engineers offer a wide range regarding proprietorship: of the three, Sigfox is the most "shut", in that all rush hour gridlock through a Sigfox organization should be steered through the Sigfox cloud stage, which expects clients to sign with Sigfox and keeping on paying the firm to keep up the arrangement. An open component anyway is that clients can purchase Sigfox equipment from a wide assortment of sellers. LoRa is considerably more "open" in that clients can source LoRa modules and passages from equipment sellers, then send their own organizations and oversee them secretly. The shut component in LoRa is that Semtech is the as it were association right now producing the radio chips themselves, however this doesn't represent a severe limitation as numerous merchants farther downstream sell the necessary correspondences equipment. Ingenu offers the two models: clients can purchase equipment straightforwardly from Ingenu, then convey and deal with their own answers, while Ingenu too sells information plans to public organizations that the firm oversees itself. Application-explicit execution is a fundamental factor for fruitful LPWAN arrangements. Contingent upon the necessities of an answer with regards to information move rate, bundle size, power utilization, directionality, and distance range, there is a wide assortment of principles to address these issues. A caution that is rarely set off and sends a straightforward on/off signal from the endpoint to the cloud may be best tended to by a Sigfox sending, while a higher-transfer speed framework for a siphon regulator that calls for genuine investment, bidirectional correspondence would be better tended to by Ingenu. It ought to likewise be noticed that these guidelines experience troubles while venturing into new locales with different range authorizing scenes - LoRa and Sigfox both accomplished critical reception in Europe previously driving into North America, so, all in all both experienced defers in arrangements due to acclimating to various recurrence ranges and nearby administrative necessities. The future for LPWAN arrangements will probably include various guidelines being sent in lined up in their objective specialties, while doing combating each other at the boundaries between their ideal execution boundaries. Not at all like the IoT stage space declarations of new LPWAN principles tightened sometime prior and seem to have leveled with the guidelines referenced above, despite the fact that a periodic new LPWAN standard really does spring up at times (like Wi-Fi HaLow, reported in January2016). Sigfox and Ingenu have accomplished supported development and subsidizing, and both can possibly turn into worldwide IoT MNOs - offering district wide IoT information designs a lot of the manner in which Verizon and Vodafone give telephone plans. Sigfox and Ingenu are likewise both incredible obtaining focuses for MNOs hoping to become major M2M empowering agents. Clients keen on sending LPWAN arrangements ought to play out an extensive evaluation of target organization execution boundaries, and line up with the possession model that appears to be legit for their drawn-out arrangement objectives.

The cellular IoT technology which can be retrofitted in the existing networks is Narrow Band IoT This is another radio access innovation determined by 3GPP delivery 13 to address the quick growing business sector of the low power wide region network connectivity [3]. Nb-IoT is coordinated in the LTE standard, yet it is viewed as another air interface. It has been kept as straightforward as conceivable to decrease the gadget costs and limit battery utilization. Consequently it eliminates many elements of LTE, including handover, estimations to screen the channel quality, transporter accumulation, and double network. It utilizes the authorized recurrence groups, which are a similar recurrence numbers utilized in LTE, and utilizes QPSK tweak. There are different recurrence band arrangements, which are independent, monitor band, and in-band organization [7]. The subcarrier data transfer capacity for NB-IoT is 15 kHz, and every gadget is planned on at least one subcarrier in the uplink.

Moreover, uplink transmissions can be stuffed nearer together by diminishing the subcarrier dividing to 3.75 kHz. NB-IoT beats different advancements, having a 95 %-tile uplink disappointment likelihood of under 4 % in any event, for ten gadgets. The reasons incorporate the best inclusion and the utilization of connection transformation, while a downside is the most significant length of time on air [10].
Then again LTE Feline M works with heritage LTE utilizing more extensive framework data transfer capacity, using 1.4 MHz transmission capacity. It works in half duplex mode utilizing restricted max transmission power. LTE-M1 support just the predetermined number of transmission mode: TM 1,2,6,9 which can work in single layer. LTE-M1 use another actual channel design that send SIB/RAR/Paging in dull mode without utilizing control channel. All the asset distribution data (subframe, TBS, Subband File) for SIB1 not entirely settled by a MIB boundary (No Control Channel is utilized for this). All the asset assignment data (subframe, TBS, Subband File) for SIB2 not set in stone by a few SIB1 boundaries (No Control Channel is utilized for this). LTE-M1 support the drawn-out Paging (DRX) Cycle [11].

In total there are a total of 4 commercial Nb-Iot zones, with several almost on the verge of a commercial launch, with 40 networks in 29 countries whereas 2 commercial networks of LTE CAT M [11].

Figure 2.1 gives us a clearer insight into the deployment of the two technologies more clearly:

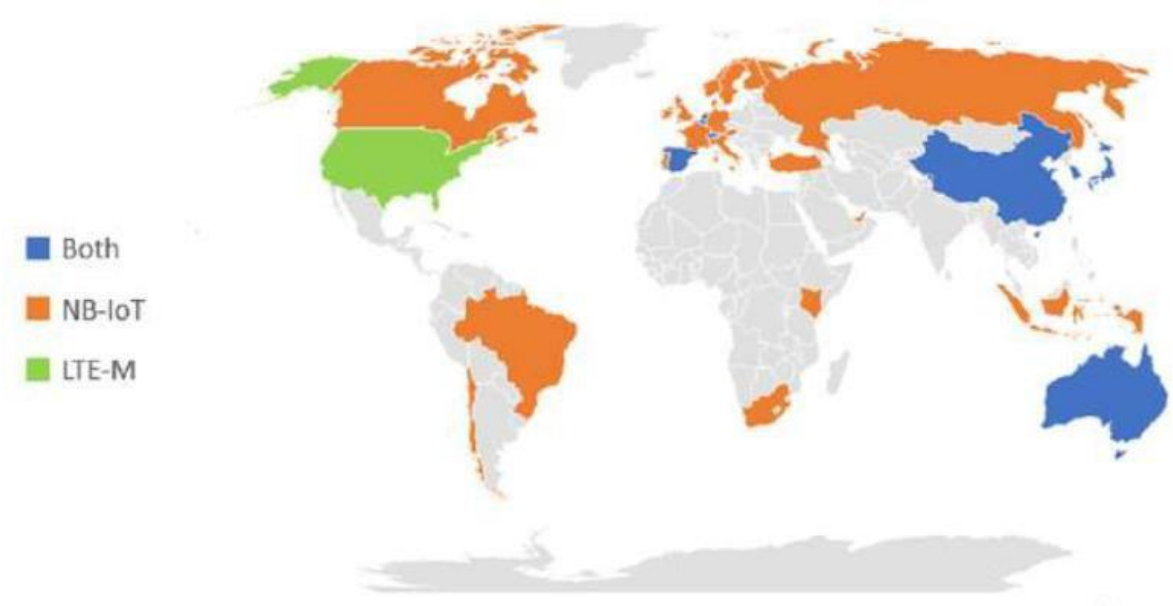


Fig 2.1: Worldwide deployment of NB-IoT and LTE-M [11]

Narrowband Web of Things (NB-IoT) has arrived at minimum amount with reported arrangement plans developing dramatically. Last year, the NB-IoT market was driven by a modest bunch of administrators, basically in Asia and Europe. Today, U.S. administrators Verizon, Run and T-Portable are optimizing their NB-IoT advancement. Toward the finish of 2018, the majority of the U.S., Europe and Asia Pacific will be covered by no less than one NB-IoT organization. Regardless of the early lead by unlicensed Low Power Wide Region (LPWA) organizing innovations, for example, LoRa® and Sigfox, the NB-IoT environment is quickly over taking them. Double mode choices have driven a large part of the underlying NB-IoT market where both LTE-M, a higher data transfer capacity choice that help voice and versatility and NB-IoT conventions are coordinated into the equivalent chipset. Lower chip costs, better execution and a guide that incorporates over-the air-updates, voice and versatility will guarantee that NB-IoT surpasses LTE-M in the close to term and Sigfox and LoRa over the course of the following five years [5].
We have further covered the two technologies (Nb-IoT and LTE CAT-M) for the niche prospective of smart campus and thereafter developing a business case on it.

2.2 IoT & Smart Campus

2.2.1. Definition of a Smart Campus

The word "smart" is ordinarily used to depict the capacity of an article in introducing the knowledge that has been embedded in it. The word "smart" is nailed to the telephone to show its insight to help numerous exercises or regular human existence through different administrations gave. Shrewd idea proceeds to develop and isn't

simply restricted to a solitary article however it likewise covers the parts of human existence all the more broadly, like brilliant city, savvy grounds, shrewd lattice, and so on. The improvement of the idea in the shrewd space has turned into a fascinating examination, so the specialized council was brought into the world in a worldwide specialized proficient association like IEEE, for instance: IEEE Brilliant Urban areas Local area that fosters the idea of savvy city and its execution, IEEE Savvy Framework that eclipses the improvement of brilliant lattice idea and execution. Besides, noticing the advancement of the idea of shrewd grounds turns into an intriguing conversation since there is no specialized advisory group that shades, so there is no standard utilized for the improvement of savvy grounds idea and execution.

The ongoing importance or meaning of brilliant grounds has not been funnel shaped to a typical comprehension. Different scientists who have fabricated a shrewd grounds. convey the definition in light of various methodologies. Whenever gathered, there are 3 (three) approaches utilized in characterizing shrewd grounds, in particular:

1. technology driven
2. smart city idea reception
3. based on the improvement of an association or business process

In light of the mechanical methodology utilized by a ground, shrewd grounds is an unmistakable distribute coming about because of the improvement of computerized grounds [12]. [13], [14] through the usage of the suitable arrangement of advances and the arrangement of administrations over the web [15] utilizing IoT specialist organization [16] and distributed computing to incorporate secluded frameworks [13]. The IoT administration is incorporated by changing normal items in a college climate into a savvy object by adding sensors and an exhaustive knowledge to help keen dynamic in a grounds climate. Brilliant grounds makes a concentrated computerized sensory system (DNS) that coordinates a total learning cycle across the grounds environment and works with the improvement of fitting applications or administrations to further develop grounds execution and graduate quality [15] and to work with all partners in a versatile climate including three variables: educating, the executives and administration [12].

In view of the methodology of savvy city idea reception, it is expressed that shrewd grounds has likenesses with a brilliant city with different difficulties looked by colleges and urban communities. Through a similar worldview shrewd ground takes on present day innovation to help various clients (understudies. workers, and guests) playing out various errands in multifunctional structures [17]. At the end of the day. the shrewd grounds is viewed as a little independent city in certain viewpoints like the quantity of capabilities, clients, exercises. furthermore, associations [18].

The third methodology characterizes shrewd grounds in view of the improvement of association or business process at a college The fundamental idea of savvy grounds is to foster the grounds through productive utilization of assets

[19] by applying a few kinds of knowledge to give great [20] and savvy administrations to grounds and natural networks in this manner decreasing functional expenses and making life more straightforward and better [19]. Knowledge is executed by including different sensor advancements to help detailing into all parts of grounds life naturally. counting joining. social cooperation for work coordinated effort, astute structure the board. what's more, a savvy climate.

In light of the three methodologies above, I presume that the fundamental thought of savvy grounds is a work to execute a bunch of cutting edge knowledge innovation by the college to work on the exhibition, the nature of the alumni, and the simplicity of life through the arrangement of data innovation benefits that are significant, for learning exercises as well as covering a more extensive viewpoint. counting: social cooperation, climate, office the board, energy saving. and so on.

Number of articles on Smart Campus [21]

Based on a crude search of strings like "smart campus", "Smart university" on popular sites following were the number of papers found:

TABLE II : Smart campus publications

Database journal	Article founds
IEEExplore	95
Sciencedirect	2
Springerlink	100
Scopus	52
Total	249

2.2.2. Roadmap to smart campus [21]

A university evolves into a smart campus after going through 3 (three) stages: traditional campus, e-campus, and digital campus [2].

TABLE III: Difference between Digital and smart campus

	Digital campus	Smart campus
Technical Environemn	Local area network internet	IoT, cloudcomputing wireless network, mobile terminal, RFID
Application	Learning resource in digtal form, distance learning, digital library, network management	Intelligent system using sensor, interoperability, and control ability
System Managemen t	Isolated	System sharing intelligent, push

2.2.3. Smart campus technologies[21]

A interplay between 7 major technologies constitutes building up a smart campus, Table IV shows publications based on these 7 technologies below.

TABLE IV: Smart campus technologies

No	Technology	Publications
1	Radio-frequency identification	8
2	Internet of Things	7
3	Cloud Computing	5
4	AR and VR	1
5	Sensor technology (motion, temperature, light, humidity, etc.)	6
6	Mobile technology (include NFC, QR code, GPS)	6
7	Web service	3

2.2.4. Smart campus Applications [21]

Various application areas form part of the smart campus model. Table V presents a grouping of the use cases into application domain and application within that domain and number of publications pertaining to it.I will be making use of these individual use cases to develop the smart campus model.

TABLE V: Smart campus applications

Domain	Smart Campus Application	Publications
Learning	Smart Learning Management	3
	Personalized Learning	3
	Assessment	3
	Smart Classroom	6
	Library Management System	2
Social	Market Management System	1
	News Management System	2
Management	People Identification	3
	Smart Attendance	2
	Safe Learning Environment	3
	Smart Parking	1
	Campus Geographic Information System	4

	Bathroom Management System	1
Governance	Teaching Management System	1
	Financial System	1
Green	Smart building	5
	Waste and water management	2

It can be seen that there is no researcher who has made any implementations in the health domain for campuses.

Research in the field of brilliant grounds to date keeps on developing. Over the most recent 5 years (2013-2017), consistently the quantity of exploration distributions increments around 1.5 times. Different applications have been executed to understand the idea of savvy grounds and I map these into a brilliant grounds model. Savvy grounds improvement regions are not restricted exclusively to help learning and showing processes, yet additionally support all parts of grounds life like climate, building, public activity, wellbeing and college administration.

CHAPTER 3
RESEARCH METHODOLOGY

The research project involves two important aspects, namely, the technological aspect with respect to cellular IoT technologies and the business aspect with respect to smart campus. Thus I have spent a considerable amount of time in performing analytical study of cellular IoT technologies and also its counterpart - LPWAN technologies. However our focus remains on cellular IoT since this is the only possible way a telecom operator could utilise the present infrastructure to get into IoT and hence generate new revenue streams.

The major source of data collection for this report include data from secondary source of information. Several market study reports, case studies, whitepapers and research data were referred as part of the secondary research.

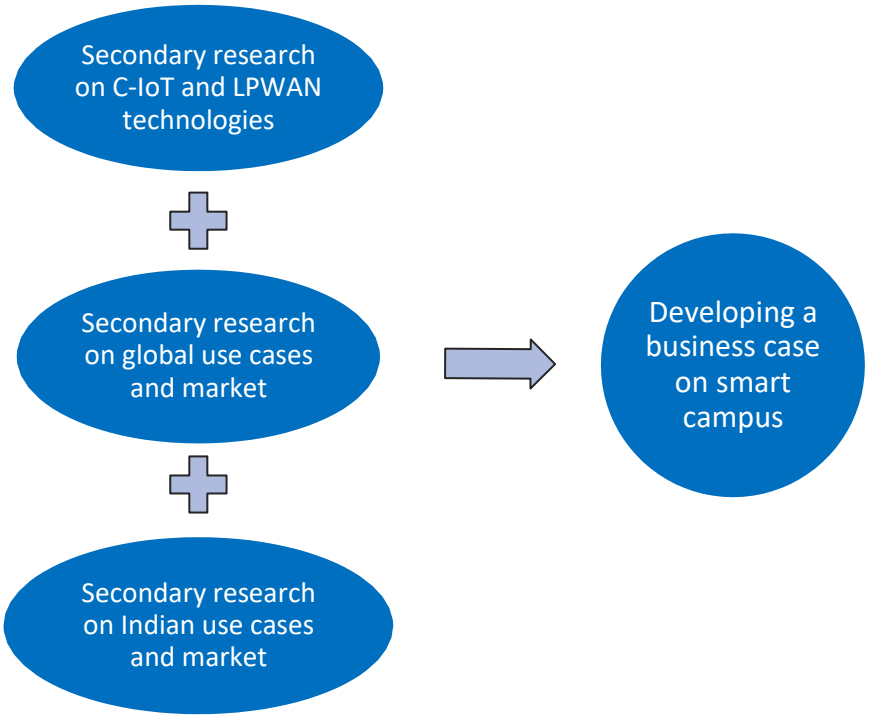


Fig 3.1 : Research Methodology

In order to focus on building the smart campus model I developed a few research questions. These are as follows

Q1. What are the features of a smart campus?
Q2. What kinds of technology support smart campus?
Q3. Is there any model for smart campus?
Q4. What are the implementations currently ?

I have focused on picking up problems from our campus itself - DTU and mapping the smart campus use cases to solve these problems. I conducted a small survey from the students, campus admin and various stakeholders like security guards, hostel staff, mess staff in order to understand the pain points and areas I should be focusing upon. Following were the crude areas I narrowed down upon based on the survey

TABLE VI: Pain points survey

Area	Pain points
Attendance	• Too much time wasted on taking attendance manually • ID cards cost money and also get lost • Proxy attendance • Logs
Smart classrooms	• How to make lectures interesting? • How to involve students? • Time wasted in setting up projectors, audio, video, laptops
Security	• Guards manually keep track of vehicles entering • Have to focus on sticker on car • Cabs wait in between for customers • Students take lifts, do not carry ID cards • Anyone can hop onto the bus,car enter the campus without appointments - no way of checking
Transport	• Crowd at bus stops differs based on timings and hence busses fall either short OR at times travel empty • Bicycles counts need to be maintained at pick up points • Anyone can hop onto the bus
Parking	• Constant arguments over parking • No way to find out who parked where, who does the car belong to • Jammers
Campus management, Energy management, Waste management, Water management	• Huge campus, no way of tracking • Hostels monitoring • Wastage, water, food management • Students go out for internships, holidays - this data should be used for optimizing water flow, food preparations and so on • Lights are turned on and off manually • Dashboard
Examinations	• Copy cases • Students forget ID's • Pen Paper based exams • Checking takes time

Based on the above points I tried to come up with one stop solutions to solve multiple issues, in orderto reduce capital expenditure and give economically viable solutions. I have also presented a cost analysis of the solution in terms of the technology needed.

The end result of the research project is a theoretical pilot of a smart campus which can be considered for implementation in future.

CHAPTER 4
NARROW-BAND INTERET OF THINGS (NB-IoT)

4.1 NB-IoT use cases and market potential

A solid development in the NB-IoT industry has spurred different examiner firms to make estimates showing the normal quantities of associations as well as income potential. As indicated by Huawei, the worldwide IoT market is supposed to be worth trillions of dollars by 2020. To comprehend this, it is important to comprehend the income potential in the nations they work in.

The verticals or enterprises distinguished, where NB-IoT can increase the value of the business incorporate the accompanying as indicated by Huawei:

i. Agriculture
ii. Automotive and Logistics
iii. Energy and Utilities
iv. Health Care/e-Health
v. Manufacturing
vi. Retail
vii. Safety and security
viii. Smart City
ix. Smart Home

In view of the profound country explicit exploration which incorporates social and segment information assessments, Huawei have displayed how the reception paces of various NB-IoT applications will create during the following couple of years. Unmistakable NB-IoT applications are in many cases sent in more than one industry. The models incorporate north of fifty use cases, covering many help classifications, for example,:

- Smart metering
- Facility management services
- Intruder alarms & fire alarms for home and commercial properties
- Connected personal appliances measuring health parameters
- Tracking of person, animals or objects
- Smart city infrastructure such as street lamps and dustbins
- Connected industrial appliances

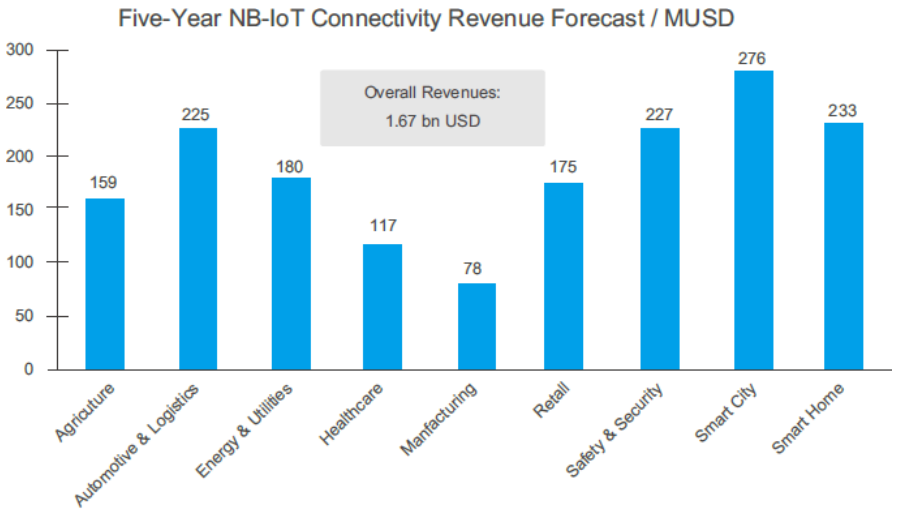


Fig 4.1 Five-Yr NB-IoT Revenue Forecast (Source: Huawei, 2016) [22]

4.2 NB-IoT Standardization History

In May 2015, the air interface advancements that had been proposed by Huawei and Qualcomm were combined thusly bringing about the two players consenting to involve FDMA in uplink and OFDMA in downlink, the name as at then was changed to NB CIoT (Narrowband Cell IoT).

After the innovation proposition of both Huawei and Qualcomm have been consolidated, different sellers including Ericsson expanded the speed of their examination of the Narrowband IoT innovation and later presented the NB-LTE (Narrowband LTE) idea during the August 10, 2015 GERAN Meeting.

In September 2015, 3GPP acknowledged the two NB-LTE and NB-CIoT as Work Thing in R13; in this manner, the name was changed to NB-IoT, additionally because of contrasts in perspectives of the air interface. Choice for the air interface has been deferred to the following gathering. Following a two-month time of conversations, an agreement was arrived at in December 2015.

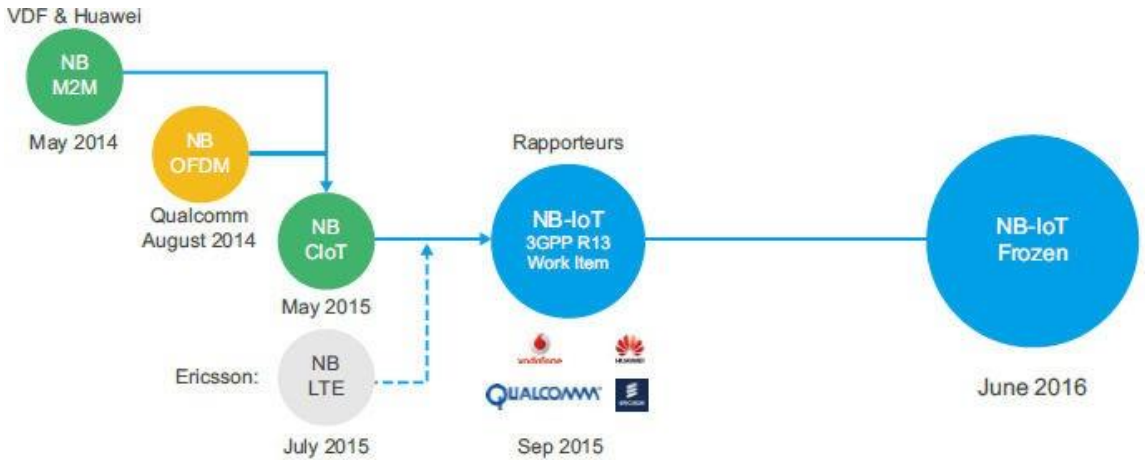


Fig 4.2: NB-IoT Timeline (Source: Huawei, 2016)[22]

The final air interface description agreed by all parties is as follows:

1. NB-IoT upholds 180 KHz transfer speed for both uplink and downlink.
2. OFDMA innovation in downlink - 15 kHz sub-transporter dividing
3. SC-FDMA innovation in uplink: two choices
    a. Single tone transmissions with 3.75 kHz or 15 kHz data transfer capacity.
    b. Multi-tone transmissions with 15 kHz UL subcarrier dividing.

4.3 GSMA Definitions

a) NB-IoT

Narrowband IoT (NB-IoT) is another 3GPP radio innovation standard that tends to the necessities of the Web of Things (IoT). The innovation gives worked on indoor inclusion,
backing of enormous number of low throughput gadgets, low defer responsiveness, super low gadget cost, low gadget power utilization and improved network design.

b) MIoT

Mobile Internet of Things, a GSMA expression that alludes to the 3GPP normalized low power wide region advancements utilizing authorized range groups (otherwise known as LTE-M, NB-IoT and EC-GSM-IoT). From 3GPP Delivery 13 and the accompanying Deliveries, the classification of client gear that supports power utilization enhancements, broadened inclusion and lower intricacy are important for MIoT (Class M1, Class NB1 from Delivery 13 and Feline M2, Feline NB2 from Delivery 14). As this specific term is generally utilized all through the GSMA, it is likewise used in this report.
It ought not be mistaken for the expression "MIoT" and that implies 5G gigantic IoT in 3GPP phrasing.

4.4 Power Saving Mode (PSM) – 3GPP Release 12 Feature

Power Saving Mode (PSM) was presented in 3GPP Delivery 12, to further develop the gadget battery duration of IoT gadgets as long as 10-years. The main advantage of this component is the UE has more control as far as power the executives expected for its application. There are an extensive variety of IoT applications where adaptability of the UE to deal with its power is vital and furthermore execution of PSM can forestall network blockage. The clocks of the multitude of gadgets can be overseen utilizing PSM, and the wake-up periods can be acclimated to be balanced however much as could reasonably be expected. This way each of the gadgets won't wake simultaneously and endeavor to get to the organization. The PSM mode is like power-off however the UE stays enlisted on the organization. [25]

The UE actuates PSM by remembering cheat values for the Join or Following Region Update (TAU). The newbie is the T3324, which characterizes the time the UE stays dynamic after inactive mode following the Append or TAU method. The subsequent clock is a lengthy T3412 which characterizes the drawn out time for a UE to send intermittent TAU.

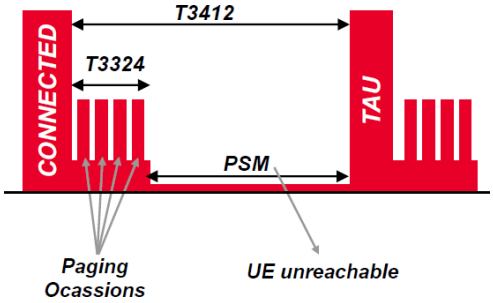


Fig 4.3: Power saving mode timers (Source: GSMA)[23]

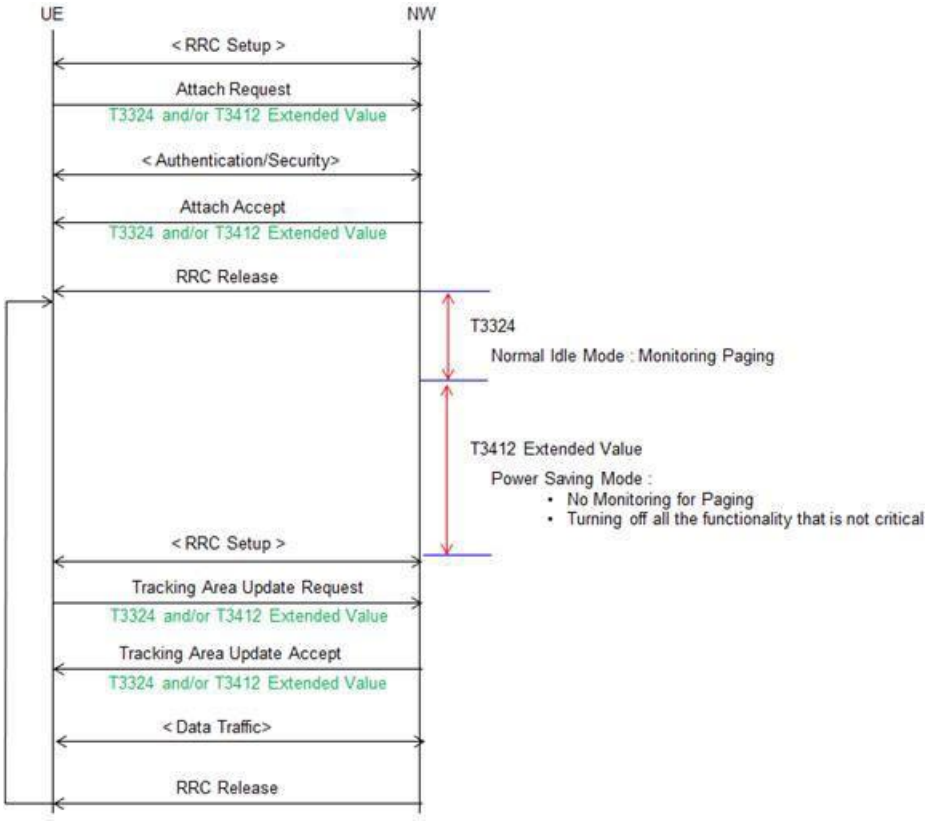


Fig 4.4: Power saving mode signalling (Source: GSMA)[23]

4.4.1 Power Saving Mode Clocks [3]

a) T3324 Dynamic Clock

The UE demands for a T3324 Dynamic Clock esteem during Join and TAU strategies. The MME assigns the T3324 worth to the UE. The T3324 dynamic clock decides the length during which the gadget stays reachable for portable ended exchange on change from associated with inactive mode. The gadget begins the dynamic clock when it moves from associated with inactive mode and when the dynamic clock terminates, the gadget moves to Power Saving Mode. The MME considers the UE mentioned esteem and MME neighborhood arrangement for deciding the Dynamic Clock esteem. The MME incorporates the T3324 esteem IE in the Append Acknowledge/TAU Acknowledge message provided that the T3324 esteem IE was remembered for the Connect Solicitation/TAU Solicitation message. A UE utilizing PSM is accessible for portable ending administrations just for the time of a Functioning Time after a versatile started occasion like information move or motioning for instance after an intermittent TAU/RAU methodology. The MME permits a worth of '0' for the T3324 clock. For this situation the UE enters the Power Saving Mode right away.

b) T3412 Expanded Clock

The T3412 clock is additionally alluded to as the occasional Following Region Update (TAU) clock. Intermittent following region refreshing is utilized to advise the accessibility of the UE to the organization occasionally. The method is controlled in the UE by the occasional following region update clock (clock T3412). The worth of clock T3412 is sent by the organization to the UE in the Append Acknowledge message and can be sent in the Following Region UPDATE Acknowledge message. The UE will apply this worth in all following region of the rundown of following regions doled out to the UE, until another worth is gotten. A more drawn out occasional TAU clock is conceivable utilizing T3412 broadened clock. At the point when the UE incorporates the T3324 esteem IE and the UE shows support for broadened occasional clock esteem in the MS network highlight support IE, it might likewise incorporate the T3412 expanded esteem IE. Aside from the worth mentioned by the UE, the MME confirms the neighborhood setup into account while choosing an incentive for the T3412 broadened clock. At the point when the MME incorporates the T3412 expanded esteem IE in the Connect Acknowledge message or Following Region UPDATE Acknowledge message, the MME utilizes clock T3412 broadened esteem IE as the worth of clock T3412.

4.4.2 Power Saving Mode Limitations

During the PSM the UE disconnects itself from the network. Hence any network-initiated messages will either be in buffer or will be dropped depending on the configuration. The PSM mode puts the mobile into sleep in order to save the battery life which totally loses contact with the network. The UE is then available for a certain period of time to transmit the data to server before it informs the network and goes to sleep. The UE wakes up at periodic intervals to check if there are any incoming messages. The time between the two data transfers in called as the Tracking Area Update (TAU) period.

At the point when a gadget starts PSM with the organization, it gives two favored clocks (T3324 and T3412); PSM time is the distinction between these clocks (T3412-T3324). The organization might acknowledge these qualities or set various ones. The organization then holds state data and the gadget stays enrolled with the organization. In the event that a gadget rises and shines and sends information before the lapse of the time span it concurred with the organization, a reattach method isn't needed.

In PSM, the gadget will rest for extremely extensive stretches of time and subsequently not send any information. On the off chance that the firewall erases the GTP meeting, this could prompt another enrollment of the UE once it awakens (assuming it is utilizing Join with PDN association) or to the need to restore the PDN association. This cycle will lessen battery lifetime.

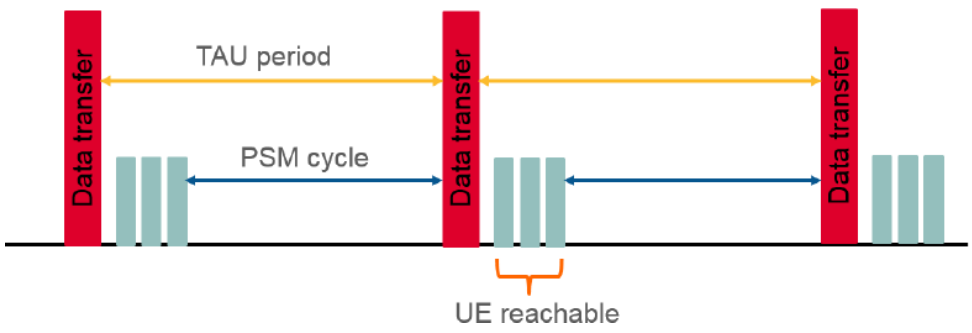


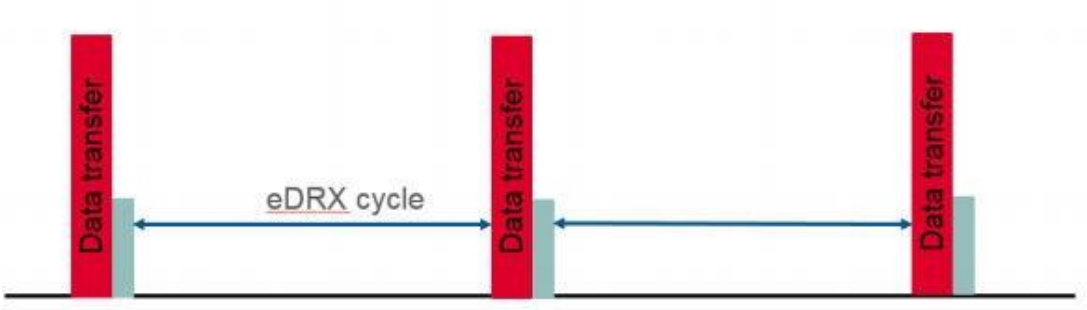
Fig 4.5 PSM Limitations - UE disconnect (Source: GSMA)[23]

4.5 Extended Discontinuous Reception (eDRX) – 3GPP Release 13 Feature

Expanded broken gathering (eDRX) is a system utilized by the UE and the organization to decrease UE power utilization by broadening its resting cycle out of gear mode. It could be utilized rather than, or notwithstanding, PSM characterized in the Delivery 12 of 3GPP.

Expanded Irregular Gathering (eDRX) is an augmentation of a current LTE includes which can be utilized by IoT gadgets to lessen power utilization. eDRX can be utilized without PSM or related to PSM to get extra power reserve funds.

Today, a large number utilize intermittent gathering (DRX) to expand battery duration between re-energizes. By immediately turning off the get part of the radio module for a small portion of a second, the cell phone can save power. The cell phone can't be reached by the organization while it isn't tuning in, yet on the off chance that the timeframe is kept to a concise second, the cell phone client won't encounter a recognizable corruption of administration. For instance, whenever called, the cell phone could just ring a negligible part of a second after the fact than if DRX was not empowered.



eDRX permits the time span during which a gadget isn't paying attention to the organization to be incredibly expanded. For an IoT application, it very well may be very OK for the gadget to not be reachable for a couple of moments or longer. While not giving similar degrees of force decrease as PSM, for certain applications eDRX might give a decent split the difference between gadget reachability and power utilization. [4]

Fig 4.6 eDRX (Source: GSMA)[23]

As per the standards set by GSMA for the eDRX cycle lengths, the device may sleep for various time lengths as follows:

eDRX cycle length
20.48 seconds
40.96 seconds
81.92 seconds (~1 minute)
163.84 seconds (~ 3 min)
327.68 seconds (~ 5 min)
655.36 seconds (~ 11 min)
1310.72 seconds (~22 min)
2621.44 seconds (~44 min)
5242.88 seconds (~87 min)
10485.76 seconds (~175 min)

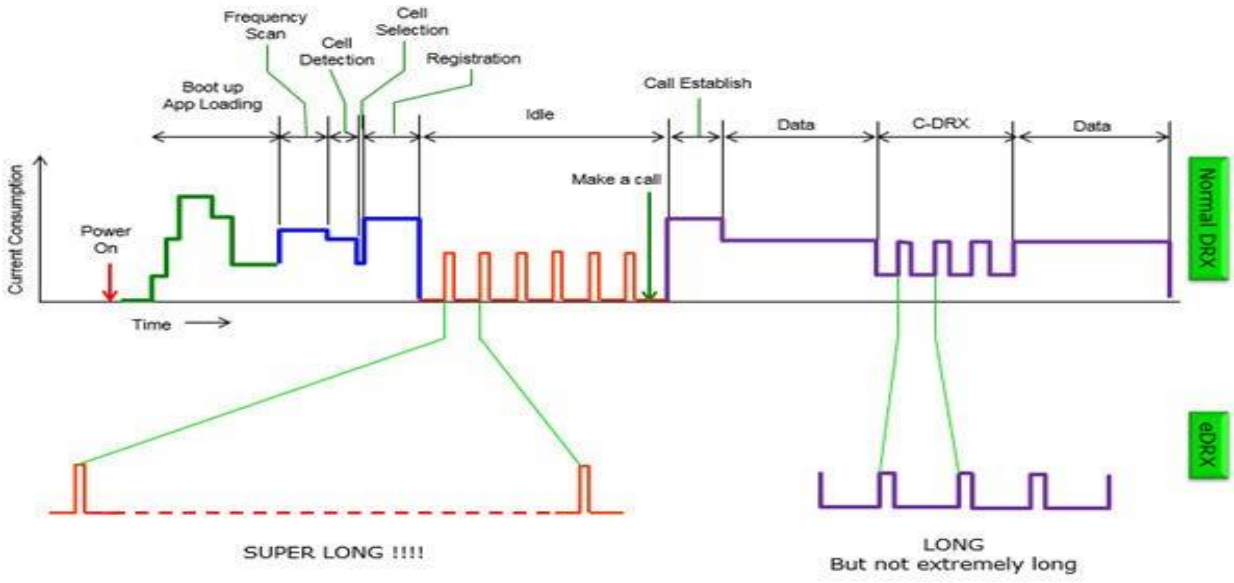


Fig 4.7 : eDRX timing diagram (Source: GSMA)[23]

PSM and eDRX are complementary features and a customer's application might need both. This guide recommends that customers should be informed about the implications of their choice for power consumption versus reachability.

The device can request the use of both PSM and eDRX during an attach or TAU procedure, but it is up to the network to decide to enable none, one of them or both.

4.6 NB-IoT Deployment modes

a) Standalone Deployment

Standalone deployment is a deployment scenario in which operators deploy NB-IoT using existing idle spectrum resources. These resources can be the operator's spectrum fragments with non-standard bandwidths or spared from other radio access technologies (RATs) by reframing.

b) Guard-band Deployment

Monitor band sending is an organization situation where administrators convey NB-IoT in watch groups inside existing LTE range assets.

c) In-band Deployment

In-band organization is a sending situation where administrators convey NB-IoT utilizing existing LTE in-band asset blocks (RBs).

4.7 NB-IoT Architecture

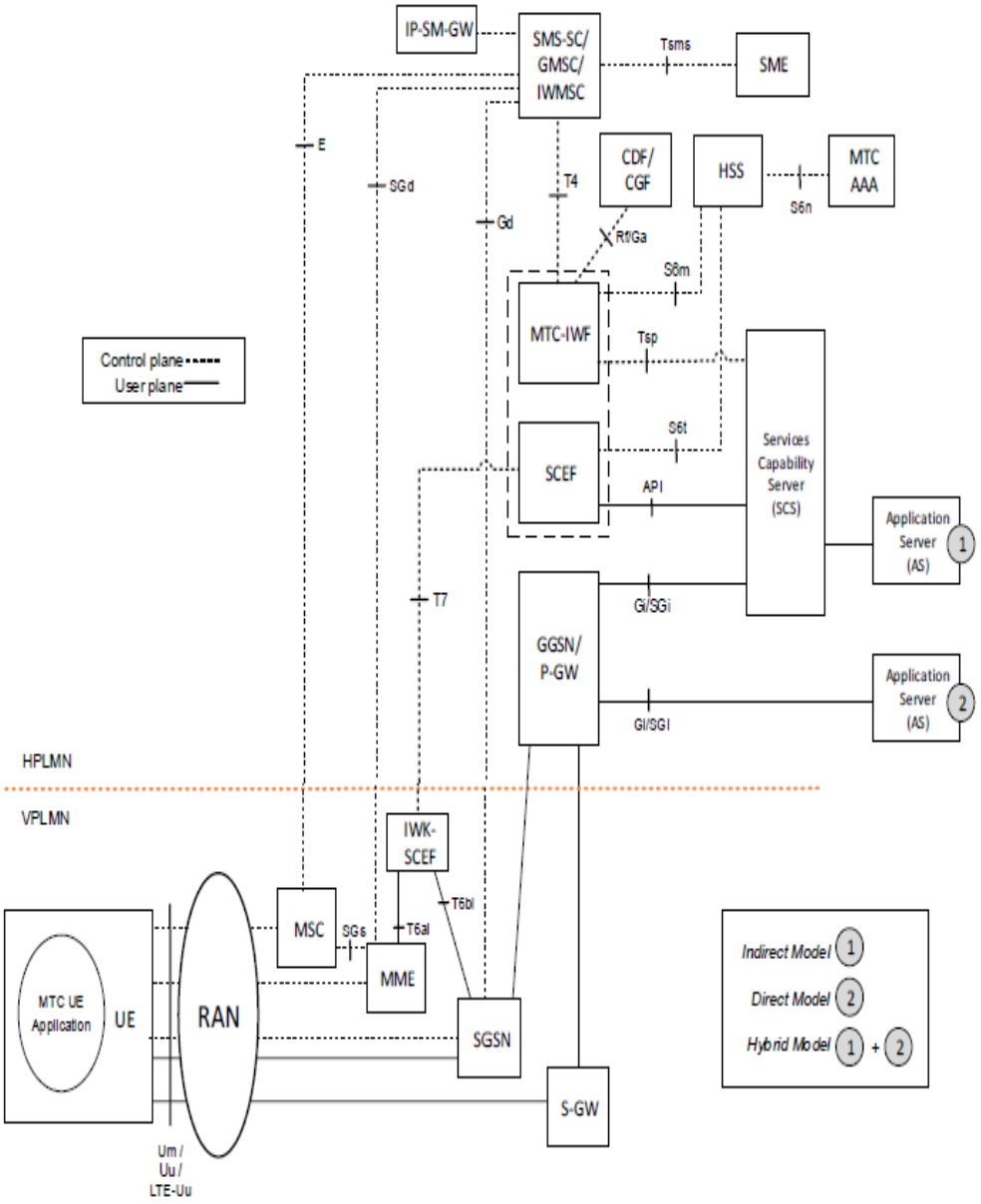


Fig 4.8 : NB-IoT architecture (Source: GSMA)[23]

CHAPTER 5
Long Term Evolution – Category – Machines (LTE-Cat-M)

5.1 Market Demand and Potential

With increasing global demand for internet of things, the need for low power, low throughput and low-cost cellular devices is on the rise. LTE Cat-M and NB-IoT, the two cellular technologies proposed by 3GPP in release 12 and release 13, are leading the cellular IoT industry. Depending on the business case requirements and application, one of the above two technologies is preferred over other. Both the technologies are competing for position and adoption across the world. The LTE Cat-M is preferred over NB-IoT in United States as majority of the networks in U.S. are based on the LTE backbone. Conversely, the European nations prefer to go ahead with NB-IoT due to the flexibility and network-agnostic characteristic.

Both the technologies share several crucial beneficial elements over the existing technologies. Both offer a low-cost technology solution and slightly defer in terms of costs. While each technology has its own pros and cons, the decision of selecting them purely relies on the local coverage. In general, NB-IoT is preferred technology for non-mobility and metered application where the transmission is in short bursts, such as street lighting, periodic utility readings and smart parking. CAT-M applications add up the mobility, high data payloads and enable to transmit data streams in applications like smart bicycles, vehicle tracking, traffic monitoring, asset tracking, etc.

According to the public statement by Market Watch in September 2018, the C-IoT market is supposed to observe a consistent development of 26.7% CAGR by 2026 end. Based on end use industry, the worldwide cell IoT market is sectioned into horticulture, medical services, retail, energy, auto and transportation, foundation, and others. Income commitment in the phone IoT market from the energy section is supposed to extend at a CAGR of 28.1% during the gauge time frame.

5.2 Geographical Classification

Currently, countries including U.S., China, European nations, Japan and Korea support either NB-IoT or LTE-Cat-M. It is expected that operators who exclusively started with NB-IoT will incorporate CAT-M technology within the next two years to leverage some of the maturity features of CAT-M that were created by U.S.-based operators. It is also seen that operators who started with CAT-M will add NB-IoT to their networks.

The two largest networks in North America, Verizon and AT&T, currently support CAT-M only. Initially, the decision to support CAT-M was driven by its ability to support a wider range of applications, earlier standardization in 3GPP, and its requirement for simpler infrastructure changes. However, since most current infrastructure vendors already support both technologies, North American operators are expected to integrate NB-IoT and adopt the dual-mode concept within the next two years. Additional leading operators in other regions, including Europe, Japan and Australia, are demonstrating similar integration trends as well.

5.3 Standardization

The connectivity in CIoT devices can be cellular or non-cellular. In case of local unlicensed band standards, there is a need of router to reach the internet. Conversely, in case of LTE Cat-M, the operator is benefited as the existing infrastructure is reused and rolled out. [1]

In not so distant past, LTE-M could have been viewed as the less fortunate cousin to NB-IoT and expected to just be famous in the North America area, because of framework restrictions in the organizations around there, forestalling simple move up to NB-IoT. In any case, it has been getting forward movement inside Europe and Asia with Orange, Telefonica, China Versatile and KPN presently supporting LTE-M as an assistant to their own LoRa plans.

LTE-M activity is like a sluggish 3G association with speeds normally under 1 megabyte each second. It upholds development between base stations and it additionally upholds voice administrations. Supporters of LTE-M say that it can address a variety of fixed IoT applications (for example Brilliant Meters), too IoT applications moving, for example, cargo following, likewise upholds use cases requiring somewhat higher transmission capacities.

5.4 Deployment module

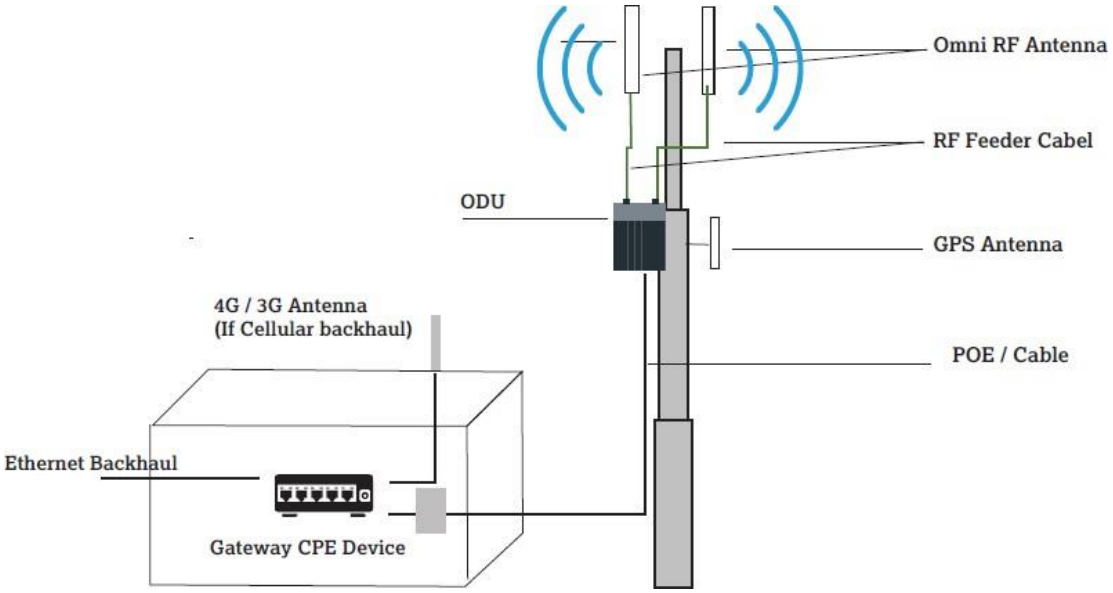


Fig. 5.1. LTE Cat-M Deployment Module (Source: Tata Tele Business Services) [9]

Because of the rearrangements presented in 3GPP for the impending LTE Feline M norm, compositional improvements are likewise conceivable. The heaviest calculations as far as sign handling are as yet run on devoted gas pedals to meet timing and lessen power. [24]

5.5 LTE Cat-M Deployment [3]

According to 3GPP, including Release 14, there is a defined set of frequency bands for which LTE-M can be used. 3GPP specification from Release 13 provides the list of the supported bands: 1, 2, 3, 4, 5, 7, 8, 11, 12, 13, 18, 19, 20, 26, 27, 28, 31, 39, 41 and Release 14 added the bands: 25 and 40.
From the input received by the LTE-M Task Force members so far there are a variety of bands that have been indicated to be used. In order to achieve global roaming support, the following bands will need to be covered in order to produce global modules that cover North America, Latin America, Europe and parts of Asia:

Bands 1, 2, 3, 4, 5, 12, 13, 20, 25, 26, 28

As indicated above only a subset of the bands supported by 3GPP Release 13 are envisioned to be used, currently 11 frequency bands for a global coverage in all the countries for which the LTE-M members have provided input. As indicated there has been input from 11 MNO groups covering North America, Latin America, Europe and parts of Asia.

5.6 LTE Cat-M Features [3]

a) LTE Inclusion Improvement (CE)

UE utilizes improved inclusion usefulness to get to the cell. This is a RAN include in light of the reiteration of messages between the UE and the eNB. A solitary vehicle block is sent over numerous sub outlines, consequently giving higher communicate energy per data bit for a given send power.

b) **High Inertness Correspondence**

High inertness correspondence is a component utilized for gadgets utilizing PSM or potentially eDRX. It permits a lengthy buffering of downlink information bundles in view of organization consciousness of UE power saving cycle until UE becomes reachable once more

c) Attach without PDN Association

Join without PDN association foundation permits the UE to be joined without having a Default PDN association laid out. SMS is accessible to UE that has joined without PDN association

d) Monitoring Upgrades

The organization identifies and reports occasions that M2M Application Servers/Administrations Capacity Server have arranged, connected with their gadgets: relationship of the UE and UICC, UE reachability, Accessibility after DDN disappointment, Current Area, Loss of availability, Wandering status. The help of checking highlights in meandering situations suggests a wandering understanding between the HPLMN and the VPLMN.

CHAPTER 6
C-IoT COMPARISON, EVOLUTION & MARKET

6.1 Comparison 3GPP Technology Releases [26]

TABLE VII: Comparison of 3GPP Technology Releases

	Release 8	**Release 8**	**Release 12**	**Release 13**	**Release 13**
	Cat. 4	**Cat. 1**	**Cat. 0**	**Cat. M**	**NB-IoT**
Downlink peak rate	150 Mbps	10 Mbps	1 Mbps	1 Mbps	200 kbps
Uplink peak rate	50 Mbps	5 Mbps	1 Mbps	1 Mbps	144 kbps
Number of antennas	2	2	1	1	1
Duplex mode	Full duplex	Full duplex	Half duplex	Half duplex	Half duplex
UE receive bandwidth	20 MHz	20 MHz	20 MHz	1.4 MHz	200 kHz
UE transmit power	23 dBm	23 dBm	23 dBm	20 dBm	23 dBm
Modem complexity	**100%**	**80%**	**40%**	**20%**	**<15%**

6.2 LTE-M evolution for CIoT [27]

LTE upholds both recurrence division duplex (FDD) and time division duplex (TDD) modes utilizing a typical subframe design of 1ms. Having such a short subframe length considers idleness to be limited, hence guaranteeing a decent client experience.

3GPP Rel-12 has determined minimal expense M2M gadgets (Feline 0), the subtleties of which are summed up in the following segment. In Rel-13, normalization is continuous to additional upgrade inclusion, battery duration, and lower intricacy contrasted with existing LTE gadgets. 3GPP for LTE-M has the accompanying targets:

- Determine another gadget classification for M2M activity in all LTE duplex modes in light of the Rel-12 low intricacy gadget classification supporting the accompanying:

i. Reduced gadget data transmission of 1.4 MHz in downlink and uplink.
ii. Reduced most extreme communicate force of 20 dBm.

- Provide an LTE coverage improvement – corresponding to 15 dB for FDD – for the device category defined above and other devices operating delay tolerant M2M applications with respect to nominal coverage.
- Enhance the DRX cycle in LTE to allow for longer inactivity periods and thus optimize battery life.

The narrow band NB LTE-M proposal is set for approval in 3GPP Rel. 13 with the following improvements over LTE-M:

a) Reduced device bandwidth of 200 kHz in downlink and uplink.
b) Reduced throughput based on single PRB operation.
c) Provide LTE coverage improvement corresponding to 20 dB (5 dB better than LTE-M)

6.3 Selecting between LTE-M and NB-IoT

Both LTE-M and NB-IoT are LPWA advancements for low-transmission capacity IoT applications characterized by the 3GPP in Delivery 13 and meet the necessities for minimal expense, low-power and expanded inclusion. The decision between LTE-M and NB-IoT relies to a great extent on how much information that you anticipate utilizing and how much inactivity is satisfactory for your application (for example whether you call for ongoing correspondence).

a) Latency

Inactivity is how much time it takes to get on an organization and communicate something specific. A gadget can either gather data and send a parcel to the cloud in spans or it can impart progressively. This is where most contrasts between LTE-M and NB-IoT should be visible.

For strategic applications, LTE-M is the main choice. It upholds gadgets that need to impart continuously to guarantee the application meets client experience necessities. A few instances of continuous correspondence incorporate voice, crisis information and accuracy following information. With regards to voice, there two or three things to explain. In the first place, although LTE-M innovation upholds voice, it will ultimately depend on each organization administrator with regards to whether it gets executed on their LTE-M organization. Second, in expanded inclusion circumstances, voice wouldn't work by any stretch of the imagination with LTE-M. Voice is just upheld in standard inclusion situations.

b) Speed

Higher rates imply that information can be pushed more through the organization in a given time span. Speed is particularly significant for additional information serious IoT applications like home security or wearable gadgets. Even though LTE-M won't ever rival the standard LTE and LTE-Progressed network transmission capacity or paces, it takes into consideration more information throughput contrasted with NB-IoT. One more significant truth to consider is that there are no NB-IoT use cases that LTE-M can't likewise uphold. At the end of the day, LTE-M backings any LPWA application, while NB-IoT is intended for less difficult static sensor type applications.

c) Use Case Reliance

Choosing LTE-M and NB-IoT won't just rely upon the determination yet additionally on the utilization case to be executed, accessible data transmission, network clogs and criticality of the utilization case.

6.4 LTE-M Release 12 Optimization

Rel.12 presents a new low intricacy gadget classification ("Feline 0"). This minimal expense classification characterizes a bunch of diminished prerequisites empowering lower intricacy and cost of gadgets. The key decreases concurred in Rel. 12 are:

- Half duplex FDD activity permitted. This makes it conceivable to work LTE FDD time multiplexed staying away from the duplex channel.
- Diminishing the gadget get transfer speed to 1.4 MHz takes into account significant intricacy decrease. The gadget can in any case work in all current LTE framework data transmissions up to 20 MHz
- Single get chain. This eliminates the double recipient chain for MIMO.
- Lower information rates. Presenting a lower information rate necessity, the intricacy and cost for both handling power and memory will be decreased fundamentally.

6.5 LTE-M Release 13 Optimization

Further simplification of devices will be achieved in Rel-13:

- Low RF bandwidth support (e.g. 1.4 MHz). This would further reduce complexity as a narrowband RF design would be sufficient
- A lower device power class of 20 dBm will allow integration of the power amplifier in a single chip solution.

6.6 NB-IoT Release 13 Cost Optimization

The thin band NB LTE-M proposition is a development of the LTE-M expense enhancements with the accompanying upgrades contrasted and LTE-M:

- Decreased gadget transfer speed of 200 kHz in downlink and uplink.
- Decreased throughput in view of single PRB activity to empower lower handling and less memory on the modules.

6.7 Control Plane CIoT EPS Optimization

It transports client information or SMS messages going through MME. This is finished by typifying them in NAS, decreasing the all-out number of control plane messages while taking care of a short information exchange.

For the Control Plane CIoT EPS advancement, information trade between the UE and the eNB is finished on RRC level. In the DL, information parcels might be piggybacked in the RRC Connection Setup message or in the UL in the RRC Connection Setup Complete message. On the off chance that this isn't adequate, information move might be kept utilizing the two messages DL Information Transfer and UL Information Transfer:

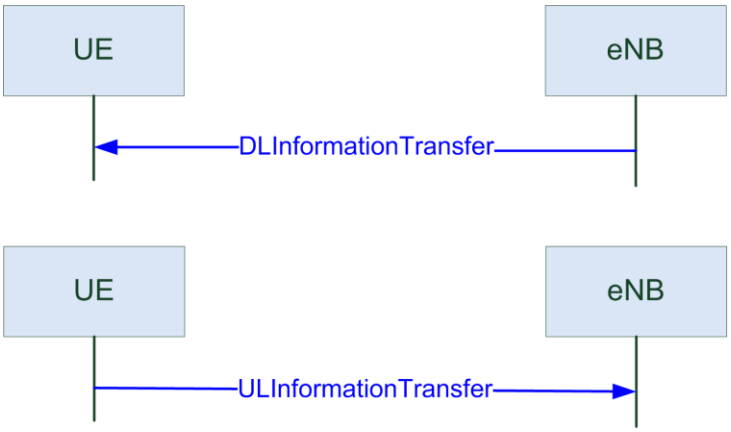


Fig. 6.1: NAS dedicated information transfer between the UE and the eNB (Source: 3GPP)[27]

Contained in all these messages is a byte array containing NAS information, which in this case corresponds to the NB-IoT data packets. Consequently, it is transparent to the eNB, and the UE's RRC forwards the content of the received DL Information Transfer directly to its upper layer. Between the eNB and the MME, the dedicated Info NAS is exchanged via the S1-MME interface.

For this data transfer method, security on AS level is not applied. As there is also no RRC connection reconfiguration, it may immediately start after or during the RRC connection setup or resume procedure, respectively. Of course, the RRC connection has to be terminated afterwards with the RRC connection release. These enhancements can be utilized:

• Independently: Assuming the UE or the organization upholds one of them.

• In Equal: Assuming the UE or the organization upholds both. On the off chance that both the Control Plane and Client Plane CIoT EPS enhancements are upheld for a UE, the PDN associations that utilization just control plane CIoT improvements are taken care of through the Control Plane CIoT EPS improvements. For instance, the MME that has incorporated the "control plane just pointer" in the ESM solicitation will be taken care of by the control plane CIoT EPS enhancement.

Any remaining PDN associations are dealt with utilizing Control Plane or Client Plane CIoT EPS advancements. Moreover, the Control Plane CIoT advancement can be utilized to help PDN associations with a SCEF.

6.8 User Plane CIoT EPS optimisation

In the Client Plane CIoT EPS streamlining information is moved over the traditional client plane through the organization, for example the eNB advances the information to the S-GW or gets it from this hub. To keep the UE intricacy low, only a couple of DRB might be designed all the while.

Two cases must be recognized: When the past RRC association was delivered with a potential resume activity demonstrated the association might be mentioned as a resume technique. In the event that this resume method is effective, security is laid out with refreshed keys and the radio carrier are set up like in the past association. On the off chance that there was no past delivery with a resume sign, or on the other hand on the off chance that the resume demand was not acknowledged by the eNB, security and radio carrier must be laid out.

6.9 Call Flows [28]

a) Non-IP Data Delivery over the SGi Interface

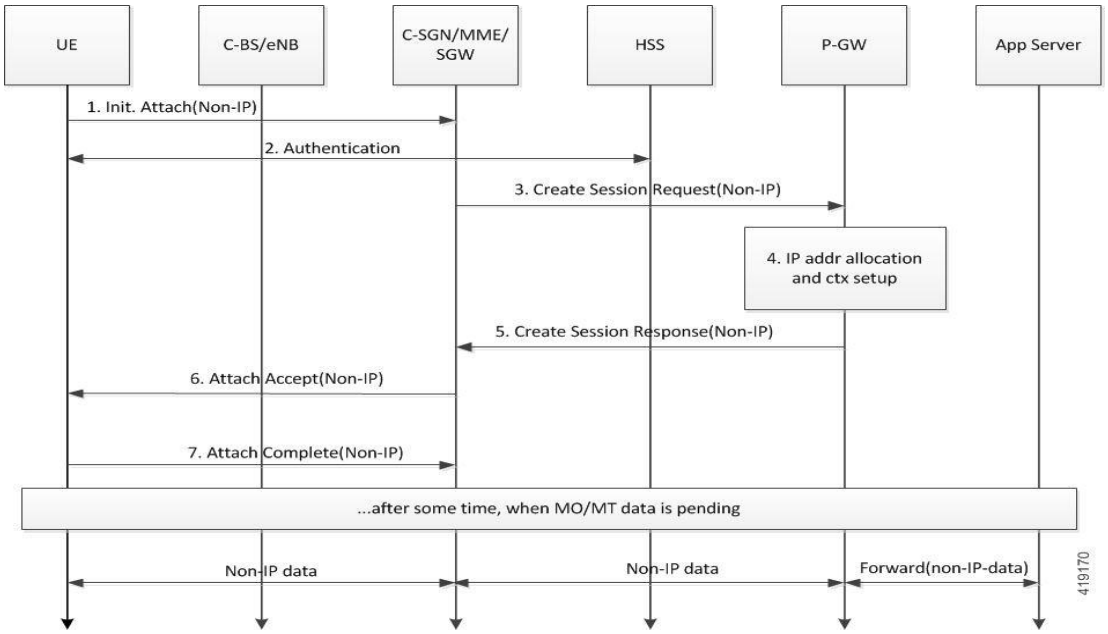


Fig. 6.2 Non-IP Data Delivery over the SGi Interface

b) Data Paths - CIoT Optimization for IP and Non-IP Data

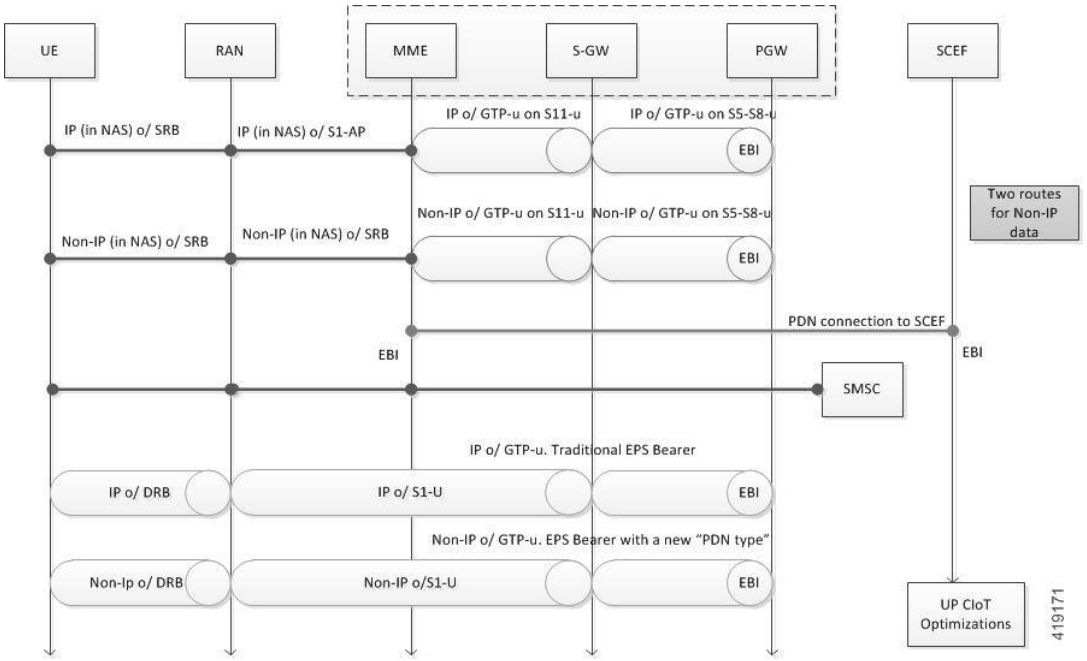


Fig. 6.3 CIoT Optimization for IP and Non-IP Data

c) Attach with PDN using CIoT Optimization

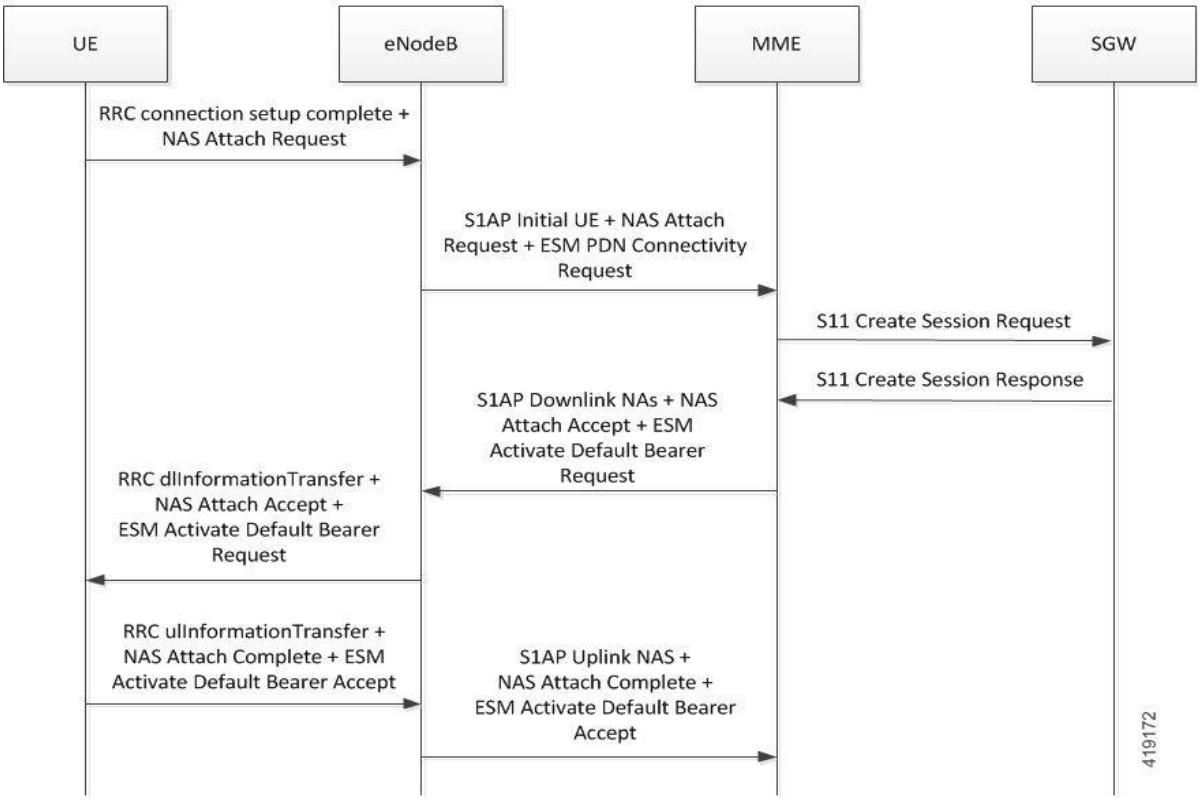


Fig. 6.4: CIoT Optimization

d) NAS Control Plane Service Request Procedure

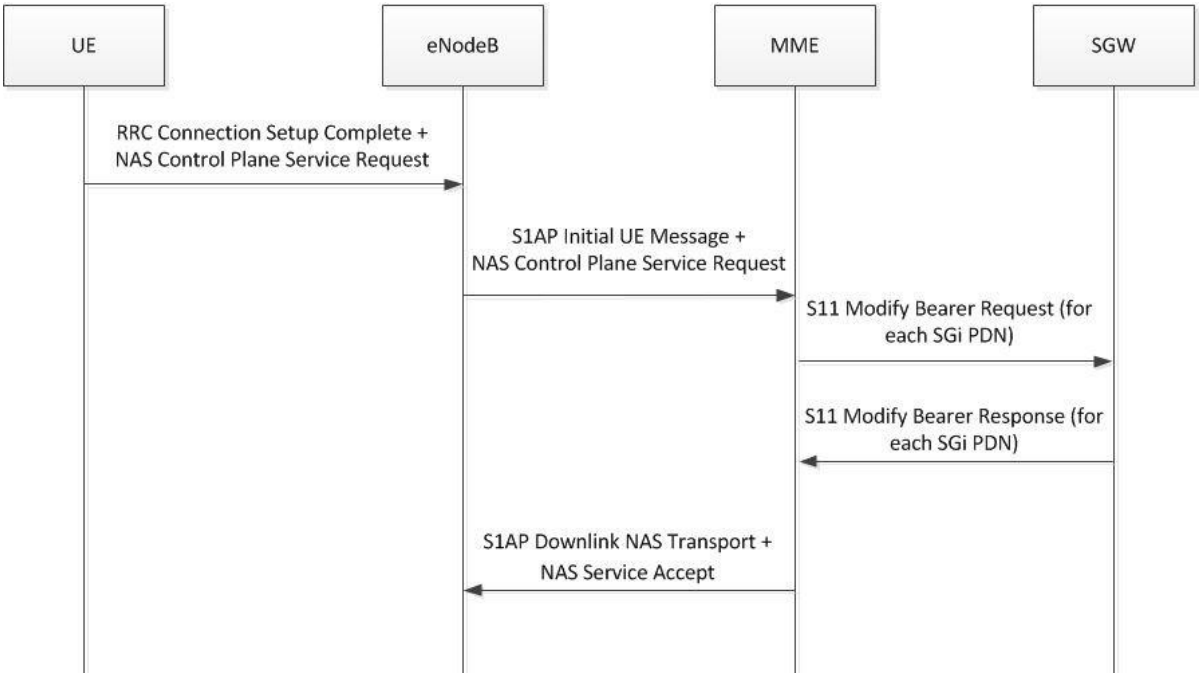


Fig. 6.5: NAS Control Plane Service Request Procedure

6.10 Comparison of C-IoT with LPWAN

Although LPWAN technologies are not a focus of the research project it would be worthwhile to know compare C-IoT technologies with respect to LPWAN technologies in order to understand the pros and cons. However it should be noted, Cellular IoT is the only way for telcos to get into IoT space by using current infrastructure. Licensed technologies also give a better way of regulating the IoT space. Although LPWAN captures the current market, the future has to be C-IoT due to the huge risk of LPWAN being proprietary and company specific.

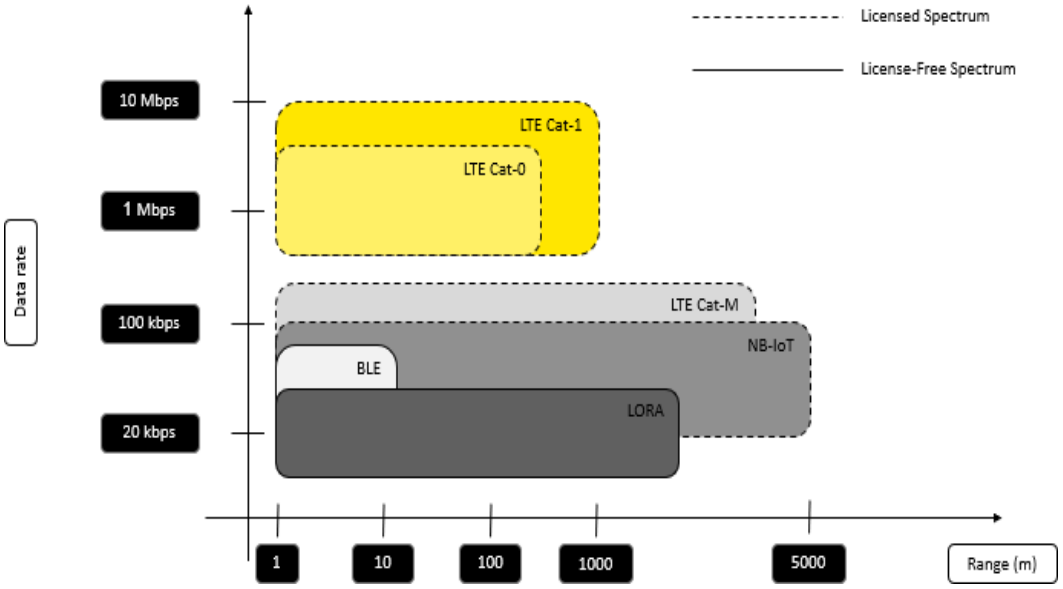


Fig. 6.6: Range Vs. Data Rate Mapping

TABLE VIII : Comparison of LPWAN and C-IoT technologies

Technology	LoRa	SigFox	Ingenu	LTE-M Or Cat-M	NB-IoT	3G/4G
Module Cost	$4-$6	<$3	$10	$10-$15	$10-$15	$20-$40
Annual Connectivity Cost/Device	$1-$15	$1-$13	Not Available	$24	Not Available	$25- $36
Range	Up to 30 miles	Up to 30 miles	Up to 8 miles	Up to 6-7 miles	Not commercially deployed	Up to 43 miles
Max packet size	242 bytes	12 bytes	Flexible	Flexible	Flexible	flexible
Max Data Rate(kbps)	5	0.3	41	1000	200	200
Battery life	High	High	Moderate	Low	Low	Low
Deployment	Macro based, cost optimizecd picocells	Macro based	Macro based	Macro, small cells	Macro ,small cells	Macro, small cells
Frequency &spectrum	915 MHz-ISM	915MHz-ISM	2.4 GHz	700-2000 MHZ Licensed	700- 2000 MHz Licensed	Multiple bands
Standardization	LoRa Alliance	Single source network	Global IEEE Standard	3GPP	3GPP	3GPP
Gateway mode	Full or half	Half duplex	Half duplex	Full or half	Half duplex	Full or half

	duplex			duplex		duplex
Total number of devices	20 M	10M	Not Available	Not available	Not available	Deployed at scale

6.11 C-IoT Market deployments - Global and Indian

TABLE IX : C-IoT Global Deployments

Region	Country	Operator	NB-IoT	LTE-M
Africa				
	South Africa	Vodacom	✓	
Asia & Pacific				
	Australia	Telstra		✓
	China	China Telecom	✓	
	China	China Unicom	✓	
	China	China Mobile	✓	
	Singapore	M1	✓	
	South Korea	KT Corp		✓
	South Korea	SK Telecom		✓
Middle East				
	UAE	Etisalat	✓	✓
	Turkey	Turk cell	✓	
U.S. & Canada				
	United States	AT&T		✓
	United States	Verizon		✓
Western Europe				
	Germany	Telekom Deutschland	✓	
	Ireland	Vodafone Ireland	✓	
	Netherlands	T-Mobile	✓	
	Netherlands	Vodafone/Ziggo	✓	
	Norway	Telia Norge	✓	
	Spain	Vodafone Spain	✓	

TABLE X : Indian Telecom Operators in C-IoT

Operators	Present Connectivity	Future Connectivity
Vodafone	**Cellular GSM (2G/3G), LTE (4G)/LPWAN (not as extensive as cellular)**	**NBIoT**
Airtel	**Cellular GSM (2G,3G), LTE(4G), TD-LTE, GPRS, EDGE, HSPA+, HSDPA, UMTS**	**Cellular 5G**
Reliance Jio	**Cellular LTE 4G, NBIoT(Mumbai)**	**NBIoT**
Idea Cellular	**Cellular LTE 4G**	**Cellular 4G/4G+/5G**
BSNL	**NA**	**Cellular 5G**
Tata Communications	**LPWAN- LoRa**	**LPWAN-LoRa**
Sigfox	**Cellular LTE-M, NBIoT/ Sigfox/ dual connectivity**	**Cellular/ LPWAN/dual connectivity**

CHAPTER 7
THEORETICAL BUSINESS CASE PILOT

7.1 Introduction

I, a student at Delhi Technological University (DTU), am trying to research and develop a theoretical model for a business case pilotof a smart campus system. When I state about the smart campus, I intend to exploit the wireless cellular IoT in our pilot applications, which in turn should prove to be a business case for a telecom operator.

In this advanced period, things are getting less difficult as nearly everything is being programmed, supplanting the old manual frameworks. These days, web has turned into a necessary piece of human's day to day existence and a mechanism of correspondence. Around here case Web of Things (IoT) gives a stage where gadgets can be associated, detected, and controlled from a distance across an organization framework. The IoT gadgets controls and screens the electronic, electrical and the mechanical frameworks that are to work in a ground. One individual has some control over different gadgets associated with the cloud server and furthermore work with various sensors and control hubs. The framework planned is prudent and versatile as it very well may be extended by interfacing and controlling of various gadgets. The interconnected things have physical or virtual portrayal in the computerized world, detecting/incitation capacity, a programmability highlight and are particularly recognizable. The portrayal contains data including the things character, status, area or some other business, social or secretly pertinent data.

Different regions can be looked at when as a shrewd ground is to be thought of. A school grounds needs a ton of IoT innovation for tasteful climate to use got and current innovation for e-grounds exercises in scholarly game-plan. Overall setting, the school are associated with Web, and their comparative articles that can be changed over into brilliant items inside importance of the IoT. There are numerous normal items like PCs, printer, projectors, books, posts, tables and so on there are complicated articles, for example, building, labs, stopping and so on. This multitude of articles can be changed over into savvy objects by embracing sensors. QR labels like (geographic, text, URL) RFID and giving a critical degree of insight to permit activity of actuators. Furthermore, even navigation. This multitude of parts of improvement regions. Generally, I have zeroed in on human solace in school and security and power saving in labs, streetlamp and following and savvy stock. Every one of these can likewise be applied in a ground. The essential focal point of Shrewd grounds is in the schooling region, yet they likewise drive the adjustment of different angles like administration, wellbeing, and natural assurance. The accessibility of fresher and more up to date innovation considers how the applicable cycles ought to be acted in the ongoing quick changing advanced time. This prompts the reception of various brilliant arrangements in grounds conditions to upgrade the personal satisfaction and to work on the exhibitions of the two educators and essential focal point of shrewd grounds is in the training region, however they additionally drive the adjustment of different perspectives like administration, security and ecological assurance.

7.2 Scope

While I plan to develop this theoretical business case for the smart campus project by exploiting the benefits of CIoT, I have taken into consideration the DTU, Bawana Campus, as a reference. The campus not only has the academic infrastructure but also has many amenities including residential hostels, health center, library, auditorium, mess and cafeteria, biogas plants, guest house, gymnasium and sports facilities. The campus consists of up to 5000 to 5500 students. Apart from the above-mentioned amenities, the campus has community bicycles, faculty transport (buses), student transport (buses), golf cart services, visiting students' parking and faculty parking.

Following is the blueprint of the campus:

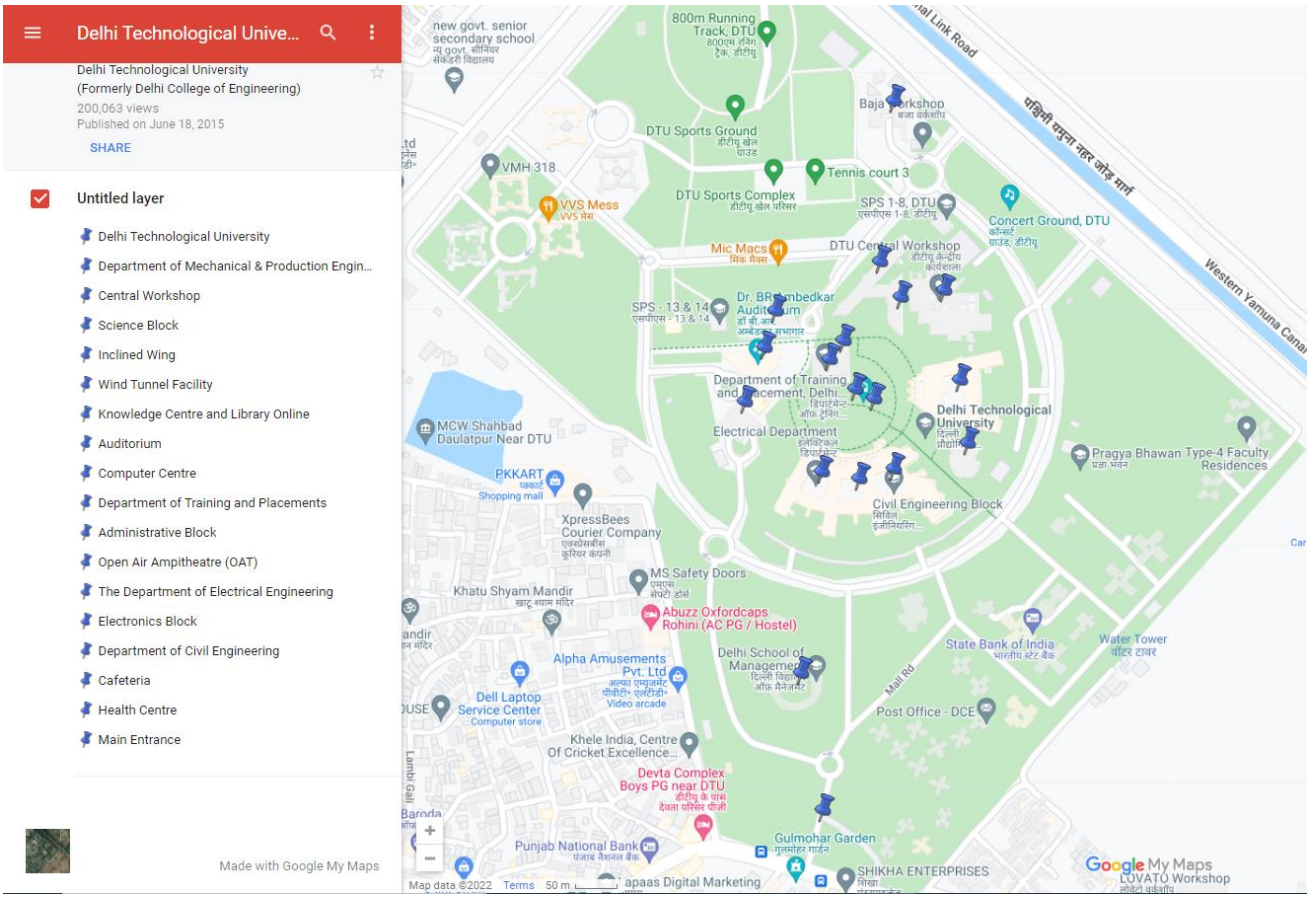


Fig. 7.1 Blueprint of DTU- Rohini Delhi Campus (Pilot campus)

While exploiting the CIoT features to make this a smart campus, I have taken the following areas into consideration:

- **i.** Smart Attendance System
- **ii.** Smart Examination
- **iii.** Flipped Classrooms
- **iv.** Transportation
- **v.** Payment and Services
- **vi.** Metering

7.3 Smart Attendance System

i. Problem statement

Traditional methods of marking the attendance are very time consuming and may not be accurate. The students and faculty both lose the precious time and if the system fail to record the attendance which happens occasionally, all the effort is in vain. Moreover, fraudulent marking of proxy and human errors are very common in attendance.

ii. Solution

Personal mobile phones of students along with RFID tags should be used to connect to the small cells and record the presence. This can be done using the NB-IoT network as this will come under the low-mobility and short bursts. The faculty can then do a physical verification if required before submission. Whenever the student will enter the classroom premise, the cell phone and RFID should be accessing the NB-IoT node and thus register the attendance, which can be without any human interference. If the student moves out during the lecture, then the timings of the student leaving and entering will be captured and recorded onthe server for further processing.

iii. System diagram [30]

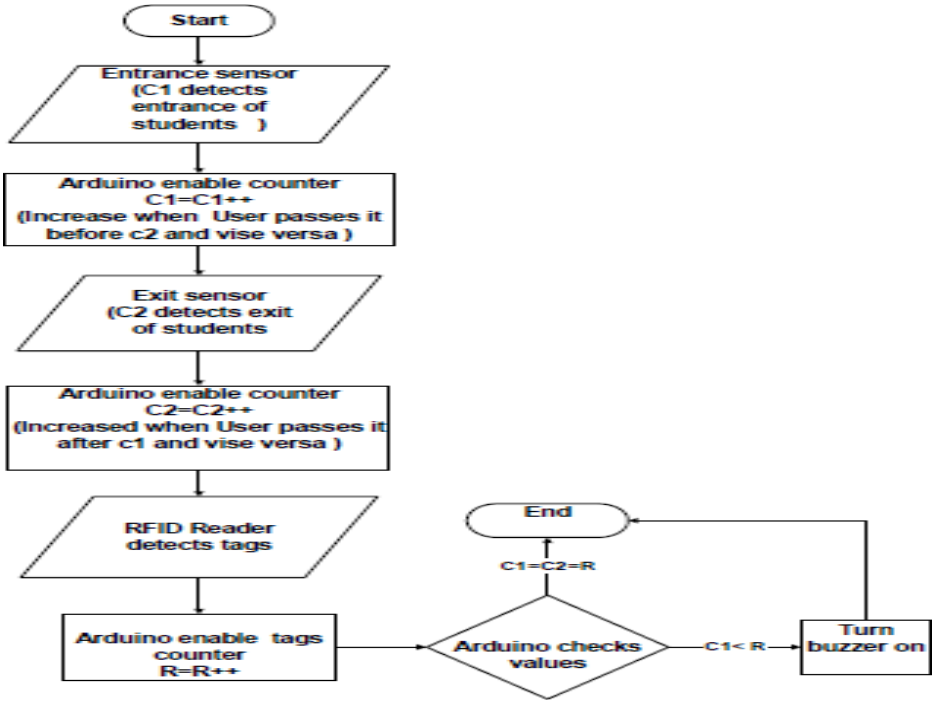


Fig. 7.2 Flowchart of attendance management system using IoT

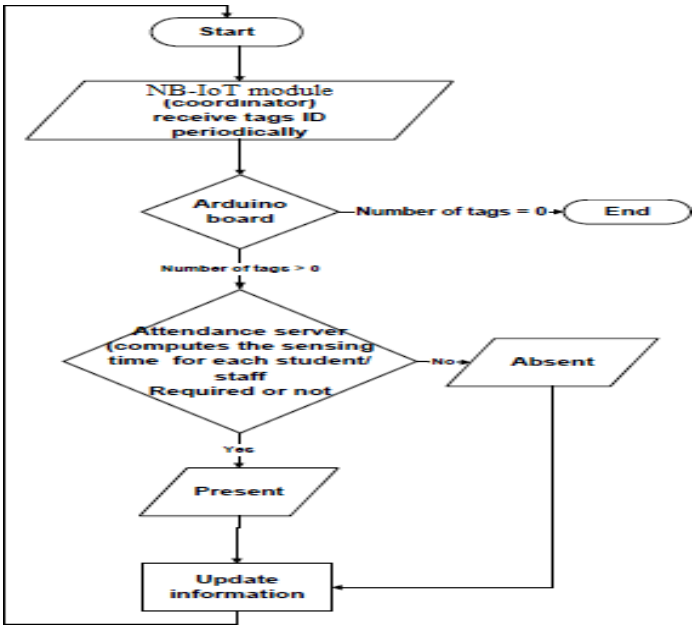


Fig. 7.3 Smart attendance working flowchart

Fig. 7.4 Smart Attendance Architecture

iv. Conclusion

A savvy college model created utilizing long reach RFID innovation, movement sensors, phone (module) and Arduino microcontroller. These advancements ought to be coordinated to assemble to further develop respectability, genuineness of participation and electrical power preservation in a brilliant way. The magnificence of the framework is giving these highlights economically. The utilizing of RFID labels opens the method for incorporating the framework with remote hub camera to authorize the validation approach..

7.4 Smart Examination

i. Problem statement

The test insights are significant for educators to more readily evaluate the test measurements, e.g., test span. Be that as it may, measurements, for example, time spent on composing the test and legitimacy of the understudy to show up for the test is tedious interaction just by human perception. I propose a brilliant test framework that gets such measurements and sends information to a web application for additional handling by utilizing a web of-things based innovation. [31]

The cumulative gathering of academic data of students like attendance, internal examination marks etc. determines the validity of the student to appear for a particular examination. This is done manually by human analysis of the data and printing of the examination hall ticket. This is a time-consuming process which can be shortened by the used of RFID based IoT applications.

ii. Solution

In this structure, multi-facet validation approach is utilized. The arrangement comprises of different stages to deliver solid confirmation structure. for example Enrollment stage, share creation and age stage, share encryption stage, Online assessment stage, Offer decoding stage lastly Verification stage. At first understudies gather login-id and secret key by entering all private and scholarly detail into online server and furthermore transfer their photograph and mark into it. During share creation stage, understudy signature picture and photograph picture are taken together to deliver stego picture and this stego picture is then store in unique host picture and afterward produce the offers. Every one of the offers are scrambled before given to understudy by email. The essential focal point of proposed answer for secure understudy confirmation for online assessments. At the point when understudy transfer his portion during verification process, programming on server side, stack the offers together (one at client side and other at server side) to uncover the host picture. In this technique, for encryption and unscrambling of offers, RSA calculation is utilized to make approach safer. In the proposed strategy visual cryptography method is applied to understudy verification framework. Single offer uncovers no data. Thus it gives greater security to framework. [31]

iii. System diagram

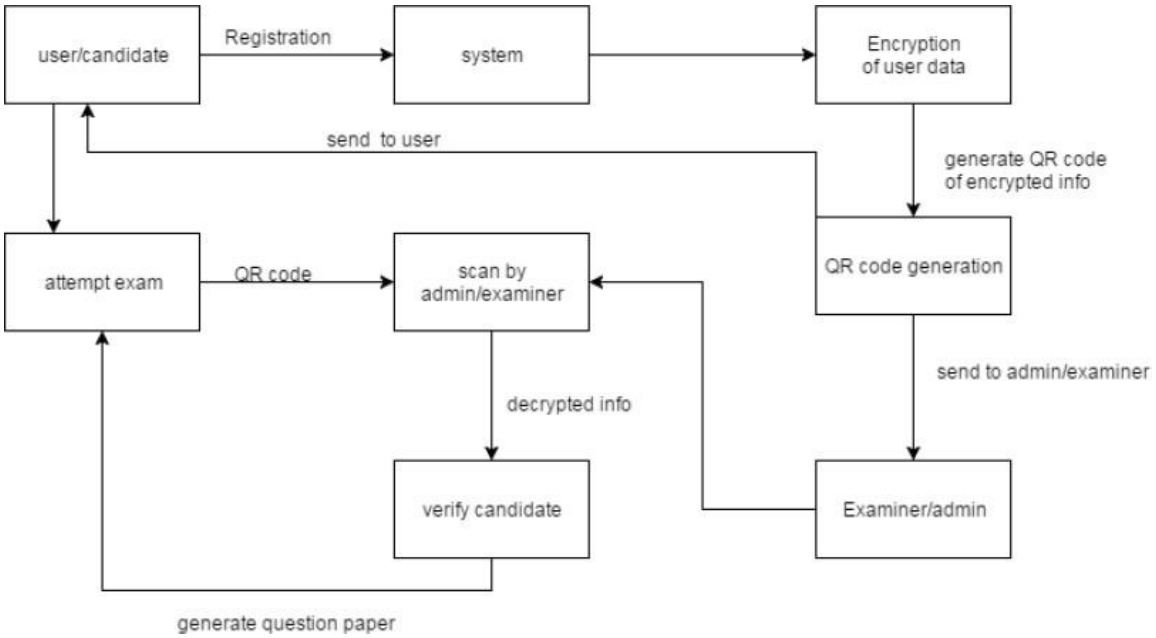


Fig. 7.5 Smart Exam Registration Process

iv. Conclusion

The proposed framework gives safer understudy confirmation framework for online assessment utilizing three layers of safety. The principal layer gives client id and secret key to understudy who apply for online assessment by email. so just those understudies have sign in id and secret word are permitted to show up for assessment. Second layer create the portions of stego picture, so understudy need to transfer the one offer and just certified client can give this offer. In any case access isn't allowed to them, in this way greater security is given by framework. Third layer give security to shares additionally, so no publicist can't modify its piece arrangement and not ready to make counterfeit offers. The proposed framework is uniquely evolved to forestall misrepresentation in web-based assessment. [33]

7.5 Flipped Classrooms

i. Problem statement

Flipped Homeroom (FP) is a piece of instructive IoT application that isn't executed in many emerging nations yet. FP is a model when understudies have addresses at home and do schoolwork in study hall with the assistance of educator and groupmates, tests, courses and some other exercises held in study hall.

ii. Solution

The teacher plans video examples and offers them with understudies, understudies need to watch them furthermore, get ready for subject before they will take part in classes and class time utilized by teacher to gauge information token by understudies from video illustrations, gives assignment and assist with settling undertakings to combine passed materials. CIoT Flipped study hall gives an amazing open door for understudies to learn subject whenever and any spot, at college, at home, on the way or during noon. Also, to make break of the example, he can stop video or on the other hand on the off chance that he missed something, he can replay video once again. Educator gets ready video illustration once and the equivalent can be utilized for a long time.

Execution of CIoT advancements to college as a piece of shrewd grounds helps teachers, understudies, and organization to robotize the course of schooling, IoT Flipped Homeroom execution is genuine model in demonstrating proclamation. The educator trains the examples at home in a flipped study hall. For this situation, the understudy gadgets can be followed involving the IoT for area and updates. Recordings, webcasts, digital books, and sites can be utilized for this situation. During the homeroom communications, understudies function collectively to comprehend the ideas applications and associations made to the substance. Understudies get the help that they need in the issues which they face in their

examinations.

iii. System diagram

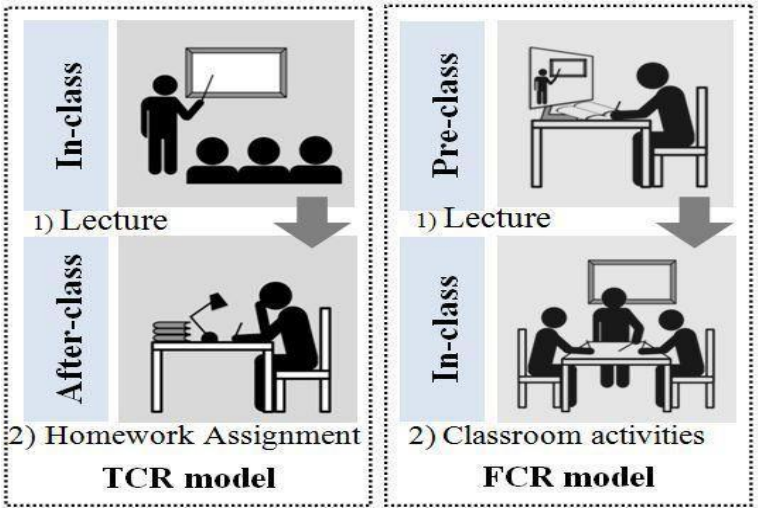


Fig. 7.6 Traditional vs. Flipped Classroom Model Comparison

iv. Conclusion

C-IoT can be executed for this in web-based local area stages, savvy portfolio frameworks, high level information examination and gamification, virtualization and admittance to processing. Following gear can be utilized for something very similar:

- Smart Interactive Board
- Smart Table
- Video conferencing
- HD Cameras
- Smartphones and Tablets

7.6 Transportation

i. Problem statement

In the current business pilot campus selected, transportation is a very crucial area as the campus location is relatively away from the city. Thus, when I look at transportation, I talk about two parts; in-campus transportation including buses and bicycles and city-campus transportation including university buses. There is a possibility of a third category which includes private/personal vehicles and public transport. The existing system involves lot of documentation and paperwork. Monitoring these transportations and their health is not available as of now.

ii. Solution

Using CIoT and specifically LTE Cat-M can be used for tracking the vehicles for out of campus transport. Additionally, GPS systems will help is acquiring the accurate coordinates and relay the information to the core system. A dashboard can be setup and this transportation can be tracked and corrective actions can be taken when required in case of re-routing.

For the personal transportation access, the campus admin need not provide a length approval. Rather, the student identity can be a mobile phone and vehicle registration details. The students cell phone will now act as a node and an RFID can be allocated to the vehicle. RFID readers can be placed at the campus checkpoints in order to track the vehicles. In this way, not only the vehicles with permission will gain access but also the timings of the entry/exit can be accurately captured in the systems. Transfer of permission would be very simple.

Public transport entry in the campus is more of a security concern and needs to be monitored closely. Hence, when the vehicle is trying to enter the campus, it will be handed with the smart card containing RFID and the vehicle number will be captured via CCTV footage/camera which will relay the information to the server. Using the LTE Cat-M system, the vehicle movement in the campus can be tracked and if found invalidly parked in the campus, can be easily tracked and penalized.

iii. System diagram

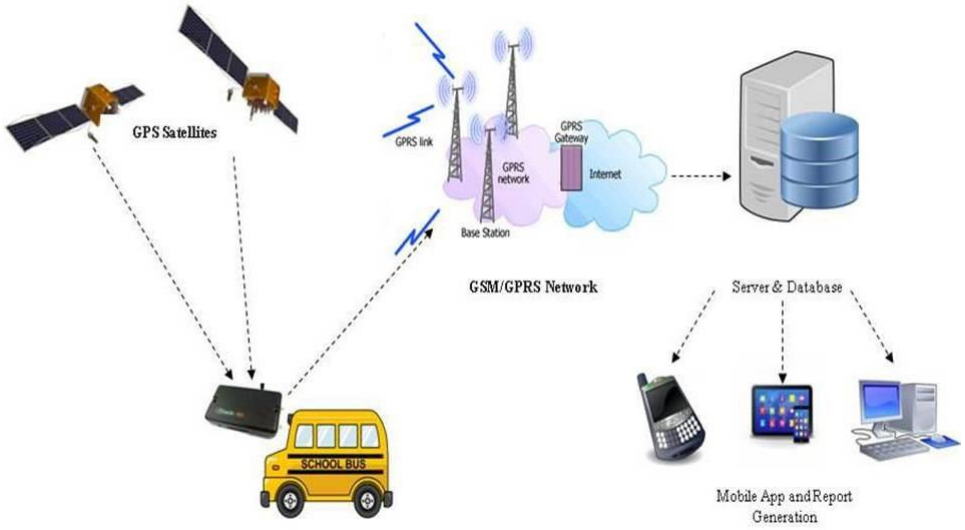


Fig. 7.7 Smart Transportation

iv. Conclusion

Using the cellular IoT technologies, not only can the vehicles be tracked, but can be monitored using the CCTV footage. The timings, details, in and out paperless procedures can be easily implemented and if required finding data would be much easier.

7.7 Smart ID card for Payment and services

i. Problem statement

Contrasted with a faithfulness card framework, an installment card framework is situated to get and confirmed exchanges. Electronic obsession of exchange normally results through utilization of specific installment card, hence there are fundamentally stricter security necessities laid out for an installment card - the card should be extortion evidence; unapproved utilization of the card should likewise be barred. Because of high misrepresentation wellbeing and extraordinary security level, an ID-card is thus an ideal instrument to involve it as an installment card. [5]

ii. Solution

The ID-card based installment card framework empowers acknowledgment of installment administrations with various security level: contingent upon how agreeable and quick the obsession of the exchange should be, and how severe the necessities for secure exchange check are.

General rationale of all installment card arrangements is somewhat comparative - a client is recognized electronically by their ID-card, from that point they can utilize installment usefulness. The utilization of an ID-card gives the administrator of the installment framework sureness that an individual is related to adequate precision; it likewise assists with supporting the dangers of the abuse of installments. The installment usefulness itself isn't consistently connected to the ID-card.

The genuine monetary exchange can be acknowledged contrastingly in ID-card based installment plans - either connected by a bank card installment, by portable installment arrangement of versatile administrators, or a client is basically conceded a credit right now of installment and the client embraces to make up for this under the consequently given receipt.

On a fundamental level, the accompanying kind plans are discernable inside the ID-card based installment plans:

- An ID-card is utilized to go into a concurrence with a client; then the ID-card is not generally utilized while performing installments. Such a plan is utilized in situations where at the hour of installment an ID-card can't be utilized because of a nature of administration; or its utilization is badly designed according to installment viewpoint.
- An ID-card is utilized to perform installments without entering a PIN code. In such a case, a client understanding, by which the client assents the utilization of such an installment conspire, ought to be closed ahead of time. This plan is reasonable when a speed of the installment is significant.
- An ID-card is utilized to perform installments by entering a confirmation PIN code. Essentially, the previously mentioned plans, a client normally goes into an understanding by which they assent the utilization of such a plan.
- An ID-card is utilized to perform installments by entering computerized signature PIN code. In such a case, an earlier concurrence with a client isn't required, on the grounds that a specific understanding could be connected even to marked installment messages. The realness of exchange confirmation in the arrangement is ensured. This plan is utilized in situations where a potential most extreme degree of installment exchange confirmation should be accomplished.

iii. Benefits of using an ID-card within payment solutions:

1. An ID-card is actually and electronically planned regarding security and extortion evidence. Issuance, steady turn of events and the board of a card with undifferentiated from wellbeing is exorbitant and requires exceptionally gifted subject matter experts.
2. ID-card is essentially extortion evidence - there has been no misrepresentation related to this kind of card.
3. An ID-card empowers actual individual ID, electronic individual recognizable proof and advanced marking.
4. An installment specialist co-op doesn't need to manage card issuance or card lost and shutting techniques - these are now covered by the state.

iv. Conclusion

Acknowledgment of the ID-card based installment card framework relies generally upon the business rationale of whole arrangement. Regularly, there is a particular arrangement of the specific installment card framework - instant universally useful buyer programming doesn't exist.

The improvement comprehensively comprises of the accompanying activities:

• Investigation. Setting exact business processes, explaining an origination of specialized arrangement, characterizing the volume of improvement. Since the whole philosophy of business arrangement must be worked out, the span of this stage would basically be one month.

• Improvement of a part that speaks with an ID-card. Equipment and programming answer for installment card usefulness to impart to the vital degree with an ID-card - distinguishing an ID-card, perusing individual data, initiating advanced marking. Essential low-level parts are accessible as an ID-card application; however it is important to foster significant level programming, through which all the necessary usefulness will be connected as entirety. A work content of creating and testing a part speaking with an ID-card is roughly 40 hours. Notwithstanding, acknowledgment of the whole business rationale of the arrangement can be very work serious.

• Acknowledgment of important business processes - exchange account, invoicing, detailing, and so forth. Work content relies significantly upon the idea of the arrangement.

7.8 Smart App for hostel maintenance and housekeeping:

i. Problem statement

The use of housekeeping app was originated in the hospitality industry to improve the customer experience and therefore boost sales. However, for the maintenance of hostels and to provide housekeeping services to students, this app can be effectively used which will result in saving of resources like stationary and also induct a streamlined workflow in the maintenance staff. [7]

ii. Solution

Housekeeping work has been evidently the most tedious and human asset consuming processes in the hostel activities. Expanding efficiency and proficiency has been the first concern, which would bring about a major improvement in functional execution.

The required application will empower the housekeeping and the lodging staff through a web-based task trough to design, smooth out and improve on the work and increment the efficiency and effectiveness of the activities. The fundamental elements of the application will remember constant data for tasks, interior correspondence, oversee errands and issue reports, plan the work, reports, and insights.

iii. Features

1. Task the board: Make and configuration undertakings and get continuous data about the advancement of the errand and the situation with the rooms.
2. Booking: Work proactively and plan repeating assignments.
3. Lost and Found: Monitor the things that have been lost and found on the grounds so they can be guaranteed without any problem.
4. Shortcoming reports: Make issue and breakage gives an account of the application by means of a picture and get it fixed in a split second.
5. Report and measurements: Track the work process comparable to arranging, get time usage insights and get data to help future ventures.

iv. Conclusion

Implementation of an app for maintenance of the hostel will streamline the unorganized workflows like purchasing estimates of materials required for maintenance, return of lost property of students, repairing broken or non-functioning appliances and increase the visibility of the niche business processes of the campus therefore increasing the profits by reducing operational expense.

7.9 Smart Parking:

i. Problem Statement

Gridlock brought about by vehicle is a disturbing issue at a worldwide scale and it has been developing dramatically. Vehicle leaving issue is a significant donor and has been, still a significant issue with expanding vehicle size in the sumptuous portion and restricted parking spots in metropolitan urban communities. Looking for a parking spot is a daily schedule (and frequently disappointing) movement for the overwhelming majority individuals in urban communities all over the planet. Since the space is a requirement in an instructive ground, execution of shrewd stopping arrangement will be of high significance for this business case. [6]

ii. Solution

The Parking Assistance System include three modules- Observing module, Control module and a showing unit. Alongside over three module it will likewise have concentrated administrative framework to keep an information base of parking spot and will have a SMS passage.

- The observing module incorporates ultrasonic sensors/surrounding light sensor which distinguishes the free parking spots and sends the Data to control unit through Nb-IoT.
- Aside from recognizing the vehicle the sensor additionally gives extra data like the timespan the vehicle has been left and furthermore its wellbeing status.
- The control units process the data and sends the data to Incorporated administrative framework.
- Brought together administrative framework gets data of parking spot from the regulator through UDP. It then, at that point, sends the data, for example, opening distributed, time stopped, charging data and directional subtleties to the client's cell phone.

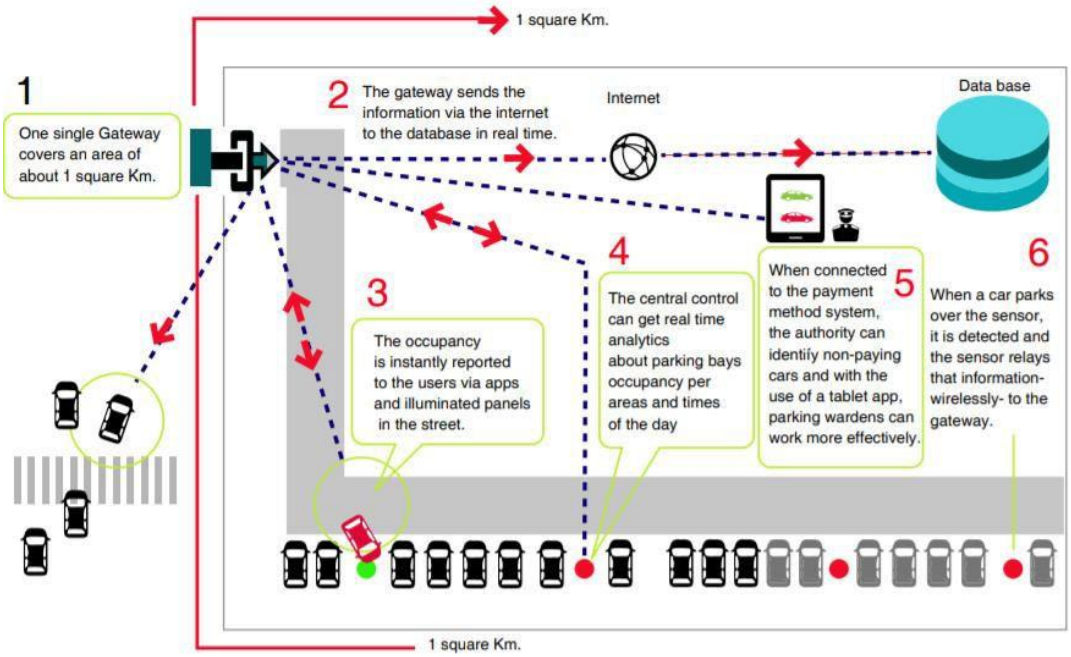


Fig. 7.8 Smart Parking

iii. Conclusion

A smart parking system would facilitate prediction and sensing spot/vehicle occupancy in real time. Guiding residents towards available parking spaces. Also, it will optimize parking space usage and save fuel, reducing carbon emissions.

7.10 Costs Aanalysis

Expenses of gadgets expected in C-IoT availability, significantly LTE-M and NB-IoT frameworks.

i. Module Costs

A LTE and NB-IoT module bought in extremely high volume will cost somewhere in the range of $10 and $15. As LPWA networks mature — inside the following couple of years — the cost per module ought to plunge somewhere in the range of $5 and $10. That distinction can be huge load of cash when it's duplicated in large numbers (or a great many) modules that might be required.

ii. Recurring Fees

The LPWA networks that are being conveyed today (generally in Europe) are charging in the scope of a couple of dollars a year. Contrast that with cell information charges today — in the scope of a couple of dollars a month — and you'll see a major distinction when you begin duplicating these numbers in large numbers of gadgets sent. Keep in mind, in the event that you're sending your own foundation, as numerous associations accomplish for their LPWA applications, there is definitely not a month to month repeating cost.

iii. Miscellaneous Fees

The other thing to remember for certain cell frameworks is that there are different expenses, as SIM expenses, charges for initiating and deactivating, and then some. These kinds of changes can pile up if clients don't watch out. Furthermore, a few organizations will charge clients regardless of whether they are sending information. LPWA organizations might do exactly the same thing, however the expense is such an excess of lower that it could be an ostensible charge.

Table XI : Cost Analysis

System	Component	Cost per unit (in Rs.)	Number of Components (units)	Total Cost	Comments
Smart Attendance System	RFID tag	₹ 90	2000	₹ 1,80,000	Depends on the number of students
	NB-IoT Module	₹ 840	10	₹ 8,400	Depends on the number of classrooms
	Overheads	₹ 1,40,000	-	₹ 1,40,000	Maintenance Charges
Sub Total		**₹ 1,40,930**	**2010**	**₹ 3,28,400**	
Smart Examination	User Smartphone	₹ 0	0	₹ 0	User bears cost
	Software (RSA)	₹ 6,300	2000	₹ 1,26,00,000	License cost x user
Sub Total		**₹ 6,300**	**2000**	**₹ 1,26,00,000**	
Flipped classroom	Application cost	₹ 21,000	1	₹ 21,000	
	Network infrastructure maintenance	₹ 1,00,000	-	₹ 1,00,000	
Sub Total		**₹ 1,21,000**	**1**	**₹ 1,21,000**	
Smart Transportation	LTE Cat-M module	₹ 700	1500	₹ 10,50,000	
	Application Development	₹ 21,000	1	₹ 21,000	
Sub Total		**₹ 21,700**	**1501**	**₹ 10,71,000**	
Smart ID cards	Smart Card	₹ 1,000	2000	₹ 20,00,000	
	Software (Payment Interface)	₹ 50,000	1	₹ 50,000	
Sub Total		**₹ 51,000**	**2001**	**₹ 20,50,000**	
Smart Housekeeping	Application	₹ 50,000	1	₹ 50,000	
	Smart Card	₹ 1,000	500	₹ 5,00,000	Depends on the count of working staff and janitors
Sub Total		**₹ 51,000**	**501**	**₹ 5,50,000**	

Smart Parking	NB-IoT module	₹ 840	₹ 100	₹ 84,000	Depends on the number of parking slots available
	Maintenance cost (per year)	₹ 12,000	₹ 1	₹ 12,000	
Sub Total		**₹ 12,840**	**₹ 101**	**₹ 96,000**	
Grand Total				**₹ 1,68,16,400**	

CHAPTER 8
CONCLUSION, LIMITATIONS, FUTURE SCOPE

8.1 Conclusion

- Analysis of C-IoT in comparison to LPWAN technologies resulted in following conclusions
  - C-IoT is the only option when it comes to large scale IoT solutions.
  - C-IoT provides is easier to regulate due to licensed spectrum usage.
  - Proprietary technologies risk is eliminated in case of C-IoT
  - Can be implemented by telecom operators on current infrastructure
- Analysis of NB-IoT and LTE-CAT-M shows that each of the two technologies has its own pros and cons and its usage depends on type of application.
  - For deeper penetration and easier implementation on current infrastructure NB-IoT is better.
  - For mobility based solutions LTE-CAT-M is better
- Reliance Jio would be a good option for implementing the IoT solutions since they are already in process of installing small cells in the DTU campus

8.2 Limitations

- The pilot provided above is theoretical and its implementation feasibility needs to be tested out.
- Majority of the research is based on secondary data.
- The scalability of proposed model is not taken into consideration since it is prepared wrt to DTU campus
- From the above solutions, not all are priority to an educational institute
- The above solutions cannot be brought under one unique technology solution

8.3 Future Scope

- To try out pilot implementations
- To try to come up with one stop technology solution, for example one ID card and app that can be used in all solutions

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APPENDIX

3GPP	Third Generation Partnership Project
APAC	Asia Pacific
BLE	Bluetooth Low Energy
BTS	Base Transceiver Station
CAGR	Compounded Annual Growth Rate
C-EPS	Cellular Evolved Packet System
C-IoT	Cellular Internet of Things
CP	Control Plane
CPE	Customer-premises equipment
C-SGN	C-IoT Serving Gateway Node
dB	Decibel
DL	Downlink
DRX	Discontinuous Reception
DSSS	Direct Sequence Spread Spectrum
EC-GSM	Extended Coverage GSM
eDRX	Extended Discontinuous Reception
EMEIA	Europe, Middle East, India and Africa
EMM	EPS Mobility Management
eMTC	Enhanced Machine Type Communication
eNB	Enhanced Node B
EPC	Evolved Packet Core
eSIM	Enhanced Subscriber Identity Module
ESM	EPS Session Management
EY	Ernst & Young LLP
FOTA	Firmware Over-The Air
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile communications
HF	Hyper Frame
IE	Information Elements
IoT	Internet of Things
kbps	Kilo Bits Per Second
kHz	Kilo Hertz
LoRa	Long Range
LoRaWAN	LoRa Wide Area Network
LPWAN	Low Power Wide Area Network
LTE	Long Term Evolution
M2M	Machine to Machine
Mbps	Mega Bits Per Second
MCL	Maximum Coupling Loss
MHz	Mega Hertz
MME	Mobility Management Entity
MTC	Machine Type Communication
NAS	Non-access stratum
NB-IoT	Narrow Band Internet of Things
NPDCCH	Narrowband Physical Downlink Control Channel
NPDSCH	Narrowband Physical Downlink Shared Channel
NPUSCH	Narrowband Physical Uplink Shared Channel
ODU	Outdoor Unit
OSS	Operating Support System
PDN	Packetized Data Network
P-Gw	PDN Gateway
PLMN	Public Land Mobile Network
POE	Power over Ethernet
PSM	Power Saving Mode
QoS	Quality of Service
RF	Radio Frequency
RRC	Radio Resource Control
SFN	System Frame Number
S-Gw	Serving Gateway
SIB	System Information Blocks
TAU	Tracking Area Update
TCP/IP	Transmission Control Protocol/Internet Protocol
UE/CE	User Equipment/Consumer Equipment
UL	Uplink
UMTS	Universal Mobile Telecommunications System
UNB	Ultra-Narrow Band
UP	User Plane
UTRAN	UMTS Terrestrial Radio Access Network