PART 13

OUTDOOR DIGITAL CONNETED & IOT BASED ROAD LIGHTING

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[Please use A4 size sheet of paper only and type within fields indicated. Comments on each clause/sub-clause/ table/figure, etc, be stated on a fresh row. Information/comments should include reasons for comments, technical references and suggestions for modified wordings of the clause. **Comments through e-mail in MS WORD format to eetd@bis.gov.in shall be appreciated.**]

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Part 13 Outdoor Digital Connected & IOT Based Road Lighting		
Clause No. with Para No. or Table No. or Figure No. commented (as applicable)	**Comments / Modified Wordings**	**Justification of Proposed Change**

BUREAU OF INDIAN STANDARDS

DRAFT FOR COMMENTS ONLY

Draft NATIONAL LIGHTING CODE OF INDIA

PART 13 Outdoor Digital Connected & IOT Based Road Lighting

Chapter 1 Connected Lighting -Wired Control Systems

Chapter 2 Connected lighting - IOT Based Street Lighting Systems

[First Revision of SP 72 (Part 13)]

Illumination Engineering and Luminaries Sectional Committee, ETD 49	**Last Date for Comments: 02 October 2024**

FOREWARD

Beginning of this century the most successful transition of lighting though solid-state technology made a great change in lighting technology and lighting application. LED transition is the most success story of the lighting history that ever happened such a short time. Its transformation was fastest in all segments of lighting applications. On reaching energy efficiency at very high level and in the era of digital electronics and communication, lighting system got a new dimension in its applications called digital connected lighting and IoT (Internet of Things) based connected lighting.

Wired connected intelligent lighting was the first step to make lighting more dynamic and entertaining with many options of flexibility with all possible energy saving. Many facades of wired connected lighting driver and controller lighting system possible to create the light dimming, dynamic and colourful which made the lighting designer dream come true. This is a combination of high energy efficient, with the feature like intelligence, monitoring and control, feedback, style and comfort. This lighting system added a level of functionality to the lighting system, in a manner that increases its responsiveness to outside stimuli of various benefit on human known as human centric lighting.

Professionalization of city operations management to increase efficiency cities are looking for efficient ways to manage their assets, including lighting. Outdoor lighting control systems provide the means and tools to reduce operating costs by automatically identifying failures, reduce number of onsite trips, enable to control, and reduce energy use, while at the same time increase safety and comfort and also beautify the city. There is high pressure in the city to reduce energy consumption and CO_2 day there is a strong need to reduce energy consumption in order to reduce our CO_2 footprint. In traditional lighting scouting team were driving during the night to spot failed lights with paper maps and files were used to manage the maintenance of the lighting installation.

With advancement of communications and integration of embedded technology in lighting the new generation Internet of things (IoT) has been emerged. IoT means a thing connected to internet and exchange data with another machine /server. IoT based lighting equipped or combined with sensors, control electronics and communication interfaces. Lighting through internet and cloud services for data storage and access. It also connects non lighting devices.

IoT based lighting is the latest technology in the lighting system and it is gaining lot of attention in the lighting applications.

This being an emerging technology, so lot of new things keep on evolving regularly and it will continue till technology is matured. Therefore, practically lot of technology around make the matter most complicated and cumbersome. At the end decision making process become bit difficult. This chapter is conceived to meet the present day need of the lighting fraternity.

Many wired and wireless protocols individually and together are available today. Selection based on the size of the installation, type of lighting effect required, interoperability with other device and system, the range of communications, scalability of the network, security arrangements, device management requirements, cost of installation and maintenance, survey of the protocol usage etc. Wired protocol offer reliable performance and good control However, the cost of the wiring, installation and maintenance cost can be higher than IoT based control system. At the same time initial cost of IoT based lighting will be higher may be particularly in outdoor applications for a small project.

1 SCOPE

The different wired connected lighting controller as well as driver plus communications protocol and system in the IoT based lighting has been put forward the benefit of lighting professional, lighting consultant, electrical consultant, specifiers, and utility professional. This section comprises of two chapters.

Chapter 1 covers basic features, applications, advantages and constrains of different wired connected lighting controller and drivers. It also included the building management system.

Chapter 2 covers IoT based street lighting in details.

2 NORMATIVE REFERENCES

IS Standards/ Other Standards	*Title*
IEC 62386:2022	Digital addressable lighting interface - Part 101: General requirements - System components
IEC 60929: 2011	AC and/or DC-supplied electronic control gear for tubular fluorescent lamps - Performance requirements
ISO/IEC 14543-3-1:2006	Information technology — Home electronic systems (HES) architecture
CENELEC - EN 50090-1	Home and Building Electronic Systems (HBES) - Part 1: Standardization structure
CEN - EN 13321-1: 2021	Open data communication in building automation, controls and building management - Home and building electronic system – Part 1: Product and system requirements
ANSI/ASHRAE 135: 2020	BACnet® - A Data Communication Protocol For Building Automation And Control Networks
GB/T 20965: 2013	Control network HBES technical specification. Home and building control system
IEC 62443 series	Industrial Cybersecurity
UL 2900	Cybersecurity for Medical and Healthcare Systems

3 TERMINOLOGIES

Following are the few main related technical term to be familiar while dealing this subject matter:

3.1 Network

Infrastructure that connects a set of endpoints, enabling communication of data between the digital entities reachable through them

3.2 Interoperability

Property permitting different components to work on other system for a specified purpose

3.3 Gateway

Entity of an IoT that acts as a data aggregator by collecting information from controllers and transmitting it to the Central management System (CMS)

3.4 Controller

End point device attached to a LED driver or smart meter etc that enables communication and data transfer of the said product eg LED Driver or smart meter etc to a gateway.

3.5 Data access

Information stored in the SMART device (Eg LED Driver or Smart meter etc) is available for accessing via the Central management System (CMS)

3.6 Security

Data security using either AES 128 or Blockchain to ensure that data is not intercepted or corrupted when it is transmitted over the air.

3.7 Field Devices

It is similar to a controller as an end device.

3.8 GPRS

It is a Mobile Network standard using 2G Technology

3.9 GSM

Global System for Mobile Communications covers protocols for 2nd Generation Digital cellular network

3.10 NBIOT

Narrow band Internet of Things is a low power wide area network using radio technology using standard mobile technology developed by 3GPP for cellular network devices and services. The bandwidth is limited to narrow band 200kHz

3.11 LowPan

IPv6 over Low-Power Wireless Personal Area Networks enables each Field device to have its own IP Address in combination with the MAC ID of the device. This allows low-power devices with limited processing capabilities to participate in the Internet of Things.[1]

These devices operate over the IEEE 802.14.4 based networks.

3.12 Centralized Management System

It is the Software based system that allows all end points to be commissioned, controlled and queried. The CMS system is installed either on premises or hosted on the cloud. The system allows varying degree of control to users based on role and also allows automating reports etc to be generated based on set conditions like faulty devices, alerts etc.

This is transmitted either via email, SMS, Messaging Apps or alerts on Mobile devices that have the CMS access via a dedicated Mobile App.

3.13 Node

Node or a controller have the same function as they are end devices connected to LED Drivers or SMART Meters

3.14 OTA (Over the air)

It is the manner of communication of data from the CMS to the Gateways and Nodes/ Controllers

3.15 Field Device Network

It is the same as Node or Controller

3.16 Router

It is a field device allowing nodes to connect to the CMS similar to a gateway.

3.17 DCUI

Data Collection User Interface? Is this what is meant as there are multiple meanings for this.

3.18 Access Point

It is s a device, in this case a node or field device, that permits wireless devices to connect to a network.

3.19 TCP/IP

Transmission Control Protocol/Internet Protocol are the various communication protocols used to interconnect detwork devices to the Inter

3.20 CCMS

Central Control and Monitoring System is the same as a CMS in 3.12

3.21 Star Topology

A network technology where every network component is wired physically to the Router/Gateway

3.22 Mesh Network

Typiaclly a wireless network of interconnected Nodes/Controllers that form a subset network to communicate with each other and allow hopping to connect to the gateway/router etc. These are self healing in nature in that the nodes dynamically find the most effective way of being connected

3.23 Back Haul Network

Term used for mobile network connectivity that comprises the network between the backbone or core networks and the Nodes/Field devices etc.

3.24 Zhaga Connector

It's a global industry body that focuses on the standards for connection interfaces for hardware like led drivers, led module and communication device. These are all open standards and none of them are proprietary in nature.

Zhaga Book 18 Ed. 2 – Is the current standard interface used in SMART street lights**.**

3.25 NEMA

National Electrical Manufactures Association in the USA is an industry body that is a ANSI authorised standard developing organisation to develop standards for various electrical products and applicances

3.26 NEMA Socket

This is the interface device used using NEMA based Nodes or field devices. This is either a 3/5/7 pin based on the application

4 LED DRIVER TECHNOLOGY

4.1 Analog LED Driver

4.1.1 *0 -10V Control Driver or 1 – 10V Control Driver*

It is one of the earliest and simplest electronic lighting control signaling systems. The control signal is a DC voltage that varies between 0-10V or 1 – 10V. There are two recognized ways to connect external load to circuit by current sourcing and current sinking. In theatrical dimming, the controller sends voltage to the device. The controlled lighting should scale its output at 10 V, the controlled light should be at 100% of its potential output, and at 0 V at 0% output (i.e., off). In the case of 1 – 10V an additional device is used to switch off the loads

Dimming devices may be designed to respond in various patterns to the intermediate voltages, giving output curves that are linear for: voltage output, actual light output, power output, or perceived light output.

4.1.2 *Advantages and Disadvantages*

The simplicity of the lighting system makes it straightforward to understand, implement and diagnose, and its low current (typically 1 mA) means it can be run along relatively thin cables with little voltage drop. However since it is a Voltage signal there could be chances of interference from the mains voltage and hence is not a 100% reliable system.

However, since it requires one wire per control channel (plus a common return wire), a sophisticated system could have hundreds of wires, requiring expensive multicore cables and connectors. Over a long cable, the voltage drop requires every channel of the receiving device to be calibrated to compensate for the voltage losses. (This is only a theoretical limitation as the resistance of the thinnest practical wire is around 20 Ω/1000 m.) Capacitive coupling from nearby AC power cables can affect the signal to the fitting and even cause flickering. Signal wire running parallel to power cables for a fair distance would need to be screened.

4.2 Digital

4.2.1 *DSI Protocol*

Digital Serial Interface (DSI) is a protocol for the controlling of lighting in buildings (initially electrical ballasts). It is based on Manchester-coded 8-bit protocol, data rate of 1200 baud, 1 start bit, 8 data bits (dimming value), 4 stop bits, also the basis of the more sophisticated protocol Digital Addressable Lighting Interface (DALI). The technology uses a single byte to communicate the lighting level (0-255 or 0x00-0xFF). DSI was the first use of digital communication in lighting control, and was the precursor to DALI.

As it is a digital signal it there is no problem of interference in the signal from Mains voltage.

4.2.2 *Advantages*

a) Its simple nature makes it straightforward to understand, implement, and diagnose, while its low voltage means it typically runs along relatively thin cables.

b) Each device has its own wire to the controller (rather than being part of a network) therefore there is no need of an address to be set, so can be replaced simply by unplugging the faulty one and plugging in the new.

c) It dims to off, so does not require mains switching equipment to turn them off.

4.2.3 *Disadvantages*

a) All DSI devices are looped in parallel like DALI devices however they work only in broadcast mode and cannot be controlled individually. There is no bi directional communcaiton between the driver and the system.

4.3 DALI

Digital Addressable Lighting Interface (DALI) is a trademark, of the Digital Illumination Interface Alliance) for network-based systems that control lighting in building automation. DALI protocol uses a 16 Bit Manchester Code for Bi Directional Communication. The underlying technology was established by a consortium of lighting equipment manufacturers as a successor for 0–10V lighting control systems, and as an open standard alternative to other proprietary protocols

There is nothing like SL Bus in DALI) DALI is specified by technical standards IEC 62386 and IEC 60929. Standards conformance ensures that equipment from different manufacturers will interoperate. The DALI trademark is allowed on devices that comply with the current standards when manufactured.

4.3.1 *Technical Overview*

A DALI network consists of a controller, a power supply (which may be built into the controller) and one or more slave devices (e.g., electrical ballasts, LED drivers and dimmers) that have DALI interfaces.

The controller can monitor and control each device by means of a bi-directional data exchange. The DALI protocol permits devices to be individually addressed and it also allows multiple devices to be addressed simultaneously via multicast and broadcast messages.

Each device is assigned a unique short address in the numeric range 0 to 63, making possible up to 64 devices in a basic system. Address assignment is performed over the bus using a "commissioning" protocol after all hardware is installed. DALI gateways can be used to implement systems that have more than 64 devices. Data is transferred between controller and devices by means of an asynchronous, half-duplex, serial protocol over a two-wire bus, with a fixed data transfer rate of 1200 bit/s.

A single pair of wires comprise the bus used for communication to all devices on a DALI network. The network can be arranged in a bus or star topology, or a combination of these. Each device on a DALI network can be individually addressed, unlike DSI and 0–10V devices. Consequently, DALI networks use fewer wires than DSI or 0–10V systems.

The bus is used for both signal and power. A power supply provides ≤ 250 mA at 16 V DC, each device may draw up to 2 mA. While many devices are line-powered, low-power devices such as motion detectors may be powered directly from the DALI bus. Each device has a bridge rectifier on its input so it is polarity-insensitive. The bus is a wired-AND configuration where signals are sent by briefly shorting the bus to a low voltage level. (The power supply is required to tolerate this, without supplying more than 250 mA).

Although the DALI control cable operates at ELV potential, it is not classified as SELV (Separated Extra Low Voltage) and must be treated as if it were at mains potential. This has the disadvantage that the network cable is required to be mains-rated, with 600 V isolation, but has the advantage that it may be run next to mains cables or within a multi-core cable which includes mains power. Also, mains-powered devices (e.g., HF ballasts) need only provide functional insulation between the mains and the DALI control wires.

The network cable is required to provide a maximum drop of 2 V along the cable. At 250 mA of supply current, that requires a resistance of ≤ 4 Ω per wire. This wire size needed to achieve this depends on the length of the bus, up to a maximum of 16 AWG (1.3 mm2) at 300 m.

The speed kept low, so no termination resistors are required and data transmits during relatively high voltages (0±4.5 V for low and 16±6.5 V for high) enabling reliable communications in the presence of significant electrical noise. (This also allows plenty of headroom for a bridge rectifier in each slave).

Each bit is sent manchester coded (a "1" bit is low for the first half of the bit time, and high for the second, while "0" is the reverse), so that power is present for half of each bit time. When the bus is idle, it is high voltage all the time (which is not the same as a data bit). Frames begin with a "1" start bit, then 8 to 24 data bits in first order (standard RS-232), followed by minimum two bit times of idle.

DALI has evolved into a robust system that required certification by the DiiA in order to use the DALI and DALI2 logo on any products.

The key change apart from certification is DALI networks must have an application controller. This acts as a hub for all signals which are then distributed to the programmed devices based on various inputs like sensors, switches etc.

DALI2 has multiple parts to address different devices on the network like sensors, led drivers etc. For this application currently the following parts are relevant for SMART Lighting:

DALI Part 101 – General requirements – System Components

DALI Part 102 – General requirements – Control Gear

DALI Part 103 – General requirements – Control devices

DALI Part 207 – Particular requirements for Control Gear for LED Modules

DALI Part 150 – General requirements – AUX Power Supply

DALI Part 250 – Integrated Bus Power Supply

DALI Part 251 – Luminaire Data (Memory Bank 1 Extension)

DALI Part 252 – Energy Data Energy Data

DALI Part 253 – Diagnostics & Maintenance Data

DALI Part 303 – Occupancy sensors

DALI Part 304 – Light sensors

In progress:

DALI Part 351 – Luminaire-mounted Control Devices

D4i – DALI for IoT (Incorporates Part 150 (optional) Part 250, Part 251, Part 252 and part 253

4.3.2 *DALI Wireless Extension*

A wireless extension to DALI, which carries the logo DALI+, is available that enables DALI networks to communicate via wireless, radio frequency communication.

4.3.3 *DALI and Bluetooth*

The Mesh Professional Lighting Subgroup was created as a forum to discuss and develop bluetooth mesh technology as a foundation for the wireless lighting standard. This is very new establishment and will take some time to get fully developed.

4.3.4-*Future Perspective of DALI*

DALI driver will play a very important role in the smart streetlighting system and as a cruicial component in luminaires as a SMART. . The DiiA is working very closely with standards bodies to integrate DALI as a standard in IEC. D4i technology today offers the most robust and comprehensive Asset Management of Street Lights thanks to Data being available from the driver itself.

The D4i specifies 5 distinct parts that makes each luminaire a standalone intelligent system that are:

Dali Part 150 – Powers a communication device that is connected to the Luminiare (Device Type A)

DALI Part 250 – Enables a DALI intra luminiare bus so that the Application controller (Usually in the Communication Node) can send and receive data from the LED Driver and Different Sensors connected on the DALI Bus (Device Type B)

DALI Part 251 – OEM luminaire/project data can be saved in the driver enabling Asset Management

DALI Part 252 – Energy Metering with class 1 capability. Also stores the data of energy consumption on the driver which can be retrieved as and when required.

DALI Part 252 – Diagnostics and Maintenance feature like, High/Low Voltage Instances and shut downs, Over-temperature instances and shutdowns, Monitor PCB temperature via a thermocouple, Burning hours, Residual Driver life based on historical data stored on the device among other features

4.4 DMX

DMX is not really an option for street lighting. It is used only for decorative and fascade lighting. Not sure if this needs to be incorporated or another IS stnadard for dynamic lighting required.

DMX512 (Digital Multiplex) is a standard for digital communication networks that are commonly used to control stage lighting and effects. It was originally intended as a standardized method for controlling light dimmers, which, prior to DMX512, had employed various incompatible proprietary protocols. It soon became the primary method for linking controllers (such as a lighting console) to dimmers and special effects devices such as fog machines and intelligent lights. DMX has also expanded to uses in non-theatrical interior and architectural lighting, at scales ranging from strings of christmas lights to electronic billboards.

DMX512 does not include automatic error checking and correction, and so it is not an appropriate control for hazardous applications, such as pyrotechnics or movement of theatrical rigging. False triggering may be caused by electromagnetic interference, static electricity discharges, improper cable termination, excessively long cables or poor quality cables.

4.4.1 *Network Topology*

DMX512's popularity is due to its robustness. The cable can be abused without any loss of function, that would render ethernet or other high speed data cables, although cable faults can occasionally lead to intermittent problems such as random triggering. Unexpected fixture behavior is caused by addressing errors, cable faults, incorrect data from the controller, or multiple DMX sources inadvertently applied to a single chain of fixtures.

A DMX512 network employs a multi-drop bus topology with nodes strung together in what is commonly called a daisy chain. A network consists of a single DMX512 controller– which is the master of the network and one or more slave devices. For example, a lighting console is frequently employed as the controller for a network of slave devices such as dimmers, fog machines and intelligent lights.

Each slave device has a DMX512 "IN" connector and usually an "OUT" (or "THRU") connector as shown in Fig.1 as well. The controller, which has only an OUT connector, is connected via a DMX512 cable to the IN connector of the first slave. A second cable then links the OUT or THRU connector of the first slave to the IN connector of the next slave in the chain, and soon. For example, the block diagram below Fig. 2 shows a simple network consisting of a controller and three slaves.

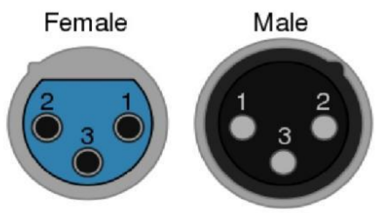

Fig.1 DMX Connector

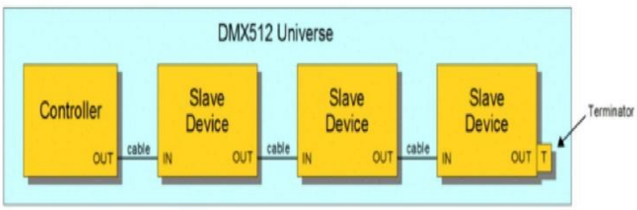

Fig.2 DMX Data Connections

The specification requires a 'terminator' to be connected to the final OUT or THRU connector of the last slave on the daisy chain, which would otherwise be unconnected. A terminator is a stand-alone male connector with an integral 120 Ω resistor connected across the primary data signal pair; this resistor matches the cable's characteristic impedance. If a secondary data pair is used, a termination resistor is connected across it as well. Although simple systems (i.e., systems having few devices and short cables) will sometimes function normally without a terminator, the standard requires its use. Some DMX slave devices have built-in terminators that can be manually activated with a mechanical switch or by software, or by automatically sensing the absence of a connected cable.

A DMX512 network is known as "DMX universe". Each OUT connector on a DMX512 controller can control a single universe. Smaller controllers have a single OUT connector, enabling them to control only one universe, whereas large control desks (operator consoles) have the capacity to control multiple universes, with an OUT connector provided for each universe.

4.4.2 *Physical Layer Electrical Specifications*

DMX512 data is transmitted over a differential pair using EIA-485 voltage levels. DMX512 electrical specifications are identical to those of the EIA-485-A standard, except where stated otherwise.

DMX512 is a bus network less than 400 metres (1300 ft) long, with less than 32 unit loads (individual devices connected) on a single bus. If more than 32unit loads need to communicate, the network can be expanded across parallel buses using DMX splitters. Network wiring consists of a shielded twisted pair, with a characteristic impedance of 120 Ω, with a termination resistor at the end of the cable furthest from the controller to absorb signal reflections. DMX512 has two twisted pair data paths, although specification currently only defines the use of one of the twisted pairs. The second pair is undefined, but required by the electrical specification.

For short cable runs of less than about 45 metres (148 ft) with only a few devices, it is sometimes possible to operate without termination. At short distances, cables with higher capacitance and different characteristic impedance such as microphone cable can be used. As the cable length or number of devices increases, following the specification for termination and correct cable impedance becomes more important. For protocol at the data link layer, a DMX 512 controller transmits asynchronous serial data at 250kbit/s.

Summary of DMX protocol is still widely used in commercial lighting control system, one can find several devices available in the market based upon DMX control.

4.5 KNX

KNX is once agin more of an indoor solution. Any wired street light solution will always have limitations and a more complex architecture. Should be omitted. Most of the text below relates to bms and indoor solutions

KNX is not based on a specific hardware platform. The most common form of installation is over twisted pair medium. KNX is an approved standard by the following organisations:

a) International standard (ISO/IEC 14543-3)
b) European standard (CENELEC EN 50090 and CEN EN 13321-1)
c) US standard (ANSI/ASHRAE 135)
d) China Guobiao (GB/T 20965)

4.5.1 *Architecture*

KNX devices are commonly connected by a twisted pair bus and can be modified from a controller. The bus is routed in parallel to the electrical power supply to all devices and systems on the network linking:

a) Sensors (e.g. push buttons, thermostats, anemometers, movement) gather information and send it on the bus as a data telegram.
b) Actuators (dimming units, heating valves, displays) receive data telegrams which are then converted into actions.
c) Controllers and other logic functions (room temperature controllers, shutter controllers and other)
d) System devices and components (e.g. line couplers, backbone couplers).

Many actuators include controller functionality and also sensor functionality (for instance measuring operating hours, number of switch cycles, current, electrical power consumption, and more).

Application software, together with system topology and commissioning software, is loaded in the devices via a system interface component. Installed systems can be accessed via LAN, point to point links, or phone networks for central or distributed control of the system via computers, tablets and touch screens, and smartphones.

4.5.2 *Devices*

A KNX installation always consists of a set of devices connected to the bus or network. Device models vary according to node roles, capabilities, management features and configuration modes. There are also general-purpose device models, such as for bus coupling units (BCUs) or bus interface modules (BIMs).

Devices may be identified and subsequently accessed throughout the network either by their individual address, or by their unique serial number, depending on the configuration mode. (Unique serial numbers are allocated by the KNX Association Certification Department.) Devices can also disclose both a manufacturer specific reference and functional (manufacturer independent) information when queried.

KNX S/W architecture is shown in Fig.3

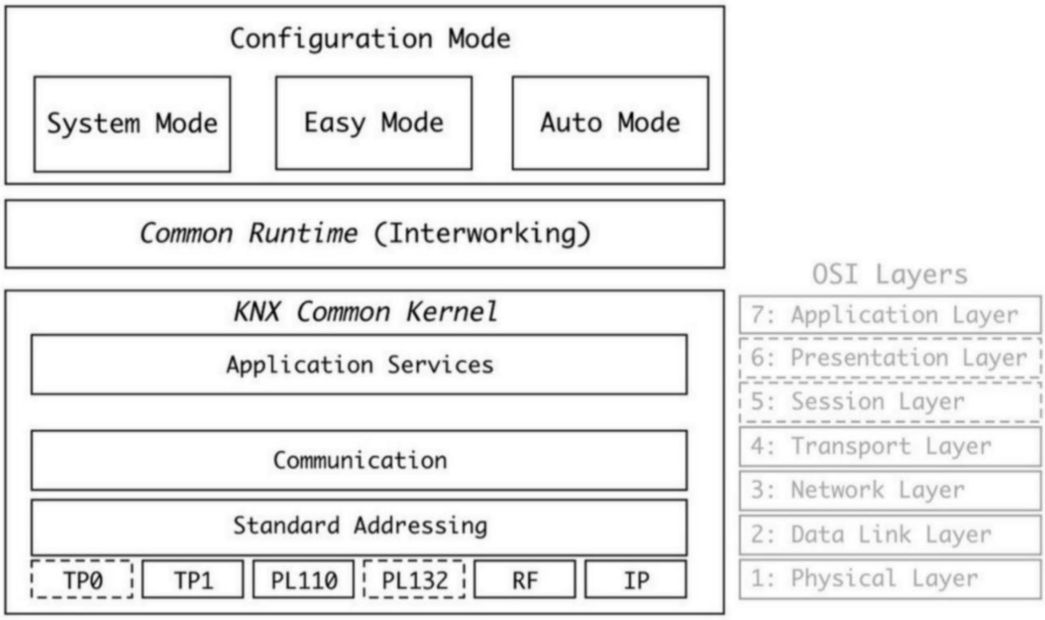

Fig.3 KNX Software Architecture

4.5.3 *Logical Topology and Individual Address Space*

A KNX wired network can be formed with tree, line and star topologies, which can be mixed as needed; ring topologies are not supported. A tree topology is recommended for a large installation.

a) KNX can link up to 57,375 devices using 16-bit addresses.

b) The lowest eight bits provide up to device 256 addresses within one line, which can consist of up to 4 segments, each having a maximum of 64 devices. Each segment requires a local power supply and the maximum length of a segment is 1000 m. (The actual number of devices supported is dependent on the power supply and the power load of the individual devices.) Segments connected with line repeaters and can extend to a length of 4000 m and link up to 256 devices.

c) Lines may be grouped together into an area, with up to 15 lines connected to a main line via line couplers. The next four bits of the address are used to identify individual lines.

d) An entire domain can be formed with 15 areas linked by a backbone line using backbone couplers, and the top four bits of the address space identify an area. (Line repeaters may not be used on a backbone or mainline.)

e) Coupling units allow address filtering which helps to improve performance given the limited bus signal speed. An installation based on KNXnet/IP allows the integration of KNX sub networks via IP as the KNX address structure is similar to an IP address.

4.6 Building Management Systems (BMS)

It is this relevant for a city wide outdoor network?

Nowadays it is hard to imagine a modern building functioning without an effective and reliable management system, which is capable to ensure safety and comfort for people living or working in the building, as well as an efficient and reliable maintenance and optimization of resources used.

A building management system (BMS) as shown in Fig. 4, also known as a building automation system (BAS), is a computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security system.

Fig.4 Typical BMS Model

A BMS consists of software and hardware, the software program, usually configured in a hierarchical manner, can be proprietary, using protocols such as C-Bus, Profibus, and so on. Vendors are also producing a BMS that integrates the use of Internet protocols and open standards such as DeviceNet, SOAP, XML, BACnet, LonWorks and Modbus.

A list of systems that can be monitored or controlled by a BMS like Illumination (lighting) control , electric power control, heating, ventilation, and air conditioning , security and observation ,access control, fire alarm system lifts, elevators etc. plumbing closed-circuit television (CCTV), Other engineering systems, control panel, PA system, alarm monitor, security automation.

4.6.1 *BACnet*

BACnet again a n outdated protocol. The world is moving to api which allow the same idea of allowing different systems to be represented ona single platform. However with API no specific software is required. The integrator will take different API of different solutions and bring it on a single platform

Building Automation Controls Network (BACnet) is a network protocol specifically used for multiple devices to communicate across building automation systems by system users and building system manufacturers.

4.6.1.1 *BAC net protocol* — The BACnet protocol defines a number of services that are used to communicate between building devices. The protocol services include ‘Who-Is, I-Am, Who-Has, I-Have’, which are used for device and object discovery. Services such as read-property and write property are used for data sharing. As of ANSI/ASHRAE 135-2016, the BACnet protocol defines 60 object types that are acted upon by the services.

The BACnet protocol defines a number of data link / physical layers, including ARCNET, Ethernet, BACnet/IP, BACnet/IPv6, BACnet/MSTP, Point-To-Point over RS-232, Master-Slave/Token-Passing over RS-485, ZigBee, and LonTalk.

4.6.2 *LonWorks*

It is also dated and used exclusively for indoor BMS

LonWorks (local operating network) is a networking platform specifically created to address the needs of control applications.The platform is built on a protocol created by Echelon Corporation for networking devices over media such as twisted pair, powerlines, fiber optics, and RF. It is used for the automation of various functions within buildings such as lighting and HVAC.

The technology has its origins with chip designs, power line and twisted pair, signalling technology, routers, network management software, and other products from echelon corporation.

4.6.2.1 *Usage* — Many devices have been installed with LonWorks technology. Manufacturers in a variety of industries including building, home, street lighting, transportation, utility, and industrial automation have adopted the platform as the basis for their product and service offerings. Statistics as to the number of locations using the LonWorks technology are scarce, but products and applications built on top of the platform include such diverse functions as embedded machine control, municipal and highway/tunnel/ street lighting, heating and air conditioning systems, intelligent electricity metering, subway train control, building lighting, stadium lighting and speaker control, security systems, fire detection and suppression, and newborn location monitoring and alarming, as well as remote power generation load control.

4.6.2.2 *Applications* — It has various applications in lighting control systems, energy management systems, heating/ventilation/air-conditioning system, security systems, home automation, consumer appliance controls, public street lighting, monitoring, petrol station control, rail electronically controlled pneumatic braking, semiconductor manufacturing.

4.7 Niagara

It's a platform that allows systems to interconnect. Not sure of its relevance for outdoor solutions. Typically used indoors and requires devices to be on a physical network.

The Niagara Framework connects different components, operating systems and applications and allows devices and protocols to integrate into unified, smart systems.

Niagara is an open, Java-based framework that can connect almost any embedded device or system regardless of manufacturer or communication protocol. It includes a comprehensive graphical toolset that lets you build rich applications in a drag-and-drop environment and easily manage assets using a standard web browser.

The Niagara Framework (*see* Fig.5) is adopted in multiple markets and industries, and deployed in more than 70 countries and its many benefits are easy to see. Reduce project implementation requirements. Free up your organization from supporting high-cost, time consuming development functions. Increase capacity for product innovation. Build products and applications with unparalleled reliability, security, operational integrity, flexibility and bottom-line value.

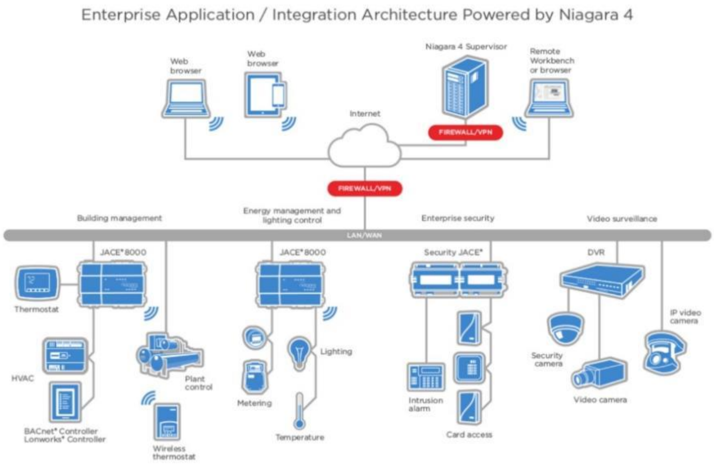

Fig. 5 Niagara Application Architecture

4.7.1 *JACE Controller*

JACE (Java Application Control Engine) is the hardware that run niagara software, JACE controllers unleash the full power of Niagara. To integrate diverse devices and systems, a physical connection is required. The JACE controller is the mechanism that provide connectivity. By connecting common network protocols such as LonWorks®, BACnet®, Modbus®, OPC, oBIX and many proprietary networks, a unified system emerges. Scalability and reliability are maintained with the unique distributed architecture that a network of JACE controllers creates.

JACE controllers combine integrated control, supervision, data logging, alarming, scheduling and network management functions, integrated IO with internet connectivity and web-serving capabilities all in a compact platform. A JACE controller makes it possible to control and manage external devices over the internet and present real-time information to users in web-based graphical views.

Chapter 2

Connected Lighting - IOT Based Street Lighting Systems

5 WIRELESS CONNECTED TECHNOLOGY AND ERA OF COMMUNICATIONS

Wireless technology provides the ability to communicate between two or more entities over distance without the use of wires or cables. This includes communications primarily using radio frequency (RF). Wireless technology has always been preceded by wired technology and is usually more expensive, but provides the additional advantage of mobility, allowing the user to receive and transmit information while on the move. That's why wireless access to the internet is expected to exceed wired access in the next few years, and the prospects for the future are exciting. There are huge number of wireless technologies currently available and can be organized into a groups based on functionality, data speed, and operating range.

In conjunction with the rapid growth of the Internet of Things (IoT) market, low power wide area networks (LPWAN) have become a popular low-rate long-range radio communication technology.

SIGFOX (is proprietary and not available in India), LoRa, 6LowPAN, and NB-IoT are the leading LPWAN technologies that compete for large-scale IoT deployment. This section provides a comprehensive and comparative study of these technologies, which serve as efficient solutions to connect smart, autonomous, and heterogeneous devices. The merit of these system analyzed and recommended. As per recent condition and parameter of analysis, it looks that SIGFOX and LoRa are advantageous in terms of battery lifetime, capacity, and cost. Meanwhile, NB-IoT offers benefits in terms of latency and quality of service.

6 SURVEY OF DIFFERENT IOT TECHNOLOGY

The Internet of Things (IoT) refers to the inter connection and exchange of data among devices/sensors. Recently with the explosive growth of the IoT technologies, an increasing number of practical applications can be found in many fields including security, asset tracking, agriculture, smart metering, smart cities, and smart homes .

IoT applications have specific requirements such as long range, low data rate, low energy consumption, and cost effectiveness. The widely used short-range radio technologies (e.g., ZigBee, Bluetooth) are not adapted for scenarios that require long range transmission. Solutions based on cellular communications (e.g., 2G, 3G, and 4G) can provide larger coverage, but they consume excessive device energy. Therefore, IoT applications requirements have driven the emergence of a new wireless communication technology and low power wide area network (LPWAN).

6.1 LowPAN

LowPAN is gaining popularity in industrial and research communities because of its low power, long range, and low-cost communication characteristics. It provides long-range communication up to 10–40 km in rural zones and 1–5 km in urban zones. It is highly energy efficient (i.e. 10+ years of battery lifetime and cost economy. These promising aspects of LPWAN have prompted experimental studies on the performance of LPWAN in outdoor and indoor environments. In summary, LPWAN is highly suitable for IoT applications that only need to transmit tiny amounts of data in long range, as shown below in Fig. 6.

Many LPWAN technologies have arisen in the licensed as well as unlicensed frequency bandwidth. Among them Sig fox, LoRa, and NB-IoT are recently leading emergent technologies that involve many technical differences.

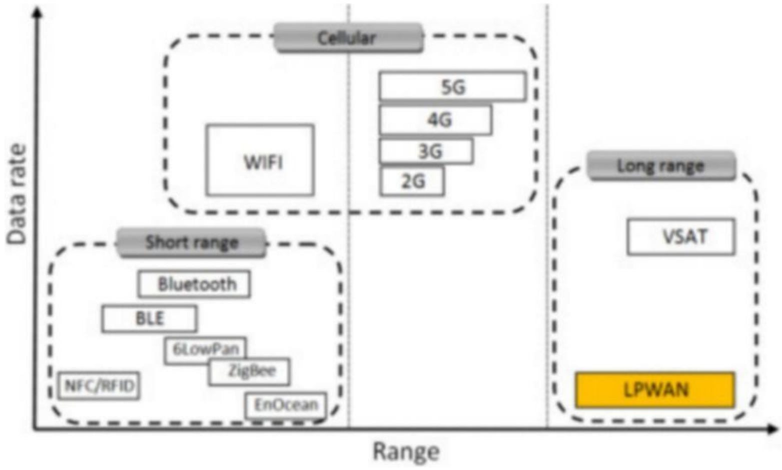

Fig.6 Required Data Rate Vs. Range Capacity of Radio Communication Technologies

6.1.1 *LoRa*

LoRa is a physical layer technology that modulates the signals in sub-GHZ ISM band using a proprietary spread spectrum technique . LoRa uses unlicensed ISM bands, i.e., 868 MHz in Europe, 915 MHz in North America, and 433 MHz in Asia. The bidirectional communication as shown in Fig. 7 is provided by the chirp spread spectrum (CSS) modulation that spreads a narrow-band signal over a wider channel bandwidth. The resulting signal has low noise levels, enabling high interference resilience, and is difficult to detect or jam.

LoRa uses 6 spreading factors (SF7 to SF12) to adapt the data rate and range trade off. higher spreading factor allows longer range at the expense of lower data rate, and vice versa. The LoRa data rate is between 300 bps and 50 kbps depending on spreading factor and channel bandwidth.This maybe a theoretical value however it is more in the region of 5kps. LoRa is also a single plex communication protocol to the end device. Further, messages transmitted using different spreading factors can be received simultaneously by LoRa base stations maximum payload length for each message is 243 bytes.

A LoRa-based communication protocol called LoRaWAN was standardized by LoRa-Alliance (first version in 2015). Using LoRaWAN, each message transmitted by an end device is received by all the base stations in the range. By exploiting this redundant reception, LoRaWAN improves the successfully received messages ratio. However, achieving this feature requires multiple base stations in the neighborhood, which may increase the network deployment cost. The resulting duplicate receptions are filtered in the backend system (network server) that also has the required intelligence for checking security, sending acknowledgments to the end device, and sending the message to the corresponding application server. Further, multiple receptions of the same message by different base stations are exploited by LoRaWAN for localizing end devices. For this purpose, the time difference of arrival (TDOA)-based localization technique supported by very accurate time synchronization between multiple base stations is used. Moreover, multiple receptions of the same message at different base stations avoid the handover in LoRaWAN network (i.e., if a node is mobile or moving, handover is not needed between the base stations).

In addition, LoRaWAN provides various classes of end devices to address the different requirements of a wide range of IoT applications, e.g., latency requirements.

Fig.7 Bidirectional Communication between End-Device and Base Station for LoRaWAN Class A

6.1.1.1 *Bidirectional end devices (class A)*— class-A end devices allow bidirectional communications where by each end-device's uplink transmission is followed by two short downlink receive windows as shown in Fig. 7. The transmissions lot scheduled by the end device is based on its own communication needs with a small variation based on a random time basis. This class-A operation is the lowest power end-device system for applications that only require short downlink communication after the end device has sent an uplink message. Downlink communications at any other time will have to wait until the next uplink message of the end device.

6.1.1.2 *Bidirectional end devices with scheduled receives lots (class B)* —In addition to the random receive windows of class A, class B devices open extra receive windows at scheduled times. To open receive windows at the scheduled time, end devices receive a time-synchronized beacon from the base station. This allows the network server to know when the end device is listening.

6.1.1.3 *Bidirectional end devices with maximal receive slots (class C))*— Class C is an end devices have almost continuously open receive windows, and only close when transmitting at the expense of excessive energy consumption.

The specifications of the next version of LoRaWAN are still being developed by LoRa-Alliance. The new features expected are roaming, class-B clarification, and the temporary switching between class A and class C.

6.1.2 *NB-IoT*

NB-IoT is a Narrow Band IoT technology. It can coexist with GSM (global system for mobile communications) and LTE (long-term evolution) under licensed frequency bands (e.g., 700 MHz, 800 MHz, and 900 MHz). NB-IoT occupies a frequency band width of 200 KHz,which corresponds to one resource block in GSM and LTE transmission. With this frequency band selection, the following operation modes as shown in Fig. 8.

a) Stand-alone operation: a possible scenario is the utilization of GSM frequencies bands currently used.

b) Guard-band operation: utilizing the unused resource blocks within an LTE carrier's guard band.

c) In-band operation: utilizing resource blocks within an LTE carrier.

For the stand-alone operation, the GSM carriers in the right part of Fig.8 are shown as an example to indicate that the operation is possible in NB-IoT deployment. In fact, the 3GPP recommends the integration of NB-IoT in conjunction with the LTE cellular networks. NB-IoT can be supported with only a software upgrade in addition to the existing LTE infrastructure.

The NB-IoT communication protocol is based on the LTE protocol. In fact, NB-IoT reduces LTE protocol functionalities to the minimum and enhances them as required for IoT applications. For example, the LTE backend system is used to broadcast information that is valid for all end devices within a cell. As the broadcasting back end system obtains resources and consumes battery power from each end device, it is kept to a minimum, in size as well as in its occurrence. It was optimized to small and infrequent data messages and avoids the features not required for the IoT purpose, e.g., measurements to monitor the channel quality, carrier aggregation, and dual connectivity. Therefore, the end devices require only a small amount of battery, thus making it cost-efficient.

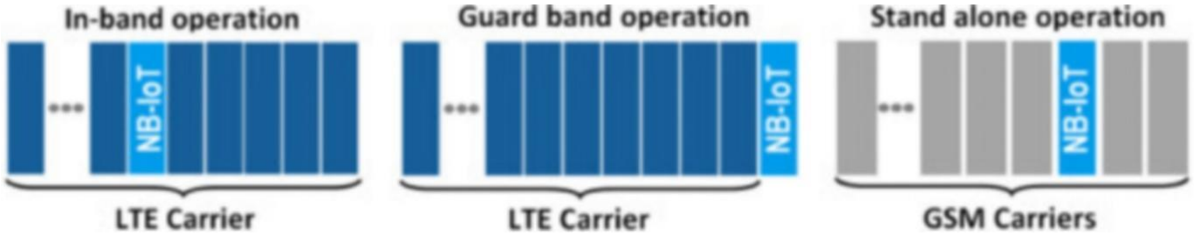

Fig. 8 Operation Modes for NB-IoT.

Consequently, NB-IoT technology can be regarded as a new air interface from the protocol stack point of view, while being built on the well-established LTE infrastructure. NB-IoT allows connectivity of up to 100 K end devices per cell with the potential for scaling up the capacity by adding more NB-IoT carriers. NB-IoT uses the single-carrier frequency division multiple access (FDMA) in the uplink and orthogonal FDMA (OFDMA) in the downlink, and employs the quadrature phase-shift keying modulation (QPSK) . The data rate is limited to 200 kbps for the downlink and to 20 kbps for the uplink. The maximum payload size for each message is 1600 bytes. NB-IoT technology can achieve 10 years of battery lifetime when transmitting 200 bytes per day on average.

The improvement of NB-IoT continues with Release 15 of the 3GPP. According to the 3GPP's current plan, the NB-IoT will be extended to include localization methods, multicast services (e.g., end-devices software update and messages concerning a whole group of end devices), mobility, as well as further technical details to enhance the applications of the NB-IoT technology.

In this section, we highlight the emerging proprietary technologies and the technical aspects of Sig fox, LoRa, and NB-IoT as summarized in Table 1 below:

Table 1 Overview of LPWAN Technologies: Sig Fox, LoRa, and NB-IoT (*Clause* 6.1.1 & 6.3.3)

Sl.No	**Modulation**	**SIGFOX** **BPSK**	**LoRa** **CSS**	**NB-IoT** **QPSK**
(1)	(2)	(3)	(4)	(5)
i)	Frequency	Unlicensed ISM bands (868 MHz in Europe, 915 MHz in North America, and 433 MHz in Asia)	Unlicensed ISM bands (868 MHz in Europe, 915 MHz in North America, and 433 MHz in Asia)	Licensed LTE frequency bands
ii)	Bandwidth	100 Hz	250 kHz and 125 kHz	200 kHz
iii)	Maximum data rate	100 bps	50 kbps	200 ps
iv)	Bidirectional	Limited / Half-duplex	Yes / Half-duplex	Yes / Half-duplex

v)	Maximum messages/day	140 (UL), 4 (DL)	Unlimited	Unlimited
vi)	Maximum payload length	12 bytes (UL), 8 bytes (DL)	243 bytes	1600 bytes
vii)	Range	10 km (urban), 40 km (rural)	5 km (urban), 20 km (rural)	1 km (urban), 10 km (rural)
viii)	Interference immunity	Very high	Very high	Low
ix)	Authentication & encryption	Not supported	Yes (AES 128b)	Yes (LTE encryption)
x)	Adaptive data rate	No	Yes	No
xi)	Handover	End-devices do not join a single base station	End-devices do not join a single base station	End-devices join a single base station
xii)	Localization	Yes (RSSI)	Yes (TDOA)	No (under specification)
xiii)	Allow private network	No	Yes	No
xiv)	Standardization	Sig fox company is collaborating with ETSI on the standardization of Sig fox-based network	LoRa-Alliance	3GPP

6.2 LPWAN

This technology combines both IPV6 and LWPAN. Each end device is given a unique IP address as it combines the MAC ID of the device hence exponentially increasing the number of possible unique addresses available for IoT devices.

These end devices work on 868Mhz which is a licence free band India and create a mesh network which allows large scale deployment in cities.

Rather than a mobile network to each device this system works on a gateway which can connect between 250 and 1000 end devices. Each end device then is visible on the CMS via the gateway. In the event of Gateway failure the end device will connect via the mesh to the next available gateway.

6.3 Comparison in Terms of IoT Factors

In this section, the technical differences of Sig fox, LoRa, 6LowPAN and NB-IoT are presented and compared in terms of physical/ communication features. In addition, these technologies are compared in terms of IoT success factors such as quality of service (QoS), coverage, range, latency, battery life, scalability, payload length, deployment, and cost. Further, we consider application scenarios and explain which technology fits best.

Many factors should be considered when choosing the appropriate LPWAN technology for an IoT application including quality of service, battery life, latency, scalability, payload length, coverage, range, deployment, and cost. In the following, SIGFOX, LoRa and NB-IoT are compared in terms of these factors and their technical differences.

6.3.1 *Quality of Service*

6LOWPAN and LoRa employ unlicensed spectra and asynchronous communication protocols. They can bounce interference, multipath, and fading. However, they cannot offer the same QoS provided by NB-IoT.

NB-IoT employs a licensed spectrum and an LTE-based synchronous protocol, which are optimal for QoS at the expense of cost, i.e., licensed LTE spectrum auctions are over 500 million euro per MHz. Owing to QoS and cost tradeoff, NB-IoT is preferred for applications that require guaranteed quality of service, whereas applications that do not have this constraint should choose LoRa or SIGFOX.

6.3.2 *Battery Life and Latency*

In 6LOWPANLoRa, and NB-IoT, end devices are in sleep mode most of the time outside operation, which reduce the amount of consumed energy, i.e., long end-devices lifetime. However, the NB-IoT end device consumes additional energy because of synchronous communication and QoS handling, and its OFDM/FDMA access modes require more peak current. This additional energy consumption reduces the NB-IoT end-device lifetime as compared to SIGFOX and LoRa.

However, NB-IoT offers the advantage of low latency. Unlike SIGFOX, LoRa provides class C to also handle low-bidirectional latency at the expense of increased energy consumption. Therefore, for applications that are insensitive to the latency and do not have large amount of data to send, SIGFOX and class-A LoRa are the best options. For applications that require low latency, NB-IoT and class-C LoRa are the better choices.

6.3.3 *Scalability and Payload Length*

The support of the massive number of devices is one of the key features of SIGFOX, LoRa, and NB-IoT. These technologies work well with the increasing number and density of connected devices. Several techniques are considered to cope with this scalability feature such as the efficient exploitation of diversity in a channel, as well as in time and space. However, NB-IoT offers the advantage of very high scalability than SIGFOX and LoRa. NB-IoT allows connectivity of up to 100 K end devices per cell compared to 50 K per cell for SIGFOX and LoRa.

Nevertheless, NB-IoT also offers the advantage of maximum payload length. As presented in Table 1, NB-IoT allows the transmission of data of up to 1600 bytes. LoRa allows a maximum of 243 bytes of data to be sent. In contrary, SIGFOX proposes the lowest payload length of 12 bytes, which limits its utilization on various IoT applications that need to send large data sizes.

6.3.4 *Network Coverage and Range*

The major utilization advantage of SIGFOX is that an entire city can be covered by one single base station (i.e., range >40 km). NB-IoT has the lowest range and coverage capabilities (i.e., range <10 km). It focuses primarily on the class of devices that are installed at places far from the typical reach of cellular networks (e.g., indoors, deep indoors). In addition, the deployment of NB-IoT is limited to LTE base stations. Thus, it is not suitable for rural or suburban regions that do not benefit from LTE coverage.

6.3.5 *Deployment Model*

The NB-IoT specifications were released in June 2016; thus, additional time will be needed before its network is established. However, the SIGFOX and LoRa ecosystems are mature and are now under commercialization in various countries and cities. LoRa has the advantage that allows it to be currently deployed in 42 countries versus 31 countries for SIGFOX. Nevertheless, the worldwide deployments of LoRa and Sigfox are still under rollout.

In addition, one significant advantage of LoRa ecosystem is its flexibility. Unlike SIGFOX and NB-IoT, LoRa offers local network deployment, i.e., LAN using LoRa gateway as well as public network operation via base stations. In the industrial field, a hybrid operating model could be used to deploy a local LoRa network in factory areas and uses the public LoRa network to cover the outside areas.

6.3.6 *Cost*

Various cost aspects need to be considered such as spectrum cost (license), network/deployment cost, and device cost. Table 2 shows the cost of LoRa, and NB-IoT. It is apparent that 6LOWPANand LoRa are more cost-effective compared to NB-IoT.

In summary 6LOWPAN LoRa, and NB-IoT each has their respective advantages is shown in Fig. 9 in terms of different IoT factors. (cant change this graph below)

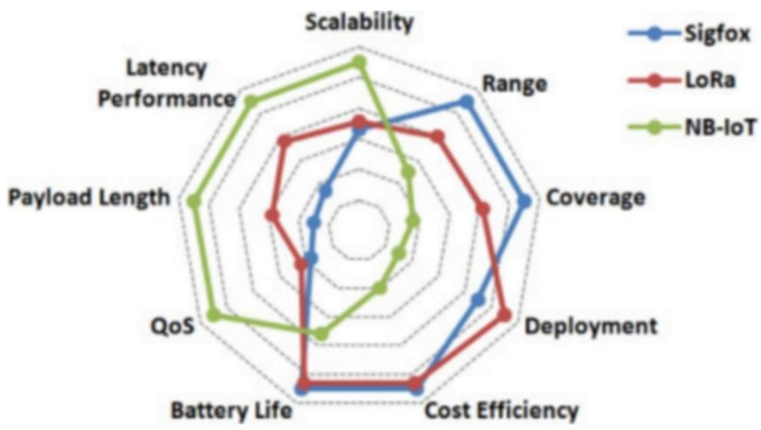

Fig. 9 Respective Advantages of Lora, and NB-Iot in Terms of IoT Factors.

The deployment cost, end device cost and running cost are varying with time but at the time of installations all these need to be study thoroughly and checked to take a proper decision.

The IoT factors and technical differences of Sigfox, LoRa, and NB-IoT will determine their feasibility for specific applications. One technology cannot equally serve all IoT applications. In this section, various application use cases are discussed with a summary of the best-fitting technology. This is a recommendation looking into the present condition and based on the above parameters. We limit ourself on lighting related applications.

6.4 Technology Inference

This section describes the technical differences of 6LOWPAN, LoRa, and NB-IoT, and discussed their advantages in terms of IoT factors and major issues. Each technology will have its place in the IoT market. SIGFOX and LoRa will serve as the lower-cost device, with very long range (high coverage), infrequent communication rate, and very long battery lifetime. Unlike SIGFOX, LoRa will also serve the local network deployment and the reliable communication when devices move at high speeds. By contrast, NB-IoT will serve the higher-value IoT markets that are willing to pay for very low latency and high quality of service.

The cellular companies tests, the lack of NB-IoT commercial deployments currently leaves open questions on the actual battery lifetime and the performance attainable by this technology in real-world conditions.

6.5 Types of IoT Based Street Lighting

In this section, different types of popular IoT based street lighting is systems covered keeping in mind their need and benefit as well proven installation in India. Below Fig. 10 give a very clear picture of how the street lighting system in utilities evolved over the years in India.

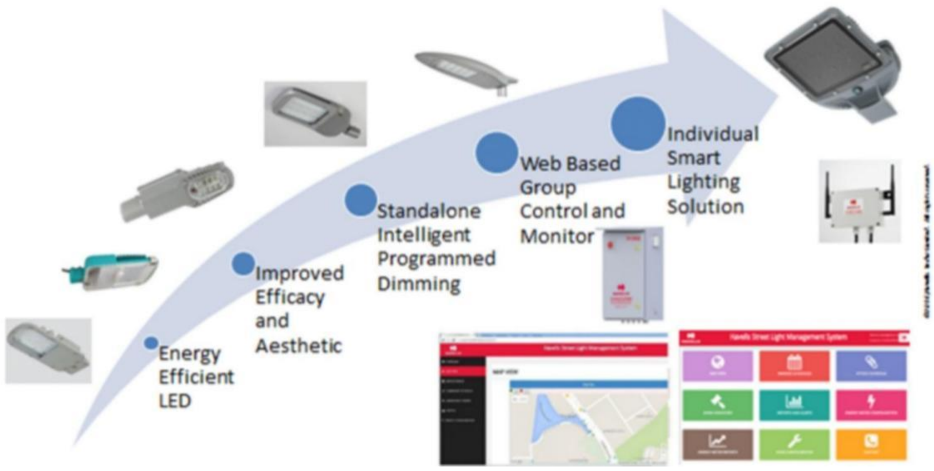

Fig.10 Trend of IoT Based Street Lighting System Applications

6.6 Group Control of IoT Based Street Lighting

Group control IoT based street lighting normally called CCMS (Central Control Management System) for controlling, monitoring, measuring energy consumption details of the group getting the fault detection feedback etc. has been successfully carried out and implemented in very good number of successful projects in India. CCMS is a group control of the lighting system say 50 to 150 no of street lighting are clubbed in one system to have all the operation and management data system. CCMS is group control, energy measurement for the group of street lighting fittings, fault status reporting for the group, on and off for the group, group scheduling for ON & OFF . Control of the group by Gateway (CCMS system panel for the group). Remotely controlled and data access through CCMS gate way panel. Any issue of MCB tripping the whole group. Below Table 2 shows requirement for central management software.

Table 2 Requirement for Central Management Software

(*Clause* **6.3.6 & 6.6**)

Sl. No	Requirements	
(1)	(2)	
i)	Multi –User Web Application Server	The central Management Software should be based on an open Web Application Server. Its

		user interface should be 100% Web based and accessible from computer on the network through various types of web browsers.
ii)	Enterprises Server And Cloud Based Server	The Central Management Software should be available be installed on the city's server as well as available ,as an option, on a web-hosted server (Le. Cloud or SaaS model).
iii)	Smart phone and tablet user interfaces	User interface should be available for phone,tablets or devices with any screen size.
iv)	Based on open technologies	The Central Management software should be developed with open and standardized languages including Java,XML configuration files and SQL database. It should enable the development of additional features without the need to acquire any development software license.
v)	Open database engine	The Central Management Software should record all the data in a centralized SQL database and should compatible with MYSQL or PostgreSQL to avoid being obliged to purchase additional software license for database engine.
vi)	User authentication system	The Central Management Software should enable administrators to create, modify, delete users, passwords ,groups and access controls. It should provide modern and efficient security features.
vii)	Wireless Gateways	The Central Management Software should be able to provide interconnectivity and interoperability between solutions from different hardware manufactures to guarantee independence between Central Management Software layer and field hardware layer.
viii)	Support multiple models of individual lamp controllers from various manufacturers	The Central Management Software should support configuration, programming, control and monitoring of many different types/

		models of individual Lamp Controllers from many competing suppliers.

Limitation of CCMS has been felt in smart city projects as full exposure and benefits of present communication not being explored. Next step forward of CCMS is individual lamp monitoring lighting control by IoT. CCMS street lighting is reasonably good and so far cost efficient in energy saving projects (ESCO) installation. But CCMS has its own limitation and drawback as it works for a group of lamps in the installation therefore information and addressing to individual lamp not possible which, therefore next step forward individual lamp control IoT based street lighting has come though. Table no. 3a and 3b describes individual lamp monitoring and control say ILMS is superior than the CCMS. ILMS -Atomized remote accessibility (communication) and addressing the Individual lamp (individual fitting) for dimming and monitoring in all aspects of lamp ON/OFF, fault status feedback, Individual lamp energy measurement data with geo positioning, ILMS gives actual data with respect to all information for individual fitting. This is also called lamp level control (LLC).

With the introduction of D4i standards the ILMS and LLC are possible to get data in real time.

6.7 Lamp Level Control

Below Table 3a and 3b clearly explained the requirement and function of the single lamp control IoT based lighting.

Table-3(a) Transition from CCMS to an Open Individual Lamp Control

(*Clause* **6.7**)

SI. No		**Centralized Control And Monitoring System**	**Individual Lamp Control Based on D4i**	**Standard /Open Individual Lamp Controller (Not Sure Why This Is Here)**
		Type 1	**Type 2**	**Type 3**
(1)	(2)	(3)	(4)	(5)
i)	Energy Saving from dimming	Not easy	Yes	Yes
ii)	Stepless Dimming	Not easy	Yes	Yes

iii)	ON/ OFF control scheduling and astro clock	Standard Feature	Standard Feature	Standard Feature
iv)	Real time remote lamp control and monitoring	No	Yes	Yes
v)	Automatic lamp and other failure detection	Partly	Yes	Yes
vi)	Alarms via web portal /cell phone	Only for cabinet alarms	Yes	Yes
vii)	Automatic energy saving calculation	Yes for the group	Yes	Possible
viii)	Increased lamp lifetime	No	Yes	Yes

Table-3(b) Transition from CCMS to an Open Individual Lamp Control

(*Clause* **6.7**)

Sl. No		**Centralized Control and monitoring system**	**Individual Lamp Control Based On D4i**	**Open Individual Lamp Controllers**
		Type 1	**Type 2**	**Type 3**
(1)	(2)	(3)	(4)	(5)
i)	Support sensors and dynamic lighting	Applied to the group	Possible for each lamp	Possible for each lamp
ii)	Support constant light output	No	Yes. This is dependent on the	Possible

			DALI driver not system	
iii)	Compatible with open central management software	No at present	Yes. TALQ and uCIFI already have these in place.	Yes
iv)	Smart city extension	No	Yes based on 6LOW PAN all types of products can sit on the same network	Yes
v)	Feature Level	30%	100%	90%

Below Table 4 shows requirement of individual lamp control system

Table-4 Requirement of Individual Lamp Control System

(*Clause* **6.7**)

Sl. No (1)	**Requirements** (2)	
i)	Compatible (interchangeable) with other Individual Individual Lamp controllers from other manufactures	By using a standardized protocol, individual lamp controllers should be interchangeable with other individual lamp controllers supplied by other manufactures. D4i and Zagha specify this already.
ii)	Repeat the communication signal in the mesh topology or go by Star network.	Individual lamp controllers should act as signal repeaters to establish automatic mesh networks and to simplify the deployment of the systems. This is the key feature of 6LOWPAN creates a local mesh Alternatively, star network uses LORA-WAN or NB-lOT
iii)	Detect various failures and alarms	Individual Lamp controllers should be able to detect lamp failure low/high mains voltage,

		low/high current, lower power factor, cycling lamps and day burners This is part of the driver and the CMS functionality already.
iv)	Measure electrical values	Individual Lamp controllers should be able to measure mains voltage, current power, and power factor. D4i drivers come with class 1 monitoring of energy data.
v)	Measure cumulated energy consumption	Individual Lamp controllers should be able to measure and store the cumulated energy consumption in kWh. This is done by the driver
vi)	Measure number of burning hours	Individual Lamp controllers should be able to measure and store the cumulated numbers of lamp burning hours. This is also specified in D4i
vii)	Over the air software update	It should be possible to upgrade individual Lamp controllers embedded Software via the communication network.This is Over the Air Update,.
viii)	Need to fit with any shape of lumarine	Individual lamp controllers can be integrated either at the bottom of the pole or inside the luminaire. This point is not valid. The OEM will decide the luminaire design based on application.
ix)	Easiness of installation	Individual lamp Controllers should be easy for installers to install and to commission
x)	Low energy consumer	Individual Lamp Controllers should consume less than 1 watt The current standard is <0.5W during communication and even lower in standby mode
xi)	Operation Temperature	Individual Lamp Controllers should be support operating temperatures from -20˚C to +70˚C to support temperatures in luminaires and / or pole base. Since this is in the ambient atmosphere 70 degrees is too high as humans would perish leave alone electronic.
xii)	Switching control	Individual Lamp controllers should have relay to switch the light point ON/OFF through the control system. It should be able to run an astro timer to

		derive the switching timings for the day for the location . It may use a sensor along with Astro timer to offer finest switching In standby mode the DALI driver will consume under 0.35W considering Controller consumption of <0.5W (during transmission) the total is <0.85W
xiii)	Stepless dimming control	Individual Lamp Controllers should be capable to stepless dimming with the possibility to set the dimming level at any % (with accuracy of 1%) Dimming interface should be either 1-10 volts or PWM to fit with most of the LED drivers. 1-10V can never offer stepless dimming. PWM can. DALI2 D4i drivers already have this so please add DALI2 D4i drivers
xiv)	Communication using standardized ISO protocol	Individual Lamp Controllers should implement bi- directional communication using a standardized ~~Indian~~ approved protocol that is adopted by all manufactures of individual Lamp controllers to provide interoperability with different central Management Software solutions. It should receive and execute time switching and dimming commands. It should accept information reading commands and it should a answer such Energy meter reading requests in real time TALQ is already working on this standard which is going to be based on 868Mhx with mesh networks.
xv)	Implement a commonly agreed functional profile	On top of using a standardized communication protocol, Individual Lamp controllers should implement a Commonly agreed functional profile agreed and implemented by multiple competing vendors to offer EESL a way to interchange Individual lamp controller from various vendors.
xvi)	Security	The controller should come with AES 128 bit standard encryption

6.8 Focus Area of Smart Lighting System

IoT based single lamp control derived very many possible configurations and applications as well addition of many other non-communications gadgets, therefore few specific areas need to look into specially before and during the project.

a) *Energy Reporting*— Data-driven energy management can significantly reduce energy consumption, but effective test methods are needed to characterize measurement accuracy. compatible with other lamp controller.
b) *Interoperability and Interchangeability (Compatible*) — System performance is dependent on the ability of devices to work together, and common platforms and standardized protocols are needed to enable the exchange of usable data between lighting systems, other systems, the internet, and cloud services. Technology independent system.
c) *System Configuration Complexity*— Systems that are overly complicated and time-consuming to configure have historically delivered less than ideal performance.
d) Cybersecurity— Increased connectivity introduces cybersecurity risks that are new to the lighting industry and that must be addressed if next-level energy savings are to be fully realized.
e) Key New Features— Emerging CLS features (e.g., resource and process optimization, health and productivity gains, new revenue streams) may offer benefits with value that matches or exceeds those derived from improved lighting and energy performance.
f) Stakeholder Collaboration— Broad-based collaboration among the lighting, semiconductor, computing, and information technologies (IT) industries is essential to realizing the full potential of CLS.

6.9 Product and Systems – Hardware and Software

The following and the main component/constitute in the lamp level control:

a) LED Street Light Luminaire
b) Dimmable Driver (Control Gear)
c) Controller
d) Communication System Architecture
e) Control and Command Centre
f) Command and Monitoring Device like Laptop, Mobile, Monitor etc.
g) Cyber Security

6.9.1 *Luminaire*

In general LED street lighting luminaire requirement for IoT based street lighting system with respect to its construction, IP rating, light source LED characteristic, optics, light distribution/ photometry characteristics, lighting design and layout, wattage requirement, safety and performance requirement etc are of the same as stated in the Part 6/Sec 8 of this code.

In addition, for IoT based street lighting luminaire have few added electrical features and few may be optional as well are need based on project requirement. CCMS system luminaires is the normal street lighting luminaire of general purpose to meet any road condition and normally housed the standard electronics driver. For reliability and safe operation internal surge protector of appropriate value (say 4 to 10KVA) sometimes housed inside as recommended by authority. In the case of lamp level control appropriate dimmable driver used instead of normal driver and luminaire may also houses the controller depend on the project specification. Luminaire construction can have additional NEMA/Zagha socket provision so that the controller or any other optional attachment can be added.

Most important is luminaire traceability/coding number either to be embossed or permanent marking for identification the same thought its life. (D4i allows you to store the luminaire part number, brand etc already this is called asset management.)

6.9.2 *Dimmable Driver*

In the CCMS applications generally normal standard driver is used and in the case of lamp level IoT based lighting dimmable driver either DALI or 1-10V analog used depend on the controller and project requirement. The details characteristic of the driver and dimmable driver has already adequately covered in the Part 3/Section 2 of this code.

However, for more better understanding and clarification, some aspects has been covered specially requred and related with IoT based street lighting purpose. Dimmable Driver is of two type — Analog 1-10V and DALI (Digital). For all function of lamp level operation both should be compatible with the controller and two way communications with the luminaire system either by driver or controller should be done. Particular 1-10V analog dimmable driver has to compatible controller to serve the two-way communication. In case of DALI that driver do the two-way communication itself. (1-10V drivers have no intelligence and therefore cannot send data back. In this case the controller has the required fucntinality)

Standard requirement for both types of dimmable driver could be as follows:

a) 120V-270V universal electronic dimmable (CEA defines India grid at 240V)
b) IP66 rated outdoor type potted drivers with internal surge protection of 3kV (If the lum is Ip there is no reason for the driver to be IP)
c) Programmable output current of 350 mA-700 mA. Why limit this current range?
d) The fully programmable driver shall be suitable for ambient temperature range of -40 to +55 C with max. total harmonic distortion of 20% (should be less than 10%) also add flicker of +/- 5% and should be compatible with automated outdoor street lighting control system through compatible interfacing units. The driver should be isolated type for protecting the LED Boards from abnormalities and safety.
e) The driver should maintain min 0.9 PF when dimmed down to 40%. The PF should not fall below 0.8 even at lower levels of dimming.

6.9.3 *Controller*

The street light controller unit (SLC) unit is a wireless node which makes the street light IoT enabled for remote monitoring and control. It communicates over low power radio frequency and support wireless mess network. It allows remote on/off/dim the street light and communicate with IoT cloud platform via LPRF -GPRS /Ethernet IoT gate way. SLC has a automatic street light fault detection, on/off/dim action based on sensor events etc.

SLC form a self-forming, self-healing wireless mesh network communications ~~DCU~~. Support around 250 wireless nodes in single network, support connectivity of ~~two~~ any number of wireless sensors (can be motion, radar), Remote configuration via DSU supported. Easy commissioning of wireless nodes on a single click, Remote OTA firewire upgrade of all wireless nodes on single click. It has secure 128 bit AES wireless communications, it has also two-way communications with DCU / CLOUD platform for better control.

The general characteristics of IoT based individual street lighting controller can be of as follows:

a) Interchangeable with other individual lamp controllers supplied by other manufacturers.
b) Use star network using LORA-WAN or NB-IOT/GPRS/6LOWPAN
c) Upgrade Individual Lamp Controllers embedded software via the communication network.

In general specification can be stated as follows:

Advance 32 bit Microcontroller based design.

a) Very easy key board operation
b) Data Measurement for monitoring and controlling data monitoring through Class 1 type multi–function panel mounted energy meter: By using this to measure the individual phase voltage, individual phase load lamps, PF, KW, KVA, KVAR, Phase to Phase voltage, Average PF, KWH etc. (Local display of 36 and 28 for remote display in software)
c) Auto / Manual facility by way of contactor / relay operation for faster service mode. From local panel in manual mode it shows individual line / channel current and show no of lamp which is not working which helps to judging the problem in line (by difference of calibration current and existing line current. Judgment is possible for approximately find out no of lamps are not working
d) Double Inrush current capability of electrical switch gears to support LED luminaires
e) Real time clock with battery with life of more than 7 years (Manufacturer provided 10 years life for the battery with the accuracy of +/- 60 second per month. Power reserve of more than 60000 hours)
f) System parameter data protection with special RAM, which hold the parameter for more than 10 years without any power
g) Master and user Password Protection
h) Power supply 90-270VAC, 50HZ, Withstand/Isolation voltage 3,000V/AC

Below Fig. 11 shows enabled street light controller.
Next to it is the Zagha Based solution

Fig.11 Enabled Street Light Controller

6.9.4 *IOT based Street Lighting Ecosystem*

Table 5 describes total system requirement. It is bit complicated as many options are available but selection of the combinations to be used as per the specific need of the project and there are no hard and fast rule can be employed. In the start of this chapter, a comparative study of different system has been done. For selection different communication system stated before need to study and per project requirement as shown in Fig.12.

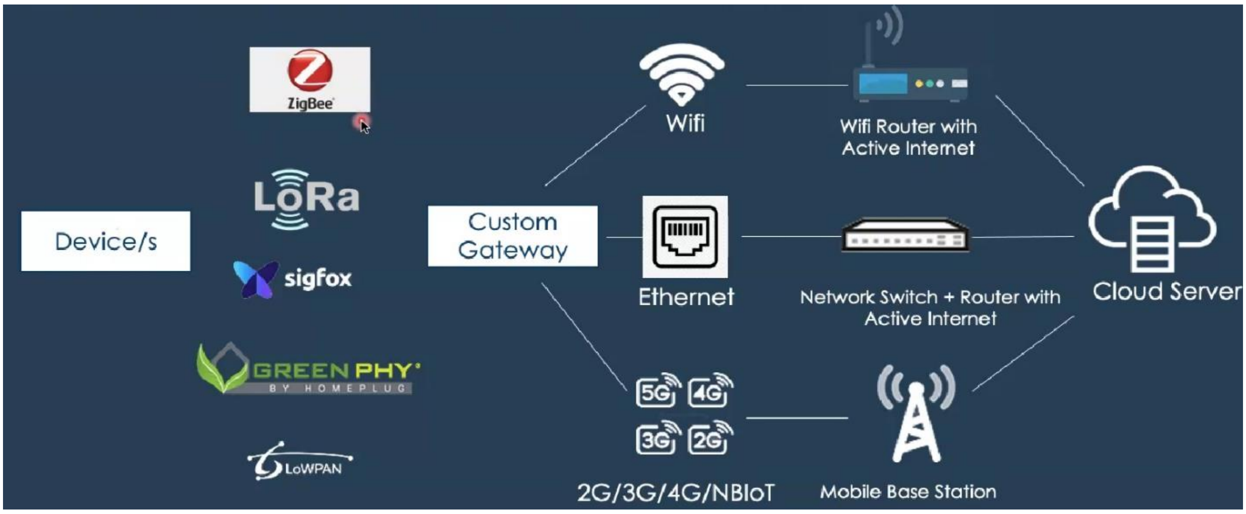

Fig.12 Different Communication Systems

6.10 LOW PAN Wireless Mesh Network Topology showing different SMART city components on the same network (*see* Fig. 13)

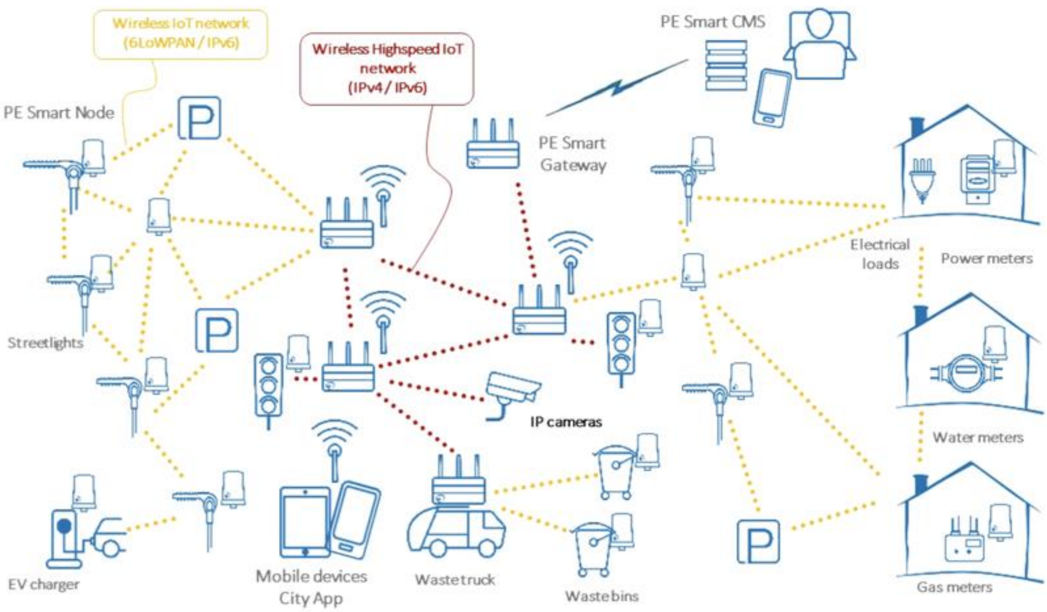

Fig. 13 LOW PAN Wireless Mesh Network Topology

Table 5 Total System Requirement

(*Clause* **6.9.4**)

Sl. No	Operations& Management	Access Network	Local Area Network
(1)	(2)	(3)	(4)
i)	Network Management	GSM	SMS
ii)	Business Operation Support system	CDMA	LPRF
		Satellite Network	PLC
		Dedicated line Access	Gateway
iii)		3G/4G/5G	M2M Terminals and Sensor Nodes

6.9.4.1 *Communication Architecture Models*

From the above table, it is clear and evident that many systems, combinations of system and components are possible. There are mainly RF MESH, WiFi, LORAWAN, GSM/NBOT /PLCC architecture and connectivity options for IoT based street lighting is being considered.

The schematic presentation given below to illustrate the architecture configuration for street lighting operation.

a) *RF mesh for street lighting* is shown in Fig.14

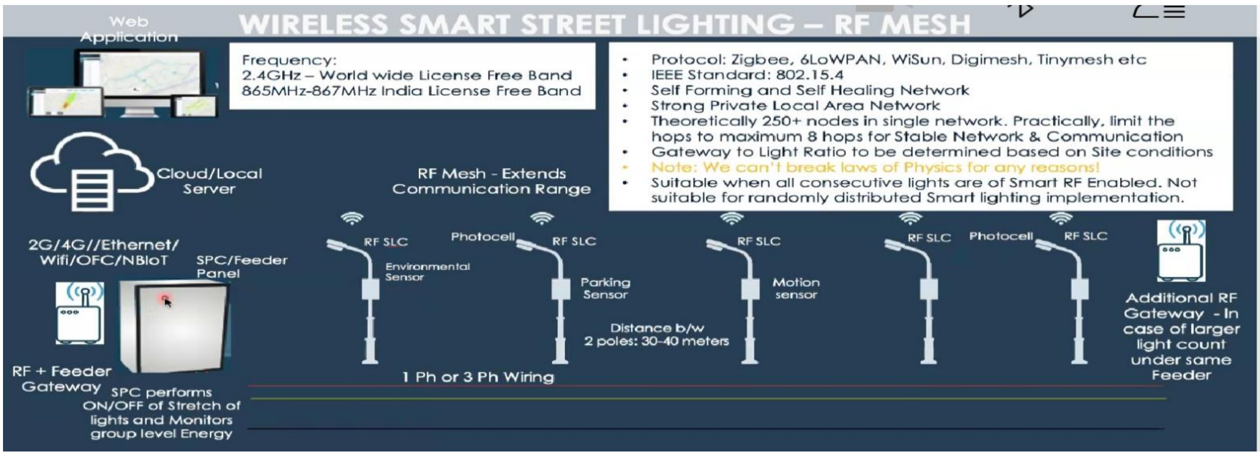

Fig.14 RF Mesh for Street Lighting

b) *WiFi Configuration* is shown in Fig.15

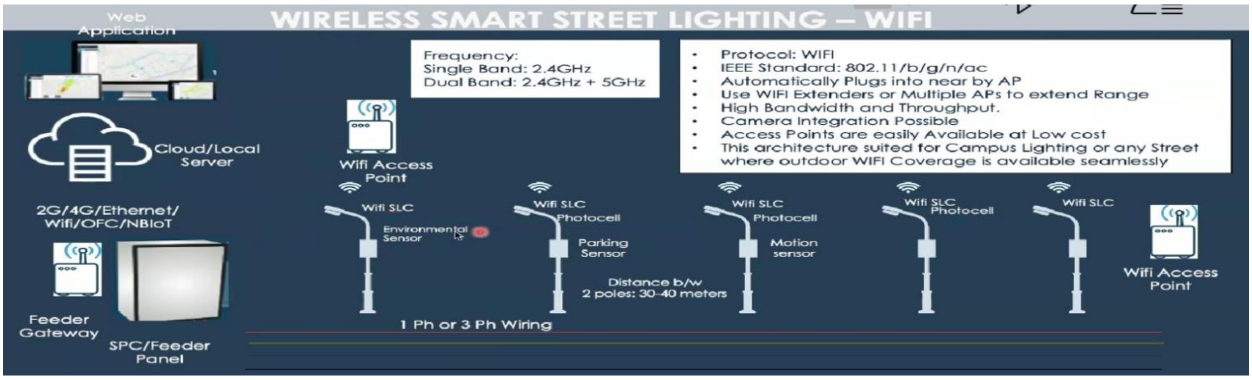

Fig.15 Wifi Configuration

c) *LORAWAN* is shown in Fig.16

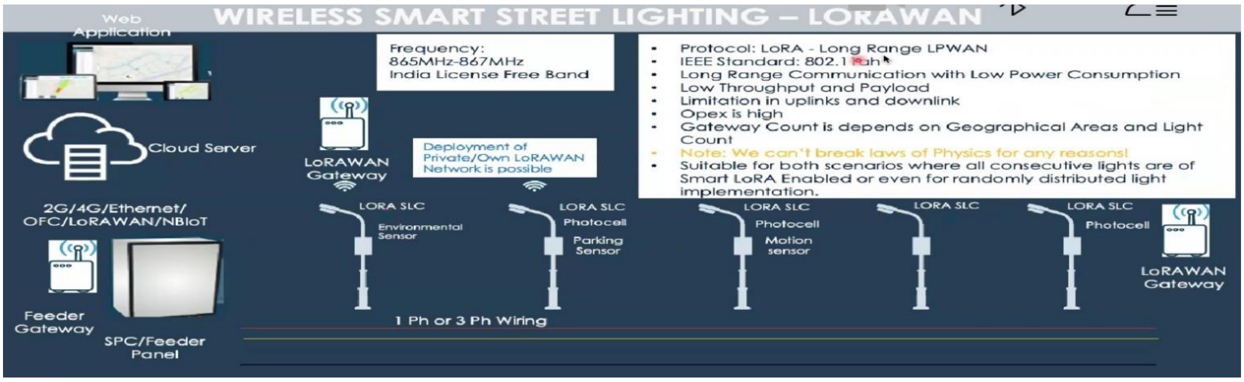

Fig.16 LORAWAN

d) *GSM/NBIOT* is shown in Fig.17

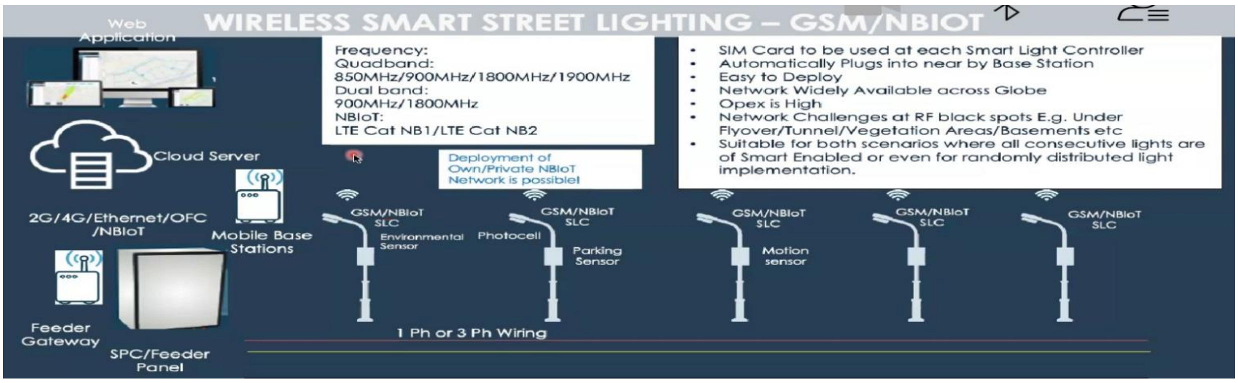

Fig.17 GSM/NBIOT

e) *PLCC* is shown in Fig.18

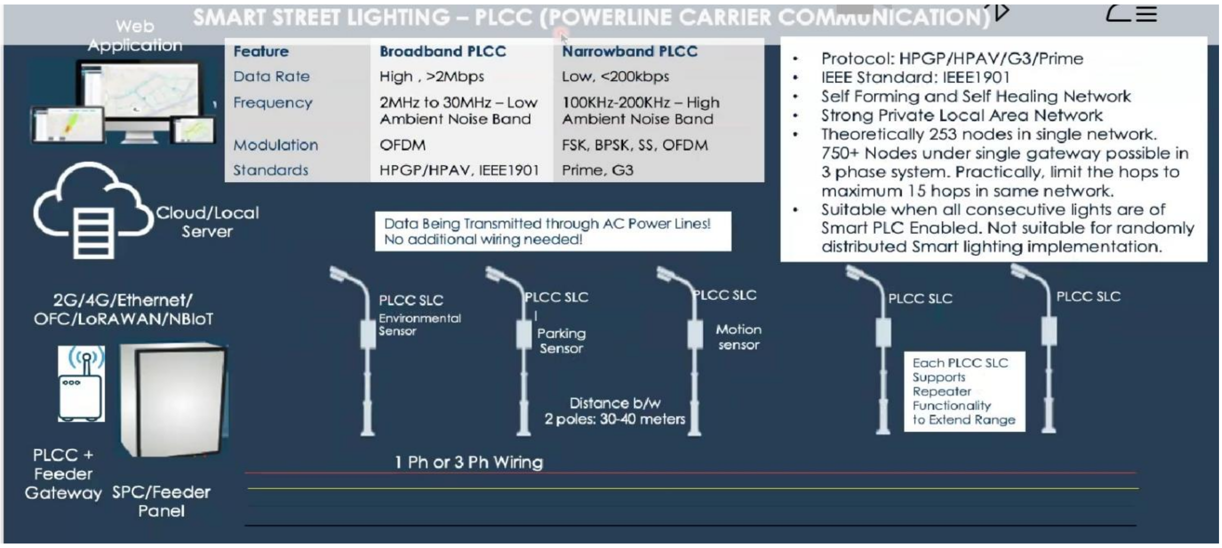

Fig.18 PLCC

6.9.4.2 *Comparison of Different Protocol and Architecture as Shown in Table 6.*

Table 6 Technology Comparison – Outdoor

(*Clause* **6.9.4.2**)

Sl. No	**Feature**	**R F**	**GSM/2G NIOT**	**PLCC**	**LORAWAN**
(1)	(2)	(3)	(4)	(5)	(6)
i)	Network topology	2.4 GHz/865 MHz Mesh Topology	Quadband GSM/4G band	Wired MHz Band	865MHz(India) Point to point Communication
ii)	Street Light Gateway	Required	Not Required	Required	Not Required
iii)	Communication between SLC and SLG	RF mesh	Not Applicable Communication Through Mobile Base statins	Through Existing Powerline No additional lines required	Not Applicablel Communication through LORAWAN Gateway
iv)	Communication between Server and SLG	Through SLG	Communication Through Mobile Base Statins	Through SLG	Communication throught LORAWAN Gateways

v)	Control Latency	Medium 10sec to 3 minutes Depending on network Bandwidth between SLG and Server	Low 5 sec to 3 minutes* Depending on 2G/3G network connectivity at that point of time	Medium 10 Sec to 3 minutes Depending on networks Bandwidth between SLG and Server	High 1 minute to 20 minutes Depending on LORAWANS Base station/Gateway bandwidth
vi)	Periodic Data Collection	8 minutes to 15 minutes per light nod Assuming 50 light per gateway	As Low as 1 minute Depending on configuration	8 minutes to 15 minutes per light node Assuming 50 light per gateway	Theorefically. As low as 1 minutes,practically,it depends on number of uploads per day
vii)	Ease of deployment	East/Medium	Very Easy High	Easy/Medium	Easy
viii)	Opex	Low	High	Low	High

6.9.4.3 *Smart Pole* — Smart pole is now most talked subject and going to be future trend in street lighting applications. The schematic illustrates the all possible integration, function with street lighting pole as shown in Fig. 19.

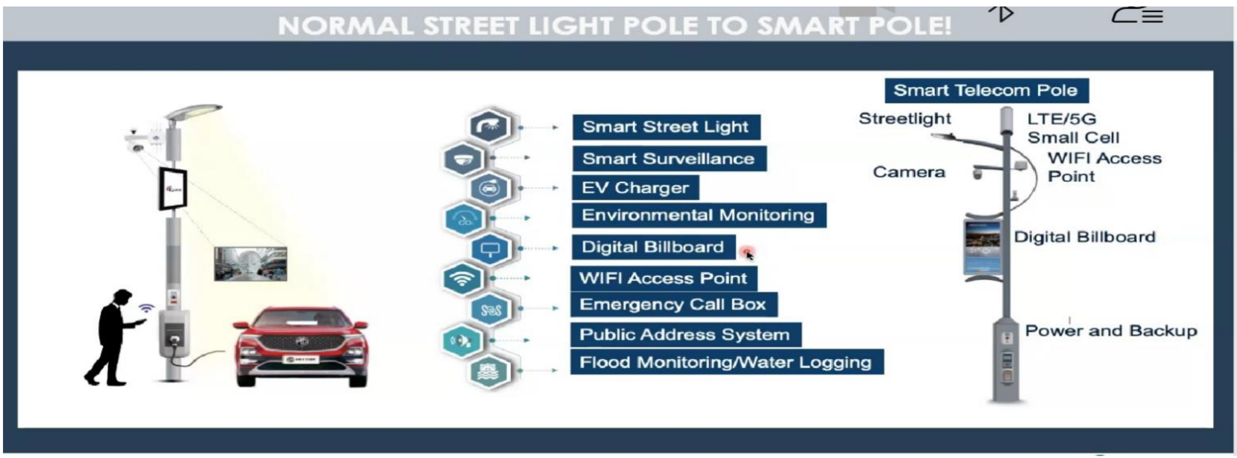

Fig.19 Smart Pole

6.9.4.4 *Gate Way -the Data Concentrator Unit (DCU)* — Gate way/ Data concentrator is playing the role of facilitator for communication to server.

6.9.4.5 *Data Concentrator Unit*— Overview:

a) The Data Connector Unit (DCU) is a wireless IoT gateway. Its communication with the wireless nodes over Low Power radio frequency (LPRF) and has a support of backhaul communication network of GPRS OR Ethernet with cloud. The communication is two ways.

b) DCU provide advance monitoring and control from the cloud of the wireless nodes in smart metering, smart street lighting, commercial lighting, industries automation, solar monitoring, windmill farm monitoring etc.

6.5 Command and Control Centre

Generalized Methodology /Scope/ Specification / Working Principle

The implemented system will comprise of various applications and field level equipments which will provide data and information to the Centralized Command and control Centre (CCC). The CCC will process these inputs and provide the integrated view to the various decision makers like emergency response team for actionable intelligence. The below diagram shows the interaction of various entities with the various functions of the CCC as shown in Fig. 20.

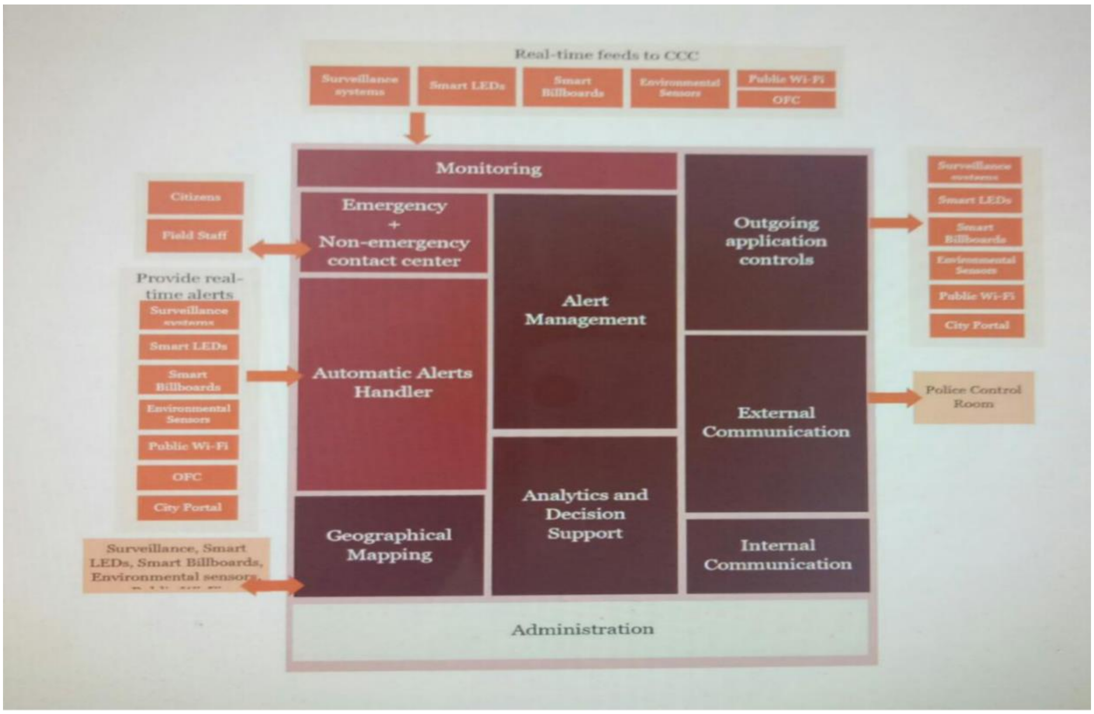

Fig.20 Command and Control Centre

In the CCM system is a combination of many electrical, electronics and IT based components. In general main components can be - control Room Video-wall Solution that includes screen, controller software and Video wall operation , Contact Center/Helpdesk , Data Center infrastructure, Data Center infrastructure, Aggregation Level Routers, Central (Core) Router ,Firewall & its separate unit or as a module in firewall ,Workstation with Joystick Controller, Application / Database/ Recording / Viewing / Other Servers, the Enterprise Management System, Network Management System , Network Performance management , Server Performance Monitoring System , Centralised Helpdesk System, Enterprise Management System etc.

The basic guide line of specification is project based and best practice followed by the industry for higher performance. Special point to be informed that Enterprise Management System (EMS) is an important requirement of this Project with various key components

a) SLA and Contract management System
b) Network Monitoring System
c) Server Monitoring System
d) Helpdesk System

EMS Solution shall be based on industry standard best practice framework such as ITIL

6.6 Central Management Software

A brief requirement CMS is summarized as follows.

a) Based on an open web application server the user interface should be 100% Web-based and accessible from any computer on the network through various types of web browsers.
b) Available to be installed on the city's server as well as available, as an option, on a web-hosted server. User interface should be available for phones, tablets or devices with any screen size.
c) Developed with open and standardized languages including Java, XML configuration files and SQL database. It should enable the development of additional features without the need to acquire any development software license.
d) Record all the data in a centralized SQL database and should be compatible with MYSQL or PostgreSQL to avoid being obliged to purchase additional software license for database engine.
e) Administrators to create, modify, delete users, passwords, groups and access controls. It should provide modern and efficient security features.
f) Able to provide interconnectivity and interoperability between solutions from different hardware manufacturers to guarantee independence between central management software layer and field hardware layer. It should support configuration, programming, control and monitoring of many different types/models of Individual Lamp Controllers from many competing suppliers..
g) Support multiple languages and dictionaries shall be exportable and modifiable by the administrator of the system.

h) Create any object and enable users to group objects per geographical zone, to move and delete objects on the maps.
i) Enable the end-user to select the map source of his/her choice: Microsoft Bing, Google, Nokia map, ESRI, etc…
j) Support independent lamps, CCMSs, Gateway, Energy Meters and other types of objects to provide evolution to smart city applications.
k) The central management software should provide streetlight-specific features such as:

    i) Programming and commissioning schedulers
    ii) Real time control and monitoring of individual lamp Controllers
    iii) Real time control and monitoring of CCMS if opted for.
    iv) Big data and automatic data collect.

6.6.1 Data analytics includes maintenance reporting, lamp failure analysis, energy consumption reporting, energy saving calculation, complex alarm triggering and notification, lamp lifetime analysis and data history analysis provided HTTP REST XML web service to interface with third party software.

Device shall offer the following operational features.

a) Web Base Software replaces visual inspections of individual streetlighting with sitting at PC with Internet connectivity. Also by fault alarm and monitoring of data user can judge the fault status and severity of fault
b) Remote switching through Web Base Software to override local controller
c) User can demand any time live status of feeder pillar for current electrical and real time parameters
d) Emergency Stop / Manual ON / Manual OFF / Test Mode of feeder pillar
e) User can monitoring and change all settable parameter setting and clock time setting
f) Control at any level of individually Street lights. Generate electrical profile of any individual feeder pillar
g) Unit can be Direct mapping on Google Map

The software shall receive the self-generated data message from individual Feeder Pillar like, ON time, OFF time, Dim time, Power Down time, Auto mode / Manual Mode, Volt Fault, Over Current Fault, Short Circuit Fault, Neutral Fault, RTC Fault, ADC Fault, Memory Fault, Low Ampere Fault, Door Open, Relay Fault, Calibration Data and acknowledgement of massage demand by WEB of Parameter writing, E Stop, Test Mode, E Profile, All this massage contain all electrical parameter with real-time clock date and time.

The software generates report of any date or any date range for fault and message of individual unit or all the units. The software also generates range report for fault, Message, Voltage graph, Current Graph, Streetlight On time, VA Consumption, etc

All the data collected by the software can be export to worksheet format for further analysis as per requirement. User can generate graph and report as per requirements

System is easily expanded and maintained. New configurations can be made remotely. Web Interface gives instant status of the street lights on the dynamic Google map

6.7 Environmental Sensors

To improve the quality of life of city residents there is a need to capture the pollution level in the city. In order to capture the environment data, environment sensor will be installed. It will sense the level of air pollution, temperature and humidity. The data will be send to the command and control centre for further actions.

6.8 Cyber Security

This being a very composite system of internet, communication, digital, embedded electronics with data management system for the city road lighting plus allied other environmental scanning gadget including WIFI facility. This leads to increase the risk of cybercrime. Therefore, cyber security assurance program is very important.

Two standards IEC 62443 which deals with security process focused and UL 2900 which is product testing focused.

6.9 Test Protocols and Standards

IoT based street lighting is a very composite system having many components and technologies built into it .Therefore many test or test protocols are involved in the process of project selection, tendering and implementations. The test process can be divided into areas like safety, performance/functional of the equipment/component as per product specification or tender specification, software testing or validation, operational/functional testing/validation as per tender specification. Finally cyber security testing as a whole of the system. Many testings are involved and therefore a ready reference and guide line given below with respect to mainly lighting.

Below Table 7 describes test protocols and standards

Table 7 Test Protocols and Standards

(*Clause* **6.9**)

SI. No	**Description**	**Test Standard /Test Protocol**	**Operational test**	**Test protocol /Process**
(1)	(2)	(3)	(4)	(5)

i)	Luminaire -safety	IS 10322	Remote Switch off & on, Wide voltage operation test	Verification test at lab
ii)	Driver Safety , Driver Ballast Efficiency	IS 15885	Astronomical test	Verification at
iii)	Controller safety includes all like thermal aging test, over voltage , under voltage, operating tem,environmental test etc	UL 8750	Energy data test at different dimming mode, Individual communication mode with plug and y installation	Verification at lab
iv)	EMI/EMC	IEC61001 , IS15111	Luminaire code identification ,Real time monitoring	Verification at lab
v)	Surge	IEC61000	Lighting Uniformity	LM 79 ITable data
vi)	PF, THD	IS15111	Strong pass word, 2 factor authentication of pass word, Monthly update of pass word	Verification test
vii)	Communication safety	RTTE directive, RED Radi equipment directive	Software of the controller have HTTPS access ovet the internet	Verification at lab
viii)	Light distribution, CRI,CCT, efficiency of the system	LM79	Sytem fault detection, antitheft alarm,	Verification lab
ix)	NEMA socket	UL 773	Cibersecurity	UL2900 ,IEC 62443
x)	DALI 1 & DALI2 driver/controller	ProbitLab & ProbitBench	Open source issue or bug / Defect tracing tool	Bugzilla tool