IoT Smart Radio Control of SMIT Street Lights

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Abstract: **World is entering into a new era of Internet technology , the Internet of Things (IoT). Machine to machine, machine to infrastructure, machine to environment, everything will be in a connected world through and its potential is huge. Lots of challenges are involved in this new era of connected world. It has been proposed that the IoT is considered as billions of smart, connected "things" that will encompass every aspect of human lives, and its foundation is the intelligence that embedded processing provides. The IoT is engaged with smart machines interacting and communicating with other machines, objects, devices environments and infrastructures. As an outcome a huge volumes of data are being generated, and being processed into useful actions that can "command and control" action, to make things more easier and safer. Keeping this view in mind, in this paper, the authors have tried to control street lights using Narrow band IoT signal. Each device is communicating using FM band carrier throughout a society or in a city. In this case study, it has been experimented using 107 MHz over SMIT campus and they are able to control the Smart Lamps.**

Index Terms : **IoT, FM, NB-IoT, MXG, DSO, 4G, 5G**

I. INTRODUCTION

Recently, Govt. of India has taken initiatives towards make-in-india programme which majorly has the vision of building 'Digital India'. The objective is to establish more than 100 Smart Cities throughout India. With the Proliferation of 5G-IoT in every sector of our Society, Smarter world is looking for realization of Smart Homes, Smart Cities, Smart Wearable, Smart Agriculture, Smart Energy, Smart vehicle, Smart Health, Smart Industries. Some definitional boundaries are required to guide cities in the Mission. In the imagination of any city dweller in India, the picture of a smart city contains a wish list of technical infrastructure and services that describes his or her level of aspiration. To provide for the aspirations and needs of the citizens, urban planners ideally aim at developing the entire city to be smart. This necessitates the four pillars of comprehensive development- (i) Institutional, (ii) Physical, (iii) Social and (iv) Economic infrastructure.

The total number of 100 smart cities have been distributed among the States and Union Territories of India on the basis of an equitable criteria. [1]

II. MOTIVATION

With the challenges taken by Govt. of India, for building Smart Cities, one of the major issues is to save the wastage of electrical power by means of precise control over the power distribution grids and consumer usages of electricity. The NAAC, Govt of India has strictly initiated the scheme of introducing LED lamps throughout the Institutional campus area. The lighting of the campus should be done by LEDs only. As per the directives of NAAC, a quantitative report is also being generated at SMIT regarding this issue. [2]

Issue-1: Within the SMIT campus, the space is sufficiently available for installing solar cell panels to welcome the renewable energy. As per the availability of space, some quantity of solar cell panels has been already installed at the rooftop of SMIT. The generation of electricity by these solar cells would be useful but, again, the distribution of this electrical power towards the load over the campus is totally uncontrolled and not optimized. [3] So, the requirement is how to control the utilization of the solar energy towards load could be auto controlled or electronically optimized? As the generation of renewable energy is concerned, it is good but, the optimized control of the power needs to be sufficed with intelligent method so that the wastage of solar power /electricity could be reduced. This leads to NB-IoT control scheme from a centralized base station using wireless technology.

Issue-2 : Looking into the present trends of development, Sikkim Manipal Institute of Technology (SMIT), Sikkim Manipal University already has thought for replacing the high wattage Sodium vapor street lamps by LED lamps throughout the SMIT campus area. The objective is to bring down the electricity bill by optimized use of electrical power. The SMIT campus has been equipped with the LED street lamps. Those LED lamps are better in power saving in comparison to Sodium vapor lamps, but, the LED lamps are not the optimal solution for saving of electricity. So, this project has taken the initiative to make these LED lamps smart enough so that it can be controlled over the air (by means of wireless communication) from a centralized base station. The lamps should be upgraded to some wireless interface maintaining the 3GPP standard for Narrow Band Internet of Things (NB-IoT) of Release 13.

The Department of Electronics And Communication Engineering, SMIT are engaged in upgrading those LED lamps into smart lamps. The major scope of work is mapped with the involvement of 4G based Wireless Narrow Band Internet of Things (NB-IoT) to precisely monitoring and controlling of the lamps even finding the location wise faults/trouble shooting options of those lamps from a centralized base station.

The system will be evolved in this manner for the optimization of electrical energy at SMIT campus.

Difference between LED Lamps and Sodium Vapor Lamps

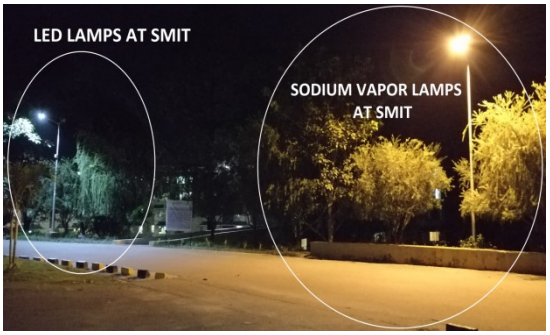

Fig. 1. LED Lamps are installed at SMIT Campus, but those lamps are to upgraded to NB-IoT based Smart Lamps

III. NARROW BAND IOT (NB-IOT) AT SMIT

The Fig.-4 & 5 represent a conglomeration of infrastructure which is truly fit for a Narrow Band IoT system. Coincidently, the Department of Electronics & Communication Engineering, SMIT is running a Project '5G_IoT' since November, 2016. With the funding authority and Institutional support, the project is running successfully in the ECE Department, SMIT.

As there are interesting results and observations achieved till so far in this project, the motivation goes to inherit those results/outcomes into the Advanced Communication Laboratory (AC LAB) of B.Tech experiments. So, students of AC Lab are motivated to do the experiemnts with the same objective as it is highly focussed to achieve the goal of a smart city and smart world.

As a result, the students are further motivated to join this newly proposed area of research viz. "NB-IoT Based Control Over A Smart Campus". [4]

IV. LITERATURE SURVEY

Table 1. Reviewed Papers for NB-IOT related works

Sl. No.	Title Of The Paper	Summary of the work
1.	"Smart Home System based on IOT Technologies", Yin Jie, Ji Yong Pei, Li Jun, Guo Yun, Xu Wei Department of High Technology Shenzhen Academy of Inspection and Quarantine Shenzhen, China, 2013 International Conference on Computational and Information Sciences [3]	This paper proposes architecture to enable the users to control and monitor smart devices through internet. It creates an interface between users and smart home by using GSM and internet technologies, or it simply creates GSM based wireless communication from the web server into the smart home. In this architecture the users give commands through web then the users inputs are converted into GSM-SMS commands. These commands are sent to embedded system module (embedded system directly connect with devices) through GSM network, and finally the user commands are parsed and executed by microcontroller to control any electronic objects like home appliances, lights, etc and it sends the acknowledgement. The embedded system module can place anywhere in the world and it will controlled by IoT Agent through GSM network.
2.	A simple IoT project with the ESP8266 Wi-Fi module, electronut.in/an-iot- project-with-esp8266 [4]	In this paper, a system will be designed which will automatically control and monitor the industrial applications and also allow the user to control the application from anywhere in the world. Having control over the applications over the internet is one of the best ways to deal with the industrial applications.

V. PROBLEM DEFINITION

(1) The renewable energy source has also been considered at SMIT campus on the rooftop with the use of arrays of solar cells. But, again, the solar cells will be able to produce electricity and its distribution over the campus is uncontrolled. As the generation of renewable energy is concerned, it is good but, the optimized control of the power needs to be sufficed with intelligent method. This leads to NB-IoT control scheme from a centralized base station using wireless technology.

(2) As the no. of lamps will be needed more for a campus, it is recommended to control the lamps through an NB-IoT signal having 180 KHz bandwidth and RF carrier of 107 MHz. 3GPP has standardized the signal for IoT control to be the LTE-A In-Band, Guard-Band & Standalone mode. Agent through GSM network will not be feasible at all, as no. of machines or lamps when increased to a large value, the IoT network will fail due to insufficiency of bandwidth in GSM technology.

VI. PROPOSED SOLUTIONS

At the ECE Laboratory, already the following hardware and software are available for the development of an NB-IoT control system.

A. Set Up using 2.1 GHz RF:

Hardware Resources :

(1) Agilent Mixed Signal Generator (0.01 KHz to 3 GHz)

(2) Agilent InfiniiVision DSO (350 MHz)

Software Resources :

(3) Keysight VSA Software

(4) Keysight SystemVue Software

B. Proposed Development Plan For The Hardware

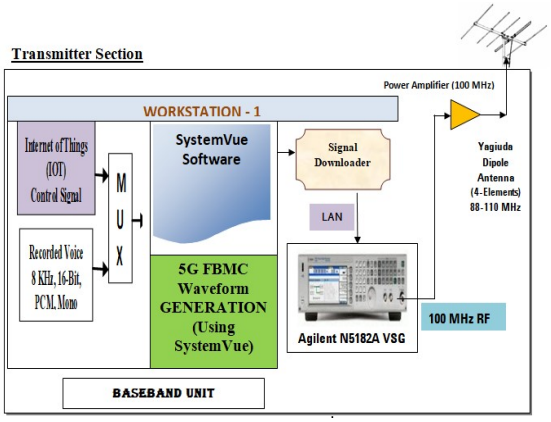

Fig. 2. Transmitter System to be placed at site-1 with NB-IoT control activities

The signal of interest (viz. NB-IoT Control Signal from SMIT server) are needed to be communicated from the office site to the remote smart home site. An NB-IoT SystemVue Application Programming Interface has been used to generate a single baseband signal which is undergone by a MODEM, The design/model is shown in the following figure. This signal formed in this manner, is passed through 'N' no. of paths within the SystemVue model- Path-1 is direct with no delay, Path-2 is passed through a Delay-2, Path-3 is passed through a Delay-3 and so on. After passing through N no. of Delay blocks, the individual path is getting added up within the SystemVue.

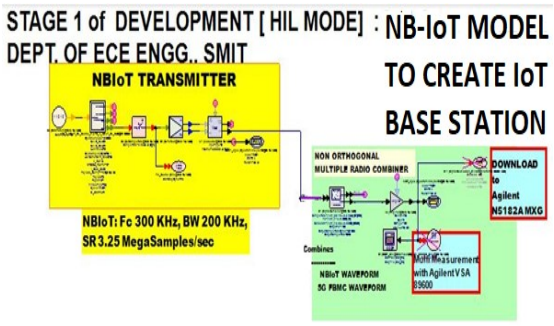

Fig. 3. Narrow Band IoT source model

Finally, this summed up signal is downloaded to a Agilent N5182A VSG hardware for the hardware realization. The base station realization of narrowband IoT signal is done by the available hardware resources at the rooftop laboratory (5G_IoT Lab) of ECE Department, SMIT. The following figure shows the base station of NB-IoT signal transmitted over the air with a carrier frequency of 107 MHz.

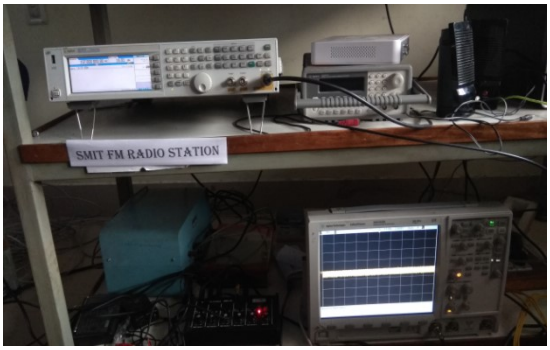

Fig. 4. 107 MHz NB-IoT Base station designed at 5G_IoT Lab, ECE Department, SMIT

This 107 MHz RF signal coming out of the VSG, is amplified by a Power amplifier and finally radiated through 107 MHz band Yagiuda Dipole Antenna. The NB-IoT part of the system uses a control bit pattern (or a code of 1 MHz bit rate) which is transmitted by the above system over 107 MHz RF carrier. After retrieval of this code pattern at the receiver side, it is used to control a relay or an electrical switch interfaced finally with the control port of the Smart Street LED Lamp.

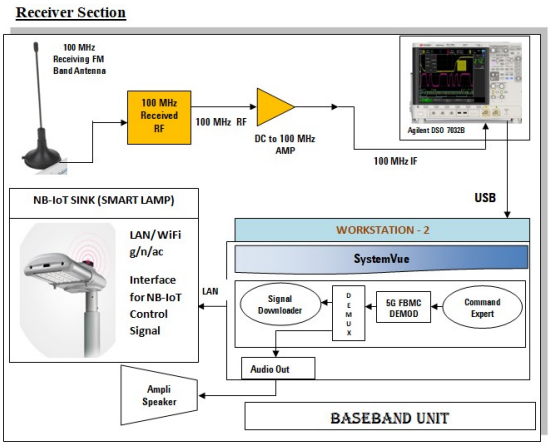

Fig. 5. Receiver System situated on a trolley at the ECE Department Rooftop Laboratory. The Smart Lamp is fitted onto the roof of the Laboratory.

The smart lamp is to be tested by LAN interface or over the air WiFi g/n/ac link between the Workstation-2 and the WiFi module embedded within the lamp. The above set-up for Transmitter and receiver have been configured for a field trial over the rooftop of ECE Departmental Library. In the rooftop space of the SMIT building, there are no lamps and it remains dark at night. Instead of fitting high wattage sodium vapor lamp, if the smart lamp (with LAN / or WiFi g/n/ac interface) is installed at the roof of the laboratory and other lamp at the top of

the staircase room, then its smart control performance can be tested with the help of the NB-IoT receiver which is designed in the above Fig.- 2. The complete receiver system can be placed onto a movable trolley. The trolley can be moved at the position of the Smart lamp post and then connect the LAN port to the LAN interface of the lamp. Then the controlling signal can be retrieved at the NB-IoT receiver designed in SystemVue platform within the Workstation and the retrieved signal can be sent through the LAN or WiFi to the Smart lamp for its intensity control or Switching ON-OFF control and other performance testing of the lamp.

The receiver for NB_IoT is designed in SystemVue which demodulates and thereby decodes the NB-IoT spectrum and retrieves the control code pattern and this pattern is sent to the smart lamp through the LAN or WiFi g/n/ac module fitted with the Workstation-2 By this control code pattern, the lamp can be controlled optimally in terms of its power utilization and saving. The NB-IoT spectrum formulation is as per the Release 13 of 3GPP where it uses 4G In-Band LTE signal property. [5]

Receiver details:

(1) Keysight DSO InfiniiVision 7032B- acts as the high speed digitizer with 2 Gsps

(2) Keysight VSA 89600B software- for analyzing the received NB-IoT waveform/spectrum [Presently tested with FM receiver of a Samsung Smart phone]

(3) Standard UPS- To power the receiver hardwares

(4) FM band antenna- To receive the NB-IoT signal

(5) Philips 25W Greenline Smart LED Street Light/ Smart lamp [Presently tested with an LED fitted with the earphone output of the Samsung smart phone]

A Diode bridge rectifier circuit is used in between the earphone output and the LED on a bread board.

Low cost solution: To reduce the cost of the receiver, a low cost mobile handset can be employed to receive the 100 MHz NB-IoT spectrum by enabling the FM Radio Apps within the mobile. The decoded signal coming out of the Aux 3.5 output of the mobile can be passed through a bridge rectifier to convert it into a DC and then charging a capacitor (reasonably moderate value) to glow an LED. If the particular control signal pattern is not sent through NB-IoT band from the transmitter, the LED will not be glowing or remaining OFF. As soon as the control signal pattern is sent through the NB-IoT transmitter, the LED will start glowing. The above circuit can be interfaced also with the smart lamp to control its switching operation. So, a low cost mobile handset (with FM receiver) is to be fitted with the Smart Lamp for its controlling operation.

Results

The following is the transmitting and receiving antenna of 107 MHz band fitted onto the roof of 5G_IoT Lab. The OTA range is taken as to be 20 meter for preliminary testing. The objective is to decode the NB-IoT signal at the commercially available smart phone handset which is less cost. The FM receiver of the mobile handset has been used to demodulate the NB-IoT signal carried over 107 MHz. The decoded signal is emitted as a varying DC signal out of the earphone port. This signal is fed to the input of a bridge rectifier circuit. The rectified voltage is fed to the input of an LED. The ON-OFF mode of the LED lamp has been successfully controlled by switching the modulation option ON-OFF at the NB-IoT base station. So, the wireless narrowband IoT control operation is achieved for energy saving of an LED. Further, the base station signal has been fed to one of the input ports of an audio mixer having gain control against each port. In the above experiment, the modulated NB-IoT signal is dumped into the dynamic memory of the Keysight Mixed Signal Generator (MXG) and it's modulated output is fed to the 4th channel of the audio mixer. Finally, the output of the audio mixer is connected to the 107 MHz Yagi-uda antenna for transmission over the air (shown in Fig-6). Under this architecture, the variation in gain of the 4th channel of the audio mixer (situated at NB-IoT base station), the retrieved DC voltage (at the receiver) is varied and accordingly, the intensity of the LED has been successfully controlled over the air. The result is displayed in following Fig.-7.

Fig. 6. Transmitting and Receiving antennas fitted onto the rooftop of the 5G_IoT Lab having the OTA range of 20 meter.

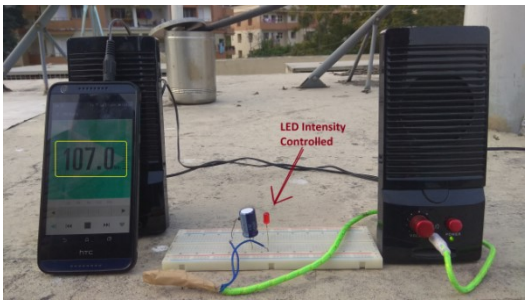

Fig. 7. LED Intensity is controlled in over the air mode by using NB-IoT control signal

The above experiment has successfully been executed to prove the control operation of LED using wireless NB-IoT. [6] By employing this method, the LED can be

replaced by a street lamp. So, smart LED is achieved using NB-IoT technology. This proof of concept can be extended towards smart control of street lamp and other IoT end nodes.

VII. CONCLUSION

The experimental set up used in the above case study done at ECE Department, SMIT, can be a reference for further developing an wide range of Internet of Things devices. The successful implementation of NB-IoT base station and the control over the air having a range of 20 meter can support many other end nodes like smart lamps, surveillance cameras etc. within a campus. So, SMIT is going to adopt this technology for solar power utilization control for smart lamps throughout the campus. The future scope of this work is to design the embedded smart part of the IoT end node devices in a cost effective manner. [7] This will in turn lead ECE Department, SMIT to be a solution provider to the external industries in the same domain. Further, the ECE Department can be the best suitable candidate for providing consultancy in this regards in the North-Eastern part of India.

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