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Wireless Communication Technologies for Smart Metering-Opportunities and Challenges

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ABSTRACT:A smart meter is an electronic device which intends to compute energy, store and transmit the data to the central server.The central idea behind the smart metering initiative stems from the logic that the use of analytics on the energy consumption data of the consumer will result in insights, enabling utilities to engineer better solutions for providing more reliable and efficient power supply at a lower cost. In the era of a smart grid, where devices are interconnected in anetwork and enabled with the two-way communication. In order to ensure safe, secure and efficient operation of a Smart grid, deploying a suitable communication technology has become the need of the hour. Wireless communication options includes but not limited to such as RF, cellular communication, Wi-Fi, Zigbee, NB-IoT, Wi-SUN etc. This paper aims to investigate wireless communication technologies like RF, GPRS and NB-IoT in terms of – Concepts,Features, Opportunities and Challenges. The paper also discuss about the communication conundrum in a smart metering given the contingencies involved in a few of the technologies.

KEYWORDS: Smart Metering, RF, 6LoWPAN, NB-IoT, GPRS, Smart Grid.

I.INTRODUCTION

Smart metering is an important part of the vision of smart cities around the globe. Major components of smart metering project consists of the smart meter itself, along with communication network infrastructure, data collection system and data management system.India is expected to continue growing 6-7 % annually. A consistently growing economy with evolving demographics will certainly steer the society towards rapid urbanization, increasing the energy consumption of the country. By 2019, It is expected to have 180 million connected devices in India which is around 13.5% of the world's total population of interconnected devices. In the context of a smart metering, As per the Power Ministry's initiative to roll out Advanced Metering Infrastructure (AMI) in India, smart meters are to be installed in phases, with those consuming 500 kWh (kilowatt-hour or unit) or more to be provided with smart meters by the end of 2017, those consuming over 200 units by December 2019, and all consumers getting smart meters by 2027. Consequently, number of devices will further rise in the network will rise sharply as smart meters are expected to send real-timedata,power outage notification and power quality information to the Head End System (HES) .

A robust communication infrastructure is must for meeting the primary objectives of smart metering and thus realize the vision of smart cities in India.Communication network is central to the smart metering concept. The idea is to reliably collect relevant metering data from all the meters deployed by the power distribution companies / utilities which can later be processed using big-data analytics to realize a more efficient power distribution and power maintenance in future smart cities of the country.The success of smart metering in India fundamentally rests on the strength and reliability of underlying communication technology.The choice of underlying communication technology is dependent on many variable such as –Specific advantages offered, Ease of Deployment, Upfront up-gradation costs, Long-term maintenance costs, Coverage area.The inherently multivariate nature of choosing a communication network complicates the process of selecting a particular technology for the smart metering.

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II.COMMUNICATION TECHNOLOGIES

1] RF

As per wiki,Radio frequency (RF) refers to alternating (AC) electric current or radio waves, oscillating in the frequency range used in radio. RF itself has become synonymous with wireless and high-frequency signals, describing anything from AM radio between 535 kHz and 1605 kHz to computer local area networks (LANs) at 2.4 GHz. However, RF has traditionally defined frequencies from a few kHz to roughly 1 GHz. If one considers microwave frequencies as RF, this range extends to 300 GHz. Table 1 shows the different frequency range and its description.

A smart meter must reliably send data back to the server, and information technology (IT) systems should be able to pull these data out and process them. Incorporating RF in smart meters is a very efficient outcome not only in terms of productivity but also in reliability. Radio frequency mesh (RF mesh) technology, uses radio waves to communicate among groups of meters that send the data to a data concentrator unit (DCU) for further transmission to the server. Depending upon the frequency and the type of mesh network, there are a number different RF mesh technologies. Examples of such RF technologies are shown in table 1.

Name of Technology	**Operated Frequency**
Zigbee	2.4GHz, 900MHz
6LoWPAN	Sub-1 GHz
LoRaWAN	902.3MHz-914.3MHz
DASH7	315MHz, 915MHz
Z-Wave	908.42MHz
MyriaNed	2.4GHz, 868 MHz

Table**1**: Different types of RF technologies.

1.1] Why 6LoWPAN:

With the growing number of embedded smart devices, it is essential to have addresses that are non-exhausting. With the current addressing scheme of IPv4 the number of addresses, thus the number of devices that can be connected are limited to 4,294,967,296, or about 4 billion. The solution was for IPv6 to accommodate the increased demand by providing a much larger address space, along with improved traffic routing and better security. 6LoWPAN makes use of this IPv6 addressing and thereby overcomes other RF technologies by having better security, expanded addressing, interoperability and better optimization.6LoWPAN is a networking technology or adaptation layer that allows IPv6 packets to be carried efficiently within small link layer frames, such as those defined by IEEE 802.15.4. While this seems a straightforward approach to the development of a packet data wireless network or wireless sensor network, there are incompatibilities between IPv6 format and the formats allowed by IEEE 802.15.4. This differences are overcome within 6LoWPAN and this allows the system to be used as a layer over the basic IEEE 802.15.4.

1.2] 6LoWPAN for Smart Electricity Metering:

The use of resources in large facilities can be reduced and better controlled through more intelligent metering of electricity, gas and water using an automatic metering infrastructure (AMI). AMI requires communication modules present inside individual meters to communicate with a central server which can be used by the end user to download the required data. Figure 1 shows the mesh network of individual meters attributed as nodes.

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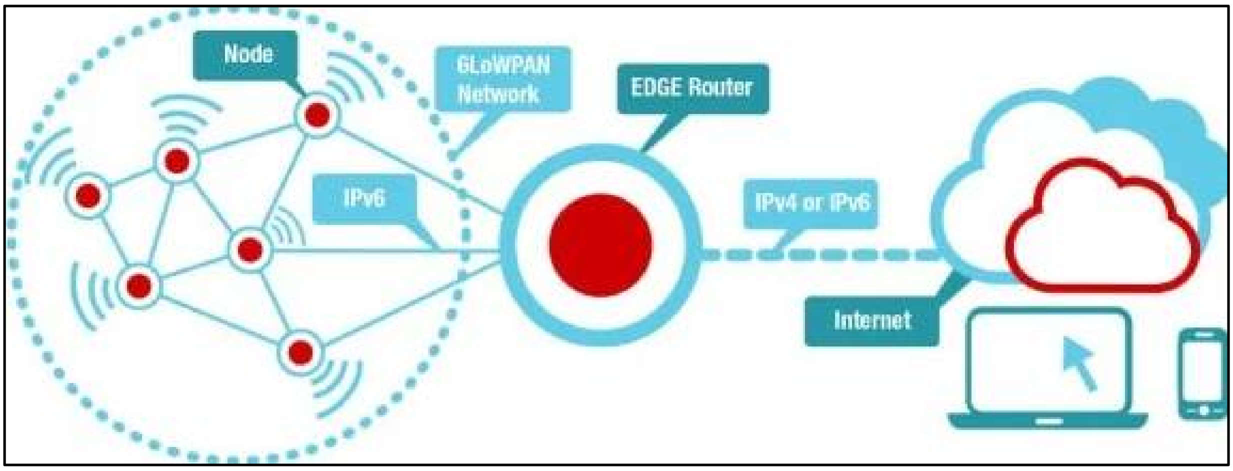

Figure 1. 6LoWPAN Mesh Network.

It is not required for each individual meter to be connected to the Edge router. Individual meters are connected to each other while one of them is connected to the edge router. The meter which is connected to the edge router is known as the ROOT while other meters are called as coordinators. In order to optimize the packet data i.e. to increase the payload per packet, coordinators communicate with roots using PAN ID set by the root of a particular network. Whereas the communication with edge router is possible with the root node only. The primary purpose of inculcating 6LoWPAN technology is to read the contents of the meter from a remote location. Secondary purposes include implementation of smart grid by having load switch inside the meter which can be used to cut off the supply as and when required. These purposes are fulfilled because of continuous connectivity of meters in the presence of power. Thus the main rationales for facility management are improvements in energy and resource efficiency, an increase in worker productivity, and more secure and comfortable buildings. For the enterprise users of buildings, an even more important benefit is improved worker efficiency along with better comfort and security in general. Substantial cost savings may be possible through the productivity improvements.In order to send packet data, IPv6 over 6LowPAN, it is necessary to have a method of converting the packet data into a format that can be handled by the IEEE 802.15.4 lower layer system. IPv6 requires the maximum transmission unit (MTU) to be at least 1280 bytes in length. This is considerably longer than the IEEE802.15.4's standard packet size of 127 octets which was set to keep transmissions short and thereby reduce power consumption. To overcome the address resolution issue, IPv6 nodes are given 128 bit addresses in a hierarchical manner. The IEEE 802.15.4 devices may use either of IEEE 64 bit extended addresses or 16 bit addresses that are unique within a PAN after devices have associated.

2.GPRS

GPRS or General Packet Radio Service is the packet-oriented mobile data service. It is also known as “2.5G" technology between the second (2G) and third (3G) generation of GSM. Unlike the older Circuit Switched Data Services (or CSD), GPRS uses packet switching. GPRS uses 4 coding schemes CS1 to CS4, which is selected according to the signal/noise ratio to guarantee the best and most effective data transmission. These schemes give 8 to 20 kb/s data rate per timeslot (TS). A commonly used class 10 (4 Downlink TS + 2 Uplink TS) offers on highest CS4 coding scheme 80 kb/s data rate. But GPRS is a best-effort service, implying variable throughput and latency that depend on the number of other users sharing the service currently, as opposed to circuit switching, where a certain quality of service (QoS) is guaranteed during the connection.GPRS support following protocols:

1: Internet protocol (IP)

2: Point-to-point protocol (PPP).

Even though 2G networks are typically more than adequate for basic metering communications, 3G and 4G systems do provide flexibility to support future services. Available data services over 3G networks include Wideband CDMA (W-CDMA), High-Speed Downlink Packet Access (HSDPA), and Evolution-Data Optimized (EVDO) Revision A. Newer HSDPA technologies are now comparable to W-CDMA in cost, and have become the preferred solution.

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2.1GPRS in smart metering:

In a smart metering GPRS is mainly used to connect data concentrators to servers. Concentrators used TCP/IP protocol to exchange data, collected from managed meters, with server. But same manufactures also offer meters directly with GPRS support, where sensors network is realized through GSM network. In this scenario all the meters in the field will be installed with a SIM card and will always be directly connected to the server with the TCP/IP protocol. As the number of devices will always needs to be connected to the network it can lead to the issues like congestion. Communication taking place via GPRS would be secure as cryptography applied on the wireless link between the mobile device and base station. Also TCP/IP is connection oriented protocol it further improves the reliability of data packet. One of the major concern is the power consumption as the maximum output power during transmission is 33dBm.This becomes arduous in the case of power outage notification as battery or super-capacitors has to provide the backup for communication.

3. NB-IoT

Narrowband IoT (NB-IoT) is a new low power wide area (LPWA) technology specifically developed for the Internet of Things (IoT), for devices that require small amounts of data, over long periods and indoor coverage.

Low-power, wide-area wireless technology (LPWA) is the response to the need for ubiquitous, battery-efficient, professionally managed, and out-of-the-box connectivity.The term LPWA was coined in 2013 for a Class of wireless technology used for machine-to-machine (M2M) or IoT communications its technology was absorbed by the Third Generation Partnership Project (3GPP) standards body. Ubiquitous wireless connectivity means a business can track its assets as they travel across countries and borders without having to worry about any of the connectivity issues going on in the background; the public network is simply professionally managed by the wireless provider. Low-power connectivity means that the company's trackers don't need to have the batteries changed or charged every few days or weeks. This is what low-power, wide-area (LPWA) wireless connectivity gives to organization tapping into the IoT for business value.LPWA devices use very little power, cover a large area, and should require very little human interaction. LPWA, at its core, is a public wide-area network (WAN) with the capability to connect tens of billions of devices spread out over hundreds of millions of square miles.LPWA delivers lower data rates than a traditional WAN (like an LTE network). This is intentional, as 86% of all current IoT devices use less than 3MB of data per month. 3GPP predicts that as the Internet of Things progresses 99.9% of LPWA devices will use less than 150 Kbytes of data per month. The carrier, or wireless provider, owns and operates the LPWA network. They manage the infrastructure, repair and maintain the infrastructure, plan its deployment to optimize tower placement, arrange for backhaul to the cloud, and work with the many governments to get permitted and legally operate. The carrier invests in building this network and charges applications for the use of this network. The successful carrier business profits by the revenue (connectivity fees from the applications) exceeding the expenses of running the LPWA network (tower rental, backhaul expenses, construction costs, human resources, etc.).Applications or devices are benefitted by the connectivity that the LPWA network provides. The device is what provides the data and interactivity the end user is seeking to obtain business value from the IoT. For an application to participate in an LPWA network, there must be a positive return-on-investment (ROI) of this connectivity. In other words, the value provided by the device combined with the LPWA connectivity must exceed the connectivity fees paid to the carrier and the costs to develop and maintain the device. The capabilities of the connectivity directly influence the capabilities of the devices and the value they bring the people and organizations using them.

3.1 NB-IoT in smart metering :

Each device in the field will be connected via NB-IoT module and will send data to the server. As it uses IPv6 addressing for the communication, therefore mitigates the problem of limited unique addresses posed by the IPv4 based addressing. Traditional cellular options such as GPRS and LTE networks consume too much power and don't fit well with applications where only a small amount of data is transmitted (e.g. Smart Meters).NB-IoT consumes about 23dBm of transmit power and uses power saving modes to save the power and thereby increasing the battery life .Scalability makes NB-IoT as one of the key technologies to be deployed as millions of devices can be connected in the network simultaneously. NB-IoT is the potentially less expensive option as it eliminates the need for a gateway. Other infrastructures typically have gateways aggregating sensor data, which then communicates with the main server. With NB-IoT, sensor data is sent directly to the main server. For this reason, market players like Huawei, Ericsson, Qualcomm, and Vodafone are actively researching and making an effort to commercialize NB-IoT.

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III.COMMUNICATION CONUNDRUM IN SMART METERING

Success of the communication technology deployed will decide the success of the smart grid. Each of the technologies discussed above are having lucrative advantages but the discouraging drawbacks as well, making it a highly confounding to choose one technology above the other. Let's start with the GPRS, the whole purpose of real-time connectivity gets lost as connections are highly susceptible to communication drops, and reconnection time is nearly 20 seconds. The problem can be magnified in the rural areas where the range is limited. Theoretical speed of 200kbps can be achieved, but in reality it is just 15kbps.GPRS was designed with the idea of higher data download speed than upload speed. As the upload bandwidth is limited, meters in the field will take more time to send the data to the server. All the time connectivity of millions of devices will make the server design extremely complicated and costly. It would also additionally burden the telecom operators with the huge operational cost to allow continuous logging of millions of SIM cards on their network. The SIM card change on site would require extraordinary efforts and manpower if service operator discontinues the operation in that circle. For utility boards also it would be a recurring cost as they are obligated to pay for the bill amount of SIM tariff. On the positive side, the existing communication ecosystem and infrastructure can be used for communication for GPRS.If properly chosen, a single modem will be compatible with different networks like 2G, 3G, 4G etc., hence mitigating the risk of technology obsolescence.
When we look at the RF technology it has some highly attractive features such as 100kbps of Uplink and Downlink speed. In-built broadcast and multicast commands for load control and tariff management. Low power consumption than GPRS hence reducing the BOM (bill of material) cost of devices. There is only one-time cost of installing meters in the field with the DCU(Data concentrator unit). There is one challenge in RF due to reduction in range when line of sight of device gets obstructed by some concrete structure. This issue can be tackled by the use of repeaters and high gain antennas considering geological positioning of devices. Unlike GPRS, RF provides 100% uptime making it suitable for real-time management in the effective implementation of smart grid system. Latency involved in the communication is almost negligible compared to GPRS based system. High success rate in communication provides the quality of service. NB-IoT is a fine balance between the abovementioned technologies. It can run on the existing telecom infrastructure with the deeper coverage area and lower power consumption. Additionally, it is proposed by the 3GPP and in line with 5G requirements makes it one of the promising and futuristic technology.

IV.RESULT AND DISCUSSION

In order to compare and analyse this communication technologies an experiment was conducted incorporating GPRS and RF technology. NB-IoT is not included as it is in a nascent stage and not yet rolled out in India. 5 device were connected with the GPRS and then with RF and 70 times data downloaded was attempted from a remote location.Drop in the connection in the case of a GPRS is considered as a failure in data download and experiment was resumed with re-establishing the connection. RF data download is the communication between DCU and device, whereas GPRS data download is the communication between server and device. It is important to note that gateway of DCU is excluded in the experimentation performed. Resultsare tabulated in the table 2.

Device Id	Data download in RF	Success rate in RF	Data download in GPRS	Success rate in GPRS
1	70	100%	70	100%
2	70	100%	69	99%
3	70	100%	70	100%
4	70	100%	67	96%
5	70	100%	70	100%

Table 2. Data download in RF and GPRS

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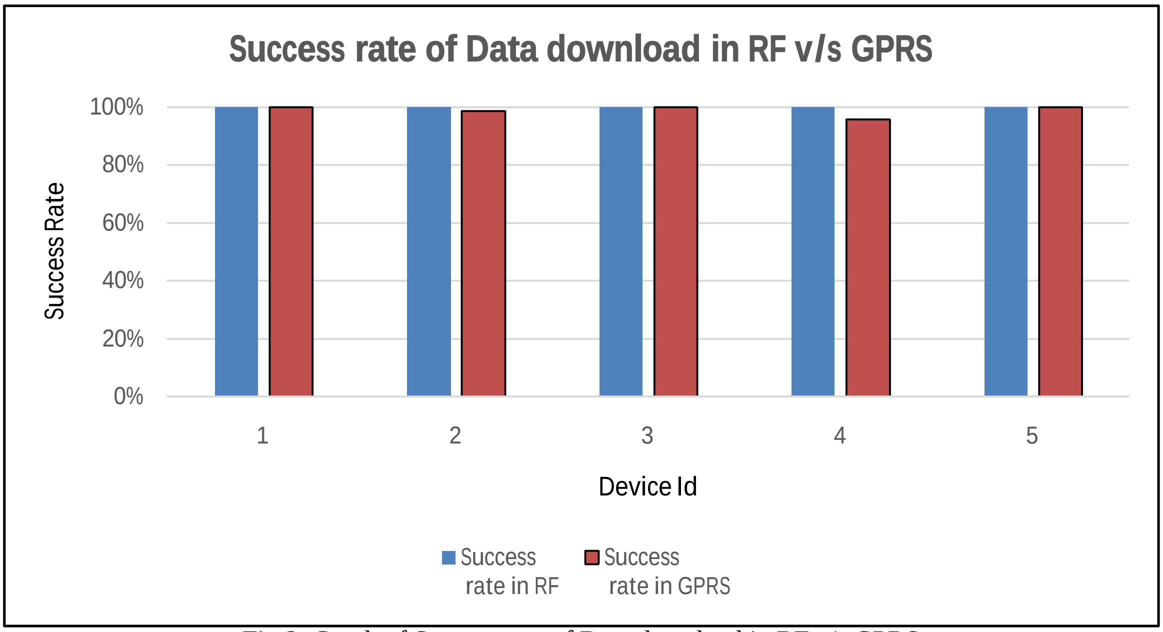

Fig 2. Graph of Success rate of Data download in RF v/s GPRS

As stated in the above graph out of 70 attempts made to download data from the DCU, all resulted in success for all 5 the devices, in the case of RF communication. In the case of GPRS Except device id 2 and 4, remaining all devices performed with 100% success rate. For the device id 2 and 4 success rate was 99% and 96% respectively. Given the real-time network issues and other contingencies, performance of RF as well as GPRS found to be satisfactory.

V.CONCLUSION

Communication is a backbone of any smart grid implementation. In This paper we explained about three major communication technologies –RF,GPRS and NB-IoT. Each has their own unique characteristics along withattractive benefits and few discouraging drawbacks, which one must be informed of before selecting any specific technology for the given application. Results discussed above confirms that the uptime for the devices is maximum in the case of RF as it provides a dedicated link between the device and data concentrator unit. Future scalability is simple with NB-IoT as it is emerging technology equipped with the M2M requirements. Further research can be carried out to determine the reliability and exact value of latency in the communication.

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