ISGF
India Smart Grid Forum

ISGF White Paper

Next Generation Smart Metering – IP Metering

Abstract

Although the Smart Metering or Advanced Metering Infrastructure (AMI) being rolled out by electric utilities worldwide, the last mile connectivity continues to haunt the efficiency as well as the rollout programs in many countries. The widely adopted communication architectures deployed in AMI projects involve RF/PLC/BPL for last mile connection from a Data Concentrator Unit (DCU) to a group of meters; and the DCUs transmit the data to the utility's sever on the wide area network – GPRS/fiber networks. This architecture evolved over the past ten years particularly because early mover utilities wanted dedicated communication network which they could control. Now that most buildings and campuses (even in smaller towns in developing countries) have broadband internet connections, utilities can leverage the existing communication infrastructure for AMI. The meters may be directly connected to internet on Wi-Fi in homes/buildings/factories/commercial centres/campuses etc. Once meters are connected on the internet, the meter data can be aggregated on a server anywhere – in utility's control room or on the cloud. This White Paper describes ISGF vision for the next generation of smart metering using internet – the era of ***IP Metering*** *that would reduce the total cost of ownership and provide excellent last mile connectivity.*

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About India Smart Grid Forum

India Smart Grid Forum (ISGF) is a public private non-partisan initiative of the Ministry of Power (MoP), Government of India for accelerated development of smart grid technologies in the Indian power sector. ISGF was set up in 2010 to provide a mechanism through which academia, industry; utilities and other stakeholders could participate in the development of Indian smart grid systems and provide relevant inputs to the government's decision making.

Table of Contents

Abbreviations

6LoWPAN – IPv6 over Low Power Personal Area Networks
AMI – Advanced Metering Infrastructure
AMR – Automatic Meter Reading
BPL – Broadband over Power Line
BSP – Broadband Service Provider
CDMA – Code Division Multiple Access
CLC – CENELEC (European Committee for Electrotechnical Standardization)
DA – Distribution Automation
DCU – Data Concentrator Unit
DDUGJY – Deen Dayal Upadhyaya Gram Jyoti Yojana
DoT – Department of Telecommunications
DSL – Digital Subscriber Line
DT – Distribution Transformer
EIA – Electronic Industries Alliance
ETSI – European Telecommunications Standards Institute
FAN – Field Area Network
FPI – Fault Passage Indicator
FRTU – Field Remote Terminal Unit
GPRS – Global Packet Radio Service
GSM – Global System for Mobile Communications
HAN – Home Area Network
HES – Head End System
IEC – International Electrotechnical Commission
IEEE – Institution of Electrical and Electronics Engineers
IETF – Internet Engineering Task Force
IHD – In Home Display
IPDS – Integrated Power Development Scheme
IR – InfraRed
ISO – International Organisation for Standardisation
ITU – International Telecommunication Union
LPWA – Low Power Wide Area
NAN – Neighbourhood Area Network
NFC – Near Field Communications
NOFN – National Optical Fiber Network
OSGP – Open Smart Grid Protocol
P2MP – Point to Multi Point
P2P – Point to Point
PLC – Power Line Carrier
RF – Radio Frequency
RFC – Request For Comments
RFID – Radio Frequency Identification
RTU – Remote Terminal Unit
SCADA – Supervisory Control and Data Acquisition
TS – Technical Specification
TVWS – Television White Space
TWACS – Two Way Advanced Communications System
WAN – Wide Area Network
WPC – Wireless Planning and Coordination

1. Introduction

In the recent past, the metering industry has made giant leaps in their endeavor to enhance both, electric utility operations and quality of service to end-consumers. In the journey from electromechanical meters to electronic meters to AMR (Automated Meter Reading) and prepaid meters; and to smart meters, the industry made impressive progress. The current scenario of smart metering uses communication network elements such as gateways, Data Concentrator Units (DCU) interfacing with numerous mesh nodes in the last mile. This paper proposes the next generation smart metering or Advanced Metering Infrastructure (AMI) solution that we call the "**IP Metering**" which will use the broadband internet for providing last mile connectivity and in turn, overcomes the limitations of the existing last mile connectivity solutions such as latency, reliability, scalability, total cost of ownership etc.

2. Characteristics for Communication Technologies for Smart Metering and other Smart Grid Applications

Different smart grid applications have different bandwidth and latency requirements. For example, smart metering requires less bandwidth with no severe latency conditions whereas substation automation poses requirements of higher bandwidth and improved latency. Apart from availability, reliability of communication networks is a key characteristic for critical applications such as SCADA and substation automation. Using standards-based technologies will ensure a high degree of scalability and interoperability. The choice of operating frequency is vital for deciding the power consumption of the devices and range of the communications network. Having a long technology life-cycle, compliance to regulations and total cost of ownership are other key characteristics. Moreover, all communication technologies must possess the necessary measures to be resilient to cyber attacks.

The selection of a technology will depend on the envisaged application. For mission critical applications such as SCADA, substation automation etc., security, reliability and latency will be the key criteria for deciding a communication technology. Cost will not be the main criterion. For non-critical applications such as AMI, Electric Vehicles etc., cost will be decisive.

3. Overview of present Communication Technologies/Protocols

A number of communication technologies are available today. Following are the popular options for the last mile network/Neighborhood Area Network (NAN)/Field Area Network (FAN): 6LoWPAN-based RF mesh, ZigBee, Wi-Fi, Power Line Carrier (PLC), Ethernet and serial interfaces. For the Home Area Network (HAN), 6LoWPAN-based RF mesh, ZigBee, Wi-Fi, Bluetooth, Z-Wave, Near Field Communications (NFC), PLC, Ethernet, and serial interfaces are being used commonly. Depending upon the requirements, cellular and satellite communications, Low Power Wide Area (LPWA) technology, Long Wave Radio, Television White Space (TVWS), Optical Fiber, Ethernet, PLC, Digital Subscriber Line (DSL), Private Microwave Radio Links (both, P2P and P2MP) etc. could be used for the backhaul/Wide Area Network (WAN) and Backbone networks. These are summarized in the Table 1 below.

Table 1 - Snapshot of Available Communications Technologies/Protocols

Technology/ Protocol	Last Mile/NAN/FAN	Home Area Network (HAN)	Backhaul/WAN and Backbone
Wireless	6LoWPAN-based RF mesh, ZigBee, Wi-Fi, Millimeter Wave Technology	6LoWPAN-based RF mesh, ZigBee, Wi-Fi, Bluetooth, Z-Wave, NFC	Cellular, Satellite, LPWA, Long Wave Radio, TVWS, Private Microwave Radio links (P2P and P2MP)
Wired	PLC, Ethernet, Serial interfaces (RS-232, RS-422, RS-485), DSL	PLC, Ethernet, Serial interfaces (RS-232, RS-422, RS-485)	Optical Fiber, Ethernet, PLC, DSL

4. Popular Communication Architectures Deployed for AMI Worldwide

In the present scenario of smart metering, Data Concentrator Units (DCU), aggregators and gateways are key elements. These devices not only increase the total cost of ownership, but also fail to offer reliable, scalable and interoperable last mile connectivity. Experiences from around the world shows that none of the solutions offer 100% reliable connectivity all the time. The best range often heard is between 95-98%; and in many cases it is well below 90%!

Some of the popular communication architectures deployed for AMI worldwide are:

Fig-A: Architecture deployed by Enel (Italy) – an early mover

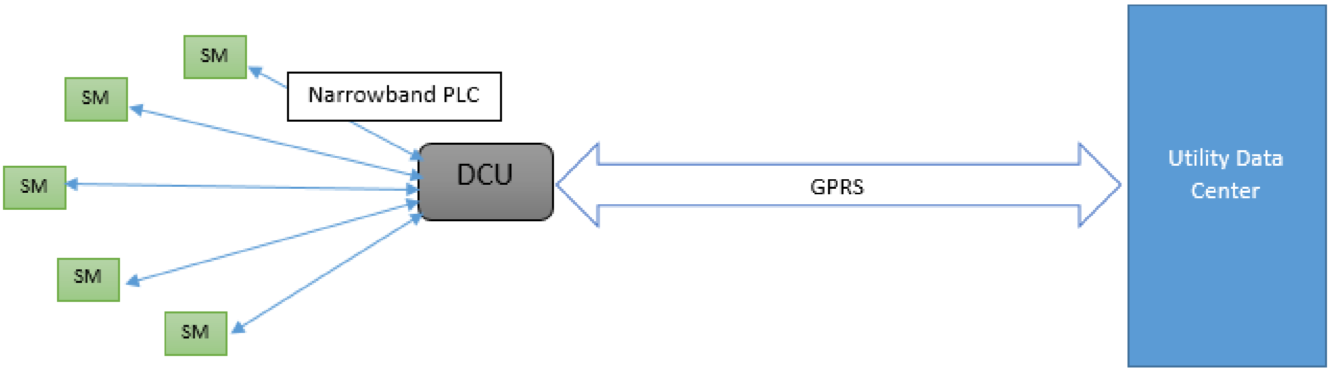


Fig-B: Architecture deployed by CenterPoint Energy (Houston, USA) – another early mover

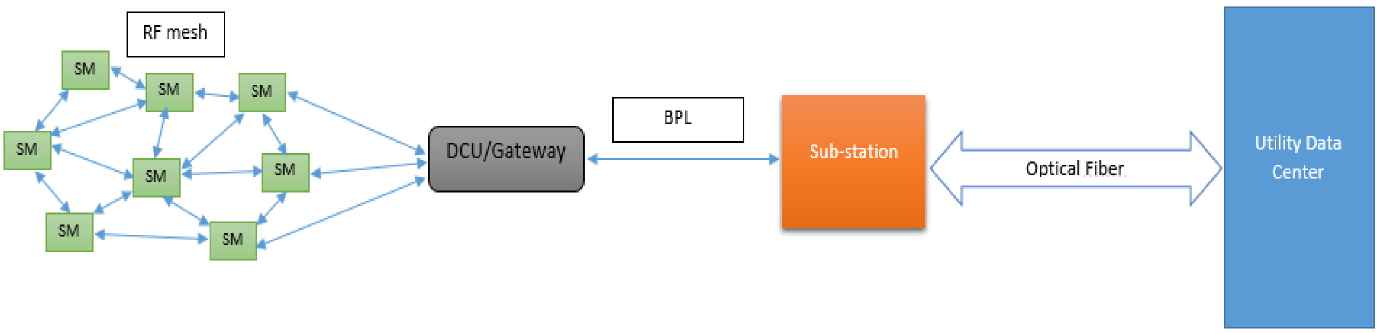


Fig-C: Typical AMI architecture with RF mesh as last mile – this has emerged as a popular solution amongst utilities in many geographies

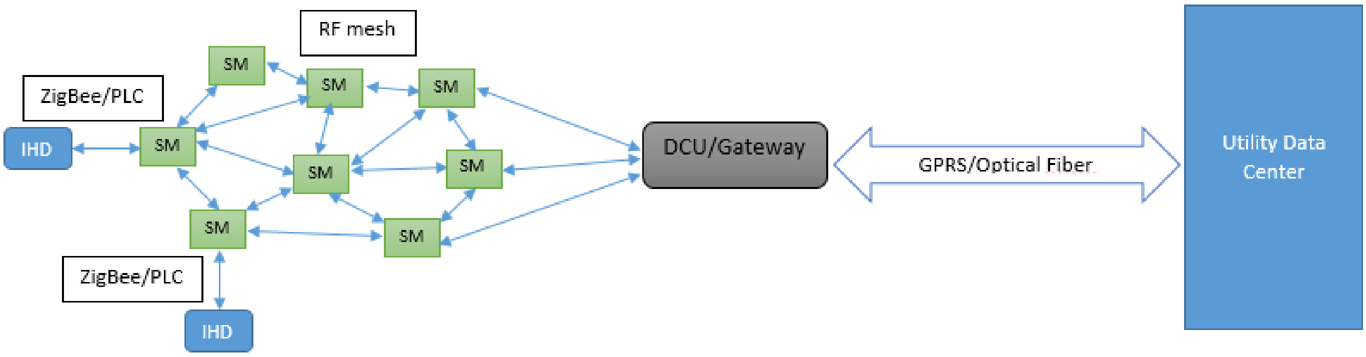
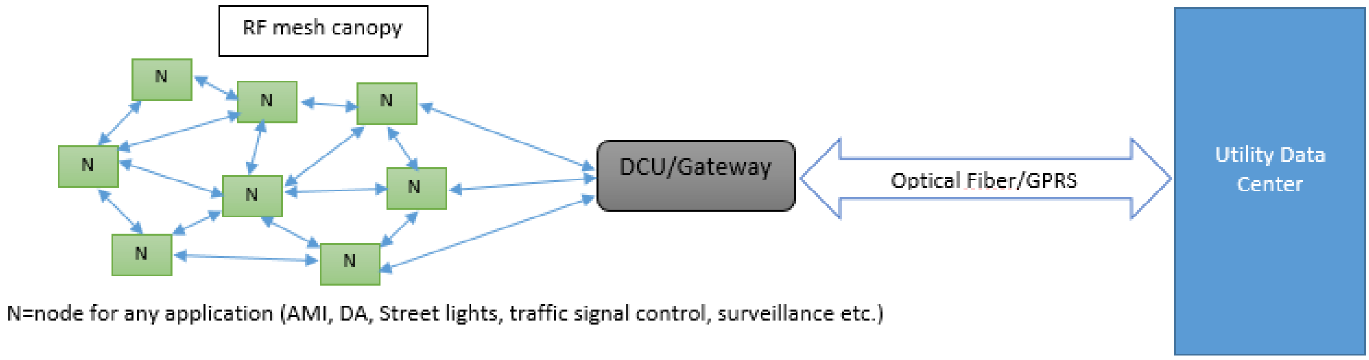


Fig-D: Emerging Architecture for Smart Grid and Smart City Applications – RF mesh canopy networks is the latest trend



5. RF Bandwidth available in India for Utility Applications

The Wireless Planning and Coordination (WPC) wing of the Ministry of Communications and IT, Government of India has the authority of allocating frequency bands in India. Table 2 provides a summary of various bands that can be used for low power RF applications by the utilities.

Table 2 - Snapshot of Frequency Bands in India for Low Power RF Applications

Frequency Band	Characteristics	Applications
433-434 MHz	Maximum effective radiated power = 10mW Maximum channel bandwidth = 10 KHz Inbuilt antenna	Indoor applications only
865-867 MHz	Maximum transmitted power = 1W Maximum effective radiated power = 4W Maximum channel bandwidth = 200 KHz	Any application

2.4-2.4835 MHz	Maximum transmitted power = 1 W (in a spread of 10 MHz or higher) Maximum effective radiated power = 4 W Maximum antenna height = 5 meters above the roof-top of an existing authorized building	Any application
5.150 - 5.350 GHz and 5.725 - 5.875 GHz	Maximum mean effective isotropic radiated power = 200 mW Maximum mean effective isotropic radiated power density = 10 mW/MHz in any 1 MHz band. Inbuilt antenna	Indoor applications only
5.825 - 5.875 GHz	Maximum transmitted power = 1 W (in a spread of 10 MHz or higher) Maximum effective isotropic radiated power = 4 W	Any application

Presently, there are no regulations for PLC usage, although WPC approval is required post installation where lines on which PLC has been deployed are running parallel to telecom lines/cables in near vicinity. The Department of Telecommunications (DoT) is planning to allocate frequency band(s) for PLC communications in the near future.

6. Standards for Various Communication Technologies

As discussed above, a number of communication technologies/protocols are available for the NAN/FAN, WAN and Backhaul networks for smart grid applications. The following tables (3, 4 and 5) mention the standards for these technologies/protocols:

Table 3 - Communication Protocols/Technologies and Standards for Wireless HAN/NAN

Protocol/Technology	**Standard**
ZigBee	IEEE 802.15.4 (Physical and MAC layers) IEEE 2030.5-2013 (IEEE Adoption of SEP 2.0 Application Protocol Standard)
6LoWPAN-based RF mesh	IEEE 802.15.4 (Physical and MAC layers), IETF RFC 4944 and IETF RFC 6282 (6LoWPAN layer)
Wi-Fi	IEEE 802.11ac
Bluetooth	IEEE 802.15.1
InfraRed (IR)	IEEE 802.11IR
Near Field Communication (NFC)	ISO/IEC 14443 - defines the ID cards used to store information ISO/IEC 18000-3 - specifies the RFID communication used by NFC devices ISO/IEC 18092- Telecommunications and information exchange between systems - Near Field Communication - Interface and Protocol (NFCIP-1)
Z-Wave	ITU-T G.9959 (Physical, MAC, Segmentation and Reassembly (SAR) and Link Logical Control (LLC) layers)
Millimeter Wave Technology	IEEE 802.11ad

Table 4 - Communication Protocols/Technologies and Standards for Wireless WAN

Protocol/Technology	**Standard**
Cellular	3GPP TS 45.-series (3G), WiMAX (IEEE 802.16) – (4G), LTE (3GPP Release 8 and 9) – (4G), CDMA2000 (3GPP2) – (3G)
Satellite (VSAT)	ETSI EN 301 428
Low Power Wide Area (LPWA)	Weightless-N and Weightless-P(Defined by Weightless – a non-profit global standards body) LoRaWAN R1.0 (Published by LoRa Alliance)
Television White Space (TVWS)	IEEE 802.19.1, IEEE 802.11af, Weightless-W

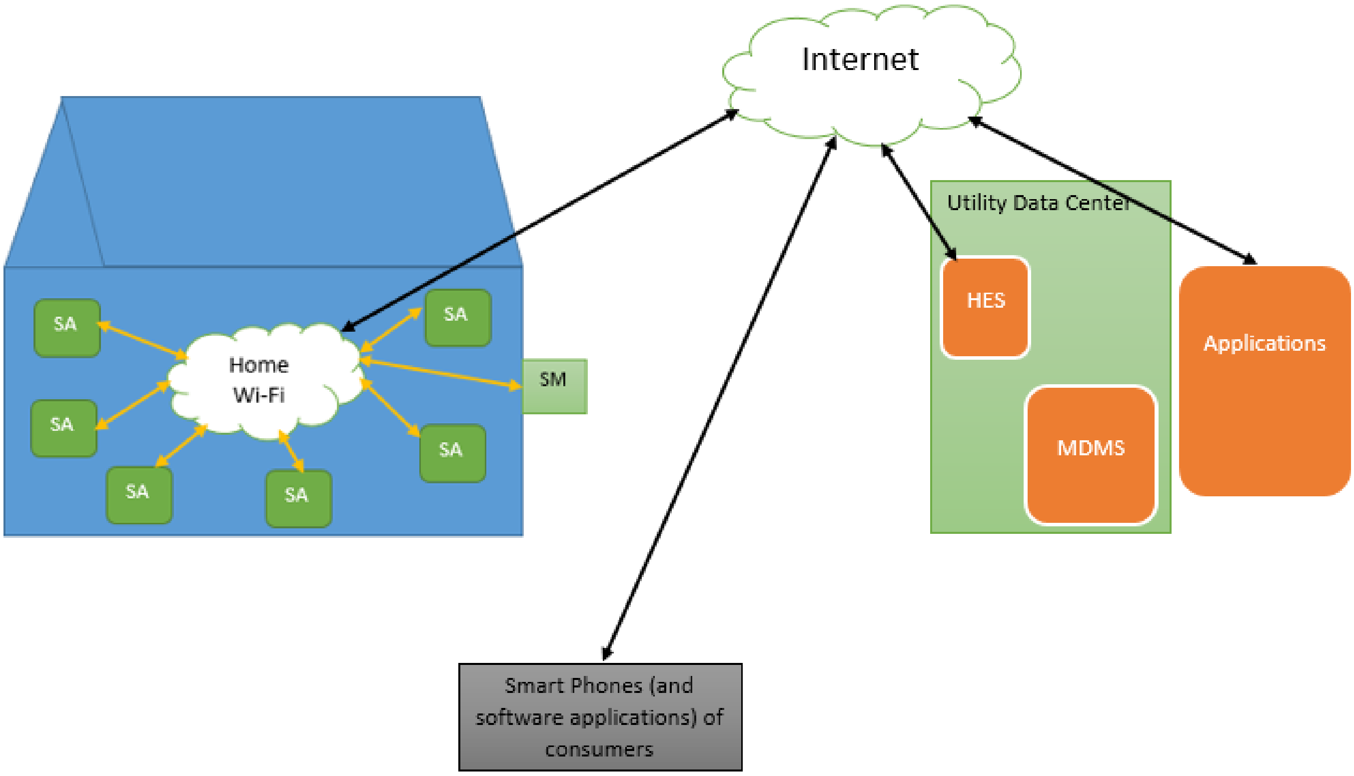
Table 5 - Communication Protocols/Technologies and Standards for Wireline HAN/NAN/WAN

Protocol/Technology	**Standard**
PRIME	ITU-T G.9904
G3-PLC	ITU-T G.9903
Meters and More	CLC TS 50568
OSGP	ETSI TS 103 908, IEC/ISO EN 14908.1, ETSI GS OSG 001 (Application layer)
TWACS	Proprietary (by Aclara, Sumitomo)
IEEE 1901.2	IEEE 1901.2 – Narrowband PLC
IEEE 1901-2010	IEEE 1901- 2010– Broadband PLC
ITU-T G.hnem	ITU-T G.hnem - Narrowband PLC
IEC 61334	IEC 61334 - Narrowband PLC
HomePlug	HomePlug Green PHY – Narrowband PLC HomePlug Command & Control – Broadband PLC. (Published by HomePlug Alliance)
ITU-T G.hn (G.9960/G.9961)	ITU-T G.hn (G.9960/G.9961)- Broadband PLC
Serial Interfaces (RS-232, RS-422, RS-485)	EIA-232, EIA-422 and EIA-485. (EIA = Electronics Industry Alliance)

7. ISGF Vision for Next Generation Communication Architecture for Smart Metering – IP Metering

We at ISGF believe that by 2020, almost every building (residential/commercial/industrial/public institutions etc.) in urban and semi-urban areas on earth will have broadband internet connectivity (perhaps except in some conflict regions). The smart meter, smart appliances, utility's Head End System (HES) and other applications can connect to the Internet and eliminate the need of intermediate entities such as DCUs/gateways. As shown in Fig. E, smart meters and smart appliances can be connected to the Wi-Fi network in the home/building/campus. Meter data is sent over the broadband internet which can be accessed by the utility's HES and received in the MDMS which integrates the meter data with all utility applications; and applications with consumers on their smart phones eliminating the need for in-home displays (IHDs).

Fig. E – Communication Architecture for next generation Smart Metering – IP Metering



Legend:

SA	Smart Appliances
SM	Smart meter
HES	Head End System
MDMS	Meter Data Management System

8. Rationale for IP Metering in India

The Govt. of India was pursuing a program, National Optical Fiber Network (NOFN), to provide broadband connectivity to 250,000 villages, which the Modi-Government has decided to expand to 600,000 villages under the "Digital India" program for providing universal broadband access to all. Ministry of Power has proposed to fund the extension of NOFN to all 33kV and above substations as part of Integrated Power Development Scheme (IPDS) and Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY) programs. These schemes are going to provide broadband access to most part of the country as well as create a dedicated fiber backbone network for the power system.

The advantage of the proposed architecture is that it leverages the existing communication infrastructure, that is, broadband connection in buildings and homes, and hence reduces the total cost of ownership as additional network elements such as data concentrator units, gateways etc. are not required. Wi-Fi connectivity is maintained by Broadband Service Providers (BSP) who have the expertise and resources to maintain such networks with very high reliability. IP networks are scalable and reliable and can be monitored and controlled in real time. Questions regarding the security of Wi-Fi networks cannot pose a major threat as people are widely using their laptops and other mobile devices for all kinds of online transactions when connected to Wi-Fi networks. As far as interoperability is concerned, if all the meters follow common data models/routing tables, the MDMS can accept data from different makes of meters – similar to smart phones of different makes with different operating systems connected on Wi-Fi are able to communicate with each other so long as the users understand the same language.

9. Conclusions

The communication architectures presently deployed for smart metering include intermediate entities such as data concentrator units/gateways and creation of a dedicated parallel communication network for the electric utility which they have no expertise in maintaining and upgrading as new communication technologies are evolving at a faster pace. This also involves use of wireless spectrum which is a limited and expensive resource in every country today. Experiences from around the world indicate that none of the communication solutions presently deployed for smart metering have 100% reliability despite having a dedicated network. These architectures not only increase the total cost of ownership but also fail to offer reliable, scalable and interoperable last mile connectivity.

In today's world where internet is everywhere, smart meters and smart appliances could be connected directly on internet; and utility's HES can leverage internet to collect the meter data on the server and the MDMS can integrate that with other applications. In other words, the broadband internet that is present in almost all homes, buildings and campuses, can be used for providing last mile connectivity for smart metering. By doing do, devices such as data concentrator units, gateways and in-home displays will not be needed and highly reliable, scalable and interoperable last mile connectivity can be provided. Wherever there are no Wi-Fi, the electric utility may provide Wi-Fi which will be cheaper than other last mile connectivity options.

In the IPv6 regime where every meter can have an IP address, the proposed IP Metering solution can offer multiple benefits to utilities and governments:

- No need for a parallel telecom infrastructure – huge savings in cost of deployment and maintenance for the utility
- No need for separate spectrum for utility applications – instead government can allocate that spectrum to telcos and/or other users for additional revenue
- More reliability, scalability, security and capability to monitor and control – IP networks can be monitored in real time which itself is a good measure against cyber attacks