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Role of IT and ICT in Smart Grid

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Abstract

The new era will be of Smart Grid in comparison with existing electricity grid.Smart grid is a combination of electricity grid and communication infrastructure. To give sustainable electricity supply, Smart grid connects with all the connected components to form a logical power network. To increase the effectiveness of power grid many sophisticated communication technologies have been recognized. These communication technologies increase the efficiency taken as a whole of electrical grid.This paper details the relevance and challenges of various communication technologies. Two major challenges have been found for implementing smart grid technology, first is standard inter operability and cognitive access to unlicensed radio spectrum. Paper also discusses the problems to implement smart grid communication on an evolutional path. Recent and future trends in Smart grid are elaborated. The paper provides the broad review of state of art research available on Smart grid communication.

***Keywords**: - Cognitive Radio, Smart grid communication, Wireless Sensor network.*

INTRODUCTION

The demand of electrical energy is increasing day by day worldwide. The present power grid faces the new challenges of distributed generation and injection of renewable energy sources.The distribution system, feeding load, is very extensive but is almost entirely passive with little communication and only limited local controls. Other than for the very largest loads (for example, in a steelworks or in aluminium smelters), there is no real-time monitoring of either the voltage being offered to a load or the current being drawn by it. There is very little interaction between the loads and the power system other than the supply of load energy whenever it is demanded. The present power grid face problem of thermal constraints, lack of circuit capacity, ageing assets, operational constraints and security of supply [1].

Some of the methods and technologies are required to improve the performance of the existing power grid system.

1. Two Way Integrated Information and Communication Technology (ICT) ,
2. Substation automation,
3. Sensing and Measurement Technologie including Smart Meters.
4. Demand response.

It is clear that the grid of the 21st century will be a "Smart Grid."

A smart grid is a flexible, living, and proactively operating infrastructure as compared to the present power grid, which is static, centralized network.

The present revolution in communication systems, particularly stimulated by the internet, offers the possibility of much greater monitoring and control throughout the power system and hence more effective, flexible and lower cost operation. The Smart Grid is an opportunity to use new ICTs (Information and Communication Technologies) to revolutionize the electrical power system. However, due to the huge size of the power system and the scale of investment that has been made in it over the years, any significant change will be expensive and requires careful justification.

Smart Grid – A definition

According to Public Law 110–140-DEC. 19, 2007 [2], the United States of America (the USA)"is supporting modernization of the electricity transmission and distribution networks to maintain a reliable and secure electricity infrastructure that can meet future demand growth and to achieve increased use of digital information and controls technology; dynamic optimization of grid operations and resources; deployment and integration of distributed resources and generating; development and incorporation of demand response, demand-side resources, and energy-efficient resources; development of 'smart' technologies for metering, communications and status, and distribution automation; integration of 'smart' appliances and consumer devices; deployment and integration of advanced electricity storage and peak-shaving technologies; provisions to consumers of timely information and control options and development of standards for communicat e-on and inter-operability."

Table I *gives the comparison between existing and Smart grid .*

	Existing Power Grid	Smart Grid
Communication	One Direction	Bidirectional
Electricity Generation	Centralized generation	Distributed Generation
Demand Response	Nil	Exist
Grid Topology	Radial	Network
Sensors	Very few	Lots of sensors
Grid Monitoring	Usually blind	Self monitoring
Metering	Electromechanical	Smart meter
Recovery of outage	Manual	Self-reconfiguration
Testing	Manual	Remote
Control	Limited and passive control	Active Control
Overall efficiency	Low	High
Environmental Pollution	High	Low

TABLE I: THE EXISTING POWER GRID versus SMART GRID [3]

Therefore It is clear from the table that for two-way communications, active control capabilities, and efficient use of electricity Smart Grid plays an important role.

Grid Components of Smart

The conceptual functional blocks of SG are depicted in Fig. 2. SG is built on communication and information technolog ies, and electric power systems. It is supported by new approaches and applications such as DR, distributed energy resources and pervasive monitoring etc.

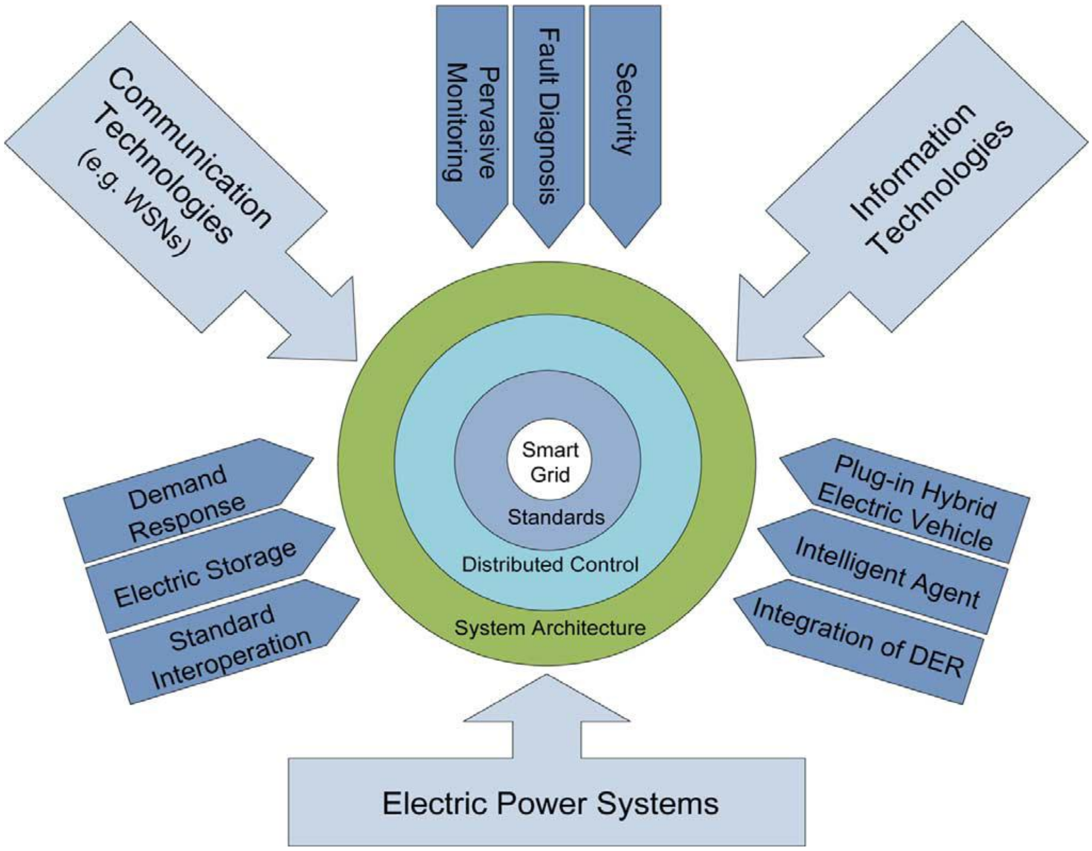

Fig. 2. *Conceptual Functional Blocks of Smart Grid.[3]*

ICT: Information and Communication Technologies and Smart Grid:
Any coordinated control of the power system relies on effective communications linking a large number of devices. Status information related to power system for example Voltage transformer, Current transformer etc are communicated between Intelligent Electronic Device (IED) and workstation. This information is sent through a data communicationsystem for display .
The communication channel is the path along which data travels as a signal [1].
Communication channels run through physical media between a Source and a Destination. On account of devoted channels, a solitary medium is for the most part utilized. Shared correspondence channels may include more than one medium, contingent upon the course the flag ventures. A correspondence station might be given through guided media, for example, a copper link or optical fiber or through an unguided medium, for example, a radio connection.
The different types of Communication channels available are:

1. Wired Communication
2. Optical fiber
3. Radio Communication
4. Cellular mobile communication
5. Satellite Communication.

The communication infrastructure of a power system typically consists of SCADA systems with dedicated communication channels to and from the System Control Centre and a Wide Area Network (WAN). A fundamental advancement of the Smart Grid is to expand correspondence all through the dissemination system and to set up two-path interchanges with clients through Neighborhood Area Networks (NANs) covering the regions served by conveyance substations. Clients' premises will have Home Area Networks (HANs). The interface of the Home and Neighborhood Area Networks will be through a brilliant meter or keen interfacing gadget. The various communication sub-networks that will make up the Smart Grid employ different technologies are discussed below:

1.HAN uses Ethernet, Wireless Ethernet, Power Line Carrier (PLC), Broadband over Power Line (BPL), ZigBee.
2.NAN uses PLC, BPL, Metro Ethernet, Digital Subscriber Line (DSL), EDGE, High Speed Packet Access (HSPA), Universal Mobile Telecommunications System (UMTS), Long Term Evolution (LTE), WiMax, Frame Relay.
3.WAN uses Multi Protocol Label Switching (MPLS), WiMax, LTE, Frame Relay

***SG Transmission Communication*.**
***Wide-Area Frequency Monitoring Network*:**
[8]Status of Electrical energy is noted by implementing most up-to-date frequency monitoring networks (FNETs), which smoothen the progress of wide-area monitoring networkspresented some latest implementations of frequency monitoring networks (FNETs), which facilitate wide-area monitoring networks for observing various statuses in an electrical grid. In FNET systems, frequency disturbance recorders (FDRs) are implemented as sensors to measure phase angle, amplitude, and frequency of a voltage source. Phasor measurements of a power grid are transmitted via the Internet or other wireless WAN technologies to a local client or a remote data center. A conceptual model of FNET in SG is depicted in Fig. 2. FDRs can be installed in many locations in the grid, such as power plants, substations, office buildings, and premises. Measured data from FDRs are processed in a data center by multilayer agents in a multilayer fashion. The top layer is a FNET data concentrator, which is responsible to receive data from FDRs, create GPS time-aligned records, share data with real-time application agents, and forward data records to data storage agents as well as subscribed clients. The real-time application agents and data storage agents are located in the second layer of the data center hierarchy. The third layer is a non-real-time analysis agent, in which applications implemented on this layer are operated on the saved data from the data storage server.

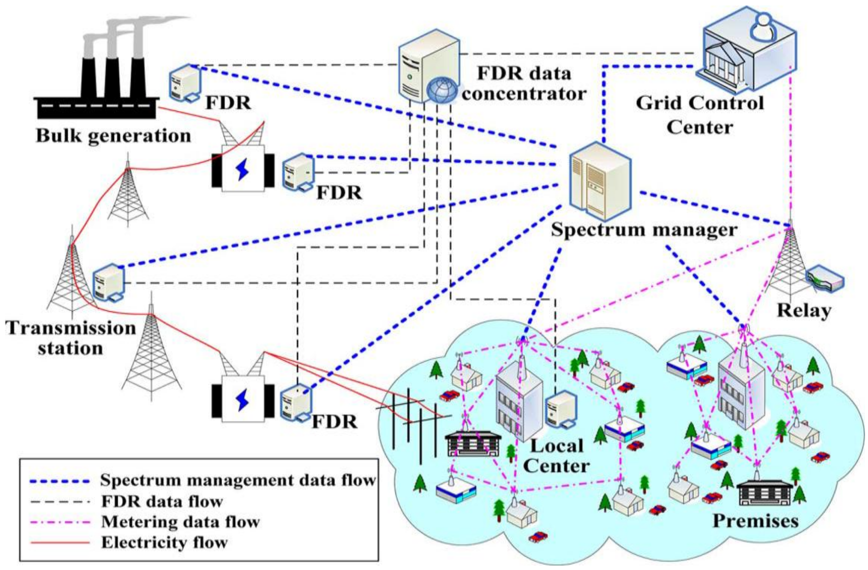

***Fig. 2.**FNET and cognitive radio in smart grid information networks.*

FNET applications can be classified into two categories, one is real-time applications and the other is non-real-time applications. Real-time applications require immediate response after receiving data, while non-real-time applications have more flexible timing requirements. Real-time applications operate on data in a memory cache. The real-time applications include frequency monitoring interface, event trigger and inter-area oscillation trigger. The frequency monitoring interface can display unit name, IP information, connection status, and dynamic frequency curve of one certain FDR. FNET event trigger module can detect frequency variations, which always reflect a mismatch between generation and demand in a power system. In addition to generation losses, a system-wide frequency disturbance caused by load shedding can also induce a positive response in this module. The inter-area oscillation trigger module possesses a high accuracy on measuring system dynamics. Power system oscillations, which are associated with events load shedding and generation trips, can be monitored and detected according to both FNET phase angle and FNET frequency recordings. A FNET system was well designed for high volume data transfer, processing, storage and utilization. Due to the desired sensing ability of FDR, FNET system now comprises a variety of real-time dynamic monitoring applications. Because FNET system is a mature, multifunctional, low-cost voltage phase or measurement system with stable performance, it is expected that it will be capable to dynamically estimate and control the grid in a real-time manner. These desired features make FNET system a suitable monitor and control system for smart transmission grid. Some more works on SG transmission systems can be referred to [9] and [10].

2) Cognitive Radio Based WRANs for SG: Due to scarce frequency resources, works have been reported in the literature to apply cognitive radio (CR) technologies to SG communications to access unlicensed bands and white space available in TV bands. In [11], the authors proposed to use CR based IEEE 802.22 standard in wireless regional area networks (WRANs) for SG backhaul data flows. They proposed two different architectures for CR-based WRANs, i.e., stand-alone radio and secondary radio, for SG communications according to specific circumstances and applications. They proposed that CR-based WRANs work suitably as an optional radio especially in urban territories and as a reinforcement in a fiasco administration. At the point when there exist higher limit necessities and subsequently less accessibility of unused TV groups, CR-based WRAN can sharply transmit non-basic SG information and give a reinforcement radio in the event of a cataclysmic event or a security rupture. In rustic regions, i.e., like the spots in which client thickness is low and there is more blank area accessible in TV groups, they recommended that a remain solitary radio in view of IEEE 802.22 can give broadband access to utility spine interchanges as a result of wide range scope because of the great spread attributes of TV groups.

The authors highlighted the issues that, in both of their proposed architectures, transmission of SG time-critical data is challenging because of inherent sensing delays and cognitive nature specified in IEEE 802.22. Accordingly, the authors proposed a concept of dual-radio architecture for CR-based WRAN transmission where one radio chain is used only for SG data transmission and reception, while the other chain is dedicated for spectrum sensing. The sensing radio constantly searches for new available channels, so that transceiver chain does not have to postpone its data transmission in order to seek for idle channels. By employing the proposed dual-radio architecture, a higher spectrum efficiency and sensing accuracy can be achieved compared with a single-radio architecture, since spectrum sensing is performed all the time, and thus a clear channel for SG data flow can be quickly allocated whenever required. According to their discussions, it is convinced that their proposed CR-based WRAN is well suited for SG backhaul networks and offers four benefits, which are briefly discussed and listed as follows.

a) Soft capacity limit: The proposed CR-based WRAN for SG communications has a soft capacity limit as it can opportunistically and dynamically use available TV channels to increase system capacity.

b) Wide coverage area: The BS coverage area for IEEE 802.22 standard is much larger than the other 802 standards, which means that less BSs and hence less capital expenditure will be required by CR-based SG communication systems.

c) Fault tolerance and self-healing: Their proposed architecture is inherently robust to failures because if one link has a breakdown due to a natural disaster or security breach, a new connection can be established in a timely manner to maintain connectivity due to the fact that available channels are constantly sensed.

d) Ease of upgradability: CR-based systems are generally implemented using software-defined radio (SDR) systems, which are usually implemented by means of software on a personal computer or embedded computing devices.

Consequently, they are more flexible and can be easily modified through software upgrades. Fig. 2 illustrates the role of CR technology in SG. In conjunction with the control center, there is a spectrum manager that plays an important role in sharing spectrum resources amongst different NANs concentrators and the main information stations in wide areas.

Communications in SG Distribution Systems

Distribution system forms another critical part of SG. In this subsection, we will discuss those relevant communication technologies implemented in distribution grid.

1) Coexistence of SUNs With Other Networks: IEEE 802.15.4g smart utility networks (SUNs) task group, i.e.,TG4g, founded in December 2008, was established to create a PHY amendment to IEEE 802.15.4 to provide a global standard that expedites large-scale process control applications such as SG distribution network [12], [13]. SUNs enable multiple applications to operate over shared network resources, providing monitoring and control of a utility system. The major technology that employs SUNs is the advanced metering infrastructure (AMI), which has the abilities of monitor, command, and control for service providers at the end-side of the grid, as well as measurement, data collection, and analysis for electricity usage at utility's back office. Since IEEE 802.15.4g is a recently created standard that works in territorially accessible and permit absolved groups, the concurrence attributes required by this new standard should be tended to. Besides, the concentration of SUNs are the components that fit between existing models, which might be utilized as a part of the utility spine and in-premises process, modern and home region systems. In this specific situation, the SUNs frame some portion of a heterogeneous system, filling the hole between wide region systems

(WANs), neighborhood area networks (NANs), and home area networks (HANs). Therefore, it is essential to provide coexistence mechanisms that enable SUNs to coexist with the other heterogeneous standards in the same license-exempt bands. The authors in [12] provided an overview of all the mechanisms specified or proposed in IEEE 802.15.4g that are applicable for interference avoidance and mitigation, which are able to facilitate coexistence amongst heterogeneous and homogeneous systems. These coexistence mechanisms include multi-PHY management scheme, clear channel assessment, and link quality indicator (LQI), to just name a few. It is believed that more advanced on-demand coexistence mechanisms should be developed for SUNs in order to mitigate the interference from the heterogeneous systems in crowded license-exempt bands.

2) SUNs in TVW hite Space: An overview of the recent innovative concept of deploying SUNs in TV white space (TVWS) was presented in [13], in which the main purpose is to provide readers with a detailed discussion to explore the potential of combining these two technologies based on their current developmentas well as their regulatory status. The authors reviewed SUNs and TVWS as two different green technologies, and then merged them to propose a hybrid solution that integrates their respective merits. A usage model for SUNs was depicted in [13], in which there exist four kinds of SUN components, i.e., utility provider base stations (BSs), data collectors, smart meters, and mobile data collectors. In SUNs usage model, smart meters of different utilities in a neighborhood area network (NAN) are connected via SUN radio frequency (RF) link. Each house is connected to at least one of its neighbor, and therefore an *ad-hoc* topology is formed by SUNs. A collective number of households form a service area that is covered by a data collector. Data collectors form a mesh network and are connected to the utility provider BSs via wireless or other wired solutions. Data collectors may be deployed as an alternative in the case of an emergency or malfunctions of fixed data collectors are encountered. Unlicensed TVWS devices, also known as TV band devices (TVBDs), can be classified into two different types, i.e., fixed and portable devices. Fixed devices operate at a fixed location with a high-power outdoor antenna like BSs of a cellular network. Portable devices operate at a lower power and could act as an access point in HAN. Portable devices can be further divided into two different modes, in which Mode I devices are client portable devices controlled by a fixed device, and Mode II devices are independent portable devices with the ability to access available channels. In order to utilize unused spectrum in must consent to administering principles and correspondence conventions which are particular to get to the TVWS. With an expect to accomplish this, SUNs and TVWS must be created and conveyed with a specific level of homogeneity as far as usage situation and framework conduct. Subsequently, the creators mapped the SUN segments into TVWS correspondence framework design. They recommended that the utility suppliers have high-control BSs at home office and control communities for building up metropolitan zone systems, with the goal that BSs at utility's home office can be seen as settled TVBDs. From the point of view of TVWS directions, they considered that the information authorities can be seen as Mode II autonomous TVBDs. The savvy meters are proportional to Mode I customer TVBDs in light of the fact that information gatherers are associated with the client's premises. A versatile information authority in SUNs can be viewed as a detecting just gadget with low power utilization and no geo location mindfulness capability. The eventual fate of SUN and TVWS joining advancements is promising; however there still exist a few impediments to their potential.

Several crucial recommendations were made by the authors from both regulatory and technical standpoints for the sake of making SUN able to fully utilize the advantages of TVWS. From a regulation standpoint, the authors suggested that, the requirements specified by regulators for occupying TVWS should be relaxed and the TVWS licensing issue should be considered. On the other hand, from a technical standpoint, it is recommended that the differences in respective system demands must be aligned or regulators should make efforts to engineer a brand-new system that includes merits from both eco-friendly technologies.

3) Hybrid Communication Networks in Smart Grid: Although WiMAX may not be able to compete with LTE-A as a most popular 4G broadband technology, it has been considered to be utilized as a communication backbone in SG. The pilot

SGs that use WiMAX as part of their data communications have already been implemented in San Diego, Michigan, Texas, and parts of Australia. A hybrid network architecture using WiMAX and wireless mesh networks (WMNs) was described in [14], as shown in Fig. 6. In this hybrid architecture, a group of electric utility subscribers are clustered into wireless mesh domains, each of which can be easily managed by a local control center using wireless standards such as IEEE 802.15.4g (SUNs), IEEE 802.11 family, or wireless sensor networks (WSNs). The remote control center in a global network monitors each wireless mesh cluster over WiMAX. With the integration of WMNs and WiMAX, electrical utilities can exploit full advantages of multiple wireless networks. The wireless mesh domain in a hybrid network is also known as NAN, which bridges the gap between HAN and WAN. A NAN usually contains thousands of communication nodes distributed in a very large area, and the formation of WMN can improve reliability and self-healing of the whole network. Needless to say, SUN is the most reasonable standard for SG NANs. Then again, IEEE 802.11s may be another decision as it broadens IEEE 802.11 MAC convention for WMNs and backings outline conveyance and course determination at MAC layer through radio-mindful measurements. In the topology of an IEEE 802.11s work organize, a focal entryway is utilized for information transmission to work stations. Work get to guides offer the entrance interfaces toward the end clients in either static or dynamic state. IEEE 802.11s backings rapid information transmission, which is not the same as SUNs. Along these lines, it may fill in as a choice to execute solid and fast remote NANs in SG. With the help of WiMAX technology, the capacity of a network backbone can be increased up to 1 Gbps fixed speed. Furthermore, electric systems suffering from environmental impairments can benefit from WiMAX technology to improve the performance of their communication systems, since WiMAX is characterized by its ability to cover a long distance. A large coverage as well as sufficiently high data rates makes the hybrid network topology more suitable for wireless automatic meter reading (WAMR) as part of utility automatic metering infrastructure [15].

Implementation of WAMR for revenue metering offers several advantages to electric utilities and service providers by eliminating the needs for human meter readers. Hybrid network can be used to provide real-time pricing information based on real-time energy consumption of the customers. This capability is very beneficial to let customers to shift off their loads during peak load times and lower their electricity bills. Due to the advancement achieved in wireless communications and digital electronics, hybrid network architectures can enable scalable wireless communications and provide different quality of service (QoS) requirements of electric systems in an economical manner. Major benefits of hybrid network architectures include improved communication reliability, lower installation costs, larger network coverage, and better network connectivity.

4) M2M Communications for HEMS: Recently we have seen increased attention given to machine to machine (M2M) communications in wired and wireless links. The aim of M2M communications is to enable M2M components to be interconnected, networked, and controlled remotely with low-cost, scalable, and reliable technologies. Diverse applications of M2M have already started to emerge in various sectors such as healthcare, smart home technologies, and so forth. The evolution of M2M has also taken place in SG. The focus of network infrastructure has shifted over from an emphasis on wired and fixed communications to flexible connectivity of wireless communications. The paper [16] provided extensive discussions of a number of existing communication technologies that can be adopted for M2M communications in SG, such as Bluetooth, IEEE 802.11 (WiFi), ultra-wideband (UWB), IEEE 802.15.4 ZigBee, 6LoWPAN, and so forth. Fig. 3 shows the roles of M2M in SG HANs. As demonstrated by the authors, ZigBee is a superior technology for HAN communications due to its characteristics of low power consumption, flexibility and short wake-up time. In addition, they presented a technique to improve the performance of conventional ZigBee-basedM2M communications in SG by incorporating intelligence in the gateway (GW) and M2M devices of the HAN.

In a conventional HAN, if M2M devices always attempt to send their periodic messages to a HAN GW, the HAN GW is relied upon to get a generally substantial number of messages. To this end, the creators proposed another methodology for transmitting power necessity message, in which a M2M gadget stays in noiseless mode unless its energy prerequisite changes. Along these lines, a HAN GW won't get any rehashed demands from the sameM2M gadgets and in this manner is less inclined to be overpowered by approaching solicitations from numerous M2M gadgets in the meantime. In [17], the creators introduced a diagram of M2M correspondences.

The empowering advancements and in addition the open research themes on M2M correspondences, for example, institutionalization, activity portrayal, convention re-outline, range administration, and ideal system plan. They tended to the system configuration issues of M2M interchanges for a home vitality administration framework (HEMS) in SG. The HEMS movement from the brilliant meter in each house can be amassed at a concentrator (i.e., door) to limit establishment and correspondence costs. Concentrator establishment cost remains for the physical organization (i.e., steering way) and the transmission capacity utilized by HEMS to transmit information to the base station.

This cost is assumed to be fixed over a certain time period. On the other hand, the deployment cost of a concentrator has to be minimized due to QoS degradation from packet delay and losses. For QoS degradation, the corresponding cost (i.e., the impact of QoS degradation on HEMS) is increased if HEMS traffic is not delivered to a control center quickly and reliably. To minimize the total cost, the nodes have to be divided into clusters, and each concentrator is assigned to one of the clusters. This is actually an optimal cluster formation problem, which can be solved by utilizing dynamic programming algorithms. For more works about SG distribution systems, the reader may refer to [21]–[23].

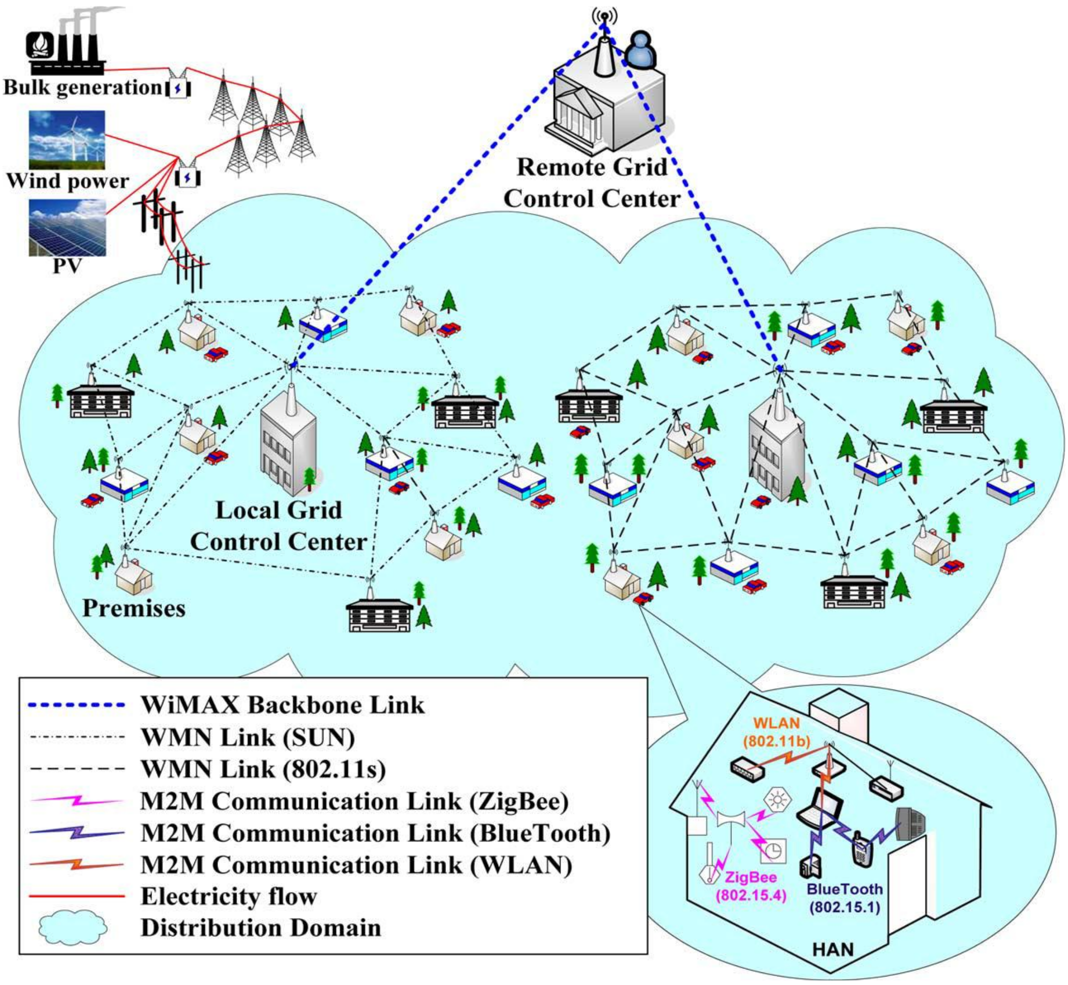

Fig. 3.*A hybrid network architecture uses WiMAX and wireless mesh networks, where ZigBee, BlueTooth, and WLAN are adopted for M2M communications in HANs. Local grid control centers monitor each wireless mesh domain using SUNs, IEEE 802.11s, or WSNs. The remote grid control center in a global network monitors each wireless mesh cluster using WiMAX.*

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