Communication Network for Smart Grid

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Abstract-*Smart grid is an intelligent power network featured by its two-way flows of electricity and information. With an integrated communication infrastructure, smart grid manages the operation of all connected components to provide reliable and sustainable electricity supplies. In smart power grid, an efficient reliable communication architecture plays an important role in improving efficiency, stability and sustainability. The communication infrastructure is multilayered structure that extends the whole smart grid from home area network (HAN) to neighborhood area network (NAN) and wide area networks (WAN). For communication between the subnet works a cognitive radio technology is added which improve spectrum efficiency by utilizing all available spectrum resources in smart grid. This paper focuses on cognitive radio based communication architecture for smart grid. The cognitive radio is mentioned to achieve dynamic spectrum access, interference avoidance, data throughput adaptive and act as a backup wireless communication technique in emergency situations for critical data transmission.*

I. INTRODUCTION

The existing U.S. electric power grid was built over 100 years ago with the aim to deliver electricity from large power stations to customers [1]. While there are some inconveniences that people face in their daily life because of the grid failures. Thus there is a need to make the current electricity network more reliable, efficient, secure, and environmentally friendly. This can be achieved by the next-generation power grid, i.e., the smart grid, which is characterized by a two-way flow of electricity and information, creating an automated, widely distributed energy delivery network. Smart grid is an intelligent power network that combines various technologies in power, communication, and control, which can monitor and optimize the operations of all functional units from electricity generation to end-customers [2].Based on which an optimized energy delivery network can be constructed. By introducing distributed control and pervasive communications into the grid, real-time information can be delivered and exchanged amongst all domains [2]. Customers can optimize their electricity usage for minimizing utility costs, and the control centers can make real-time power pricing and many other decisions according to energy demands [2]. Thus, a balance of power generation and demands in the entire grid can be achieved to significantly improve power quality and efficiency.

The smart grid is usually deployed in a considerably large geographical field. Accordingly, the communications infrastructure of the smart grid has to cover the entire region with the intention to connect a large set of nodes. The communication infrastructure is multilayered structure that extends the whole smart grid from home area to neighborhood area and wide area. The home area network (HAN) communicate with various smart devices to provide energy efficiency management and demand response. Neighborhood area networks (NANs) connect multiple HANs to local point. Wide area networks (WAN) provide communication links between the NANs and the utility systems to transfer information. As one of the core technologies, an efficient, reliable, and secure communication network plays an important role in realization of all the goals of smart grid NANs.

II. STRUCTURE OF SMART GRID

In the perspective of energy transmission, smart grid consists of four functional domains which includes bulk generation, transmission, distribution, and customer, which are normally deployed in a large geographical area. Correspondingly, the communication infrastructure of smart grid is assumed to be a hierarchical structure based on heterogeneous communication and networking technologies [1, 3], as depicted in Fig. 1.Bulk generation and transmission domains contains a number of distributed substations and transformer devices, which require pervasive monitoring and measuring to achieve wide area self healing and situation awareness control. Thus, WANs naturally can serve as a suitable networking choice which connects grid control centers and NAN data concentrators with long distances in very large areas, and transmits data in a very high-speed manner. The distribution domain includes distribution feeders and transformers to transmit electricity to customers. This domain provides two-way communications between smart meters and local utility centers (i.e. NAN data concentrators), forming so-called last mile communications in smart grid. Its data transmission rate is not as high as WANs and the transmission power is usually low based on short distance transmission.

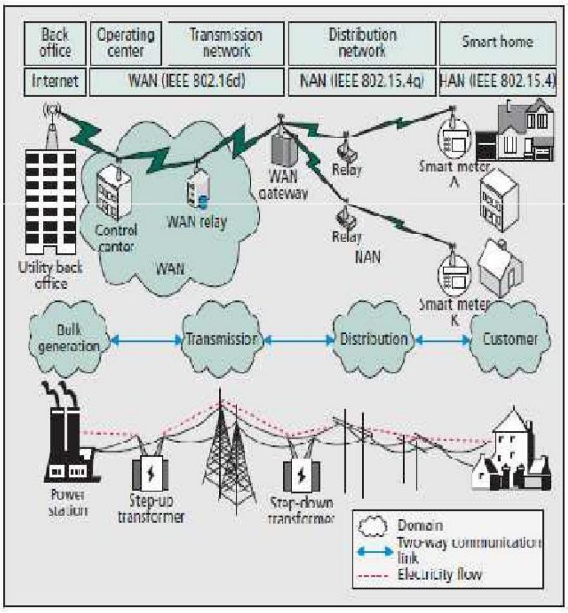

Fig.1. A conceptual model for deployment of smart electricity grid [2].

The electric devices with communication functions are irregularly distributed in this domain, where wireless communication technologies of NANs can be adopted. The customer domain includes intelligent electric appliances and smart meters, which are usually installed in buildings or home areas. Communication networks within such areas are required to support data traffic and control instructions delivered between the utilities and intelligent electric appliances. These networks are commonly known as home area networks (HANs). HANs connect various smart devices to achieve optimum energy usage and to implement demand response (DR) and advanced metering infrastructure (AMI). NANs fulfill the gap between HANs and WANs. WANs form the backbone communication links between NANs and the utility control centers [3].

III.COGNITIVE RADIO BASED COMMUNICATION TECHNIQUE FOR SMART GRID

Fig.2 shows the communication architecture for smart grid consisting of three-tiered hierarchical structure HAN, NAN and WAN. This architecture heavily leverages cognitive radio technology to enable the communications infrastructure more economically, flexibly, efficiently and reliably. On one hand, cognitive communications that operate in the license-free bands are applied in the HAN to coordinate the heterogeneous wireless technologies; on the other hand, cognitive communications that operate in the licensed band are applied in the NAN and WAN to dynamically access the unoccupied spectrum opportunities for emergency communication and additional communication.

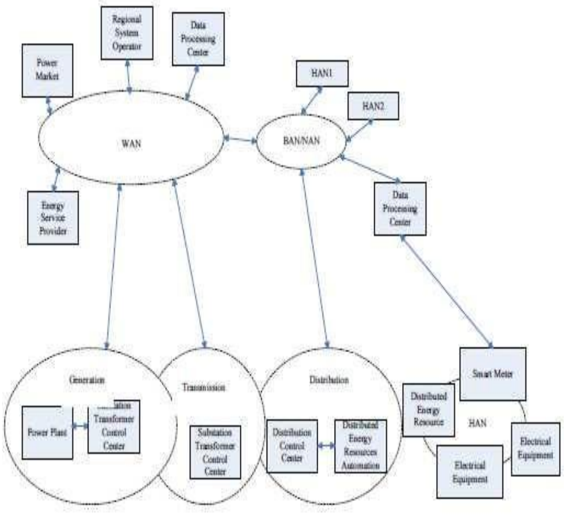

Fig.2. the Smart Grid Communication Infrastructure [3].

A. Cognitive Communication in HAN

HANs communicate with various smart devices to provide energy efficiency management and demand response. The communication technologies used in HAN includes wired and wireless, such as power line communication, ZigBee, Bluetooth and WiFi. Consequently, HAN is an essentially heterogeneous network with a number of complementary technologies. ZigBee recently defined an application layer standard for smart energy for HANs with intention of low-cost devices and low energy use [8]. However, operating on the license-free industrial, scientific, and medical frequency band, ZigBee is subject to interference from various devices that also share this license-free frequency band, ranging from IEEE 802.11 wireless local area networks or WiFi networks, Bluetooth, to baby monitors and microwave ovens. Studies have shown that WiFi is the most significant interference source for ZigBee within the 2.4GHz ISM band [9]. As the adoption of ZigBee for smart grid applications within homes, campuses, and commercial buildings becomes widespread, their usage in environments with prevalent WiFi networks introduces ZigBee and WiFi coexistence problems. To solve this problem the cognitive radio technology is introduced. In cognitive radio system, we need to select nodes to perform spectrum sensing, such as primary user detection, interference user detection, which will achieve spectrum efficiency and interference avoidance.

B. Cognitive Communication in NANs and WANs

In smart grid applications, NANs typically comprise multiple utility meters, each of which is installed on or outside of a house. NANs will collect energy consumption information from households in a neighborhood and deliver the information to a utility company through WANs. The majority of data is somewhat deterministic in the smart grid scenario since, by default, smart meters may periodically send information back to the utilities every 60 minutes for residential energy use, 15 minutes for commercial use, and 24 hours for gas and water meters data retrieval [3]. While the time period of data collection from various sources for different purposes can always be adjusted based on utilities' needs, the overall traffic pattern can be seen as ON/OFF and bursty. In order to effectively manage mountains of data generated in the smart grid, mechanisms for the network resource allocation and scheduling should be strategically planned and designed. In a cognitive radio based NANs, one can categorize and prioritize data so that these data will be treated appropriately during data transport through various paths/routes and possibly across heterogeneous networks before reaching the destination. Data are treated to be time-critical based on the occurrences of abrupt emergency, disaster, and the corresponding consequences. Examples include voltage drops, switching commands, and physical network links removals for maintenance during normal operation or abnormal destruction. The data should be distinguishable, handled differently in terms of class of service, and not interspersed with others. In such cases, the data should be transmitted by common wireless communication network to improve effectiveness and robustness, such as cellular communication, Internet etc. For the general data, such as Automatic Meter Reading data, logs and energy quality information, they may be transmitted by cognitive radio communication technology to provide broadband access and opportunistic access to unused spectrum. So data throughput adaptive is achieved especially in peak hours. Also, cognitive radio communication can act as a backup radio in emergency situations for critical data transmit [3].

IV. CONCLUSION

Smart grid relies on a dependable information and communication system. The smart grid is comprising of three sub networks namely HAN, NAN and WAN, communication between these three subnet works is achieved by using cognitive radio based technology. The cognitive radio based communications infrastructure for the smart grid is deployed for spectrum regulations and it specifies the new communications paradigm in the smart grid which gives better QoS support by utilizing all available spectrum resources in the smart grid, either licensed or unlicensed

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