Journal of Global Knowledge and Innovation (JGKI)

Volume 1, Issue 2, October-2024

ISSN 0000-0000

DOI: https://doi.org/10.5281/zenodo.13892318

JGKI: Volume 1, Issue 2, September 2024, online: ISSN 0000-0000

www.jgkijournal.com

SURVEY PAPER OPEN ACCESS Check for updates

Research on the architecture of electric power information communication network for smart grid.

[1]*Md sabbir pk, [2]Rafiqul Islam Roky

[1]Electrical Engineering and It's automation, North china electric power university, School of Electronic and Electrical Engineering, Ningxia University, Yinchuan.

sabbirpk30@gamil.com; rokyrafiqul@gmail.com;

Abstract

The integration of advanced information and communication technologies (ICT) is crucial for the successful implementation and operation of smart grids. In this research, we focus on the architecture of the electric power information communication network for smart grids. The aim is to develop an efficient and robust network infrastructure that can support the diverse and demanding requirements of a modern smart grid. This research begins with a comprehensive review of the existing literature and standards related to smart grid communication networks. It examines the challenges and limitations of current architectures and identifies the key requirements for a reliable and secure communication infrastructure. Based on this analysis, a novel architecture is proposed, taking into account the unique characteristics and needs of smart grids. The proposed architecture utilizes a hybrid approach, combining both wired and wireless communication technologies. It incorporates a multi-layered structure, consisting of the field, access, distribution, and core layers, to facilitate efficient and scalable communication. The field layer focuses on the integration of sensors, meters, and other devices at the edge of the grid, while the access layer provides connectivity for data transmission.

Keywords

Smart grid, Electric power, ICT

Journal of Global Knowledge and Innovation (JGKI)
Volume 1, Issue 2, October-2024
ISSN 0000-0000
DOI: https://doi.org/10.5281/zenodo.13892318

Introduction

The concept of a smart grid has gained significant attention in recent years as a promising solution for addressing the challenges faced by traditional power grids. Smart grids leverage advanced technologies to enhance the efficiency, reliability, and sustainability of electricity generation, distribution, and consumption. One key aspect of a smart grid is the integration of an efficient and robust information communication network that enables seamless communication and data exchange between various components of the grid. This research focuses on investigating the architecture of the electric power information communication network for smart grids, with the objective of designing a reliable and secure infrastructure to support the evolving needs of modern power systems. In the past, power grids were predominantly characterized by a unidirectional flow of electricity, with limited monitoring and control capabilities. However, with the integration of renewable energy sources, distributed generation, electric vehicles, and advanced monitoring devices, the traditional grid infrastructure has become inadequate to handle the complexities and dynamics of the modern energy landscape. Smart grids aim to overcome these challenges by integrating ICT into the power infrastructure, enabling real-time monitoring, control, and optimization.

The architecture of the electric power information communication network plays a crucial role in enabling the seamless flow of data and control signals across the smart grid. It needs to be capable of handling massive data volumes, supporting real-time communication, ensuring data integrity and security, and accommodating various types of devices and applications. Moreover, the architecture should be scalable, resilient, and adaptable to accommodate future technological advancements and evolving grid requirements. To design an effective architecture, it is essential to understand the existing literature, standards, and technologies related to smart grid communication networks. By conducting a comprehensive review, this research identifies the limitations and challenges associated with current architectures, including issues related to scalability, security, reliability, and latency. Building upon this knowledge, the research proposes a novel architecture that addresses these limitations and provides a framework for the development of an efficient and robust communication infrastructure for smart grids.

The proposed architecture embraces a hybrid approach, leveraging both wired and wireless communication technologies. It incorporates a multi-layered structure, including the field, access, distribution, and core layers, to facilitate efficient and scalable communication. Each layer focuses on specific functionalities, such as device integration, data transmission, information exchange, and data processing. By adopting a layered approach, the architecture ensures optimized resource utilization, improved network management, and seamless interoperability among different grid components. Furthermore, the research investigates the security and resilience aspects of the proposed architecture. As smart grids handle sensitive data and are potential targets for cyberattacks, robust security measures are essential. The research explores various security protocols, encryption techniques, and authentication mechanisms to ensure the confidentiality, integrity, and availability of data in the communication network. Additionally, fault-tolerant mechanisms and redundancy strategies are examined to enhance the resilience of the infrastructure against failures and disruptions.

To evaluate the effectiveness of the proposed architecture, simulations and real-world experiments are conducted. Performance metrics such as latency, throughput, scalability, and reliability are analyzed under different scenarios and traffic conditions. The results demonstrate the superiority of the proposed architecture in meeting the communication requirements of a smart grid, while maintaining high levels of reliability and security. This research contributes to the understanding and design of electric power information communication networks for smart grids. By addressing the limitations of existing approaches, the proposed architecture provides a foundation for the development of robust and efficient communication infrastructures, essential for the successful implementation of smart grids in the future. The research findings can guide utility companies, policymakers, and researchers in making informed decisions regarding the design and deployment of communication networks in smart grid systems.

Research motivation and contributions

As previously discussed, the smart grid presents new challenges for energy providers. This research aims to examine the communication needs of the smart grid and propose viable solutions to address future communication issues in the energy industry. Currently, a crucial aspect of the energy network gaining significance is the customer premises and the equipment installed on-site. These components consume the majority of the energy but are inadequately monitored. Additionally, the growing presence of distributed generators in consumer premises has underscored the necessity for effective control instruments to prevent power outages and soaring energy prices. Wireless communication technologies such as WiMAX have been suggested to facilitate communication with consumer premises, particularly for Smart Meter connections. However, the sheer number of smart meters in neighborhoods and the low traffic volume from each smart meter pose a challenge to the network's initial design, which caters to a limited number of users with substantial traffic on each connection. Consequently, novel packet schedulers, power control methods, and resource allocation algorithms are required to ensure satisfactory Quality of Service (QoS) while maintaining reasonable network throughput.

Therefore, the primary objective of this research is to devise a suitable wireless communication architecture that fulfills the communication requirements of smart grid applications. This wireless network should provide seamless connectivity and guarantee QoS capabilities. Worldwide Interoperability for Microwave Access (WiMAX) is a versatile wide area wireless network that has been selected to support smart grid applications, offering long-range communication channels and QoS support for diverse applications. The main contribution of this research lies in the examination of the WiMAX network standard for smart grid applications, as well as the development of communication models, architectures, and applications for various smart grid devices with varying QoS requirements. This contribution encompasses the analysis of path loss models for WiMAX devices and power control algorithms for the physical layer using the OFDMA technique.

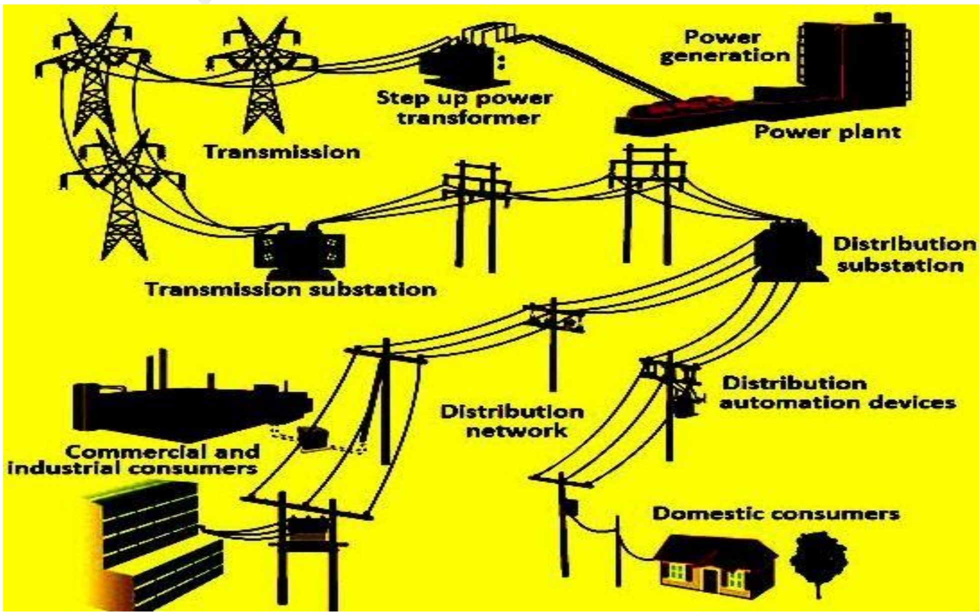
Volume 1, Issue 2, October-2024
ISSN 0000-0000
DOI: https://doi.org/10.5281/zenodo.13892318

Moreover, it involves the utilization of polling techniques and resource allocation methods for applications with diverse QoS requirements. Finally, this work provides insights into the mapping of smart grid applications and QoS parameters utilized in the WiMAX standard.

Smart grids

The smart grid represents an innovative concept that will facilitate the development of an advanced architecture for electricity distribution networks. This concept has garnered significant attention from researchers, industries, and governments in recent years. The smart grid, also referred to as the intelligent grid, signifies an evolutionary progression towards transforming the power distribution grid into an intelligent and self-healing architecture capable of meeting the demands of future electricity distribution networks. [3]Smart grid systems are recognized as multidisciplinary technologies, wherein control mechanisms, communication networks, and information technology components are integrated into the existing electricity distribution network. This integration aims to achieve a harmonious balance between energy generation and consumption while ensuring reliability, efficiency, cost-effectiveness, and environmental sustainability.

To facilitate effective operation of the electric distribution network, a communication network is superimposed on the energy distribution infrastructure. This communication network must possess sufficient transmission capacity to facilitate the exchange of information among all devices within the electric distribution network. It should support responsive control mechanisms to maintain the normal operation of the network. However, in current electricity grids, the deployment of communication networks is limited and not uniformly spread across the entire energy network. Many devices within the network lack satisfactory access to communication channels or have no communication capabilities at all. In response to this limitation, it is crucial to develop a communication architecture that ensures comprehensive connectivity for all devices throughout the network, adreing their information traffic requirements.



ISSN 0000-0000
DOI: https://doi.org/10.5281/zenodo.13892318

Figure 1: Realms of the conventional energy grid.

The subsequent section provides a brief overview of the smart grid architecture, highlighting the connection between future energy networks and control, communication, and information technology solutions. It elucidates how these technologies can enhance the operational performance of a smart grid network. Subsequently, the needs and challenges of the smart grid are discussed, with a specific focus on telecommunications network-based solutions. [4]–[6]The proposed smart grid models, such as the National Institute of Standards and Technology (NIST) and the Institute of Electrical and Electronics Engineers (IEEE) IEEE P2030 architecture, are explored from the perspective of telecommunications network architecture and smart grid applications. Following that, a review of several communication technologies applicable to smart grids is presented.

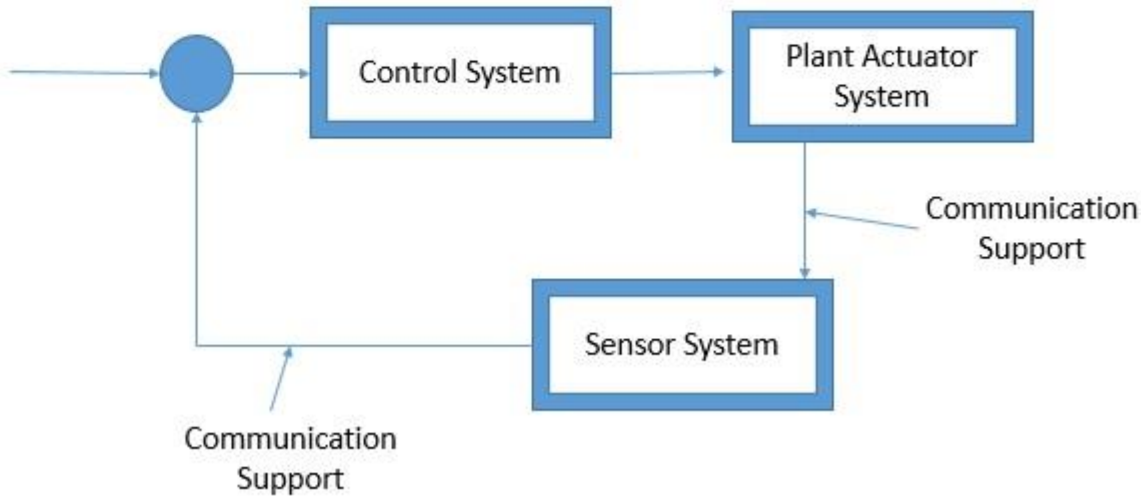


Figure 2: A feedback loop-based electric grid model leveraging sensor data.

Smart grid proposed architectures

The conceptual model for smart grids, as defined by the National Institute of Standards and Technology (NIST) under the U.S. Department of Commerce, categorizes smart grids into seven domains. These domains encompass the technical functions of the electric network as well as the stakeholders involved in power delivery. The seven domains are generation, transmission, distribution, customers, markets, operations, and service providers [14]. Figure 3 illustrates the NIST framework, showcasing a set of communication pathways essential for the optimal performance of the network. This model outlines the communication paths, electricity flows, and interconnected domains. The bottom four domains - generation, transmission, distribution, and customers - align with the domains explained in section 2.1.1, which describe the stages of power delivery and energy flow. It is crucial to note that energy flows are bidirectional, especially in the distribution-to-customer path. The market domain handles the negotiation of the

ISSN 0000-0000
DOI: https://doi.org/10.5281/zenodo.13892318

electricity market with other electric networks, determining the energy price for users based on supply and demand. [15] The operation domain encompasses applications such as billing, consumer consumption, user account management, and various operational aspects of the power company. Finally, the service provider domain focuses on developing services and applications for power companies and consumers to enable intelligent control of electricity usage. These seven domains must be interconnected through specific communication paths that meet diverse requirements, including real-time communication, end-to-end Quality of Service (QoS), long-range connectivity, and cybersecurity, among others.

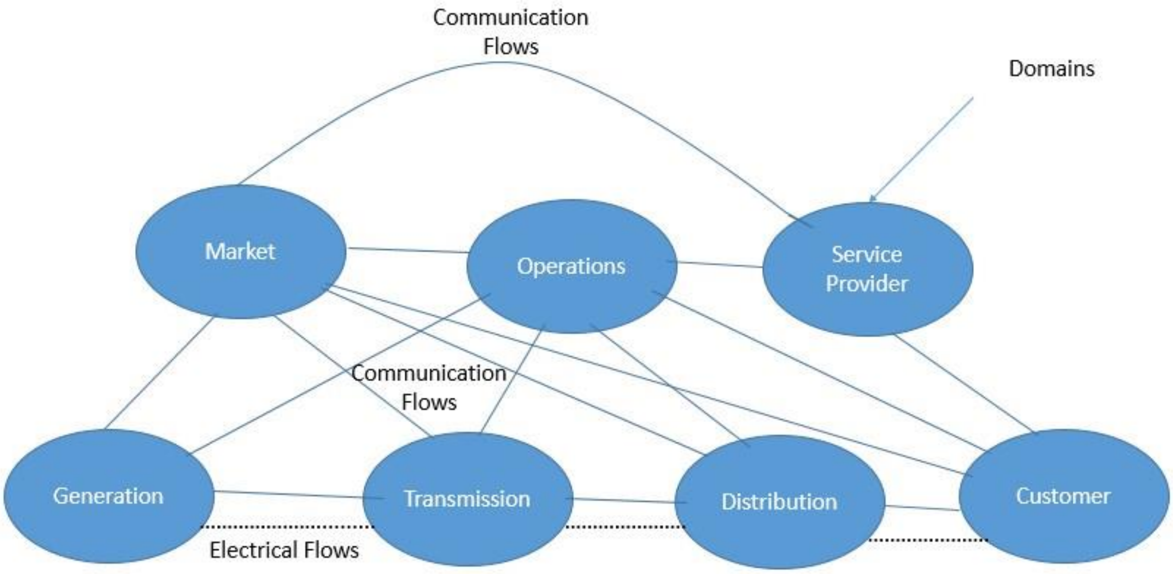


Figure 3: Smart Grids Framework as per NIST (National Institute of Standards and Technology).

According to the NIST model, several area networks have been proposed to facilitate communication between devices, databases, and controllers within a smart grid. Since each domain serves a different purpose and employs applications with distinct QoS requirements, the chosen networks vary accordingly. Examples of such networks include Local Area Networks (LAN) and Wide Area Networks (WAN). Each domain possesses an intra-domain network that supports communication among devices within the specific domain. Additionally, secure communication channels should be established to transmit information across different domains.[16]

Within the bulk generation domain, a set of industrial Local Area Networks (LAN) is deployed to facilitate communication within the generation plants. Furthermore, the transmission and distribution domains utilize Wide Area Networks (WAN) and Field Area Networks (FAN) to connect substations, transformers, data collectors, field devices, and other relevant components. FAN refers to wireless networks deployed in urban and suburban locations to serve field equipment and mobile workers in utility companies like power companies. These networks inherently possess long-range capabilities due to the

Volume 1, Issue 2, October-2024
ISSN 0000-0000
DOI: https://doi.org/10.5281/zenodo.13892318

extensive distance over which electricity is delivered. Moreover, the customer domain implements a premise network utilizing various communication technologies, including ZigBee, Wi-Fi, and Bluetooth.

[6]The NIST reference model is categorized into domains, information networks, actors, gateways, and communication paths. The seven domains represent the electricity delivery process, along with the markets, operations, and services discussed earlier in section 2.1.1. The information networks provide an abstraction layer through which information is transmitted to support the electricity delivery process. Different aspects of the network are represented by various information networks. First, the Internet/e-Business networks encompass internet-based networks designed for business purposes. Their architecture includes corporate LANs with business servers, Virtual Private Networks (VPN), firewalls, and security protocols. Second, the enterprise bus network describes networks within the utility company or its affiliated entities, typically comprising LAN or WLAN setups. Third, the substation LAN is an industrial-capable network designed to withstand the harsh environment of substations, which often involves high levels of electromagnetic contamination. While wireless LANs are not common in substations, they may be employed for specific applications. Fourth, Wide Area Networks and Field Area Networks serve the communication needs of the transmission and distribution domains. Notably, WAN and FAN networks boast long-range communication capabilities spanning tens of kilometers. Lastly, the premises network, also known as Home Area Network (HAN), is established to facilitate communication among electric appliances within households. The clouds depicted in Figure 4 represent various information networks supporting a smart grid, including Internet/e-business, enterprise bus, substations LANs, WAN, FAN, and HAN.

Inter-domain gateways play a crucial role in enabling communication across domains by providing specific application solutions tailored to each domain's requirements. For the market domain, the energy market-clearing house establishes connectivity between the markets and the e-business network, collecting information from aggregators, retailers, wholesalers, and regulatory bodies. In the operations domain, four gateways ensure the smooth operation of the system: Regional Transmission Organization (RTO), supervisory control and data acquisition (SCADA) system, transmission SCADA system, and distribution SCADA system, along with the metering system. In the service providers' domain, two important gateways are the billing system and the Customer Information System (CIS). The generation domain features three gateways that provide information from the plant control system and generators, enabling the exchange of specific generation-related information. The transmission and distribution domains share common and shared gateways, including the substation subsystem, substation controller system, data collector system, energy storage system, and device information system. These systems gather information about the transmission and distribution processes and operate according to control procedures. Lastly, in the user domain, the meter and the energy services interface collect information from all appliances within consumer premises and facilitate information exchange among the markets, services, and user needs. Table 2 provides a mapping between the actors, gateways, and domains, highlighting their relation to the smart grid task force and the NIST architectural model.

Domain	Related NIST diagram actors	SG network task force reference actors
Generation	Bulk generators	Generators
	Plant control system	Plant control system
Transmission	Distributed generator	Distributed generator
	Field Area Network Gateway	Field Area Network Gateway
	Field device	Voltage regulators
		Field sensors
	Storage system	Distributed storage
	Substation controller	Distribution Application Controller (DAC)
	Substation device	Substation device
Distribution	Distributed generation	Distributed customer generation
	Field device	Capacitor bank
		Circuit breaker
		Recloser
Customer	Appliances	Smart Appliances
	Customer EMS	Customer Energy Management System (EMS)
	Customer equipment	In Home Device (IHD)
		Load Control Device (LCD)
		Heating, Ventilating and Air Conditioning (HVAC)
	Distributed generation	Distributed Electric Resources (DER)
	Meter	Smart Meter
Markets	Aggregation Retail Energy	Retailer Wholesaler
	Aggregator	Aggregator
	RTO/ISO	Regional Transmission Operator (RTO) / Independent System Operator (ISO)
Operations	Demand Response	Demand Side Management (DSM)

Volume 1, Issue 2, October-2024
ISSN 0000-0000
DOI: https://doi.org/10.5281/zenodo.13892318

	Distributed SCADA	Distributed SCADA Front End Processor (FEP)
	DMS	Utility Distribution Management System (DMS)
	EMS	Utility Energy Management System (EMS)
	RTO SCADA	Regional Transmission Operator (RTO) SCADA
	Transmission SCADA FEP	Transmission SCADA Front End Processor (FEP)
Service Provider	Bill Payment / Bank organization	Bill Payment
	Internet external gateway	Internet Gateway
	Utility billing	Utility CIS Billing
	Web portal	Web portal

Wireless networks for the smart grid

The design of various area networks supporting the requirements of smart grids presents its own set of technical challenges. A key aspect in meeting the demands of data traffic is to establish connectivity among sensors, actors, and other communication devices throughout the entirety of the smart grid, whether in rural areas or densely populated urban centers. The specific needs of smart grid networks differ significantly from existing broadband mobile networks or point-to-point networks currently utilized in power energy networks. This crucial issue will be thoroughly examined in this research endeavor.[19]

Researchers widely agree that the optimal approach to meet the aforementioned requirement is through the utilization of Wireless Networks (WN) rather than fixed networks. WN offers connectivity over expansive areas with the necessary bandwidth capacity and ensures Quality of Service (QoS) maintenance, including low-latency connections. The advantages of wireless communications lie in the cost-effective deployment of WN across large areas compared to wired channels, particularly when smart grid data traffic requirements are relatively low compared to multimedia applications. Additionally, wireless networks provide scalability and facilitate easy upgrades without the need for an entire architecture overhaul. The industry currently considers two wireless networks for future implementation in smart grids: WiMAX and Long Term Evolution (LTE) standards. The IEEE P2030 standard, within the communication interoperability section, recommends the inclusion of both technologies when designing the last mile access for the distribution domain and WAN to support applications in the transmission and distribution domains. Previous research has extensively explored the WiMAX standard as a solution for wireless broadband network applications. Moreover, WiMAX is recognized for offering comprehensive end-to-end Quality of Service specifications based on the IEEE 802.16 standard, making it a suitable

Volume 1, Issue 2, October-2024
ISSN 0000-0000
DOI: https://doi.org/10.5281/zenodo.13892318

solution for smart grid applications utilizing private networks. In contrast, LTE is typically associated with public networks. To date, limited research has been conducted to investigate the performance of WiMAX networks for smart grid applications, which constitutes the primary focus of this study.

Wimax in the smart grid

The WiMAX wireless network technology is built upon the IEEE 802.16 standard. WiMAX employs point-to-multipoint (PMP) connections designed to facilitate long-range connectivity with support for various Quality of Service (QoS) types. The QoS is maintained through the utilization of appropriate resource allocation mechanisms, scheduling schemes, and service class definitions. Each scheduling class employs packet scheduling algorithms that analyze incoming traffic and transmission channel status, mapping the information onto frames transmitted over the wireless channel. While the IEEE 802.16 standard does not specify the algorithms for practical implementation, this presents opportunities for researchers to develop suitable resource allocation methods for diverse applications such as smart grids. Currently, there are no proposed algorithms specifically tailored to smart grid applications, particularly for low-latency and sporadic bandwidth requests, which will be the primary focus of this research.[20] The WiMAX standard is a progressive technology recognized for its ability to reach users situated at significant distances. Long-range connectivity is achieved through adaptive transmission techniques enabled by the selection of Modulation and Coding Scheme (MCS) for users with high Signal-to-Noise Ratio (SNR) connections. Terminals experiencing low SNR conditions are assigned appropriate MCS values to mitigate packet losses.

However, employing the WiMAX standard to reach a large number of customers and electrical devices poses challenges for wireless networks due to the dynamic characteristics of wireless channels and the variability in network user distribution patterns. Preliminary simulation results of a WiMAX network utilizing smart meter traffic sources demonstrate that serving a substantial number of meters is impacted by the number of admitted connections and link quality. Two main issues arise for low SNR users. First, the use of Adaptive Modulation and Coding (AMC) schemes in low SNR conditions results in higher MCS values, increasing the number of symbols required to transmit the same amount of data compared to good SNR connections, leading to rapid depletion of WiMAX frame capacity. The second problem occurs for terminals with extremely low SNR, where bandwidth requests (BWReq) from these terminals fail to reach the Base Station (BS), consequently resulting in no resource allocation. As a result, these terminals do not receive any mapping information on the Downlink Map (DL-MAP) and are unable to transmit any data. Receiver sensitivity significantly impacts this parameter in WiMAX radio transmitters.

Smart grids applications, requirements and characteristics

Smart grid applications encompass a multitude of parameters and prerequisites crucial for optimal grid performance. These parameters are contingent upon the specific characteristics of each application. The IEEE P2030 standard introduces a framework

Journal of Global Knowledge and Innovation (JGKI)
Volume 1, Issue 2, October-2024
ISSN 0000-0000
DOI: https://doi.org/10.5281/zenodo.13892318

that outlines these characteristics, enabling the classification of applications based on a range of values or qualitative considerations. These attributes encompass diverse aspects, including coverage, end-to-end delay, packet size, data generation characteristics, reliability, and security factors. Through this classification, the most suitable communication technology for a given application can be determined based on its specific parameters. Table 3 displays the data characteristics alongside their respective classification values for each category.[14] The initial characteristic pertains to coverage range, which can span from short distances under ten meters to over a kilometer. Application latency can be categorized into four groups, ranging from seconds to a few milliseconds, indicating real-time or non-real-time communication links. Synchronization requirements are divided into two groups: applications necessitating synchronization with others across the entire network and those that do not require any synchronization. The subsequent characteristic addresses data generation parameters, including data burst size, occurrence interval, broadcast method, and priority. Data burst sizes can vary from small byte packets to gigabytes of information, while occurrence intervals encompass values in milliseconds, seconds, minutes, and even hours. The broadcast method may involve unicast, multicast, broadcast, or a combination of these approaches, and the qualitative priority level can be classified as none, low, medium, or high. The following group encompasses qualitative parameters related to information reliability, such as information quality, information availability, and the impact of specific information on smart grids. Information quality can be characterized as informative, important, or critical, while availability is classified as low, medium, or high. The impact of not having the information is defining as limited, serious, severe, or catastrophic. Lastly, the last group covers the security aspects of information, including confidentiality, integrity, and availability. These three parameters are classified into none, low, medium, or high values.

Data Characteristic		Classification/ Value Range			
Coverage		< 10m	<100m	<1Km	>1Km
Latency		Real time		Non-real time	
		Low-low < 5 ms	Low < 20 ms	Medium < 1 sec	High > 1 sec
Synchronicity		yes		No	
Data generation	Burst Size	Bytes	Kilobytes	Megabytes	Gigabytes
	Occurrence interval	Milliseconds	Seconds	Minutes	Hours
	Broadcast method	Unicast	Multicast	Broadcast	All
	Priority	None	Low	Medium	High
Information reliability	Quality	Informative		Important	Critical
	Availability	Low		Medium	High
	Impact	Limited	Serious	Severe	Catastrophic
Security	Confidentiality	None	Low	Medium	High
	Integrity	None	Low	Medium	High
	Availability	None	Low	Medium	High

Table 3. Data categorization chart for the IEEE P2030 reference model.

Wimax network architecture for smart grid communications

This chapter provides an overview of the WiMAX IEEE 802.16e standard and its significance in designing the communication architecture for a smart grid. WiMAX technology has been developed as a wireless broadband network (WBN) to cater to the communication requirements in the distribution domain of smart grids. It is based on the IEEE 802.16 standard and backed by the WiMAX forum, which was established in June 2001. The WiMAX 360 community consists of multiple industrial organizations with the goal of guaranteeing compatibility among WiMAX products through accredited practices and offerings. According to the WiMAX 360 community, WiMAX technology can deliver services comparable to high-performance Wi-Fi networks while offering long-range coverage. It also provides Quality of Service (QoS) similar to cellular networks, enabling connectivity for thousands of users connected to a single base station. Furthermore, the WiMAX standard supports various applications, including machine-to-machine (M2M) connectivity, which forms the foundation of a smart grid communication network. The WiMAX standard encompasses Wireless Metropolitan Access Networks (WMAN) and Wide Area Networks (WAN) architectures. WiMAX networks are designed to operate in both NonLine-of-Sight (NLOS) mode for carrier frequencies below 11GHz and Line-of-Sight (LOS) mode for frequencies ranging from 10 to 66GHz. Additionally, WiMAX employs two types of channel structures: Single Carrier (SC) and Orthogonal Frequency Division Multiplexing (OFDM). The data rates of WiMAX networks can reach up to 70Mbps, depending on the radio channel conditions and the adaptive modulation and coding (AMC) technique employed. The coverage radius of WiMAX can span from 0Km to 50Km. This chapter examines the WiMAX standard, specifically the IEEE 802.16-2009 version (commonly known as 802.16e), and explores various modifications proposed by different researchers.

Wimax physical layer services

The initial assessment focuses on the fundamental layer of the WiMAX protocol, as it performs vital functions in shaping a wireless communication system for the intelligent grid. It manages the performance metrics of a network, which define the cell's capacity and dimensions, along with the protocols governing network access, power control, and distribution of resources, working closely with the MAC layer. This segment introduces the fundamental elements of the WiMAX physical layer that pertain to the development of the architecture for the smart grid.

Network entry procedures

When a network device wishes to join a WiMAX network, several operations must be carried out before the device is acknowledged as an active user. This section investigates the initial process known as the ranging procedure. The ranging process allows the user to synchronize with the network's timing and adjust power levels for data transmission based on the quality of the connection.

The first consideration for a network device seeking to join the network is to scan the DL broadcast messages of the network and synchronize with the frame timing of the base station (BS). This entails locating the preamble field in the OFDMA frame by scanning the potential DL channels and retrieving the network's downlink map organization (DL-MAP), uplink map organization (ULMAP), downlink channel representation (DCD), and uplink channel representation (UCD) messages. These messages are transmitted using the strongest modulation and coding scheme, namely QPSK with a ½ rate coder. After collecting all the configuration data for the downlink (DL) frame, the user then proceeds to send an initial ranging message (RNG-REQ) using CDMA codes in the initial contention ranging slot, with a null value assigned to the connection identifier (CID). If the transmission is successful, the BS responds with a RNG-RSP message containing information on the ranging status, timing adjustment values, power adjustment values, offset frequency adjustment values, basic and primary management CIDs, a 48-bit MAC address, and a DL burst profile or ranging subchannels, among other response details. Subsequently, the users proceed to send the initial ranging message known as DBPC-REQ, employing a selected power level where the transmission power is denoted by equation 1:

Equation 1: PTX_IR_MAX= EIRxPIR, MAX + BS_EIRP-RSS

Here, EIRxP represents the maximum equivalent isotropic received power at the subscriber stations, while BS_EIRP denotes the equivalent isotropic transmitted power by the BS (this value is transmitted in the DCD message). RSS stands for Received Signal Strength. By utilizing equation 1, initial power corrections are made by calculating the path loss based on the received power, the BS transmitted power, and the receiver's sensitivity. However, the calculation is not precise due to the usage of different channels for the UL and DL. As a result, the base station (BS) replies with a DBPC_RSP message to rectify or uphold the current power transmission level. This process can conclude in one of three scenarios: firstly, a 'success' indicating the fulfillment of the ranging and initial ranging procedures; secondly, a 'continue' ranging process with fresh tuning parameters for the SS power values; thirdly, an 'abort' ranging when the BS chooses to prematurely terminate the ranging process without success. If the first RNG_REQ message fails to reach the BS, the SS resends the RNG_REQ message while incrementing the transmission power in steps of 1 dB. The retransmission and power increment processes continue until the maximum transmission power is reached. Once a user receives a 'success' RNG_RSP message, it becomes connected to the network. However, the connection stage does not imply activation. To activate the user, the following process must be completed. SS authorization and key exchange procedures provide security levels for data transmission and authenticate the connected user. Subsequently, registration to the network must be finalized to identify the user within the network. The SS must establish IP connectivity using the Dynamic Host Configuration Protocol (DHCP) services to obtain an IP address.

Journal of Global Knowledge and Innovation (JGKI)
Volume 1, Issue 2, October-2024
ISSN 0000-0000
DOI: https://doi.org/10.5281/zenodo.13892318

Finally, a service connection is established through the Dynamic Service Addition (DSA) service procedure. Further details regarding this last process are outlined in section 3.2.1., which is mandatory for every network entry procedure.

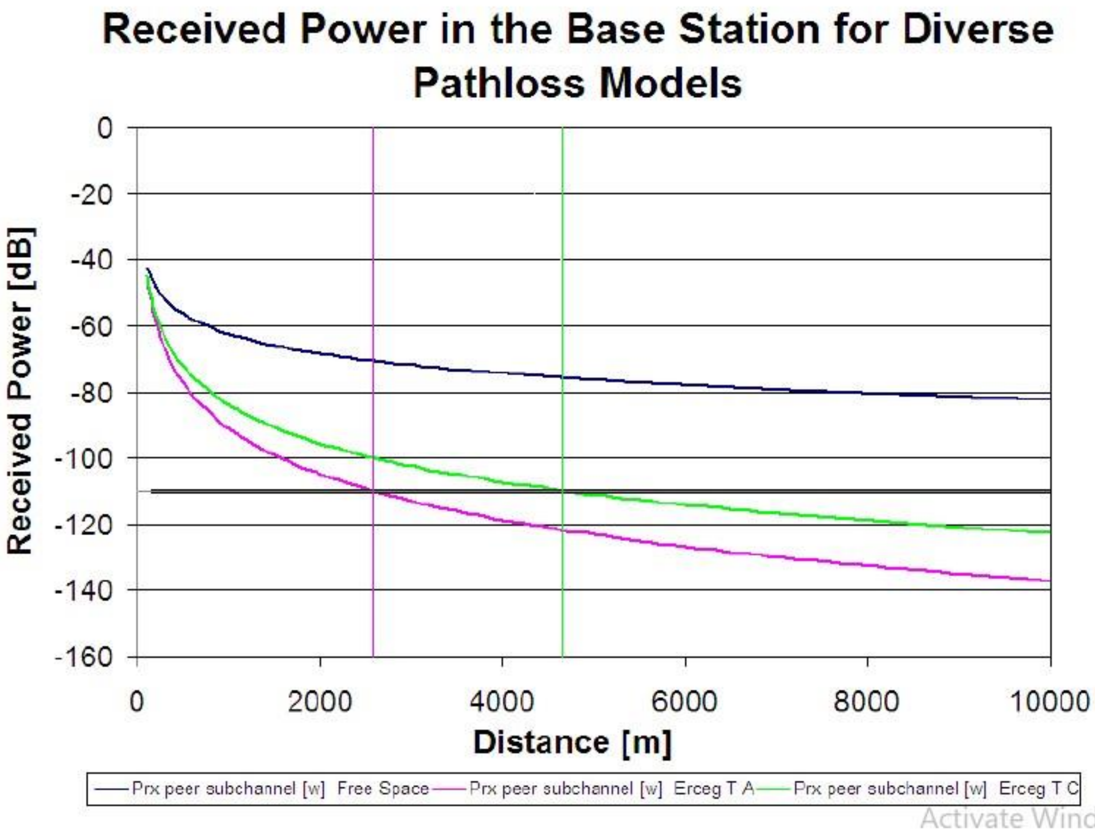


Figure 4: Illustration of received signal strength for various distances utilizing a transmission power of 62.5mW.

The power control algorithms are initiated after the completion of the ranging process. The control process, occurring at the BS, utilizes the path loss reported by the SS during periodic ranging or the bandwidth request process to calculate the SS's transmitted power. The power control algorithm establishes the target value for received power. If the measured received power exceeds the target value, a PMC_Req message is sent to reduce the transmitted power level. Conversely, if the power level is too low, a PMC_Req is sent to increase the transmitted power level. The transmitted power level is incremented step by step, with a default step size of 1 dB. Figure 16 illustrates the SNR measured at the BS for a user using three different path loss models, considering both the absence of power control and open-loop control options. The results demonstrate a reduction in SNR within

Journal of Global Knowledge and Innovation (JGKI)
Volume 1, Issue 2, October-2024
ISSN 0000-0000
DOI: https://doi.org/10.5281/zenodo.13892318

the first kilometer of the graph, highlighting the impact of the open-loop control technique.

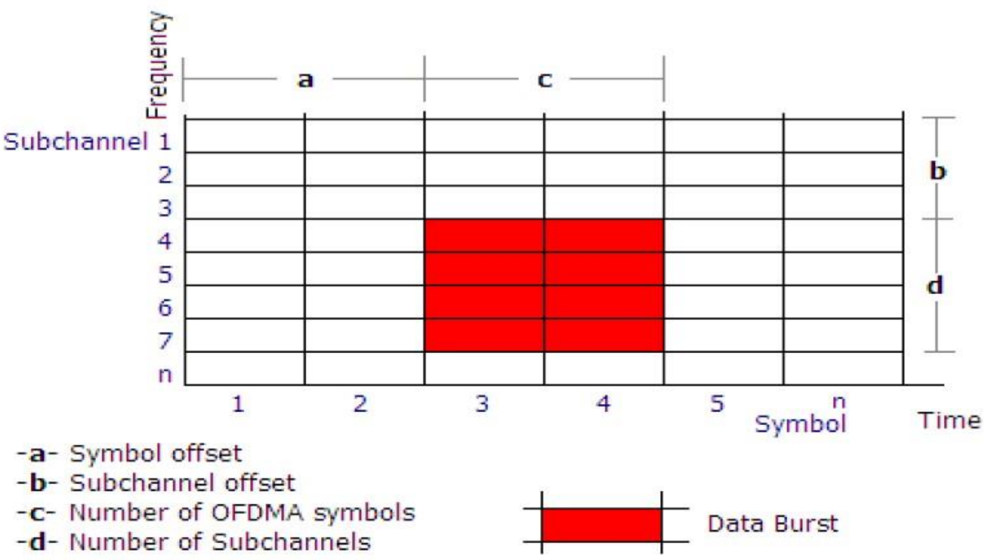
However, when the received power exceeds the limits of the receiver sensitivity, the SS attempts to increase the transmitted power, but it is automatically reduced to the ranging stage due to the maximum power level limitation, which defaults to half of the maximum power. This parameter can be modified in the ranging and network entry algorithms.

The DL subframe structure

The DL subframe consists of a preamble, frame control header (FCH), DL-MAP information slot, UL-MAP information slot, and DL data bursts. The preamble is a one-symbol message that transmits one of 128 distinct patterns, utilizing all subcarriers and employing BPSK modulation. This preamble serves purposes such as initial and handoff synchronization of users, cell/sector identification, and channel estimation. The frame control header (FCH) contains information regarding the size and position of the DL-MAP and UL-MAP messages. It is transmitted in four contiguous subchannels at the beginning of the DL Subframe, utilizing QPSK modulation and a coding rate of ½. The DL-MAP carries information about the structure of the DL subframe. It defines multiple zones within the frame and specifies the position of each data burst through the inclusion of DL-MAP IEs (DL mapping information elements). These information elements encompass details such as symbol offset, subchannel offset, the number of OFDMA symbols, the number of subchannels, CID (Connection ID) of the destination user, and transmission power boosting information. Figure 19 illustrates the significance of these parameters in the DL subframe. Similarly, the UL-MAP in OFDMA contains information related to the UL subframe. It maintains the same configuration as the DL-MAP but employs the UL-MAP IE. The size of both the DL-MAP and UL-MAP increases with the number of users, which is a common scenario in a smart grid network. Hence, it is crucial to minimize these fields within a network to optimize data capacity.

The UL Subframe structure

The UL subframe comprises the initial ranging zone, periodic ranging zone, contention zone, fast feedback channel, and UL data bursts. The positions of each zone and data bursts are specified in the UL-MAP.



Volume 1, Issue 2, October-2024

ISSN 0000-0000

DOI: https://doi.org/10.5281/zenodo.13892318

Figure 5: Information elements for mapping channels in the OFDMA scheme

The ranging zones are designated for users entering the network or those who have lost synchronization and need to transmit information to the BS. The contention slot is utilized by users polled in multicast/broadcast mode (refer to section 3.2.3). The fast feedback channel serves the purpose of providing channel quality information from specific users to adjust transmission power characteristics based on CINR (Carrier-to-Interference plus Noise Ratio) reports. Lastly, it accommodates the UL data burst from the allocated users.

Wimax mac layer services

The WiMAX MAC services in a WiMAX network work in conjunction with the physical layer to grant users access and uphold their QoS requirements. This section elucidates the process of data transmission that follows the network entry procedure. When a terminal joins a WiMAX network, it undergoes the network entry procedures to gain acceptance into the network. Subsequently, the terminal requests admission from the BS to enable data transmission and reception based on various QoS parameters. [21]After connection admission, if the terminal intends to transmit data, it submits a resource request specifying the size of the data to be transmitted. The BS receives this request and forwards it to the schedulers. Once the schedulers allocate the necessary bandwidth, a transmission slot is assigned to the specific SS in the UL-MAP. The SS utilizes the allocated slot to successfully transmit the desired data. This section provides a comprehensive explanation of these procedures and their implications for smart grid applications. The WiMAX technology supports MAC layer QoS through the definition and implementation of techniques outlined in the subsequent sections. Service classes, traffic classifiers, service flows, bandwidth requests, scheduling, mapping, and allocation are fundamental techniques that uphold QoS in the network.

Traffic services classes

A variety of service classes are employed in WiMAX networks to provide flexibility for different services across various BSs. Consequently, the responsibility of generating service classes shifts from the servers to the BS, eliminating the need for server-generated classifications. These service classes aim to define distinct QoS levels for different traffic sources. Notably, the priority level plays a significant role in determining how a particular

ISSN 0000-0000
DOI: https://doi.org/10.5281/zenodo.13892318

class is serviced, with schedulers handling the priority level. The schedulers allocate resources based on parameters such as the maximum sustained traffic rate (MSTR), minimum reserved traffic rate (MRTR), maximum latency, maximum traffic burst, unsolicited grant interval (UGI), and unsolicited polling interval (UPI), all of which hold relevance for smart grid applications.

Various scheduling algorithms define the procedures used to support different traffic flows. Within the WiMAX standard, schedulers utilize the following service classifications for resource allocation: unsolicited grant service (UGS), extended real-time polling service (ertPS), real-time polling service (rtPS), non-real-time polling service (nrtPS), and best effort. However, if different applications require the same class of service but with different parameters, they can be distinguished by other service parameters depending on the scheduling algorithm employed.[22]

Scheduler algorithms describe how a BS handles the traffic of specific applications. The UGS class caters to constant-rate video applications by serving a fixed traffic rate in periodic intervals. The ertPS class is utilized for voice calls with silence suppression, as it accommodates variable burst sizes with periodic allocations. The rtPS class is suitable for delay-sensitive applications that do not require frequent allocations, such as error and alarm messaging. The nrtPS class offers minimal QoS support for delay-sensitive applications with low data traffic rates. Lastly, best effort connections do not enforce delay constraints, and their resource allocations are based on network resource availability. The MSTR parameter determines the maximum transmission rate allowed for a connection. It is a six-bit code that describes the transmission rate in bits per second, excluding upper layer protocol overheads. MSTR is calculated based on a long-term average of transmission bursts rather than the instantaneous burst size. However, the BS is not obligated to serve at this rate; instead, the MRTR establishes a lower limit for the traffic rate that the scheduler must guarantee for the specific connection. The maximum burst parameter, similar to MSRT, defines the maximum transmission rate for an instantaneous burst. It is configured in bits per second, and the burst size within a frame is calculated based on the size of the OFDMA frame. The maximum queue latency denotes the maximum time a packet can wait in the queue before transmission. Although optional, this parameter helps determine the maximum acceptable delay prior to transmission. The unsolicited grant interval (UGI) and unsolicited polling interval (UPI) represent the same parameter used for different scheduling types. UGI refers to the time between consecutive grants for UGS and ertPS connections. It is calculated by dividing the configured average burst size by UGSMRTR and is solely utilized for UGS and ertPS connections. UPI, or inter-polling time (IPT), is employed for rtPS and active nrtPS connections, defining the time between consecutive polls. Further details regarding the last parameter are discussed in section 3.2.4.
As explored in section 2.4.1, the service classes for smart grid applications are associated with the priority of data generation, service type, and latency requirements of these applications. Table 14 presents the parameter values for service classes used in smart grid applications, specifically focusing on the relevant parameters for nrtPS and rtPS.

Volume 1, Issue 2, October-2024
ISSN 0000-0000
DOI: https://doi.org/10.5281/zenodo.13892318

Service Class name	Scheduling type	MSTR	MRTR	Maximum burst	Maximum latency	Interpolling time
Metering	nrtPS	40bps	40bps	1kbps	N/A	500 sec
Demand	rtPS	100bps	100bps	1kbps	150 sec	120 sec
Sensor	rtPS	200bps	200bps	1kbps	150 msec	100 msec
Default	BE	1kbps	NA	NA	NA	NA

Service category definition for the smart grid.

The traffic classifiers employed in SSs and BSs are responsible for assigning packets from users/servers to specific service classes and subsequent service flows. They utilize the IP type-ofservice (ToS) field in the IP packet header, which has already been designated for a service class as outlined in section 1.4.1. These classifiers are obligatory and play a crucial role in the network's QoS differentiation procedures. Based on the prioritization of data generation for the defined applications and the ToS values specified in section 1.4.1, Table 15 presents the classifier table utilized for smart grid applications. This table illustrates the relationship between the assigned IP ToS flag of each packet and the corresponding service class it should be assigned to. In cases where packets do not match any IP ToS values in the table, they are allocated a best effort connection, which serves as the default classification.

Contention-based and multicast/broadcast polling

The contention-based polling serves as a mechanism employed in conjunction with multicast and broadcast transmissions. The primary goal of contention-based polling is to minimize the space used for individual allocations, particularly when users are idle and do not require polls to be issued. The BS establishes broadcast or multicast groups and assigns users to these groups, creating a group CID. Subsequently, polling is transmitted with a group CID corresponding to the desired group, expecting that users in need of transmission will utilize the allocated space. However, the BS may lack awareness regarding the number of users expected to respond and which allocations will be utilized, thereby increasing the likelihood of collisions. To address this issue, the WiMAX MAC protocol suggests that users can respond using the contention area designated for this purpose. Within the contention area, there exist two types of contention slots: initial ranging and periodic ranging. The periodic ranging zone, also referred to as the contention slot or Request IE, serves as the zone where contention BWReqs are sent back to the BS. Due to the nature of the contention mechanism, only SSs with BWReq needs are expected to respond. In a WiMAX network, users can respond in two ways. First, they can employ only the MAC Header Type I with a stand-alone BWReq, as explained in the preceding section. Alternatively, they can utilize the CDMA-based contention mechanism, which is elaborated upon below.

The CDMA-based contention mechanism employs a series of pseudorandom CDMA codes defined in the standard. The code is randomly chosen with equal probability from a set of Periodic Ranging Codes and is inserted into the Randomly selected Ranging Slot. An SS that needs to transmit a BWReq sends the CDMA code in the ranging slot and waits for a response from the BS. Since the BS cannot determine which SS sent the code due to the nature of the CDMA code, it replies with a broadcast allocation. The CDMA allocation IE is a broadcast/multicast ranging response message that contains the same CDMA code as the requested user. The user decodes the CDMA allocation IE and employs the allocation for transmission. In WiMAX, this allocation is solely permitted for sending BWReqs and has a fixed size of six bytes.

The contention mechanism utilizes transmission opportunities, which are defined as the allocations assigned in the UL-MAP for SSs assigned to a specific group. The number of transmission opportunities depends on the size of the allocation made and the size of the BWReqs, and this information should be included in the UL Channel Descriptor (UCD) (i.e., UCD TVL 'BWReq opportunity size'). Figure 24 provides an example of a Request IE sent in the UL-MAP containing three opportunities.

Figure 6: Illustration of a Request Information Element (IE).

When an SS connection has data to send using the contention algorithm, it sets an internal backoff window equal to the initial size specified in the UCD message. Subsequently, it selects a random number within the window, representing the number of transmission opportunities that the SS must wait before sending a BWReq within a Request IE. Following the transmission of the BWReq, the SS awaits a response (Data Grant Burst Type IE) within a timeout period. If the contention-based timeout expires, the SS assumes that the transmission was unsuccessful, indicating a collision occurred, and triggers a reattempt. The SS duplicates the size of the internal backoff window up to the maximum size described in the UDC message and selects a new random value. This reattempt process continues until the maximum Requests Retries value is reached.

Demand management system architecture using the wimax standard network

This chapter examines the effectiveness of a smart grid network utilizing multiple applications. In comparison to the content presented in chapter 4, this chapter introduces

Volume 1, Issue 2, October-2024
ISSN 0000-0000
DOI: https://doi.org/10.5281/zenodo.13892318

a traffic model for various smart grid applications, thereby achieving the architecture of a demand management system. To assess its performance, the smart grid communication network model incorporates a Demand Management System (DMS) application and an Emergency Sensor Reading application as the primary sources of traffic. These applications were selected because one of the primary objectives of the smart grid network is to regulate the processes of energy generation and consumption. The integration of renewable energy sources in the generation process has necessitated the inclusion of a consumption management system, whether in real-time or non-real-time. While an application like smart meter reading effectively acquires consumers' information, it lacks the ability to control their consumption or provide provisions for appliance controls. Consequently, the implementation of demand management system control applications and sensor reading throughout the smart grid network could enable control over distributed generators and meet consumers' electricity demands.

The smart grid can employ a WiMAX network as a communication interface linking customer applications, smart grid operational entities, and service domain entities. This network can support household-related applications such as Smart Meter Reading and Demand Side Management. Likewise, sensors deployed across the distribution network can utilize the WiMAX communication interface similar to the one employed by smart meters. However, the sensor readings could be given higher priority within the WiMAX network.

This chapter elucidates the particulars of various smart grid applications and their association with the WiMAX network. Subsequently, it introduces a simulation model employed to integrate the new applications, encompassing distribution and application models, as well as the appropriate WiMAX network parameters. The chapter then presents a performance analysis of a demand site management system and smart reading applications, investigating parameters like delay, capacity, and packet losses within the smart grid communication network. Following the analysis of the DMS performance, a similar examination is conducted for emergency data reading applications derived from a distribution sensor network. Lastly, the chapter summarizes the findings and emphasizes the design of the communication network to optimize the operational characteristics of a smart grid network.

Applications description

As outlined in section 2.4, this smart grid communication network encompasses three applications, namely Metering Reading, Demand Management systems, and Sensor data reading. To simplify matters within this study, we will refer to these applications as metering, demand, and sensor, respectively. Figure 61 provides an overview of the message behavior for these applications, highlighting the distinctions between them.

Volume 1, Issue 2, October-2024
ISSN 0000-0000
DOI: https://doi.org/10.5281/zenodo.13892318

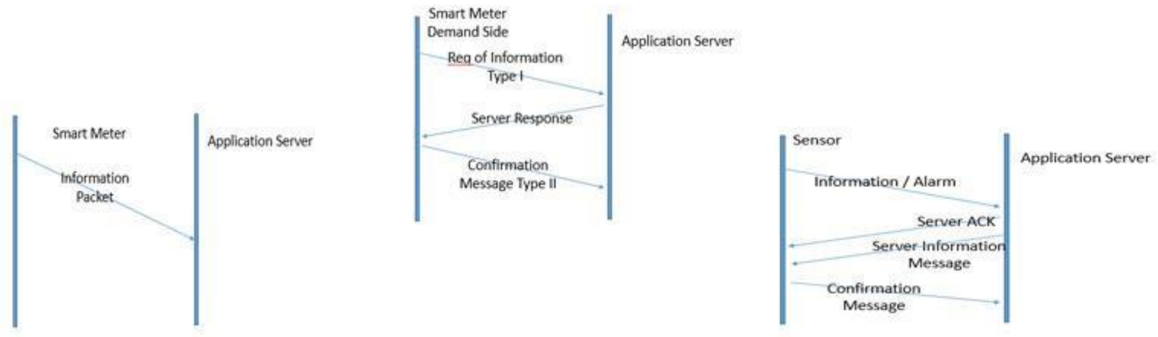


Figure 7: Various data transmission methods employed in metering, demand response, and sensor applications.

Devices configured with the demand and metering applications are designed to accommodate various priority levels. In this context, control information originating from the demand application holds higher priority than metering information. Consequently, we have assigned distinct service classes to each set of messages. The Meter-reading domain employs the nrtPS configuration, while the demand mode and sensor mode employ the rtPS configuration. Specific configuration details are presented in Table 27.

Service Class name	Scheduling type	Traffic Rate	Interpolling time	Average SDU
Metering	nrtPS	40bps	500 sec	2 Kbytes
Demand	rtPS	100bps	120 sec	2 Kbytes
Sensor	rtPS	200bps	100 msec	750 bytes

Figure 8: Parameters for configuring QoS service categories.

The packet scheduling techniques and service classes employed in this study adopt the same parameters as those presented in table 7 of chapter 2. Table 27 below specifies the particular values used for these parameters in this work. In this scenario, the applications align with the service classes, which, in turn, correspond to the scheduling types. The rtPS type facilitates a connection within a defined range of maximum delay and minimum traffic rate. As for nrtPS type traffic, it only requires a minimum traffic rate, without guaranteeing a minimum delay. Round robin schedulers, as described in chapter 3, are well-known for effectively supporting small-sized packets, such as those detailed in Table 27.

Future work

The development of communication systems for Smart Grids is an ongoing area of research. This study serves as an introduction to utilizing the WiMAX communication network to establish effective communication channels for smart grid applications.

First and foremost, it is crucial to address an aspect that was not covered in this document, namely the maximum capacity of the network. Given the relatively small traffic per device, the theoretical number of connections that a single base station (BS) could support would be in the hundreds of thousands. However, the limitations imposed by MAC capabilities and unicast polling mechanisms pose a barrier to accommodating such a massive number of connections. Therefore, it is necessary to explore new MAC connections and bandwidth request methods that can overcome these limitations and mitigate the capacity loss caused by unicast polling.

Secondly, rural scenarios are characterized by a low device density. In such cases, a single BS will only serve a small number of devices within its coverage area. Consequently, extending coverage becomes a new challenge for communication networks in these settings. One potential solution is to implement Relay WiMAX, which utilizes WiMAX-enabled access points that possess BS capabilities at a more affordable cost than a complete BS. Additionally, cooperative networking utilizing mesh networks could be employed to expand coverage range while maintaining the necessary QoS requirements. Lastly, by leveraging the customer access network, further exploration of VPN connectivity to the service and operator network can enhance the reliability and capacity of the smart grid communication architecture at a reduced cost. This avenue should be investigated to optimize the overall performance of the communication system.

Acknowledgements

First and foremost, I would like to express my gratitude to my supervisor, Associate Professor Qui Yinghui, for his unwavering commitment, guidance, and consistent assistance in the development of this thesis. Without him, his continuous mentorship, and his meticulous feedback; this project could not have been accomplished. Furthermore, I would like to acknowledge the backing provided by my home university, North China Electric Power University, for their support, belief in my abilities, and granting me the necessary time. This support was complemented by the BGS scholarship program, which enabled me to pursue my studies. I extend my heartfelt appreciation to all my friends and classmates for their invaluable support. I am truly thankful to them. I would also like to express my deepest gratitude to my family, specifically my mother and elder brother, who have shown immense support despite being thousands of kilometers away. I send them my utmost love and appreciation. Finally, but certainly not least, I want to express my sincerest thanks to my beloved wife, for welcoming me into her heart, home, and life. Thank you for being by my side throughout these months, providing unwavering support and strength.

Authors' Contributions

Equal contributions. All authors have read this manuscript and agreed with the changes and results described in it.

Availability of Data and Materials

Not applicable.

Declarations

Ethics Approval and Consent to Participate

Not applicable.

Consent for Publication

Not applicable.

Competing Interests

The authors declare that they have no competing interests.

Referances

[1] .P. Parikh, "'Opportunities and challenges of wireless communication technologies for smart grid applications,' Proc. Power and Energy Society General Meeting, 2010 IEEE, 2010, pp. 1-7.".

[2] El-Hawary, "Comments on the Change in the Power Industry (Avoiding Chaos on the Way to an Optimal Market Structure)," Power Engineering Review, IEEE, vol. 22, no. 12, 2002, pp. 42-45.".

[3] German Castellanos, "Wireless Communication Network Architecture for the Smart Grid applications".

[4] A.P.S. Meliopoulos, "'Smart Grid Technologies for Autonomous Operation and Control,' Smart Grid, IEEE Transactions on, vol. 2, no. 1, pp. 1-10.".

[5] IEEE, ""IEEE Standard for Local and metropolitan area networks," vol. Part 16, no. 2009, pp. C1-2004.

[6] 2009, pp. National Institute of Standards and Technology, "NIST Framework and Roadmap for Smart Grid Interoperability Standars Release, Book NIST Framework and Roadmap for Smart Grid Interoperability Standars Release 1.0 (Draft), Series NIST Framework and Roadmap for Smart Grid

Interoperability Standars Release".

[7] U.S.D.o. Energy, "The Smart Grid: An Introduction, U.S.D.o. Energy, 'The Smart Grid: An Introduction,' Book The Smart Grid: An Introduction, Series The Smart Grid: An Introduction, ed., Editor ed.^eds., 2008, pp.".

[8] V.K. Sood, "'Developing a communication infrastructure for the Smart Grid,' Proc. Electrical Power & Energy Conference (EPEC), 2009 IEEE, 2009, pp. 1-7.".

[9] M. Shreedhar and G. Varghese, "Efficient fair queueing using deficit round robin," ACM SIGCOMM Computer Communication Review, vol. 25, no. 4, pp. 231–242, Oct. 1995, doi: 10.1145/217391.217453.

[10] L. Bakule, "'Decentralized control: An overview,' Annual Reviews in Control, vol. 32, no. 1, 2008, pp. 87-98.".

[11] C. So-In, R. Jain, and A.-K. Tamimi, "Capacity Evaluation for IEEE 802.16e Mobile WiMAX," Journal of Computer Systems, Networks, and Communications, vol. 2010, pp. 1–12, 2010, doi: 10.1155/2010/279807.

[12] D. G. Sanchez, T. Ruiu, I. Biswas, M. Schulze, S. Helmly, and K. A. Friedrich, "Local impact of humidification on degradation in polymer electrolyte fuel cells," J Power Sources, vol. 352, pp. 42–55, Jun. 2017, doi: 10.1016/j.jpowsour.2017.03.057.

[13] H. Farhangi, "Smart Grids for Smart Cities: Challenges, Opportunities, and Solutions".

[14] NIST, "'Wide Area Monitoring, Automation, Communications and Control (WAMACC) for the Bulk Transmission System (Draft 1.0),' Book Wide Area Monitoring, Automation, Communications and Control (WAMACC) for the Bulk Transmission System (Draft 1.0), Series Wide Area Monitoring, Automation, Communications and Control (WAMACC) for the Bulk Transmission System (Draft 1.0), ed., Editor ed.^eds., National Institute of Standards and Technology, 2010, pp.".

[15] H.M. Ryan, "'High Voltage Engineering and Testing,' Book High Voltage Engineering and Testing, Series High Voltage Engineering and Testing No. 32, 2nd ed., Editor ed.^eds., Institution of Engineering & Technology, 2001, pp.".

[16] "Modelling and Analysis on Smart Grid Against Smart Attacks," University of Rhode Island, Kingston, RI, 2013. doi: 10.23860/thesis-yan-jun-2013.

[17] Sarkar, M. R., Hossain, M. A., & Ahamed, S. S. (2024). POSSIBLE CAUSES AND SOLUTIONS OF

ISSN 0000-0000
DOI: https://doi.org/10.5281/zenodo.13892318

THE TRAFFIC JAM IN DHAKA, BANGLADESH. European Journal of Social Sciences Studies, 9(6).

[18] B. Godwin and C. Lima, "Progress Energy Network Architecture for the Smart Grid Mapped to P2030 TF3 Reference Architecture, 2010.".

[19] A. Sabri, "'Video Scheduling in the Uplink over WiMAX Networks by the Novel Concept "Adaptive Minimum Service Interval",' Proc. Computer Engineering and Applications (ICCEA), 2010 Second International Conference on, pp. 3-7.".

[20] WiMAX Forum, "WiMAX Forum comments for 'NIST Priority Plan 2 Wireless Standards for Smart Grid v6'," Book WiMAX Forum comments for 'NIST Priority Plan 2 Wireless Standards for Smart Grid v6', Series WiMAX Forum comments for 'NIST Priority Plan 2 Wireless Standards for Smart Grid v6', ed., Editor ed.^eds., 2011, pp.".

[21] Y. Z. Z. Z. Y. Z. J. W. Y. Xu, "Smart Grids with Electric Vehicles: Charging Optimization and Integration".

[22] A. A. F. M. S. N. A. Y. Abdelaziz, "Demand Response Management Using Game Theory for Smart Grids: A Comprehensive Review".

[23] 2006, pp. 0_1-822. Editor ed.^eds., "IEEE Standard for Local and Metropolitan Area Networks".

[24] O. Asad, "'Sensor network web services for Demand-Side Energy Management applications in the smart grid,' Proc. Consumer Communications and Networking Conference (CCNC), 2011 IEEE, pp. 1176-1180.".

[25] K. Moslehi and R. Kumar, "'A Reliability Perspective of the Smart Grid,' Smart Grid, IEEE Transactions on, vol. 1, no. 1, 2010, pp. 57-64.".

[26] O. Do Eun, "'Consumer energy information exchange for the smart grid service,' Proc. Power Electronics and ECCE Asia (ICPE & ECCE), 2011 IEEE 8th International Conference on, pp. 1211-1218.".

[27] Z. Alliance, "'Zigbee Smart Energy Profile Specification,' Book Zigbee Smart Energy Profile Specification, Series Zigbee Smart Energy Profile Specification, ed., Editor ed.^eds., 2011, pp.".

Journal of Global Knowledge and Innovation (JGKI)
Volume 1, Issue 2, October-2024
ISSN 0000-0000
DOI: https://doi.org/10.5281/zenodo.13892318

Received: 9 August 2024 **Published: 5 October 2024**