Communication Requirements and Analysis of UMTS Based Smart Grids Distribution Networks

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Abstract- A smart grid (SG), an enhancement of the 20th century power grid also called smart electrical/power grid, intelligent grid. The SG originate a two-way flow of electricity and information to create distributed energy delivery and automated network. While the traditional power grids are commonly used to carry power from a few central generators to a great number of consumer. Hence, the next step for conventional power grid toward Smart Grid is to provide efficient management along with great reliability via smart services, in which the application of Information and Communication Technology (ICT) is predestined. A well-known technology that have the ability to fulfill the requirements of smart grid's applications, among which 3G Umts technology is seen as a great candidate. In this paper we analyze the communication requirements in electrical power distribution network of the smart grids. As the communication in a Distribution Area Network (DAN) merge the AMI payload from the consumer area, it is important to analyze the data flow from the consumer area to control centers and also the different applications involved through a DAN. Parameters namely overall network delay, packet loss and network capacity are studied using OPNET 14.5.

Index Terms- Smart grids, UMTS, DANs, applications, Quality of Service (QoS).

1 INTRODUCTION

Today's electric power grid exist for over 100 years ago with the aim to deliver electricity from power stations to consumers. In the past, blackouts and failures in the grid have become a noticeable Problem, which can cause great damages to people's daily life. However, communications network that exist is insufficient due to the factor that it does not cover the distribution side. Thus there is a need to make the current electricity network more reliable, secure, efficient, and environmentally friendly. This can be achieved by the next-generation power grid which is the smart grid [1]. The transition of smart grid happens at the various grid Levels (i.e., generation, transmission and distribution), much attention is going toward distribution grid. Also, typically the problems of power system trace back to the distribution level [2]. One of the important tasks toward establishing a smart grid is recognizing a suitable communication network for supporting the requirements and features of the new power grid, the major realization of smart grid applications can be visualized in the DAN. An intelligent substation in a smart grid contains a range of Central to the smart grid concept is convergence of a two-way flow of electricity and information, creating an automated, widely distributed energy delivery network. With an emerging smart grid, various intelligent and automated applications can be enabled. Some of these applications are home/building automation, automated meter reading, distribution automation and outage and restoration management [3].

From the available communication technologies for DAN, the UMTS satisfies the communication requirements and cost of the SG. IN this paper we first analyze the different applications involved in DAN and the communication requirements of each application. Then, we simulate using the UMTS technology to analyze the performance of five different applications along with the smart metering application and the QOS performance for a given network scenario. The rest of the paper is organized as follows. The communication network requirements are discussed in 2 and 3. The simulation environment of DAN using UMTS and the result are presented in 4. Lastly, the section 5 is the conclusion.

2 UMTS FOR DAN NETWORK

Distribution area network (DAN) is the Communication architectures connecting the access network that handle metering and different SG application traffic to the control center through the core network, serve different applications like Advance Metering Interface (AMI) and Distribution Automation Systems (DAS). AMI is a pervasive and scalable two-way communication infrastructure which is used to interface smart meters installed at the end of customers' premises. Classical AMI system can send the metering data to the control center every 15 minute or once per hour [4]. Smart grid communication infrastructure system can be based on Wired or Wireless communication Technologies. Wireless technologies have some advantages with respect to the wired technologies, such as the low-cost and connecting the inaccessible areas. To make the best solution, during the operation of deploying a smart metering infrastructure it is substantial to take in to account the implementation time, the availability of technology, the operating costs and the deployment scenario (rural /urban or indoor / outdoor, etc.). Advanced wireless systems offer the advantages of inexpensive products, rapid deployment, low cost installations and widespread access which the older wireless technologies often cannot provide as well as wired technologies. DAN applications include meter reading, distribution automation (DA), outage and restoration management, demand response (DR), customer information and messaging.

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Communication technologies for these applications need to support higher data rate and larger coverage distance (up to 10 km). Coverage area and data rate requirements for different DAN applications can vary depending on applications for example, a typical data size requirement for scheduled meter interval reading is 1600–2400 bytes, whilst it is 25–1000 bytes for distribution automation applications [5]. The communication technologies supporting these requirements are 3G UMTS (WCDMA) technology which is a radio network distributed over land areas each equipped by at least one fixed-location transceiver known as a cell site or base station. By using the existing 3G cellular communication systems, its quick and in expensive to have data communication over large geographical area [6].

3 THE DISTRIBUTION AREA NETWORK IN SMART GRID

The power network in SG system divided into seven domains according to the National Institute of Standards and Technology (NIST) in the Smart Grid Interpretability Standards Roadmap, where it consists of bulk generation, transmission, distribution, user segment, markets, management and service provider as shown in Fig. 1. Each domain includes one or more SG actors, contain devices, systems, or programs which make decisions and interchange information necessary for performing applications [7].

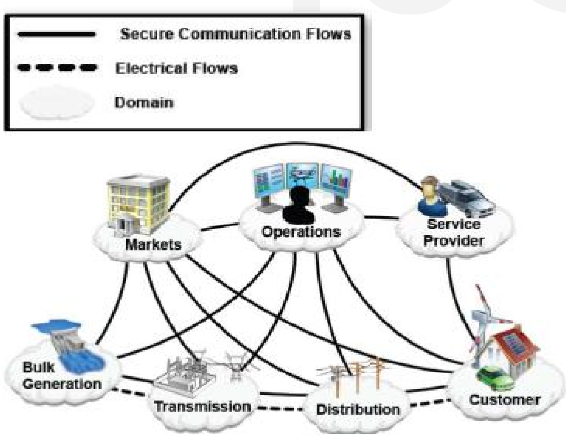

Fig.1. smart grid framework according to NIST [7].

Smart grid access network consists of home area network (HAN) and neighbor area etwork(NAN)where HAN are needed in the customer domain to perform monitoring and control of smart devices in customer premises [8]. Fig. 2 shows the system communication model based on UMTS where several houses are connected to the utility center.

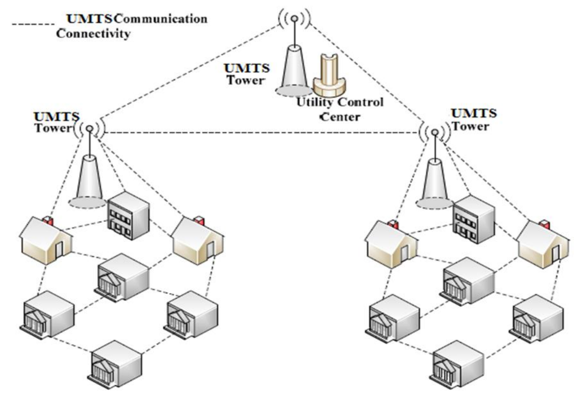

Fig. 2. UMTS communication network.

The DAN connects the access network and distribution substation networks to the control center. For an access network, it handles the metering traffic and Load control messages for distribution automation. For distribution sub-station, it handles the traffic of substations and distribution automation. Aggarwal, et al. [9] proposed a method to calculate the bandwidth in distribution networks. They assumed that a distribution system consists of 100,000 meters and the network generates 1 million messages / second during busy hours. If the messages follow the Poisson distribution and each message is 100 bits, then the bandwidth needed for the system is 100 Mbps and the latency requirement is 10ms.and finally, it requires large consumer area coverage. The communication requirements of some major applications in DAN are presented in Table 1 [10].

TABLE 1

SMART GRID APPLICATIONS QOS REQUIREMENTS [10].

Smart Grid Application	Bandwidth (kbps)	Latency Traffic	Type
Smart Meter	10-100 /meter	2000 ms	Random
Substation Automation	9.6 -56	15-200 ms	15-200 ms
Outage Management	56	2000 ms	Random
Demand Response	14 - 100	500 ms-min	Continuous
WASA	600 - 1500	15-200 ms	Periodic/Random
Distribution Automation	9.6 -100	100 ms -2 s	Periodic
DSM	14 – 100	500 ms-min	Occasional

4 SIMULATION OF DANs AND RESULT ANALYSIS

In this section, we explain the simulation results. To evaluate

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the performance of the proposed network model, three scenarios are designed and simulated using OPNET 14.5. OPNET simulation model of the proposed UMTS based DAN communication network comprises user equipment's, Radio Network Controller (RNC) which is connected to the packet switched network via GPRS Support Node (SGSN) and through GPRS Gateway Support Node (GGSN) which in turn is connected to the IP Network is shown in fig.3. The simulation results help us to analyze the network performance parameters including (delay, packet loss and throughput). Scenario I was simulated where the number of smart meters was 50 per cell along with the six applications. Scenario II and III in which 100,200 smart meters respectively with six different smart grid applications.

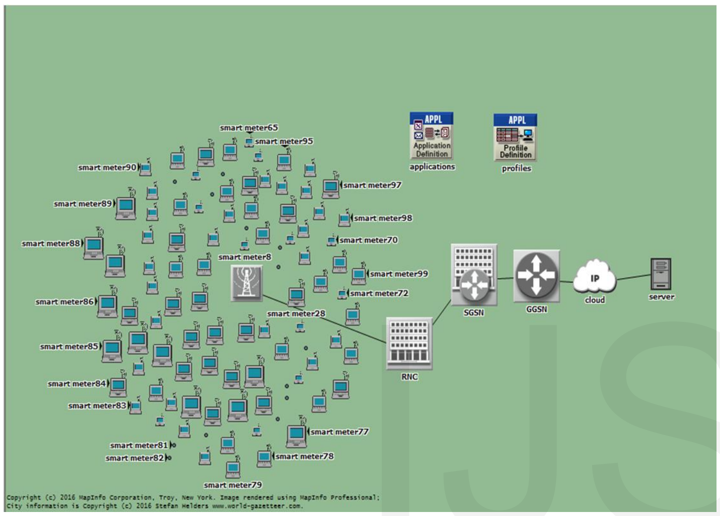

Fig. 3. OPNET simulation model of the proposed UMTS communication network.

For this simulation, we consider a UMTS network to cover the distribution area. Since the uplink dominates and is crucial, only the uplink traffic is considered. The simulation parameters, traffic models, and performance metrics are specified in Table 2 and Table 3.

4.1 Applications Profiling and Parameters

Depends on the smart grid application, a profile may have different inter- arrival rate and distribution but all share the same communication protocol and file size. For example, distribution automation application has one profile, one inter-arrival time, one communication protocol and file size. Table II shows the seven smart grid applications along with their related profiles, inter-arrival times, distributions, communication protocol and file size.

TABLE 2

APPLICATIONS PARAMETERS

Smart Grid Application	Inter-arrival Time	Distribution	Protocol	File Size
Energy consumption reading	15 mn	Periodic	FTP over TCP	1500 (bytes)
Substation Automation	1 sec	Exponential		
Outage Management	5 mn	Exponential		
Demand Response	30 mn	Exponential		
WASA	5 sec	Exponential		
Distribution Automation	1 sec	Exponential		
Demand side management	30 mn	Exponential		

4.2 Profiles Parameters

In order to simulate the UMTS proposed design, the smart grid applications must be profiled. Each application must be profiled in term of operation mode, start time, duration and repeatability. The seven applications have been profiled based on their functionally. Five different profiles are defined; demand, profile, distribution, utility, and smart meter profiles. Each application may have a unique profile or share more than one profile with other applications. Table III shows the five different profiles and their related parameters. For example, outage management application has all the five profiles. On the other hand, distributed automation has one profile.

TABLE 3

PROFILES PARAMETERS

Profiles	Operation Mode	Start Time	Duration
Smart Meter Profile	Simultaneous	30-300 s	One cycle
Profile	Random		
Demand profile			
Utility Profile	Random		
Distribution Profile	Simultaneous		

4.3 Simulation results

For the simulation, the number of applications other than metering data is tested. In a 1-hour simulation time, the packet loss performance, latency and throughput are measured by increasing the number of meters and adding different applications.

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Packet loss: From the reliability requirement, packet loss is an important parameter to measure the quality of the data transmission. In this fig.4 is shown to determine the packet loss to deliver the information to the utility station (communication). the packet loss performance of the DAN for various numbers of smart meters and applications.

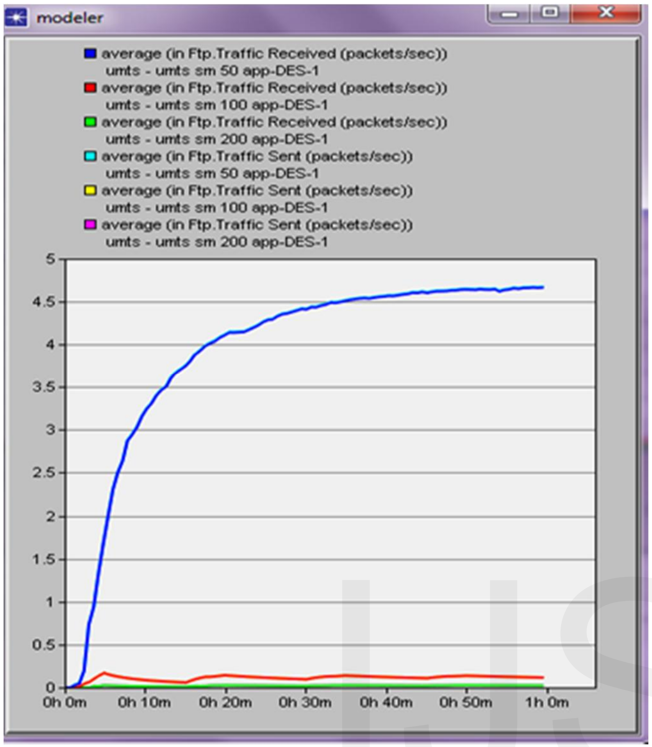

Fig.4. Packet loss performance.

Delay: This part will illustrate delay performance, figure 5 display the delay for the scenarios designed in this project, to deliver the information to the utility station (communication). The maximum latency for different traffic is given in Table I. The scheduler drops the packet if the latency goes beyond the limit. The average latency of the applications increases slightly but for smart metering, the latency is bit higher because the traffic is generated for a short period of time to simulate the AMIs and wait in a queue for scheduling.

Fig. 5. delay performance.

Throughput: This part will illustrate the throughput in each scenario, the throughput will be affected by all other parameters, throughput is the rate of successful message delivered over a communication channel without affecting the packet loss or the latency performance. Since the average latency for all applications are within a limit, the maximum

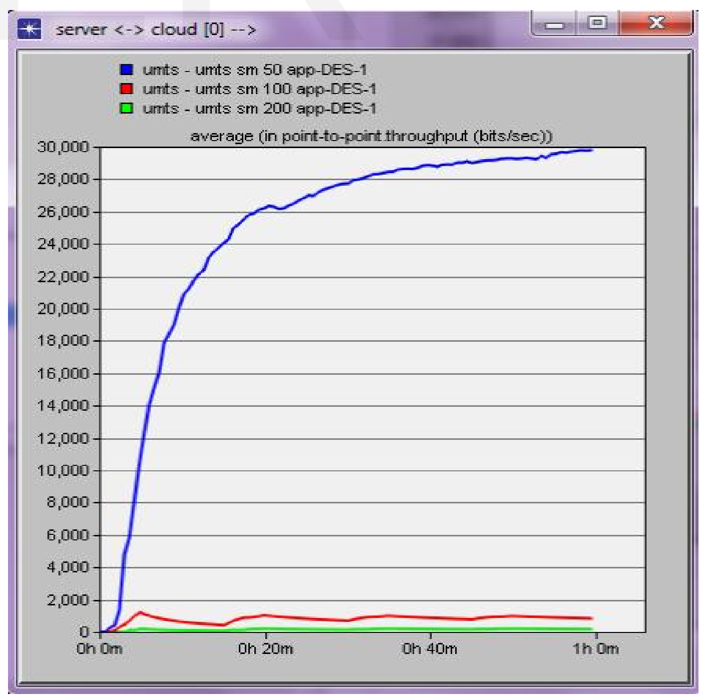

Fig. 6. Throughput performance.

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capacity is only based on the packet loss performance based on the simulation parameters. Fig.6 shows the throughput performance the same media in its' ideal state; the useful part is usual.

5 CONCLUSIONS

The SG is very challenging for communications researchers because its requirements differ greatly from those of traditional data networks. UMTS technology has been proposed as a good option for DANs due to its native capabilities for real-time traffic. In this paper, we analyzed the smart grid applications involved DANs. seven major applications of smart grid DAN network are defined. To the best of our knowledge, no papers were found in the literature that uses simulations to study the performance of a DAN and its potential scalability. In this initial effort, the smart grid applications considered for the simulations are fixed, except the AMIs. In real world, the smart grid applications other than AMIs may slightly vary. Therefore, the metering capacity may change based on the other applications that exist in a DAN.

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