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A Survey on Delay Time in Smart Grid Communication Networks using D2D

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Abstract—**Delay time defines as the time between when the state occurred and when it was acted upon by an application. Each application has its own latency requirements depending upon the kind of system response it is dealing with. Among the other delays, communication delay also adds to the latency and needs to be minimized. The communication delays on the network are comprised of transmission delays, propagation delays, processing delays, and queuing delays. Each of these delays must be looked into to understand the complete behavior of the communication network for a given network.**

The network here represents the smart grid communication networks, which will be a network of networks that may use different communications technology or just one, allowing two-way, reliable, and secure communications. It will be formed of millions of smart meters at customer premises connected to a Few thousand substations which in turn will be connected to fewer control centers and power plants. In this paper numbers of previous studies was provided of such delay time problems in the smart grid networks. Also delay time in smart grid treated in different position not only in the communication networks and that making conflict in concept sometimes with delay time over all smart grids.

Keywords: ***Smart Grid; latency; wireless communications; Device to Device (D2D); distribution networks; Phasor measurement unit (PMU)and* Advanced Meter Infrastructures *(AMI).***

1. Introduction

Latency is the delay in the network or the expression of how much time it takes for a packet of data to travel from one point on the network to another. There is a need for a communication infrastructure with exceptionally tight latency characteristics as it is one of the most stringent requirements for the grid. If the control center misses any input, then it might substitute the missing input with inputs from other sensors which can produce different actions that could lead to erroneous results. In the smart grid communications network the latency explained that the network will have different latency times; the grid is huge so if the data sent for the purpose of system wide coordinated controls it should have higher latency than if the data is required for local analytical needs or responding to rapid events [1]. The network will be huge; thus, it is recommended to take the form of clusters according to geographical locations. Each cluster will have a limited number of smart meters ranging from a few hundred to a few thousand connected to a few substations and control centers [2].

2. Smart Grid Background

The current power grid is facing many challenges that it was not designed or engineered to handle which range from congestions and major blackouts to the overwhelming increase in demand and security concerns. The current electric grid was established before the 1960's [3]. It is believed that the electric grid is the most complex and gigantic machine ever made in human history; it consists of wires, cables, towers, transformers and circuit breakers installed together in outdated manner. During the 60's, computers and sensors were used to monitor and slightly control the grid; however, fifty years later these sensors are considered less than ideal. The term grid is traditionally used for an electricity delivery system that may support all or some of the operations of electricity generation, electricity transmission, electricity distribution, and electricity control. By using two-way flows of electricity and information, smart grid is an enhancement of the traditional power grid, attempts to create an automated, distributed, and advanced energy delivery network. This enhanced grid is expected to provide distributed power generation, self-monitoring, self-healing, adaptive and islanding microgrid, pervasive control, and various customer choices [4][5].

In most cases, a smart grid focuses on three main areas: house hold devices and automatic meter reading; remote sensing devices for grid monitoring and control, and distributed energy resource, such as wind and solar management. The key components in a smart grid are: the Advanced Meter Infrastructures (AMI) at houses or buildings, Phasor Measure Units (PMU) for transmission lines and power generations such as distributed generations and substations. PMUs provide phasor measurements of voltages and currents in an electrical grid for high fidelity sensing. The phasor measurements are calculated via Discrete Fourier Transform (DFT) and delivered to devices called Phasor Data Concentrators (PDC). In PDC, the measurements are time-synchronized, stored for future reference and forwarded to application and Super PDCs.

3. Delay Time in SG

As communication requirements for the smart grid, in 2011 by Mohamed D. and Xavier F., the access layer of the smart grid network show that no single available communication technology can be used for all layers of the smart grid. Thus, different technologies for different layers are needed [6]. A new protocol for optimizing the smart grid is recommended [44]. In Wireless Communication and Networking Technologies for Smart Grid: Paradigms and Challenges in 2011 by Xi F, Dejun Y and Guoliang X, An advanced information and communication system underlying the smart grid will play critical role. In the part of network availability malicious attacks targeting network availability attempt to delay or block information transmission in order to make system resources unavailable to nodes that need to exchange information in the smart grid [7]. As a result, the real-time monitoring of critical power infrastructures may be lost, which may further lead to a possible global power system disasters [8].

As the effects of time delay in the electric power grid in 2012 by Hasan Ali and Dipankar D, there is no doubt that the smart grid will lead to better power supply services and a more environmentally sound future. However, they still have a long way to go before this vision comes true. [39]. Communication delays in smart power grid affect the performance of control systems and can cause power losses. The analysis of causes and effects of delay employs a simulated power network comprising several generators for which braking resistors with intelligent controllers are used for transient stability control.

In the Virtual Laboratory for Micro-Grid Information and Communication Infrastructures in 2012 by James W, Yuzhe X, Carlo F, Karl H, Per L, Craig D, Ariane S, Lennart E. Testing smart grid information and communication (ICT) infrastructures is imperative to ensure that they meet industry requirements and standards and do not compromise the grid reliability [9]. Within the micro-grid, this requires identifying and testing ICT infrastructures for communication between distributed energy resources, building, substations, etc. To evaluate various ICT infrastructures for micro-grid deployment, this work introduces the Virtual Micro Grid Laboratory (VMGL) and provides a preliminary analysis of Long-Term Evolution (LTE) as a micro-grid communication infrastructure. Latency requirement for the smart grid communication network, latency is one critical technical requirement. Measurements and commands must be available within specific delays based on the application area [10].

Cellular Communications for Smart Grid Neighborhood Area Networks in 2016 by charalampos k, linus T and Jesus A, the evolution of cellular communications is a key enabling technology for fundamental operations of smart grid neighborhood area networks (NANs). The latest releases of the LTE standard, representing the recent advancements in cellular technology, offer significant benefits to the modernization of the aging power distribution grid compared with other communication technologies. However, since LTE was not originally designed for smart grid applications, important challenges remain unsolved before it can efficiently support advanced NAN functionalities. As device-to-device (D2D) [11][49] communications in LTE standards are a promising technology for reducing delay and boost reliability, this can be achieved by enabling direct communication using cellular networks. NAN use cases in the power distribution grid. The currently achievable end-to-end latency in LTE (close to 100ms) is not sufficient to enable delay-critical applications (e.g., control or protection related) in the distribution grid according to the IEC 61850 Standard [12] [47]. While LTE can meet the latency requirements for slow automatic interactions, fast automatic grid operations require end-to-end message delivery in the order of tens of milliseconds or, as stated in the vision of 5G, even below 5ms. Therefore, LTE needs to be optimized to meet these stringent constraints. Latency over the radio link can be lowered by reducing transmission-time intervals and spreading data over frequency rather than time. In addition, to avoid a scheduling request-grant phase prior to data transmission, which introduces an additional delay related to connection establishment handshake, the medium access control should allow for immediate access by providing instant-access resource allocations [13][21].

In Performance Evaluation of Communication Technologies and Network Structure for Smart Grid Applications in 2019 by Desong B.; Manisa P.; Saifur; Rahman; Di Shi. The design of an effective and reliable communication network supporting smart grid applications requires a selection of appropriate communication technologies and protocols. Study and quantify the capabilities of an AMI to support the simultaneous operation of major smart grid functions represent important factor, These include smart metering, price-induced controls, distribution automation, demand response and electric vehicle charging/discharging applications in terms of throughput and latency [14]. Recent Trends on Performance Analysis of Latency on Wide Area Technologies in Smart Grids in 2018 by Gopakumar P; Balimidi M and M, numerous researches and real time studies are being conducted on wide area technologies for emerging smart power grids. These technologies include measurements, control and protection. The backbone of wide area technologies is synchronized measurements using PMU. One of the major challenges faced in practical implementation of wide area technologies is time delay (latency) in communication. Various researches have highlighted that latency study is essential for effective wide area schemes under contingencies [15]. Time delays in communication within wide area monitoring system (WAMS) [38] can substantially degrade the stability and quality of control actions. This paper investigates the effect of communication latency associated with wide area technologies on various smart grid operations [16]. Latency consideration in wide area technologies has been a very active research area in international perspective. The impact of time delays associated with wide-area monitoring and control systems (WAMCS) on smart power grid stability. The impact of delay was studied and validated under hardware-in-the-loop and software-in-the loop schemes. Impact of communication time delay and it is variation in an islanded microgrid system is studied in [17].

Impact of Information and Communication Technology Limitations on Microgrid Operation in 2019 by Mahmoud S and Ahmed M; Yusef E and Mohamed E. The functional requirements of communication networks, such as permissible latencies, coverage ranges, and data rates, being utilized in MGs, and in smart grids in general, depends on the control layer [18]. Delay is one of the main limitations that associated with ICTs [36] that raises concerns to electric power engineers and researchers.

4. Delay Time Analysis and Results

Mohamed D. and Xavier did a simulation for an access network where they assumed a typical mid-house size with 11 smart devices communicating through a Zigbee network to the smart meter. Also they assumed Poisson distribution for packets generation at the smart devices with a constant packet size of 1 Kbyte. Packets are sent to the smart meter as soon as they are generated at the smart devices. They simulated 24 hours of traffic on the access network and found that the end-to-end delay in the network ranged between 35 msec and 80 msec, with a spike of 0.1 sec during the peak hour of the day. Last, in this paper was found that the latency within the distribution network should be kept at 10 msec, and the required transfer rate in case of a zone containing 10 substations should be 8.1 MB/sec as shown in figure below [19].

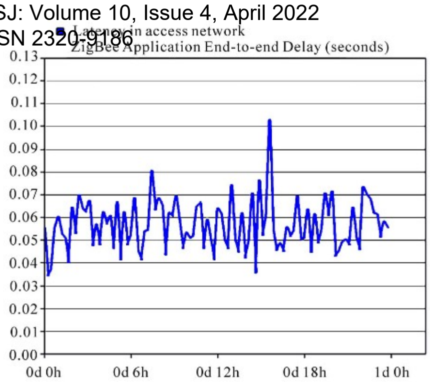

Figure 1: Average end-to-end delay in the Access Network

The simulation results for the access layer in a smart grid network point out the access layer requirements in terms of end-to-end delay, and bandwidth. Also it was concluded that no single communication technology will be able to satisfy the requirements for the whole network; rather different technologies should be used for different parts. There is still much work to be done in the smart grid area, especially in the communications part. Since all of the available communication techniques are off the shelf technologies designed for different reasons, none of them addresses the smart grid needs. Most of these technologies support mobility, handover, and many other features which are not needed for the smart grid due to its nature; thus, a communication protocol should be developed and optimized specially for the smart grids that cover end-to-end networks. This special protocol should be able to automatically set the QoS configurations when application requirements change based on the grid events, and it should translate the self-healing grid capability to self- healing communication network [20][24]. The paper also examines the delay that a system can tolerate and the cyber attacks that can cause additional delays. It is measured end-to-end between two applications running at the source and destination systems. Because electric power devices do not have communications capabilities, each device is typically attached to an embedded computer system that serves as the communications interface to the network infrastructure [21].

As Virtual Laboratory for Micro-Grid Information and Communication Infrastructures and to summarize the latency requirements, various smart grid components require different latencies ranging from less than 3 ms for protection commands within the substation to between 20 and 100 ms for distribution automation commands in normal operating modes (non-transient) [22]. Generally speaking, PMU measurements are 100~200 bytes and reported at a rate of about 4000 times a second. They are expected to meet real-time control system requirements with time delay less than 10 ms [23]. AMI is an upgrade of Automatic Meter Reading (AMR) [40] providing two-way communication and specific actuators. AMI collects information of consumption records, alarms and status from customers can impose consumption control. Based on its two-way communication and consumption metering, AMI enables real time pricing and peak shaving in a smart grid. Referring to Wide-Area Measurement System (WAMS)[45], latency less than 1 second (typically 100~200 ms) is required to achieve real time pricing requirements [24]. The communication requirements for functions and device models in a substation are defined by Standard IEC 61850-5 [25]. The size of message varies from 1 to 1024 bits. Those messages delivery latencies vary from 3 ms to 1 s. However, to be viable for distribution automation requires that the LTE network latency is less than 10 ms for interconnecting PMUs and AMIs.

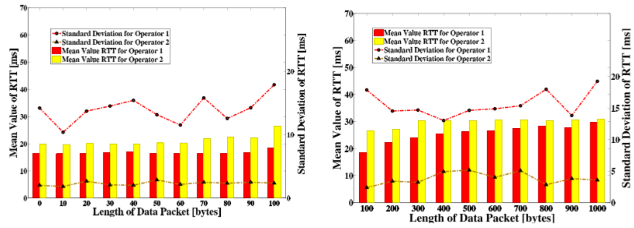

Figure2: Length of Data Packet

This indicate that when the length of data packets is smaller than 100 bytes, the RTT [26] is shorter than 20 ms under the service provided by Operator 1, while it is around 20 ms for Operator 2. The RTT values increase with the length of data packets when the length is larger than 100 bytes. But the standard deviations of RTT are approximately the same whatever sizes for the packets for each Service Operator. The mean values of RTT under Operator 1 are lower than those under Operator 2. However, the standard deviation of RTT under Operator 1 is around 4~5 times larger than that under Operator 2. In addition, the minimum latencies for RTT transmission are 10 ms and 13 ms via Operation 1 and 2 respectively.

By dividing RTT in half to calculate the latency, the minimum values of the latency for small size packet agrees with the theoretical latency given by 3GPP white paper [41], which is 5 ms. This work concludes that a virtual micro-grid laboratory for testing ICT infrastructures is introduced. The lab architecture is described and a preliminary practical evaluation of LTE for smart grid communication is presented. Based on this successful evaluation, future testing scenarios related to demand-response, distribution automation, and microgrid control are planned, as well as extensions to include capabilities to both emulate ICT [53] infrastructures within the micro-grid and to consider distributed generation scenarios [27].

Communication challenges in Smart Grid in 2016 by Eleftherios T.; Dimitrios B.; Charalambos E. and Lambros S. ABB [45] says is an evolved grid system that manages electricity demand in a sustainable, reliable and economic manner, built on advanced infrastructure and tuned to facilitate the integration of all involved elements. However, the definitions from authoritative organizations follow a common theme: Smart grids utilize information and communication technologies to manage the energy distribution and optimize the transmission from suppliers to consumers and vice versa. Intelligent control done by high speed signaling occurred when no high delay time in the whole networks nodes [28]. They conclude that cyber security and privacy issues in the smart grid are new areas in the fields of power industry, electrical engineering, and computer science [28].

As Charalampos kalalas [49] involves the LTE core network in the data transmission also affects the experienced end-to-end latency, since based on the typical network architecture, traffic is concentrated to only a few core sites from extensive geographical areas. Thus, enhancing LTE with direct D2D [51] communications among smart grid entities in close proximity with each other without routing through the core network could provide low latency figures and facilitate delay-critical grid applications where real-time transmissions are required [29]. Among the different alternatives for enhancement of LTE to support the demanding NAN applications, the option of direct communications between end-devices, so called D2D communications, is one of the most promising towards achieving extremely low end-to-end latencies and boost reliability. These constitute major challenges for turning LTE into a suitable technology for smart grid NAN use cases. For this reason, D2D communications are being further developed in future releases of LTE and constitute today focus of intense research activities worldwide [30].

Desong Bian used OPNET [46] to simulate the performance of selected communication technologies and protocols. Research findings indicate that smart grid applicati ons can operate simultaneously by piggybacking on an existin gAMI infrastructure and still achieve their latency requiremen ts [13][31]. Since different smart grid applications have different characteristics, e.g., data size, data sampling frequency, latency and reliability requirements, it is, therefore, necessary to ensure proper operation of all smart grid applications especially those sharing the bandwidth with an AMI network. Characteristics of selected smart grid applications, including DR; pricing; metering; EV; distribution Automation (DA) are summarized in Table 1. Two types of DR applications are considered: on demand DR and real-time DR [48]. While on-demand DR schedules a demand reduction at least two hours ahead, real time DR sends a request to participating customers for a demand reduction in real-time. The pricing application broadcasts time-varying pricing information to end-use customers. Two types of metering applications are considered: on-demand meter reading and meter reading with scheduled time intervals. While on-demand meter reading is used to gather customer meter information as needed, the other kind of meter reading application is to read customer meter data at every fixed time intervals (e.g., 15-minute or an hour). EV application controls the EV charging. DA [49] includes sensing the operating conditions of the distribution grid, and allows making adjustments to improve the overall power flow and distribution-level performance by controlling field devices, such as capacitor banks and switches [14].

Table (1): Characteristics of Selected Smart Grid Applications

	Package Size (bytes)	Data Sampling Frequency (time per day)	Latency (seconds)
On-demand DR [44]	100	1 per event	< 60
Real-time DR	100	As needed	< 5
Pricing	100	2-6	< 60
On-demand metering	100	As needed	< 15
Metering with scheduled time intervals	1600 - 2400	4-6 per residential; 12-24 commercial	< 4 hours
EV Application	100	2-4	< 15
Distribution Automation	100	As needed	< 5

The package size shows a number of transmitted/received bytes typically involved in each smart grid application. Data sampling frequency decides the number of packages needed. Latency is the total delay from both algorithm and communication network [32]. There case studies simulated in OPNET to analyze the throughput and latency of different communication options supporting smart grid applications. Simulation results show all case studies, the "seed" which creates the random number generation, is set as 20. As a result, simulation results presented were average of 20 simulation runs. Since the operation of the real time DR requires real-time communications, the volume of data exchanging is large. As a result, the latency of this application is a little longer than other smart grid applications [33][44].

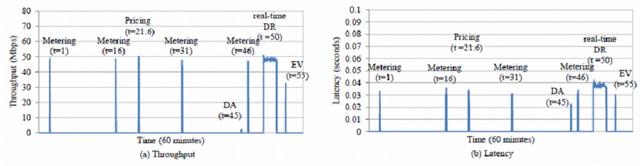

Figure 3: Simulation results: (a) throughput (Mbps) and (b) Latency

Gopakumar Pathirikkat proposed a frequency restoration methodology based on secondary control level assuming a single time delay communication network. Analysis of wide area controlled power system using a mathematical expectation model incorporating the effect of stochastic time delay. The proposed modeling approach was verified in simulation studies on a power grid modeled with eight generators and thirty-six nodes. Latency estimation methodology for measurements and control signals in a power system, The case studies presented substantiates that latency associated with control signals can degrade the performance wide area control system. Calculated latency based on comparison of clocks of GPS receiver and the time stamp of feedback signals. The latency data is then used to extrapolate trajectories of power systems, so that latency impacts on network can be compensated. Also extensive data regarding various communication delays associated with wide area technologies that can be considered in the analysis and simulation of WAMS [34]. A fuzzy logic based wide area damping controller (FLWADC) was proposed for compensating the continuous latency and to damp inter area oscillations effectively. The proposed controller was validated for its robustness against input signal variations through case studies [42].

The Cost-efficient Low Latency Communication Infrastructure for Synchrophasor Applications in Smart Grids in 2015 by Binxu Y., Konstantinos V., Wei k. and George. In the context of the medium voltage (MV) grid, this has motivated the deployment of Phasor Measurement Units (PMUs) that offer high precision synchronized grid monitoring, enabling mission-critical applications such as fault detection/location. However, PMU-based applications present stringent delay requirements, raising a significant challenge to the communication infrastructure. In contrast to the high voltage domain, there is no clear vision for the communication and network topologies for the MV grid; a full fledged optical fiber-based communication infrastructure is a costly approach due to the density of PMUs required[35][43]. They study a large set of real MV grid topologies to get an in-depth understanding of the various key latency factors. Building on the gained insights, they propose three algorithms for the careful placement of high capacity links, targeting a balance between deployment costs and achieved latencies. Extensive simulations demonstrate that the proposed algorithms result in low-latency network topologies while reducing deployment costs by up to 80% in comparison to a ubiquitous deployment of costly high capacity links [36][45].

There are several approaches that one could use to perform delay-impact as “Impact of Information and Communication Technology Limitations on Microgrid Operation in 2019” studies on simulated micro grids, such as: Co-simulation. In this approach, software for network simulation is coupled with the power grid simulator to model the behavior of the communication network, which includes the introduction of delays. The clocks of the network simulator and the grid simulators have to be synchronized to achieve realistic operation. This is mostly achieved through a third-party event synchronization tool. In Network-in-the-loop simulation, the control logic is decoupled from the simulation software, and it is implemented on hardware controllers that are interfaced with the power grid simulator through an interface which this simulator allows [37].

In the low-latency Communications for Wide Area Control of Energy Systems in 4/12/2019 by Farzaneh Masoumiyan the time delay is unavoidable when remote control signals are transmitted via the communication network in WAC. The size of time delays that can range from tens to several hundred milliseconds depends on the communication channels, transmission protocol, communication loads, distance and routines of signal transmission. In WAC, the exchange of PMU measurements and regular control commands between the substations and control centre is typically periodic with a predefined period. The information of each PMU is fed back to the WAC for the calculation of control actions. Thus, WAC crucially relies on low-latency communications support to transmit the PMU measurements [38]. For real-time purposes, the transmission of the messages should be within a very short time frame, the maximum allowed time depending on the type of protection scheme. This allowed time range originates from the fact that the disconnection of faults should be within approximately 100 ms. Due to the growth of the electricity network with the evolution of the smart grid, the volume of data is growing. Thus, the communication infrastructure should be able to transfer more data to ensure low transmission delay and reduce packet losses on transmission buffers formulate the communication requirements (i.e latency and bandwidth) from the power grid application requirements and simulate the performance of a communication network for power systems. The results provide a key insight for the average link bandwidth and latency requirements for a smart grid satisfying all applications [46]. The bandwidth should be in the range of 5 to 10 Mbps within one control area and 25 to 75 Mbps for inter-control centre communications. Latency can be contained within the 100 ms using meshed topology

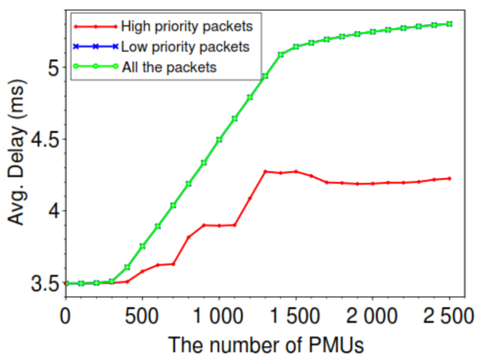

Figure 4: Average end-to-end delay versus the number of PMUs.

In the Smart Grid Virtualization for Grid-Based Routing in 2020 by Armin V.; Alexander H.; Ferdinand V.; Oliver L.; Ulrich P. and Peter D. Smart grids rely on at least two kinds of networks: on one hand, the power grid which is used to transfer the energy from producers to consumers, and, on the other hand, the communication network used to transmit data between the various participants within the smart grids. These participants include tap changers, smart circuit breakers, e-car-charging stations, smart buildings, virtual power plants, just to name a few [39].

Smart Grid Inspired Data Sensing, Processing and Networking Technologies in 14/9/2019 by Jia H.; Kun Y.; Victor C. and Ke X., They provide LTE Delay Assessment for Real Time Management of Future Smart Grids investigated the feasibility of using LTE cellular networks for the real-time smart grid state estimation. The results show that time-delay prioritized scheduling in combination with flexible PRB assignment greatly reduces the maximum delay when compared to simple random scheduling and fixed PRB assignment [40].

A Routing and Link Scheduling Strategy Smart Grid NAN Communications in 2019 by Shuchismita Biswas; Virgilio A; Centeno, Blacksburg, VA, The SG essentially, is a cyber physical system where a communication layer is overlaid on the physical electrical grid [41]. This paper addresses the limitations and proposes a Mixed Integer Linear Program (MILP) [40][49] based static routing and link scheduling strategy. The approach minimizes the total time required to deliver all messages in a network destination nodes. If all messages cannot be delivered within a stipulated time, then a schedule to minimize the number of undelivered messages is generated. The feasibility of this scheme is demonstrated using different network conditions and constraints. The proposed method is also used to generate an optimal schedule for collecting user generated bids in transactive energy market in the least possible time [50][53].

Study of Smart Grid Communication Network Architectures and Technologies in 2019 by Naeem; Muhammad; Aized and Samia. Cellular networks are most suitable wireless technology in WAN communication architecture for the transportations between SMs and the Utility companies due to its stable infrastructure. Cellular networks are offering numerous wider area services to the SG applications in a very affordable way. Emergent of third-generation (3 G) and LTE wireless communication technologies to the cellular networks provide much higher data rates in NAN and WAN networks [48][51]. To efficiently implement the fully functional SG power systems for the management of real-time energy, numerous Communication network architectures and technologies are essential to be deployed at each level of SG infrastructure from generation of electrical power to the distribution to substations centers and then electrical feeders to the actual consumers of electricity such as homes, building and industry [52]. The table below summarizes the related works

Table 2: Pervious Studies

Solution Method	Paper Title	Author(S) Name	Problem	Year	Limitations
Poisson distribution	Communication requirements for smart grid	Mohame and Xavier	Measuring delay time in access network	2011	No communication protocol designed for smart grid needs end-to-end networks
N/A	Wireless Communication and Networking Technologies for smart grid	Xi Fang, and Guoliang	Network Availability	2011	N/A
fuzzy-logic	The effects of time delay in the electric power grid	Hasan and Dipankar	causes and effects of communication delays	2012	Handling only causes and effects of delay
Use DFT and PDC	Virtual Laboratory for Micro-Grid Information and Communication Infrastructure	James; Yuzhe; Carlo; Karl; Johansson, Per; Craig and Ariane	Calculate delay time in AMI and PMU.	2012	Minimum value of the delay for small size packet agrees with the theoretical delay only.
N/A	The Cost-efficient Low Latency Communication Infrastructure for Synchrophasor Applications in Smart Grids	Binxu, Konstantin, Wei Koong and George	latency PMU-based applications in the MV domain	2015	N/A
Using communication technologies for safety requirements (survey)	Communication challenges in Smart Grid	Eleftherios; Dimitrios; Charalambos and Lambros	Cyber security and privacy	2016	N/A
D2D_LTE (survey	Cellular Communications for Smart Grid Neighborhood Area Networks	Charalampos; Linus and Jesus	Calculate delay time in NAN smart grid	2016	Delay measure in distribution grid only (Delay was 100 ms, not sufficient, theoretical)
A frequency restoration	Recent Trends on Performance Analysis of Latency on Wide Area Technologies in Smart Grids	Gopakumar; Balimidi and M Jaya	investigates the effect of communication latency associated with wide area technologies on various smart grid operations	2018	The proposed modeling approach was verified in simulation studies on a power grid modeled with eight generators and thirty-six nodes only
demand DR and real-time DR	Performance Evaluation of Communication Technologies and Network Structure for Smart Grid Applications.	Desong; Manisa Pipattanasompo rn; Saifur; Rahman; and Di Shi	Study the capabilities of an Advanced Metering Infrastructure (AMI) to support the simultaneous operation of major smart grid functions	2019	Calculated delay on AMI only
Simulation	Impact of Information and Communication Technology Limitations on Microgrid Operation	Mahmoud and Ahmed; Yusef and Mohamed	Delay time	2019	Control logic is decoupled from the simulation software
End- to end delay	Low-latency Communications for Wide Area Control of Energy Systems	Farzaneh Masoumiyan	Delay time in WAC	2019	WAC latency depend on numbers of PMU measurements
scheduling and fixed PRB	Smart Grid Inspired Data Sensing, Processing and Networking Technologies	Jia; Kun; Victor and Ke	Investigated the feasibility of using LTE for the real-time smart grid	2019	No delay time was measured
backpressure based packet scheduling scheme	A Routing and Link Scheduling Strategy Smart Grid NAN Communications	Shuchism and Virgilio; Centeno and Blacksbu	routing and packet scheduling in SG wireless mesh networks	2019	No delay time was calculated
N/A	Study of Smart Grid Communication Network Architectures and Technologies	Naeem; Muhamm; Aized and Samia	Survey	2019	N/A
N/A	In the Smart Grid Virtualization for Grid-Based Routing	Armin; Alexande; Ferdina; Oliver; Ulrich and Peter	N/A	2020	N/A
Use existing wifi home for DR	Delay characteristic of smart grid traffic in wifi home area networks with and without other traffic	N.s.weerkroon and K.L.Lyanage	Calculate delay in wifi HANs	2020	Measuring delay for 100 request only in wifi HAN and vary capacity from 100kb/s to 56 Mb/s
Using PMU based wide area measurement (WAM) framework	Communication Delay Modeling for Wide Area Measurement System in Smart Grid Internet of Things Networks	M.K. Hasan; F.RAhmed; S.Islam; M.Shafiq; S.K M.Ataelmanan; N.B. M.Babiker, and K.A.Abu Bakar	Calculate communication delays of IoT networks in the smart grid	2021	Delay on PMU only
N/A	Communication Technologies for Smart Grid: A Comprehensive Survey	M. Cheffena; Yun Ai and F.E.Abrahamsen	Survey	2021	N/A

5. Conclusion

Smart grid communication is an emerging evolution to power grid systems. Cooperation between utility centers, customers, distribution station, different system and all entities in electricity generation, distribution and consumption is achieved by smart grid communication. Delay time in SG communication is important factor since real time sending and receiving for control signal represent the basic measurement of smart network.

In this survey paper found that open area represented the research gap to solve the delay time problem in the communication networks of smart grid that D2D technology in LTE cellular networks as proposed solution. Thus, enhancing LTE with direct D2D communications among smart grid entities in close proximity with each other without routing through the core network could provide low latency figures and facilitate delay-critical grid applications where real-time transmissions are required.

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