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An Efficient Data Transmission in Smart Grids Using Edge Computing

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Abstract - In the world of smart grids, there has been improvements like protection, efficiency and environmental friendly power systems. With a huge amount of data transmitted through the IOT devices, cloud-only architecture could not hold the delay, throughput and response time of these data via the network. For that reason, the reference architecture with the involvement of the edge computing for smart grid is established. We considered discussing edge computing as an extension of the cloud, assisting the smart meters and IoT devices in smooth data transmission to and fro the entire smart grid. The edge nodes helps to ease load on cloud, improve its performance and efficiency, and also provide real-time calculating service. Performance relating to delay, throughput and response time of cloud services and edge services is shown and evaluated. Our simulation proved that the edge based smart grid architecture has a great improvement over the cloud state of the art technique.

Keywords - Smart Grid, Response Time, Delay, Throughput, Edge Computing.

I. Introduction

Information transmission in Wireless Sensor Networks (WSN) brings about a lot of challenges occurring with different essential features that differentiate this networks from other wireless networks. However, some of these challenges can be abridged with the construction of smart grid technologies using the edge node within the network. An edge computing solution for circulating grids is a decentralized technology aimed at aggregating measurement, analysis, and demanding functions. The above are the three most needed structures to consider for efficient integration of distributed energy resources at the edge of the circulating grid. A number of incoming technologies supplies complete digitalization of scattering grids and forces the grid to appear visible and stable and also enables provision of flexibility services from distributed resources. The edge computation is a key feature for smart grid technologies since distribution grids are in nature far and wide scattered and many circulated energy resources are positioned at the grid edges, where communication and big data can be serious concerns for a centralized computing solution. Most centralized computing layers for example fog computing and cloud computing can be used for the coordination between the neighboring geographical locations.

This edge computing technology can make use of the optimum control of the various distributed energy resources to ensure the technical security and stability of the grid. The control algorithms are needed to be decentralized to avoid the issue of single point of failure and the control measures should be synchronized alongside the feeders of the higher voltage levels. Therefore, the goal of edge computing is to communicate with a number of manageable resources through different communication methods and protocols. It certainly expands the existence of constraints and flexibility from dispersed resources while taking into account the impact of these services on the grid operational limits. Moreover, the edge computing solution requires, on one side, to make use of the available smart metering data for grid analysis, and also to interconnect with the existing supervisory control and data acquisition (SCADA) and Advanced Distribution Management System (ADMS) systems deployed in higher voltage levels.

For a valued information dissemination, the storage and carry forward approach is applied to the numerous smart

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devices so that delay will be lowered [10]. These kind of devices offers special services to multiple consumers in the environment [16]. However, all service requirements are assessed and monitored within the central station [17]. Since the edge computing performs efficiently in terms of request of transmission in the environment. In [18], smart grids always needs to achieve low response time, low latency, and high throughput. Smart grid produces continuous exchange of data between its key smart world infrastructures [19]. These infrastructures, are indeed intelligent things such as healthcare devices, home appliances, factories, buildings, vehicles and other things linked with sensors, embedded computers, actuators [20]. In order to ensure better performance, those applications use end-to-end transmission requirements on data communication between hundreds or thousands of network intersections [21]. In this paper, we contribute by formulating an analytical model for evaluating delay, throughput and response time and explain the results of our experiment.

In summary, the related works are presented in Section 2. The system model corresponding to the architecture is discussed in Section 3. Evaluation and experimental results are presented in Section 4. Finally, the conclusion is drawn in Section 5.

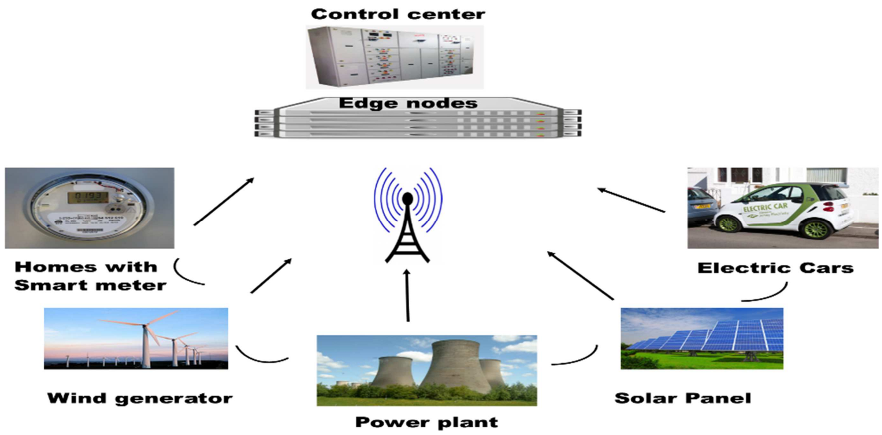

Figure 1: Edge computing in Smart grid

II. Related Works

In recent times, many IoT applications, such as smart grids, the smart cities, smart vehicles, and smart traffic lights, are upgrading their applications rapidly with EC, significantly enhancing response time as well as maintaining network resources. The authors in [1] aimed to authenticate the efficiency and resourcefulness of EC. Their survey extensively reveals the edge systems and provides a comparative study of cloud computing systems. The results of their analysis show that EC systems out-perform the cloud computing systems. In [2], it describes a smart grid (SG) as the process of applying ICT with the aim of energy consumption optimization, and energy loses reduction. Their work presented 3-tier IoT-based hierarchical framework for the smart home which is aimed at extending the smart home to micro grid level, so as to integrate all renewable distributed energy sources from the micro grid and to achieve better energy optimization. They further defined fog computing for an extended data computation and processing. Results of their simulation revealed that fog computing based on predictive filters can reduce the number of transmissions and minimize smart home network traffic. EC (and its close cousin, Fog computing) is considered a complement to cloud computing: it exploits IoT interconnected devices at the logical ends of networks. In [3], it outlines the potential for EC to aid power grids. The study analyzed the Fog Pillars and how they can assist power and smart grids in resource distribution and dissemination using candidate algorithms. The authors in [8] proposed a novel model known as Zenith intended for the allocation of computing resources in an EC platform. The prose technique allows service providers to establish contracts in resource sharing with edge infrastructure providers. Their main purpose aimed at solving the latency constraints of the network and communication channels. In [5], investigates the application of Vehicular delay-tolerant networks (VDTNs) in a smart grid technology as one of the means of data circulation to various devices interconnected in the SG using mobile edge computing. VDTNs technology makes use of the store-and-carry forward technique for information and data dissemination to several smart devices in the network resulting in delay reduction during the process of overloading and congestion in the core networks. Their empirical results demonstrated an improved performance of 10-15 percent throughput increase, 20 percent response time decrease, and 10 percent delay decrease within the proposed solution as against the existing system. For solving the issues related to data storage by the IoT devices, and too many time consumed in providing real time services from the cloud, the authors in [6] proposed a well-organized fog infrastructure communication system for data processing and dissemination in a SG and Smart Local Grid (SLG). The fog hierarchical architecture structure was also considered for security purposes. For reliability of industrial IoT and the smart grid, communicating devices must transmit with other machines and must robustly communicate without human intervention. In [7], presents results of an in-depth coverage of no-load and full-load conditions in real time large scale networks such as SG and manufacturing industries when all edge devices on the channel are simultaneously communicating over a highly populated, and short length wired IoT channel. Considering the huge amount of data generated by each home in a smart home, cloud-only architecture could not meet up the demands in the volume and velocity of this data across the network. Therefore, [15] in their paper presented a reference architecture for smart home based on fog computing using ZigBee protocol to enhance network performance, data transmission, and efficiency, and also offer real-time data calculating service. Their approach can effectively address the data amount issues and reduce the response latency. [9], [13] attempted the integration of FC into information-centric IoV to enhance mobility support by distributing different schema considering the data characteristic (user-shareable data, communication data). They applied the computation, storage and location-aware aptitudes of fog to design a mobility support technique for data exchange and communication. The result of their evaluation proves the advantages FC-based information-centric IoV have over the state of the art system. In [11], WSNs was proposed for efficient data communication in emerging smart grid. The authors merged two application domains, (VANET and smart grids), and a novel solution for effective smart grid data communication was proposed. The proposed technique tends to achieve the task of collecting data from smart meters by utilizing VANETs. Their simulations using network simulator-2 with several routing protocols, proved the efficiency of their technique in terms of average end-to-end delay and delivery ratio. To achieve the goals of reliability, efficiency, security and cost-effective energy generation, consumption and distribution in a communications infrastructure and wireless networking EC will plays important role to support data transfer and information exchange in smart grid. In [4], cooperative transmission for the meter data collection in smart grid was considered. The power consumption request from the connected nodes is measured by a smart meter and communicated to a meter data management system (MDMS) through the data aggregator unit (DAU) through the application of wireless broadband access. The proposed network technique and analysis was useful for the design and optimization of a wireless network for smart grid. The study of [12] focused on cloud-based data processing and analysis techniques of user side in smart grid. A cloud platform architecture designed for data processing was introduced and discussed. This includes data collection; analysis, storage and visualization. The authors in [14] categorized EC into different segments based on architecture, by studying their performance through network latency comparison, energy consumption, bandwidth occupation, and overhead. Furthermore, they compared the performance of various IoT applications (smart grid, smart city, smart transportation, and so on) in edge computing and traditional cloud computing architectures.

III. METHODOLOGY

In this section, the purpose is established concerning the problem formulation based on the system architecture. On the other hand, the analysis was implemented by measuring the delay, throughput and response time parameters.

Delay is said to be the total time it takes for an information packet initiated by the transmission process to carry it from the source to the destination. The time interval between the moment when an IoT node sends a service request and when it receives the response for that request.

$$Total\ Packet\ Difference = TPD = \sum_{i=t_t}^{i=t_{t+1}} p_1 t_i - \sum_{i=t_t}^{i=t_{t+1}} p_2 t_i \quad (1)$$

$$Total\ Packet\ Received = TPR = \sum_{i=t_t}^{i=t_{t+1}} p_1 p_i \quad (2)$$

$$Total\ Delay = \frac{TPD}{TPR} \quad (3)$$

where $0 \leq t_1 and\ t_1 \leq t$, where $p_1 t_i$ represents the packet received time (s), $p_2 t_i$ represents the packet sending time (s), $p_1 p_i$ represents the number of received packets (s), $t_1\ or\ t_t$ represents the selected time (s) and t represents the monitored time (s).

Throughput is said to be the total number of data packets bits per second transmitted within a specified time. Throughput is exploited by the Smart Grid (SG) for communication given that it depends on some application characteristics. Throughput in actual condition can be discussed to as bandwidth. Bandwidth is more fixed, while the throughput is dynamic, depending on the current traffic.

$$Total\ Packet\ Size\ Recieved = TPSR = \sum_{t_t}^{i=t_{t+1}} p_i \quad (4)$$

$$Total\ Monitored\ Time = TMT = t \quad (5)$$

$$Throughput = \frac{TPSR}{TMT} \quad (6)$$

where $0 \leq t_t\ and\ t_t \leq t,\ p_i$ represents the received packet size (bit).

Response time is said to be the total time it requires for the initial response to come after processing the required information. Response time is said to be bi-directional in traffic from source to destination (only in the user-to-server path). Throughput and response time are inversely proportional.

$$Response\ time = \frac{1}{Throughput} \quad (7)$$

Therefore, $Response\ time = \frac{TMT}{TPSR}, 0 \leq t_t \leq t$ ..... (8)

IV. Simulation Results

In this section, we present the assessment results of the proposed scheme by using Matlab. However, based on our edge architecture, we compare our results with the cloud computing equipment. The simulation graphs considered include delay, throughput and response time against the number of requests.

Table 1. Simulation Parameters

Simulation Parameters	Actual Value
Number of requests	$100 - 1000$
Transmission range	$10m - 1.5km$
Channel	Wireless
Number of edge nodes	4
Avg. % improvement for Delay	22.5%
Avg. % improvement for Throughput	20%
Avg. % improvement for Response Time	30%
Bandwidth	$1Mbps$
Data Packet Size	$500bytes$
Data Transmission Model	Bidirectional
Simulation Time	$3600s$

Starting off with Figure 1, as the number of requests increases from 100 to 1000 there is also a slow increase in delay. But this delay is lowered at the edge equipment compared to that of the cloud computing system used. This could be due to the fact that all computations are done at the edge where information disseminates to and fro from the smart grid are then transmitted onto the edge nodes, resulting in faster computations for making the decision about transmitting information.

In figure 2, it displays the comparison of transmission throughput based on data at the edge and the cloud. As observed from the results obtained, the edge structure provided a higher throughput between request 300 and 900 as compared to the cloud setup which also increased steadily between request 400 and 800. However, improvements can be seen at the edge because there is availability of request to be responded. Applications running at the edge take less time to offload the data about charging and possibly discharging to the cloud, so therefore the performance time of such requests is lower because of high resource availability for all such applications. As we can see from the figure, comparing data at the edge and the cloud, the throughput of the new data accessibility with edge computing equipment has been significantly improved.

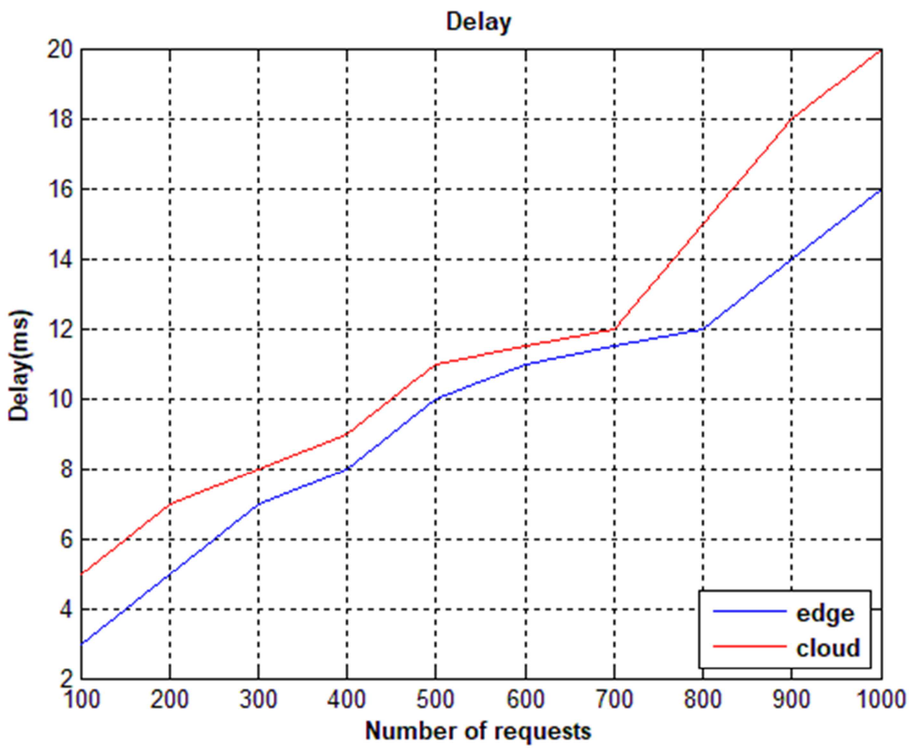

Figure 1: Deviation of delay with number of requests

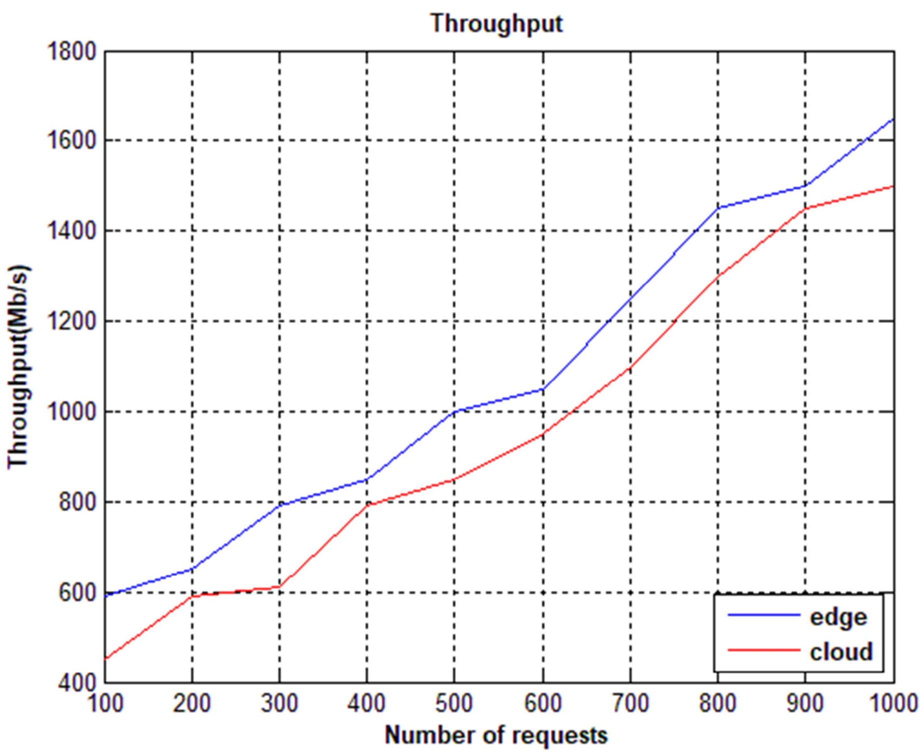

Figure 2: Deviation of throughput (megabits per second) with the number of requests.

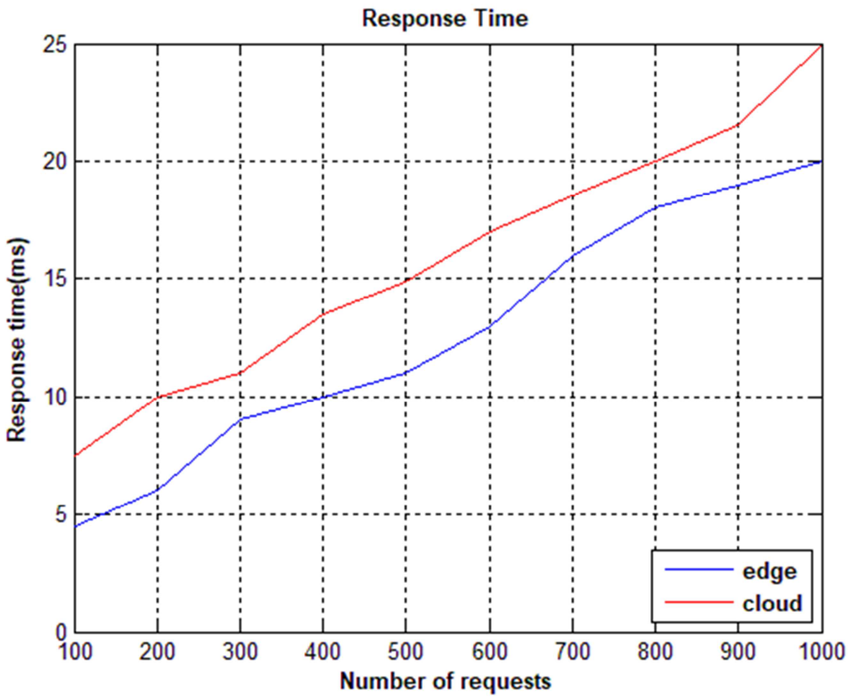

Figure 3: Deviation of response time with number of requests

Figure 3 explains the total response time produced between the applications in the smart grid and the two equipment. When the number of number of requests is increased, the edge computing approach yields a lower response time compared to the approach using the cloud computing. At request 100, the response time is almost twice as compared to the delay for both equipment. The gradual increase in response time as number of request increases is so since the cloud equipment needs to be accessed further away and that multiplies the response computation time. Meanwhile, more processing is carried out on the cloud layer than the edge layer, we can conclude that the total response time is considerably reduced at the edge.

V. Conclusion

In this paper, we mainly focus on assessing the performance of effective data transmission between the edge computing configuration and the main cloud computing approach but also considered the presence of smart grid. However, edge computing is considered to operate very fast in real time compared to the cloud which is the main data storage center through high throughput, lower delay and response time because the edge device was positioned between the smart grid and the cloud storage. The method proposed is designed for a smart grid, which is applied using the edge computing technique. The method transmits all data values from the smart grid central data center to the cloud through the edge equipment. To control this numerous requests generated during transmission, our approach transmits messages requested from the edge network to the various applications in the smart grid, in that way safe messages are delivered from the source to destination so that real time decisions can be made. The experimental concluding stages found that the edge is more suitable than the cloud.

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