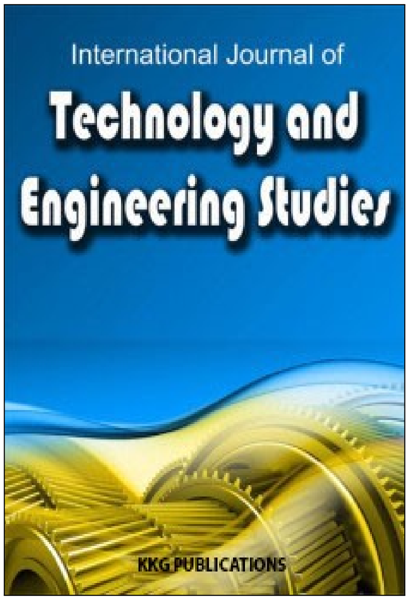

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A TRAFFIC TRANSMISSION SCHEME FOR SMART GRID COMMUNICATION

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Abstract. This paper aims to design a traffic transmission scheme with the proposed Intelligent Smart Grid Access Point (ISGAP), which can neutralize the traffic burst phenomenon. The grid communication is an obligatory affiliate required to provide essential information exchange facilities among the grid devices. To assure an effective communication process, traffic transmission controlling is necessary because deploying grid devices would produce a huge amount of data. The theoretical simulation result shows that ISGAP and its traffic transmission controlling scheme can potentially work with Bursty Traffic (BT), optimize traffic in the transmission process, and utilize bandwidth efficiently. This study has also presented a cellular network-based smart grid architecture, where the proposed ISGAP can execute its intelligent traffic controlling and transmitting functions. The proposed traffic transmission scheme would optimize the traffic and also reduce the bandwidth usage.

INTRODUCTION

A Traffic Transmission Scheme for Smart Grid Communication Smart Grid (SG) opens a new era of power grid with the promise of efficiency, reliability and sustainability. So far we have found, communication and information technology will be the significant part of the future power grid infrastructure [1]. Therefore, an uninterrupted, dependable and reliable communication process is required for the next power grid infrastructure.

Variety of communication technologies would be used for the SG device networks [2], [3], so the interconnectivity between SG network devices and backbone network needs a bridge or access point because communication technologies of SG device network differ from backbone network technology [4].

We have proposed an access point called ISGAP, which works as a communication medium or bridge of two different types of network. ISGAP also can optimize the traffic transmission process with its intelligent functions which is considered as the main objective of this paper.

Smart Grid Communication System (SGCS) needs to handle giant traffic volume by utilizing the limited resources [5]. For the efficient communication with limited resources, it is required to optimize traffic volume for avoiding traffic redundancy, reducing traffic blocking probability and cost efficient communication. Considering these issues, we developed a novel method for the optimization of traffic transmission process for both regular and irregular conditions of SGCS, which can optimize the traffic rate without any interruption within SGCS that can also reduce channel bandwidth consumption.

The method includes two rules for transmitting BT of two categorized devices. On the basis of importance and priority of BT, we categorized the SG devices. For BT generated from safety or emergency device, it will get priority to transmit without any interruption. The high priority devices' traffic needs to be forwarded with less delay [6], these rules also work on this context. At a glance the beneficial dynamism of our scheme is as below:

- Cope with BT at critical time communication
- Reduce channel blocking probability
- Efficient channel bandwidth utilization
- Defective SG devices identification with status bit
- Support two-way traffic flow establishment

The rest of the paper is presented as: related work, the smart grid architecture, analysis of traffic transmission process, conclusion and future works.

RELATED WORK

In this section, we have represented the strength and weakness of the contemporary works in this area. [7] revealed an innovative idea for bursty internet traffic management. QoS guarantee and effective Bandwidth consumption by a non-conforming traffic stream is the main focus of Yang's work. Non-conforming traffic handling also would be a challenging issue in SGCS.

In the sensitive SGCS, it needs to handle both periodic

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as well as bursty traffic with some communication protocol, which shows dissimilarity between traditional internet traffic and SG traffic from heterogeneous devices. For this reason, the traffic of SGCS differs from traditional internet traffic in nature [8]. Therefore, some additional intelligent functions are required for handling the traffic of SGCS.

[9] indicated Point Coordination Function (PCF) of MAC (Media Access Control) of IEEE 802.11 based WLAN, which can handle the bursty and Periodic Traffic (PT). PCF bears serious problem that shows unknown transmission duration of polled stations, which gives limited Quality of Service support [10]. For SGCS, real time communication is required, where this type of problem wouldn't be desired.

Bandwidth is a scarce resource, it needs to be utilized efficiently. Optimized traffic transmission is one of the best ways of bandwidth utilization. ISGAP can solve the optimized traffic transmission and critical time communication issues using the rules which we have proposed in traffic transmission part.

THE SMART GRID ARCHITECTURE

Based on the traditional Power Grid and system model presented by [11], we categorized the Smart Grid into three networks as Distribution, Transmission and Generation. In the Distribution network, every Home Area Network (HAN) is considered as single node. Many single nodes are considered as multiple nodes like Building Area Network (BAN). Multiple ISGAPs are required for multiple nodes. A registered user of a particular ISGAP would have the authority to control the devices, which are associated with that node.

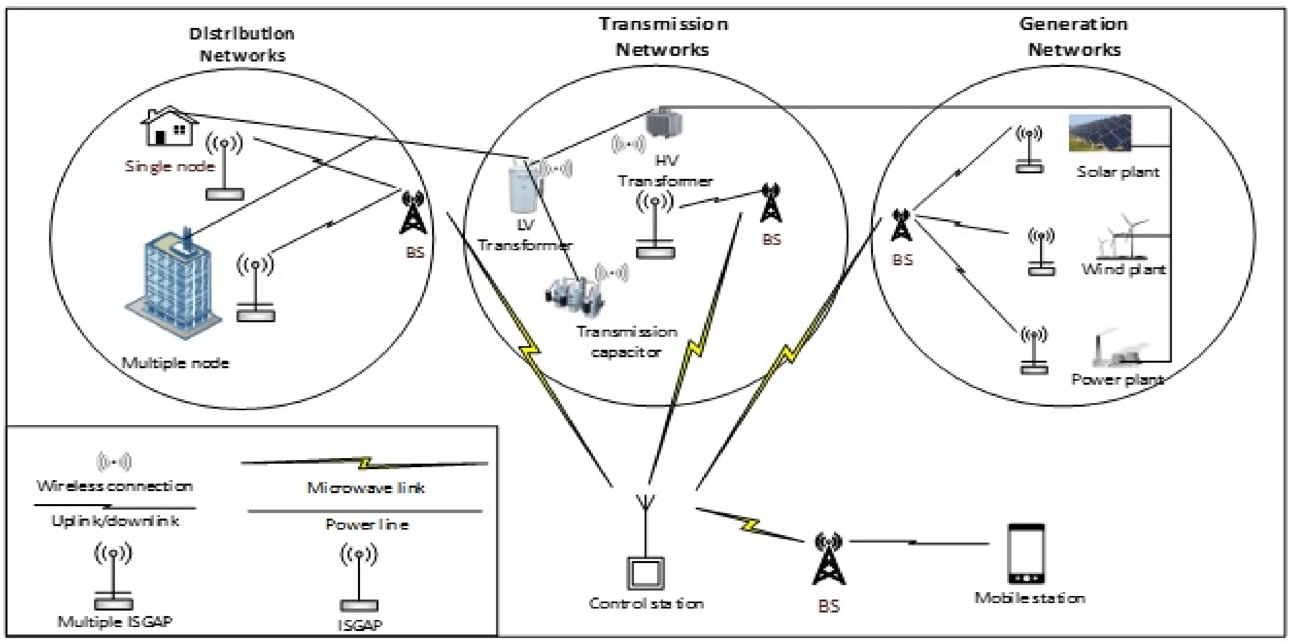

Fig. 1. Smart grid architecture

In transmission network, transmission devices are lightly populated in a region. So a wide range communication medium needs to support transmission devices. [12] proposed smart relay equipped with heterogeneous device network that supports to overcome low transmission range. Though we placed attention in our paper only on optimum traffic transmission process, the transmission range is not our concerned issue here. The generation network has the similarity with distribution and transmission networks in basic ISGAP principles and ISGAP allocation, but the device priority functions and configurations can differ from network to network. By the Grid communication process, load fluctuation and power supply-demand can easily balance with SGCS [12].

ISGAP is an intelligent device by which SG devices are connected with backbone network. The intelligence of the ISGAP is defined with some functional algorithm which works for the establishment of reliable and optimum traffic transmission process. ISGAP is more beneficial for indicating devices unwanted faults. In this paper, we only evaluated the traffic transmission process of ISGAP. ISGAP also works as a bridge or an access point between the cellular network and SG devices network like WAA [4]. Traffic optimization, BT handling, generates status flag for abnormal conditions of the devices, data aggregation and set priority for emergency devices using its intelligent traffic transmission functions that are the basic activity of ISGAP. ISGAP also has the common property of traditional access point. In this architecture, every ISGAP is connected with BS with uplink downlink channel as like the mobile stations connected and configured with BS.

Though Internet of Things (IoT) will be the future communication platform, SG devices need to collaborate with IoT [2]. Non-IP based technologies (like ZigBee, Z-WAVE, INSTEON, WAVENIS, WAVE2M, WirelessHart, PROFIBUS etc.) and IP based technologies (like 6LoWPAN, RRL, CoAP) could be collaborated with the SG devices [2], [3]. ISGAP must have the interaction with these technological standards as per the device network requirements.

According to our SG architecture model, generation, transmission and distribution devices are connected with the Base Station (BS) via ISGAP (see figure 1). BS assigns communication channel for ISGAP and the communication channel assigns for the Mobile Station (MS). The registered user can get notifications from control station and send request to the control station by using MS. This communication process is called two-way communication process. At a glance, the traffic flow of this communication process is presented below (see Figure 2).

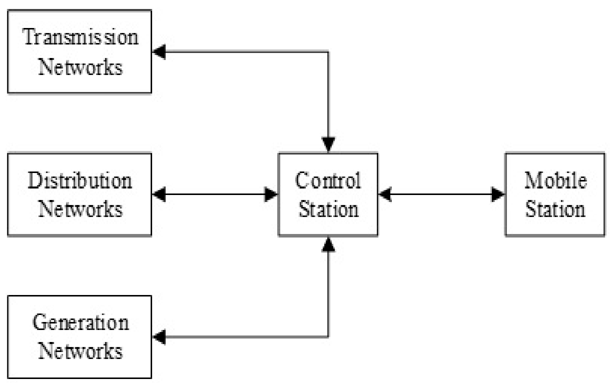

Fig. 2. Traffic flow diagram of SGCS

TABLE 1
ANALYSIS OF TRAFFIC TRANSMISSION PROCESS

A_{tu}	Uplink traffic rate of ISGAP
n_t	Number of types of devices in a network
N	Number of devices
p_l	Packet length for a particular type of device
p_{la}	Packet length of an ISGAP itself
C_{tu}	Uplink traffic transmission capacity of the channel
T	Interval time
th	Threshold time period
tp	Transmission period
O_{tv}	Optimized traffic volume

For Homogeneous Devices

We considered N numbers of homogeneous devices that are connected with an ISGAP, where N= 1, 2, 3, 4 ...n. p_l/t is the traffic rate of a particular type of device with t time interval. ISGAP has its traffic rate p_la/t. So for a particular time, the amount of traffic transferred by a ISGAP with N number of homogenous devices:

$$A_{tu} = N\frac{p_l}{t} + \frac{p_{la}}{t} \quad (1)$$

For Heterogeneous Devices

Different types of devices may connect to the ISGAP. Suppose the network has n_t types of heterogeneous devices where n_t= 1, 2, 3, 4 ...n. Considering heterogeneity in traffic rate, the actual uplink traffic is represented as,

$$A_{tu} = \sum\nolimits_{n_t=1}^{n_t}\left(\frac{N_{n_t}p_{l_{n_t}}}{t_{n_t}}\right)\frac{p_{la}}{t} \quad (2)$$

Suppose in a SG network, n_t= 3 types of devices N_1, N_2 and N_3 number of homogeneous devices and the packet lengths are p_{l_1}, p_{l_2}, and p_{l_3}, with t_1, t_2 and t_3 time interval:

$$A_{tu} = \frac{N_1 p_{l_1}}{t_1} + \frac{N_2 p_{l_2}}{t_2} + \frac{N_3 p_{l_3}}{t_3} + \frac{p_{l_a}}{t}$$

Every channel is connected with an ISGAP so that Uplink traffic transmission capacity of the channel C_{tu} must be higher than or equal to A_{tu} [5]. Otherwise communication outage can occur.

$$C_{tu} \geq A_{tu} \tag{3}$$

In this paper, our main concern is to defend the malfunctioned SGCS for burst of traffic. Some outrageous problems can occur, when BT will be generated:

- On reliability and sensitivity issue, the SG communication network must ensure the uninterrupted communication among the devices, where traffic transmission blockage may not be desired, but BT increases the blocking probability.
- Traffic volume might exceed the predetermined channel capacity due to burst of traffic.

Bursty Traffic

In a communication network, BT is not desired but gets more importance and priority if generated. Every device has two types of traffics: periodic and bursty traffic. BT is generated by a device on abnormal or faulty condition. For this region, the BT gets more priority than PT [9]. [8] has presented BT in her book as asynchronous event messages on data type. Here it is mentioned that BT "is challenging because the burst rate is undefined and many devices may respond to same grid conditions" [8]. For example, a transformer transmits higher voltage than its rated voltage. In that case, the devices those are associated with that transmission line also generate high voltage receiving signal and transmitting to the control station. Responding with the condition, BT will be generated by the devices those are connected with the transmission line with the transformer. Here traffic of the faulty transformer is important but traffic related to high voltage from the devices is not important. ISGAP transmits the faulty transformer traffic with priority but summarizes the affected device's traffic. By this process, ISGAP can easily recover communication outage and establish quality of service guarantee. We presented the traffic handling process through ISGAP into two steps:

- Traffic reception
- Traffic transmission

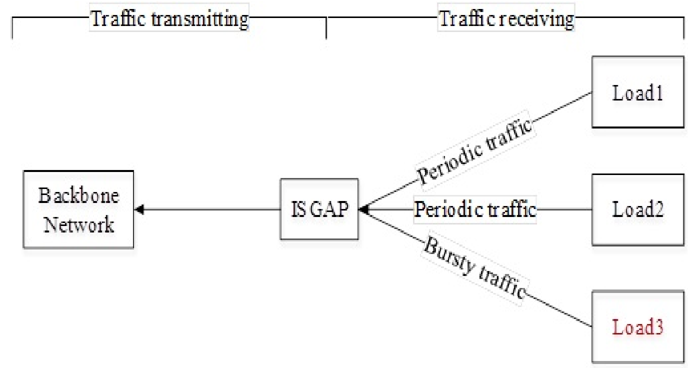

Fig. 3. Traffic reception and transmission process

Traffic Reception

Figure 3 represents traffic handling process into two parts. Device to ISGAP portion is the traffic reception part where traffic is received by the ISGAP and ISGAP transmits traffic to backbone network with transmission process. A similar solution related to BT receiving problem was given by [7]. The traffic profile for bursty internet traffic named 2bucket profile is designed, which can give solution to receive BT [7].

Traffic Transmission

Traffic transmission process is our concern of analysis in this paper. In this section, we describe elaborately our traffic transmission process. In abnormal case, device transmits BT that gets higher priority than the periodic data [9,10,13]. To overcome the abnormality and conduct a smooth communication is our main objective. We propose two traffic optimization processes to control the traffic transmission process:

- Increase the transmission period of periodic signal.
- Represent the SG device's faulty or abnormal conditions with status flag.

Using this Process, we categorized the devices into two types - (I) Security, safety and emergency devices (II) non-safety, non-security and non-emergency devices.

Rule-1 (By period increasing) is appropriate for type (I) devices, where the BT gets more importance than PT. For example, Fire sensor, Short circuit detector, Circuit fuse, transformer and so on. Here every device gets importance because of safety or security issue. Any device generating BT means the system's abnormality occurred. On that abnormal condition, PT gets less importance than BT. If we increase the period of PT, BT will get more chance to transmit without any blockage. By this process, abnormal condition would be overcome.

Rule-2 (By Status Flag) is appropriate for type (II) devices, for example Home Appliances. These types of devices' BT does not get importance as type (I) devices. The ISGAP has the intelligence to declare the device's fault or abnormality and also can summarize the BT. ISGAP consists of a Fault of Device Status (FODS) bit. If the FODS flag is activated, it means the device is faulty then it transmits Summarized Bursty Traffic (SBT), otherwise PT transmission occurs.

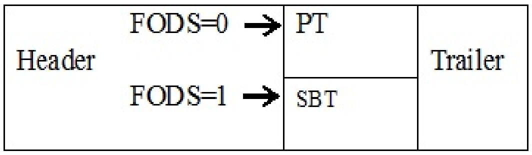

Fig. 4. A packet frame of ISGAP contains FODS bit

Proof

Homogeneous devices have similarities with their property. So within the same communication media homogeneous devices' traffic transmission process and traffic rates are similar. N number of devices in a network connected with ISGAP generate traffic p_l with t time interval. $\frac{p_{la}}{t}$ is the traffic rate of ISGAP for t time period. From equation (1), the amount of uplink traffic for t time period, we get uplink traffic rate of ISGAP A_{tu}. The threshold time period t_h indicates the marginal delay period. If a packet needs more time than t_h, packet dropout may occur. So optimized traffic volume O_{tv} with transmission period t_p will be:

$$O_{tv} = \frac{t_h}{t_p} \times N \times \frac{p_l}{t} + \frac{p_{la}}{t} \tag{4}$$

Heterogeneous devices have variety of traffic rates though the media is same. Traffic generated by a heterogeneous device A_{tu} got from (2) and optimized traffic volume O_{tv} show

$$O_{tv} = \frac{t_h}{t_p} \times \sum_{n_t=1}^{n_t} \left(\frac{N_{n_t} p_{l_{n_t}}}{t_{n_t}}\right) + \frac{p_{l_a}}{t} \tag{5}$$

By comparing (1) with (4) and (2) with (5), we can get a moral equation:

$$O_{tv} = \frac{t_h}{t_p} \times A_{du} \tag{6}$$

The equation shows that O_{tv} is inversely proportional to t_p. If we increase the t_p, optimized traffic volume (O_{tv}) will decrease, which supports our Rule-1.

To perform these two rules for traffic optimization process, we have developed an algorithm as below:

ALGORITHM FOR TRAFFIC OPTIMIZATION WITH ISGAP

```
Type1() //Defining type 1 devices function
Define bursty traffic, (BT)
//Check bursty traffic status (BTS) bit
if BTS=1 // BT generated
Transmit BT
check the PT period, PTP
define threshold period ,TP
Set period increment value, PIV
PTP = PTP+PIV
if PTP ≤TP
Transmit PT with PTP interval
else
Repeat Set PIV
else
Transmit regular PT
Type2() //Defining type 2 devices function
FOD( ) // Define fault of device (FOD) function
SBT( ) // Define summarized bursty traffic,
//Check fault of device status (FODS) bit
if FODS=1 // the device is faulty
Transmit bit 1 // declare faulty
SBT() //Transmit SBT
else
Transmit 0 //the device working properly
```

Analysis of the Simulation Results

SG network devices generate raw traffic which is transmitted through variety of communication technologies to ISGAP. ISGAP aggregates the raw traffic and prepares for transmitting structured traffic to backbone network.

In this section, we analyze the result of the Rule-1 and

Rule-2. To perform with the Rule-1 first we go back to the equation (1) and equation (2). These two equations show uplink traffic rate of ISGAP.

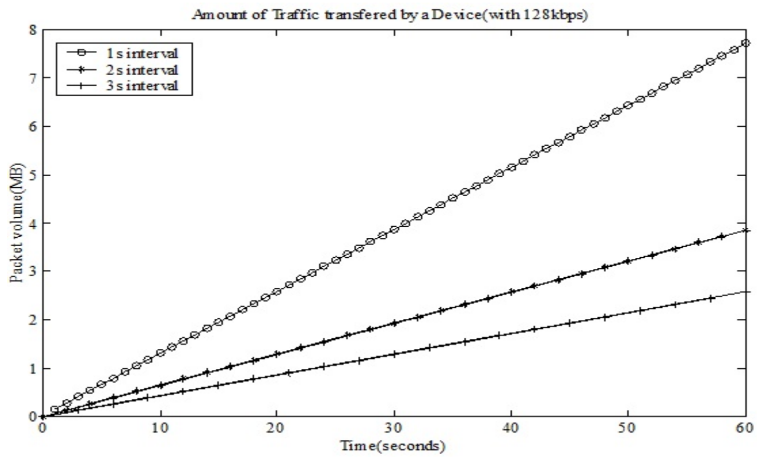

Fig. 5. Transmission interval increasing response for homogeneous devices

Responding with different time intervals, packet volume of ISGAP shows linear relations (see Figure 5). For a device, the transmission volume will be same for a particular time interval. The simulation shows within 60s, by varying the transmission time interval (for 1s, 2s and 3s) the packet volume increases with decreasing the time interval, which means $A_{tu} \infty 1/t$.

Figure 6 shows the traffic optimization response of equation (4) and (5). In simulation process, we consider t_h =60 seconds and p_{la}=32KB for both homogeneous and heterogeneous types of devices. The different numbers (here N=10) of homogeneous device's traffic are aggregated by an ISGAP. If the numbers of devices increase, the traffic volumes also increase within a particular time period. On the other hand, optimized traffic volume O_{tv} exponentially decreases with increasing transmission time period tp within a threshold time period t_h. So the transmission channel is free for transferring extra traffic without any communication break. The simulation shows for same traffic rate (here we consider 128kbps) of homogeneous devices.

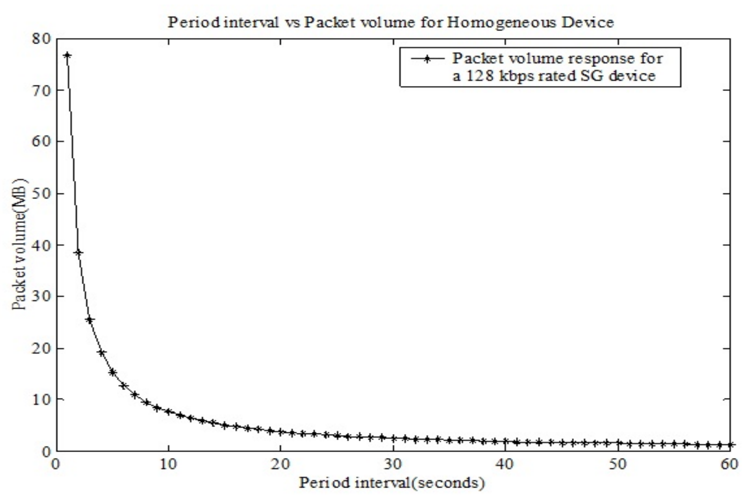

Fig. 6. A comparison of packet volume for different time intervals

Decreasing traffic transmission time period tp of the abnormal devices to transfer BT and increasing other devices tp is an additional solution for handling BT of homogeneous device.

Traffic management processes of heterogeneous SG devices are normally more complex than homogeneous SG devices because different traffic rated heterogeneous devices can be included in a network. Though the traffic rating property may vary from device to device, we can trace a common solution for traffic optimization by using (6). Finally we get that small change in t_p shows huge difference in O_{tv}, and it helps to transmit BT at critical time communication.

The above simulation results and equation's explanations support the Rule-1, which we have proposed. On the other hand, FODS bit can easily show device's condition with the help of FOD function. SBT function also can declare the traffic transmission process for abnormal traffic condition with type II devices. Status flag decreases the packet size that also indicates the device status. By using the functions, the raw traffic generated from SG devices gets structured form for the transmission to backbone network which supports the proposed Rule-2.

CONCLUSION AND RECOMMENDATIONS

SGCS requires reliability and stability in communication process. In this paper work, we have considered these challenging issues. Our traffic transmission scheme works for neutralizing traffic burst also diminishing communication channel blocking probability. In our designed Smart Grid architecture, we have proposed a new device called ISGAP that would work for performing our traffic transmission scheme. We also defined the functionality, working principles and configuration processes of ISGAP. The communication infrastructure doesn't have unlimited capacity, so it needs to be used efficiently. Our traffic transmission scheme would optimize the traffic also reduce the bandwidth usage.

Functions are the intellectual property of ISGAP. More precise function means more effective in nature. We have represented an overview of the functionality of ISGAP in this paper. The main objective of our near future work is to represent the more improved functionality of ISGAP. Communication delay with ISGAP may occur at executing the functions. How to minimize the delay, how to ensure low latency and how to make ISGAP real time responsive would also be added interests in future work.

Cellular network and Smart Grid collaboration requires more study for the implementation because the target areas of cellular network are voice and data services. Critical time communication is required for SG devices. How responsive the cellular network is to support critical time communication also needs to be studied. An extensive service outage can occur in power grid system for critical time communication failure.

Declaration of Conflicting Interests

No conflicts of interest are associated with the current work.

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