QUALITY OF SERVICE GUARANTEE IN SMART GRID INFRASTRUCTURE COMMUNICATION USING TRAFFIC CLASSIFICATION

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ABSTRACT

A fundamental requirement for smart grid is the design of a reliable and high performance communication infrastructure. The lack of timely access to information within domains of the smart grid serves as a real limit to detect and effectively react to system instability. Therefore, the delays are an important aspect and should be considered into any power system design or analysis. In this paper, we propose an IP/MPLS based communication infrastructure and optical fiber for the communication medium in the backbone network. In addition, in order to achieve the quality of service required for smart grid applications, traffic flows are classification into four classes using prioritize traffic and appropriate assignment of code point. Then, by using the Traffic Engineering with Diffserv (DS-TE) and active queue management algorithms as well as RIO, the quality of service is guaranteed in an acceptable level.

INTRODUCTION

In current infrastructure of power grid, power flow is supplied by unidirectional structure from centralized supply sources (power plants) to customers /consumers [1]. This infrastructure, due to increasing demand and population size will not be able to satisfy the growing needs of customers. Also, the main reason more blackouts and brownouts are occurring due to the slow response times of mechanical switches, a lack of automated analytics, and "poor visibility" – a "lack of situational awareness" on the part of grid operators [2]. Smart Grid (SG) with building a two-way flow of electricity and information is the solution we desperately need to solve many problems expressed. In fact, Smart grid is a modernized grid that enables bidirectional flows of energy and uses two-way communication and control capabilities that will lead to an array of new functionalities and applications Thus, this is allows electricity to be generated, distributed, and consumed more effectively and efficiently.

However, the connections capabilities of the power grids are limited to local areas and on small scales, so that communication infrastructure unable to transmission of huge amount of data in real-time and with the low delay. In General, Data traffic has been increased since systems get more complicated, and this will provide some challenges in designing SG communicational infrastructure. Therefore, paying attention to parameters like, latency and volume of the sending messages is an important problem in designing and creating communicational infrastructures for the different domains of SG. Most of the studies in the field of quality of service (QOS) assurance in power grids are concentrated on using middleware and routing [3-5].The performance of these existing approaches can be upgraded by creating some infrastructure proper for application programs and also by getting some priorities to the traffic of each level of power grids (Generation, Transmission and Distribution) and also classifying the traffic based on QoS parameters focusing on using the MPLS(Multiprotocol Label Switching) architecture in core net, in this paper an infrastructure which is proper for the requirements of SG application programs is proposed. Then by classifying information flows, an approach for guaranteeing the QoS of sent traffic to the SG control center is recommended.

QUALITY OF SERVICE IN SMART GRID

The types and quantities of data and information be exchanged through the communication infrastructure are exponential increasing. Some of the enhanced information are usable just in predefined time frames and if the communication delay gets more than the predefined time window, the information would not be usable and in the worst case, it may lead to network damages. Traditional communication techniques only provide Best Effort Service, by which traffic is transmitted as quickly as possible, but there is no guarantee as to timeliness or actual delivery [4]. While SG needs some approaches to QoS guarantee of the sent traffics in a communication networks among the substations. One of the best approaches for guaranteeing the SG send traffic QoS is to use a different model. This model puts sets of traffic which have similar properties in service classes and considers a set of flows that have the similar set required QoS to service [6]. Using the DSCP (Differential Services Code Point) field, the different levels of traffic are prioritized based on the service delivery time

Table 1. smart grid application and Example proposal for DSCP assignments

Traffic Type	*Latency (ms)*	*Bandwidth (kb/s)*	*Packet Size (byte)*	*DSCP (octal)*
Teleprotection	10	64	64	67 EF
WACS	100	1.2-64	64	73 EF
PMU	16	2048	53	64 EF
SCADA	200	512	64	55 AF4
VoIP	200	8-64	200	53 AF3
Video	1000	9.6-2048	1200	50 AF2
Power trading	1000	5091	1400	12 AF1
Event Notification	1000	1.92Mb/s	2.4M	07 BE

and the required amounts of bandwidth. In fact, when each router receives a packet, it finds out how to serve it by checking its DSCP, so the different classes are created in the network. An instance of SG traffic and its related QoS parameters are simply illustrated in table 1.

MPLS based Traffic Engineering

Using a technique like bandwidth reservation, is a method to develop the DiffServ and also traffic regulation in the power network.Traffic flows can be sent on the reserved channel by using MPLS service. These services allow the creation of bandwidth reservations within routers so that, These services allow the creation of bandwidth reservations within routers so that, required bandwidth will be guaranteed to have it regardless of the other traffic types in the network [3].In general, MPLS uses a simple forwarding method. In the MPLS networks, the label edge routers (LERs) attach labels to packets based on a forwarding equivalence class (FEC). Packets would then be forwarded through the MPLS network, based on their associated FECs, through swapping the labels by routers or switches in the core of the network called label switch routers (LSRs) to their destination [7]. The true strength of the MPLS forwarding algorithm is that analysis of the IP packet header only needs to be done once, at the ingress of the MPLS domain by an LER. Mapping the EXP in LER and defining the trunk for traffic policies for the created LSPS, the data traffic can be sent to the control center in predetermined periods.

TRAFFIC CLASSIFICATION BASED ON QOS PARAMETERS

The applications that are presented in table 1, are executed simultaneously in the network and each of them make some traffic according to their QoS requirements. And each of these traffic sets should be assigned to each of the priority levels. These traffic flows can be classified according to the different parameters; delay, bandwidth and size. In the proposed system, traffic is classified in to four classes assigned to each of these traffic sets(Table2).

Table 2. Classification of application based on QoS parameter

Traffic class	*QoS Requirement*	*Example applications*
Class 1	Low Delay Low Packet loss	WACS, WAPS: Teleprotection
Class 2	High Bandwidth Low Delay Low Packet loss	SCADA, WAMS:PMU
Class3	Moderate bandwidth	Power trading, Streaming : VoIP, Video
Class4	Delay tolerance	Event Notification

Decreasing priority

Controllability and Active Queue Management (AQM) algorithm are provided for the power companies to do some complicated combinations which is the result of using different applications that have different operational requirements.

Queuing Discipline

To achieve the desired quality of service, we use two separate queues ; Excellent service queue for packets belonging to the Expedited Forwarding(EF) class, and RIO-queue for packets belonging to a assured forwarding(AF) and best effort class (Figure1). The ES-queue is implemented as a FIFO queue, while the RIO-queue is more complicated than the ES-queue [8]. In the RIO algorithm, two thresholds are considered and no packet has been thrown away until traffic is smaller than the first threshold. If the traffic is between the two thresholds, only the packets that were used by the user very much are randomly thrown away. And if the traffic is more than the second threshold, all the received packets will be ignored.

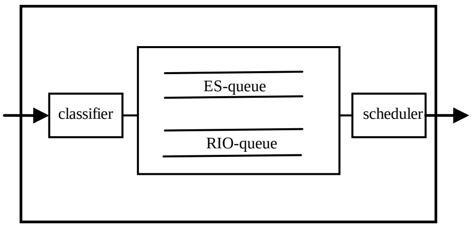

Figure 1: Queuing Discipline

Also, using strict priority queuing (SPQ) Scheduler gives this assurance that if there are enough resources, firstly the higher priority traffic are serviced in a queue. This technique considerably reduces the waiting time of time crisis traffic like teleprotection.

SIMULATION METHODOLOGY

To evaluate the recommended approach, the OPNET simulator was used as a network analyzing tool. The main advantage of the OPNET is that, it is modular which enables us to enhance the network performance mostly according to the environmental conditions [9]. The performance of the proposed approaches are evaluated in different scenarios based on communication network configurations, and traffic model substation.

Network topology in OPNET simulator

The proposed architecture is based on a optical fiber backbone network that connects to the substation routers, the substations' traffic and the other traffic like video stream and FTP are sent to the central control unit through the core net which is an IP/MPLS wide network.Since the delay due to the distance between nodes is considered part of the overall delay, hence, the geographical placement of nodes in the network simulation model is very important. Figure (2) shows the overview of communication network topology.

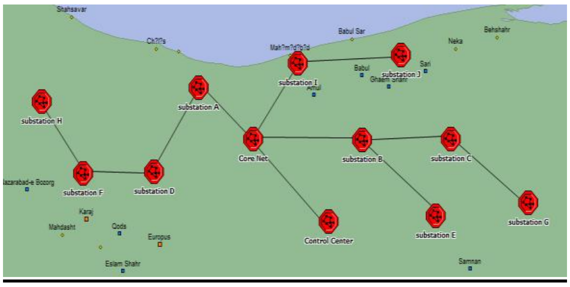

Figure 2: a high level view of topology Using OPNET Simulator

The considered topology consists of 12 nodes that connect to each other by an OPWG cable so that 10 nodes are considered as the substations, and one node as the core net and the other one as the control center. Each of these nodes is considered as a sub network.

Substation

Each substation includes telemetry equipment such as Teleportation, SCADA, WACS and the PMU device that can be connected to the substation router through the 100Base-T link and based on Ethernet LAN.

Core Network

The core net consists of 12 routers that support MPLS architecture that connects to each other by an OPWG cable on a mesh topology (Figure3). The bandwidth on all fiber optical communication links in this network is 5 MBits per second.

In order to efficiently use the network resources and provide better services to the traffic with critical situation, for each service class, an LSP is created and is mapped to the proportionate FEC.

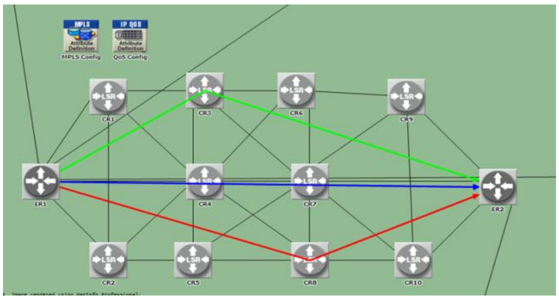

Figure 3: Routers connection based on a mesh topology in core net

Control Center

One of the most important sub networks is the control center that checks and manages the status of most distributed and far away tools. The information received in the control center, are analyzed and the required decisions are made and if needed the required proper control commands are created and sent to an IED in a predefined substation.

Scenario Simulation

To perform the simulation by using simulator OPNET, three main scenarios are considered: a) the first scenario, with all traffic will be treated in a best-effort manner and each packet is transmitted to destination in the network without any prioritize. b) In the second scenario, traffic flows classified in accordance with their priority and based on specific DSCP to be forwarded to the corresponding queue. c) In the third scenario the performance of the network is studied in a failing network. In this condition, the number of sent packets increases to more than three times as many as the usual condition.

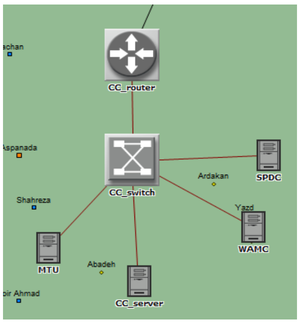

Figure 4: Control Center subnet

The protection system continuously sends four successive requests to the control center to insure that the packets containing the errors, are received. In the control center, as the main server gets the first request, it produces a 200Byte control command and sends to the IED in SubstationA.

Table 3. traffic rates of smart grid application

Application	*Distribution*	*Packet size(byte)*	*Data Rate*
Teleprotection	Constant	64	5 every second
WACS	Constant	64	20 every second
PMU	Constant	53	50every second
SCADA	Constant	64	10 every second
VoIP	Passion	200	1 every 0.2second
Power trading	Constant	1400	4 every 5min
Event notification	passion	2.4M	2 every 10 min

The video and FTP traffic are considered as the background traffic that use 30 percentage of the links bandwidths. The video traffic periodically and FTP traffic bursty will be sent to the network. It is necessary to mention that, as the notification and PMU traffic are sent to control center as off-line, the higher priority traffic like teleprotection and PMU are discussed to evaluate the results of simulation.

simulation results

The statistical results of end to end delay shows reduction in the delay of the sent traffic from DS-TE architecture in comparison with the pure IP architecture; this number has been reduced from 17.1 ms to 7.3 ms. Figure (5,6) shows the delays of teleprotection and PMU sent traffic to the control center. The ETE delay for the substation A is represented in table 4. Because of the space, results of other substations don’t be shown.

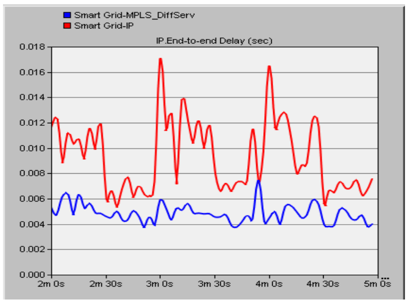

Figure 5: End to End delay for teleprotection bearer traffic

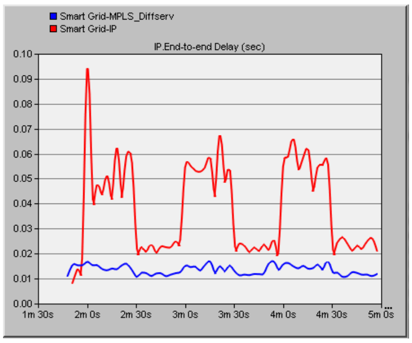

Figure 6: End to End delay for PMU bearer traffic

Table 4. End-to-End delays for Substation A

Architecture	***Maximum(ms)***				
	P	**S**	**W**	**SC**	**V**
IP	17.1	94	23.98	60.8	11.7
MPLS-DiffServ	7.3	16.9	11.29	39.11	8.46
	Mean(ms)				
IP	11.78	37.2	16.43	46.36	5.56
MPLS-DiffServ	4.83	13.5	6.7	25.72	3.6

As the traffic containing the smart grid information is time sensitive, reducing some millisecond delays is an important parameter. This delay reduction can be seen in the case of a failure. For the network to respond to the events, the sending and receiving time to/ from the control center should be reduced as much as possible. The simulated results are shown in Figure 7 and statistical values are shown in table 5 which demonstrate that the response time gets better.

Table 5. Statistical values for fault statues

	Max delay(s)	***Mean delay(s)***	***variance***	***standard deviation***
IP	0.0202	0.014	1.1529	0.00096
MPLS-DiffServ	0.00906	0.00454	9.2166	0.000370

CONCLUSION

The availability of a reliable and flexible communication network on the smart grid is critical for the support of several substations such as transmission and distribution. In this network, the delay has one of the most important parameters in characterizing the limitations of real-time access to information. Hence, in this paper Infrastructure in accordance with application requirements for smart grid based optical fiber and IP/MPLS was designed. Although fiber optic has a large bandwidth, however, if these links are shared with several substation applications data, it is important that appropriate QoS mechanisms be implemented to meet the stringent delay requirements of several mission critical smart grid applications. Therefore, an approach was proposed based on DiffServ model and traffic classification, and also, use of RIO algorithm in queuing discipline .Simulation results show that the proposed approach is significantly improved delay in the communication network. As a result, dispatching can be sure of the accuracy and the availability of information at real time, which in turn reduced to fault caused by lack of immediate access to information required.

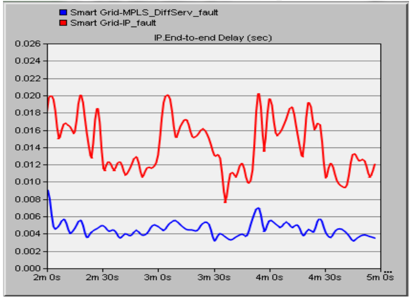

Figure 7: End to End delay in fault statues

REFERENCES

[1] F. Rahimi, A. Ipakchi, 2010, "Demand Response as a Market Resource Under the Smart Grid Paradigm",*IEEE Transaction on Smart Grid*, vol. 1, 82 – 88.

[2] NIST, 2010, " NIST framework and roadmap for Smart Grid interoperability standards", Release 1.0.

[3] K. Hopkinson, G. Roberts, J. Thorp, 2009, "Quality-of- Service Considerations in Utility Communication Networks", IEEE Transaction on Power Deleivery,vol.24, 1465 – 1474.

[4] Y. Ting, Z. Zhidong, L.Ang, W. Jiaowen, W.Ming, 2010, "New IP QoS Algorithm Applying for Communication Sub-Networks in Smart Grid", *Power and Energy Engineering Conference (APPEEC), Asia-Pacific*, 1 – 4.

[5] H.Li, W.Zhang, 2010, "QoS Routing in Smart Grid", *Global Telecommunications Conference (GLOBECOM 2010), 2010 IEEE*, 1-6.

[6] J. Babiarz , K. Chan, 2006, "Configuration Guidelines for DiffServ Service Classes", http://www.ietf.org/rfc/rfc4594 .

[7] E. Rosen, A. Viswanathan, R. Callon, 2001, "Multiprotocol Label Switching Architecture", http://www.ietf.org/rfc/rfc3031.

[8] J.Wang, K. Nahrstedt, Y.Zhou, 2000, "Design and Implementation of DiffServ Routers in OPNET", http://citeseerx.ist.psu.edu.

[9] W. Wang, J. Zhang, 2003, "OPNET modeler and network simulation", *Posts & Telecom Press, Beijing*