QOS ASSURANCE IN SMART GRID FOR IP-BASED APPLICATIONS OF MASHHAD ELECTRIC ENERGY DISTRIBUTION COMPANY

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ABSTRACT

Nowadays, the increasing demands and inadequate technology in electricity industry lead us to make it smart. To achieve this goal, the quality of service is very important for critical applications like teleprotection. Since the allowed delay for these kinds of applications are about milliseconds, having latency in packet delivery will cause serious damages. In this paper, we try to identify the verity of IP-based applications in Mashhad Electric Energy Distribution Company (MEEDC) and prioritize them based on their importance and traffic features such as allowed delay, arrival rate and packet size. After that we want to find an appropriate aggregation point for their traffics to analyse the input queue of the routers. By doing this we will be able to calculate the minimum required bandwidth for the egress link and according to the available communication network we can make decision whether the egress link is adequate or not. If not we can guarantee the QoS for critical applications.

INTRODUCTION

In order to meet increasing needs and various applications in power grid, this grid should use developed electric components and also is inevitable to use the information technology that consequently leads to smart grid. Smart grid substitutes the current hierarchical grid (generation, transmission, distribution) by a smart self-healer system which is able to control, supervise and manage the power grid more properly by gathering and processing information. Smart grid makes it possible to have reduction in power outage, less energy cost for customers, more security and confidence, less CO2 propagation by using electric vehicles, more security and reliability, effective supervisory, automated decision, better response to request, and more quick reaction to events.

To have a reliable, scalable, secure, etc., smart grid it is necessary to consider and guarantee the quality of service for the communication network. Thus recently some of the researchers try to suggest some solutions for QoS problems in different parts of smart grid. Most of these researches focus on proposing proper communication infrastructure and network architecture, classifying the traffics and determining how to treat with them, investigating the security problems and how to handle them, etc.

So in continue we first study some related works in this area and after that we propose the way we can analyse and calculate the minimum required bandwidth at each node and determine about the queuing and scheduling of different packets belonging to various applications.

RELATED WORKS

In [1] a QoS mechanism is proposed for communication system in smart grid and some criteria are explored for QoS like time delay. Then a greedy routing algorithm for quick routing in smart grid is represented based on the requirements of QoS and its performance is tested by simulation.

In [2] delay and performance of smart grid is improved for wireless network protocols by providing various services in MAC layer for different prioritized traffics, in this paper some wireless sensors are used to surveillance the distribution network tools and send collected data to sink by IEEE 802.15.4 protocol. Two types of data are mentioned: operational data and emergency. Operational data is inserted into the MAC layer queue and emergency data is inserted into the high priority queue. Emergency data can interrupt the service which is belonging to operational data and get service itself. Considering specified arrival rate and queue length, a delay model for MAC layer is proposed to provide QoS and also a model is proposed for channel service time and the packets that are sent successfully. Markov chain model is used for two traffic classes.

In [3] using MPLS and Diff Serv, an IP-based QoS algorithm is proposed for smart communications to guarantee services and packet delivery for secondary equipment and dispatching centre. In [4] the requirements of QoS are mentioned for the IP-based applications of smart grid. Then DSCP (Diff Serv Code Point) values are assigned to the applications to guarantee the quality of service. Also a strict priority queue is analysed to support critical applications. Finally by using this strict priority queue, the requirements of QoS for teleprotection application are discussed. Two cases are assumed for the problem of teleprotection packets, in the first case the teleprotection packet is in front of the priority queue and in the second case at the rear, and the worst packet delay and required bandwidth are calculated for each one. Finally the hierarchical priority queue is tested, in this method there are three queues, a queue for teleprotection packets, a queue for synchrophasor and VOIP packets, and another queue for the rest of packets. The results for the packet delay and required bandwidth is similar to the previous case.

[5] Briefly explores the requirements of QoS in smart grid and discusses the problems in defining the requirements of QoS. According to NASPInet [6] referenced in [5], it is possible to classify the data services, applications and their QoS in smart grid in five classes to investigate their various requirements such as transmission delay. In [5] there is a table exploited from Alcatel-Lucent [7] which includes some applications of smart grid and their network requirements. [5] Believes that the critical components of smart grid are: IP-based network, transmission network technology, variety in applications, network standards, bandwidth with proper size, and high security. Thus, hybrid network architecture is proposed for power system automation and includes some kind of networks such as internet, wireless sensors, WiMAX and wireless mesh.

[8] Believes that since there are various communication networks in smart grid, then there are various QoS requirements. Therefore it represents a queue model with some input queues and some output queues. The input queues consist of buffers which related to smart grid services with different QoS requirements and the output networks show the different choices for packet delivery. Finally it uses an optimization algorithm based on Lyapunov to schedule packets depending on the situation of the input and output queues while tries to guarantee the QoS of the input queues.

ANALYSING REQUIRED BANDWIDTH IN AGGREGATION POINTS

In previous sections we argued about the necessity of providing QoS in smart grid. Implementation of QoS for only some traffic classes with critical delay and priority requirements is inadequate. Distinct applications need different manner in QoS issue, therefore current methods which support only three or four classes are not proper. In order to provide QoS we need to identify all IP-based applications in MEEDC and specifying a proper point to aggregate the traffics. As Fig. 1 depict, different applications such as AMI, micro grid, distribution automation, electric vehicle, distributed energy generation and other applications can send their information packets to the routers in the substations through different communication networks. A substation can communicate its neighbour substations or connect to the core network via backhaul. Therefore it seems that the routers in substations are the best point to aggregate and analyse the traffics. In following sections we will prioritize the applications and finally based on a priority list we will calculate the minimum bandwidth for egress links to satisfy the allowed delays for all the applications.

Prioritizing smart grid applications in MEEDC

Table 1 is a list which includes all the applications that currently used in MEEDC. These applications are sorted from top to bottom based on their priority and criticality.

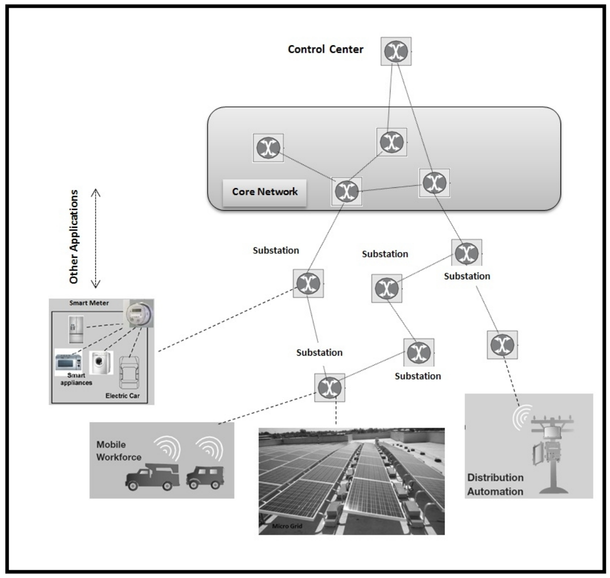

Fig. 1: A Scheme of Applications and Traffics in SG

We use some traffic specifications such as allowed delay, arrival rate and packet size and analyzing the status of networks based on these factors and also use our engineering knowledge to determine these priorities. It is obvious that allowed delay is a determinant factor but our disquisition shows that when some applications are assumed as critical with low allowed delay the other factors (arrival rate and packet size) can help to decide about their importance. Consequently as Fig. 2 shows, the required bandwidth for a critical application is studied in two situations. Having considered the graph, it can be obviously seen that when the traffic size is constant and the arrival rate is growing linearly, the bandwidth increases exponentially. On the other hand, when the arrival rate is constant and traffic size growth linearly, the bandwidth increases linearly as well. Therefore the arrival rate has great effects on the bandwidth for the applications which have a short allowed delay. Finally table 1 is created based on this information.

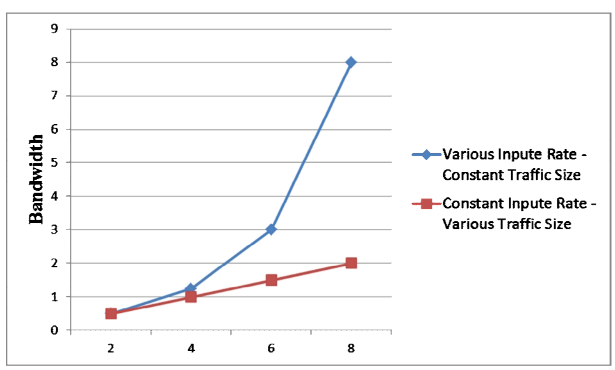

Fig. 2: Analysing Bandwidth Requirement Based on Arrival Rate and Packet Size for a Critical Application

Table 1: Smart Grid Application in MEEDC with their Delay Specification and Priority

Order	Applications	Allowed delay(MS)
1	protection information	9
2	System protection	12
3	Synchrophasor measurements	50
4	SCADA data	110
5	On demand CCTV video	200
6	AMI	300
7	Most distribution and SCADA apps	250
8	Fault detector	500
9	Customer Service	800
10	Monitoring and control information	1000
11	Distribution applications	1000
12	AMI—periodic measurements	1200

Calculating the minimum required bandwidth considering QoS

Our strategy to guarantee the QoS is calculating the minimum required bandwidth so that all the packets pass through the routers in their allowed time. As we queue packets based on their priority (specified in previous section) so required bandwidth will be minimum because the input queue is at its best status and we preferred the critical packets and the bandwidth that we compute is foremost. By considering the parameters that defined in table 2, we can assess the delay for each kind of packets based on the current status of the queue and since we know the allowed delay, we can formulate the required bandwidth.

Table 2: Parameters and Definitions Used in Calculation

Parameters	Definition
λ_i	Arrival Rate of *i*th Application
l_i	Packet Length of *i*th Application
B_i	Required Bandwidth for all Packets of *i*th Application
D_i	Allowed Delay for *i*th Application
T_o	Inter-Packet Overhead
Buf	Required Buffer Size For Queue
B_Q	Minimum Required Bandwidth

Note that we consider the arrival rate in an equal period of time for all applications. We assume this period is equal to the minimum allowed delay that according to table 1 it is nine milliseconds. Considering this assumption, the minimum size of buffer we need for queues is calculated by equation 1:

$$Buf = \sum_{i=1}^{n} l_i l_i \tag{1}$$

Where *n* is the number of applications, and in this paper it is equal to 12.

Now we want to compute the minimum bandwidth for each router queue separately so that all the packets are sent within the allowed time. To achieve this goal, the first we sort the packets at each period according to priority list which prepared in table 1, so that the most important applications are serviced earlier. Therefore the position of each packet is determined by its precedence when it enters the queue. The packets of typical application with the same delay are put beside each other and where they place in the queue is based on their priorities.

To guarantee that no packet is missed, we calculate a separate bandwidth for each kind of packet depending on its position. As a result, we have *n* minimum required bandwidth where *n* is the number of different types of packets in each queue. This calculation is performed for the last packet of each type to assure that even the last packet will be sent by the deadline. For a router queue at most we have *n* types of applications (*i*=1, 2... *n*). Therefor there are λ_1 packets of type 1, λ_2 packets of type 2… λ_i-1 packets of type *i* in front of the last packet of type *i*, and so imagining this status of a queue we can calculate the delay for each kind of application packet. Equation 2 shows the delay of the last packet of type 1 which is the sum of the time for sending all packets of that species and the overhead between packets. Then by using this equation and considering the allowed delay for this typical application, we can compute the required bandwidth via equation 3. Delay and bandwidth analysis for other types of packets can be performed in the similar way as shown in equations 4-5.

In order to pass the packets of type 2 in equation 4, first we need to wait for sending packets type 1 and this issue is included in our assessment. In this way we propose a formula in 6 which calculate the minimum required bandwidth for *i*th type of application packets.

$$D_1 = \frac{l_1 l_1}{B_1} + l_1 T_o \tag{2}$$

$$B_1 = \frac{l_1 l_1}{D_1 - l_1 T_o} \tag{3}$$

$$D_2 = \frac{l_1 l_1 + l_2 l_2}{B_2} + l_1 T_o + l_2 T_o \tag{4}$$

$$B_2 = \frac{l_1 l_1 + l_2 l_2}{D_2 - l_1 T_o - l_2 T_o} \tag{5}$$

$$\vdots$$

$$B_i = \frac{\sum_{j=1}^{i} l_j l_j}{D_i - \sum_{j=1}^{i} l_j T_o} \quad \text{for } (i=1, 2... n) \tag{6}$$

Accordingly we gain *n* bandwidth values for the router queue. Each value shows the necessary bandwidth for that kind of application to send its packets during the deadline.

Consequently to send all the packets of all applications in each queue we choose the maximum bandwidth which will be suitable for each species of application with its own traffic specifications. Hence the required bandwidth for each queue is formulized via equation 7 and also the scheme of what we explained recently is shown in Fig. 3.

$$B\_Q = Max(B_i) \quad \text{for } (i=1, 2... n) \tag{7}$$

As a conclusion, what we compute in 7 is the smallest bandwidth we need to assure QoS, therefore according to the current communication technology we can compare it with the existing bandwidth to see if we are able to guarantee QoS in MEEDC or not. If not we can suggest a communication network with a higher capability that afford sending all the packets in allowed delay. Note that in a case that our communication network is not able to satisfy the QoS we can at least guarantee that our proposed method is suitable for critical application, because the method we queue and schedule the packets is based on their importance so acute data will pass through routers in time.

Also by comparing the current status of egress link, we can compute the percentage of applications that include in our QoS policy.

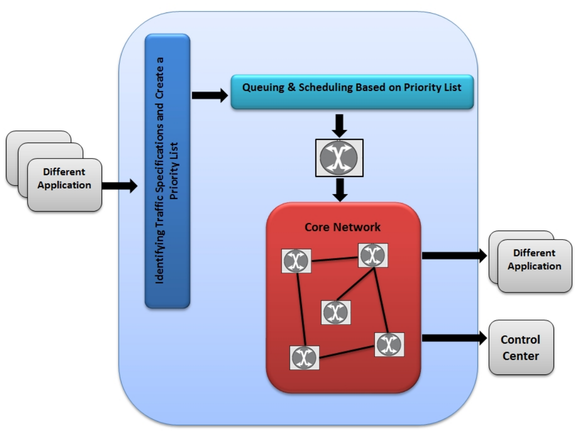

Fig. 3: The Scheme of QoS Assurance in MEEDC

CONCLUSION

In this paper after identifying the IP-based applications in MEEDC, we prepare a priority list based on three traffic specification including allowed delay, arrival rate and packet size, and also by investigating the effects of arrival rate and amount of traffics on the status of the network we conclude that the arrival rate of critical applications is highly effective. We determine the minimum size of buffer that depends on arrival rate and packet size so that we can have all the generated data by applications. Afterward we queue and sort the packets based on their importance and by considering each application's allowed delay we calculate the required bandwidth for each kind of applications and consequently we choose the biggest as the least required bandwidth. Finally we argue about the communication technology by comparing the current egress link with the one we compute in this paper. As queuing and scheduling of packets is based on their importance in smart grid so surely our proposed method keeps the quality of service for critical applications and is capable to suggest better communication network for a full QoS guarantee.

As a suggestion for future works it is possible to insert the calculation of minimum required bandwidth in routing algorithms by considering the communication network.

REFERENCES

[1] L. Husheng and W. Zheng, 2010, "QoS Routing in Smart Grid" *IEEE Global Telecommunications Conference*, 1–6.

[2] W. Sun, X. Yuan, J. Wang, D. Han and C. Zhang, 2010, "Quality of Service Networking for Smart Grid Distribution Monitoring," *Smart greed Communication*, 373–378.

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

[4] J. G. Deshpande, E. Kim and M. Thottan, 2011, "Differentiated Services QoS in Smart Grid Communication Networks", *Bell Labs Technical Journal*, Volume 16, Issue 13, 61–81.

[5] Y. Jeon, 2011, "QoS Requirements for the Smart Grid Communications System", *International Journal of Computer Science and Network Security*, Volume 11, No.3, 86-94.

[6] NASPInet Technical Specifications, 5/29/2009.

[7] Technology White Paper, Alcatel/Lucent, Smart Choices for the Smart Grid. Retrieved from the web. Feb. 2011.

[8] M. Levorato and U. Mitra, 2011, "Optimal Allocation of Heterogeneous Smart grid Traffic to Heterogeneous Networks",*Smart grid communication international conference*, 132–137.