Implementation of Universal Dynamic Bandwidth Allocation Algorithm in Smart Grid Environment

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***Abstract*— Smart grid produces tremendous volume of data traffic over the grid with each application is being treated with different quality of services (QoS) requirements. High priority applications are allowed to transmit first, followed by medium and low priority applications when the bandwidth is available. However, continuously granting the high priority queue regardless of the request from other queues will cause the high priority queue to monopolize the available bandwidth. In this paper, the universal dynamic bandwidth allocation (UDBA) algorithm is implemented into the smart grid environment to study its performance. The study is done via LabVIEW simulations and the results show that the granted bandwidth is improved by at least 10% since the bandwidth will utilize the excess bandwidth from other queues.**

Keywords—Quality of services, smart grid, bandwidth management, LabVIEW.

I. Introduction

Smart grid network is emerging due to its ability to transmit power and data in bidirectional transmission with the capability of control and monitoring. Smart grid structures support legacy power applications such as supervisory control and data acquisition (*SCADA*) and teleprotections. Due to smart grid promising features, new applications such as advanced metering infrastructure, synchrophasors and distribution automations can be implemented in the grid. With this, smart grid generates a large volume of data traffic over the grid. Without appropriate algorithm to improve the quality of services (QoS), smart grid network would not be able to cater to the demand which results in system failure.

Allowing high priority queue to transmit first in smart grid ensures that the critical application will have the priority to avoid unnecessary delay. However, continuously granting high priority queues regardless of the request from other queues may cause it to monopolize the available bandwidth. One of the best approaches to improve the fairness between queues is to cap the granted bandwidth for each queue with a certain percentage. Afterwards, using an intelligent bandwidth management algorithm to make sure each queue will transmit at a specified allocated bandwidth dynamically.

To the best of our knowledge, a bandwidth management algorithm, universal dynamic bandwidth allocation (UDBA) is incorporated for the first time in smart grid environment. Simulations are conducted to study the bandwidth granted by the central office (CO) when the request traffic mixture ratio is varied. The rest of the papers are organized as follows. Section II discusses on the related works, Section III discusses on the UDBA algorithm and the simulation setup, results and discussions is discussed in Section IV. Conclusion is done in Section V.

II. Related Works

One of the best approaches for guaranteeing the smart grid to comply with the QoS requirement is to classify the applications using Differential Service Code Point (DSCP) field [1]. Different levels of traffic are prioritized based on the service delivery time and the required bandwidth. For example, since teleprotection (*P*) is delay sensitive, it is classified as expedited forwarding (*EF*) packets with a DSCP value of 678 *EF*, while event notification which is a low priority application has a DSCP value of 078 best effort (*BE*) packets [1]. When a router receives a packet, it will be managed according the assigned DSCP codes.

Strict priority queue (SPQ) is introduced in [2] that supports multiple application traffic. SPQ will divide all the request from all substations into two queues namely Q1 and Q2 for high priority and medium/low priority respectively. Applications such as *P*, *V* and synchrophasor (*S*) belongs to Q1 while other applications such as on-demand closed circuit television, interactive video, image file, gaming and others belongs to Q2. SPQ scheduler will assure that there are available resources for critical applications. Higher priority traffic is served first in the queue, hence, reduces waiting time for time crisis traffic such as *P*.

A framework is proposed in [3] to address the QoS issue using software defined network. A better service for critical flow can be achieved by dynamically setting up the forwarding paths in the data plane. At the end, a control program will monitor the status of the network and direct the critical flows over a better path by installing OpenFlow rules on the switches. Path searching algorithm is implemented as a module for the Floodlight controller. The proposed framework significantly improves the throughput obtained by the critical flows compared with shortest path routing algorithm used in the current networks. When the developed QoS module is enabled, the network achieved higher level of utilization.

In [4], the use of multi-path and single-path QoS-aware routing algorithm under the harsh smart grid environment is investigated. The service differentiation capabilities in terms of reliability and timeliness domains is evaluated and the results show that multi-path routing accomplishes a significant service

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differentiation in both reliability and timeliness domain for smart grid environments. The proposed multi-path protocol provides a great service differentiation with different traffic flows in smart grid environments.

The related works mentioned are dealing with smart grid application classification, queuing, path and flow management. In this paper, we are using DBA approach to improve the throughput in smart grid.

III. UNIVERSAL DYNAMIC BANDWIDTH ALLOCATION (UDBA)

UDBA proposed in [5,6] allocates bandwidth to each queue without having one queue monopolizes the overall available bandwidth. In UDBA, each queue will send requested bandwidth to the CO. The CO will divide the queues into underloaded and overloaded queues. If the requested bandwidth is less than the minimum guaranteed bandwidth for queue, i in substation, j, ($B_{i,j}^{Min}$), it is grouped as underloaded. However, if the requested bandwidth is overloaded, the bandwidth will be granted with distribution bandwidth ($B_{i,j}^{Distribution}$) which is calculated using Equation (1), where (B_{total}^{Excess}) is the total excessive bandwidth for every queue, i in every substation, j and ($B_{i,j}^{Shortage}$) is the shortage bandwidth for queue, i in substation, j. ($B_{total}^{Shortage}$) is the total shortage bandwidth. Their simulation shows better bandwidth utilization by using the UDBA in the network compared with non-status reporting method.

$$B_{i,j}^{Distribution} = B_{i,j}^{Min} + B_{total}^{Excess} \times \frac{B_{i,j}^{Shortage}}{B_{total}^{Shortage}} \qquad (1)$$

In this paper, UDBA is implemented in LabVIEW according to the smart grid environment. LabVIEW is chosen due to its flexibility and interactive interface. Besides, future works on the smart grid network will be further integrated using hardware such as software defined radio peripherals which is best work with LabVIEW. Integration of LabVIEW with radio hardware has been presented in [7] to run simulations in fiber-wireless architecture that shows promising result and proved to be suitable to be used for telecommunication simulations. To simulate the UDBA algorithm in LabVIEW, the chosen architecture is as shown in Figure 1. There are two substations with central office connected using wired link. From the user interface, each of the substation will transmit different packets of different applications including P, S, V and other low priority applications (Z). The average packets size for P, S and V is 200, 80 and 200 bytes respectively [2]. Each substation is equipped with 3 queues namely Q11, Q12 and Q2 for highest, high and low priority applications as proposed in [2]. Q11 is fully dedicated for the most bandwidth and delay critical application which is *P*. Q12 is intended for *V* and *S* while Q2 is for other bandwidth and delay tolerant applications such as image and text strings which are denoted with application type *Z*. User will decide the requested bandwidth from the user interface. Then, each substation will submit a request from CO. CO will divide the queues into underloaded and overloaded substations. If the requested bandwidth is less than or equal to the capped bandwidth, it will be granted with underloaded bandwidth. The excessive bandwidth from all queues are calculated. When the request is greater than the maximum granted bandwidth, the granted bandwidth will be $B_{i,j}^{Distribution}$. With that, the available bandwidth by the CO will be fully utilized. Figure 2 shows the user interface for the granted bandwidth for all 3 queues, total bandwidth shared and the total bandwidth dropped in substation 1.

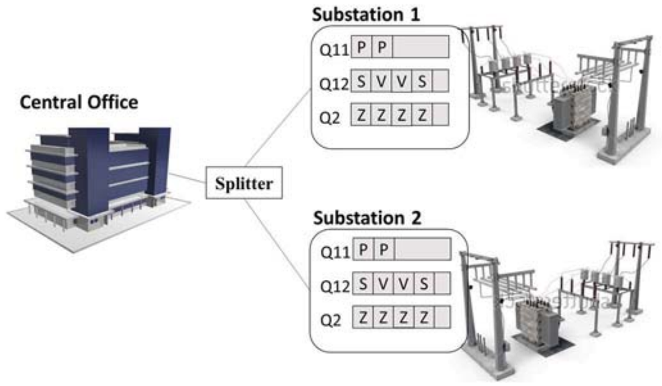

Fig. 1. Smart grid environment conceptual design

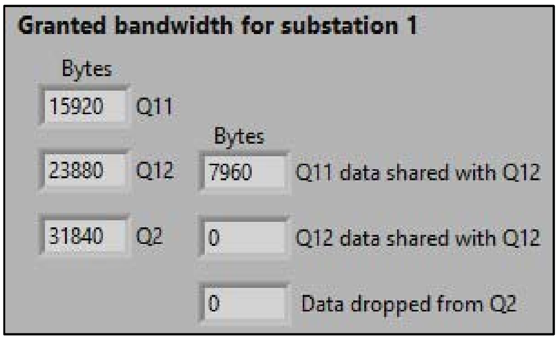

Fig. 2. Granted bandwidth user interface for subtation 1

The simulations are conducted in LabVIEW with a typical capping of traffic mixture ratio of 20:40:40 [8,9] for four different application priorities. The requested bandwidth is varied by varying the Q11, Q12 and/or Q2 with a traffic mixture ratio of 20:40:40, 30:20:50 and 20:50:30 respectively to study how the UDBA behaves when one or two of the queues in each substation are overloaded. The result is in terms of granted bandwidth versus requested bandwidth. The result is then compared with SPQ algorithm with the same traffic mixture ratios.

IV. RESULTS AND DISCUSSION

The granted bandwidth for traffic mixture ratio 20:40:40 is in-line for both SPQ and UDBA as shown in Figure 3a. This is because the requested bandwidth is within the capped granted traffic mixture ratio which is 20:40:40. The result shows that if

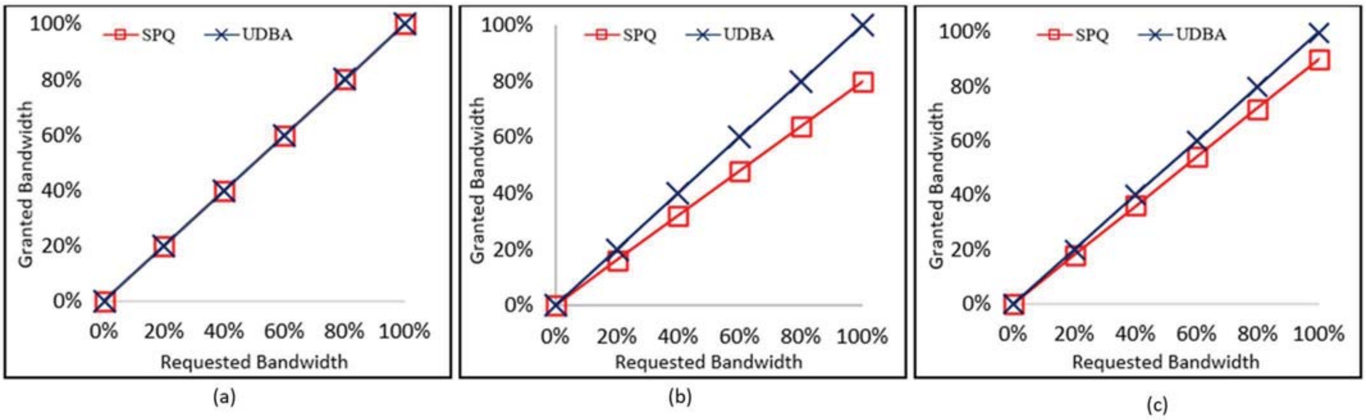

Fig.3. Granted bandwidth for traffic mixture ratio of (a) 20:40:40 (b) 30:20:50 and (c) 20:50:30

the requested is equals to or less than then capped ratio, the granted bandwidth will be as requested.

For the second simulation, the requested traffic mixture ratio is 30:20:50, Q11and Q2 has exceeded the capped ratio by 10% while Q12 have excess 20% that can be utilized by overloaded Q11 and Q2. At this point, the CO grouped Q12 as underloaded, since Q11 has the highest priority to transmit, the CO will allocate 10% from Q12 for the Q11 for transmission. The excess 10% from Q2 will also be allocated to Q12. SPQ on the other hand are capped at traffic mixture ratio of 20:40:40. For this simulation, SPQ must discard the overloaded Q11 and Q2 by 20%. Figure 3b shows that although there is available bandwidth available in the queue, but since it is not programmed to utilize the underloaded queue, UDBA has better throughput compared to SPQ.

For requested traffic mixture ratio of 20:50:30 the result is as shown in Figure 3c. For this simulation, Q11 is within the capped ratio and it is fully utilized, while Q12 is overloaded by 10% and Q2 is underloaded by 10%. For the UDBA, the CO will share the 10% from Q2 to the overloaded Q12. For that, the granted bandwidth for the UDBA is still 100% even Q12 exceeded the capped granted ratio. Similar to Figure 3a and 3b for SPQ, since it is not programmed to alter the capped granted ratio, at 100% requested bandwidth, the granted bandwidth is capped at 90%.

V. Conclusion

In this paper, UDBA is implemented in smart grid environment with simulations conducted in LabVIEW. Different requested traffic mixture ratio is used to study the performance in terms of granted bandwidth. The result is compared with SPQ algorithm. The results show that by implementing an algorithm that has the capability to manipulate the limitation bandwidth dynamically will improve the overall granted bandwidth as achieved by UDBA. The results show that UDBA achieved better granted bandwidth compared to SPQ by at least 10%.

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