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# An Efficient Dynamic Bandwidth Allotment Mechanism for Passive Optical Network using Optical Line Terminal

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**ABSTRACT:** A Passive Optical Network (PON) combines multiple service providers' in a ubiquitous city (u-City) without suffering from a bandwidth bottleneck. Multiple optical line terminals (multi-OLT) PON-based hybrid network effectively reduces the computational complexity of data packet processing of multiple service providers having different packet lengths and data rates. However, in the future u-Cities huge number of service providers, e.g., fiber to the home, wireless sensor network, femto networks, and video on demand, will be installed to provide several services. In this regards, only addition of multiple OLTs for multiple service providers are not enough to get the optimum performance from this hybrid network. In this paper, we propose a new dynamic bandwidth allocation (DBA) algorithm for improving the bandwidth sharing efficiency and reducing the time jitter in the upstream channel. Performance of this new DBA algorithm also analyzes for a multi-OLT PON based hybrid networks where a group of service providers will be connected to an optical network unit (ONU) with individual uplink wavelengths. In contrast, the other groups of service providers will be connected to the other ONUs with different wavelengths and every ONU will be shared by the multiple service providers. We have proposed the major passive optical networks in usage nowadays and have briefly explained the market status of PON technology.

**KEYWORDS:** DBA, EPON, GPON, ONU, PON, OLT.

## I. INTRODUCTION

Optical fiber systems utilize light waves for the transmission of all forms of telecommunications traffic, allowing the carriage of traffic at very high speeds with little disturbance. At the local access network level, it is utilized for transmission between network switches and nodes, and also for access to the premises of high-volume business users and multistory office buildings. The Passive Optical Networks (PONs) concept is not a new idea. It has the features of saving fiber and being transparent to network protocols, which play a more and more significant role in latest broadband access network. Compared with wireless and cable-based network, PON can save cable resources, offer large bandwidth sharing, high security for resources, and permit quick network creation. Thus, PON technology is economically attractive. With the removing of copper and wireless development, PON technology will be the mainstream technique for network access. PON technology involves broadband PON (BPON), ATM PON (APON), EPON and gigabit PON (GPON). With the development of bandwidth-intensive applications i.e. voice over IP (VoIP), internet television (IPTV) and peer-to-peer downloads, broadband access is becoming increasingly significant for the Internet. In this literature research, we widely review today's broadband access networks i.e. conventional wired access methods and wireless access techniques which also continuously expand their transmission bandwidth and radio coverage. These methods can normally support bandwidth in a range of several Mbps and a maximal transmission distance up to several hundred meters. To support even longer transmission distances and higher bandwidth, several broadband optical fiber based methods have been proposed and compared in this review. The fiber technology i.e. EPON is our particular research interest, especially the Dynamic Bandwidth Allocation (DBA) algorithms which can build a important difference to EPON's throughput.

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We can widely categorize today's fiber-based access networks into two camps: Wavelength Division Multiplexing-based passive optical network (WDM-PON) and Time Division Multiple-based passive optical network (TDM-PON). The current EPON/10GEPON, APON/BPON and GPON related to TDM-PON which often implements time division multiple accesses (TDMA/TDM) technology on downlink and uplink transmission to obtain bandwidth sharing, and the OLT signals which will be assigned to every distribution ONU have to go through the passive optical splitter. WDMPON [13] surely has the wavelength division multiplexing technique in its system of which passive optical splitter will assign signals to every ONU by determining a variety of optical wavelengths from the OLT. Because of WDMPON still un-standardized, this paper will not assume it further.

## II. APON/GPON

APON (ATM Passive Optical Network) [14]/BPON is an optical access technology that combines the physical layer and ATM data link layer. It was assumed as the best PON technology when first formulated (1997 was the ATM golden age) [14]. Due to Broadband PON (BPON) only updating or strengthening a tiny part of APON standards, it will not be proposed further in this paper. APON transfers continuous ATM cell streams. Every cell consist 53 bytes. For the down-link direction, APON employs a flooding Time-Division Multiplexing (TDM). Every Optical Networking Unit (ONU) will obtain all cells, and is capable to extract its own cells from the suitable time gap with respect to the targeted address of cells. For the uplink direction APON transfers ATM cells in burst mode. For the objective of conflict free and efficient uplink access, and for ensuring that all uplink signals for every ONU will fully reach at OLT, G.983 suggested Time-Division Multiple Access (TDMA) as the uplink access control technology. Thus, APON has to evaluate the transmissions for every ONU and coordinate signaling depending on the time delay. For achieving synchronization, every ATM uplink frame consist 3 overhead bytes. Plus the actual 53 bytes, there are 56 bytes in total. The overhead bytes roles are as follows:

a. Time protection: to prevent destructions to signal from small phase shift;
b. Prefix: to achieve bytes synchronously;
c. Delimiter: the only targeted ATM cell and the starting of micro-slots. It can also be synchronized as a byte.

**GPON**

EPON and APON both have static encapsulation formats: Ethernet encapsulation format for EPON and ATM encapsulation for APON. GPON [15] does not targeted a static encapsulation format and employs GEM (GPON Encapsulation Mechanism), which depends on the original format of subscriber signals and is also known as the "Native Mode PON" [15]. Due to its particular encapsulation format, GPON can keep high efficiency when it transfers multi service data, involving Ethernet, voice, leased lines, ATM and other service data. The efficiency can arrive above 90%. Meanwhile, GPON retains several characteristics of G.983 which are not directly concerned to PON protocol, i.e. Operation, administration and maintenance (OAM) and DBA. There are a various GPON transmission mechanisms i.e. Synchronous Digital Hierarchy (SDH)/ Synchronous Optical Network (SONET) and ITU-TG.7O9. By utilizing standard 8 kHz (125s) frames, GPON is capable to support TDM facilities directly.

## III. SIMULATION METHODOLOGY

In the simulation model, the distance between the OLT and those 16 ONUs is evenly distributed within the range of 10km and 20km (D=10+1016×$k$($k$=1,2,…16), so that different ONUs will have different RTTi in order to model the more realistic network environment. Two independent wavelength channels bit rate of the uplink and downlink can be set to 1Gbps. The transmission delay of fiber is round 5ns/m, the maximum polling cycle time normally is 2ms, and the guard time of ONU is 5µs. In order to reflect the different priorities of different ONUs, and to provide differentiated services for those ONUs, the OLT has to assign different maximum transmission window for different ONUs. We can divide all ONUs into three groups ONU. We can randomly select two ONUs in the high priority or EF group which will be assigned the maximum transmission window $Wmax$=20000 bytes, and then we can select 4 ONUs in the middle priority like AF group which will be granted the maximum transmission window $Wmax$ = 15000 bytes, after that, the remaining 10 ONUs will form a normal priority BE group which will be given a maximum transmission window $Wmax$= 14000 bytes. In addition, EPON has to support multi-service access, which means different priority services need to have different QoS. The OLT will set up the different weight coefficient for each different

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priority service based on SLA. The weight coefficient of EF, AF and BE service are 0.7, 0.2 and 0.1 respectively. Weight factor multiplied by the maximum window can be the maximum transmission window of each service queue which are described as $WmaxEF, maxAFandWmaxBE$. In order to verify the prediction algorithm performance (do not consider lost packet rate of this network model), we can set the infinite queue length for each ONU which implements the First In First Out (FIFO) mechanism to adjust or buffer packets. In order to better simulating AF and BE service which are normally burst, this simulation choose to use Pareto distribution with multiple ON/OFF source of which the self-similarity coefficient is 0.8 so that it can generate the real data source of AF and BE. The length of packets which has been used is 64-1518 bytes and subjects to the uniform distribution. Usually the high priority EF service can be presented by any voice service, so we use Poisson model to simulate the voice source of which the length is set up the fixed 70 bytes. The traffic flow range which will be generated within 0 to 120Mbps and the distribution ratio of these three services will be 2 EF: 3 AF: 5BE.

**Table 1 Simulation Parameters (KI-DBA experiment)**

| Parameter | Description | Value |
|---|---|---|
| RD | Bit rate between ONU and end users | 4 Gbps |
| N | Number of ONUs | 18 |
| D round | Round-Trip propagation delay | 200 |
| T guard | Guard time between time slots | 1 |
| W max-high | Maximum transmission windows for high priority service(EF) | 1000Bytes |
| W max-medium | Maximum transmission windows for medium priority service (AF) | 1500 Bytes |
| W max-low | Maximum transmission windows for low priority service (BE) | 1400 Bytes |
| B max | Maximum buffer size of each ONU | 10MB |
| D | Distance between OLT and ONUs | 15-20 km |
| T cycle | Maximum cycle time | 5 ms |
| S packet | Packet size | 64-1518 bytes |
| Weight | Weight factor for EF, AF and BE | 0.7,0.2,0.1 respectively |

## IV. RESULTS

Throughput can be defined as the ratio of the total amount of data reaches a destination from the source. The time it takes by the destination to receive the last message is called as throughput. It can express as bytes or bits per seconds (byte/sec or bit/sec). There are some factors that affect the throughput such as; changes in topology, availability of limited bandwidth, unreliable communication between nodes and limited energy. A high throughput is absolute choice in every network. In figure 1, 2 and 3 the graph represents the throughput in bits per seconds. The x-axis denotes the simulation time in minutes and the y-axis denotes throughput in bits per seconds. Through theoretical computation and simulations proving, the KI-DBA algorithm has been proved to be an efficient EPON upstream bandwidth allocation technique in terms of throughput and delay. It is theoretically important, and a practical way to enhance the bandwidth allocation strategy of EPON system and better support multi-services and multi-user access. A novel technology design, The OLT adjusts ONUs polling sequence according to the burst during the polling process, and postpones forwarding REPORT message for contracting the prediction region, hence the prediction accuracy of burst ONUs service is enhanced. The bandwidth allotment and time slot authentication is performed in advance before ending of polling cycle. As a result, the idle time is more completely used and the upstream bandwidth usage is increased.

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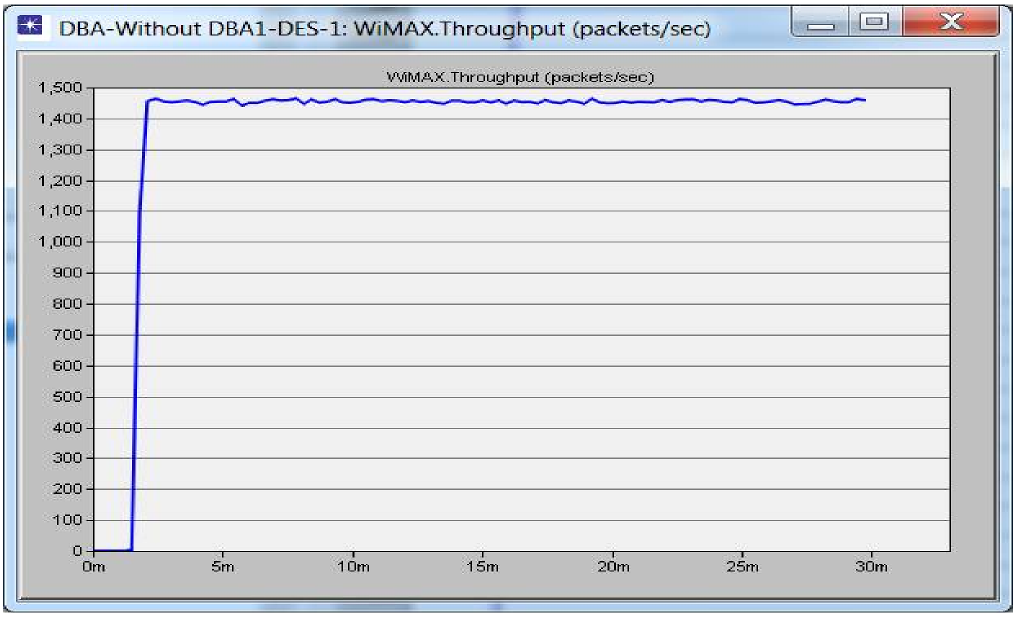


**Figure 1: Throughput without DBA**

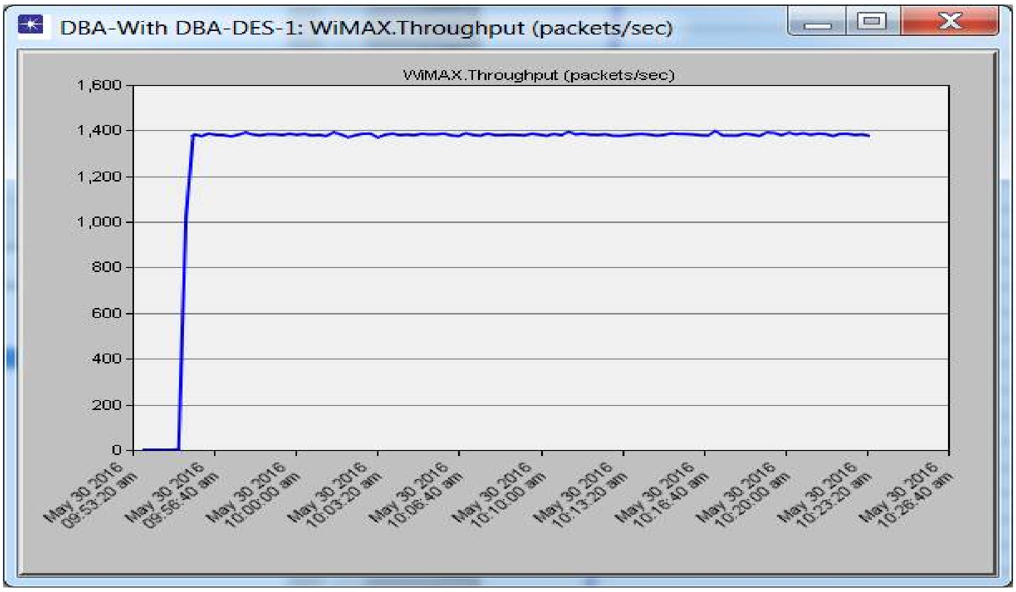


**Figure 2: Throughput with DBA**

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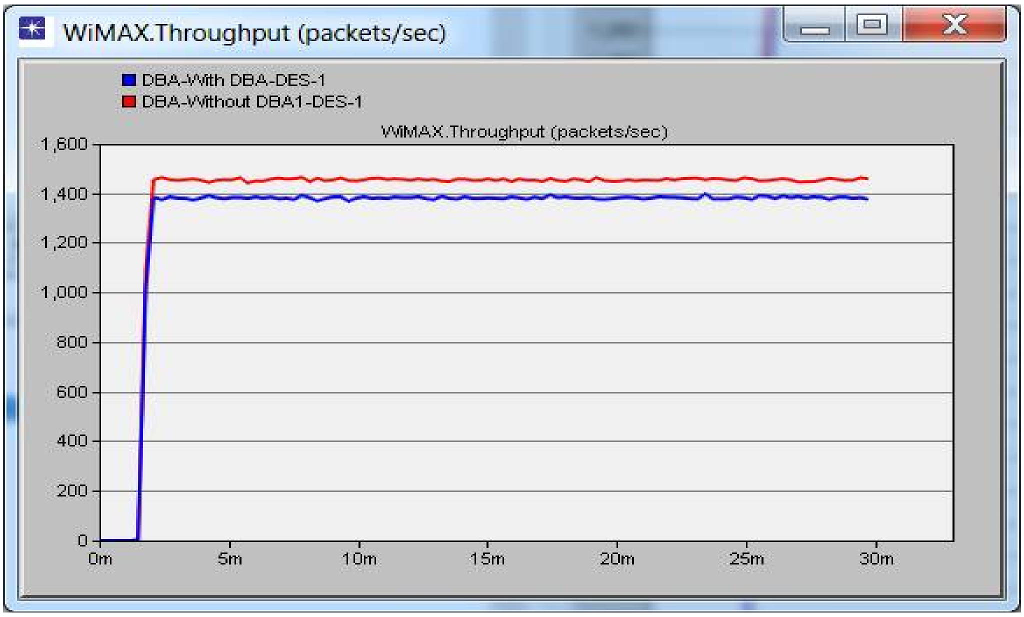


**Figure 3: comparisons between without DBA and with DBA throughput**

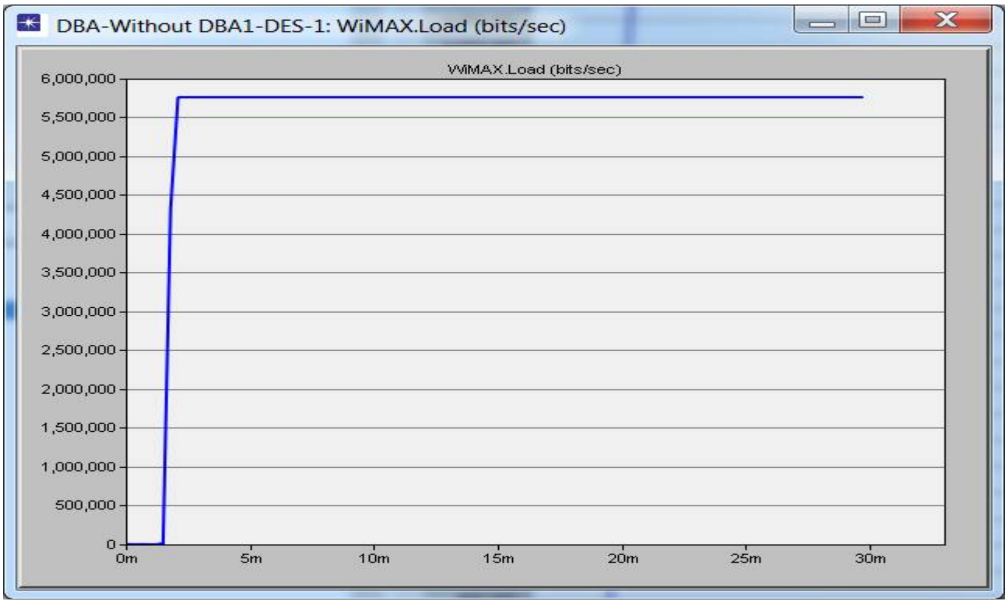


**Figure 4: network load without DBA**

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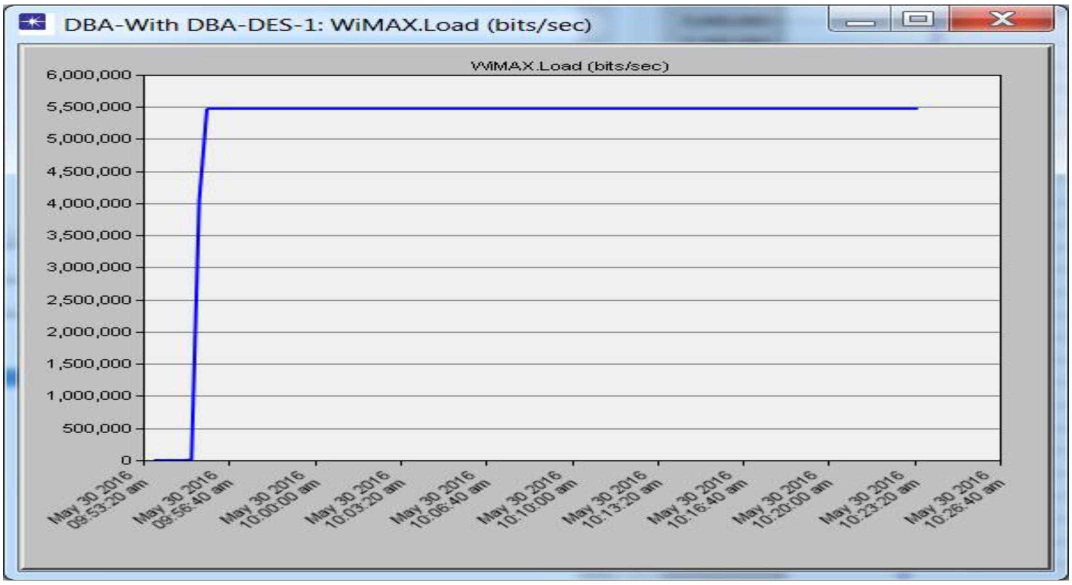


**Figure 5: network load with DBA**

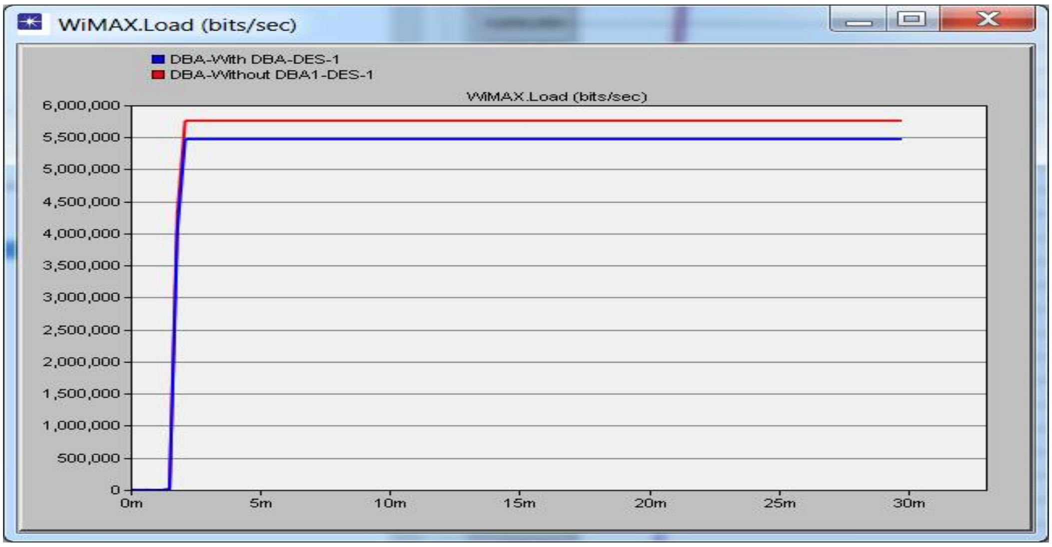


**Figure 6: comparisons between without DBA and with DBA network load**

## V. CONCLUSION

This dissertation primarily studied EPON dynamic bandwidth allotment depending on service prediction and introduced a novel EPON dynamic bandwidth allocation algorithm (KI-DBA) depending on burst service prediction and decreasing the idle time, which ensures fairness. There are four advanced points: Kolmogorov-based service prediction, decreasing the idle time technique, burst sorting polling and bandwidth allocation technique based on prediction result that ensures the bandwidth proportion, among which the former two points ensure the service prediction accuracy and the bandwidth usage of EPON upstream while the last two points decrease the average delay of the service and ensures the fairness. Through theoretical computation and simulations proving, the KI-DBA algorithm has been proved to be an efficient EPON upstream bandwidth allocation technique. It is theoretically important, and a practical way to enhance the bandwidth allocation strategy of EPON system and better support multi-services and multi-user access.

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The significant results of this paper involve the following:

(1)At first, a Kolmogorov prediction network has been proposed to EPON service prediction utilizing three layers of Kolmogorov prediction network single-step prediction structure. KI-DBA prediction algorithm is enhanced by decreasing the idle time through the prediction mechanism, hence queuing delay of the prediction algorithm is decreased and the prediction accuracy is increased during the prediction mechanism. Consequently, the adaptive prediction of EPON service is observed and prediction accuracy of burst data service is enhanced.

(2) A novel technology design, The OLT adjusts ONUs polling sequence according to the burst during the polling process, and postpones forwarding REPORT message for contracting the prediction region, hence the prediction accuracy of burst ONUs service is enhanced. The bandwidth allotment and time slot authentication is performed in advance before ending of polling cycle. As a result, the idle time is more completely used and the upstream bandwidth usage is increased.

(3) An EPON simulation platform depending on Riverbed and KI-DBA algorithm is formulated and verified. The related protocol and scheduling algorithm are enforced by designing optical network unit (ONU), optical line terminal (OLT) and passive optical splitter (POS) and their interior processor modules. According to the results of simulation, it shows that KI-DBA algorithm is proposed by this dissertation has the higher bandwidth usage and lower average packet delay in comparison of IPACT and classic prediction based DBA. QoS of low priority facilities is substantially enhanced under the precondition of guaranteeing QoS of high priority facilities when network load is very high.

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