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Ring Optical Packet switched (OPS) network: Quality of Service (QoS) and traffic model

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ABSTRACT

Optical Packet Switched (OPS) technology is under study as a promising solution for addressing the rapid growth of network-intensive applications having different Quality of Service (QoS) requirements. By employing Optical Circuit Switched (OCS) networks, an optimized Packet Loss Ratio (PLR), delay and Packet Delay Variation (PDV) performance can be obtained. It is, however, very demanding to offer a QoS comparable to OCS network through the OPS network in order to support a significant and growing number of applications. Thus, moving from OCS to OPS network, QoS is a critical issue. Hence, this paper analyzes the QoS requirements of network-intensive applications and services. Moreover, the paper derived an expression for performance metrics of a single OPS switch and ring OPS network. It is found that the International Telecommunication Union - Telecommunication (ITU-T) classification is extended with the new requirements of applications and services. For example, the upper bound delay, PDV and PLR of video streaming requires (100 ms, 400 ms), 50 ms and $1E^{-05}$ respectively. In this work, these values are improved as delay within 10 ms, PDV in micro seconds and PLR of $1E^{-07}$ at full load. It is also shown that a Fixed Delay Line (FDL) has to be considered when low PLR is required and when PDV and delay are not critical issues.

1. Introduction

In recent years, the rapid development of network-intensive applications lead to the existence of several standards to classify them in accordance with their requirements. Several research works have tried to quantify, classify and study the QoS of these services and applications. The unified QoS in OPS/OBS networks studied in Ref. [1] links the interaction among performance, secrecy and dependability for different services. The authors [2] also tried to present an extensive survey of applications and services of QoS needs, and it identifies applications that can't be supported by the current internet service model. In Ref. [3], a new hybrid network architecture has been presented to support a wide range of applications and services. All the services and application studied in the papers don't have the same QoS performance need. For instance, video and online gaming requires a very stringent latency, while multimedia applications have strict real-time demands. In downloading files from the Internet, on the other hand, may not need a strict latency requirement as the complete file with non-critical delay time is needed [3,4].

Moreover, compared to the current applications, the future application demand will increase significantly. 3-Dimensional Television (3D-TV), tele-surgery and digital video broadcasting, for example, are QoS demanding [2,3]. Hence, the network infrastructure should be designed to satisfy not only the demands of the current applications, but also the needs of the future services. The performance of OCS network is very high with respect to delay, PLR and PDV, but the bandwidth utilization is low, especially when optical fiber is used. However, future networks should be able to serve a highly dynamic connection pattern with a significant portion of bursty traffic between the communicating pairs, such as internet that couldn't be possible with OCS. Here, Optical Packet Switching (OPS) and Optical Burst Switching (OBS) come into play, technology capable of combining the advantage of high bandwidth utilization and satisfying QoS performance. But, the QoS performance provided by such network is not better than that of OCS.

A number of researches have done in optical packet switched networks [1,5–7]. The papers were focused on optimizing PLR by using different QoS differentiation policies and scheme of transport networks. The main focus of this paper is, thus, to analyze the different QoS performance metrics that are vital in delivering a suitable QoS in optical packet switched networks. The paper also proposes a packet switched architecture capable of supporting the demanding applications and services.

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This paper is organized as follows: in the first part, optical switching technologies are introduced and the requirements of the network-intensive applications are described. In the next section, the proposed network architecture that supports the network-intensive application requirement is explained. In section 5 and 6, the analytical model for the proposed optical network is developed and analyzed with respect to several performance metrics. Finally, the conclusion of the overall paper is done.

2. Optical switching technologies

2.1. Optical circuit switching (OCS) networks

In OCS network also called Wavelength Routed Optical Network (WRON), the optical network is configured in such a way that a circuit (lightpath) is established from the ingress node to egress node by adjusting the intermediate optical cross connect circuits. Hence, the data signal, in optical form, can route in all optical manner from the ingress to egress node. The established lightpath is reserved for the corresponding data signal until all data is transmitted. In the intermediate switches traversed by the lightpath, Optical-Electronic-Optical (OEO) conversion is employed, nor buffering or processing of optical signals. However, by using an appropriate optical network devices such as wavelength converter, the lightpath may be wavelength converted at the intermediate nodes in order to reduce the number of wavelengths required [8]. This optical switching network is not efficient in terms of resource utilization, especially wavelength links and requires time to set up and terminate a connection. In network employing OCS technique, the latency experienced is only the propagation time of the optical signal in the fiber link and there is no congestion and hence no packet loss. Thus, this technique is best for time sensitive services and applications [9,10].

2.2. Optical packet switched (OPS) networks

In OPS networks, packets are forwarded and processed hop by hop until they reach their destination node [11]. And also, before switching, packets are converted into electrical. This leads the speed and efficiency of optical networks to be reduced due to the increased delay. That's the reason why OPS networks are not commercially used. Buffering, processing and forwarding of packets in OPS is done entirely or partially in the optical domain. In this case, the packet header has to be converted to electrical by employing Optical-Electrical (OE) conversion in order to process it electronically. The reason is all-optical processing of header packets is not yet implemented. Recently, only simple operation such as Label matching [12] is possible.

As shown in the Fig. 1, the individual packet switching network nodes consists of an input interface, multiplexers and demultiplexers, a switch control unit, switch fabric with optical buffer and an output buffer. Packets arriving on an input buffer consisting of the data and optical header, are demultiplexed into individual wavelengths and are sent to the input interface. Then, the input interface extracts the optical header and forwards it to the switch control unit for processing, while the packet payload is delayed using input Fiber Delay Lines (FDLs). After processing the header address, the switching control unit determines an appropriate output port and wavelength for the packet. The switching control unit finally instructs the switch to transmit the packet accordingly [8]. A new header is attached and the packet is forwarded when the packet arrives at the output port. Though, this technology is not yet viable, it introduces a number of optical functionality such as optical switch architecture that provides a basic functionality of switching packets.

2.3. Optical burst switched (OBS) networks

OBS technology aims to improve the non-optimal utilization of optical network resources when compared to OCS. This technology combines the advantages of both optical circuit switching and optical packet switching [13]. In Fig. 2, the OBS consists of core network, edge node and wavelength-division multiplexing (WDM) links. Packets with similar properties (eg. the same destination address and the same quality of service requirement) are sent together as a burst of data. In the ingress node, bursts are assembled and a control packet (header packet) containing the routing information is sent to the network before the burst [14]. Within the offset time [1], all routers in the predicted path of the burst will be configured. When the path of the burst across the network is configured, the burst in the ingress node departs and travels through the network in an all-optical form. The burst usually crosses the intermediate node in the network using the pre-configured and pre-established circuit.

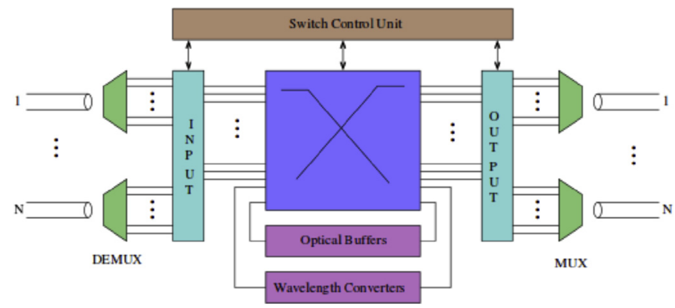

Fig. 1. OPS node architecture [11].

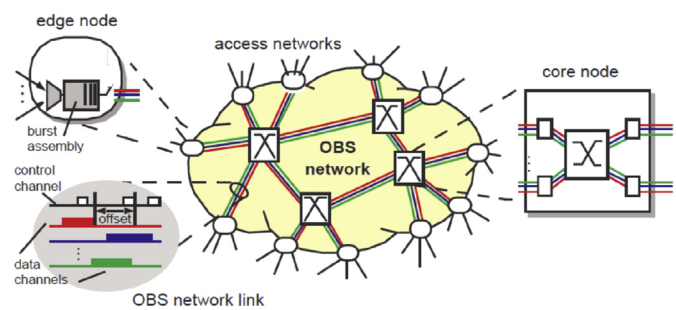

Fig. 2. Optical burst switching architecture [15].

Currently, OBS networks are under study as a future solution for addressing the ever-increasing demand of Internet traffic. Several wavelength schemes have been proposed for OBS, including Horizon [16], wavelength routed OBS [17], just-enough-time (JET) [13] and just-in-time (JIT) [18,19].

3. Network topology

There are several advantages for single and dual ring architectures to be applied as the core and mobile backhual networks. Figs. 3 and 4 show a single and dual-ring architectures respectively. In this work, simple unidirectional ring model with n number of access nodes as shown in Figs. 3 and 4 are considered. The access nodes in the networks are interconnected by an optical fiber link. All the optical fiber links are equipped with WDM channel of w wavelengths with C Gbps each. Each node in the network is capable of adding and dropping traffic to and from the ring network.

4. Requirements of network-intensive applications and services

With the advancement of Internet technology, several applications are emerging. The ever-increasing IP traffic with the resulting demand for capacity leads to the migration of the copper wired networks to optical wired networks. This inevitable shift has resulted in the availability