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Just-in-time, just-enough-time and horizon signalling protocols on optical burst switches

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Optical burst switch (OBS) is considered to be a promising switch technology for the future network. In this paper, just-in-time (JIT), just-enough-time (JET) and horizon signalling schemes for OBS are presented. These signalling schemes run over a core dynamic wavelength division multiplexing (DWDM) network. The network is proposed to support IP, ATM and burst traffic. We apply the Poisson and self-similar models to identify inter-arrival times in these protocols and the burst contention is handled by burst dropping. As a result, the variety of the simulation results show the pros and cons of the evaluated JIT, JET and horizon signalling schemas.

Keywords: dynamic wavelength division multiplexing (DWDM), just-in-time (JIT), just-enough-time (JET), horizon signalling protocols, optical burst switch (OBS).

1. Introduction

There has been many trends observed in the Internet protocol traffic in recent years. The increasing demand for transmission bandwidth and the requests for QoS of users and applications from today's communication networks, stretches the capabilities of the existing Internet backbones. The development of the wavelength division multiplexing (WDM) technology met all of these requirements.

The first fiber technology for transmission systems was presented in the 1970s. During the evolution of the fiber technology most systems used a single high-speed optical channel and all multiplexing was done in the electrical domain. Then WDM technology was proposed and gained considerable attention [1].

Optical packet switch (OPS) is one of the WDM technology types and in optical packet switching networks (OPSNs), data is carried as optical packets along with in-band control information. When this control information reaches a node, it is processed in the electrical domain [2].

The other WDM technology, *i.e.*, optical burst switch (OBS) is a developing technology that is placed somwhere between the wavelength routing and optical packet switching technologies. Although optical communication systems had been known for years, the invention of WDM technology improved the fiber technology.

In optical burst switching networks (OBSNs), before the transmission of a burst, a setup message is transmitted. The main aim is to inform the intermediate nodes about the upcoming data burst. So, the intermediate switches can configure their switch fabrics for switching the upcoming burst to the appropriate output ports [3].

OBS depends on variable length and asynchronous node operation but OPS depends on the fixed length packets and synchronous node operation [4, 5].

The explosive growth in Internet protocol traffic in the last few years has caused many researchers to undertake studies on designing new high-speed transmission and switching technologies. WDM is a kind of technology which can support a number of high-speed channels in a single fiber and at the physical layer it can also support huge bandwidth. Therefore, we can say that this technology has emerged for the next generation IP backbone network. The OBS technology has also gained a lot of attention recently because it combines the advantages of both circuit switching and packet switching [6].

The rest of the paper is organized as follows. In Section 2, we explain the all-optical networks and OBS structure. The JIT signalling protocol is given in great detail in Section 3. In Sections 4 and 5, we describe the JET and horizon signalling protocols. In Section 6, the structure of our simulation is explained and our concluding remarks are presented.

2. All-optical networks

In WDM networks, optical-to-electrical-to-optical (OEO) conversion is done over point-to-point links. But studies for future WDM networks are about the all-optical networks. In AON, the data is transmitted in the optical domain. For this reason, there is no conversion from electrical-to-optical or optical-to-electrical domain. AON can be classified as wavelength routed network (WRN), optical burst switching network (OBSN) and optical packet switching network (OPSN) [2].

The first step in AONs is the WRNs. In WRNs the circuit connections are setup with lightpaths between nodes. In WRN, the number of wavelengths per fiber is limited. In larger WRNs this limitation makes it impossible to form a full mesh of lightpaths between all end users.

In WDM networks, the broadcast and select network may be formed by connecting nodes via two-way fibers to a passive star. In order to provide a communication, at first a node performs its transmission to the star along wavelength by a laser. That laser produces an optical information stream and all of these streams from different sources are combined by the star. Then these streams are sent to all of the nodes on their receiving fibers [7].

In a WRN communication is performed over lightpaths. The lightpaths are routed by the intermediate nodes in the optical domain using their active switches. The access of the end nodes to the lightpaths is provided by the transmitters and receivers [7].

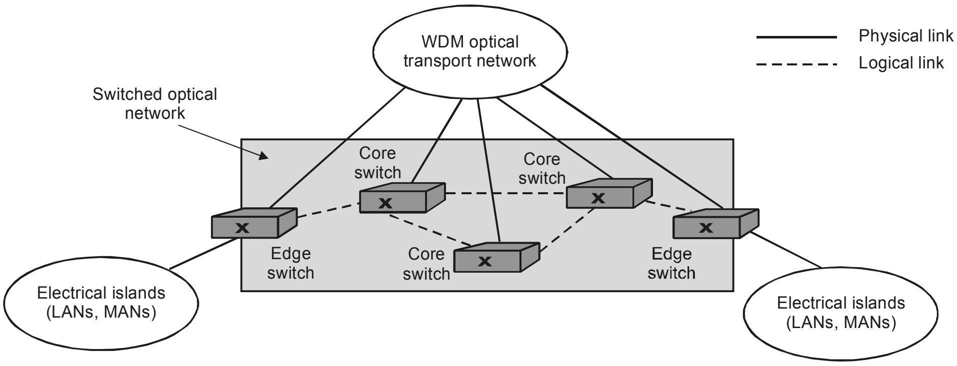

Fig. 1. Optical switched network structure [4].

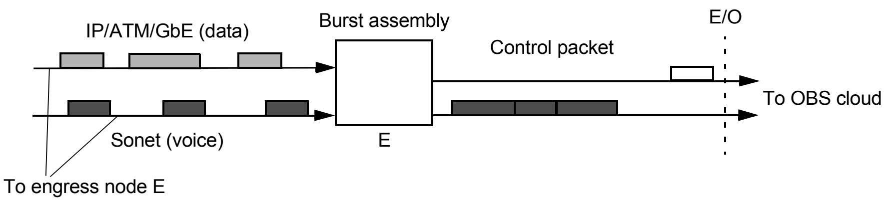

Fig. 2. Burst assembly [8].

The basic switching concepts are circuit switching, and packet switching. In circuit switching, in order to transmit data first of all a connection must be constructed and then the transmission is performed over this connection. Because of this connection, no receiver or sender addresses are needed. But in packet switching, the data is sent with its receiver and sender addresses. As a new technology, OBS combines the advantages of circuit and packet switching paradigms. In Figure 1, a basic structure of optical switched network is shown.

In the last few years, OBS has attracted much attention and for improving its performance many solutions have been proposed. In OBS, the user data is transported in various-size units called bursts [2].

OBS is one of the earliest ways which were proposed to integrate IP and WDM [1]. In an OBS network, IP packets are assembled to form a burst at the ingress node. The ingress node then sends a control packet (request or setup) over the defined control channel. The user data may be ATM/GbE/SONET as seen in Fig. 2. At each intermediate node, during the electronic processing and forwarding, the control packets are treated as ordinary IP packets. The burst of IP packets is switched all-optically by the OBS fabrics as shown in Fig. 3 [8].

In Figure 3, the offset time between the user data and the control packet is shown. Obviously, the user data and the control packet are seperated both in space and in time.

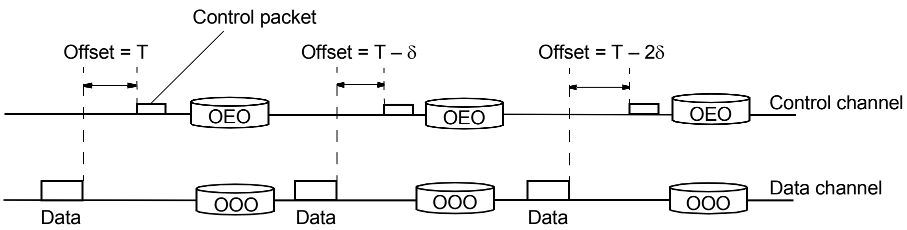

Fig. 3. Burst and offset time [8].

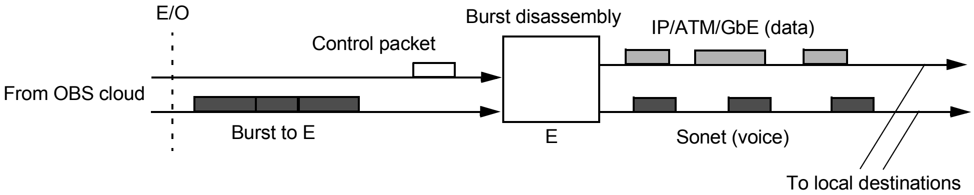

Fig. 4. Burst disassembly [8].

Also, the offset information is decided at the source by using the path information. In addition to this, in the OBS network bursts will not encounter any buffer delay so that both the end-to-end latency and jitter are not only predictable but also minimized [8].

In Figure 3, the control packet and the following data burst pass through many switching nodes. In each OBS node, processing the control packet and forming the optical switching matrix take a definite time. Each time a data burst passes through a node, the offset time between the data burst and the control packet is decreased by the needed processing time of the OBS node. Offset time is decided by the ingress node. So, the control packet always travels ahead of the user data [9].

Consequently, in an OBS network firstly some of the IP packets (going to the same destination) are assembled to form various-size bursts at the ingress node as shown in Fig. 2. Then, they are switched at the core as in Fig. 3 and at last disassembled at an egress node, as shown in Fig. 4 [8].

3. Just-in-time signalling protocol

In JIT signalling, a link unique identifier is used for each message. With the help of this label upon emergence on the other end of the link message can be cached and mapped to a new label on the exit link. With the setup message in the signalling flow a label-switched path is established and all of the messages follow this path [10, 11].

In JIT signalling protocol, time is divided into periods during which the wavelength is reserved, followed by periods during which it is free . The reserved period’s length is equal to the addition of the length of the burst and the offset time as in Fig. 5, and

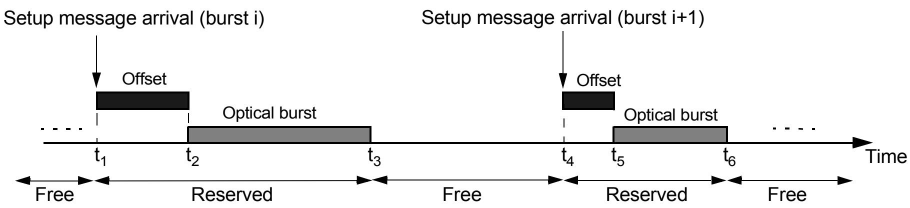

Fig. 5. Operation and departure of JIT [3].

the length of the free period is equal to the time until the arrival of the next setup message. In addition to this, the bursts are processed according to their setup message's arrival time, that is, the service on each wavelength is first-come, first-served [3].

3.1. Signalling schemas in JIT

In JIT signalling protocol there are four different signalling schemes for OBS. In all of the figures, the travel of a burst over an OBS node is shown. Every burst is transmitted after a setup message and that setup message reaches the switch over an out-of-band signalling channel just before the arrival of the burst. Sometimes a release message may be used for informing about the end of the burst transmission.

3.1.1. Explicit setup and explicit release

In this schema, as soon as the setup message is taken by the switch, the switching elements are configured for the coming burst. And until the coming of a release message they remain in that configuration, as can be seen in Fig. 6 [12].

3.1.2. Explicit setup and estimated release

The setup message carries the information about the duration of incoming burst. For this reason, there is no need for a release message to inform about the end of the burst transmission (Fig. 7). The end of the burst transmission is decided by the switch

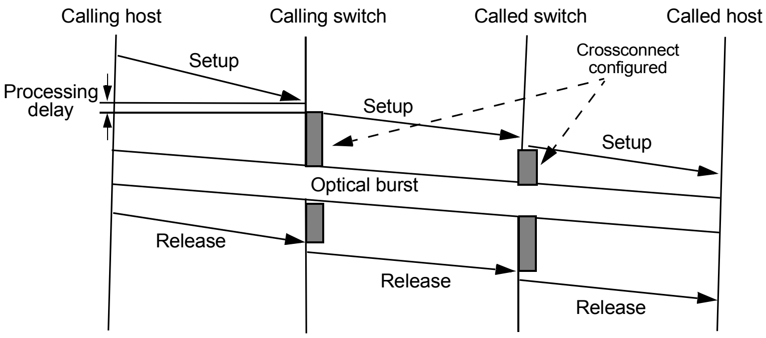

Fig. 6. Explicit setup and explicit release [12].

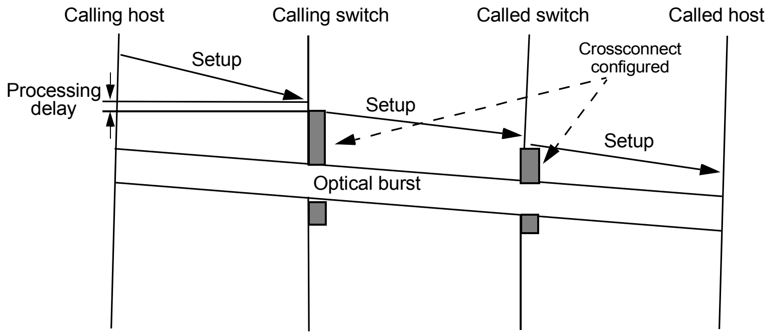

Fig. 7. Explicit setup and estimated release [12].

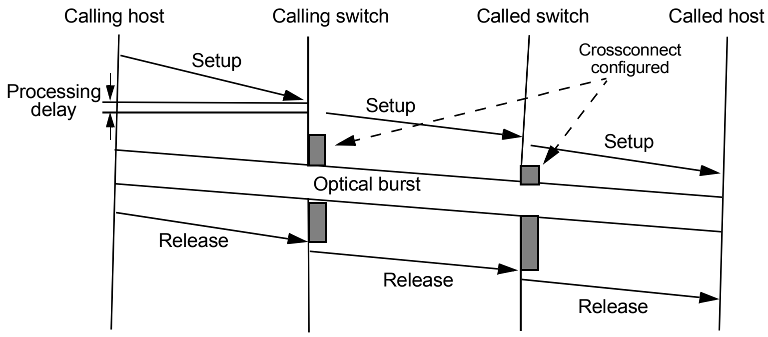

Fig. 8. Estimated setup and explicit release [12].

according to the arrival time of the setup message and the information about the length of the burst contained in it [12].

3.1.3. Estimated setup and explicit release

The beginning of the burst is estimated according to the information in the setup message. In this schema, the switch needs an explicit release message for releasing its switching elements (Fig. 8) [12].

3.1.4. Estimated setup and estimated release

Both the beginning and the end of the burst are estimated according to the information contained in the setup message (Fig. 9) [12].

3.2. Unicast signalling flow

In on the fly unicast signalling flow, with a setup message a path is established for only a single burst. The other bursts which are sent from this source to the same destination may take different routes. In these connections, the session declaration, path setup and data transmission phases are combined into a single message. The flows of messages differ slightly depending on the duration of the transmission.

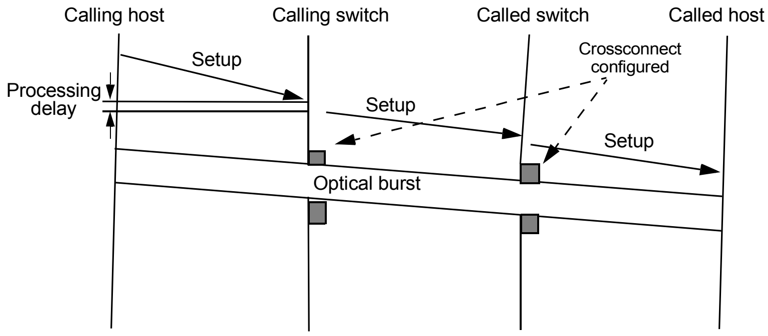

Fig. 9. Estimated setup and estimated release [12].

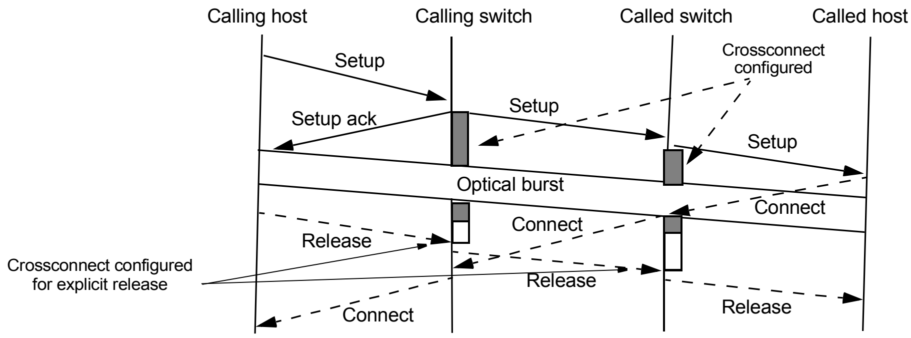

Fig. 10. On the fly unicast signalling flow [10].

The connection is established by sending a setup message from the source to the ingress switch. In the ingress switch the setup message is examined. Based on the destination address in the setup message and the congestion information of the switch itself, the delay value for the incoming burst is determined in the switch. After sending the setup message, the source node takes a setup ack message from the ingress node. This message is used to confirm the source node about the receipt of the setup message by network. In this message, the burst delay information and the channel information which will be used while sending the burst are found (Fig. 10).

The source node waits for a while according to the burst delay information and then sends its burst according to the indicated channel in the setup ack message. If no blocking occurs, the setup message continues its travel from one switch to the other until reaching the destination. And after a while the burst also reaches the destination [10].

4. Just-enough-time signaling protocol

JET is the best known signalling protocol which uses void filling. In Figure 11, two bursts are illustrated while travelling along the same output wavelength.

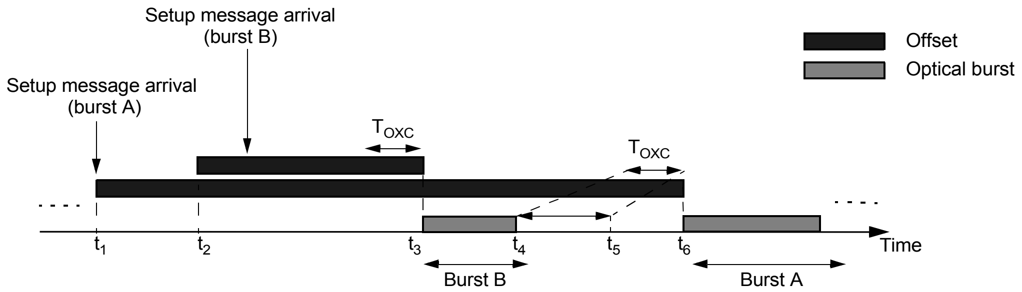

Fig. 11. Operation and departure process of JET [3].

The setup message of burst A arrives before the setup message of burst B. The burst A has a longer offset than burst B. The switch only notes the later arrival of burst A after receiving the setup message. But it does not initiate a connection within its cross-connect fabric. After receiving the setup and accepting it, a void is created. The void is an interval of time until the arrival of the first bit of the burst A. If the second setup message arrives at time t_2 in this interval, the switch runs a void filling algorithm and compares the arrival times of burst A and the new burst B. If the switch decides that the arrival of burst B will be before burst A, it accepts burst B. Here, burst B is accepted and it is transmitted before the arrival of burst A. Then burst A is accepted in the predetermined time [3, 13].

5. Horizon signalling protocol

In horizon signalling protocol, void filling is not used and each wavelength is associated with a time horizon for burst reservation purposes.

In Figure 12, the transmission of two bursts by using horizon signalling protocol over a dedicated wavelength out of an OBS node is shown. The setup message of burst i arrives at the OBS node at time t_1 and the last bit of the burst leaves the switch at time t_4. The switch needs some amount of time to reconfigure its switching elements

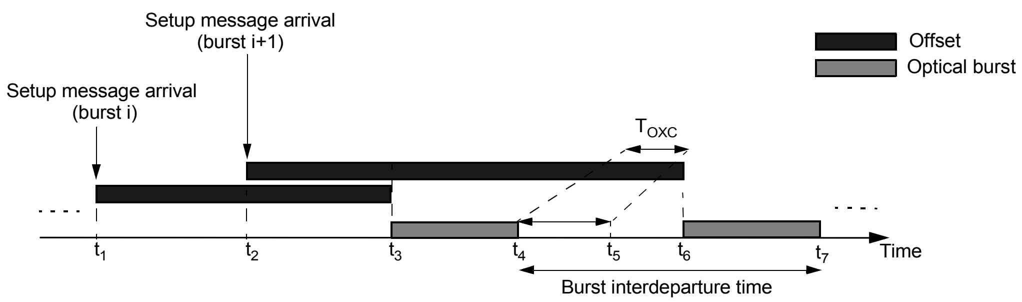

Fig. 12. Operation and departure process of horizon [3].

to perform a connection from another input port to this output wavelength. So, another new burst is not scheduled at this wavelength until time t_5. We can say that, as soon as the burst i is accepted, t_5 becomes the time horizon of this channel [3].

6. Results and conclusions

In this section, we investigate the burst drop rate of optical burst switching. In our simulation program, the bursts come from three ingress nodes which have queue and buffer structures. In the OBS, these bursts are processed and transmitted by using only queue but not buffer structures with the JIT, JET and horizon signalling protocols. We simulated the processing, transmission and dropping these bursts.

In IP and ATM traffic several packets are assembled in a single packet called burst and the burst contention is handled by burst dropping. The burst length distribution in IP traffic is arbitrary between 0 and 1, but it is fixed in ATM traffic at 0.5. Burst traffic, on the other hand, is arbitrary between 1 and 5. Also, the setup and setup ack length distributions are arbitrary. We apply the Poisson model with rate λ and self-similar model with Pareto distribution rate α to identify inter-arrival times in these protocols. We consider a communication between a source client node and a destination client node over an ingress and one or more multiple intermediate switches. We use buffering

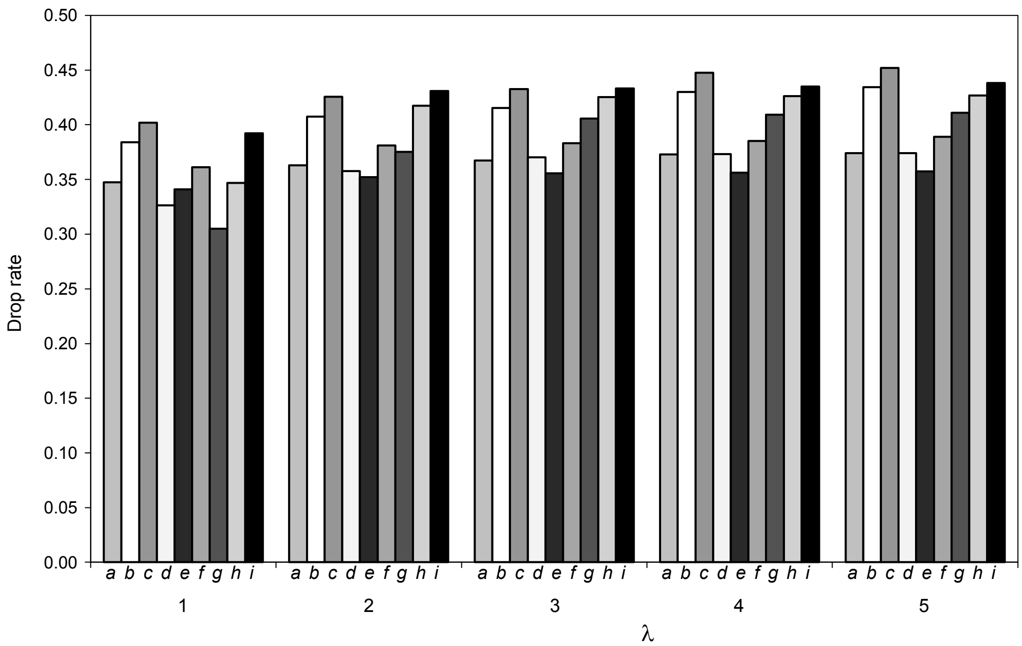

Fig. 13. Drop rates of IP, ATM packets and bursts with Poisson traffic (a – JIT-ATM, b – JET-ATM, c – horizon-ATM, d – JIT-IP, e – JET-IP, f – horizon-IP, g – JIT-burst, h – JET-burst, i – horizon-burst).

only in the ingress node. The communication is based on single burst connections in which the connection is setup just before sending a burst and then closed as soon as the burst is sent. In contention, one of the bursts is discarded. Our analysis accounts for several important parameters, including the burst setup, burst setup ack, keep-alive messages and the optical switching protocol. By computer simulations, we evaluate the QoS performance in terms of burst drop probability of the three signalling schemes on the network under a range of network scenarios.

We simulated the burst dropping mechanism when fed by Poisson and self-similar traffic and examined the behaviour of these traffics at the output. The input traffic was generated according to one of these traffics. In the first state, the packets arrive at the nodes exponentially according to the Poisson distribution. In the second state, they arrive as bounded-Pareto according to the self-similar distribution [14, 15]. The arriving packets may be IP packet, ATM packet or may be a burst. The inter-arrival times of the bursts which will go to the switch are produced according to the three-state Markov process. In this process, the first state is idle. Then the coming packets are decided whether it will be a long burst or a short burst according to the randomly generated number. The coming bursts will be a short burst with the probability of Ps or a long burst with the probability of (1 – Ps). If the coming packets are IP or ATM packet compared with the determined burst length before, then the packets are collected until forming a burst. After having a burst, it is taken to the buffer and a setup message which will carry the arrival time of the burst is sent to the OBS. After having a burst, it is taken to the buffer and a setup message which will carry the arrival time of the burst is sent to the OBS.

Figure 13 plots the burst drop rates of the simulation results for three of the signalling protocols with Poisson traffic. And the simulation also presents the drop

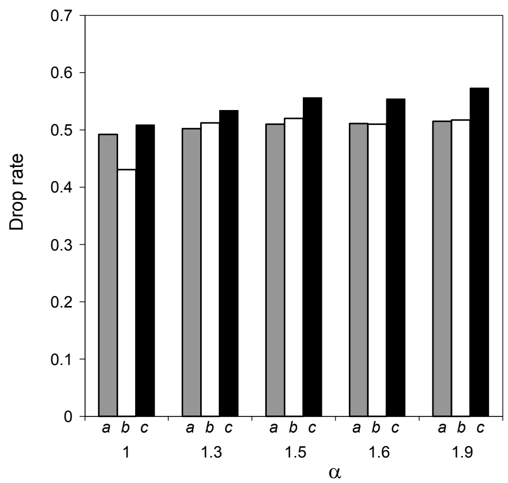

Fig. 14. Drop rate of ATM packets with self-similar traffic (*a* – JIT-ATM, *b* – JET-ATM, *c* – horizon -ATM).

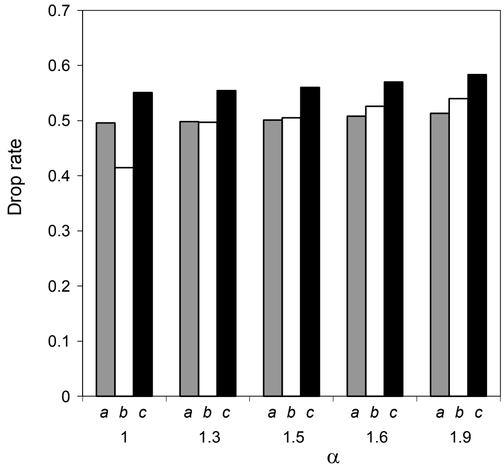

Fig. 15. Drop rate of IP packets with self-similar traffic (*a* – JIT-IP, *b* – JET-IP, *c*– horizon-IP).

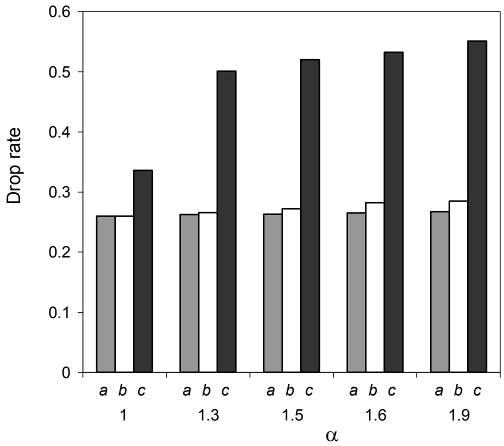

Fig. 16. Drop rate of bursts with self-similar traffic (*a* – JIT-burst, *b* – JET-burst, *c* – horizon-burst).

probability of the JIT, JET and horizon signalling protocols with IP, ATM and burst packet types.

Figures 14–16 plot the burst drop rates of the simulation results for three of the signalling protocols with self-similar traffic. And the simulation also presents the drop probability of the JIT, JET and horizon signalling protocols with IP, ATM and burst packet types.

If JIT signalling protocol is based on, then the OBS sends a setup ack message to the ingress node as soon as it takes the setup message from the node. With that setup ack message, if the switch is ready for the coming burst in the determined time, it is approved that the node can send its burst in the determined time. But if for the determined time, the switch decides that it will be busy, then the switch confirms the node with the setup ack message about the new coming time of its burst which is decided by the switch.

In JET and horizon signalling protocols setup ack message is not used. As a result, the bursts are sent from the node to the OBS in the determined time which is in setup message. In addition to this, in horizon signalling protocol a definite rate of void is formed.

When the bursts arrive at the OBS, they are processed according to their lengths and transmitted. If the OBS is still busy at the arrival time of the burst or at the same time another burst arrives to the switch from another node, then one of these two bursts is dropped. And the other one is processed and transmitted.

OBS has emerged as a viable switching technology to meet the increasing bandwidth demand. Therefore, in this paper, we examine the OBS technology which is a quickly developing solution for all-optical WDM networks and give a detailed overview of its characteristics. We studied deeply the JIT, JET and horizon signalling protocols for OBS network and the drop property of burst traffic assembled from either self-similar or Poisson traffic. In addition to this, we defined unicast traffic flow. Also, we presented numerical results of these three signalling schemes in terms of burst drop probability and used this information for comparing them. From the simulations, we found that JIT signalling protocol gives the best results when compared with the other two signalling protocols with both self-similar and Poisson traffic. The JIT signalling protocol is significantly simpler than either JET or horizon signalling protocols because of not having complex scheduling or void filling algorithms. For this reason, we can say that JIT signalling protocol appears to be a promising solution for the future. As a further work, we could extend the analysis for persistent-path and multicast traffic flows. Also, in addition to the IP/ATM and burst traffic the burst drop probability of the GMPLS traffic could be examined.

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