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AN EFFICIENT SIMPLE AND CONFLICT-FREE PROTOCOL FOR ALL-OPTICAL NETWORK

Kazi Muheymin-Us-Sakib, Ms. Upama Kabir and Mosaddek Hossain Kamal
Network and Algorithm Research Lab
Department of Computer Science,
University of Dhaka, Dhaka-1000,Bangladesh.
saykat@citechco.net, upama@du.bangla.net

ABSTRACT: *In this research work, a network protocol is proposed for all-optical network, using a combination of wavelength routing and packet routing schemes. The technique uses wavelength division multiplexing (WDM). A set of wavelengths is reserved to transfer control information, which is defined as control wavelengths. Control wavelengths are routed with packet routing scheme and the others are routed with wavelength routing scheme. In connection oriented network only the control packets are sent with the control wavelengths, data or messages are sent with other wavelengths. On the other hand, in datagram network, all the packets are sent with the control wavelengths. The allocation of wavelengths may be fully dynamic.*

1. INTRODUCTION

The fundamental purpose of the communication system was to exchange data between two stations, where the data meant only the text [1]. Nowadays, the data is expanded from text to audio-visual or multimedia. Moreover, multi-processing, parallel processing, multi-channels are very much common now. As a result, the need for speed and bandwidth is increasing. To fulfill the requirements, optical fiber communication is evolved, as the electronic networks cannot carry on. It will be seen in the future that, the whole backbone of the data communication system will only be built on optical fiber [2]. Though the optical network is the only solution that can fulfill the requirements, the existing networks cannot be thrown away. It is seen that, the optical networks are not very much compatible to existing electrical networks. Moreover, the optical network technology is still in its tender, it still hasn't touched its efficiency and cost trade-off mark.

2. PREVIOUS TECHNIQUES

The Electro-Optical Network (EON) is the second-generation optical network where the data packets are textured with appropriate header information, after that, the packet is converted to optical domain from the electrical domain. The optical data is sent to the router. The router converts the optical data to electrical domain and performs the routing decision and again converts it to optical domain, finally, the router sends it to its destination. At the destination the data is again converted to electrical domain [3]. In EON, the nodes perform optical to electrical conversion, electronic routing, e.g. virtual circuit or packet routing, followed by electronic to optical conversion. An advantage of EON is that electronic routing can be performed. However, this advantage is also its potential downfall since the total throughput on the incoming links to the node must not exceed the electronic processing speed of the node. This has been called the *electronic bottleneck* [4].

The All-Optical Network (AON) is called the third generation of optical networks. In AON the data remains in optical domain from source to destination. No intermediate conversion is needed in AON [5]. The AON eliminates the electronic bottleneck; however since the electronic routing cannot be taken part, all-optical routing methods are required. One option is all-optical packet routing. Here the nodes of the network perform basic logic functions on the optical signals in order to route the messages from the inputs to the outputs of the node. There are severe technological problems with optical packet routing at this time. First of all, only the most basic of logic functions can be implemented. Second is the lack of the optical buffers [5].

The Broadcast-and-Select method can be used in AON. But broadcast or flooding is such a technique, which is used when no other option is left. To have efficient throughput a moderate number of wavelengths is required otherwise contention will be occurred. On the other hand, the cost of switch depends on the number of wavelengths that it can handle, so a trade-off is needed between number of wavelengths and cost. Moreover, the method has inherent power splitting loss, so it is unscalable [6].

Instead of all-optical packet routing, wavelength routing can be used. In a wavelength routing all-optical network ?-routing AON), the path a signal takes is solely a function of the state of the devices, the wavelength of the signal and the location of the transmitter [7]. But in wavelength routing the number of wavelength is linearly proportional to the number of nodes generally [8]. This is why, in large networks (with respect to number of nodes) wavelength routing is very much expensive and sometimes another means of wavelength reuse in needed. Wavelength routing now only can be implemented in the all-optical backbone network where all the nodes are homogeneous.

3. A NEW EFFICIENT, SIMPLE AND CONFLICT-FREE TECHNIQUE FOR ALL-OPTICAL NETWORK

It is mentioned that, the need for large amount of bandwidth gradually makes the communication system dependent on the optical fiber, but without a solid communication mechanism the whole potential of the optical fiber cannot be used. Current optical routing protocols are suitable but for specialized cases, e.g., the broadcast-and-select method is only feasible at LANs. Many others are implemented in the Laboratory. They have a mere chance to come out at broad daylight. This research work tries to give a flavor of a new

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generalized approach for optical routing. The technique should follow the following criterion –

•Compatible to current techniques

•Increase the total throughput

•Use minimum number of wavelengths

•But it should be conflict free

•Transmit as much as possible messages/packets without conversion to electrical domain

•Moreover be generalized to LAN or WAN or MAN anything else.

The problems of the previous techniques in both electro-optical networks (EON) and all-optical networks (AON) are clearly depicted before. The criteria of an ideal technique for optical networks are also discussed. Considering those problems and based on the criteria of the ideal techniques, a new proposal is depicted. The proposed technique is textured with a novel network model first. Then it describes exclusively the circuit connection establishment procedure. To do so, modified all-optical routing node architecture is given. At the end, a set of network protocols is described for connection oriented and connectionless networks.

3.1 Network Model

Here the topology of an optical network is modeled as an undirected graph G = (V,E) where each node in V={A,B,C,D,E} represents a router and each edge in E represents two fiber links, one in each direction, which is described in the figure 1. Each node contains an injection buffer and a delivery buffer. Initially each message is stored in the injection buffer of its source. Once a message reaches its destination, it is stored in the destination's delivery buffer. During the routing, as the data will be routed with wavelength routing, storage is not needed actually for data. If anywhere the system fails to allocate any wavelength for a particular message, there should not be established any path in connection oriented method. Beyond this, the system assures that, if in connection oriented or in connection less method any data or message fails to get any wavelength, they will be discarded, which will be cost effective. As we know, optical buffers are more costly and in some points they are impossible in reality.

Each routing node contains collection of paths of the graph G, which are used as routing information. The routing node may use any routing strategies and WDM (Wavelength Division Multiplexing) [9]. But it must be remembered that, each connection between a pair of nodes in the network is assigned a path through the network. Moreover, wavelength on each link of that path is also assigned, such a way that, connections whose paths share a common link in the network are assigned different wavelengths.

The optical routing nodes are capable of routing each wavelength on an incoming link to any outgoing link. However, the same wavelength on two incoming links cannot be routed simultaneously onto a single outgoing link. That is, if there are *W* wavelengths on each link, the routing node may be viewed as consisting of *W* independent switches. Each node may have *M* inputs and outputs, that is have *M* incoming and outgoing links. In addition to routing and switching signals, the optical node also serves as source and sink of traffic in the network.

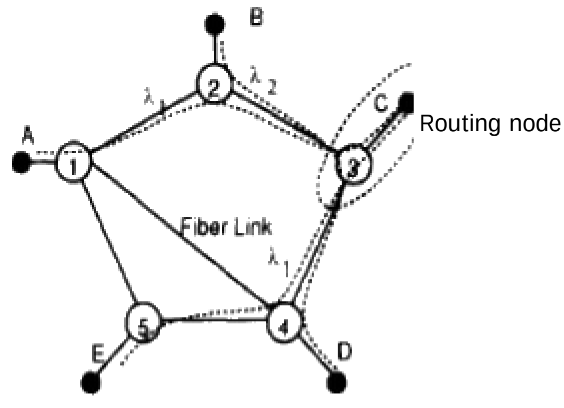


Figure 1: *A WDM network consisting of routing node interconnected by point-to-point fiber optic link*

In this network model, connection requests and terminations may arrive at random. Each connection must be assigned a specific path in the network and a specific wavelength for each links in the path as the wavelength conversion is allowed. Moreover the wavelengths and paths are assigned must be such a way that no two paths that share an edge are assigned the same wavelength [10].

3.2 The Process of Connection Establishment

The actual process of setting up routers and routes as well as wavelength assignment in optical networks is done using an electronic backbone control network [11]. It may be wondering at the use of a relatively slow, electronic, network to set up these high-speed communications. In fact, the major applications for such networks require connections that last for relatively long periods once set up; thus the initial overhead is acceptable as long as sustained throughput at high data rates is subsequently available.

It is stated before that, it is a serious problem in all-optical networks, is to interpret the address header of messages arriving at optical switches, since their switching time is still slow compared with the transmission speed in optical fibers. In AT&T and elsewhere employs a low bit-rate header, which is read on the fly [12].

In the new technique, it is proposed that for requests and connection establishment, a subset *?c*, called control wavelengths, will be used and *?c ? B*,, where *B* is the set of wavelengths. That is for control, only a subset of wavelengths is used. Any node in the network wants to transmit data to another node, requests for a connection to its router with (*?c*) wavelength. With other information, the control packet or the request contains the wavelength information, by which the data will be sent. On the other hand, whenever the switch gets any message in wavelength (*?c*), it simply converts it in electrical domain and queued it up in its request queue. The router or switch processes the request through establishing a path to the next hop, and assigning an unused wavelength for that connection. Then the router informs the source to send the messages (after priority assignment) or after a pre-specified delay the source starts to send data if it is a non-priority network. In the mean time the router gets prepare to catch the data with that pre-specified wavelength. The router sends the unconverted data to the next hop, along the proper outgoing path. The next hop then performs the same tasks and sends the messages to its next hop and thus to the destination. If the router cannot specify a suitable wavelength for the messages for its next outgoing link, it simply discards the messages. For datagram communication all the messages should be sent with the control wavelengths.

Number of the control wavelengths may be varied. That is, the optical routing nodes may dynamically increase or decrease the number of control wavelengths with the increasing or decreasing of requests.

3.3 Proposed All-Optical Routing Node

In this section a new routing node is proposed for the newer technique. The specialty of the node is that, it only converts the messages coming with control wavelength (*?c*) into the electrical domain, and the messages coming with other wavelengths, just let them pass to their next hop without converting them to the electrical domain. The routing node enables each wavelength to be converted to any other wavelength.

Figure 2 depicts the proposed routing node for all-optical network. It is based on a large optical switch, which takes a channel and switches it to any other channel (on any fiber). Before being multiplexed into the fiber, each channel is converted to the appropriate wavelength by fixed wavelength converters.

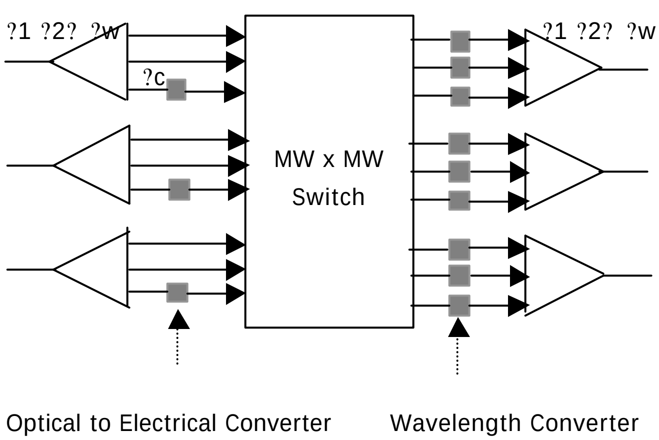


Figure 2: *Proposed all-optical routing node.*

3.4 Protocol

A set of protocols is presented for the new technique. First sub-section introduces the protocols for connection oriented all-optical networks and it follows by the protocols for datagram networks. All these two kinds of protocols have three parts. One for source, one for routing node and another is for destination.

3.4.1 Protocol for Connection Oriented AON

It is stated above that, whenever a node wants to transmit anything, it first have to request the routing node with control wavelengths. After receiving the conformation from the routing node or after a pre-specified time, the source node will send its messages with specified wavelength. The protocol for the source side is stated below.

Source:

•Send all requests to the routing node with ?c

•Wait for reply from the routing node

•After having the reply send the messages with selected wavelength

•Wait for final acknowledgement from the destination

•Delete the message from the injection buffer

The routing node or switch is always waiting for requests from the attached nodes. It performs the routing decision and allocates a wavelength for its outgoing link for each request. It passes the data coming with other wavelengths than the control wavelengths directly to the outgoing link without converting the data in electrical domain. It does not store those data anymore. The protocol for the routing node is given bellow.

Routing Node:

?? Wait for data/messages/requests from the source

?? If it is with ?c

    ?? Convert it in electrical domain

    ?? Put it in the buffer/queue

    ?? Extract a request/packet from the buffer/queue and process it

        ?? Readjust the incoming link receiver (and send a reply to its source)

        ?? Assign a wavelength to the outgoing link and send the request to its next hop

?? Otherwise select proper outgoing link and send the unconverted data to the next hop, with wavelength conversion if necessary.

?? If suitable wavelength cannot be assigned discard the message.

A flow chart of the routing node protocol is seen in the figure 3.

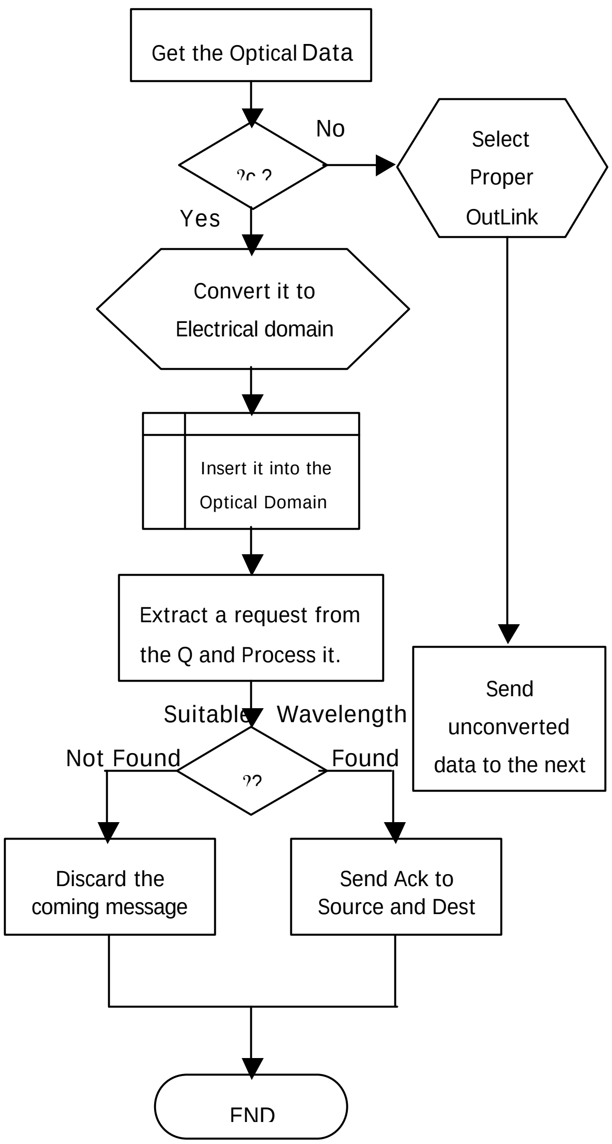


Figure 3: *Flow chart for protocol of routing node.*

Destination:

?? Store the data in the delivery buffer

?? Send an acknowledgement to the Source.

3.4.2 Protocol for Connectionless AON

In datagram network all the messages are send with control wavelengths. As the network is conflict free, all the messages must arrive in their destination.

Source:

?? Send all the messages with ?c

?? Delete the messages from the injection buffer

Routing Node:

?? Wait for data/messages/requests from the source

?? If it is with ?c

?? Convert it in electrical domain

?? Put it in the buffer/queue

?? Extract a request/packet from the buffer/queue and process it

?? Read the header and send it to its next hop

Destination:

?? Store the data in the delivery buffer

4. COMPARATIVE STUDY

In this technique the routing node assigns suitable wavelength for each single link, for every data or message, so the system is fully contention free. Moreover no extra connection establishment electronic backbone control network is needed, thus it is simple. The given routing node or switch can easily create the connection with the control wavelengths, which are shown. The switch is dynamic. It can assign or discard any wavelength to control wavelength set, which helps to reduce the rate of message discarding. The most flexibility of the network is, it can use the packet routing as well as the wavelength routing. Actually, the network uses a blend of packet and wavelength routing technique, which will give it a better outcome.

Though the proposed protocol seems simple, but it needs a new routing node or switch. The structure of the switch is little bit complex. To make the switch dynamic, it is needed that, each of the incoming link of the switch must have the electronic converter. The electronic converter must be able to handle almost all the wavelengths. At the same time the routing node must have enough storage to store the control packets. Control packets for connection-oriented network, are not a big deal, but the datagram packets are generally huge in both numbers and amounts. Moreover, the routing node has full wavelength conversion capability to make the network most flexible, which increases the complexity as well as the cost. Despite of those, the swit ch can be made compatible to other techniques and protocols. As the router supports packet routing to wavelength routing, the network can handle all the first to third generation optical transmissions.

It is stated that, the EON can perform the electronic routing e.g., virtual circuit or packet routing, but it makes the potential downfall for the electronic bottlenecks [4]. The new technique can provide the packet routing, with minimizing the electronic bottlenecks at the least.

Previous All-optical networks can perform the optical packet routing with a trade off between the performance and the cost of optical buffers. The new proposed model doesn't contain any intermediate message buffers, and it assures that, it will discard least number of messages. Unlike the broadcast-and-select network, here flooding technique is never used. So it is always ahead from the broadcast-and-select network.

Instead of all-optical packet routing, the recent all-optical networks use the wavelength routing technique. Here in the new technique, wavelength routing also used and the bottlenecks of the wavelength routings are still alive here.

5. SIMULATIONS AND PERFORMANCE EVALUATION

At the end of the research work a simulation program has been performed. The simulation program compares an existing method (for example: SONET/SDH) and the new proposed technique. This section contains the simulation the result, which is presented graphically.

The simulation program is run under some fixed parameters. The request size is taken

1000. It is assumed that, a single request contains 100 flits or packets. The propagation delay is taken 1 ? second and the switch processing time is assumed 2 ? second.

The required time, of a single request with its all messages to pass a single switch, is taken into account. The time is taken for a fixed number of requests. For some specified wavelengths and control wavelengths, the degree of parallelism is varied. Thus for various number of wavelengths, as well as control wavelengths, the result is taken. Then the result is compared.

The achieved results from the two simulated protocols are given in tabular and graphical form. Three cases are described bellow. Number of wavelengths is increased from the case-1 to case-3. Each case is evaluated by considering the number of degree of parallelism and corresponding time results are taken.

Case-1: Table 1, shows the required time for 100 requests or 10000 packets to pass a single switch of the existing protocol and the proposed protocol.

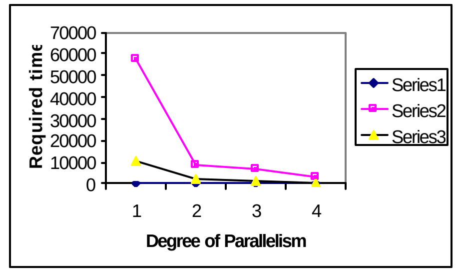
Number of Wavelengths – 4, Control Wavelengths – 1

Degree of Parallel ism	Existing Protocol (required time to pass the switch in ? seconds)	Proposed Protocol (required time to pass the switch in ? seconds)
1	385147	10701
2	99412	2675
3	59734	1337
4	40482	668

Table 1: Performance Evaluation Of Existing Protocol and Proposed Protocol

The values are taken in ? seconds and are found under the following conditions – number of wavelengths is 4 and the control wavelength number is 1. The graphical presentation of the table is given in the graph 1.

Graph 1: graphical representation of table 1



It is found, from the table 1 and the graph 1, that, the proposed protocol requires much lower time than the existing one.

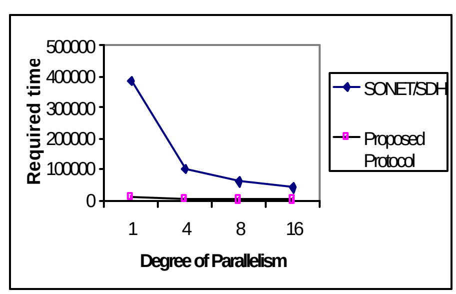
Case-2: In table 2 the results are found, when the wavelength number is increased to 16, the number of control wavelengths is 4 now. The requests number is taken 100 again. The graphical representation of the table is shown in graph 2.

No. of Wavelengths – 16, Control Wavelengths – 4

Degree of Parallel ism	Existing Protocol (Required time to pass the switch in ? seconds)	Proposed Protocol (required time to pass the switch in ? seconds)
1	76599	10701
4	15382	2675
8	18234	1337
16	7136	668

Table 2: Performance Evaluation Of Existing Protocol and Proposed Protocol

The graph 2 and table 2 shows that the result for existing protocol is improving but they are far behind from the proposed protocol.



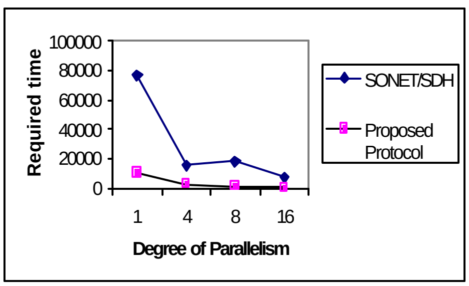
Graph 2: The graphical representation of table 2

Case-3: Table 3 is composed under following conditions – the wavelength number is now 64, and the control wavelength is now on 16. As well as the degree of parallelism is varied and the load is fixed, i.e., 100 requests or 10000 packets. The graphical representation of the table is given in graph 3.

No. of Wavelengths – 64, Control Wavelengths – 16

Degree of Parallel ism	Existing Protocol (required time to pass the switch in ? seconds)	Proposed Protocol (required time to pass the switch in ? seconds)
1	57843	10701
4	8322	2675
8	7199	1337
16	2997	668

Table 3: Performance Evaluation Of Existing Protocol and Proposed Protocol



Graph 3: Graphical representation of table 3

At the end of the performance evaluation it can be said that the new proposal is far ahead from the existing technique. Though the existing protocol's performance dramatically increases if the degree of parallelism is increased, it is behind well enough than the new protocol. In all the four cases, the tables and graphs, given above, can provide almost clear view of the difference of performances between the previous technique and the newer.

6. CONCLUSION

During the research work, different classes of wavelength division multiplexing (WDM) all-optical networks are studied. The electro-optical networks are also taken into account. For various networks various networking techniques or protocols are found. Among them the widely used protocols are taken. For example, the SONET/SDH of the EON, the "Trial and Failure protocol" of the AON. Those protocols are analyzed and simulated. The result shows the limitations of the existing techniques. In this work a new protocol for wavelength division multiplexing (WDM) all-optical network is proposed. It is believed that the main contribution of this research has been as much in opening the door of a new arena in the optical network. At the very beginning it is stated that, the existing optical techniques are very much specific. So one of the target was to provide a generalized one. During the research period, first of all the criteria of an ideal optical networking technique or protocol is fixed. Depends on those criteria, the new generalized protocol is proposed, which is simple but efficient. Moreover the protocol is fully conflict-free.

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