Performance Comparison and Analysis of Manycast QoS Routing Algorithm over Optical Burst Switched Networks

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Abstract
In network communications, there are many methods to deliver data from sources to destinations. During the past few years, we have observed the emergence of new applications that use multicast transmission. In many distributed applications require a group of destinations to be coordinated with a single source. Multicasting is a communication paradigm to implement these distributed applications. However in multicasting, if at least one of the members in the group cannot satisfy the service requirement of the application, the multicast request is said to be blocked. On the contrary in manycasting, destinations can join or leave the group, depending on whether it satisfies the service requirement or not. This dynamic membership based destination group decreases request blocking.
Manycast is proposed basing on the adaptation to QoS request, and the measures parameters involved in QoS generally include bandwidth, delay, delay jitter, packet loss rate and cost. Each application requires its own QoS threshold attributes. Destinations qualify only if they satisfy the required QoS constraints set up by the application. Due to multiple constraints, burst blocking could be high. We propose one algorithm to minimize request blocking for the manycast problems. Using NS2 based simulation results, we have analysis these parameters for manycast algorithm and then focuses on introducing how it is simulated based on NS2 and analyzing algorithm performance.

Keywords
NS2 (NetworkSimulator-2), manycast, optical burst-switched networks (OBS), quality of service (QoS), simulation.

I. Introduction

With the advent of many Internet-based distributed applications, there is a continued demand for a high capacity transport network. Networks based on wavelength division multiplexing (WDM) are deployed to tackle the exponential growth in the present Internet traffic. WDM network include optical circuit switching (OCS), optical packet switching (OPS), and optical burst switching (OBS) [4].

In OBS the user data is transmitted all-optically as bursts with the help of an electronic control plane [16]. One of the primary issues with OCS is that the link bandwidth is not utilized efficiently in the presence of bursty traffic. On the other hand, many technological limitations have to be overcome for OPS to be commercially viable. OBS networks overcome the technological constraints imposed by OPS and the bandwidth inefficiency of OCS networks. In this paper, we focus on the optical transport network being OBS. Most of the discussed algorithm can easily be modified to work for OCS and OPS networks.

There has been recent emergence of many distributed applications, such as video conferencing, telemedicine distributed interactive simulations (DIS), grid computing, storage area networks (SANs), and distributed content distribution networks (CDNs) require large amounts of bandwidths and an effective communication between single source and a set of destinations .provisioning of connections based on QoS to these applications is an important issue. QoS can include delays incurred during transmission, reliability, and signal degradation. These delay constraints can be met effectively by using OBS as the transport paradigm [14]. These distributed applications require a single source to communicate with a group of destinations. Traditionally, such applications are implemented using multicast communication. A typical multicast session requires creating the shortest-path tree to a fixed number of destinations.

The fundamental issue in multicasting data to a fixed set of destinations is receiver blocking. If one of the destinations is not reachable, the entire multicast request (say, grid task request) may fail. A useful variation is to dynamically select destinations depending on the status of the network. Hence, in distributed applications, the first step is to identify potential candidate destinations and then select the required number. This dynamic approach is called manycasting. Manycasting over optical burst-switched networks (OBS) based on multiple quality of service (QoS) constraints. These multiple constraints can be in the form of physical layer impairments, transmission delay, and reliability of the link. Each application requires its own QoS threshold attributes. Destinations qualify only if they satisfy the required QoS constraints set up by the application. Due to multiple constraints, burst blocking could be high. Manycasting has caught the attention of several researchers during the recent past, due to the emergence of many of the distributed applications described above.

A. Related Work

Apart from supporting manycasting over optical networks, we also need to provision QoS in OBS networks. This is because QoS provisioning methods in IP will not apply to the optical counterpart, as there is no store-and-forward model [11]. Such mechanisms for QoS provisioning in IP over OBS networks must consider the physical characteristics and limitations of the optical domain. Physical characteristics of the optical domain include optical-signal degradation, propagation delay incurred from source to destination, and link reliability from catastrophic effects. As the optical signal traverses in the transparent optical network, with the absence of electrical regenerators there will be significant loss of power due to much impairment. These impairments can be attenuation loss, multiplexer/demultiplexer loss, optical-cross-connect switch loss (OXC), and split loss (for multicast capable switches) [6]. ASE noise present in the EDFAs decreases the optical-signal-to-noise ratio (OSNR). Decrease in OSNR increases bit error rate (BER) of the signal. Hence, the signal is said to lost if BER is more than the required threshold. 3R regeneration of optical signal resets the effects of nonlinearity, fiber dispersion, and amplifier noise, without introducing any additional noise. This 3R regeneration requires retiming and clock recovery system, which cannot easily be carried all-optically. Hence, O/E/O conversion becomes inevitable. Delay accumulation due to O/E/O conversions can be significant when compared to the propagation delay in OBS networks. Wavelength regeneration can also result in reliability reduction and operational cost increase [18]. Challenges and requirements for introducing impairment-awareness into the

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management and the control planes in WDM networks have been discussed in [6]. Manycasting (or multicasting) requires the OXC to split the signal. Multicasting over optical networks can be done by the OXC switch incorporating the splitter-and-deliver (SaD) switch [16]. Depending on the fan-out of the switch the input power significantly decreases compared to unicast, thus decreasing OSNR. Multicasting under the optical layer constraint has been discussed in [13]. Power-efficient multicasting for optimizing BER has been studied in [9]. For the first time, impairment-awareness for implementing manycasting over OBS networks has been addressed in [6]. This paper discusses the importance of physical layer awareness and computes the loss due to burst contentions and reliability of the link. Further in [8] performance of different algorithms has been discussed and an analytical model has been proposed for calculating burst loss probability. Another important QoS parameter is the reliability of the links along the end-to-end path between the source and the destination. The work proposed in [5] discusses reliability for SANs. Analytical models are developed for calculation of longterm failures, service availability, and link failures. The reliability factor as a multiplicative constraint has been discussed in [18] .Performance analysis of end-to-end propagation delay and blocking probability for OBS based grids using anycasting has been presented in [3]. Different types of anycasting algorithms has been compared in [2] with the shortest-path unicast routing, where the destinations has a specific address. Manycasting over OBS networks based on multiple resources has been addressed in [19].

The rest of the paper is organized as follows: we first discuss the problem Formulation for service attributes in Section I. In Section II, simulation principle and extension method of NS2 is explained. Section IV discusses the analyses of simulation results. Finally, Section V concludes the paper.

II. Problem Formulation

In this section, we explain the mathematical framework for manycasting. Our work focuses on selecting the best possible destinations that can meet the service demands effectively. Destinations chosen must be able to provide quality of service attributes. A destination is said to qualify as the member of quorum pool if it satisfies the service requirements of the application. The proposed methods are based on distributed routing, where each node individually maintains the network state information and executes the algorithm. Algorithms implemented in the centralized way, may fail due to a single failure and resulting in poor performance. Our proposed algorithm has the following functionality:

1. Handle multiple constraints with the help of link state information available locally.
2. Service differentiated provisioning of manycast sessions.
3. Find the best possible destinations in terms of service requirements for the manycast sessions.

A. Notations

The algorithm description of simulated manycast QoS routing algorithm is as follows

Input: network topological graph G= (V, E),
Gs (A) = {S1… Sq} (q<n),
G (A) = {d1… dk} (k<n), crossover rate Pc, mutation rate Pm, evolution algebra maxgen
Output: optimal path that satisfies constraint conditions
{gen = 0;
Initializing population;
Calculating the fitness value of population individual;
while (dissatisfying pausing condition or gen<maxgen)
{gen++;
Selection operation ( );
Crossover operation ( );
Repair operation ( );
Mutation operation ( );
Repair operation ( );
Fitness calculation ( );
Retaining the optimal population individual;
}
Output of the path of optimal individual
}

B. Service Attributes

We define η_j, γ_j and τ_j as noise factor, reliability factor, and end-to-end propagation delay for the Link j, respectively. The noise factor is defined as the ratio of input optical signal to noise ratio ($OSNR_{i/p} = OSNR_i$) and output optical signal to noise ratio ($OSNR_{o/p} = OSNR_{i+1}$); thus we have

$$\eta_j = \frac{OSNR_{i/p}}{OSNR_{o/p}} \quad (1)$$

Where OSNR is defined as the ratio of the average signal power received at a node to the average amplified spontaneous emission noise power at that node. The OSNR of the link and q factor are related as

$$q = \frac{\frac{2\sqrt{B0}}{Be}\,\text{OSNR}}{1+\sqrt{1+4OSNR}} \quad (2)$$

Where B0 and Be are optical and electrical bandwidths, respectively. The bit-error rate is related to the q-factor as follows:

$$\text{BER} = 2\ \text{erfc}\,\frac{q}{\sqrt{2}} \quad (3)$$

We choose a route that has a minimum noise factor. Thus the overall noise factor is given by

$$\eta_R = \prod_{\forall i \in R} \eta_i \quad (4)$$

The other two parameters considered in our approach include the reliability factor and the propagation delay of the burst along the link. The reliability factor of the link j is denoted γ_j . This value indicates the reliability of the link, and its value lies in the interval (0, 1]. The overall reliability of the route γ_R is calculated as the multiplicative constraint and is given by

$$\gamma_R = \prod_{\forall i \in R} \gamma_i \quad (5)$$

The propagation delay on the link j is denoted τ_j , and the overall propagation delay of the route τ_R is given by

$$\tau_R = \sum_{\forall i \in R} \tau_i \quad (6)$$

III. Simulation Principle and Extension Method of NS2

NS2 (Network Simulator Version 2) developed by UC Berkeley is a kind of open-source free software simulation platform in allusion to network technology [1]. It's essentially a discrete event simulator. There are 2 levels in the simulation of NS2: one is based on configuration and construction of Otcl, which can use some existing network elements to realize the simulation by writing the Otcl scripts without modifying NS2; the other is based on

C++ and Otcl. Once the module resources needed do not exist, NS2 must be upgraded or modified to add the required network elements. Under these circumstances, the split object model of NS2 is used to add a new C++ class and an Otcl class, and then program the Otcl scripts to implement the simulation. The process of network simulation in NS2 is shown in Fig. 2. NS2 now has become one of the first selected software to implement network simulation in the academic field.

A. The Basic Composition of NS2

NS2 is a software package including some basic components like Tcl/Tk, OTcl, NS2, Tclcl, etc. (such as Fig.1) [13].

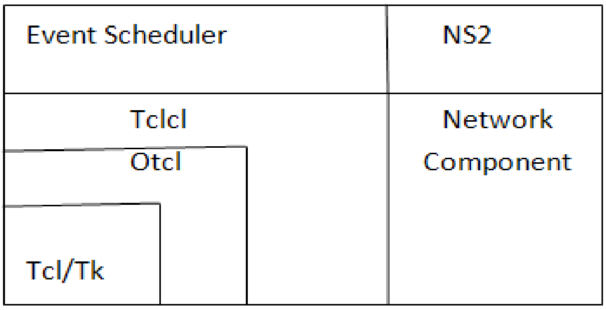

Fig. 1: Structure of NS2

Tcl is an open-script language which is used to program NS2; Tk is a development tool of graphical interface which can help users to develop graphical interface in graphic environment; OTcl is an object-oriented extension based on Tcl/Tk and it has its own class hierarchy; NS is the core of this software package, and also object-oriented simulator programming with C++, with OTcl interpreter to be front end; Tclcl provides interfaces of NS2 and OTcl, it is object and variable appeared in two languages. In order to observe and analyze the simulation results intuitively, NS2 provides selectable Xgraph, Gnuplot, selectable component Nam.

B. Basic Simulation Procedure of NS2

Fig.2 shows the basic procedure of network simulation with NS2.

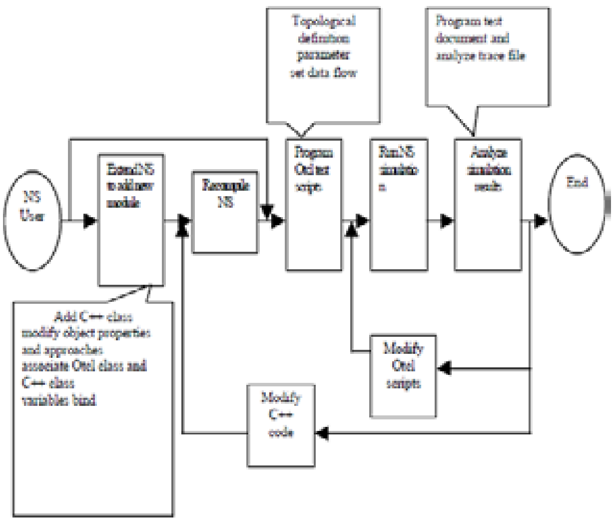

Fig. 2: The simulation process of NS2

NS simulation can be divided into two layers. At first we should analyze which layer is involved before the network simulation. One layer is based on OTcl programming. There are no needs to modify NS itself to implement simulation by use of existing network elements of NS, just to compile OTcl scripts. Another layer is the one based on C++ and OTcl programming. If there aren't required network elements in NS, it's needed to extend NS, adding required ones which also mean adding new C++ and OTcl class, then to compile OTcl script.

C. Extension of C++ level

Since manycast is a new network model and there is little simulation implementation with NS2, our simulation experiment was conducted basing on the C++ and Otcl levels. NS2 needs first to be extended to support the simulation of manycast QoS routing algorithm. The main steps are as follows:

1. Declare relevant variables

In programming, the relevant variables of routing algorithm shall be first declared, which can be extended in /ns2.34/routing/route.h.

2. Add compute route function

When the compute_routes ( ) function is extended in /ns2.34/routing/route.cc, we add a compute_routes _delay ( ) function, and the manycast QoS routing algorithm is embedded into this compute_routes () function.

3. Modify command ( ) fuction

In accordance with the separation of C++'s compiled class and Otcl's interpreted class in NS2, the configuration of nodes and structure of network topological graph are implemented on Otcl level, and some related parameters are transmitted to C++ level through Tclcl mechanism to assist the implementation of C++ function. When the manycast QoS routing algorithm is implemented in C++, we need to know the numbers of request nodes and service nodes, and the command () function is used to transmit the contents of relevant parameter argv [2] and argv [3] in Otcl to C++. Since the data types on Otcl level belong to character types, the data types need to be transferred when they are transmitted. After C++ is modified, the work on compiling level is basically finished.

D. Program Otcl test scripts

1. Create NS simulation object and define routing simulation module.
Set ns [new Simulator]
2. Define the way of routing for simulation object.
$ns multicast
$ns mrtproto manycast
3. Create node object.
In this experiment, we use a for circle of tcl grammar to create node_n simple nodes.
for {set i 0} { $i < $node_n} {incr i} {set n($i) [$ns node]}
4. Create connections between different nodes.
$ns simplex-link <node0> <node1> <bandwidth> < delay> <queue_type>
5. Create tracking object.
set f [open out.tr w]
$ns trace-all $f
$ns namtrace-all [open out.nam w]
Where an out.tr file is created to record the trace data during simulation process and make variable f pointing at this file; an out, nam file is created to record the trace data of nam.
6. Create receiving source.

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set group [Node allocaddr]
set rcvr1 [new Agent/LossMonitor]
set rcvr2 [new Agent/LossMonitor]
7. Create the sending and finishing time of packets.
$ns at 0.2 “$n (1) color blue”
$ns at 0.2 “$n (1) label Request”
$ns at 0.2 “$n (1) request-anycast $rcvr1 $group”
$ns at 1.2 “finish”
8. Finish nam.
Proc finish {} {
global ns
$ns flush-trace
puts "running nam..."
exec nam out.nam &
exit 0}
To transfer the finish process of various nodes at 1.2 seconds to end the whole program and to close out.tr and out.nam files.
9. Run Tcl script.
$ns run

IV. Analysis of simulation Results

In this section we validate our proposed algorithm with the help of discrete-event simulation. The National Science Foundation (NSF) network is considered for our simulation study. The topologies shown in Figs. 3 consist of bidirectional links, each carrying data at a rate of 10 Gbits/s. We assume that there is no wavelength conversion and regeneration capability for the network. Burst arrivals follow a Poisson process with an arrival rate of λ bursts/s. The length of the burst is exponentially distributed with the expected service time of 1/μ s. The network load is defined as λ/μ. Links in Fig. 3 benefit from in-line erbium-doped fiber amplifiers (EDFAs) placed 70 km apart. The calculation of the noise factor is based on linear impairments such as attenuation, mux/demux loss, tap loss, and amplified spontaneous emission noise [6]. There are no optical buffers, and hence the burst that finds the channel occupied will be dropped or lost. The reliability factor of the link indicates that the reliability is affected by damage caused by faults, fiber cuts, and catastrophic effects.

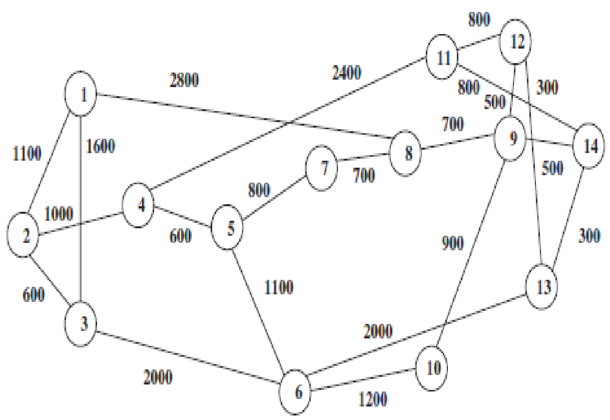

Fig. 3: Network topology of NSF network, consisting of 14 nodes and 21 bidirectional fiber links.

Based on the above NSF network topology we created the OTCL script for 14 nodes with same link properties. After program running, we can use Nam tool and Xgraph tool to obtain clearer experimental results. The following experimental results are obtained basing on this basic experimental environment.

Assumptions

1) Only one wavelength is considered for analysis. Hence, the dependency of q-factor on the wavelength is ignored.
2) Calculation of noise factor is based on losses due to attenuation, multiplexing/ demultiplexing, tapping, and splitting.
3) Only amplified spontaneous emission (ASE) noise can be considered for OSNR. The shot noise and beat noise are ignored.
4) Effects of offset time are ignored.
5) In line amplifiers along the links are placed, with spacing of 70 km between the amplifiers.
6) There are no optical buffers or wavelength converters in the network.
7) The reliability factor is same along both directions of the fiber.

A. Analysis of Nam animated results

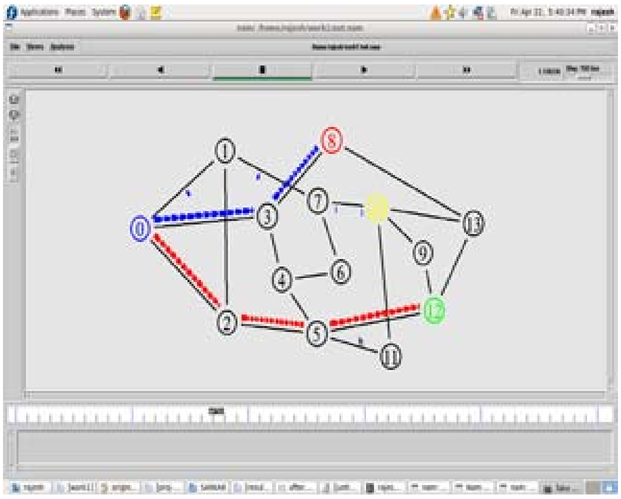

Fig. 4: Animated demonstration of 14 nodes (Before running)

Fig. 4 shows the network topological graph that is randomly generated, and the regular network check-up is necessary before the running of manycast routing algorithm program. As demonstrated in the Fig., the data transmission between node 0 and node 12 show that the network works well. Under this circumstance, the node 0 requests a service, and the nodes 8 and 12 are service nodes, the simulated algorithm is to select an optimal node from service nodes 8 and 12 to communicate with the node 0.

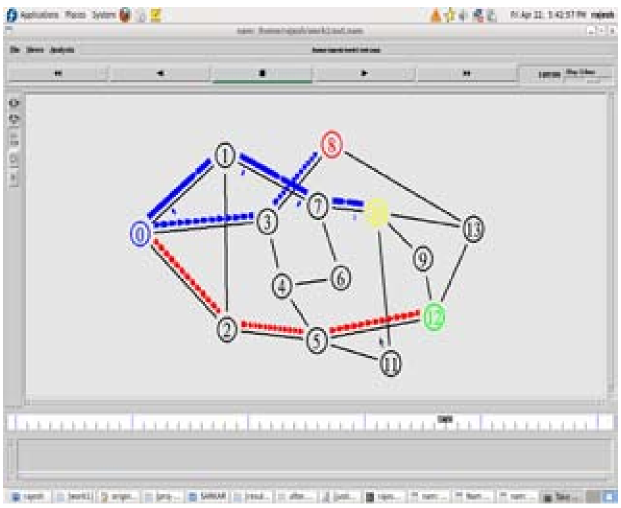

Fig. 5: Animated demonstration of 14 nodes (During running)
Fig. 5 shows that the simulated manycast routing program finally chooses the node 8 that can provide optimal service to communicate

with the request node 0.

B. Xgraph curve

1) Average end-to-end propagation delay of data message

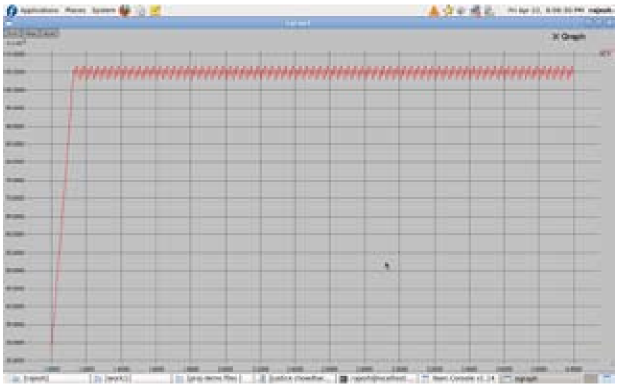

Fig. 6: End-to-end propagation delay of data message

Fig. 6 shows the average delay of packet transmission between 0 and 8. As shown in Fig. 4, a routing path is obtained from the simulation of manycast routing algorithm, on which the average delay of packet transmission remains a basically stable value, which shows the performance stability of this algorithm.

2. Delay jitter

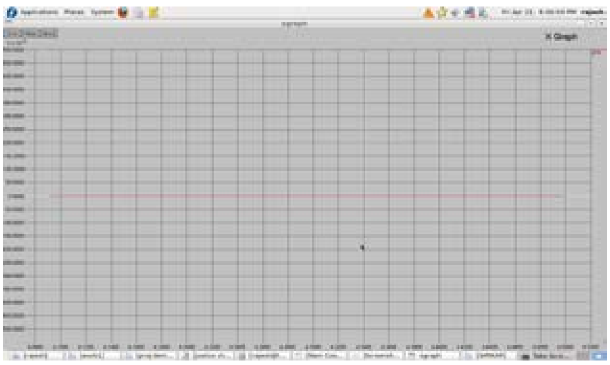

Fig. 7: Delay jitter.

The results show that, under circumstances of network stability, the delay jitter on the routing path obtained from the simulation of manycast routing algorithm tends to be 0. Sequentially we can conclude that the manycast path based on this algorithm is a path with relatively good performance.

3. Throughput

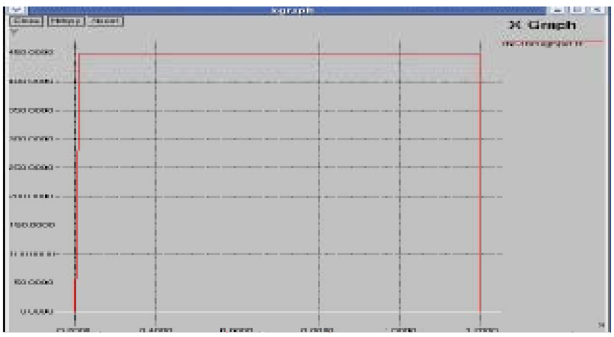

Fig. 8: Throughput of the neighbor nodes

The results show that the throughput of all nodes, except for the source node and the destination node, on the routing path obtained from the simulation of manycast routing algorithm remain a stable value. Once the routing is formed, there is little packet loss among different nodes, what is transmitted into equals to what is sent out.

4. Comparison with traditional routing algorithm

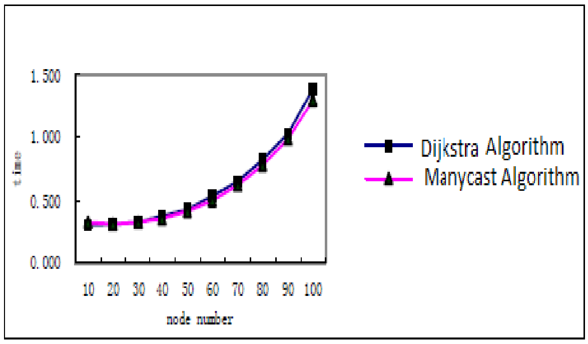

Fig. 9: Comparison of path finding time between Dijkstra and Manycast

Fig. 9 shows that, under the same manycast transmission and the same network environment, when the number of nodes is small, the path finding time of manycast algorithm is relatively slower than that of Dijkstra. However, as the number of nodes increases, manycast shows more advantages. It not only uses less time compared with Dijkstra but also finds an optimal QoS path to provide services. When the path finding time and path fitness are comprehensively considered, the manycast QoS routing algorithm has good application perspective in manycast communication models.

V. Conclusion

In this paper, we propose algorithm to support QoS-based manycast in optical burst–switched networks. Our QoS model supports certain service parameters for transmission of optical bursts, such as physical impairments, reliability and propagation delay. Since manycast is a new network model, many researchers are researching various routing protocols and routing methods to satisfy QoS demands in application layer and network layer. It is important for the application development of manycast routing software to simulate various QoS manycast routing algorithm in NS2 so as to implement the evaluation and analyses of algorithm performances. This shall be an important perspective in the research of manycast routing algorithm.

APPENDIX A

CALCULATION OF NOISE FACTOR THRESHOLD

We calculate the noise factor threshold η_{max} using (1) – (3). From (1), the noise factor of the link j is given by

$$\eta_j = \left(\frac{P(j)}{Pase(j)}\right)\left(\frac{Pase(j)}{p(j+1)}\right) \qquad (7)$$

For the path from source s to the destination d, the overall noise factor is given by

$$\eta_{<s,d>} = \left(\frac{P(s)}{P_{ase}(s)}\right)\left(\frac{P_{ase}(d)}{p(d)}\right) \quad (8)$$

We assume the transmitting power of the receiver is P(s) =1 mW. The ASE noise power at source node s is given by

$$p_{ase}(s)=p_{ini}L_d L_m L_t L_{ins}(G_{in}-1)G_{out}+p_{ini}L_t[G_{out}-1] \quad (9)$$

$p_{ini}(s)=2\eta_{sp}h f_c B_o$, where η_{sp} spontaneous-emission factor, h is the Plank's Constant, and f_c is the central frequency of the optical signal. L_d , L_m , L_t and L_{ins} are demultiplexer, multiplexer, tap, and insertion loss of the optical cross-connect switch, respectively. G_{in} and G_{out} are the inputs and output gains of the erbium-doped fiber amplifier (EDFA) in switch. Parameter values and the switch architecture can be found in [6], [11], and [12]. By using (9) we get the $P_{ase}(s)$ =0.0042 mW. Thus, the OSNR at s source will be

OSNR(s) =238 a.u. For BER of 10^{-12} we need q=7, for which the required OSNR (d) is obtained by solving (2)

$$7 = \frac{2\sqrt{\frac{B_o}{B_e}}OSNR}{1+\sqrt{1+4OSNR(d)}} \quad (10)$$

For a system operating B=10 Gb/s with B_o =70 GHz and B_e =0.7B, OSNR (d) =56, which is obtained by solving (10). Hence, if the OSNR (d) < 56(=OSNR min) then the BER will increase beyond

10^{-12} . Thus, the noise factor threshold η_{max} =4.25 corresponding to q=7. Similarly for q = 6, η_{max} =6. Thus, we see that as long as the noise-factor of the burst is $<\eta_{max}$, burst can be scheduled for transmission. We derive the relation for noise-factor threshold (η_{max}) and q-factor threshold (q_{th}).

$$\eta_{max} = \frac{OSNR\ (s)}{OSNR\ min} \quad (11)$$

In order for the BER to be less than the given threshold, the OSNR at the destination should be greater than the OSNR min. Thus, (2) at the threshold conditions is given by

$$q_{th} = \frac{2\sqrt{\frac{B_o}{B_e}}OSNR_{min}}{1+\sqrt{1+4OSNR_{min}}} \quad (12)$$

Solving this equation for OSNR min, we get

$$OSNR_{min} = q_{th}(q_{th} + \sqrt{\frac{B_o}{B_e}})\frac{B_o}{B_e} \quad (13)$$

Substituting (13) in (11) we get

$$\eta_{max} = \frac{OSNR(s)}{q_{th}(\frac{B_o}{B_e})(q_{th}+\sqrt{\frac{B_o}{B_e}})} \quad (14)$$

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