Computing Flow Completion Time in Optical Path/Packet Integrated Networks

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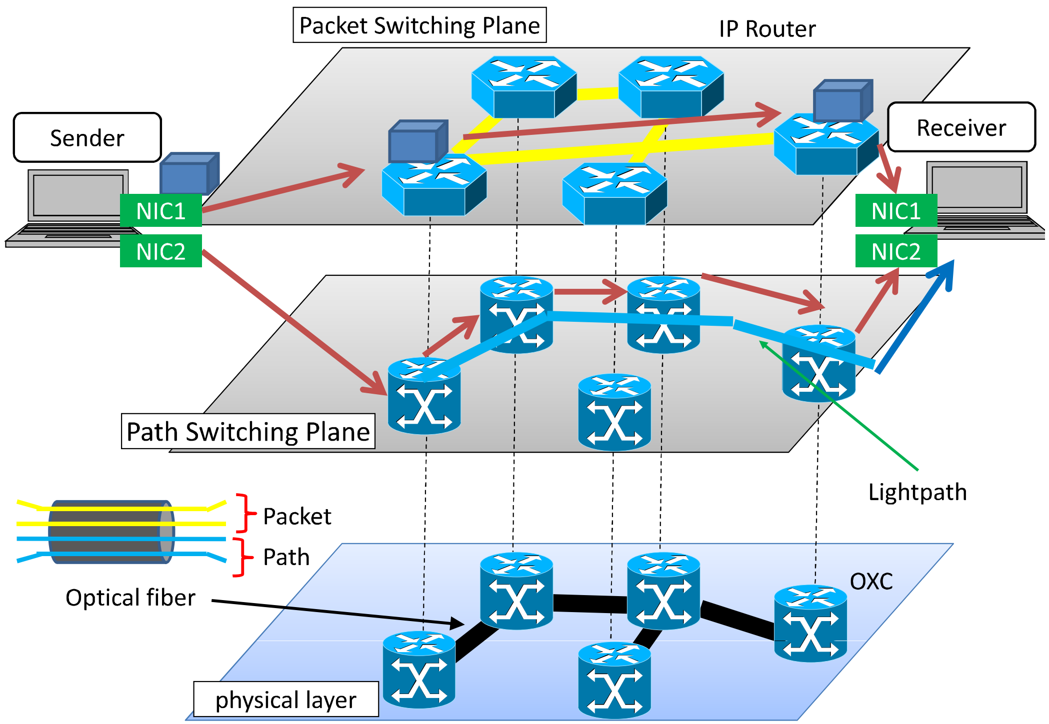
Objective

- **Analytical calculation of blocking probability in optical path (circuit) switched networks and packet drop rate in packet switched networks in order to estimate the average flow completion time as a performance metric for optimization of hybrid switching networks.**

Advantages

- **Estimation of the optimum ratio of path and packet-switching wavelengths in a path-packet integrated architecture for**
  - Decreasing the file transfer delay and increasing the efficiency.
  - Decreasing the node cost.
  - Decreasing the power requirements (ECO).

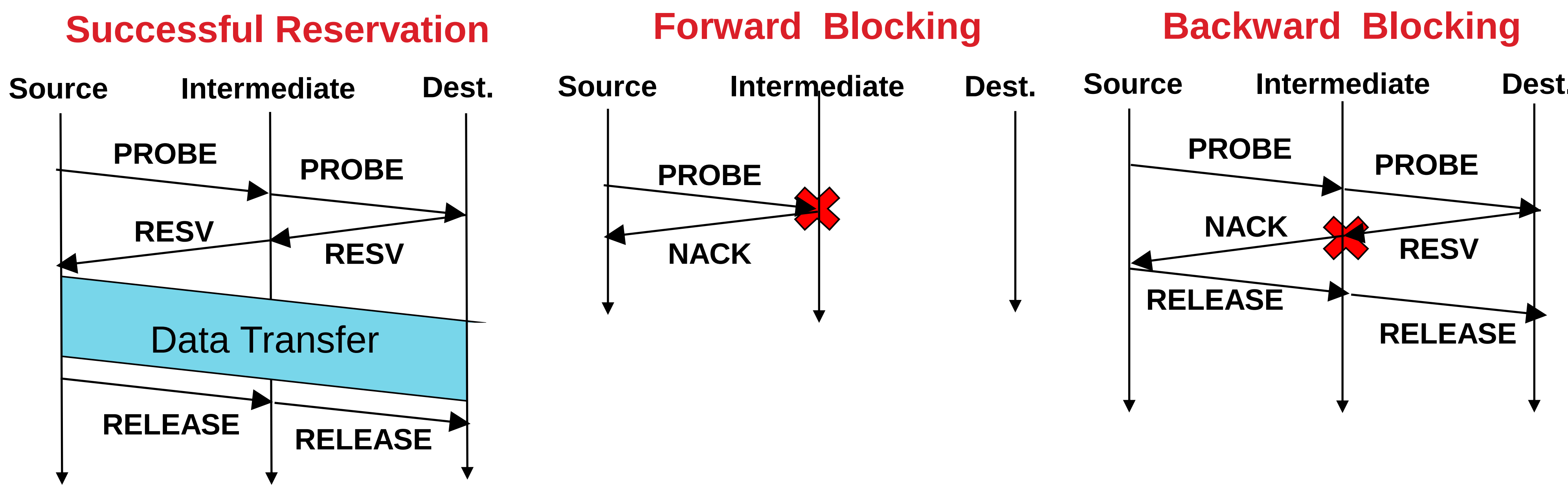
Optical Path/Packet Integrated Network



- Each end-host connecting with the router has two network interfaces; one for inject IP packets into the packet switched network and one for establish a lightpath between two end-hosts.
- When the data transfer request arises, the end-host selects the packet switched network or the circuit switched network to transfer the data.

- The sender host first tries to transfer a new coming flow in the circuit switched network. If the lightpath establishment succeeds, it transfers the flow by using the full transmission capacity of a wavelength.
- If the lightpath establishment fails, the sender transfers the data via the packet switched network using TCP protocol.

Path (Circuit) Reservation



- In case there is no idle wavelength left in the list of the PROBE packet, node sends a NACK packet to the source. This is called **forward blocking**.

- If the destination selects an idle wavelength, it sends a RESV packet to the source node in order to reserve it along the path. However, a previously idle wavelength may have been reserved by another connection when the reservation packet arrives. This is called **backward blocking**.

Analytical Solution (Path Network)

- **Applied the Reduced Load Approximation (RLA), which calculates the blocking rates in an iterative manner.**

- **The forward reservation blocking rate calculation is based on an analysis proposed by A. Birman.**
  - It is used by many analytical models in the literature.
  - Applies the Erlang-B formula for calculating the blocking probability.
  - Satisfies the wavelength continuity constraint.

- **Backward blocking rate is calculated by incorporating the wavelength reservation duration and propagation delays in the analysis to estimate the blocking due to outdated information.**
  - First proposed in a paper in year 1999 by S. Arakawa et al.
  - <u>We further improved and extended Arakawa's backward blocking analysis for more precise results and adapted it for use with Birman's forward blocking analysis for an iterative calculation.</u>

Analytical Solution (Packet Network)

- **The flows that fail reservation on the path network are carried by the packet network.**

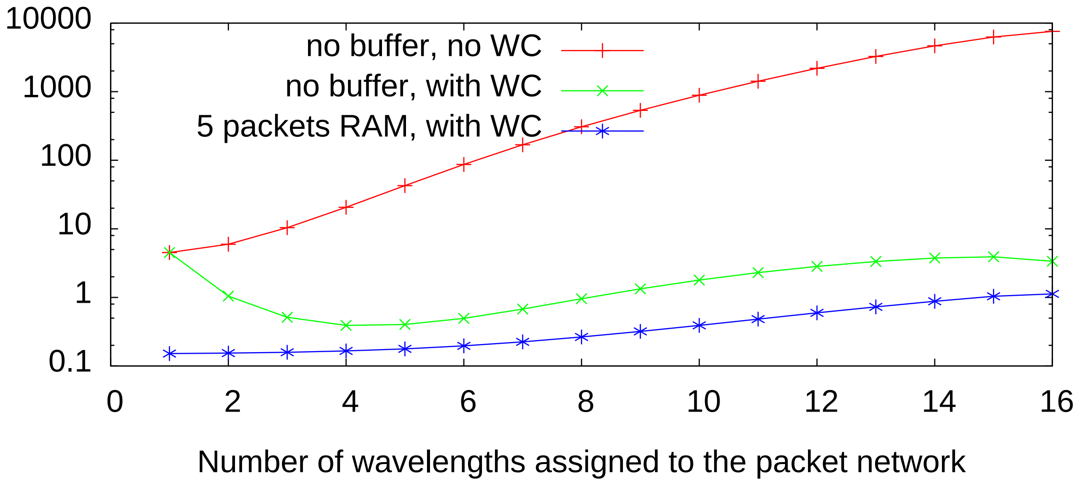
- **We used the TCP performance model from Cardwell et al. to calculate the transfer time of TCP flows on the packet network.**

- **Cardwell's model requires the packet drop rate information.**
  - When there is optical RAM buffering with wavelength conversion in the packet network, the packet drop rate on each link is calculated by solving the M/M/c/K queuing model where c is the number of packet wavelengths and K is sum of buffer size and number of packet wavelengths.
  - When there is no buffering, the packet drop rate is calculated by M/M/c/c if there is wavelength conversion and by M/M/1/1 if there is no wavelength conversion.

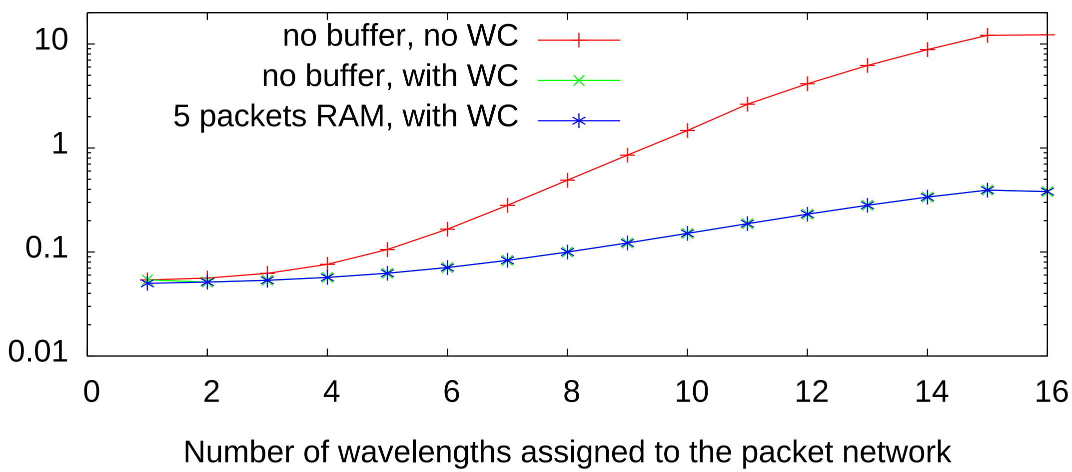
- **The TCP throughput and packet drop rates in the network are estimated by using the RLA method iteratively.**

Numerical Results

(a)



(b)



- **The figure shows the average flow transfer time for a sample flow with size (a) 10^9 Bits and (b) 10^6 Bits.**
- **EON topology (19 nodes and 39 links) with 16 wavelengths at 10Gbit/s.**
- **Link propagation delay is 10 ms.**
- **Mean flow length is 0.1 seconds.**
- **The total flow arrival rate in the network was 650 flows/s.**

- **When the flow size was 10^9 Bits, the flow transfer time was minimized with 4 packet wavelengths when there was WC without buffering.**
- **On the other hand, the flow transfer time was minimized with a single packet wavelength in the rest of analytical results for both flow sizes.**
- **We can see that the wavelength conversion ability greatly decreased the packet drop rates as we increased the number of packet wavelengths.**

Conclusions

- **We presented some analytical results on a mesh EON network and showed that using only a few packet wavelengths can minimize the flow transfer time using a an optical path/packet integrated network.**

Future Work

- **Compare the analytical results with simulation results.**
- **Extend our analytical model with fiber delay line (FDL) based buffering**
- **Adaptively change the ratio of path and packet wavelengths in the network depending on the traffic.**