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).
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.
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the wavelength reservation duration and propagation delays in the analysis to estimate the blocking due to outdated information.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.
  - 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.
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

- 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 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.