Wavelength Resource Allocation for Optical Path/Packet Integrated Networks

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11 November 2013

Outline

- **Problem Statement**
- **Objective**
- **Wavelength Reservation**
- **Analytical Solution**
- **Numerical Results**
- **Conclusions**
- **Future Research**

Problem Statement

- **Compared to electrical cabling, optical fiber with wavelength division multiplexing (WDM) allows much higher bandwidth and can span longer distances**
  - WDM is a promising solution to handle the fast-growing Internet traffic that is demanding more and more capacity.
  - WDM can employ different switching granularities in order to utilize the vast capacity of fiber links e.g., packet, burst and path (circuit) switching
- **Optical packet switching**
  - Advantage:
    - » Allows higher utilization of WDM channels thanks to its high statistical multiplexing gain and flexibility
  - Disadvantages:
    - » Has higher switch cost as it needs ultra-fast switching fabric to achieve high granularity.
    - » The current optical buffering technology is not mature enough to provide large and fast buffering space to optical packet switching.

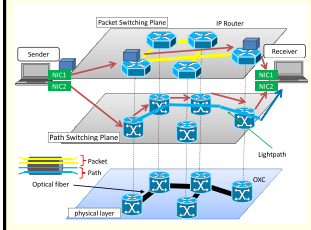
Problem Statement (2)

- **Path switching**
  - Advantages:
    - » Low switch cost and power requirements as its switching speed and frequency is lower.
    - » It does not need optical buffering at the core nodes as there is no contention of packets
    - » it has an easier and more effective QoS support for flows with strict QoS requirements.
  - Disadvantages:
    - » Has lower utilization efficiency in the dedicated channel because a connection may or may not use the capacity.
    - » Needs prior reservation of channels that adds an additional delay to flow completion time.

Objective

- **A possible solution to these issues is using a hybrid-architecture combining path and packet switching to exploit the best of both worlds**
- **Designing a path-packet integrated architecture for**
  - Decreasing the file transfer delay and increasing the efficiency
  - Decreasing the cost
  - Decreasing the power requirements (ECO)

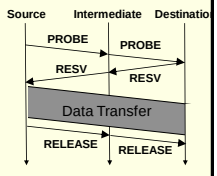
Optical Path/Packet Integrated Network



- **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.**

Wavelength Reservation (1)

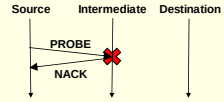
- The maximum number of simultaneous connections on a fiber is limited, so the wavelength reservation algorithm has a big impact on the blocking probability.
- One of the most popular reservation algorithms in the literature is destination-initiated reservation (DIR)
- When there is a connection request, source node sends a PROBE packet, which collects a list of idle wavelengths along the path.
- Destination node selects one of the wavelengths, which is idle on all links in order to satisfy the wavelength-continuity constraint and sends a RESV packet to source node.
- If the source node receives a RESV packet, it means that the selected wavelength has been reserved successfully along the path, so it sends the data over this wavelength.
- When the flow is finished, source node sends a RELEASE packet to remove the reservation of the reserved wavelength.



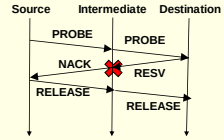
Successful Reservation

Wavelength Reservation (2)

- In case there is no idle wavelength left in the list of 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.
- In this case, the RESV packet is converted to NACK packet and reservation is no longer done in the rest of the path.
- If the source node receives a NACK packet, again it drops the connection request and sends a RELEASE packet to the destination to release the reservations done by the RESV packet.



Forward Blocking



Backward Blocking

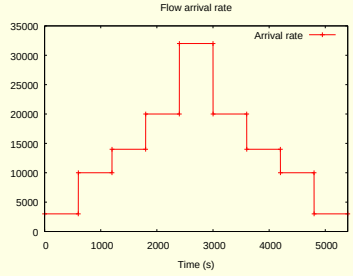
The Wavelength Allocation

- **One of the nodes in the network works as a controller node, which collects the traffic information in the network by exchanging control packets with other nodes**
- **The routers send traffic statistics (namely average flow speed in the path and packet wavelengths and the utilization ratio of packet wavelengths) to the controller node, periodically.**
- **The controller node increases or decreases the number of packet wavelengths in the network by one after each control period.**

Simulation Parameters

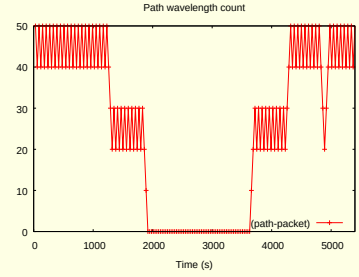
- **5-node ring topology**
- **Band switching. 10 path-switching wavelengths create one packet-switching wavelength.**
- **60 path-switching wavelengths**
- **Path wavelength speed is 100Mbps and packet wavelength is 1Gbps, so link capacity is 6Gbps**
- **Link propagation delay is 10ms**
- **Flow size is exponentially distributed with a mean value of 1Mbit.**
- **Uniform traffic matrix**
- **Control period to change path/packet ratio is 30 seconds.**
- **Packet wavelength utilization threshold is %50**

Traffic Rate



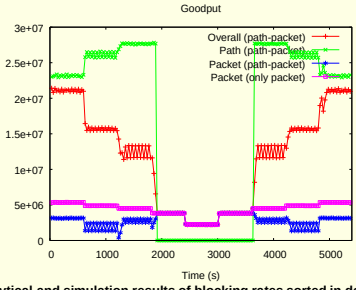
- **At the beginning of the simulation, the total flow arrival rate to the network is low (3000 flows/s), but it gradually increases to a very high flow arrival rate (32000 flows/s) at 2400s, which almost fully utilizes the links, then decreases again to a low arrival rate.**

Wavelength Distribution



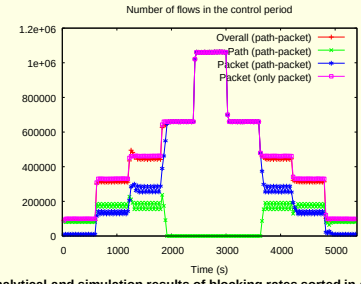
- **Initially the network is under-utilized, so the network assigns all wavelengths to the path network.**
- **Later, the utilization of packet wavelengths pass the threshold parameter 50%, so the network assigns most of the wavelengths to the packet network.**
- **Between 1800s-3600s, the network operates like a pure packet switching network.**

Goodput



- **Analytical and simulation results of blocking rates sorted in descending order by simulation results for each s-d pair in the network.**
- **Most of the analytical solutions in literature have problems when estimating blocking rate at highly loaded links**
- **Our analysis can calculate them with low error rate**

Flow Distribution



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Conclusions

- Simulation results on mesh network show that the proposed analytical model can calculate the blocking rates at both high and low link loads
- The precision of the analytical method is higher when link loads are lower

Future Work

- Increase the accuracy of forward blocking calculation
- Extend the analytical model to incorporate the retrial of blocked connections
- Calculate the average flow reservation time

Thank you