Advance Reservation of Lightpaths in Optical-Network-Based Grids

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DWDM-RAM

- Optical-network grid service architecture
  - Enable the deployment of dynamically-provisioned optical networks in grids
  - Support data-intensive grid applications through advanced optical network
  - Provide dedicated lightpaths as a service
The Network Service

NRS - Network Resource Scheduler

- Knows the topology of the network
- Supports on-demand and advance reservation
- Schedules multi-wavelength lightpaths
Our Goal

- Advance-reservation scheduling of multi-wavelength lightpaths
- Use simulation to assess the efficiency of different strategies

Main problem

- Lack of information on what the traffic on data-intensive grids will be like
- Solution: FONTS
Flexible Optical Network Traffic Simulator

- Generates traces of advance-reservation multiple-wavelength lightpath requests
- Incorporates stochastic models
- Is scalable and independent of the network interconnection
FONTS - Operation Modes

- **Request Arrivals**
  - Poisson

- **Advance Reservations**
  - Poisson, Uniform

- **Source Node and Destination Node**
  - Constant, Uniform, Arbitrary Probabilities

- **Number of Wavelengths**
  - Constant, Uniform, Heavy-Tailed

- **Data Size**
  - Constant, Uniform, Heavy-Tailed, Arbitrary Probabilities
Challenge

- Advance reservation requests are a function of
  - The time at which they arrive
  - The time in the future for which the reservation is requested
Generating Advance Reservation Requests

Step 1: Generate advance reservation request start times
Step 2: Align advance reservation request start times with lower edge of time slots

Step 3: Attribute aligned advance reservation request start times to user requests
Scheduling Lightpaths

Most used basic approaches

- **Wavelength Concentrating**
  - Goes through all the routes in a fixed order and for each route tries all the wavelengths in a fixed order

- **Wavelength Balancing**
  - Goes through all the wavelengths in a fixed order and for each wavelength tries all the routes in a fixed order

Optimizations are usually based on the ordering of routes and wavelengths
Scheduling Lightpaths

- Request: 4 wavelengths from 1 to 3

Balancing

Concentrating
Scheduling Lightpaths

- **Our goal**
  - Compare balancing and concentrating in different scenarios
  - Identify special conditions, which may favor one or the other

- **Our implementation**
  - Select routes according to the length
    - Disjoint-edge shortest-path first
  - Select wavelengths in order
Request Traffic

- Time slots = 60min
- Request inter-arrival time = 10min

<table>
<thead>
<tr>
<th>Number</th>
<th>Experiment</th>
<th>Reserv. Inter-Arrival Time</th>
<th>Number of wavelengths</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,5,9</td>
<td>High, medium, and low traffic Constant wavelength requests</td>
<td>5, 15, 30min</td>
<td>Constant: 1</td>
</tr>
<tr>
<td>2,6,10</td>
<td>High, medium, and low traffic Heavy-tailed wavelength requests</td>
<td>5, 15, 30min</td>
<td>Zipf’s Exp = 3, cap = 4</td>
</tr>
<tr>
<td>3,7,11</td>
<td>High, medium, and low traffic Uniform wavelength requests</td>
<td>5, 15, 30min</td>
<td>Uniform: [1-4]</td>
</tr>
<tr>
<td>4,8,12</td>
<td>High, medium, and low traffic Constant wavelength requests</td>
<td>5, 15, 30min</td>
<td>Constant: 4</td>
</tr>
</tbody>
</table>
Partial Mesh

Ring

Ring with a Spike

These topologies cover the most used 4-node basic blocks used to form optical networks.
Partial Mesh: Uniform Requests

Wavelength-balancing and concentrating perform comparably
Partial Mesh: Fixed 2-Hop Requests

Wavelength-balancing offers consistent improvement
Wavelength-balancing and concentrating perform comparably
4-Node Ring: Fixed 2-Hop Requests

Wavelength-balancing and concentrating perform comparably.
No Traffic on One Link: Uniform Requests

Path 2-4 is not requested

Wavelength-balancing performs consistently better than concentrating
Current Status

- Scheduling Simulator
  - Simulator has been extended to accept any topology
    - Extensive analysis of simulation results on different kinds of traffic and topologies
    - Hybrid algorithm, which combines balancing and concentrating
Current Status

- **FONTS**

  - Currently generates traces for
    - On-demand requests
    - Advance reservations
    - Periodic reservations

  - Available on line:
    - [http://students.engr.scu.edu/~snaiksat/fonts](http://students.engr.scu.edu/~snaiksat/fonts)
## FONTS

A Flexible Optical Network Traffic Simulator

### Request Type
- **current generation**: traces for on-demand, advance, and periodic reservations

### A webpage allows users to generate their own trace by describing their traffic through specific parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Request Type</td>
<td>advance reservation</td>
</tr>
<tr>
<td>Reserve Start Time Model</td>
<td>uniform</td>
</tr>
<tr>
<td>Inter Arrival Time</td>
<td>10 min</td>
</tr>
<tr>
<td>Source Model</td>
<td>uniform</td>
</tr>
<tr>
<td>Destination Model</td>
<td>uniform</td>
</tr>
<tr>
<td>Total Switching Nodes</td>
<td>2</td>
</tr>
<tr>
<td>Number of Wavelengths Model</td>
<td>constant</td>
</tr>
<tr>
<td>Num of Wavelengths</td>
<td>1</td>
</tr>
<tr>
<td>File Size Model</td>
<td>constant</td>
</tr>
<tr>
<td>File Size</td>
<td>1 TB</td>
</tr>
<tr>
<td>Reservation Duration Model</td>
<td>variable</td>
</tr>
<tr>
<td>Average Bandwidth</td>
<td>1000 Mbps</td>
</tr>
<tr>
<td>Reserve Period</td>
<td>7 days</td>
</tr>
<tr>
<td>Reserve Slot Size</td>
<td>60 min</td>
</tr>
<tr>
<td>Simulation Time Interval</td>
<td>1/29/2004 00:00:00</td>
</tr>
<tr>
<td>Start Time</td>
<td>10/05/2004 00:00:00</td>
</tr>
</tbody>
</table>

### Advanced Options

**Reservation Times**

<table>
<thead>
<tr>
<th>Number of Time Intervals</th>
<th>START</th>
<th>END</th>
<th>INTER-ARRIVAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>11</td>
<td>5 min</td>
</tr>
</tbody>
</table>

Submit
Currently generates traces for on-demand, advance, and periodic reservations.

A webpage allows users to generate their own trace by describing their traffic through specific parameters.

Example Statistics from file: tra-Hum.txt

Reservation starts at Fri Oct 29 00:00:00 2004
Reservation ends at Thu Nov 4 22:59:59 2004
Reservation window starts at Thu Nov 4 23:00:00 2004
Reservation window ends at Thu Nov 11 22:59:59 2004

1 slots available for reservation = 168
1 number of switching nodes = 2
age bandwidth per link = 1000.000000 Mbps
length = 60 mins

The arrivals follow Poisson distribution, \( \text{poissonLambdaValForReqArrival} = 0.150000 \) Inter
val Parameter = 10.00 mins
ce node choice is using uniform distribution
init node choice is using uniform distribution
er of wavelengths (\( \text{lambda} \)) are constant = 1
size is constant = 1.00 TB
Reservation start times follow uniform distribution.

cated reservation period per request is variable (depends on the size of the data to transfer
the average bandwidth per link).
Current Status

- Currently generates traces for on-demand, advance, and periodic reservations
- A webpage allows users to generate their own trace by describing their traffic through specific parameters.

Reservation Details:

- Reservation starts at Fri Oct 29 00:00:00 2004
- Reservation ends at Thu Nov 4 22:59:59 2004
- Reservation window starts at Thu Nov 4 20:00:00 2004
- Reservation window ends at Thu Nov 11 22:59:59 2004
- Number of switching nodes = 2
- Average bandwidth per link = 1000.000000 Mbps
- Length = 50 mins
- Inter-arrival follows Poisson distribution: \( \text{poissonLambdaValForReqArrival} = 0.100000 \)
- Inter-Arrival Parameter = 10.00 mins
- Node choice is using uniform distribution
- Node choice is using uniform distribution
- Set of wavelengths \( \{\text{lambdas}\} \) are constant = 1
- Disk size is constant = 1.00 TB
- Reservation start times follow uniform distribution.

Detailed Reservation Period per Request is variable (depends on the size of the data to transfer and the average bandwidth per link).

<table>
<thead>
<tr>
<th>ReqArrivalTime</th>
<th>ResvStart</th>
<th>ResvEnd</th>
<th>SourceNode</th>
<th>DestNode</th>
<th>Len</th>
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<tbody>
<tr>
<td>Fri Oct 29 00:21:00</td>
<td>Wed Nov 10 05:00:00</td>
<td>Wed Nov 10 07:14:00</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Fri Oct 29 00:21:00</td>
<td>Fri Nov 5 18:00:00</td>
<td>Fri Nov 5 20:14:00</td>
<td>1</td>
<td>2</td>
<td>2</td>
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<tr>
<td>Fri Oct 29 00:34:00</td>
<td>Sun Nov 7 10:00:00</td>
<td>Sun Nov 7 12:14:00</td>
<td>1</td>
<td>2</td>
<td>2</td>
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<tr>
<td>Mon Nov 8 12:00:00</td>
<td>Mon Nov 8 14:14:00</td>
<td>Mon Nov 8 16:14:00</td>
<td>2</td>
<td>1</td>
<td>2</td>
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<tr>
<td>Mon Nov 8 21:00:00</td>
<td>Mon Nov 8 23:14:00</td>
<td>Mon Nov 8 01:14:00</td>
<td>2</td>
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<tr>
<td>Sat Nov 6 03:00:00</td>
<td>Sat Nov 6 11:14:00</td>
<td>Sat Nov 6 13:14:00</td>
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<td>Thu Nov 11 16:00:00</td>
<td>Thu Nov 11 18:14:00</td>
<td>Thu Nov 11 20:14:00</td>
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<tr>
<td>Wed Nov 10 15:00:00</td>
<td>Wed Nov 10 17:14:00</td>
<td>Wed Nov 10 19:14:00</td>
<td>2</td>
<td>1</td>
<td>2</td>
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<tr>
<td>Sat Nov 6 01:00:00</td>
<td>Sat Nov 6 03:14:00</td>
<td>Sat Nov 6 05:14:00</td>
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<tr>
<td>Fri Nov 5 18:00:00</td>
<td>Fri Nov 5 20:14:00</td>
<td>Fri Nov 5 22:14:00</td>
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<tr>
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<td>Sun Nov 7 13:14:00</td>
<td>Sun Nov 7 15:14:00</td>
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<tr>
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<td>Thu Nov 11 04:14:00</td>
<td>Thu Nov 11 06:14:00</td>
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<td>Thu Nov 11 12:00:00</td>
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<td>Thu Nov 11 03:14:00</td>
<td>Thu Nov 11 05:14:00</td>
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<td>Wed Nov 10 18:00:00</td>
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<tr>
<td>Fri Nov 5 23:00:00</td>
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<td>Fri Nov 5 03:14:00</td>
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<tr>
<td>Sat Nov 6 09:00:00</td>
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<td>Sat Nov 6 08:14:00</td>
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<td>Mon Nov 8 20:00:00</td>
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<td>Mon Nov 8 02:14:00</td>
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<tr>
<td>Tue Nov 9 19:00:00</td>
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<tr>
<td>Wed Nov 10 01:00:00</td>
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<td>Wed Nov 10 05:14:00</td>
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<td>Thu Nov 11 05:00:00</td>
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<td>Thu Nov 11 09:14:00</td>
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<td>Tue Nov 9 17:00:00</td>
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<td>Tue Nov 9 21:14:00</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
Conclusion

- **FONTS is an important tool**
  - Enables experimenting with different kinds of traffic, while real traces are not available.

- **Lightpath scheduling**
  - Specific characteristics of the traffic and topology definitely affect the behavior of scheduling strategies.