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

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

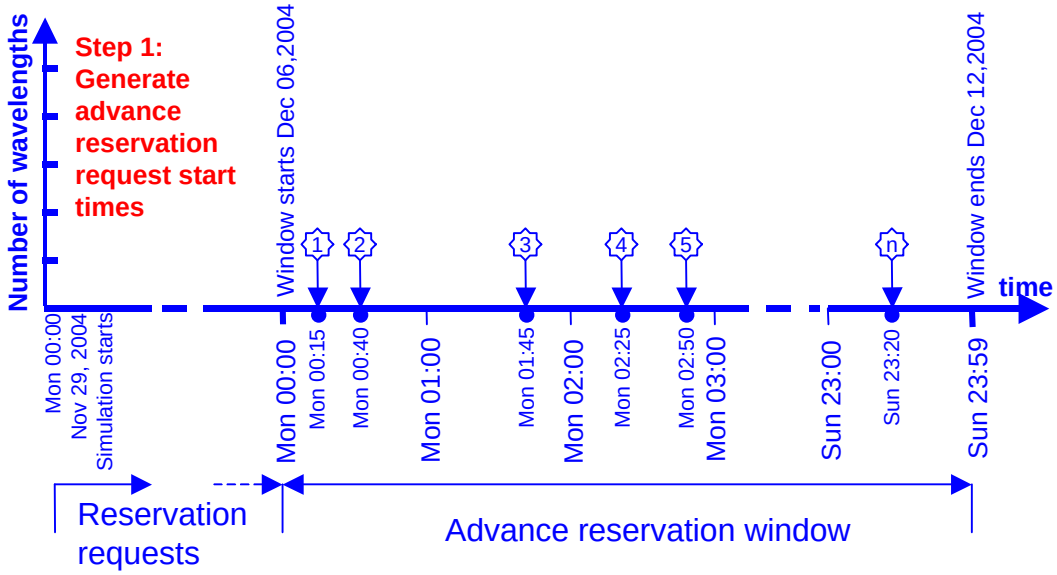
FONTS – Operation Modes

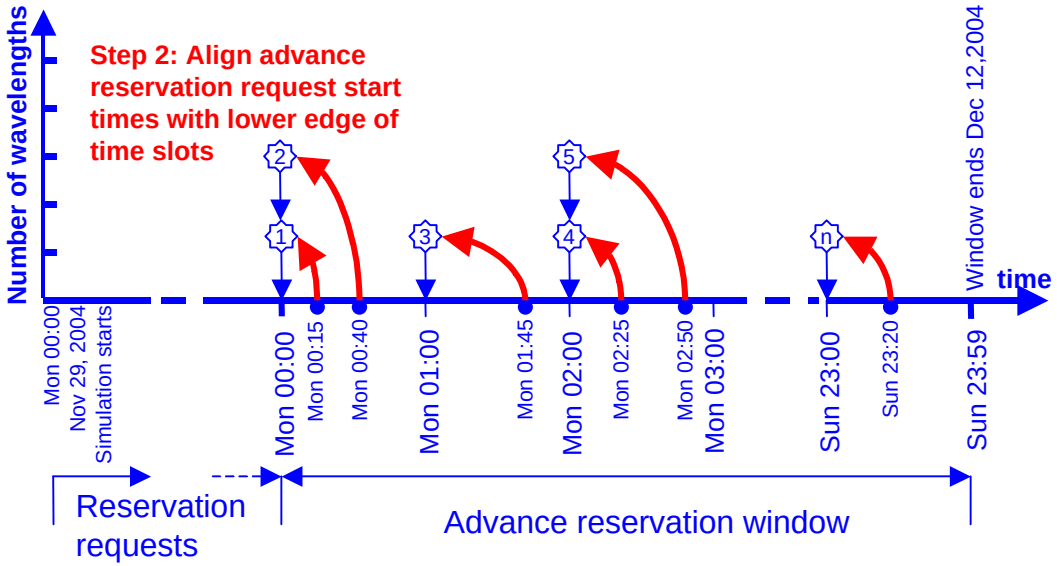
- Request Arrivals
  - Poisson
- Advance Reservations
  - Poisson, Uniform
- Source Node and Destination Node
  - Constant, Uniform, Arbitrary Probabilities
- Number of Wavelengths
  - Constant, Uniform, Heavy-Tailed
- Data Size
  - Constant, Uniform, Heavy-Tailed, Arbitrary Probabilities

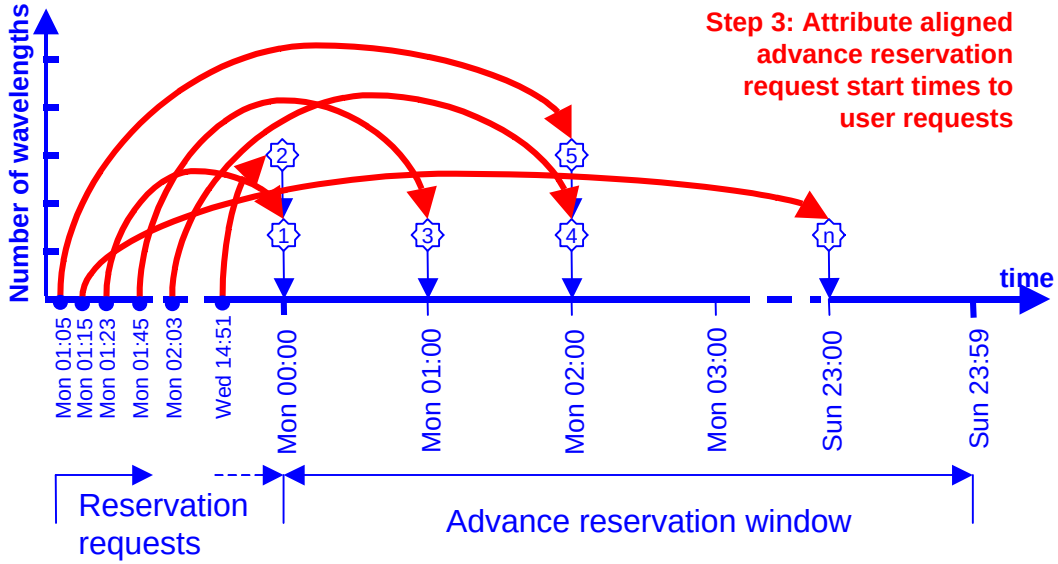
FONTS

- 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 2: Align advance reservation request start times with lower edge of time slots
Number of wavelengths
time
Window ends Dec 12,2004
Mon 00:00 Nov 29, 2004 Simulation starts
Mon 00:00
Mon 00:15
Mon 00:40
Mon 01:00
Mon 01:45
Mon 02:00
Mon 02:25
Mon 02:50
Mon 03:00
Sun 23:00
Sun 23:20
Sun 23:59
Reservation requests
Advance reservation window

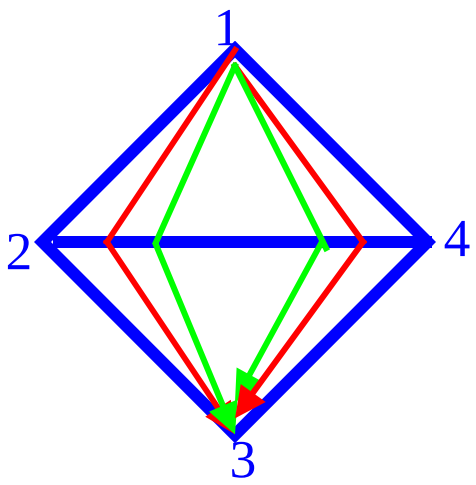

Step 3: Attribute aligned advance reservation request start times to user requests
Number of wavelengths
time
Mon 01:05
Mon 01:15
Mon 01:23
Mon 01:45
Mon 02:03
Wed 14:51
Mon 00:00
Mon 01:00
Mon 02:00
Mon 03:00
Sun 23:00
Sun 23:59
Reservation requests
Advance reservation window

Scheduling Lightpaths

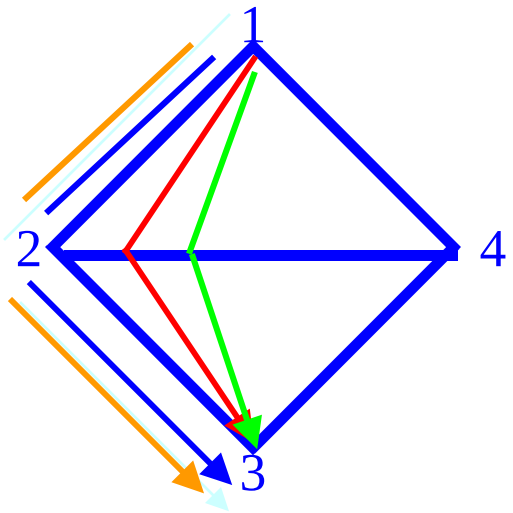
- Most used basic approaches
  - Wavelength Concentrating
    - Goes through all the routes in a fixed order and for each route tries all the wavelengths in a fixed order
  - Wavelength Balancing
    - Goes through all the wavelengths in a fixed order and for each wavelength tries all the routes in a 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

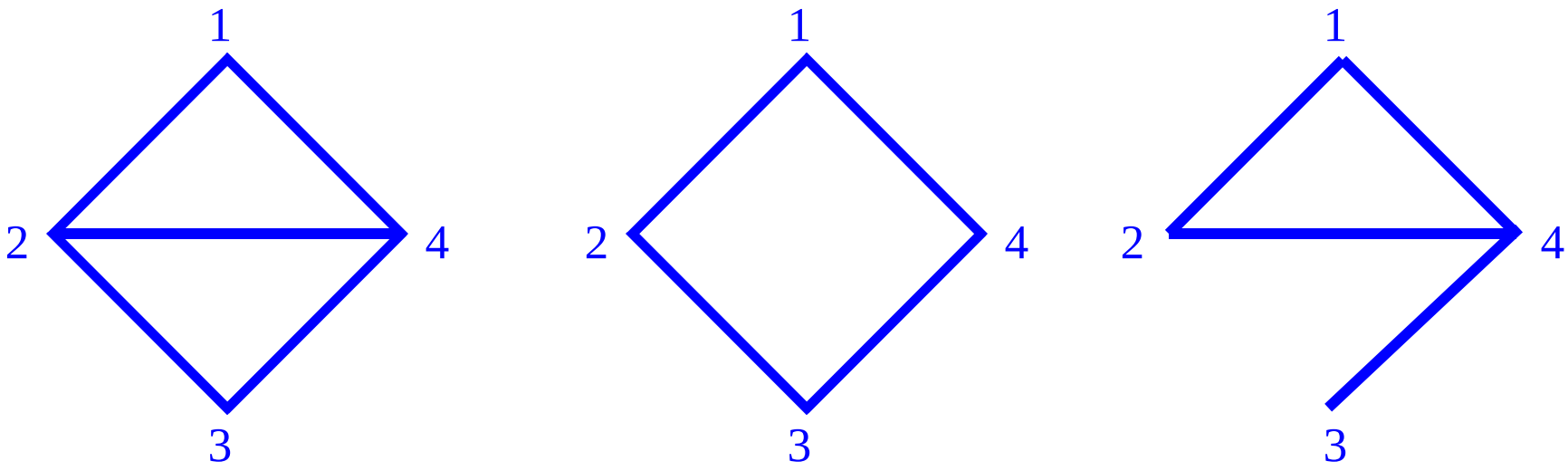
Request Traffic

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

Number	Experiment	Reserv. Inter-Arrival Time	Number of wavelengths
1,5,9	High, medium, and low traffic Constant wavelength requests	5, 15, 30min	Constant: 1
2,6,10	High, medium, and low traffic Heavy-tailed wavelength requests	5, 15, 30min	Zipf's Exp = 3, cap = 4
3,7,11	High, medium, and low traffic Uniform wavelength requests	5, 15, 30min	Uniform: [1-4]
4,8,12	High, medium, and low traffic Constant wavelength requests	5, 15, 30min	Constant: 4

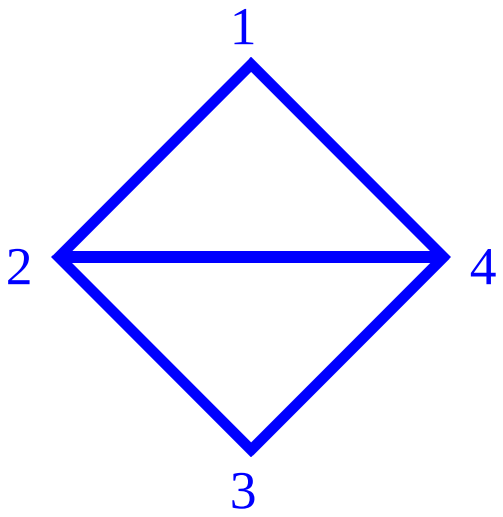
4-Node Topologies Studied

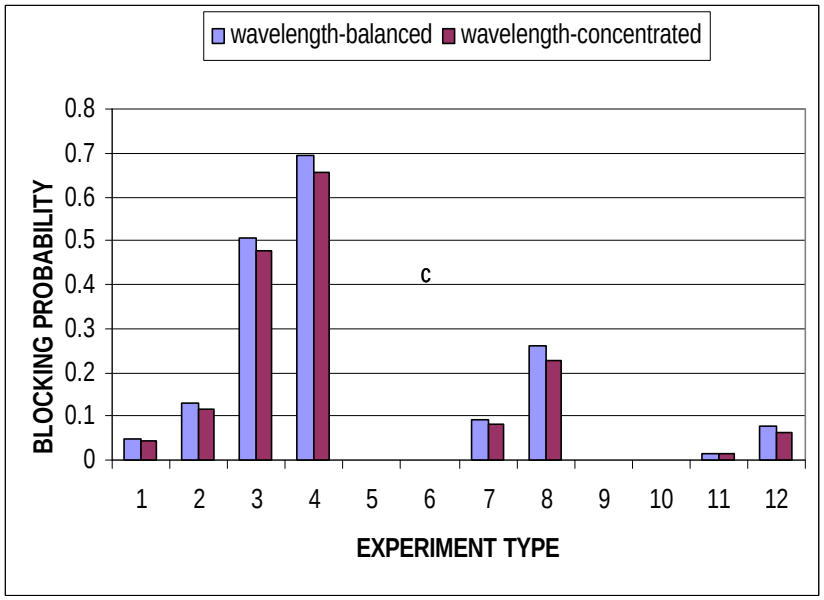
Partial Mesh	Ring	Ring with a Spike



These topologies cover the most used 4-node basic blocks used to form optical networks.

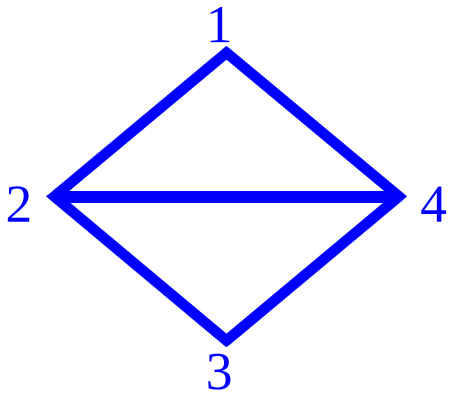
Partial Mesh: Uniform Requests



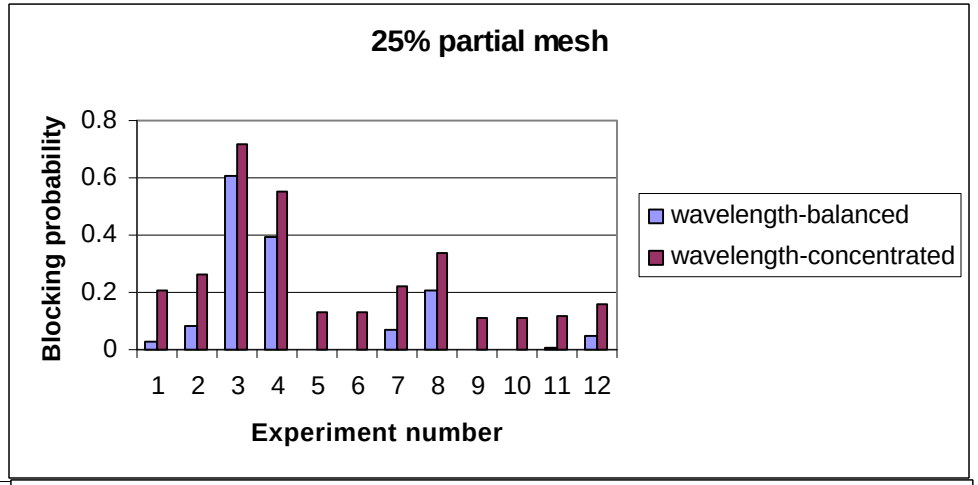


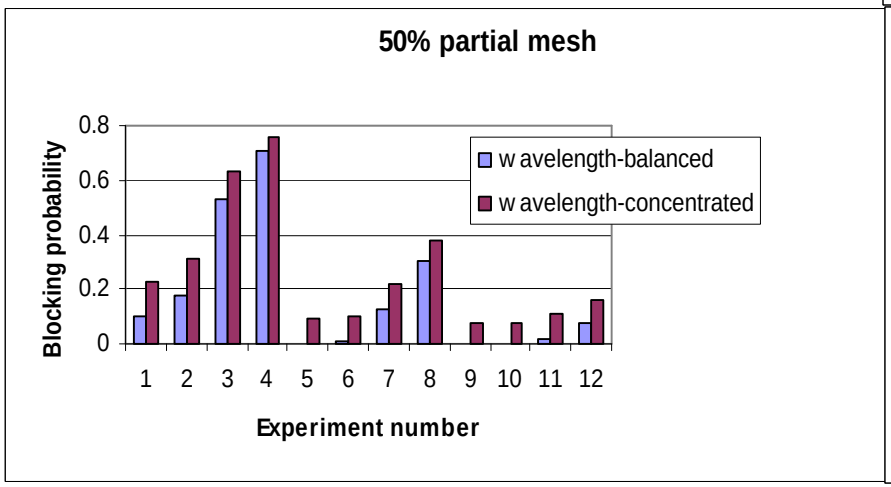
Wavelength-balancing and concentrating perform comparably

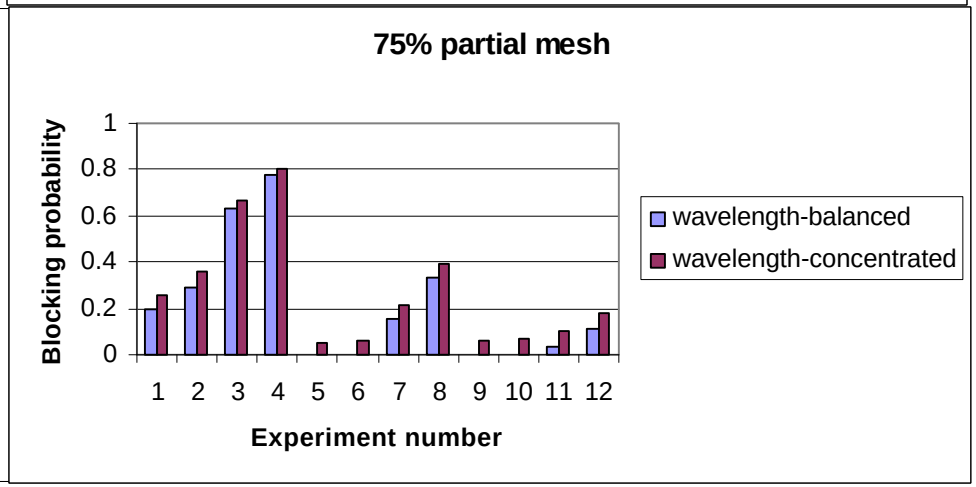
Partial Mesh: Fixed 2-Hop Requests



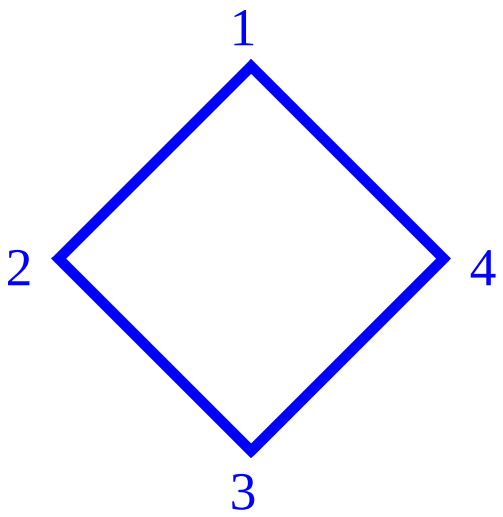
Wavelength-balancing offers consistent improvement

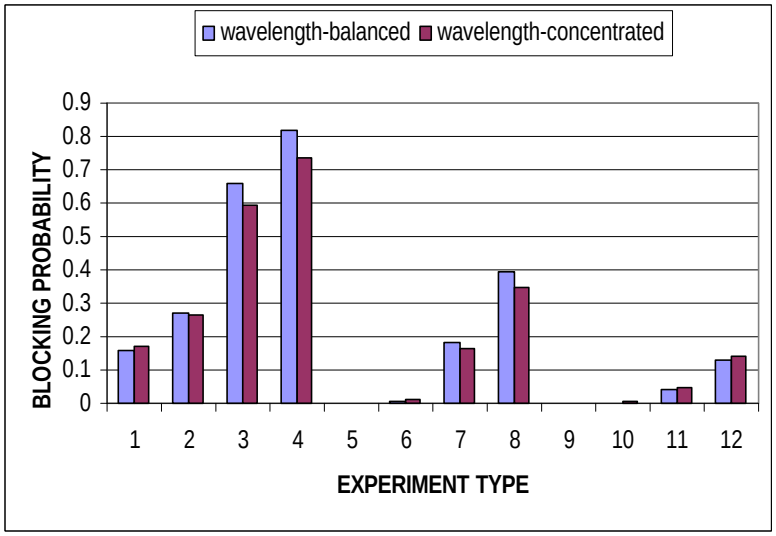






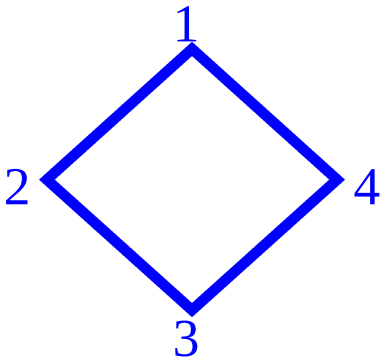
4-node Ring: Uniform Requests



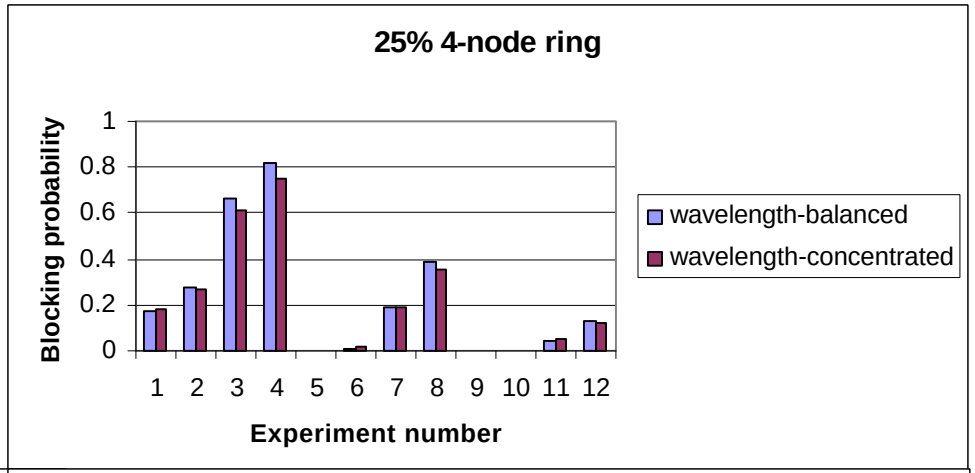


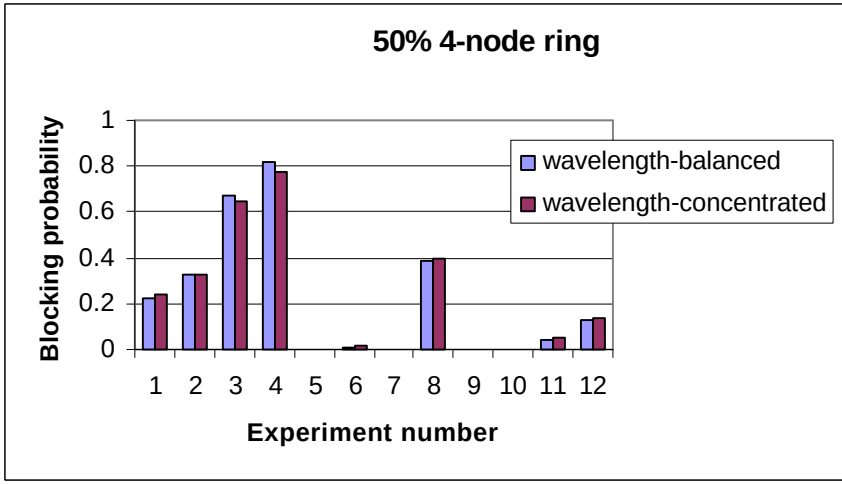
Wavelength-balancing and concentrating perform comparably

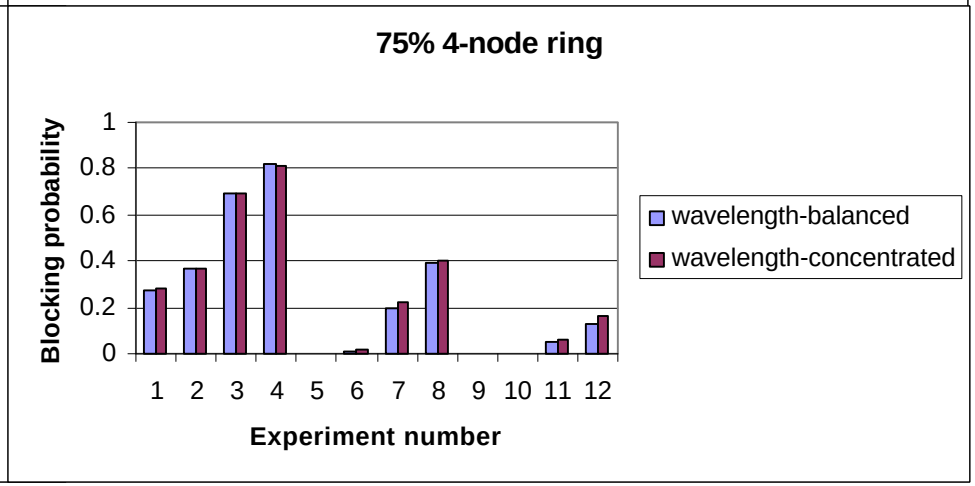
4-Node Ring: Fixed 2-Hop Requests



Wavelength-balancing and concentrating perform comparably

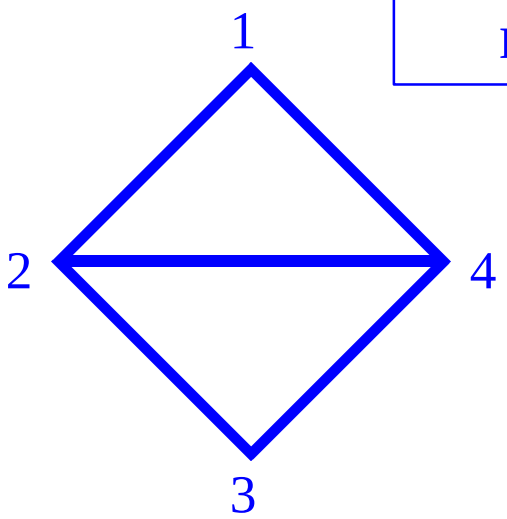


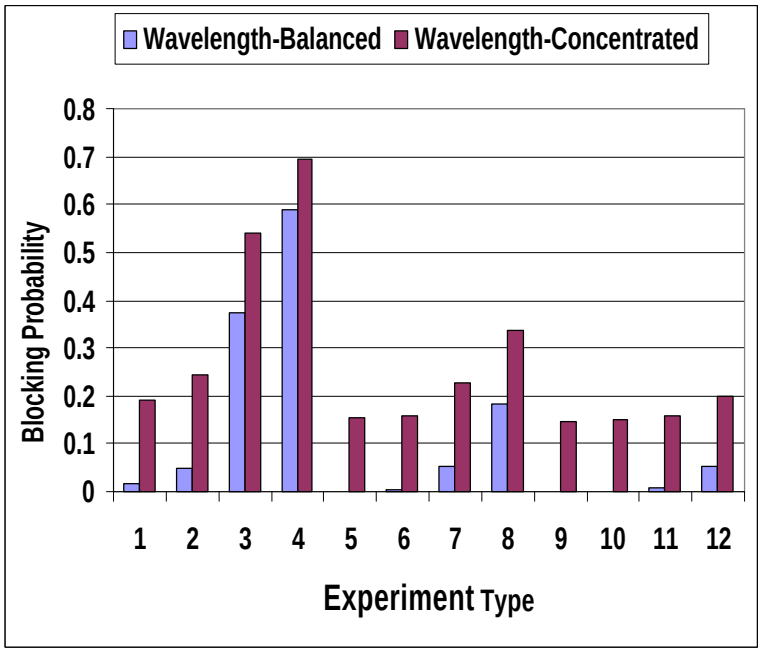




No Traffic on One Link: Uniform Requests

Path 2-4 is not requested





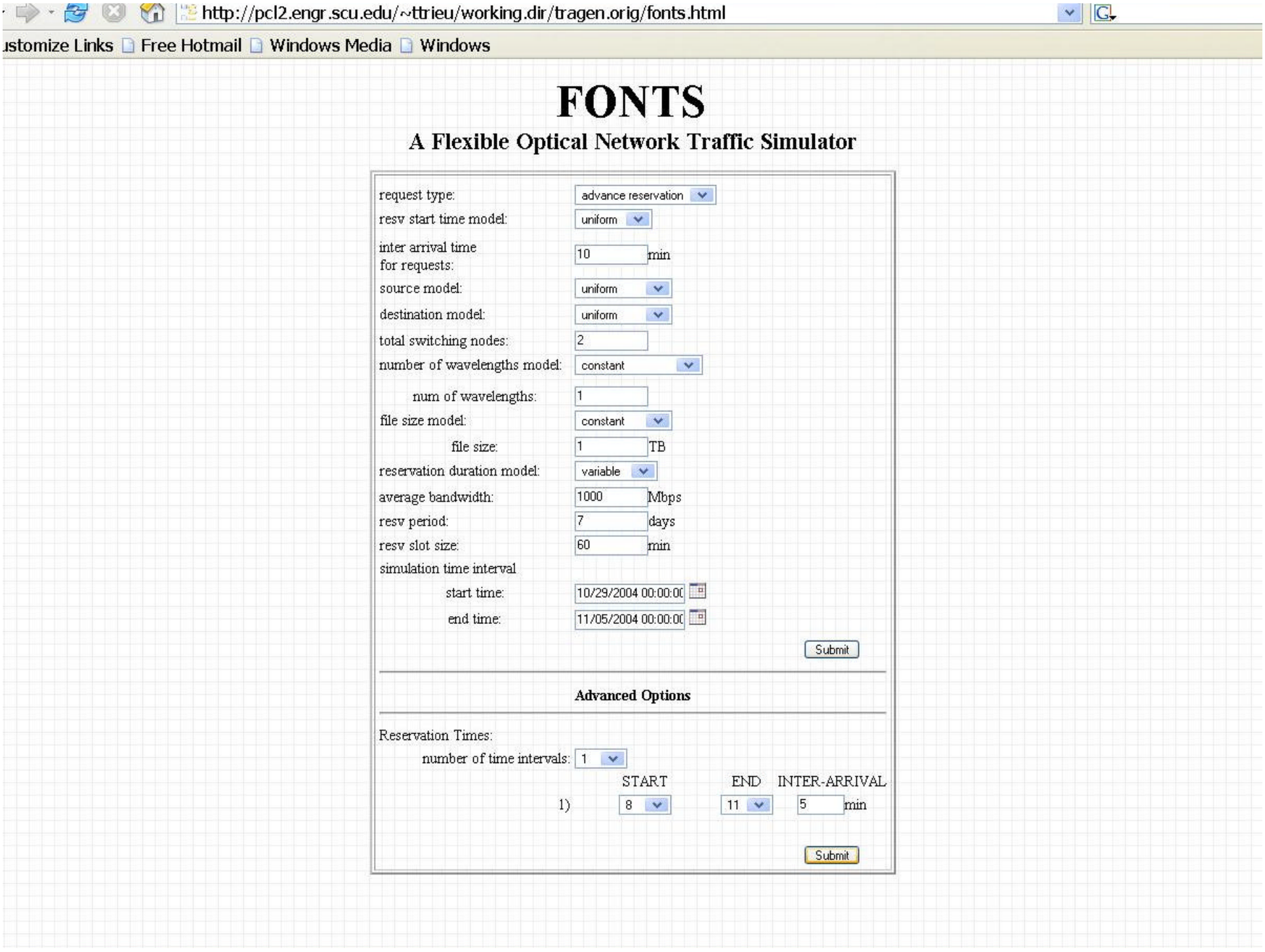
Wavelength-balancing performs consistently better than concentrating

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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FONTS
A Flexible Optical Network Traffic Simulator
request type:
advance reservation
resv start time model:
uniform
inter arrival time for requests:
10
min
source model:
uniform
destination model:
uniform
total switching nodes:
2
number of wavelengths model:
constant
num of wavelengths:
1
file size model:
constant
file size:
1
TB
reservation duration model:
variable
average bandwidth:
1000
Mbps
resv period:
7
days
resv slot size:
60
min
simulation time interval
start time:
10/29/2004 00:00:00
end time:
11/05/2004 00:00:00
Submit
Advanced Options
Reservation Times:
number of time intervals:
1
START
END
INTER-ARRIVAL
1)
8
11
5
min
Submit

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http://pcl2.engr.scu.edu/~ttrieu/working.dir/tragen.orig/htmls/grapher.html

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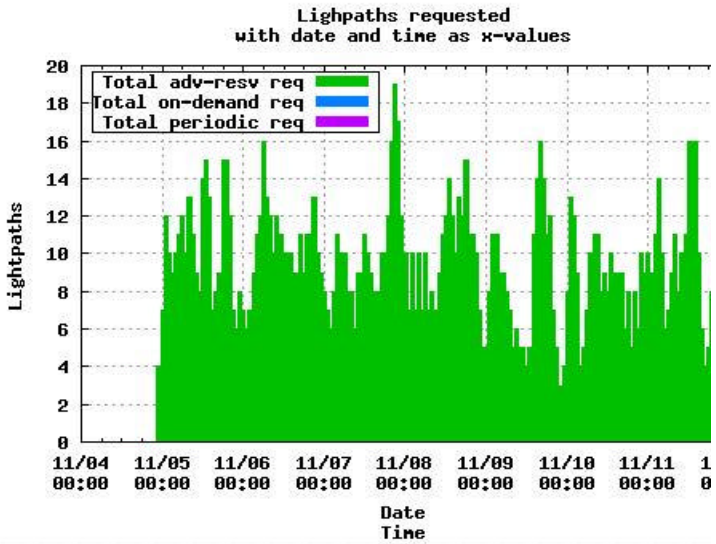
wnload Trace: String Format Numeric format

```
e Statistics from file: tra-Num.txt
: Advance Reservation
lation starts at Fri Oct 29 00:00:00 2004
lation ends at Thu Nov 4 22:59:59 2004
rvation window starts at Thu Nov 4 23:00:00 2004
rvation window ends at Thu Nov 11 22:59:59 2004
l slots available for reservation = 168
l number of switching nodes = 2
age bandwidth per link = 1000.000000 Mbps
 length = 60 mins
est arrivals follow Poisson distribution, (poissonLambdaValForReqArrival = 0.100000) Inter
val Parameter = 10.00 mins
ce node choice is using uniform distribution
ination node choice is using uniform distribution
er of wavelengths (lambdas) are constant = 1
 size is constant = 1.00 TB
rvation 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).
```



http://pcl2.engr.scu.edu/~ttrieu/working.dir/tragen.orig/tra-Str.txt

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```
:: Advance Reservation
ulation starts at Fri Oct 29 00:00:00 2004
ulation ends at   Thu Nov  4 22:59:59 2004
ervation window starts at Thu Nov  4 23:00:00 2004
ervation window ends at   Thu Nov 11 22:59:59 2004
al slots available for reservation  = 168
al number of switching nodes = 2
age bandwidth per link = 1000.000000 Mbps
 length = 60 mins
uest arrivals follow Poisson distribution, (poissonLambdaValForReqArrival = 0.100000) Inter Arrival Parameter = 10.00 mins
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er of wavelengths (lambdas) are constant = 1
 size is constant = 1.00 TB
ervation start times follow uniform distribution.
cated reservation period per request is variable (depends on the size of the data to transfer and the average bandwidth per link).
```

#	ReqArrivalTime	ResvStart	ResvEnd	SourceNode	DestNode	Lan
)	Fri Oct 29 00:21:00 2004	Wed Nov 10 05:00:00 2004	Wed Nov 10 07:14:00 2004	2	1	
.	Fri Oct 29 00:23:00 2004	Fri Nov 5 18:00:00 2004	Fri Nov 5 20:14:00 2004	1	2	
:	Fri Oct 29 00:34:00 2004	Sun Nov 7 10:00:00 2004	Sun Nov 7 12:14:00 2004	1	2	
i	Fri Oct 29 00:37:00 2004	Mon Nov 8 12:00:00 2004	Mon Nov 8 14:14:00 2004	2	1	
l	Fri Oct 29 00:44:00 2004	Mon Nov 8 21:00:00 2004	Mon Nov 8 23:14:00 2004	1	2	
;	Fri Oct 29 00:56:00 2004	Sat Nov 6 09:00:00 2004	Sat Nov 6 11:14:00 2004	2	1	
;	Fri Oct 29 01:00:00 2004	Thu Nov 11 16:00:00 2004	Thu Nov 11 18:14:00 2004	2	1	
'	Fri Oct 29 01:36:00 2004	Wed Nov 10 18:00:00 2004	Wed Nov 10 20:14:00 2004	2	1	
3	Fri Oct 29 01:52:00 2004	Sat Nov 6 01:00:00 2004	Sat Nov 6 03:14:00 2004	2	1	
9	Fri Oct 29 01:57:00 2004	Sun Nov 7 18:00:00 2004	Sun Nov 7 20:14:00 2004	2	1	
)	Fri Oct 29 03:15:00 2004	Wed Nov 10 20:00:00 2004	Wed Nov 10 22:14:00 2004	2	1	
.	Fri Oct 29 03:18:00 2004	Mon Nov 8 06:00:00 2004	Mon Nov 8 08:14:00 2004	1	2	
:	Fri Oct 29 03:46:00 2004	Wed Nov 10 21:00:00 2004	Wed Nov 10 23:14:00 2004	1	2	
i	Fri Oct 29 03:59:00 2004	Wed Nov 10 08:00:00 2004	Wed Nov 10 10:14:00 2004	1	2	
l	Fri Oct 29 04:02:00 2004	Fri Nov 5 18:00:00 2004	Fri Nov 5 20:14:00 2004	1	2	
;	Fri Oct 29 04:15:00 2004	Sun Nov 7 11:00:00 2004	Sun Nov 7 13:14:00 2004	1	2	
;	Fri Oct 29 04:28:00 2004	Thu Nov 11 02:00:00 2004	Thu Nov 11 04:14:00 2004	2	1	
'	Fri Oct 29 04:28:00 2004	Thu Nov 11 19:00:00 2004	Thu Nov 11 21:14:00 2004	1	2	
3	Fri Oct 29 04:35:00 2004	Thu Nov 11 01:00:00 2004	Thu Nov 11 03:14:00 2004	2	1	
9	Fri Oct 29 04:35:00 2004	Tue Nov 9 14:00:00 2004	Tue Nov 9 16:14:00 2004	2	1	
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.	Fri Oct 29 04:41:00 2004	Fri Nov 5 11:00:00 2004	Fri Nov 5 13:14:00 2004	1	2	
:	Fri Oct 29 05:00:00 2004	Thu Nov 11 10:00:00 2004	Thu Nov 11 12:14:00 2004	1	2	
i	Fri Oct 29 05:20:00 2004	Fri Nov 5 21:00:00 2004	Fri Nov 5 23:14:00 2004	2	1	
l	Fri Oct 29 05:29:00 2004	Sun Nov 7 15:00:00 2004	Sun Nov 7 17:14:00 2004	2	1	
;	Fri Oct 29 06:22:00 2004	Fri Nov 5 16:00:00 2004	Fri Nov 5 18:14:00 2004	2	1	
;	Fri Oct 29 07:00:00 2004	Sat Nov 6 04:00:00 2004	Sat Nov 6 06:14:00 2004	2	1	
'	Fri Oct 29 07:01:00 2004	Mon Nov 8 20:00:00 2004	Mon Nov 8 22:14:00 2004	1	2	
3	Fri Oct 29 07:10:00 2004	Tue Nov 9 19:00:00 2004	Tue Nov 9 21:14:00 2004	1	2	
9	Fri Oct 29 07:19:00 2004	Tue Nov 9 18:00:00 2004	Tue Nov 9 20:14:00 2004	2	1	
)	Fri Oct 29 07:26:00 2004	Fri Nov 5 12:00:00 2004	Fri Nov 5 14:14:00 2004	1	2	
.	Fri Oct 29 07:53:00 2004	Tue Nov 9 23:00:00 2004	Wed Nov 10 01:14:00 2004	2	1	
:	Fri Oct 29 08:06:00 2004	Thu Nov 11 03:00:00 2004	Thu Nov 11 05:14:00 2004	2	1	
i	Fri Oct 29 08:06:00 2004	Tue Nov 9 17:00:00 2004	Tue Nov 9 19:14:00 2004	1	2	

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.