A Theory of Stability for Communication Networks

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DOE PI Meeting
BNL
09/28/2005

Acknowledgment

- Work supported in part by the DOE Office of Science, under an ECPI grant

- ORNL Collaborator: Dr. Nageswara Rao

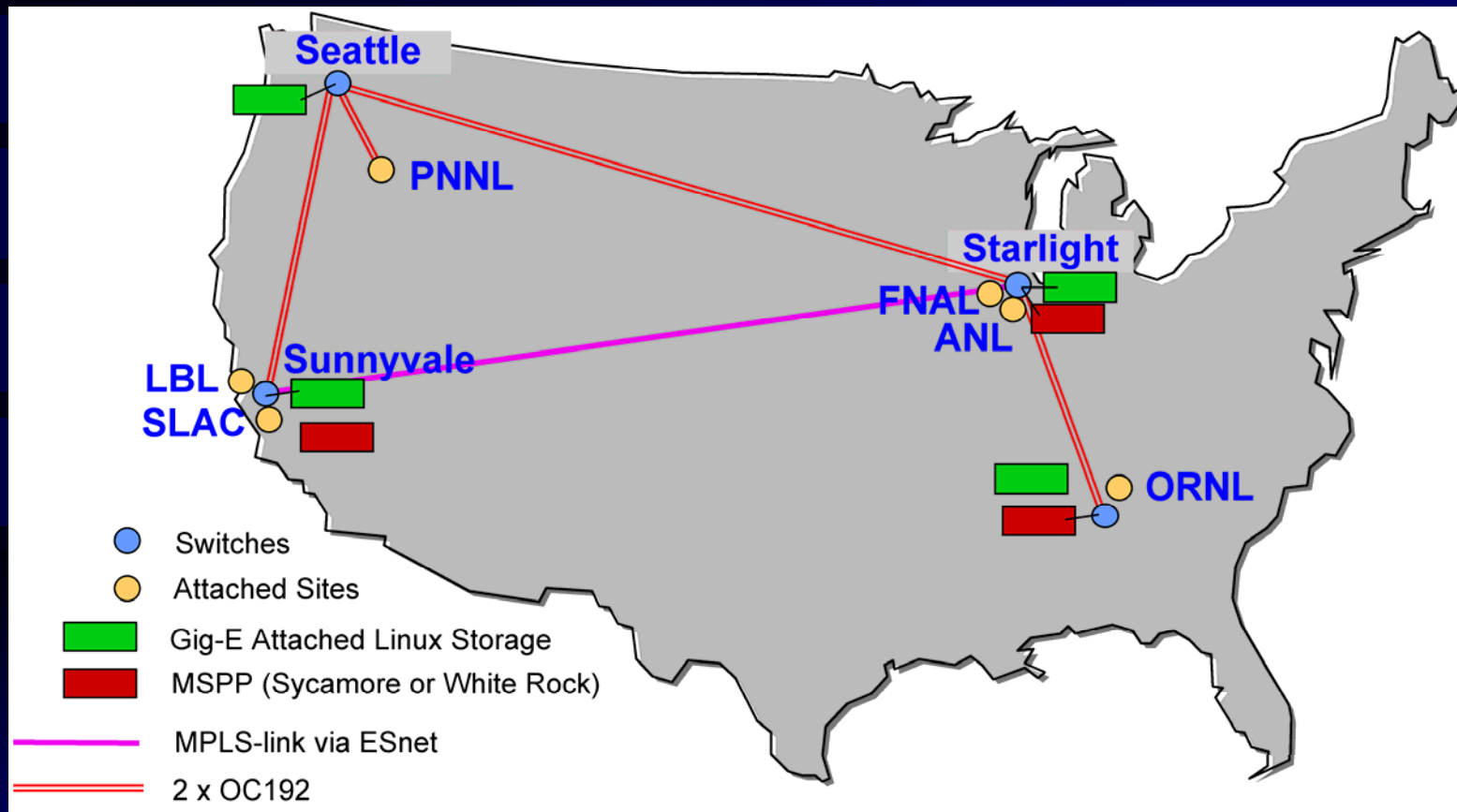- BU collaborators: Dr. Reuven Cohen, Niloofar Fazlollahi, Andres Guedez, Edy Tan

Research Thrusts

- **Thrust 1:** Formal methods and algorithms to ensure stability of control-plane protocols

- **Thrust 2:** Design and modeling of resource allocation mechanisms for Ultra Science Net
  - Algorithmic design
  - Simulation and visualization tools

Today

DOE Ultra Science Net

Ultra Science Net: Unique Features

- Channels (bandwidth) dedicated to users on demand

- Fine-grained bandwidth allocation (100's MB/s to 20 Gb/s) using SONET or 10GigE

Ultra Science Net:
User Request Format

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Src s and dest d…ORNL and PNNL

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Src s and dest d…ORNL and PNNL
Bandwidth B ... 1 Gb/s

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Src s and dest d…ORNL and PNNL
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Time interval T…2 Hours

Ultra Science Net:
User Request Format

Src s and dest d…ORNL and PNNL
Bandwidth B ... 1 Gb/s
Time interval T…2 Hours
Starting time (optional)? 09/29/2005
12PM

All-Slots Algorithm

- Return all the time slots for a path of bandwidth B and duration of at least t between a source s and destination d
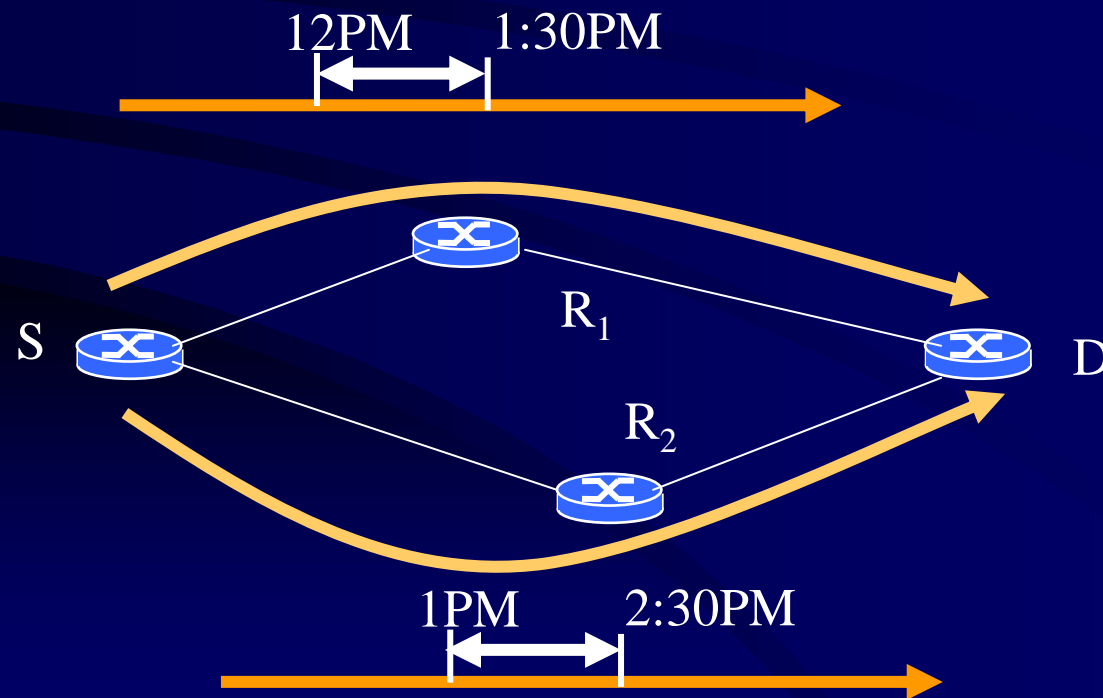
12PM   3PM   6PM   8PM

All-Slots Algorithm: Properties

- Use the same path over the entire connection

- Returns a feasible path, if several are available

Observation #1

- Possible to achieve significant performance improvement if path switching is allowed during a connection

Contribution #1: All-Slots/Path-Switching Algorithm

- Return all available time-slots where it is possible to establish a connection (possibly switching between different paths) between a source s and destination d with bandwidth B and duration at least t.

- Complexity: $O(|V|^2 R)$
  - $|V|$ is the number of vertices in the graph
  - R is the number of pending connections already scheduled

- Number of path switching during a connection upper bounded by $2R$

Contribution #2:
Optimized Path Selection Algorithm

- When several different paths are available in a given time slot, compute the "best" one according to some heuristics
    - Shortest path
    - Widest path
    - ….

- Can be implemented in conjunction with either variants of All-Slots algorithms
- Polynomial complexity

Simulator (Work-in-progress)

- Tool to compare performance of different bandwidth allocation mechanisms
- Key performance metrics are:
 - Average delay
  - Throughput

Simulation Parameters

- Network topology
- Rate of arrivals λ
- Distribution of BW request
  - Uniform (1,10) Gb/s
  - 80-20: 80% request-1Gb/s, 20%-request 10Gb/s
- Destination
  - Random
  - Hot spot (50% of requests go to a certain node, rest is uniformly distributed)
- Transfer size
  - Exponential distribution
  - Heavy tailed distribution

Typical Simulation Results
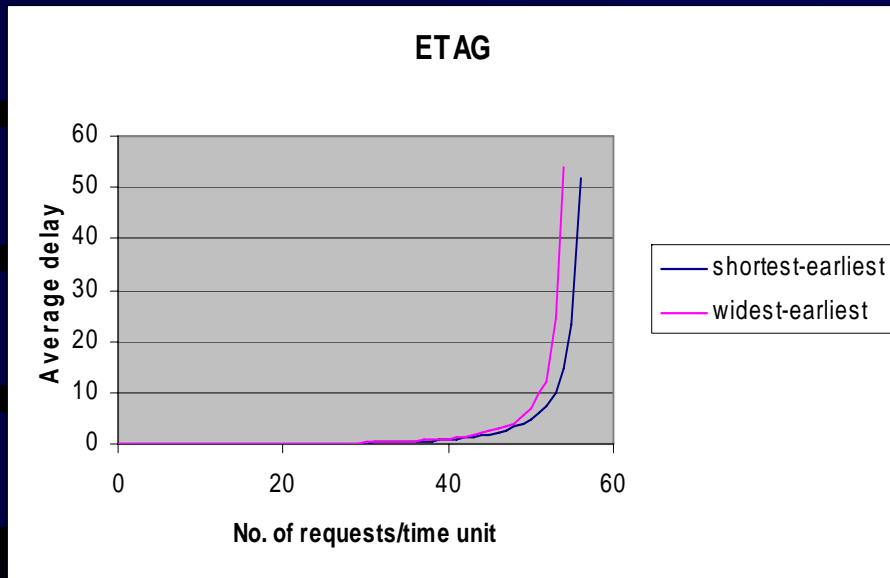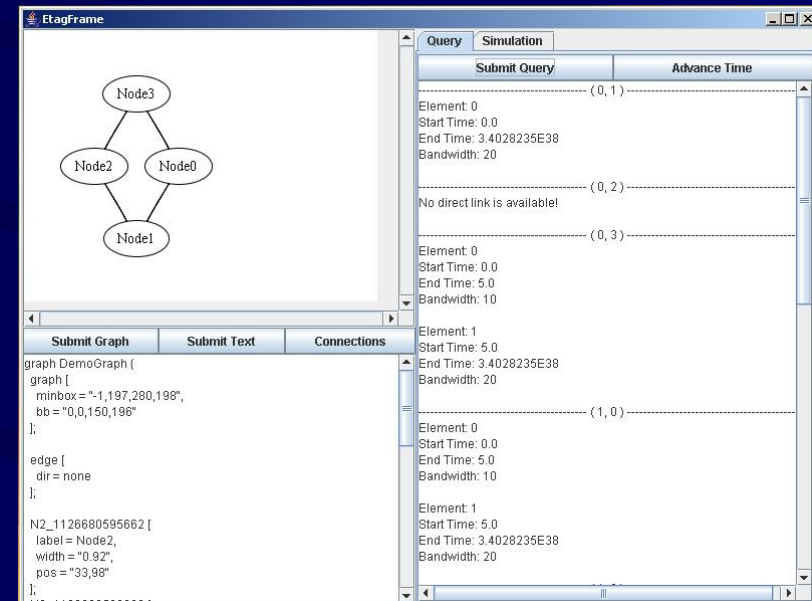

Random destination model
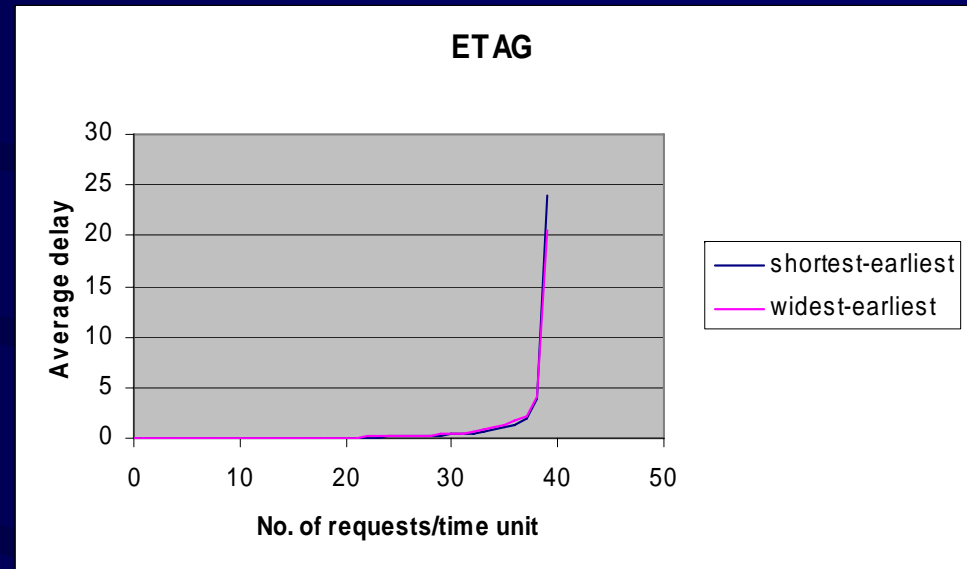
Hot spot model

Performance is sensitive to workload model!

Simulator GUI

- Designed to help understand bandwidth allocation mechanisms

- Currently allows manual requests

- Allows visualization of graph using Grappa library

Future Work

- All-Slots/Path-Switching Algorithm
  - Design and analysis
  - Simulation
  - Implementation over Ultra Science Net

- Comparison of heuristics for path selection, when multiple paths are available

- Workload characterization

Web Page

http://nislab.bu.edu/nislab/projects/stability/index.html

The end