Flexlab: A Realistic, Controlled, and Friendly Environment for Evaluating Networked Systems

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HotNets-V

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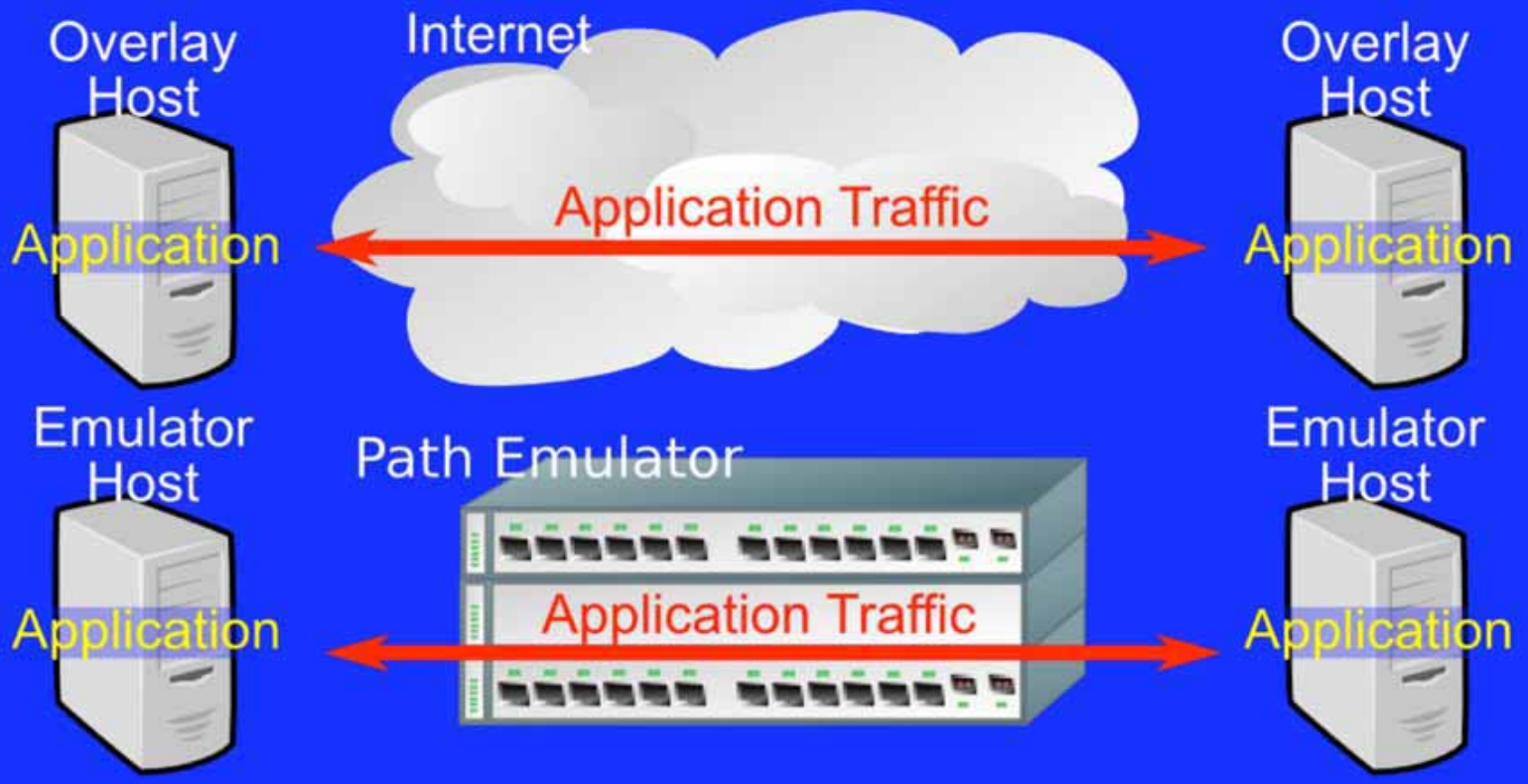
Emulators (Emulab Sucks)

- Examples: Modelnet & Emulab
- The Good: Control, repeatability, wide variety of network conditions
- The Bad: Artificial network conditions

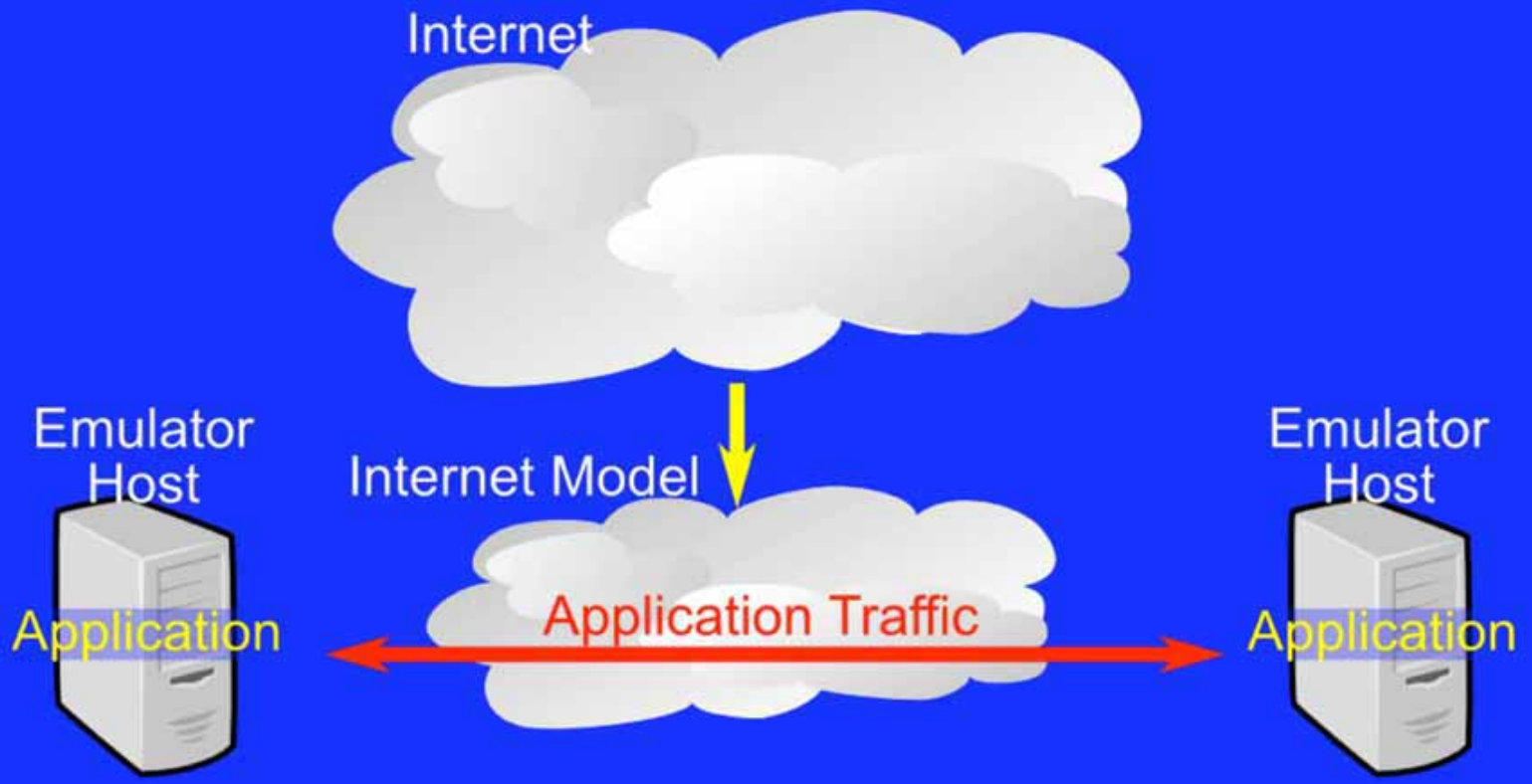
Overlay Testbeds (PlanetLab Sucks)

- Examples: RON & PlanetLab
- The Good: Real network conditions
- The Bad: Overloaded, No privileged operations, Poor repeatability, Hard to develop/debug

Goal: Best of Both Worlds (Don't Suck)



Model-driven Emulation (How not to suck)



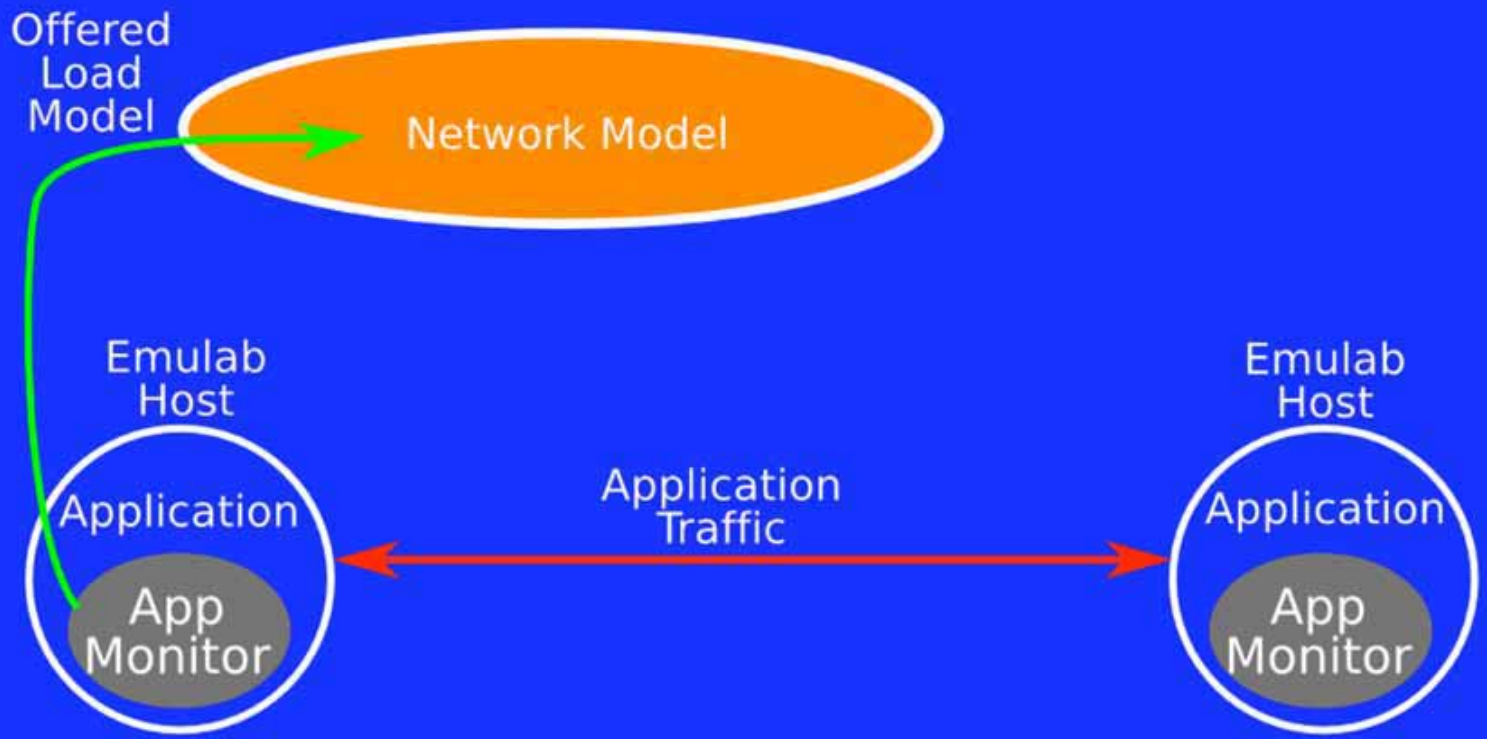
Key Points

- Flexlab is an emulation framework into which different network models may be plugged
- Exploit an overlay testbed to generate measurements for some example models
  - Models make different fidelity, overhead, and repeatability trade-offs
- Application-Centric Internet Modeling

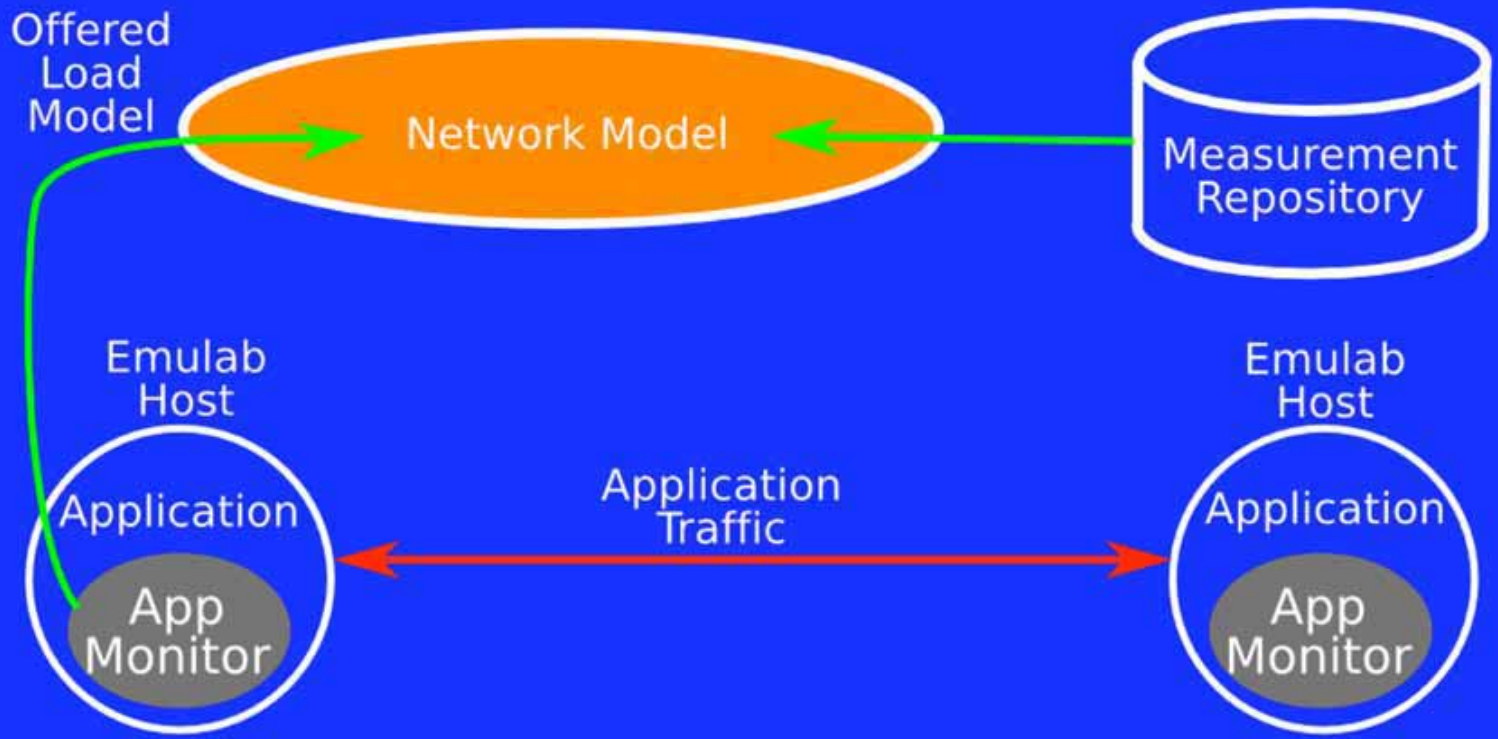
Flexlab: Application

Flexlab: Application Monitor

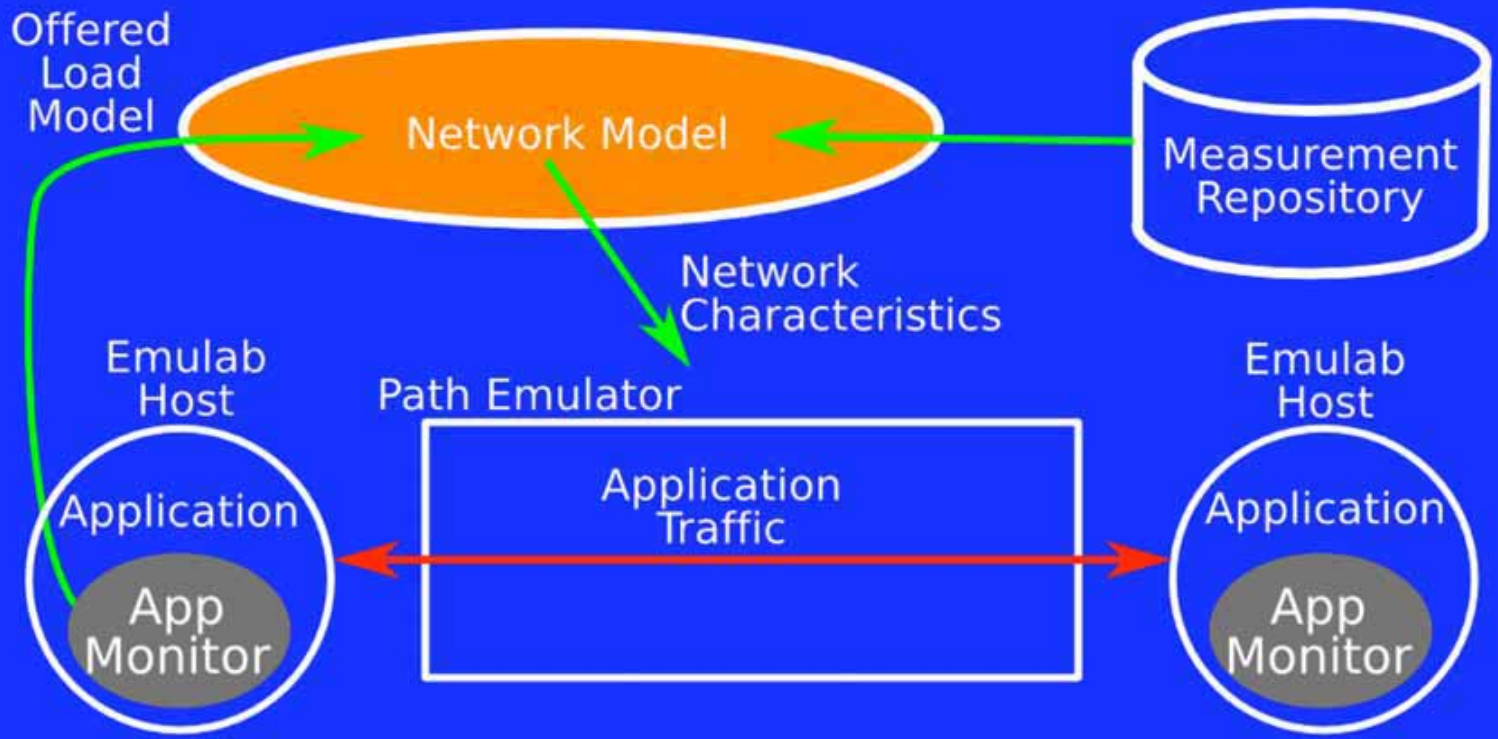
Flexlab: Network Model



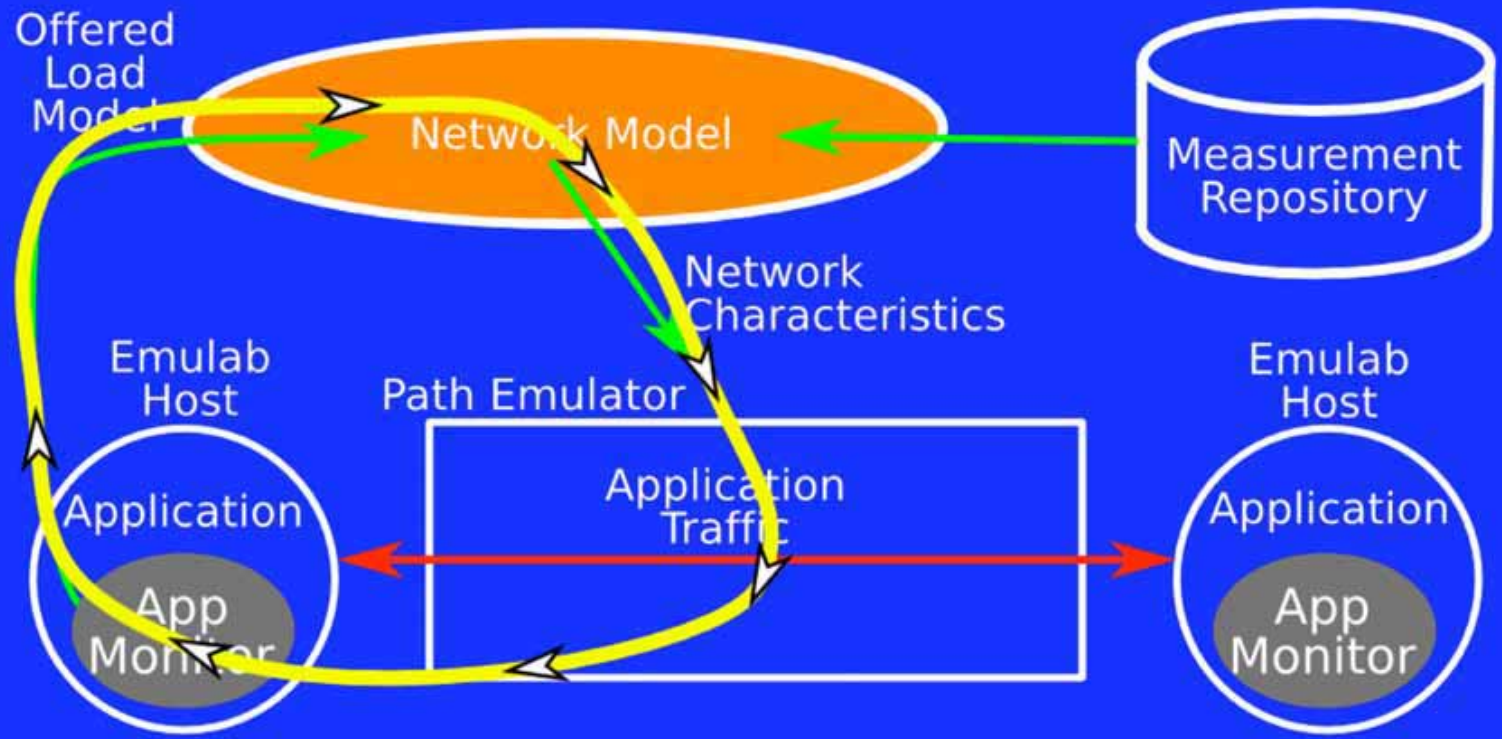
Flexlab: Measurement Repository



Flexlab: Path Emulator

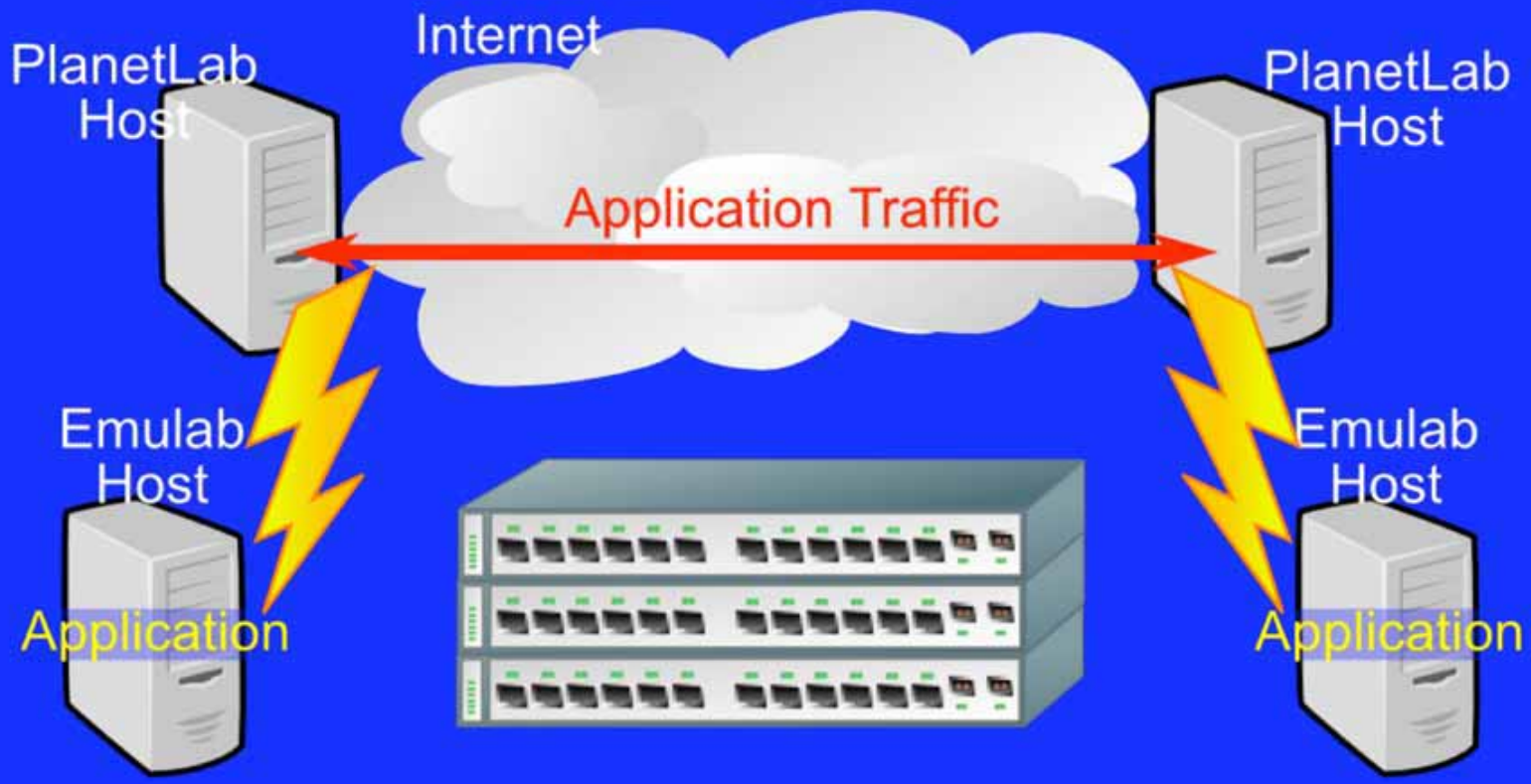


Flexlab: Feedback

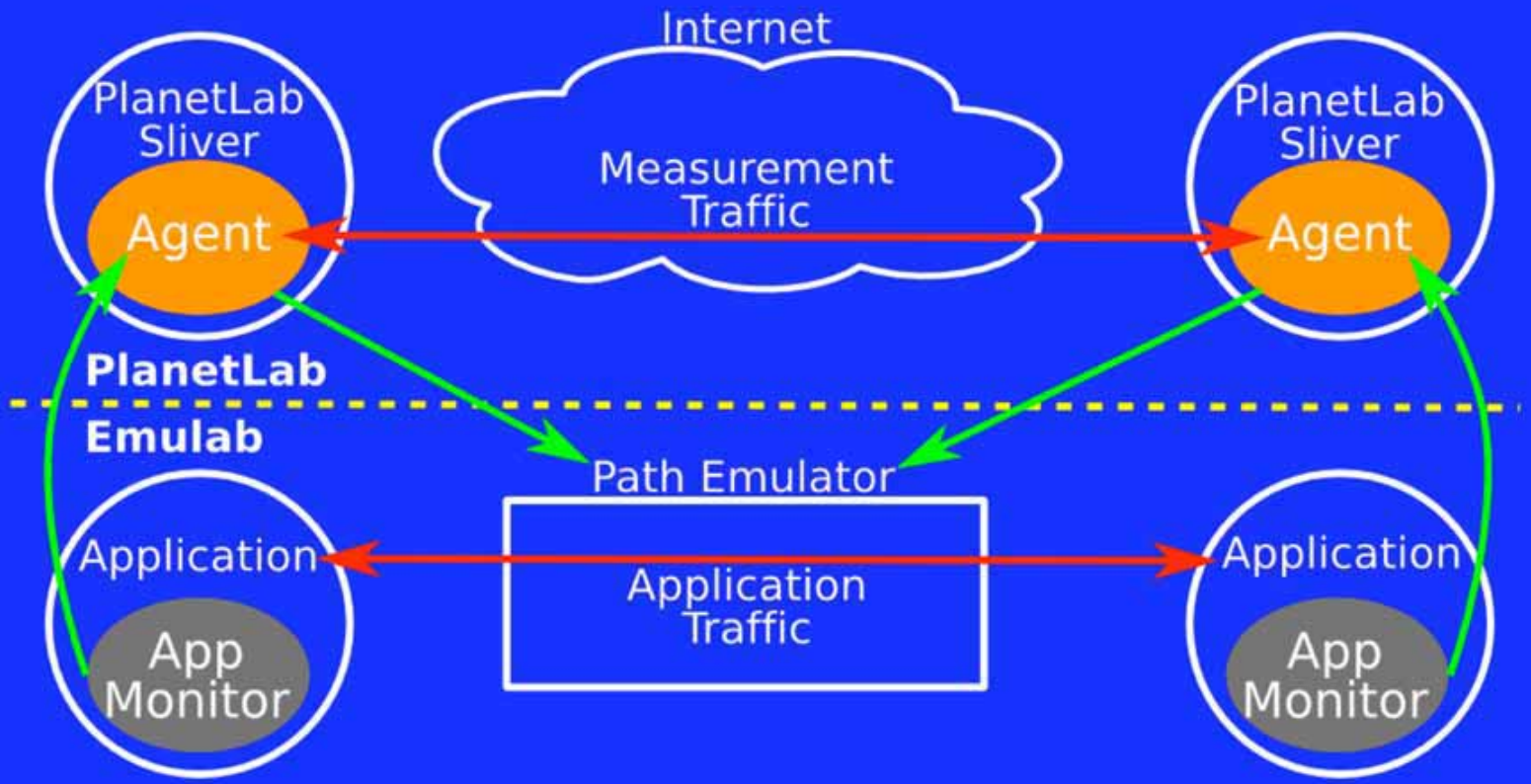


ACIM: Application-Centric Internet Modeling

Imagine Ideal Fidelity



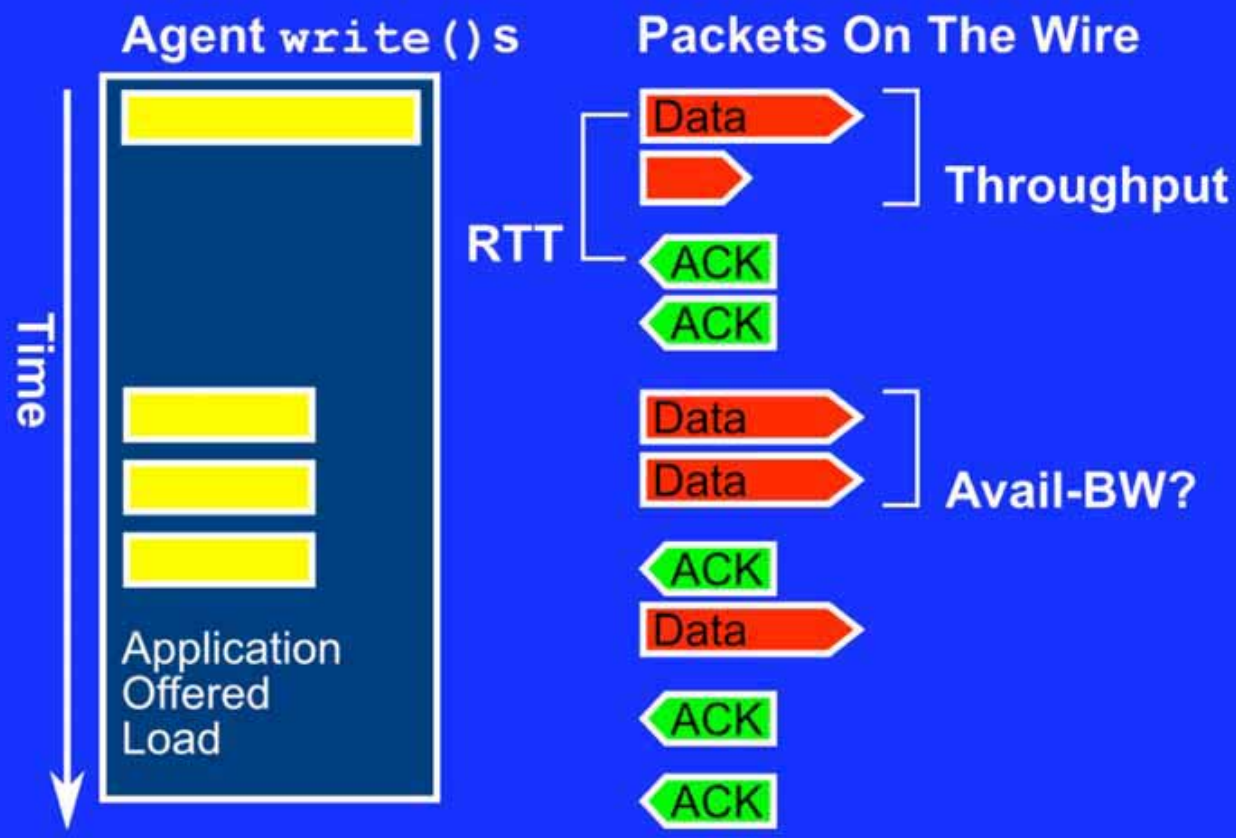
ACIM Architecture



ACIM Challenges

- Hardening implementation to deal with PlanetLab unreliability
- CPU starvation on PlanetLab
  - Host artifacts in throughput
  - Packet loss from libpcap
- Reverse path congestion
- Measuring bottleneck queue size in time
- Discovering when bottleneck link is saturated

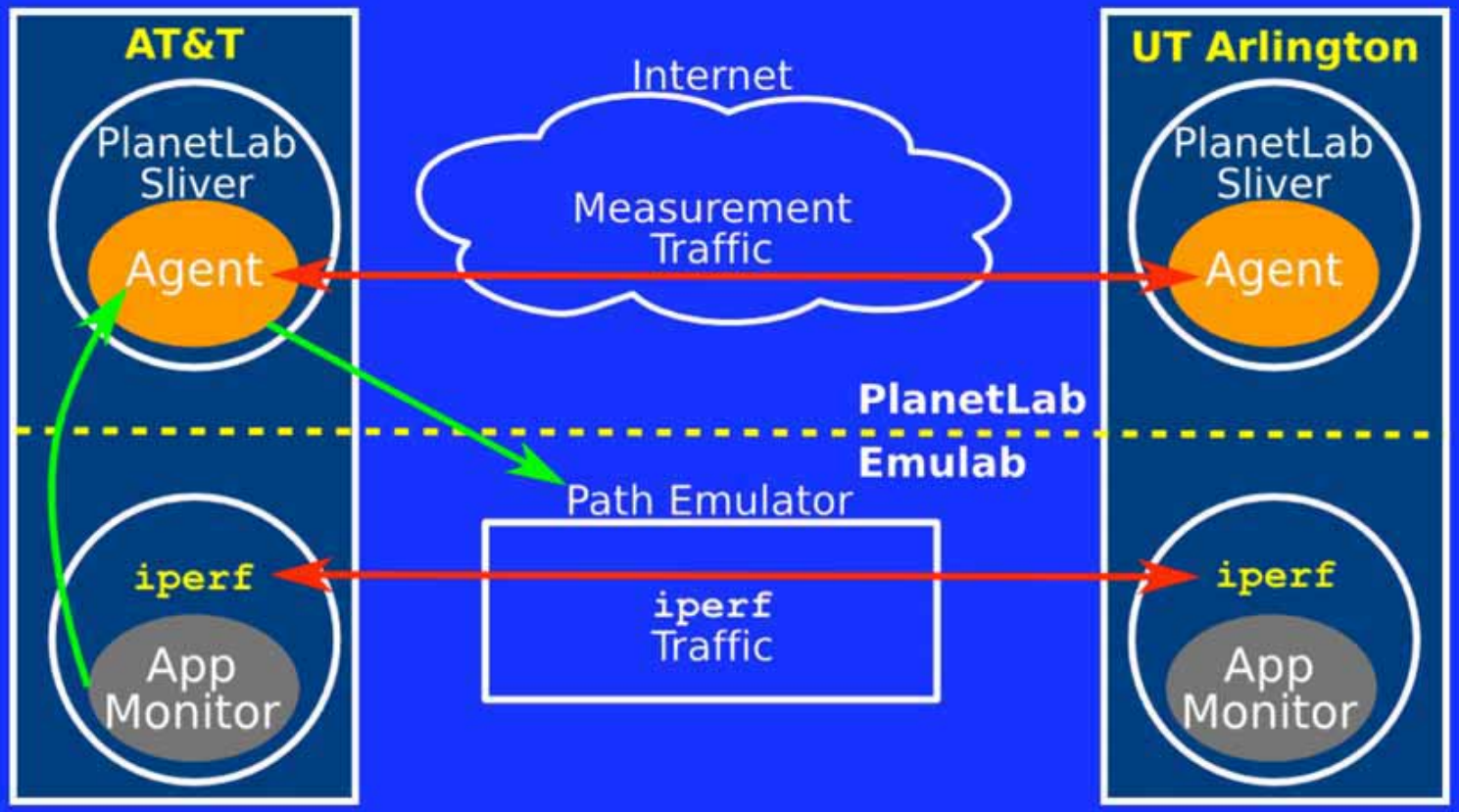
ACIM Network Conditions



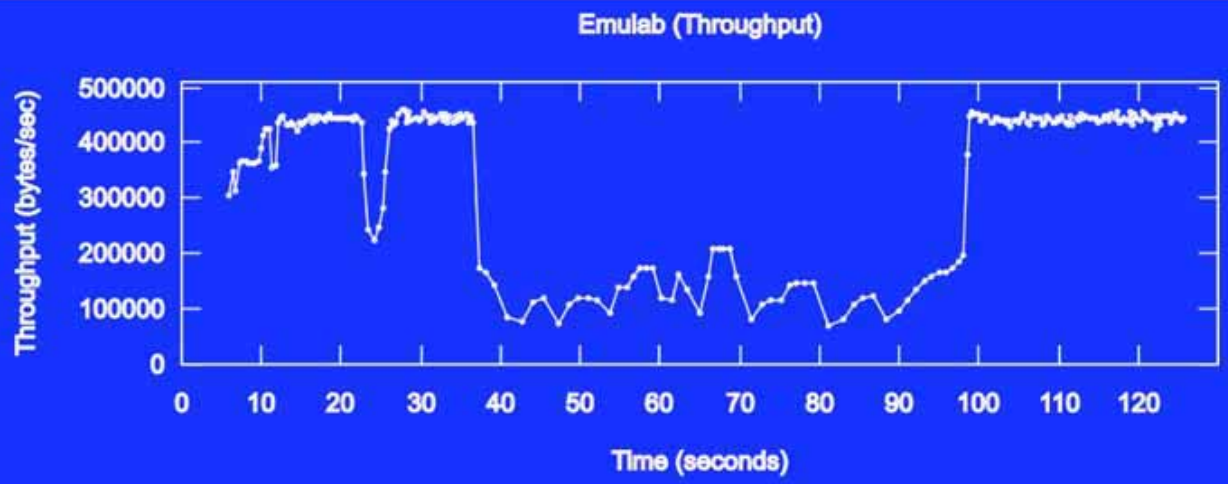
ACIM Available Bandwidth

- Throughput == available bandwidth
  iff agent is saturating
  && bottleneck link is saturated
- Agent saturating ≈ socket buffer full
- Bottleneck queue saturated
  ≈ queue filling up
  ≈ RTT increasing recently

Sample Experiment



Sample Results



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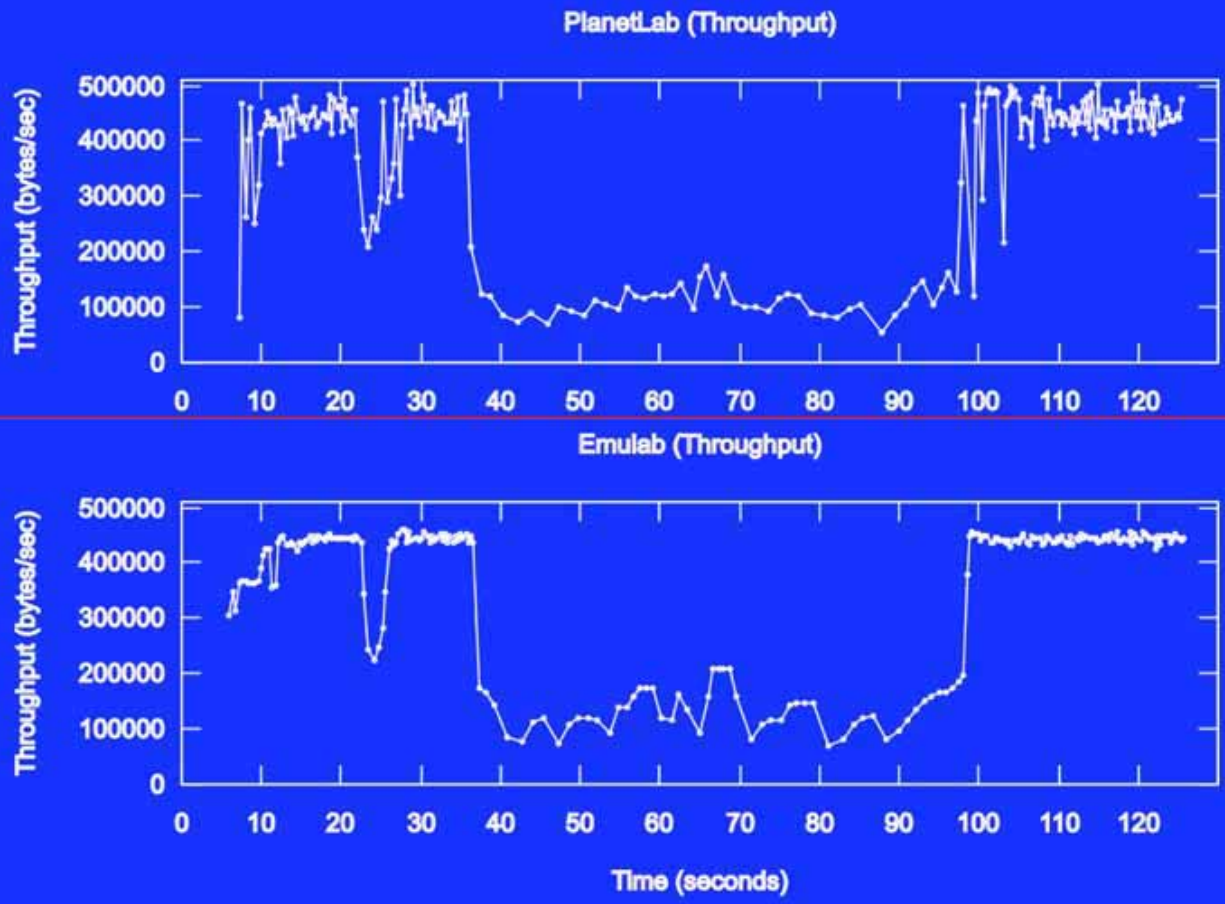

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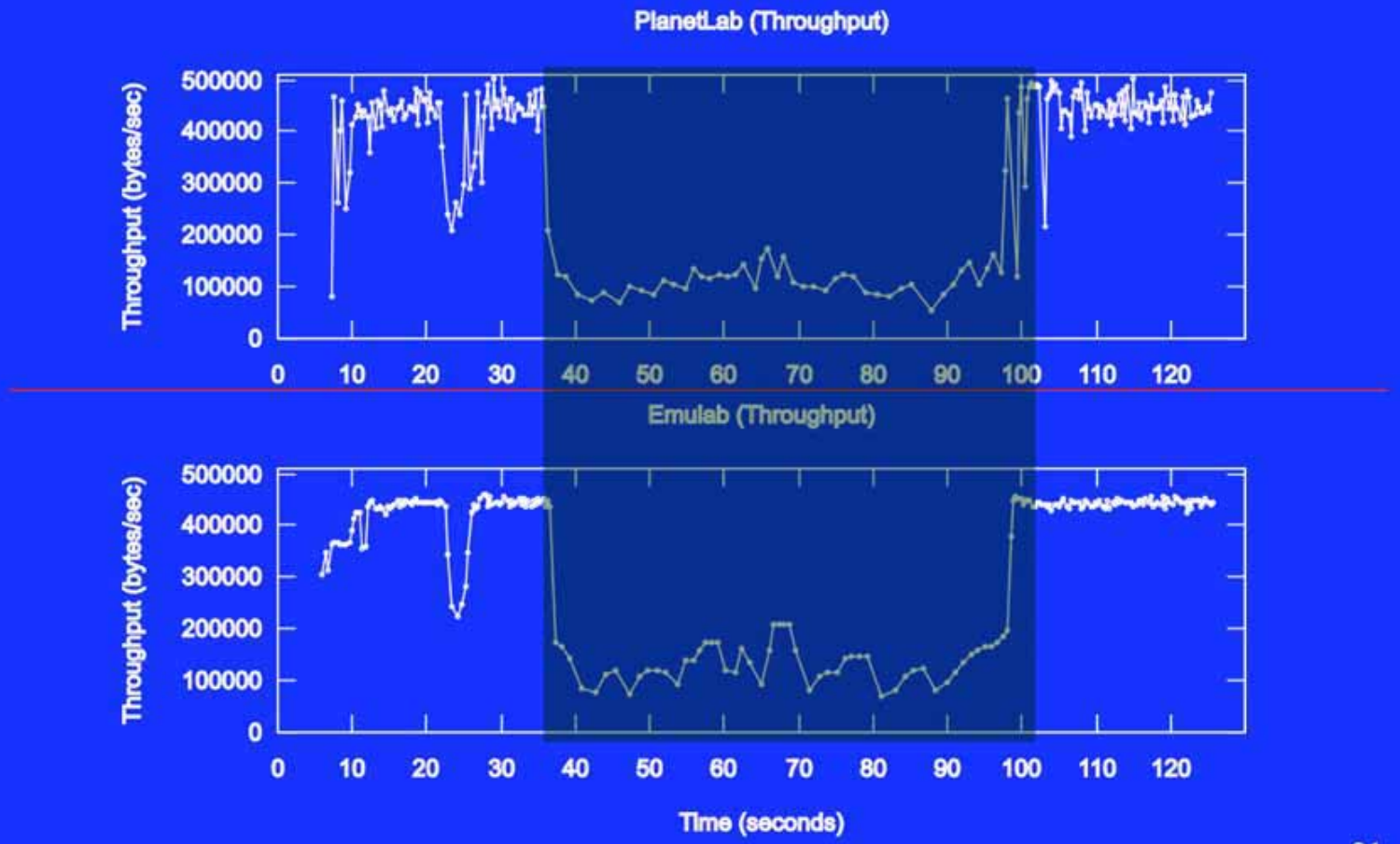

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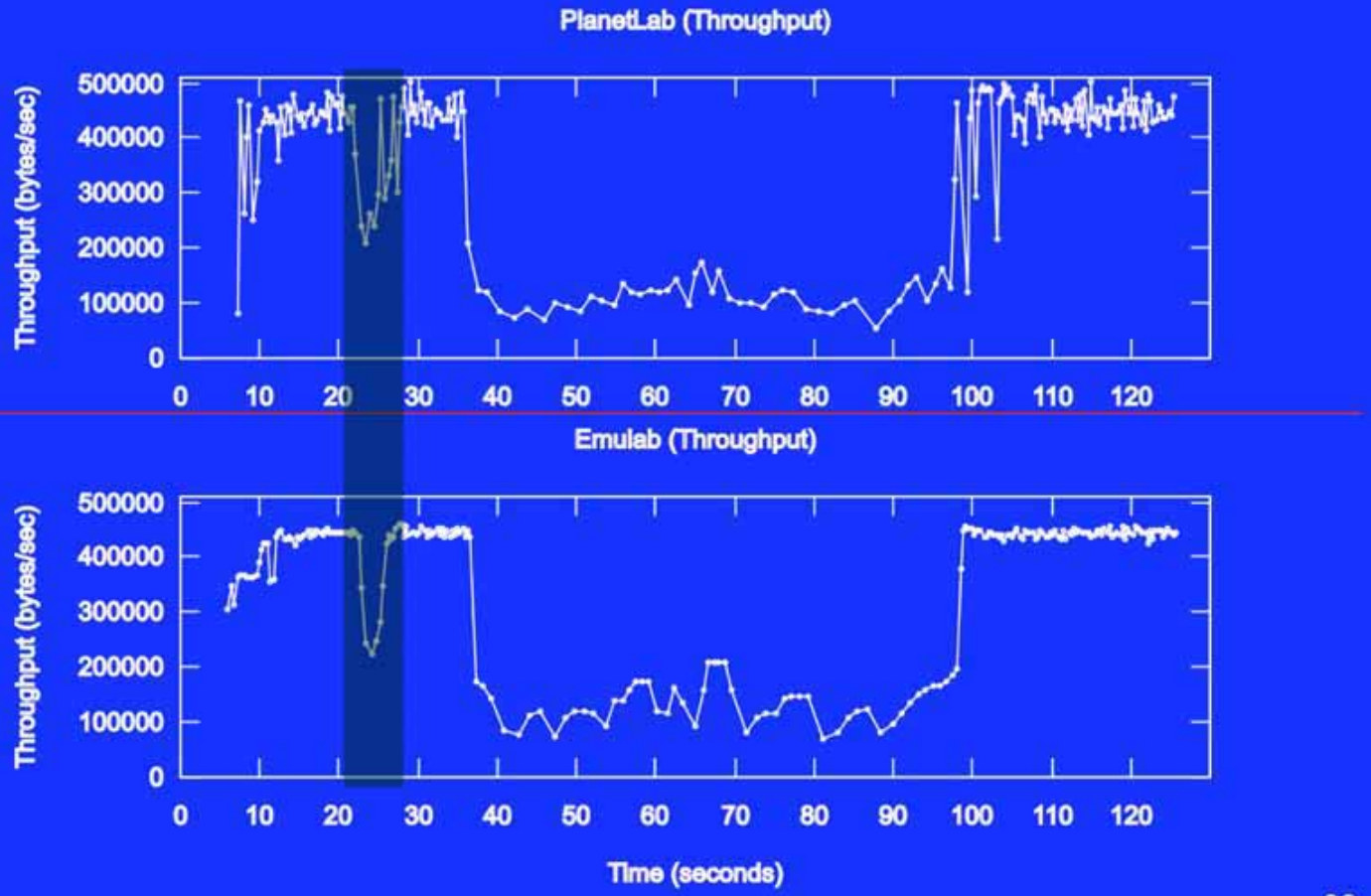

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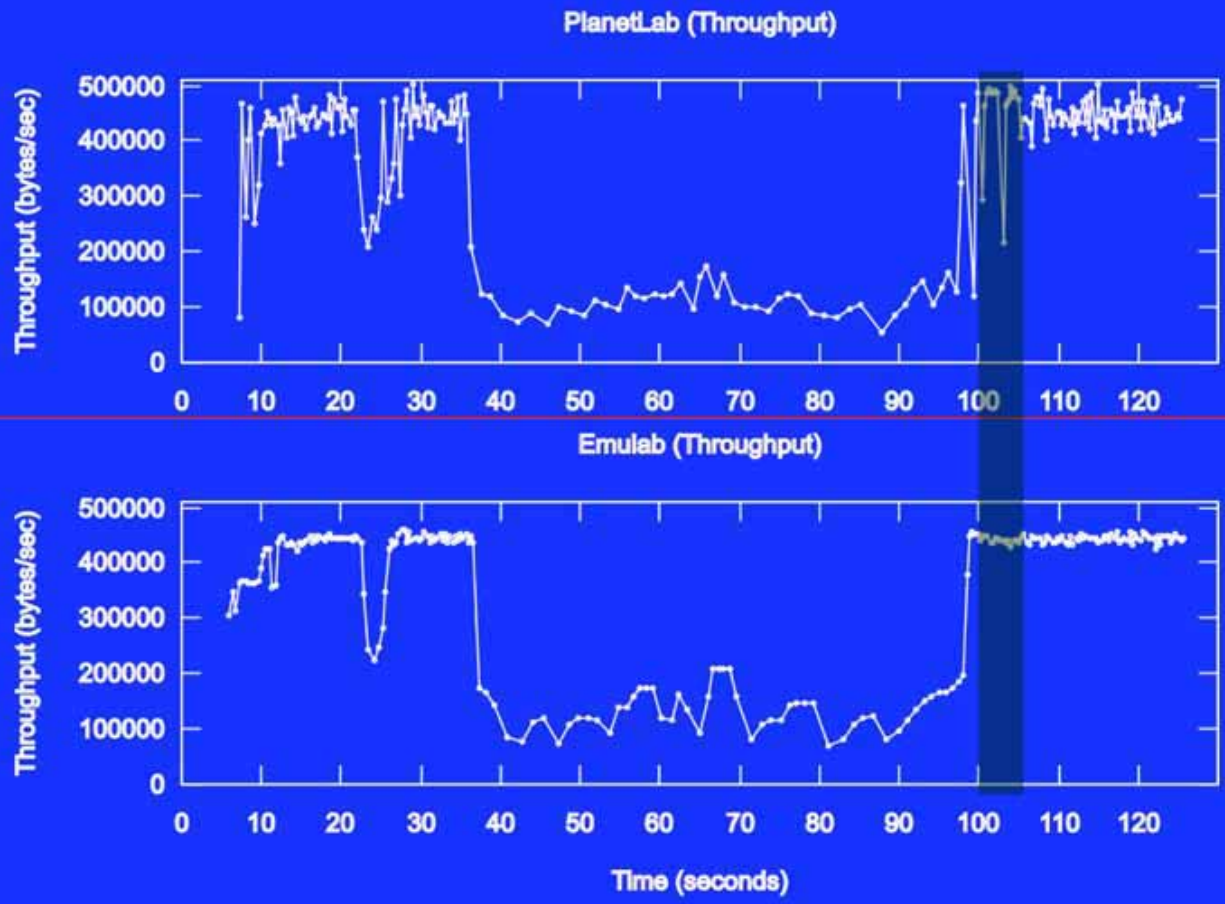
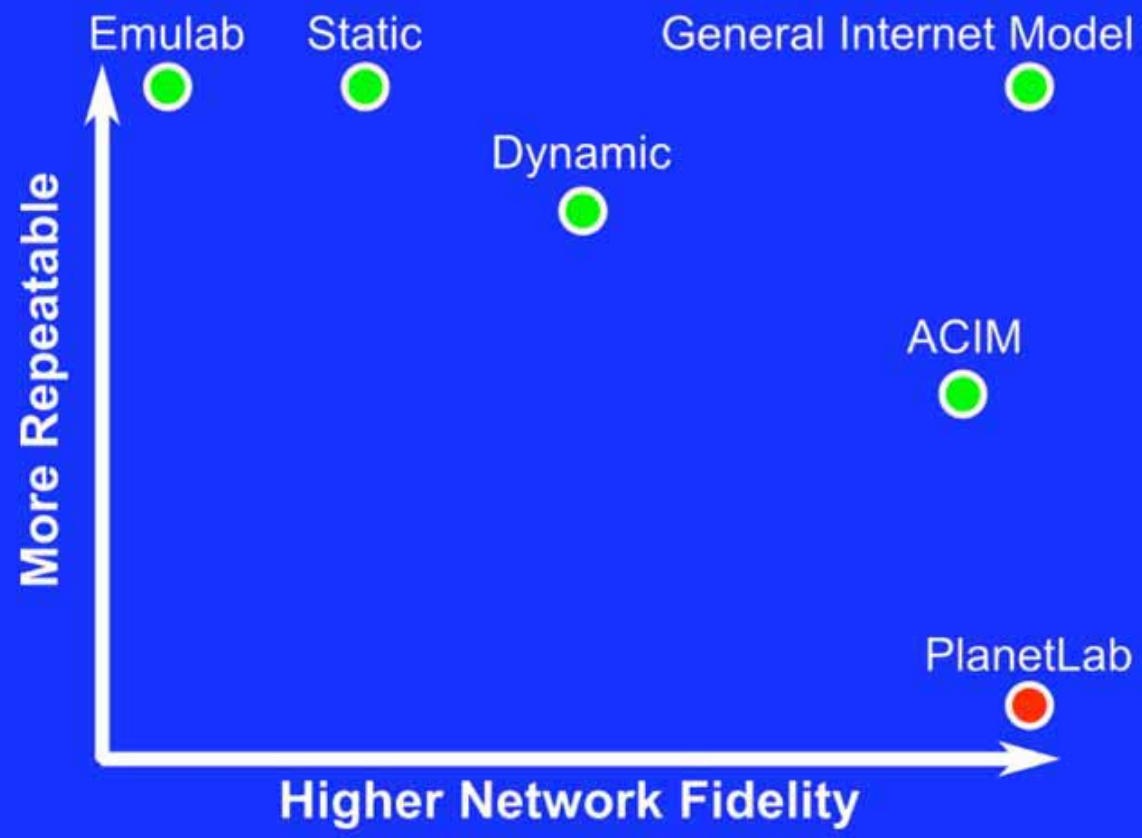
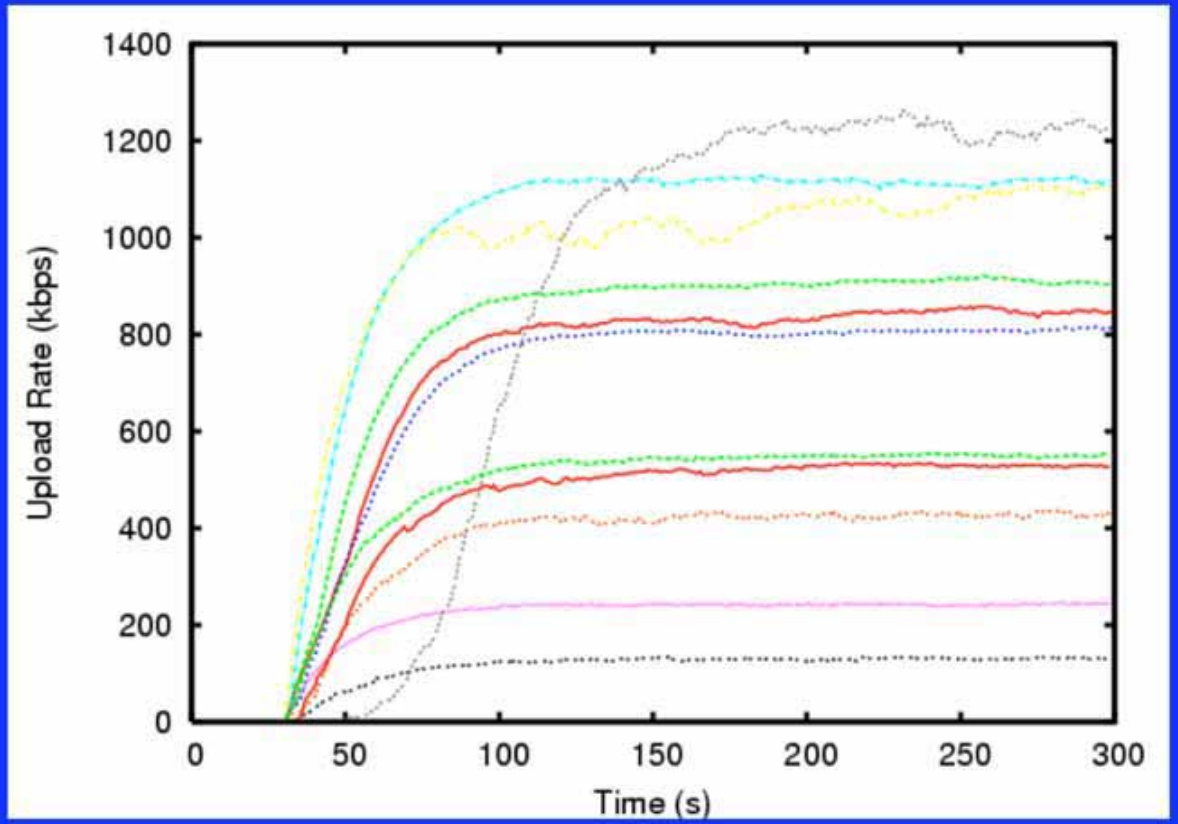


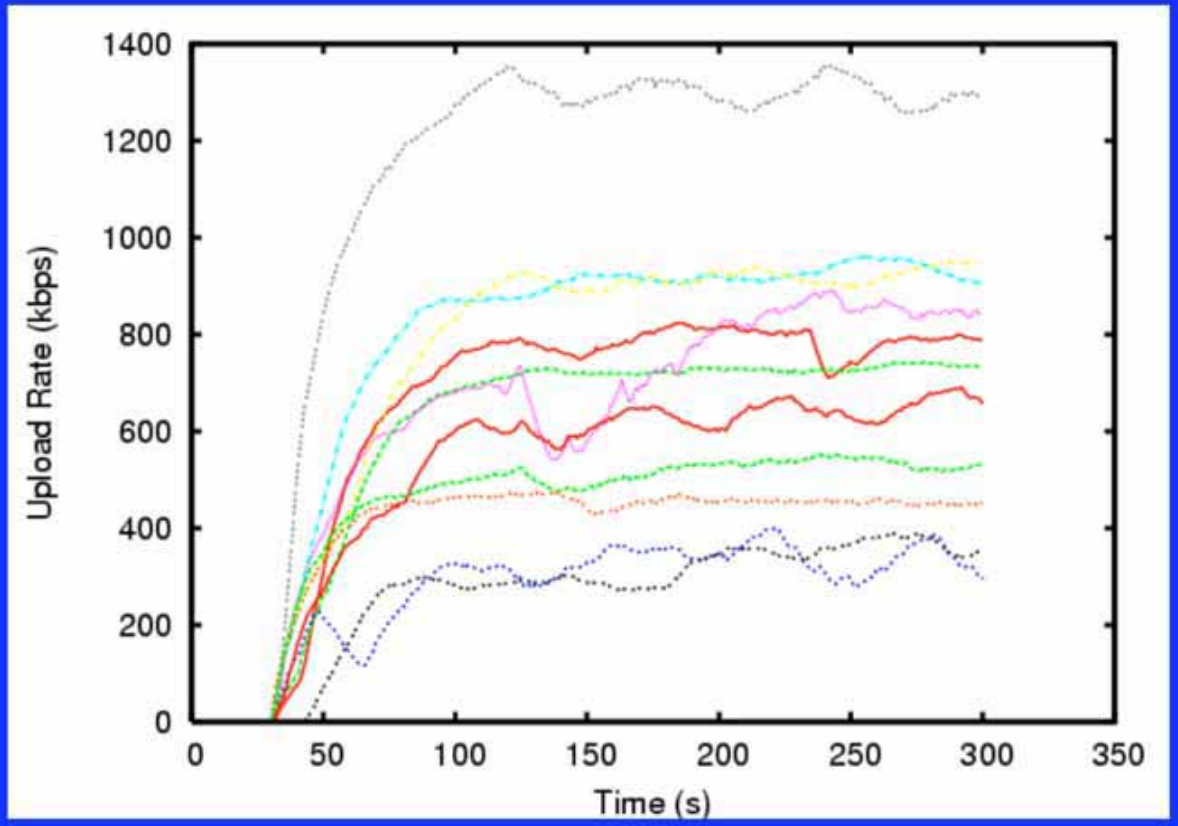
Network Model Trade-offs



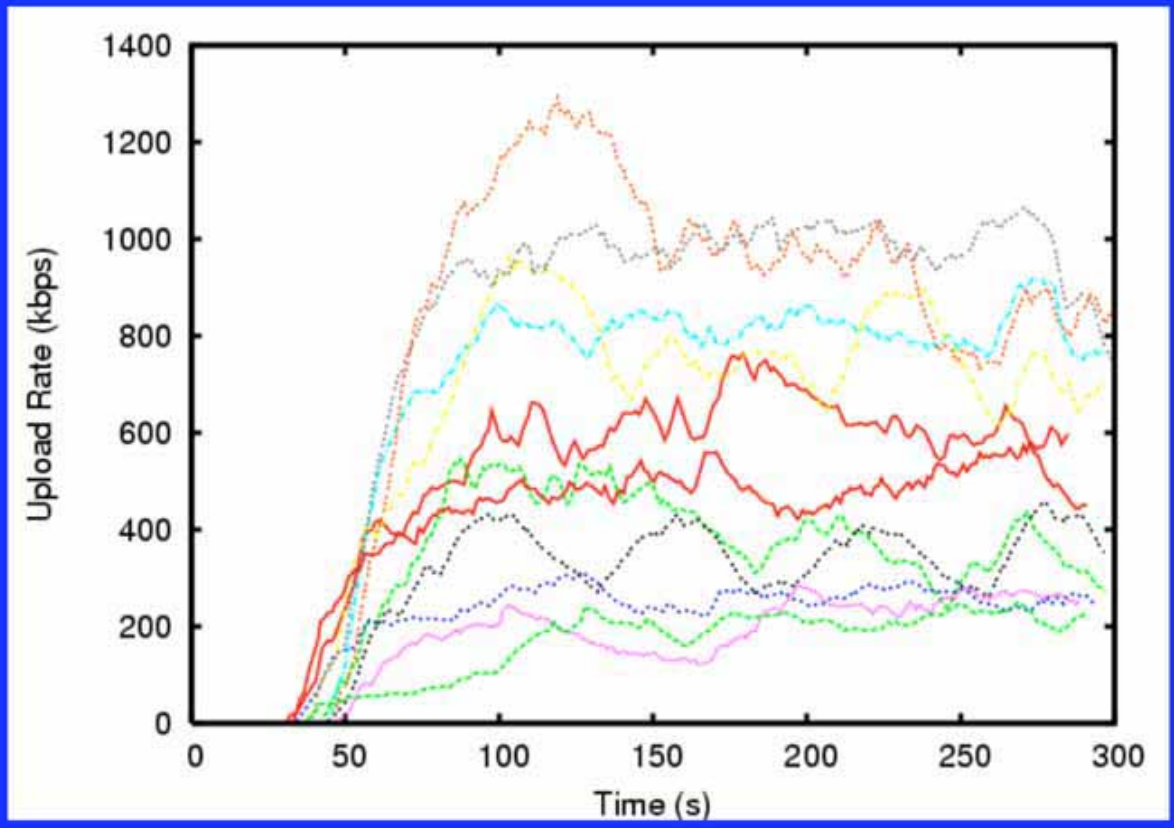
Sample Real Application: BitTorrent. with Static Model



BitTorrent w/ ACIM Model



BitTorrent w/ PlanetLab



What is “correct”? Challenging to determine; work-in-progress.

Conclusions

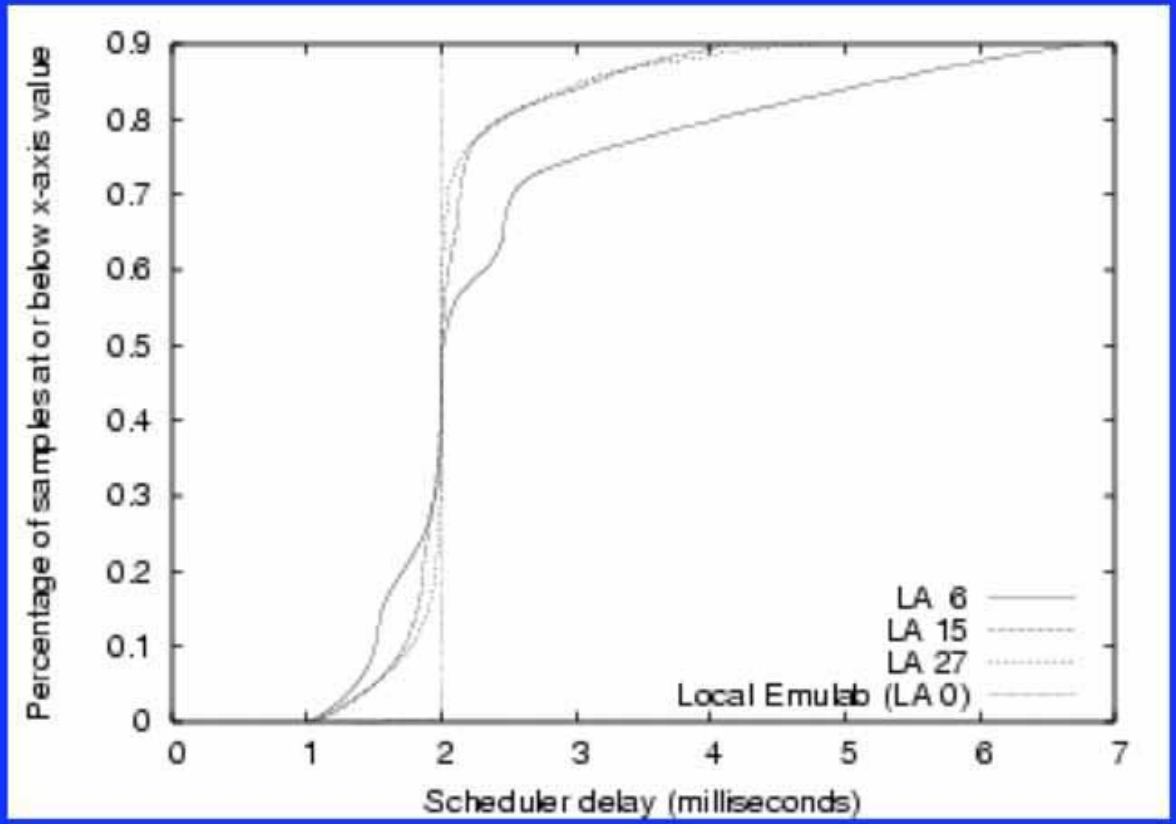
- Contribution: Modeling Framework for Emulation
  - Models can allow the experimenter to trade-off fidelity, repeatability, and overhead
- Contribution: Application-Centric Internet Modeling
- Contribution: Running on Emulab and PlanetLab in alpha stage

Backup Slides

Why not just add more nodes to every PlanetLab site? (cf. public review)

- Remaining problems:
  - Poor repeatability
  - Hard to develop/debug
  - No privileged operations
- Malicious traffic cannot be tested
- Some Flexlab network models reduce network load
- Emulab node pool stat muxed and shared more efficiently than per-site pools
- Overload can (will?) still happen with PL's pure shared-host model
- Major practical barriers: admin, cost

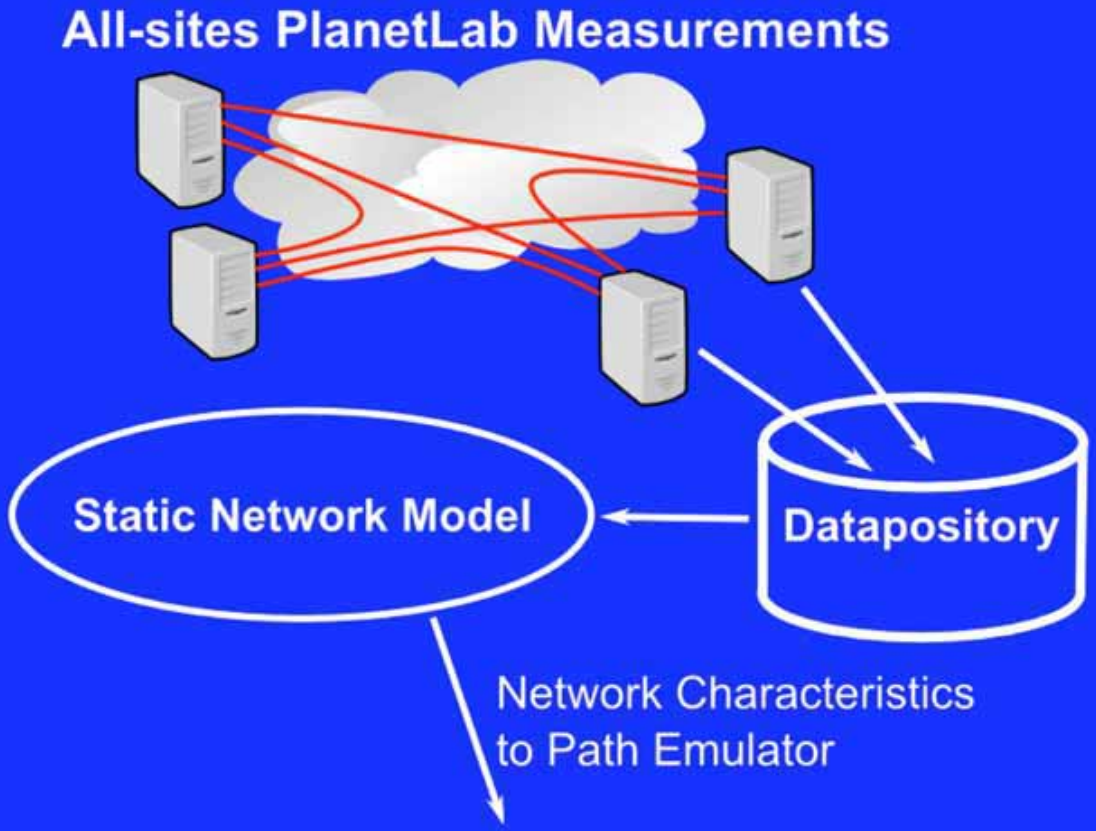
PlanetLab Overload (What)



PlanetLab Overload (Why)

- Only a few nodes per site
  - Sites supply their own nodes
  - No incentive to increase number of nodes
- No admission control
- No resource guarantees
- No incentive to minimize usage
- Typically tedious to set up experiments (exceptions: Emulab portal, Plush, other?)

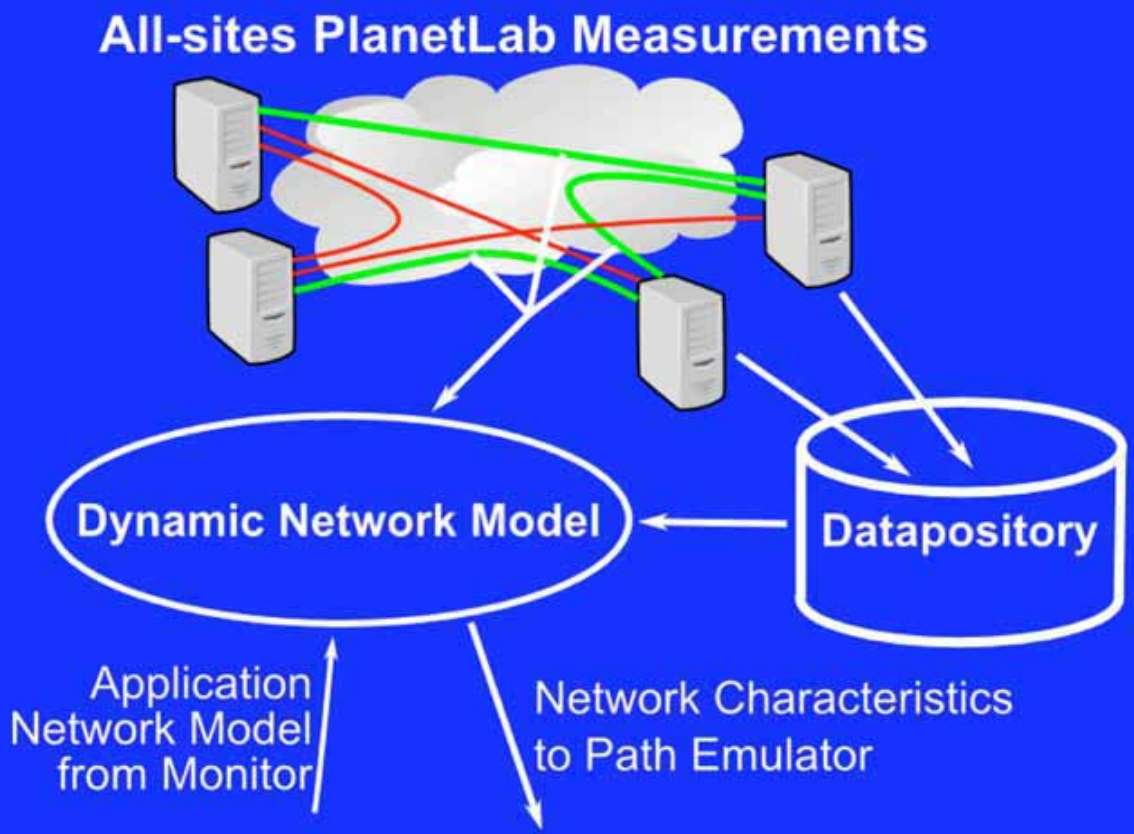
Network Model 1: Static



Static Trade-offs

- Low fidelity
- Fixed continuous overhead
- Complete repeatability

Network Model 2: Dynamic



Dynamic Trade-offs

- Moderate fidelity
- Overhead proportional to number of paths used
- High repeatability

Low-Frequency Measurements Miss Changes (Changepoint Analysis)

Path		20 Sec. Period	2 Sec. Period	
Src	Dest	Count	Count	Avg magnitude of 2 sec changes
Commodity	Commodity	2	20	39%
Commodity	Internet2	1	13	15%
Internet2	Internet2	0	0	-

Flexlab and VINI

Entirely different kinds of realism and control

- Flexlab: passes "experiment" traffic over shared path
  - Real Internet conditions from other traffic on same path, but app. traffic is not from real users
  - Control: of all software
  - Environment: friendly local dev. environ, dedicated hosts
- VINI: can pass "real traffic" over dedicated link
  - Real routing, real neighbor ISPs, potentially traffic from real users, but network resources are not realistic/representative
  - Dedicated pipes with dedicated bandwidth, that insulate experiment from normal Internet conditions
  - Control: restricted to VINI's APIs (Click, XORP, etc)
  - Environment: distributed environ; shared host resources.

Dealing with PlanetLab Unreliability

- Our initial design was optimistic
- Nodes fail
  - There is no set of 'good nodes'
  - Agents must react robustly to node failure
- Most errors are transient
  - Log **everything**
  - Replay packet analysis

CPU Starvation on PlanetLab

- Host Artifacts
  - Long period when agent can't read or write
  - Empty socket buffer or full receive window
  - Solution: Detect and ignore
- Packet loss from libpcap
  - Long period without reading libpcap buffer
  - Many packets are dropped at once
  - Solution: Detect and ignore

Handling Reverse Path Congestion

- Can cause ack compression
- Throughput Measurement
  - Throughput numbers become much noisier
  - We abuse the TCP timestamp option
  - PlanetLab: homogenous OS environment
  - Extending it would require hacking client
- RTT Measurement
  - Future work

Measuring Bottleneck Queue Size

- Important to emulate loss episodes due to congestion
- No one knows how in terms of bytes/packets
- Easier to measure in terms of time:
  - full = RTT when queue is full
  - empty = RTT when queue is empty
  - queue_time = full - empty

Initial Conditions

- Needed to bootstrap ACIM
  - ACIM uses traffic to generate conditions
  - But conditions must exist for first traffic
- We created a measurement framework
  - All pairs of sites are measured
  - Put data into measurement repository
- Set initial conditions to latest measurements

Path Emulator (detail)