Scalable Network Path Emulation

Shilpi Agarwal, Joel Sommers, Paul Barford
University of Wisconsin-Madison
http://wail.cs.wisc.edu

Internet testbeds

	simulation	laboratory emulation	*in situ*
strengths	accessibility	experimental control; system realism	realism ("it is what it is")
challenges	realism (everything)	realism of traffic, topology, and link/path conditions	experimental control
examples	ns-2, Opnet, GloMoSim	WAIL, DETER, Emulab	Planetlab, RON

A taxonomy of emulation systems

network emulation

ModelNet

packet delays, bandwidths, loss characteristics, assuming some topology

path emulation

Dummynet, NIST net

packet-oriented latency, loss, duplication, reordering

link emulation

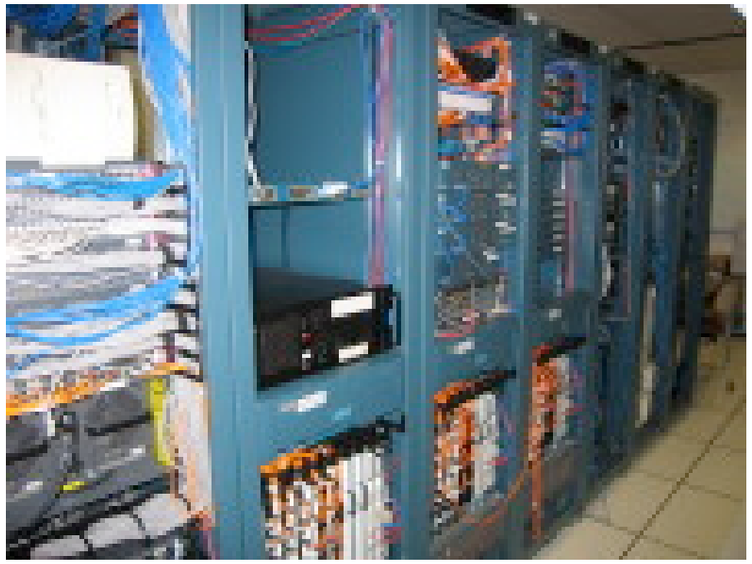
Adtech SX-14
A spool of optical fiber (!)

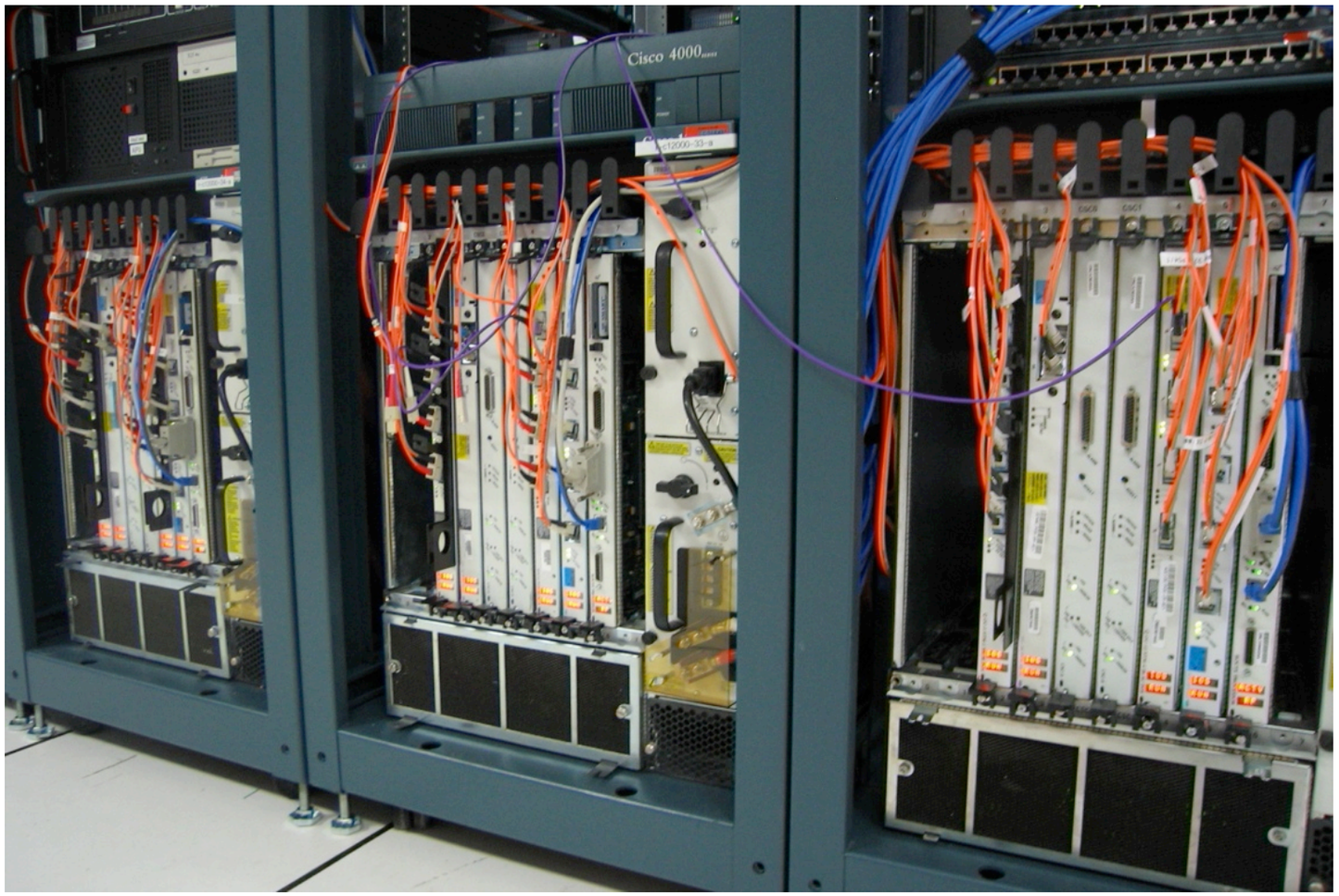
bit-oriented propagation delay and errors

Emulation challenges for today's testbeds

- Scale to many physical routers, links, and end hosts
  - Implies need for flexibility in configuration options
- Scale to Gigabit+ links
- Cost effectiveness (free software, commodity hardware)
- No existing software-based link or path emulator satisfies all these requirements

WAIL: an example of a modern testbed





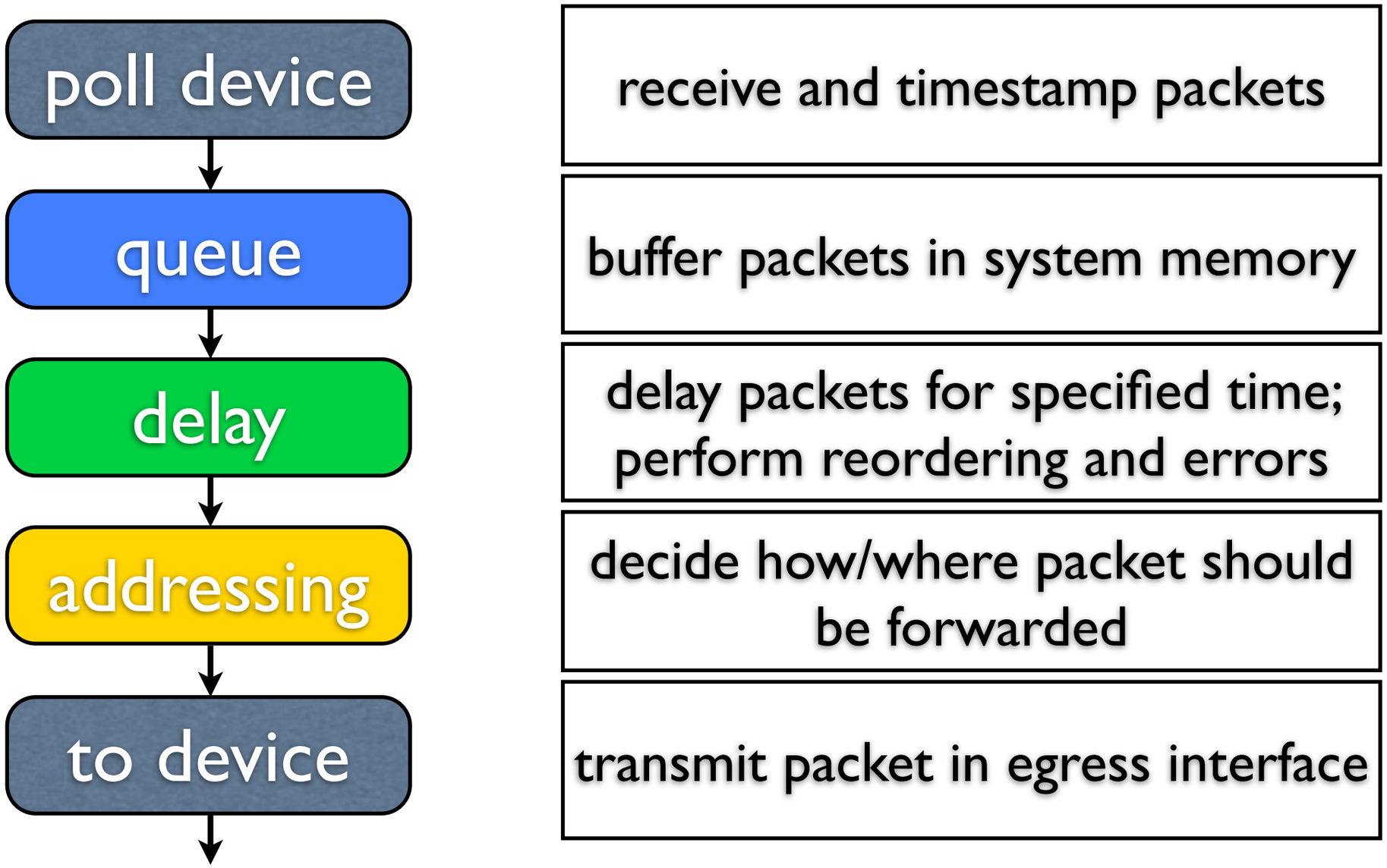
> 50 routers (hundreds of interfaces)

> 200 workstations

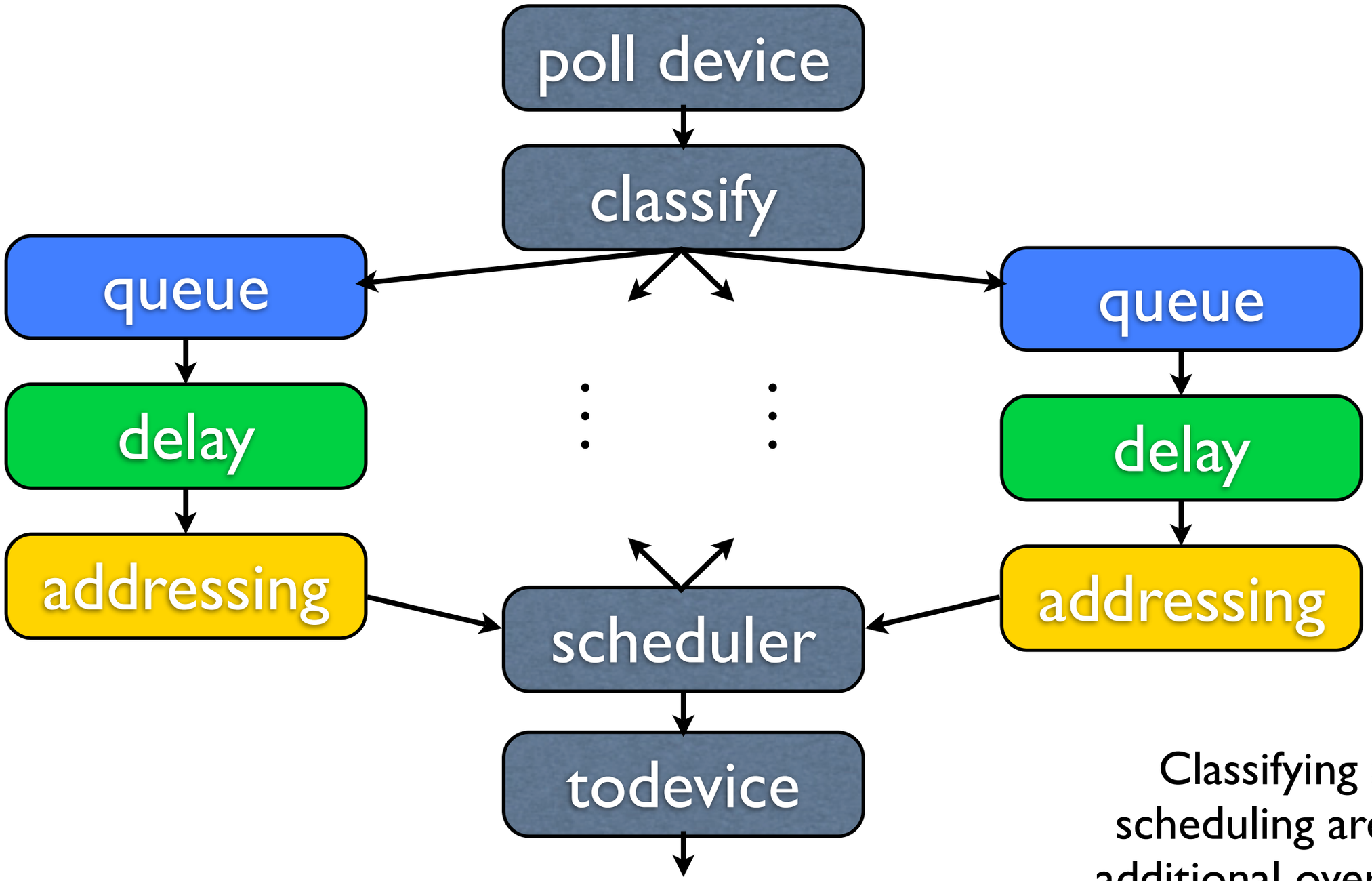
NetPath: a scalable network path emulator

- Foundations and design principles of NetPath
  - Modify Click modular router — run on commodity hardware
  - Eliminate unnecessary packet processing
  - Push functionality as close to hardware as possible
  - Exploit hardware capabilities where possible
  - Support a variety of topological and network configurations

NetPath with a single emulated path



NetPath with multiple emulated paths



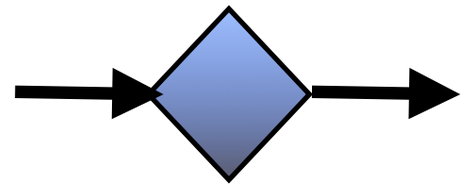
Classifying and scheduling are only additional overheads.

Exploiting system memory for high performance

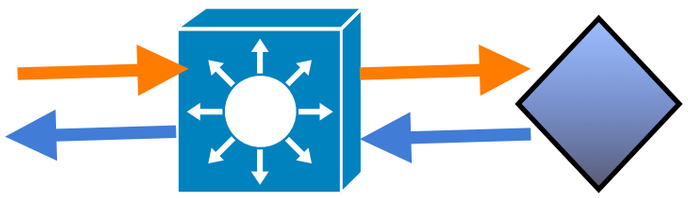
- Basic Click elements do not enable full use of memory resources
  - Packets are dropped as a result
- NetPath provides new Click elements to take advantage of system resources
  - Use available system RAM — BigQueue
  - Use disks as backing store for long delays — DiskQueue
    - Use a pair of disks to hide disk access latency — ODQM (opportunistic disk queue management)

Options for topological configuration

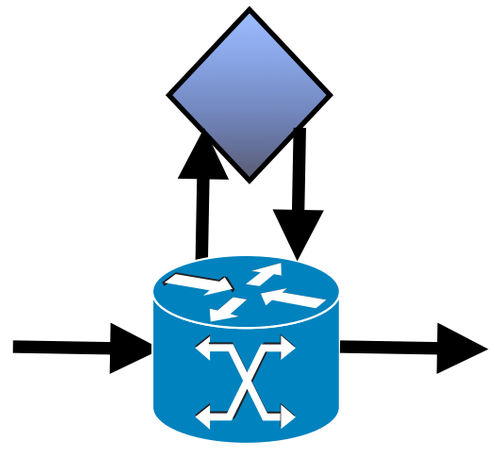
- Direct interposition



- Layer 2 — virtual interposition
  - Additional Click elements to optimize VLAN tag rewriting



- Layer 3 — interposition via IP routing
  - Leverage existing Click configuration tools



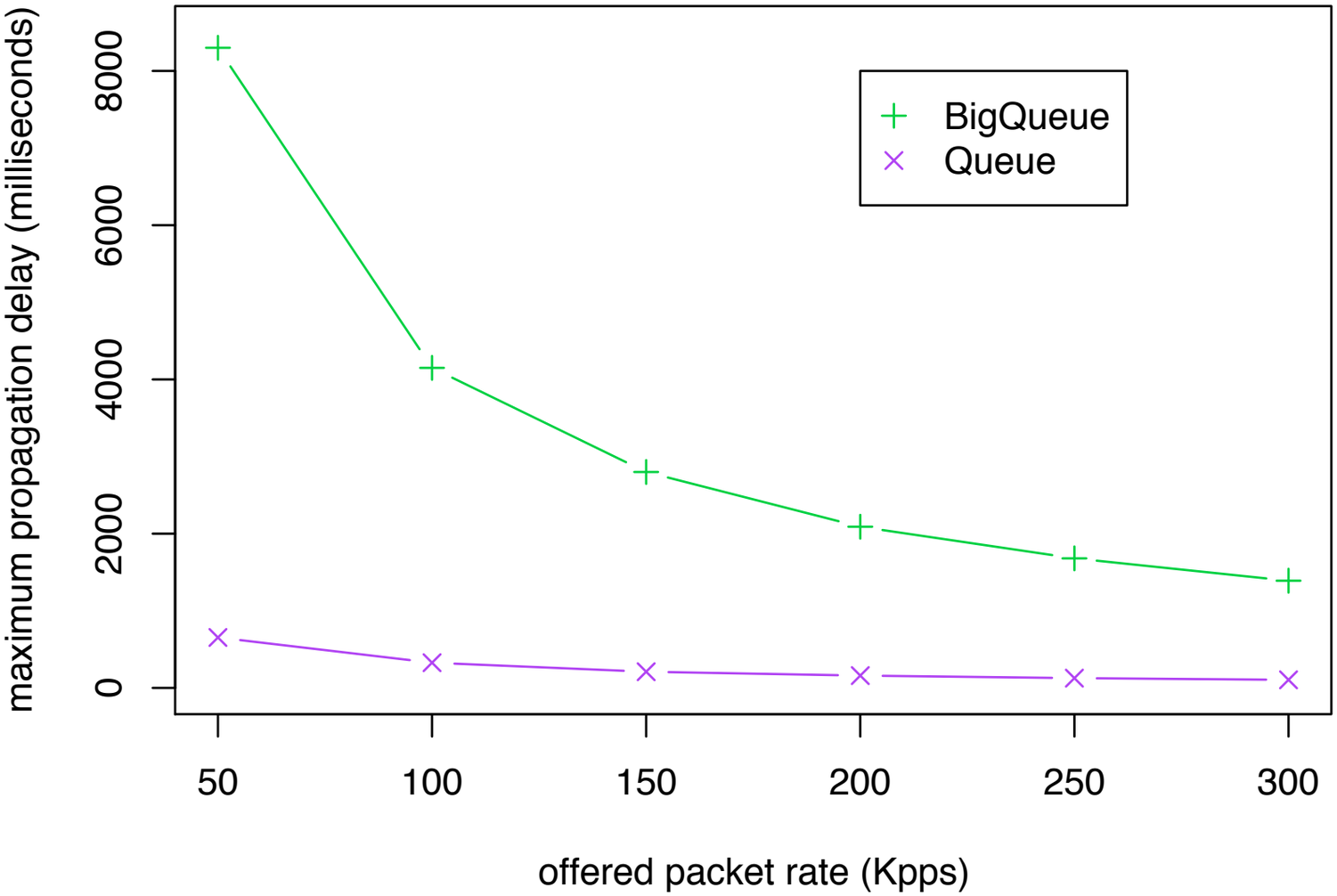
Results overview

- Accuracy & precision of NetPath over a range of operating conditions is close to a hardware-based platform
  - NetPath significantly outperforms other emulation systems
- NetPath modifications to Click significantly improve performance over out-of-the-box Click elements
- NetPath can accurately & precisely support simultaneous emulation over several paths

Comparison with a hardware-based reference

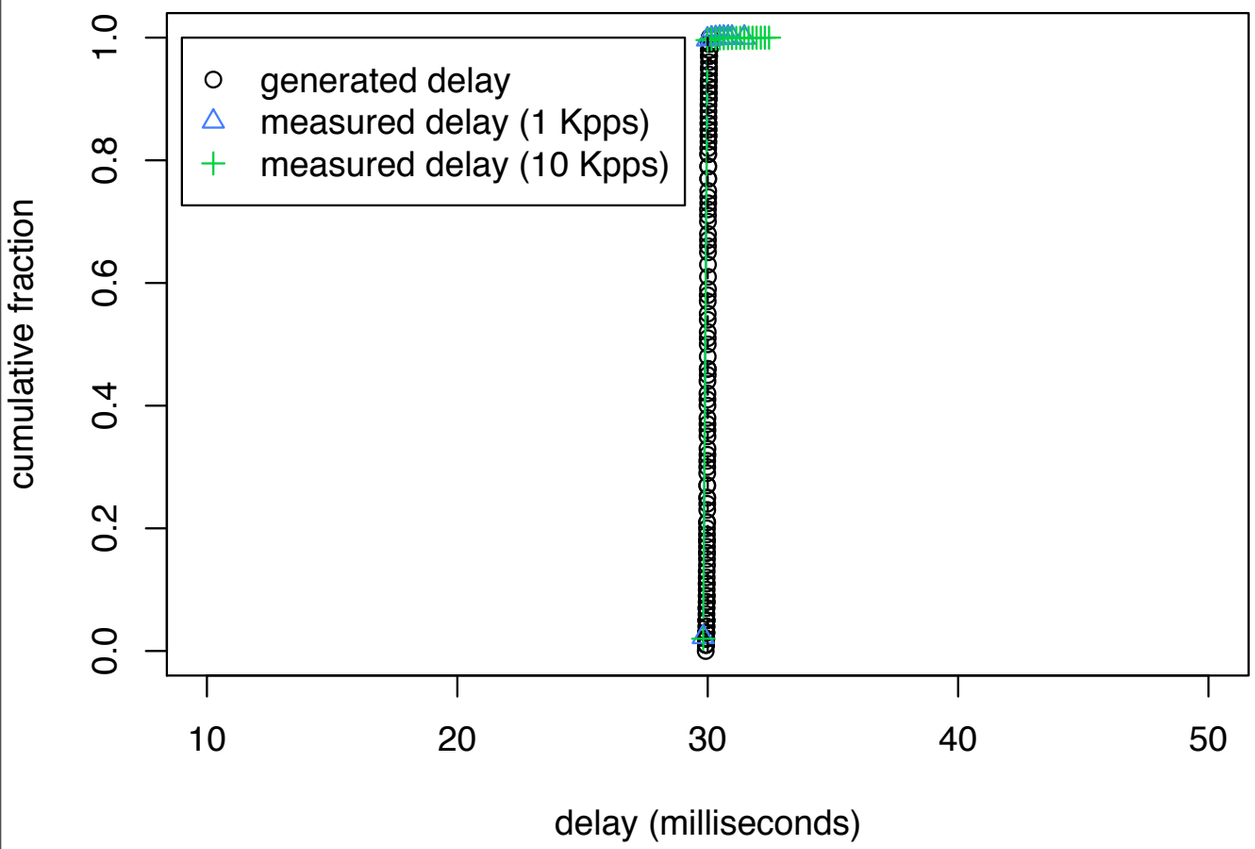
offered load (kpps)	NetPath	Adtech SX-14
50	10.03 (0.01)	9.99 (0.00)
100	10.03 (0.01)	9.99 (0.00)
150	10.04 (0.01)	9.99 (0.00)
200	10.05 (0.01)	9.99 (0.00)
250	10.06 (0.01)	9.99 (0.00)
300	10.09 (0.03)	9.99 (0.00)

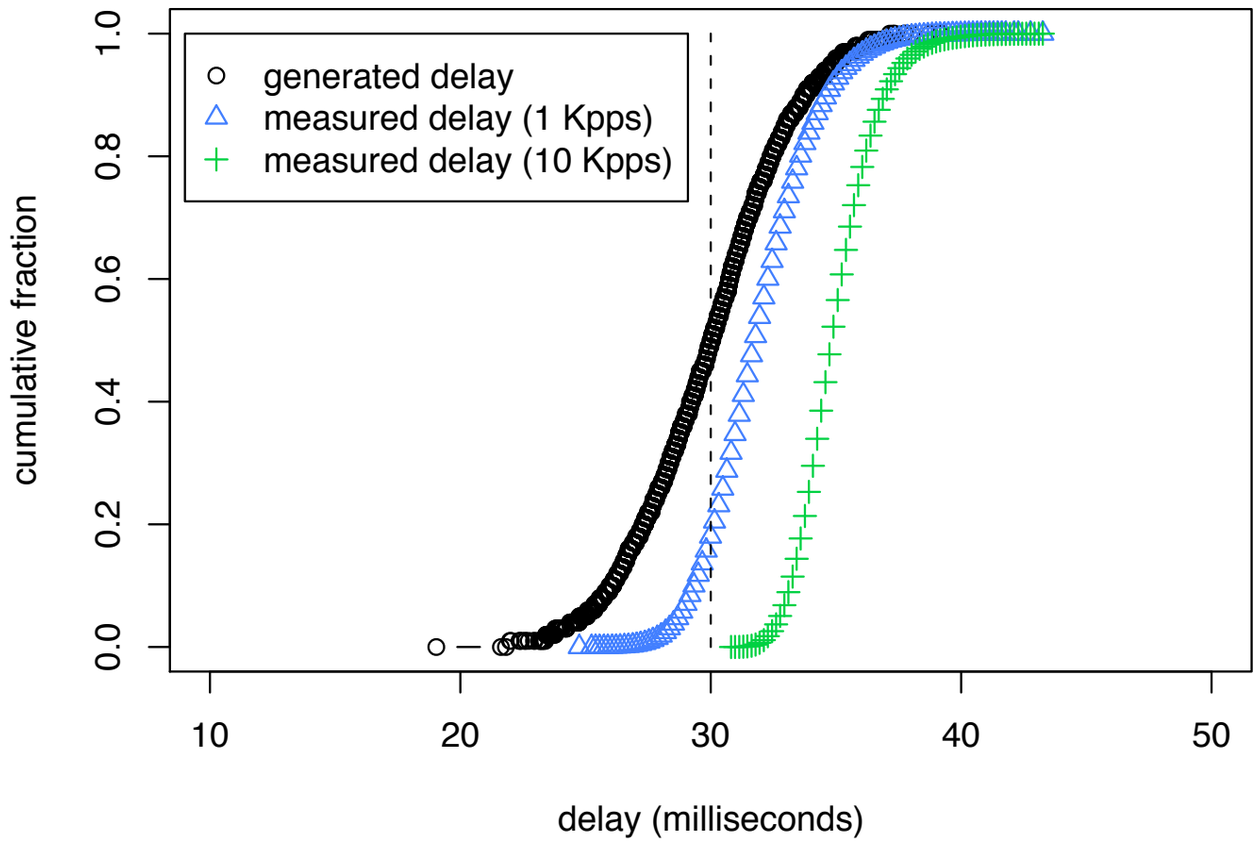
Using available system RAM for packet buffers



Using available system RAM enables longer delays at higher packet rates.

Accuracy of probabilistic delay emulation



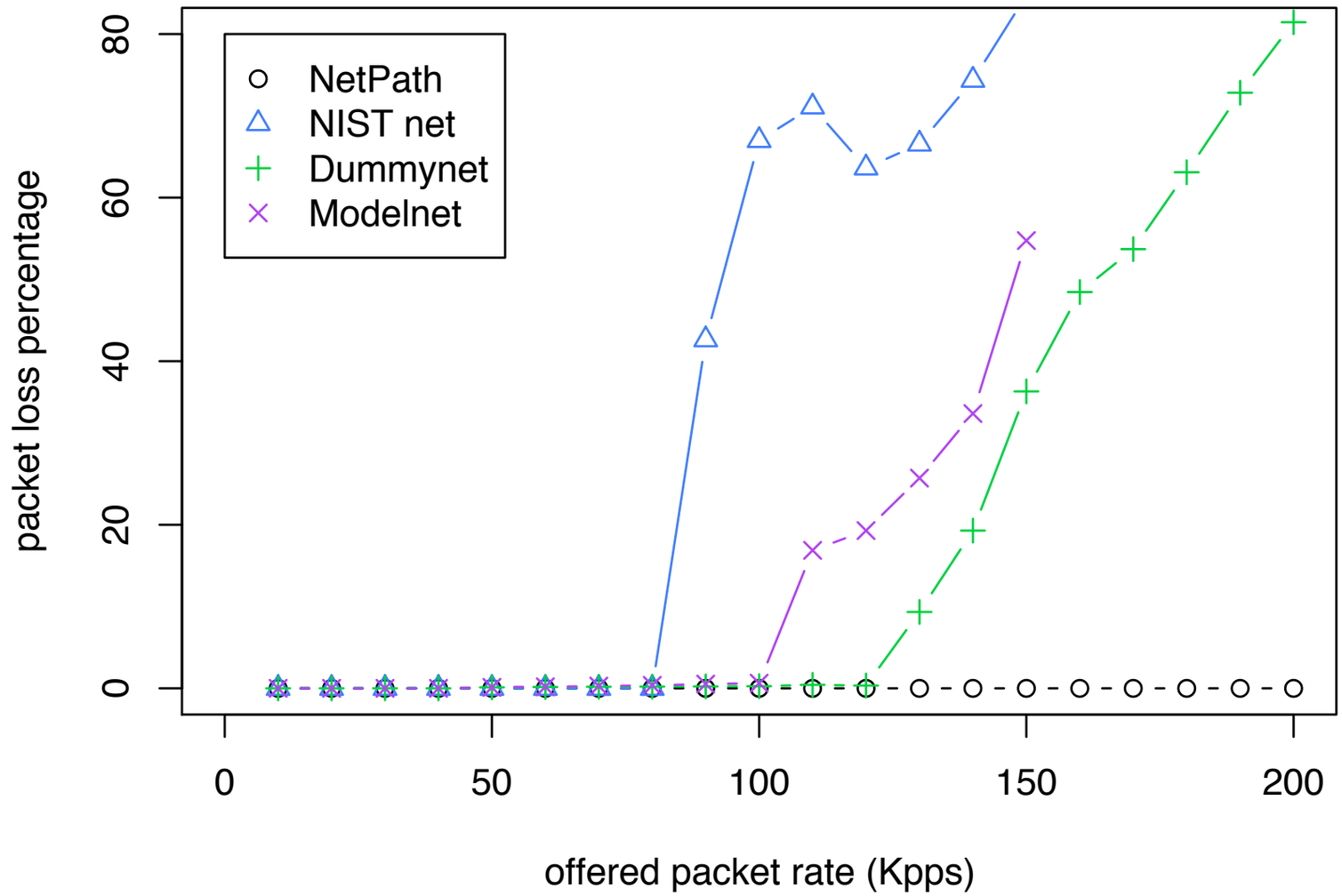


NetPath can provide high accuracy, but head-of-line blocking can be a problem.

Comparison of emulation systems

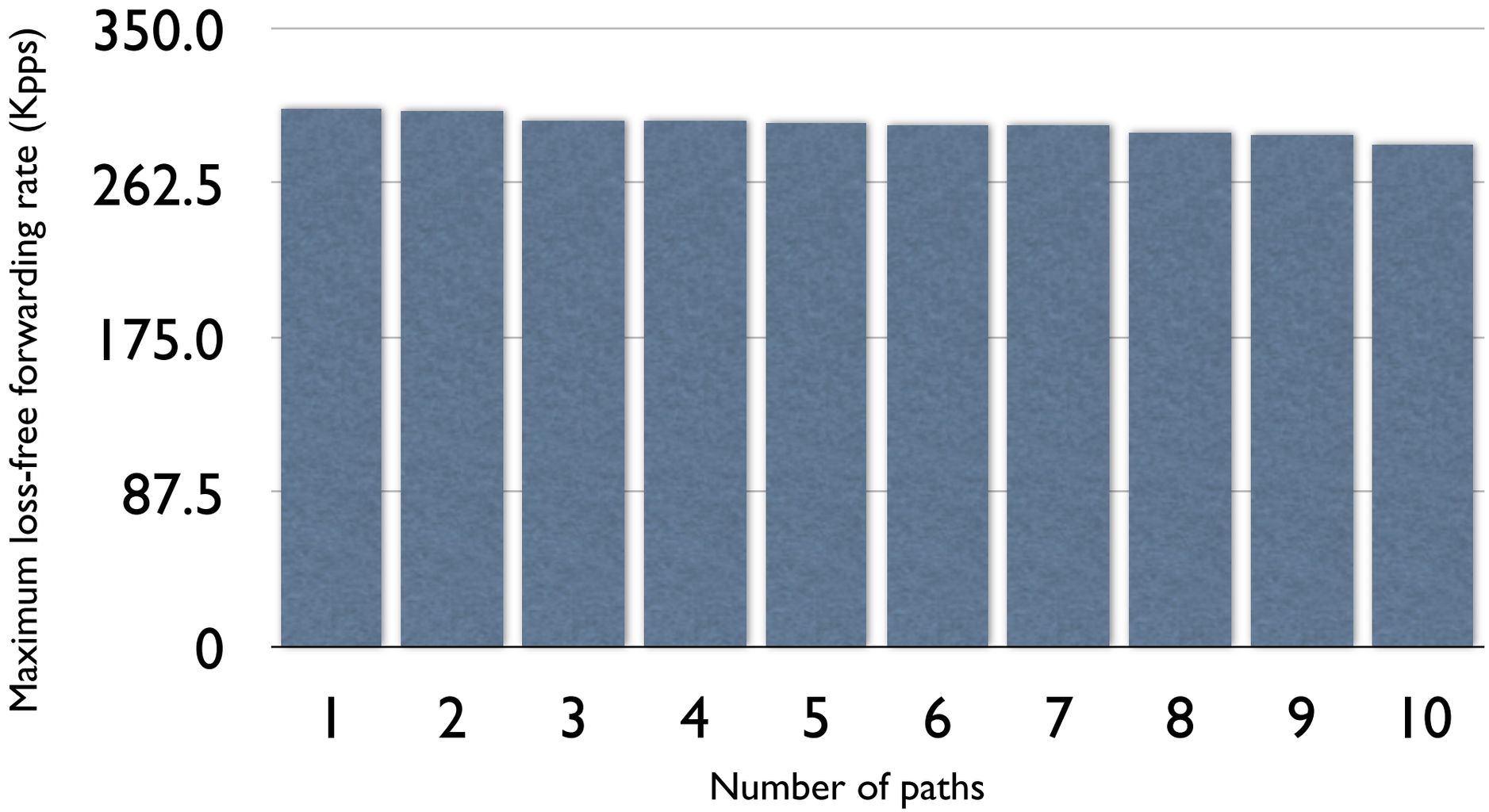
offered load (Kpps)	NetPath	NIST net	Dummynet	Modelnet
40	10.04 (0.01)	10.14 (0.03)	10.00 (0.35)	10.06 (0.13)
80	10.04 (0.01)	10.52 (0.40)	10.23 (0.46)	10.10 (0.20)
120	10.04 (0.01)	12.75 (0.84)	29.08 (1.68)	10.56 (0.45)
160	10.04 (0.01)	16.47 (1.96)	399.00 (3.50)	-failure-

Packet drops are a problem with previous emulators



NetPath accurately emulates delay without introducing packet loss for much higher rates than other emulators.

Scaling to multiple paths



NetPath enables more efficient use of resources. Slight performance degradation is due to scheduling overhead.

Summary and conclusions

- NetPath provides accurate path emulation capabilities for modern laboratory testbeds
  - Suitable for analysis of delay-sensitive protocols
  - Scalability to multi-link scenarios means that laboratory resources can be more efficiently used
  - A variety of supported configuration scenarios means that NetPath can be used in a wide variety of lab settings
  - Software will be available at http://wail.cs.wisc.edu/

the end

http://wail.cs.wisc.edu