

tulip: A tool for locating performance problems along Internet paths

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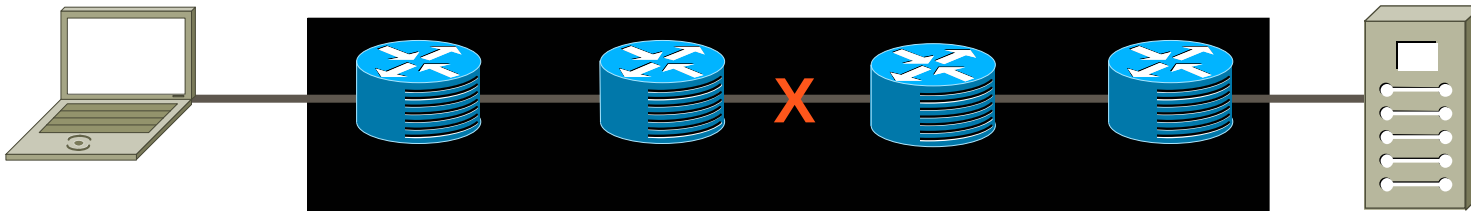
Neil Spring

David Wetherall

Tom Anderson

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Where is the problem along this path?



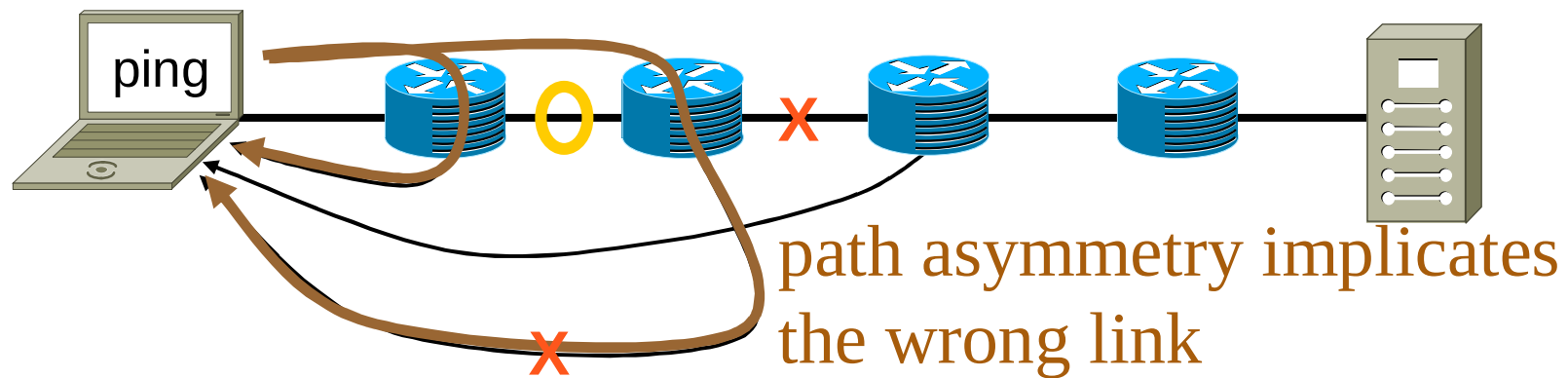
The Internet is a black box

◆ Problems such as

- packet loss, queuing (congestion) and significant reordering

Limitations of existing tools

- ◆ SNMP stats are limited in scope
 - can be used only inside your domain
 - granularity issues
- ◆ *ping* and *traceroute*-like tools don't deal with path asymmetry



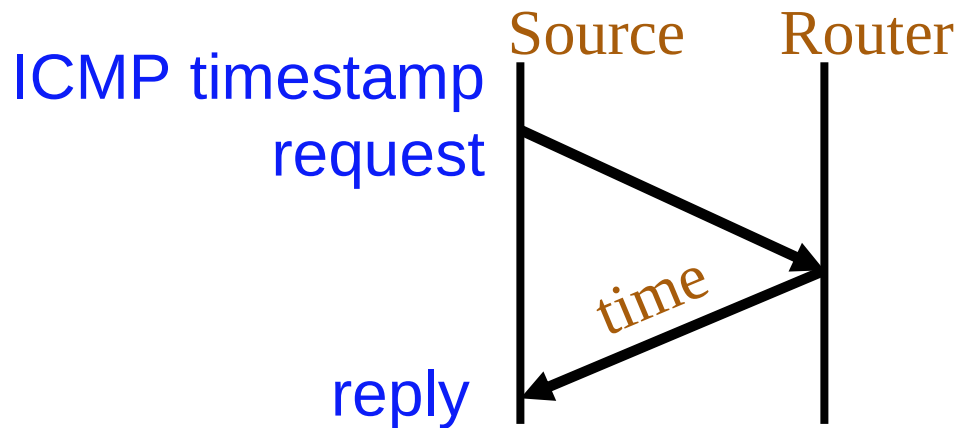
Overview of tulip

Measuring forward path to routers
is the basic building block



- ◆ Localizes reordering, queuing and loss
 - works from a host to an arbitrary IP address
- ◆ Infers link properties by subtracting path properties
 - path to router must be a prefix of the path to dst.
- ◆ Uses **ICMP timestamps** and **IP identifiers**

Queuing on the forward path [cing]



- ◆ ICMP timestamps to access router's clock
 - 1 ms resolution; supported by over 90% routers
- ◆ Queuing inferred from delay variation
 - engineering: clock calibration, response generation time

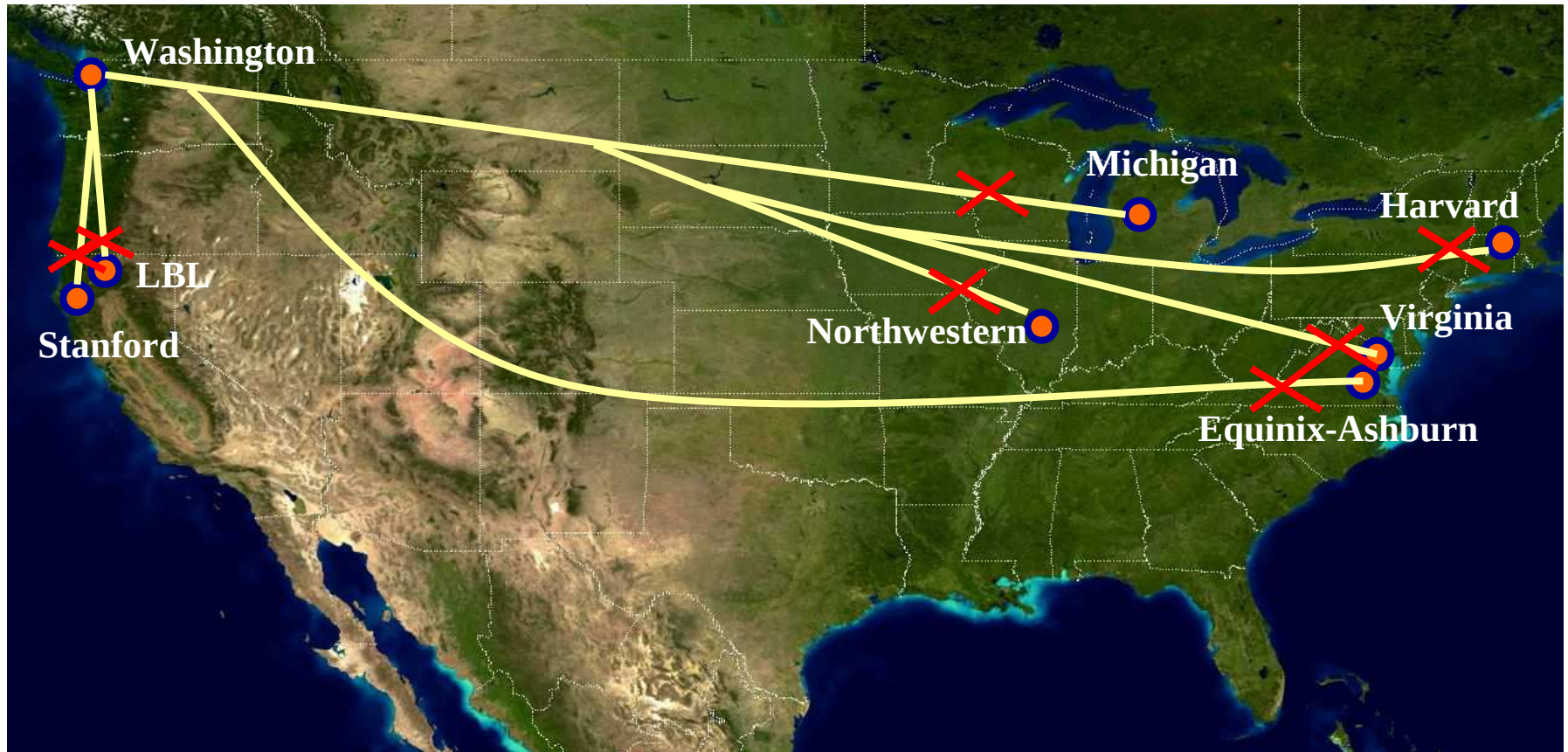
Implementation

- ◆ Implemented in ruby, on top of Scriptroute
 - runs on Linux, FreeBSD and OS X
- ◆ Runs in three phases
 1. discover routers along the path
 2. test which routers support fwd path diagnosis
 3. measure paths to routers
- ◆ Reports properties of one-way and round trip paths to intermediate routers

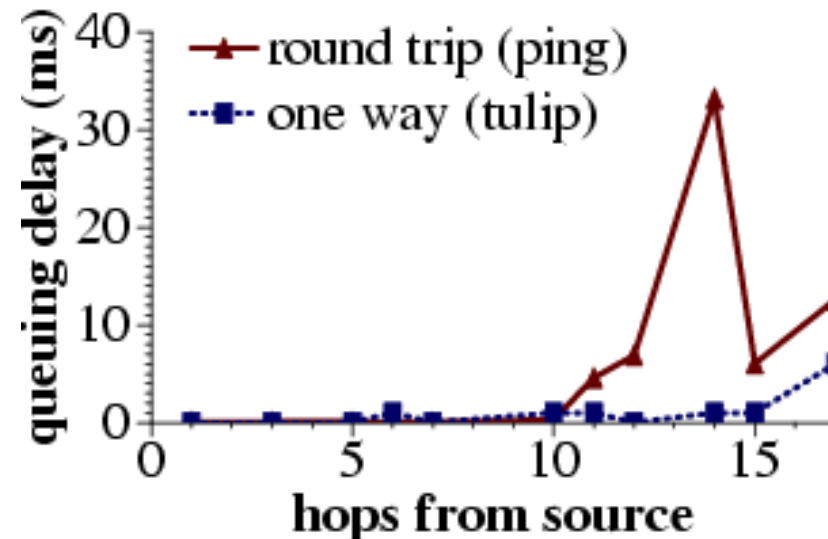
% tulip loss ratul.dhcp.nanog31.cnet.com

- 1 eureka-GE1-5.cac.washington.edu (128.208.4.100) **rt=0.000 (0/1000)**
fw=0.000 (0/1000) co=0.966 (966/1000) ro=0.000 (0/1000)
- 2 uwbr1-GE0-1.cac.washington.edu (140.142.150.23) rt=0.000 (0/1000)
- 3 prs1-wes-ge-1-0-0-0.pnw-gigapop.net (198.107.151.30) rt=0.000 (0/1000)
- 4 att-pwave-1.peer.pnw-gigapop.net (198.32.170.29) rt=0.001 (1/1000)
- 5 tbr1-p012502.st6wa.ip.att.net (12.123.203.170) rt=0.000 (0/1000)
- 6 tbr2-cl1.sffca.ip.att.net (12.122.12.113) rt=0.000 (0/1000)
- 7 gar4-p390.sffca.ip.att.net (12.123.13.178) rt=0.000 (0/1000)
fw=0.000 (0/1000) co=0.000 (0/1000) ro=0.000 (0/1000)
- 8 idf22-gsr12-1-pos-7-0.rwc1.attens.net (12.122.255.218) rt=0.000 (0/1000)
- 9 mdf3-bi4k-1-eth-1-1.rwc1.attens.net (216.148.209.62) rt=0.000 (0/1000)
fw=0.000 (0/1000) co=0.953 (953/1000) ro=0.000 (0/1000)
- 10 mdf3-bi4k-2-ve-57.rwc1.attens.net (63.241.72.146) rt=0.000 (0/1000)
fw=0.000 (0/1000) co=0.909 (905/996) ro=0.004 (4/1000)
- 11 ge4-7.cn-sfo1-6506-1.cnet.com (216.239.127.5) rt=0.000 (0/1000)
fw=0.000 (0/1000) co=0.988 (987/999) ro=0.001 (1/1000)
- 12 ge1-1.365-sfo1-6506-1.cnet.com (216.239.127.2) rt=0.000 (0/1000)
fw=0.000 (0/1000) co=0.965 (964/999) ro=0.001 (1/1000)
- 13 ge1-3-0.border.nanog31.cnet.com (216.239.118.2) **rt=0.000 (0/1000)**
- 14 gateway.nanog31.cnet.com (216.239.118.130) **rt=0.001 (1/676)**
fw=0.001 (1/676) co=0.950 (640/674) ro=0.001 (1/675)
- 15 ratul.dhcp.nanog31.merit.net (192.35.166.145) **rt=0.015 (14/904)**
fw=0.000 (0/904) co=0.989 (877/887) ro=0.003 (3/890)

Tulip in action



Consistency along the path (queuing)



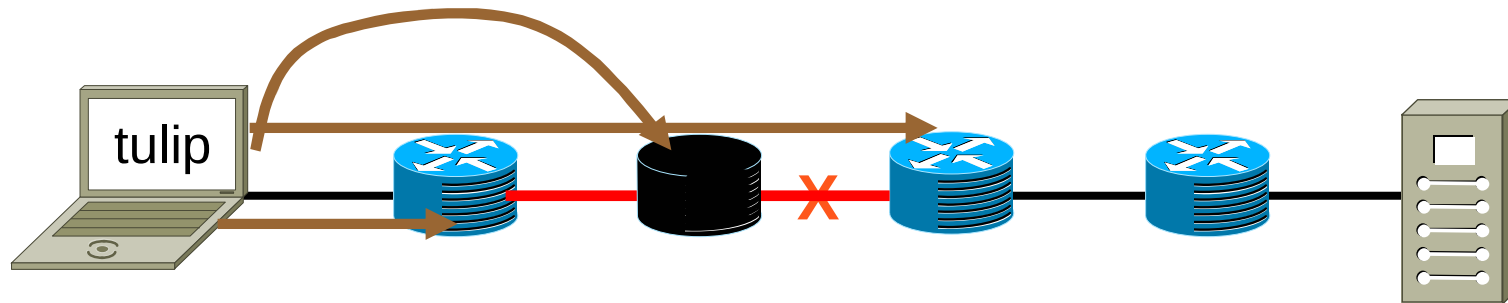
median queuing delay to intermediate routers in an example path

- ◆ One-way measurements are consistent
- ◆ Round trip measurements can be polluted

Evaluation

- ◆ Is it accurate?
 - end-to-end correctness
 - internal consistency(see the paper)
- ◆ What is the fault localization granularity?

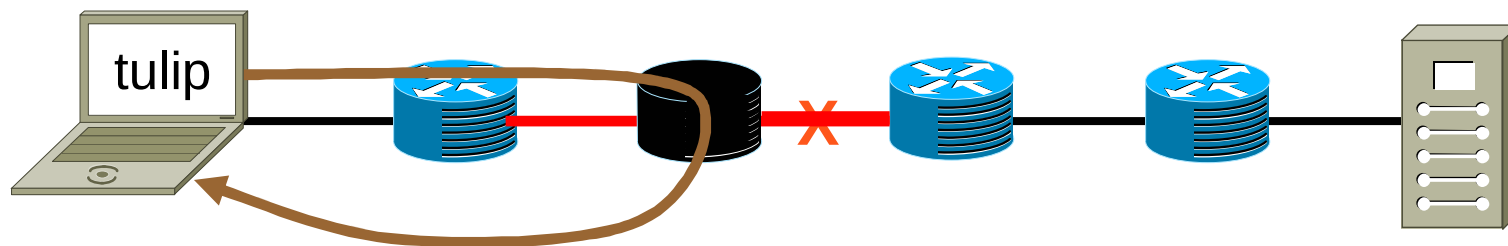
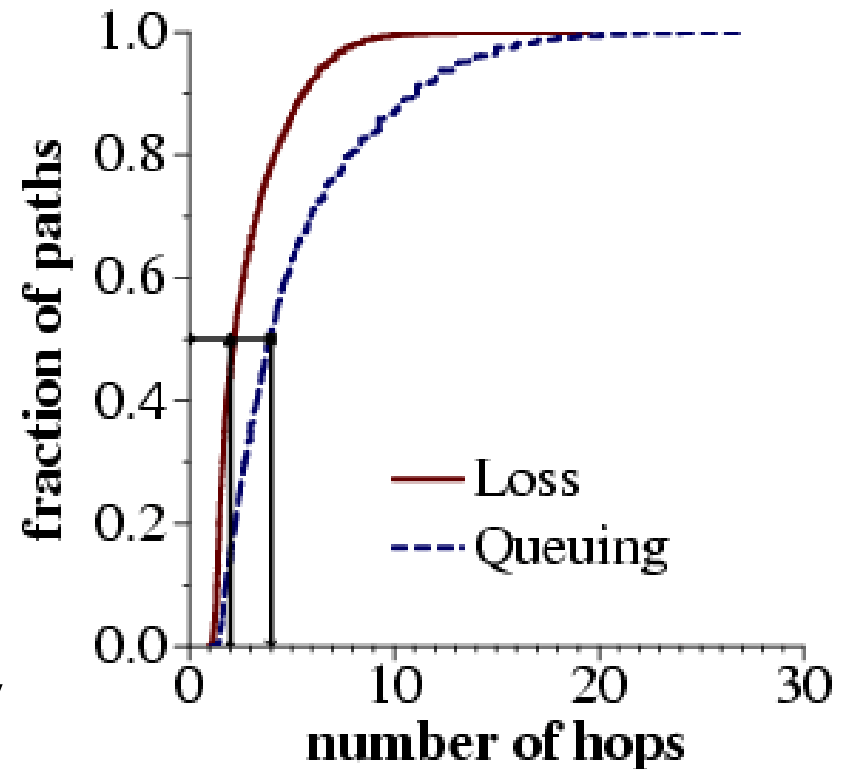
Localization granularity



- ◆ Location of the fault is uncertain when
 - a router does not support a required feature
 - probes take a non-prefix path to a router

Localization granularity (2)

- ◆ Median is 2 hops for loss and 4 hops for queuing
- ◆ Round trip probing can further improve granularity



Improving effectiveness

- ◆ Turn on the features used by tulip
 - let yourself and other operators diagnose paths through your network
- ◆ Simple router changes can further improve the diagnostic ability of tulip
 - granularity of queuing localization
 - supporting multiple simultaneous loss rate measurements

Better timing information

- ◆ Problem: ICMP timestamp requests address the router directly
 - reduces diagnosis granularity when the prefix path property does not hold
- ◆ Fix: insert timestamps in TTL-expired messages
 - backwards compatible, incrementally deployable
 - 32 unused bits in the TTL-expired messages

Better counter support

- ◆ Problem: IP-ID is a shared counter
 - what if all of you start using tulip?
- ◆ Fix: maintain N (constant) counters
 - hash source address and IP-ID of the probe to select the counter
 - backwards compatible, incrementally deployable (today, N=1)

Summary

- ◆ Tulip is a new performance diagnosis tool
 - finds where packets are lost, reordered or queued to within 2-4 hops on average
 - compatible with asymmetric routing
- ◆ Download it at
<http://www.cs.washington.edu/research/networking/tulip>