

User-level Internet Path Diagnosis

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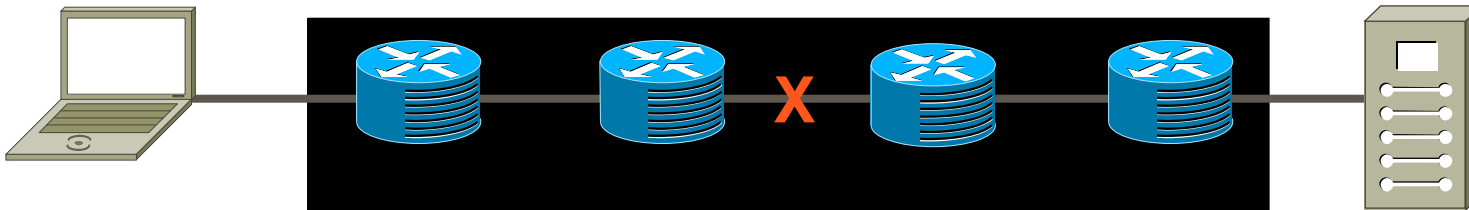
Neil Spring

David Wetherall

Thomas Anderson

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Diagnosing performance of Internet paths is hard



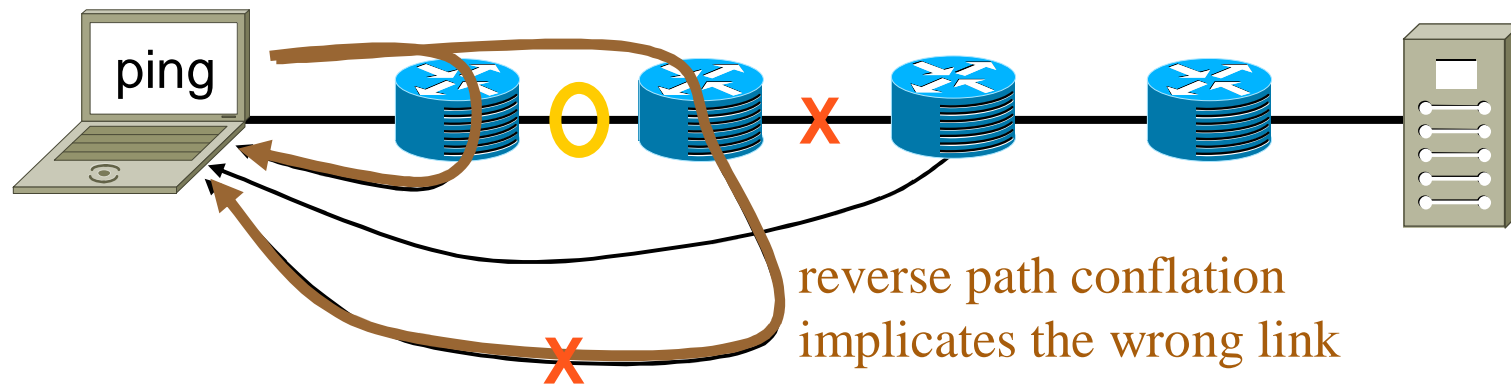
The Internet as a black box

- ◆ Multiple administrative domains
 - operators may be equally clueless
- ◆ Policy routing
 - asymmetric paths (round trip tools such as *ping* don't work well)
 - path to intermediate routers may not be a prefix of the end-to-end path to the destination
- ◆ Performance may depend on the application
 - packet size, inter-packet spacing, protocol, port number,

Our goal is “user-level” diagnosis

- ◆ **Diagnosis:** identify and localize performance faults that impact applications
 - loss, reordering, queuing delay,
- ◆ **User-level:** without privileged access to routers
 - useful for both end users and network operators
- ◆ **Diagnosis is useful (even if you cannot fix yourself)**
 - transparency will lead to faster problem resolution
 - intelligently route around the fault

Existing diagnosis tools have limitations

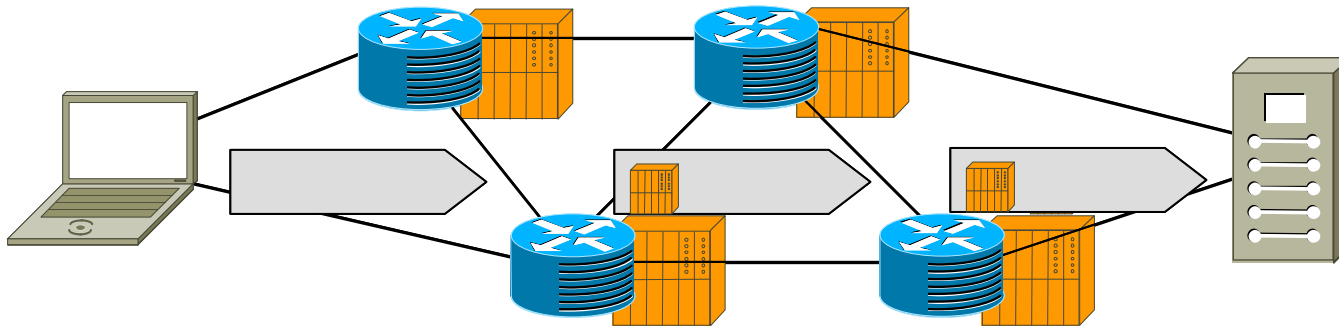


- ◆ *ping/traceroute/pathchar* measure round trip path to routers
 - path asymmetry conflates forward and reverse paths
- ◆ Effective diagnosis requires router support beyond packet reflection

Approach and outline

- ◆ Architecture
 - what minimal support is needed to enable user-level diagnosis in Internet-like networks?
- ◆ Build practical tools
 - tulip
- ◆ Explore Internet evolution to improve diagnostic support

An architecture for path diagnosis



- ◆ Start with an ideal solution
 - routers log all packets they forward
 - users diagnose their paths through trace analysis
 - complete but impractical
- ◆ Reduce to a practical architecture
 1. all routers on the path embed diagnostic info in packets
 - timing, flow counters, and path information
 2. the source samples one router to embed diagnostic info

An architecture for path diagnosis (2)

- ◆ Lightweight, in-band packet marking
 - almost as powerful as the complete path trace

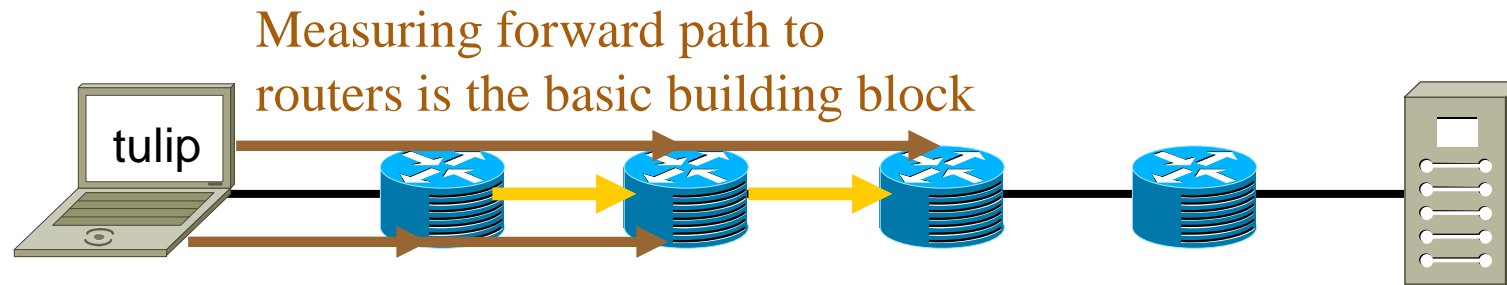
field	comments
sampler	selects the sampling router
timestamp	local time at the sampling router
flow counter	# of pkts processed for this flow
path signature	to detect path changes

- ◆ Timing, flow counters and path information provide effective diagnostic support

Approach and outline

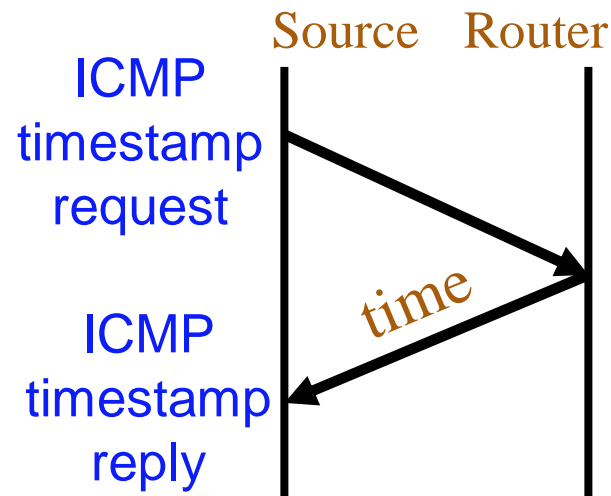
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Overview of tulip



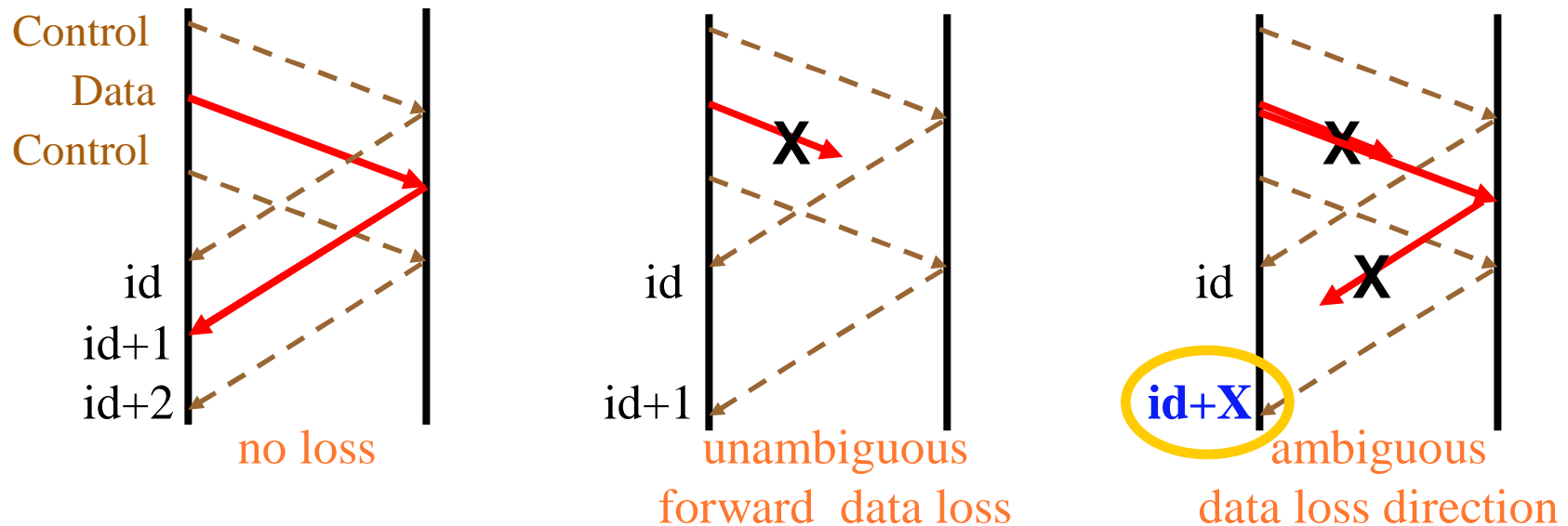
- ◆ Localizes reordering, queuing and loss (so far)
 - single-ended: works from a host to an arbitrary IP address
- ◆ Infers link properties by subtracting path properties
 - path to router should be a prefix of the end-to-end forward path

Queuing on the forward path



- ◆ ICMP timestamps are used to access router's clock [cing]
 - 1 ms resolution; supported by over 90% routers
 - prefix path property may not hold
- ◆ Queuing inferred from delay variation
- ◆ Engineering – clock calibration, response generation time

Loss on the forward path

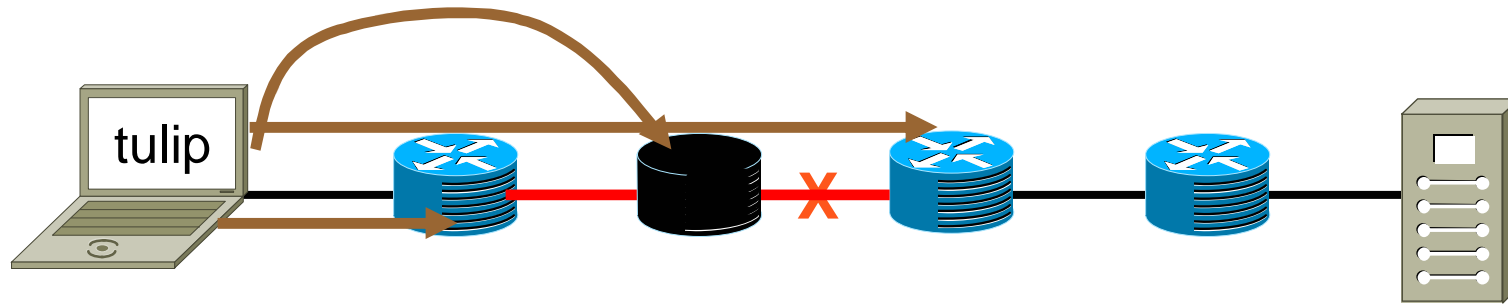


- ◆ Loss measurements use the IP identifier field in IP packets
 - over 70% of routers implement IP-ID as a counter
 - common counter for all probing sources
- ◆ Unambiguous detection of forward path loss for data packets
 - when control responses get consecutive IP-IDs
- ◆ Robust to response rate-limiting at the routers

Experimental evaluation of tulip

- ◆ What is the resolution of fault localization?
 - diagnosis granularity
- ◆ Is it accurate?
 - end-to-end correctness
 - consistency (monotonic increase along the path)

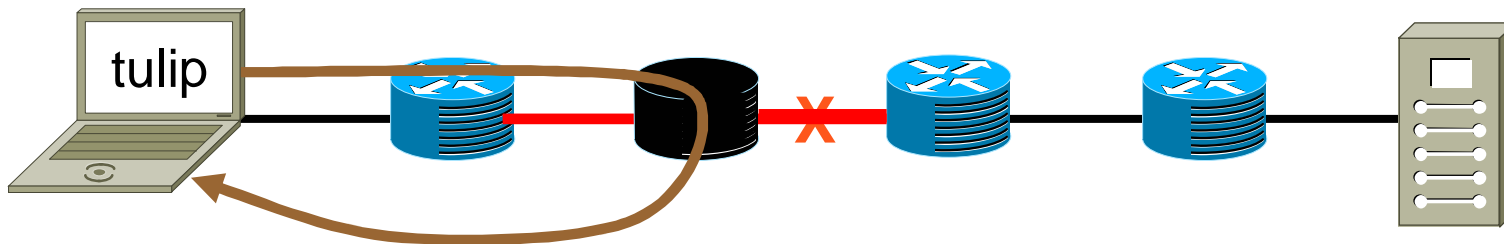
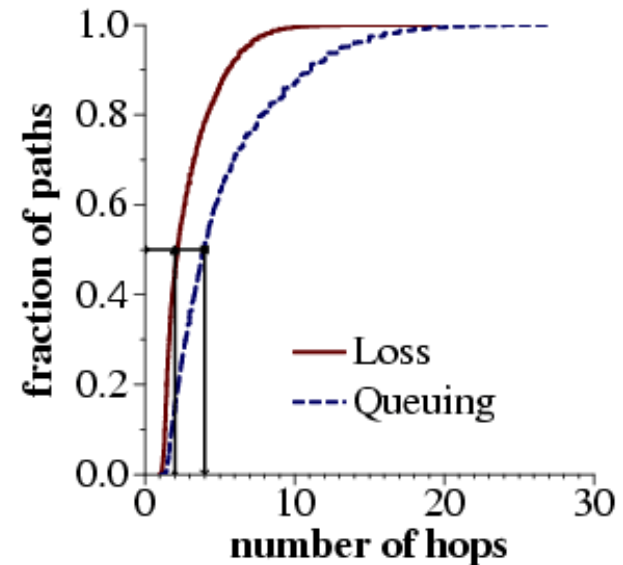
Diagnosis granularity of tulip



- ◆ Granularity: uncertainty in the location of the fault
 - when a router does not support the required features
 - when probes take a non-prefix path to a router

Diagnosis granularity of tulip (2)

- ◆ Median is 2 hops for loss and 4 hops for queuing
 - ICMP timestamp probes do not have the prefix path property

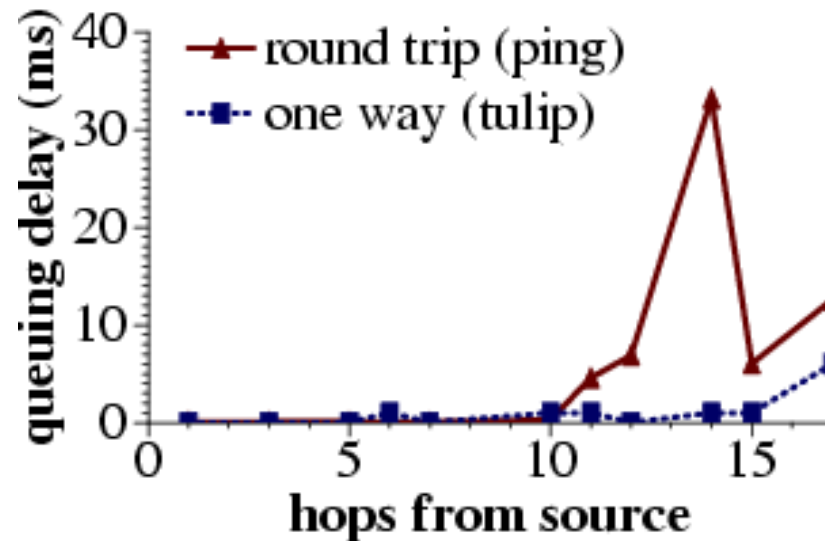


- ◆ Round trip probing can further improve diagnosis granularity

Experimental evaluation of tulip

- ◆ What is the resolution of fault localization?
 - diagnosis granularity
- ◆ Is it accurate?
 - end-to-end correctness
 - internal consistency (monotonic increase along the path)

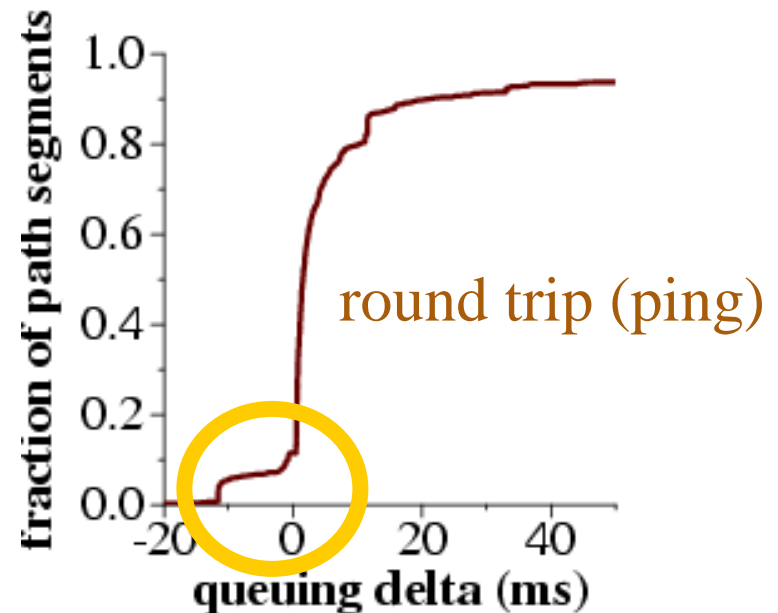
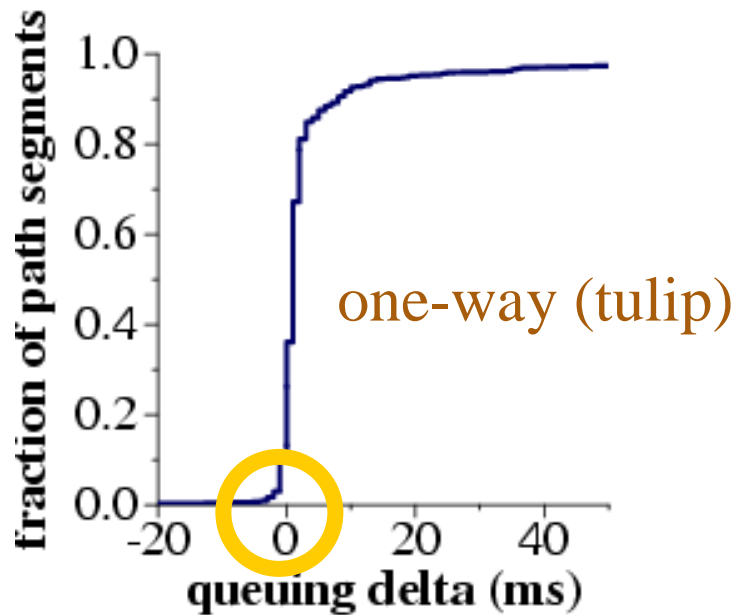
Consistency along the path (queuing)



median queuing delay to intermediate routers in an example path

- ◆ Tulip's one-way measurements are consistent
- ◆ Round trip measurements are polluted by reverse path conflation

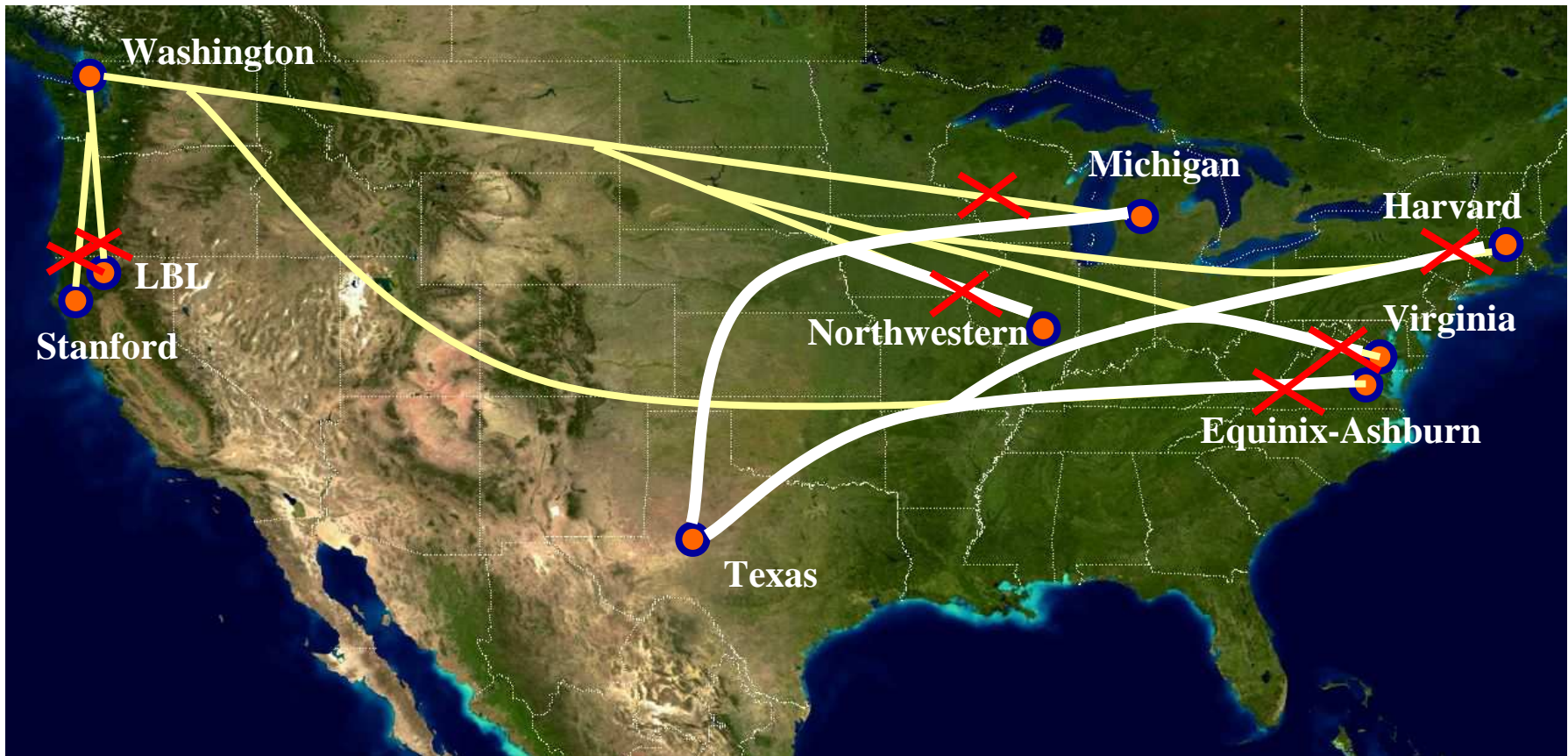
Consistency along the path (queuing)



queuing delta = delay at the far end – delay at the near end

- ◆ Tulip's one-way measurements are consistent
- ◆ Round trip measurements are polluted by reverse path conflation

Tulip in action



Tulip can help build more scalable network monitoring and overlay routing systems

Approach and outline

- ◆ Architecture
 - what minimal support is needed to enable user-level diagnosis in Internet-like networks?
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 - tulip – a tool to diagnose reordering, loss, and queuing delay
- ◆ Explore Internet evolution to improve diagnostic support

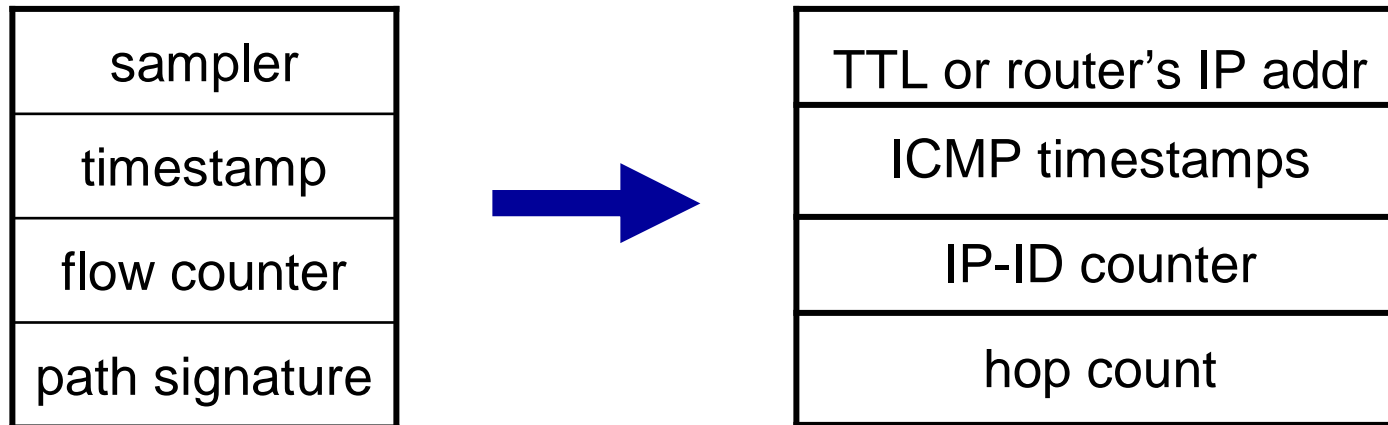
Recall: an architecture for path diagnosis

- ◆ Lightweight, in-band packet marking
 - almost as powerful as the complete path trace

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Tulip approximates the architecture in the Internet



- ◆ Approximations (and tulip) have limitations
 - measurement probes are out-of-band
 - ICMP timestamp issues (next slide)
 - IP-ID counter is shared
 - path changes can go undetected
- ◆ Moving the Internet towards the architecture improves diagnostic support
 - identify small changes with big benefits

Better timing information

◆ Problems:

- timing information is separate from flow counters
- ICMP timestamps require directly addressing the router
 - routing issues reduces their value

◆ Simple fix: timestamp TTL-expired messages

- backwards compatible, incrementally deployable
 - use 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?
 - the architecture suggests per-flow counters
- ◆ **Simple fix:** maintain N (constant) counters
 - hash source address and probe IP-ID to pick the counter
 - backwards compatible, incrementally deployable (today, N=1)

Summary

- ◆ Tulip enables end users to diagnose Internet paths
 - co-opts router support by exploiting well-deployed router features
 - <http://www.cs.washington.edu/research/networking/tulip>
- ◆ Architectural arguments:
 - features used by tulip approximate a lightweight architecture for user-level path diagnosis
 - approximations suggest evolutionary changes to improve Internet's diagnostic support
- ◆ **Future work:** extend tulip with
 - tomography to improve diagnosis granularity
 - higher layer protocol diagnosis