Diagnosing: Home Wireless & Wide-area Networks

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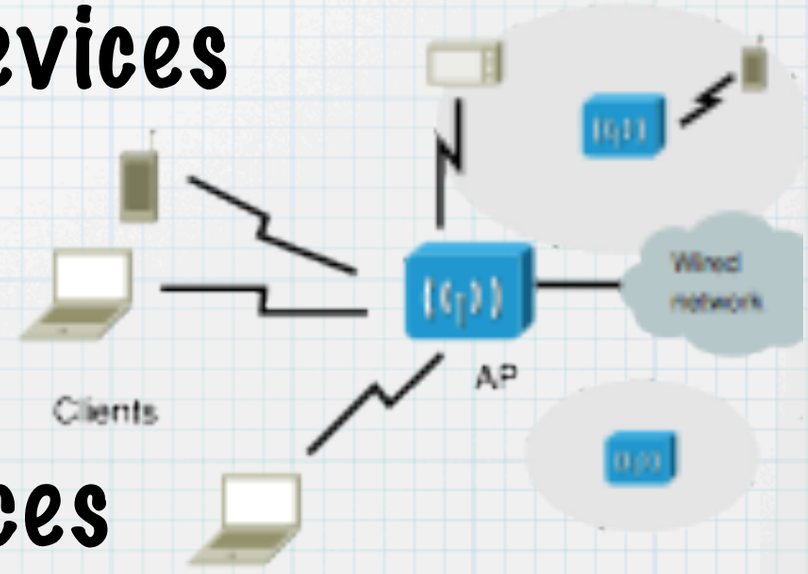
Two Parts

- Diagnosing home wireless networks [CCR'12]
  - Joint work between GT, Telefonica, CMU
- Diagnosing wide-area networks [in-progress]
  - Joint work with Constantine Dovrolis
- and a quick update on ShaperProbe

Diagnosing Home Wireless

Home 802.11 Networks

* **Ubiquitous**: most residential e2e paths start/end with 802.11 hop
* Use a shared channel across devices
  * infrastructure, half-duplex
* **Co-exist** with neighborhood wireless and non-802.11 devices (2.4GHz cordless, Microwave ovens, ...)



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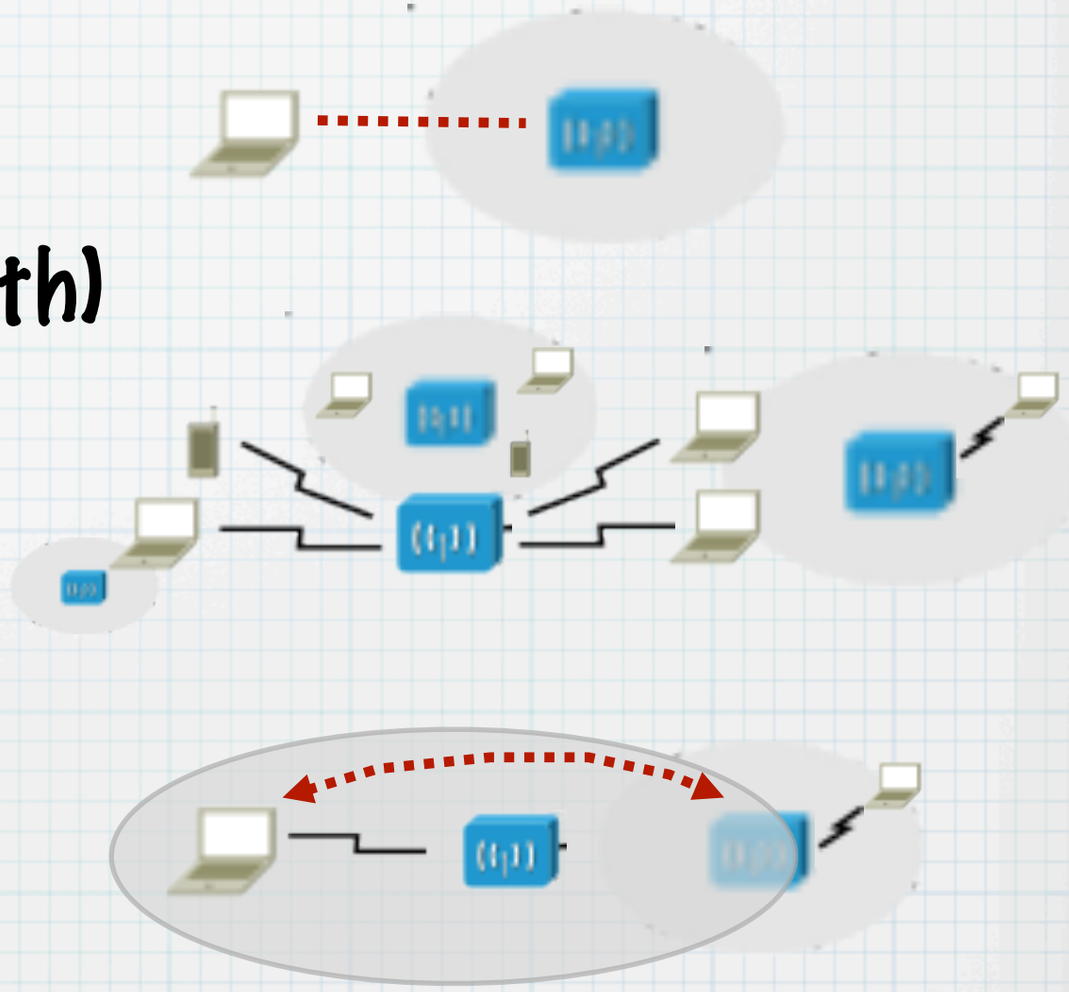
  * Non-802.11 interference (microwave, cordless, ...)



WLAN-Probe

* We diagnose 3 performance pathologies:
  * congestion, low signal strength, hidden terminals
* Tool: WLAN-Probe
  * single 802.11 prober
  * user-level: works with commodity NICs
  * no special hardware or administrator requirements

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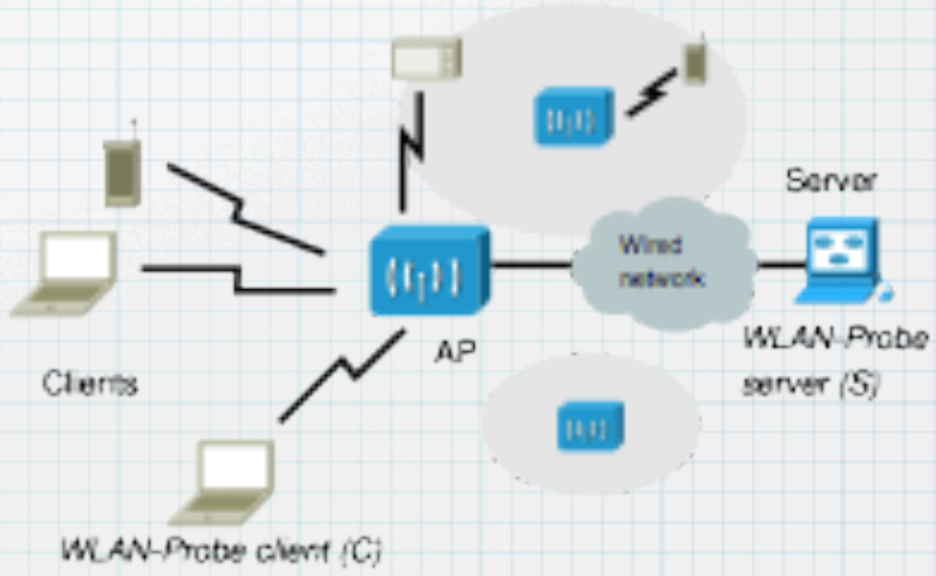

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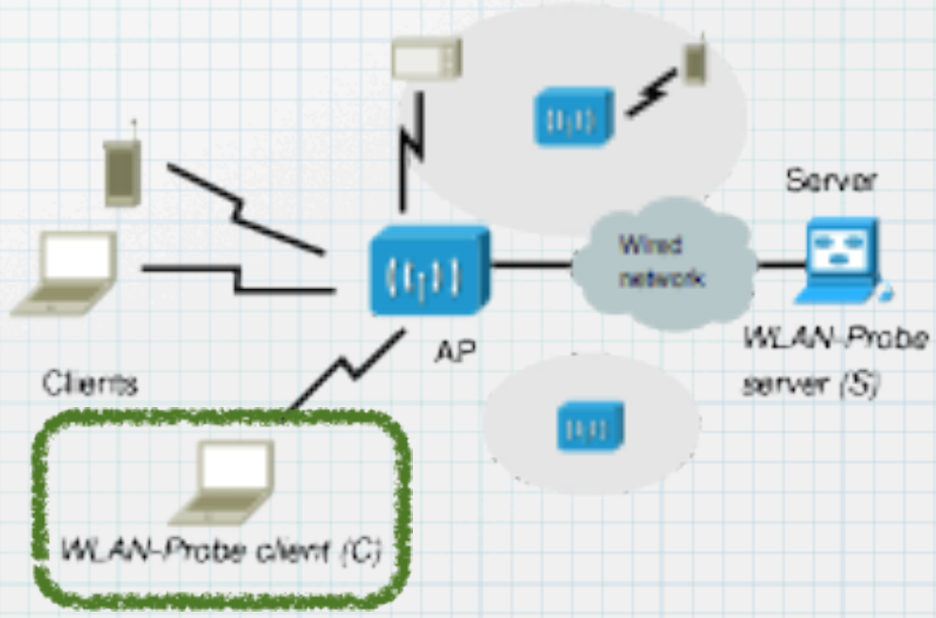

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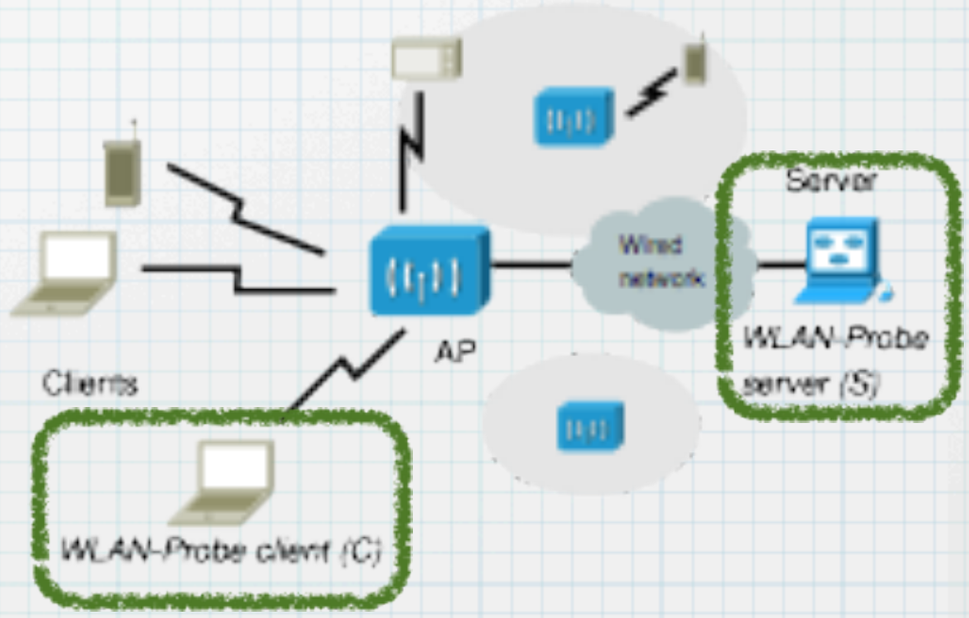
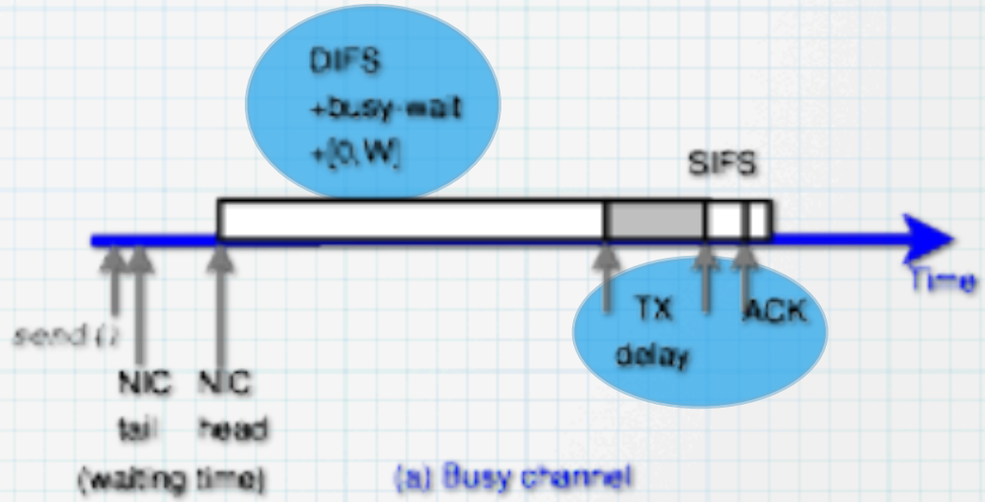
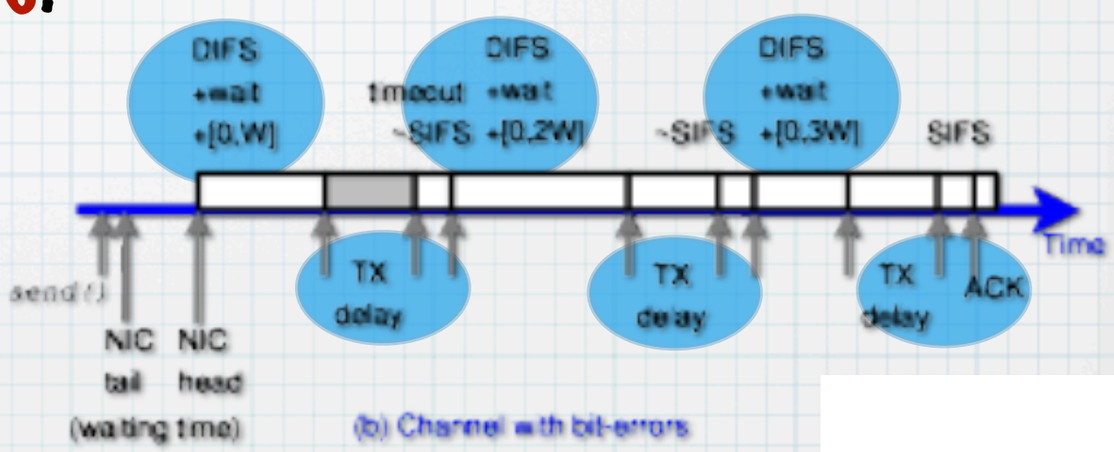


Life of 802.11 Packet

- Delays in a busy channel:
  - channel busy-wait delay
- Delays in presence of bit errors:
  - L2 retransmissions
  - random backoffs
- Unavoidable variable delays:
  - TX-delay(s) (based on L2 TX-rate)
  - 802.11 ACK receipt delay





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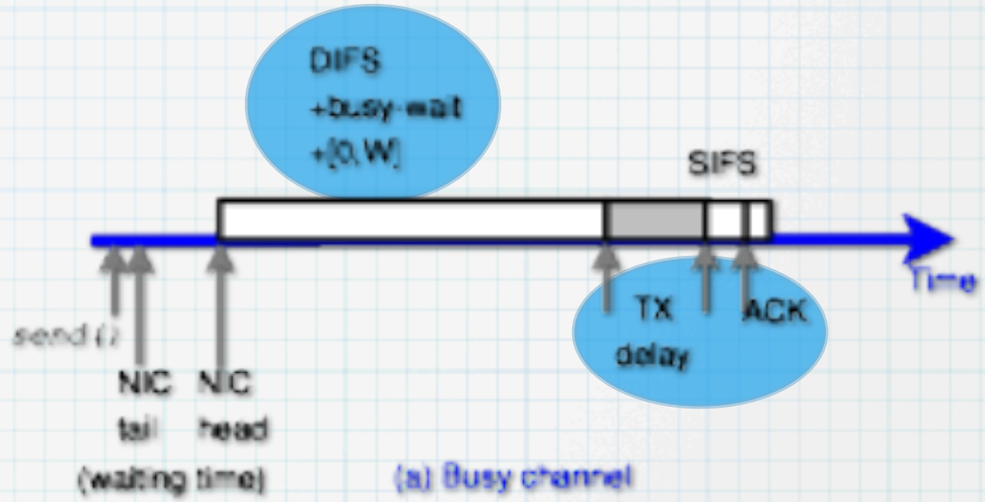

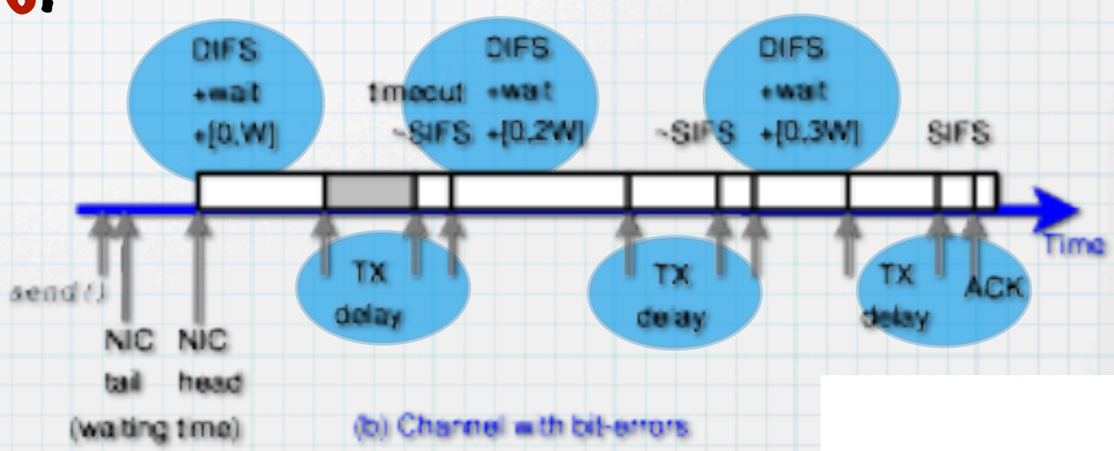

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* Usually implemented in NIC firmware

* Can we measure these delays?

* Yes!

Access Delay

busy-wait | re-TXs | backoffs | TX-delay | ACKs

Access Delay

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rate adaptation!

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rate adaptation!

* Captures channel "busy-ness" and channel bit errors
  * excludes 802.11 rate modulation effects
* d = OWD - (TX delay)

first L2 transmission

Access Delay

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rate adaptation!

* Captures channel "busy-ness" and channel bit errors
  * excludes 802.11 rate modulation effects
* d = OWD - (TX delay)

first L2 transmission

??

Access Delay: TX delay

* d = OWD - (TX delay)
* TX-rate?
  * send 50-packet train with few tiny packets
  * use packet pair dispersion to get TX-rate:

$$r_{i,1} = \frac{s_i}{\Delta_i - \Delta_{\text{tiny}}}$$

current busy-wait delays

Access Delay: noise?

d = OWD - (TX delay)

Access Delay: noise?

* Dispersion underestimates:
  * due to re-TXs, busy-waits, etc.

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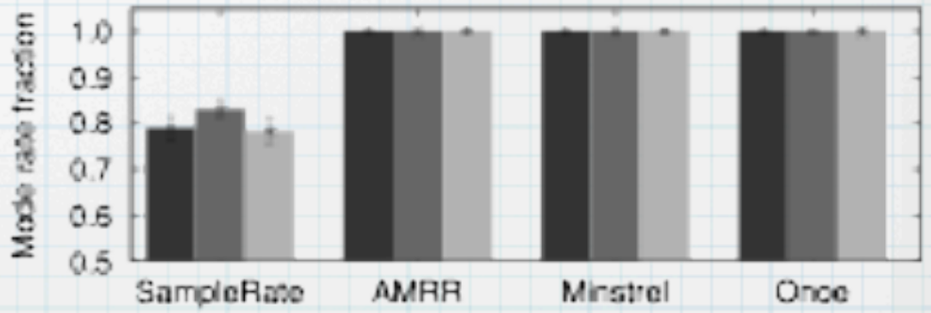
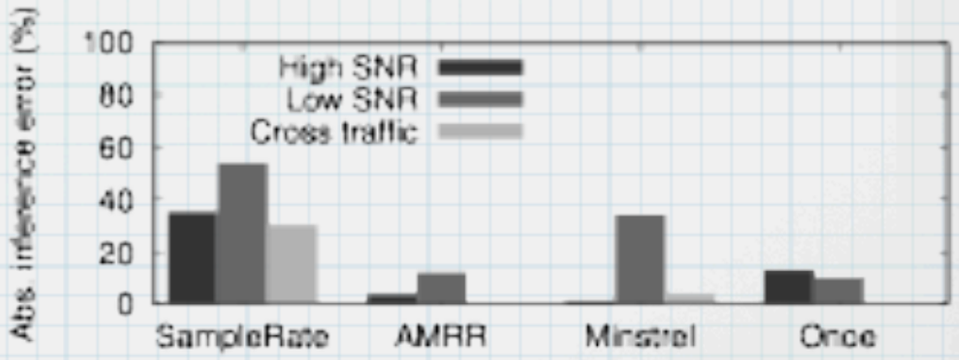
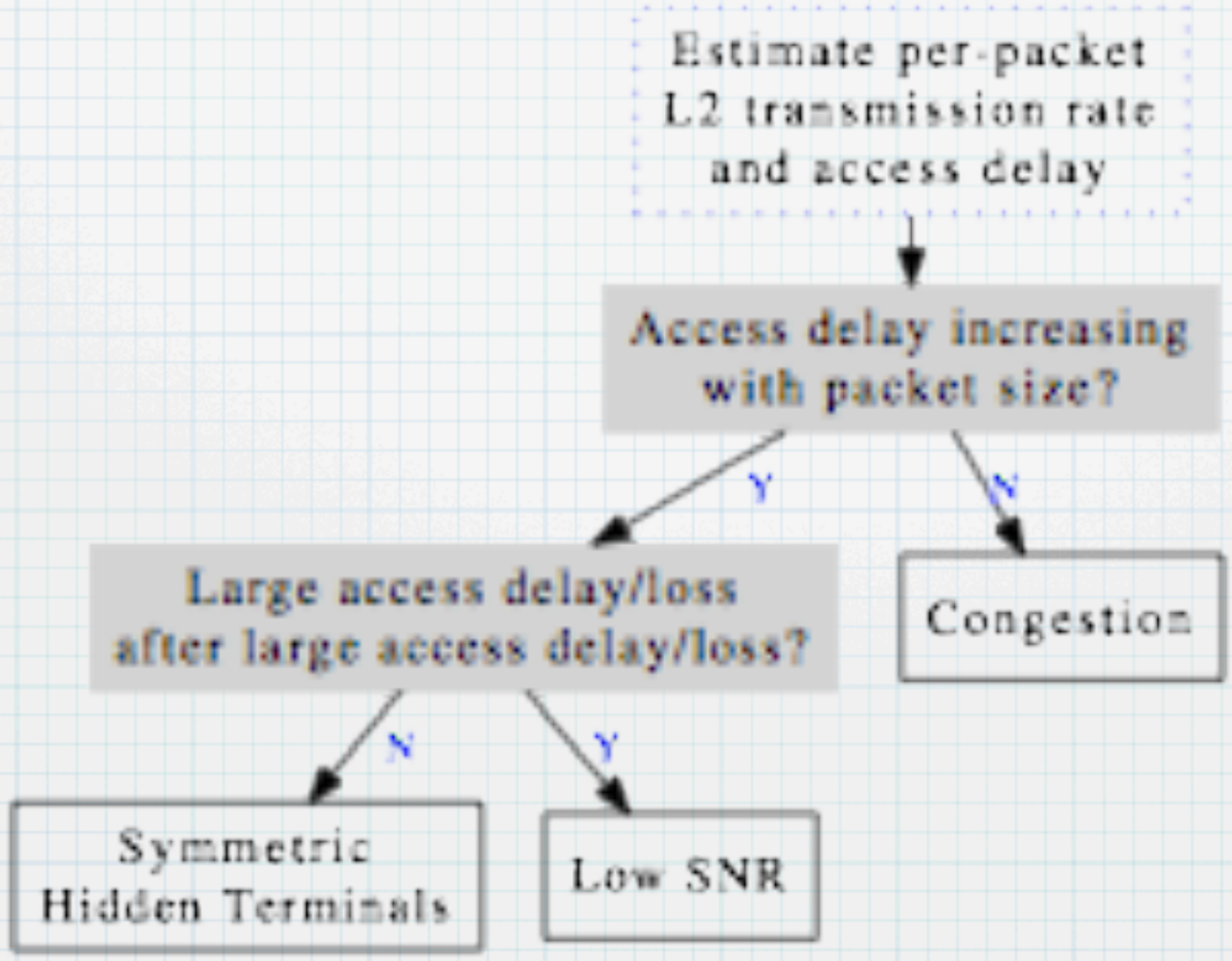
d = OWD - (TX delay)

* Insight: TX-rate typically remains same at timescales of a single train
* Find a single rate for the train!





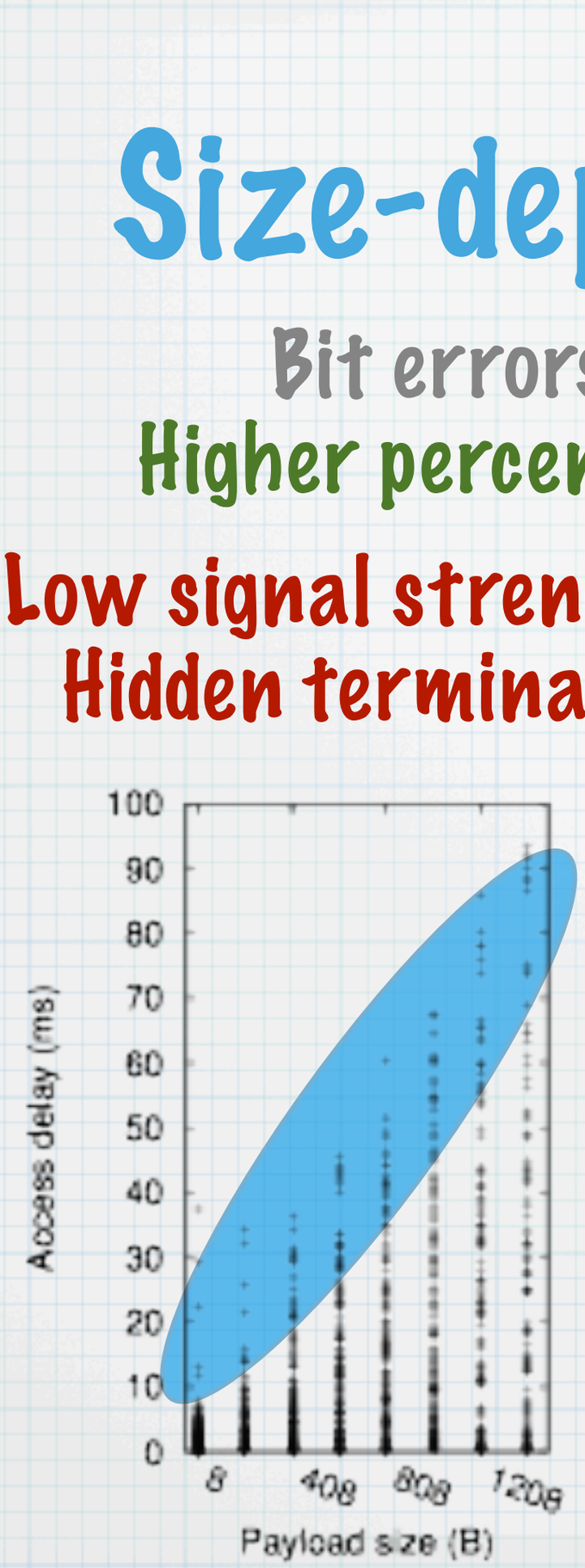
Diagnosis


Estimate per-packet
L2 transmission rate
and access delay
Access delay increasing
with packet size?
Y
N
Large access delay/loss
after large access delay/loss?
Congestion
N
Y
Symmetric
Hidden Terminals
Low SNR

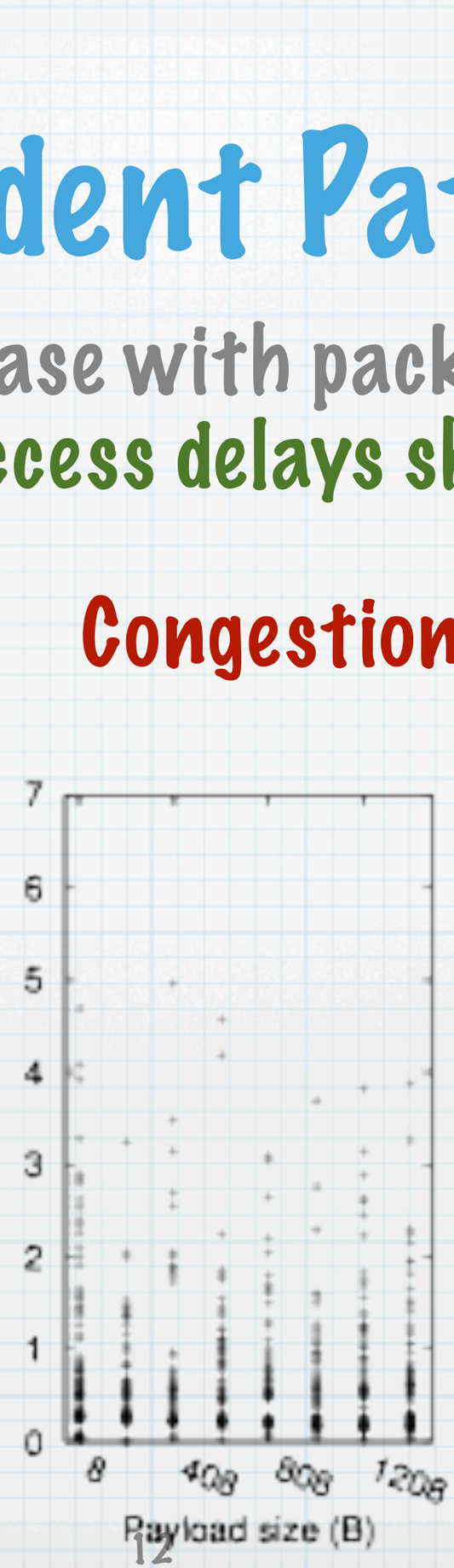
Size-dependent Pathologies

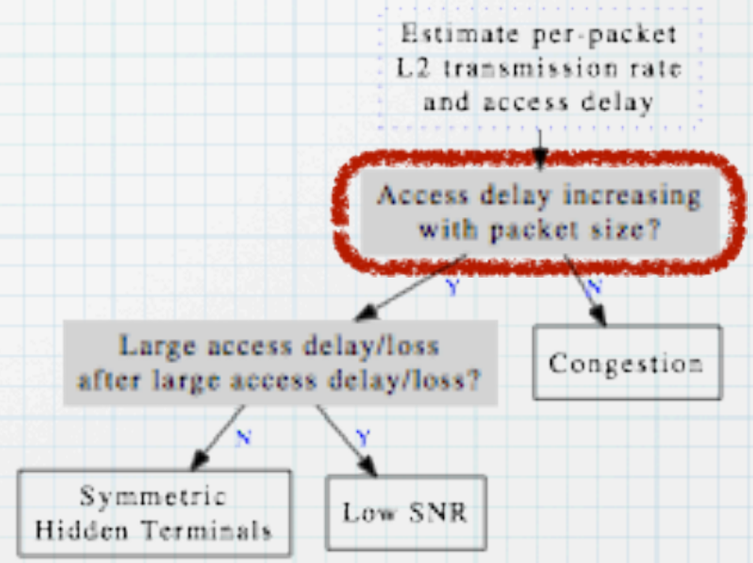
Bit errors increase with packet size:
Higher percentile access delays show trends.

Low signal strength
Hidden terminals



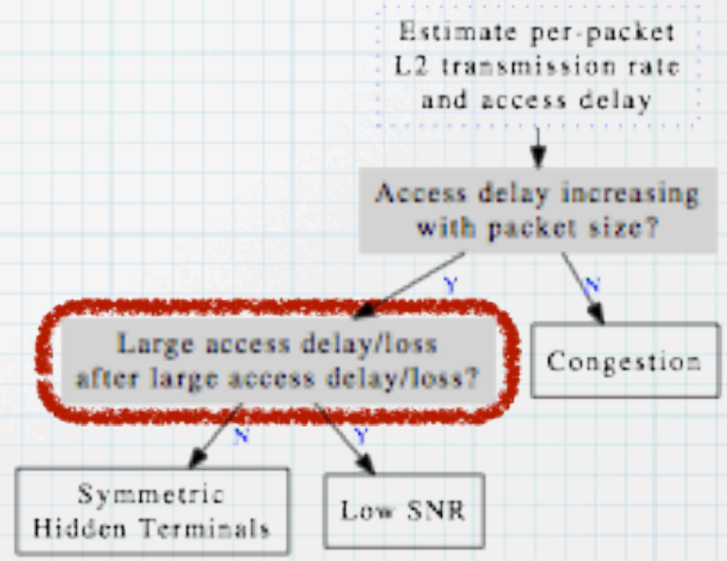
Congestion





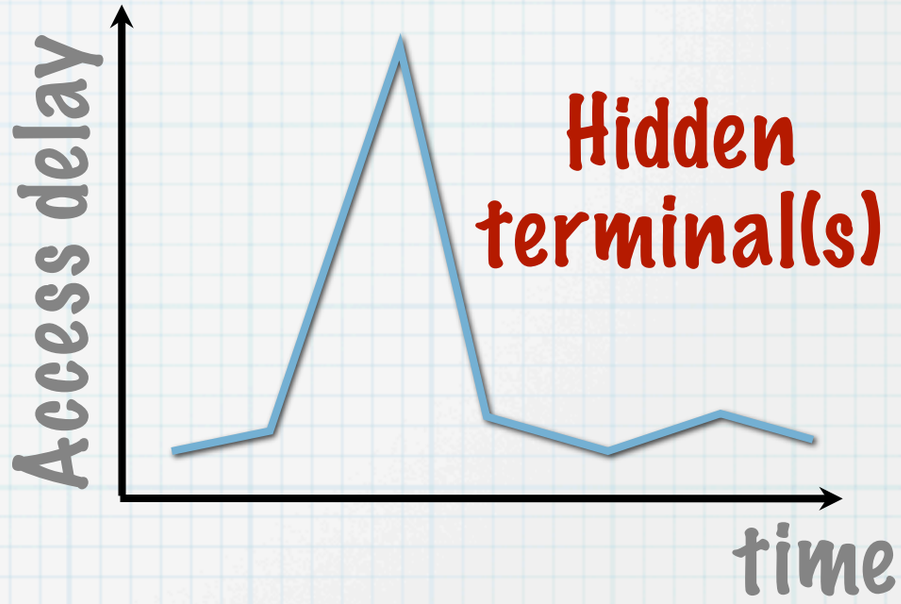
Hidden Terminals

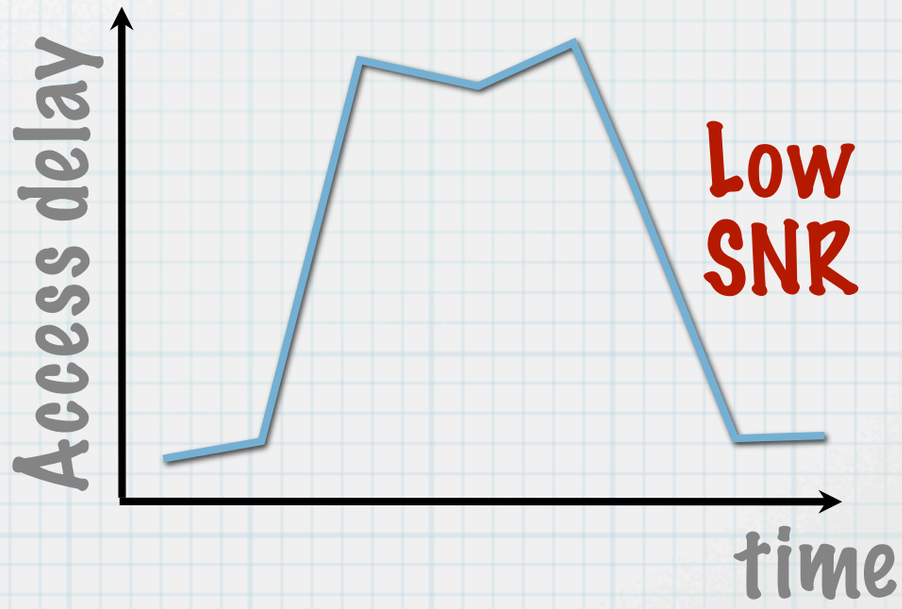
- Hidden terminals respond to frame corruption
  - by random backoffs
- Look at immediate neighbors of large delay or lost (L3) packets
  - hidden terminal: neighbor delays are small
  - low SNR: neighbors are similar



Hidden Terminals

- Define two measures:
  - p_u = P [high delay or L3 loss]
  - p_c = P [neighbor is high delay or L3 loss | high delay or L3 loss]
- Hidden terminal:
  - $p_c \approx p_u$

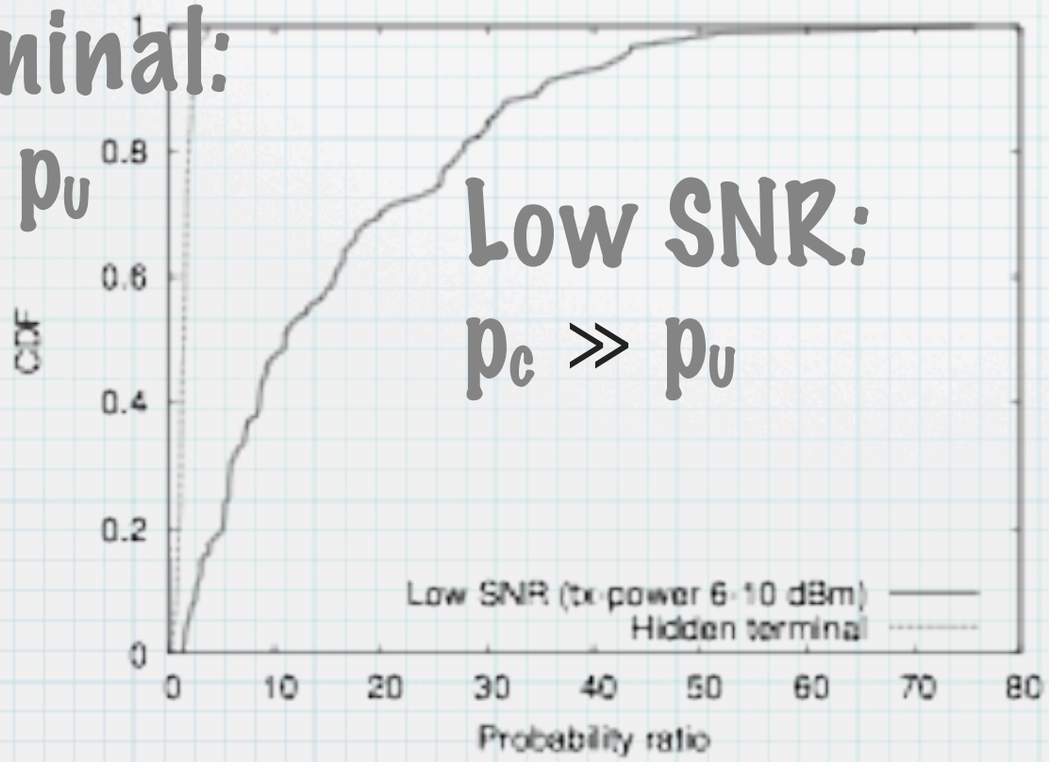




Hidden Terminals

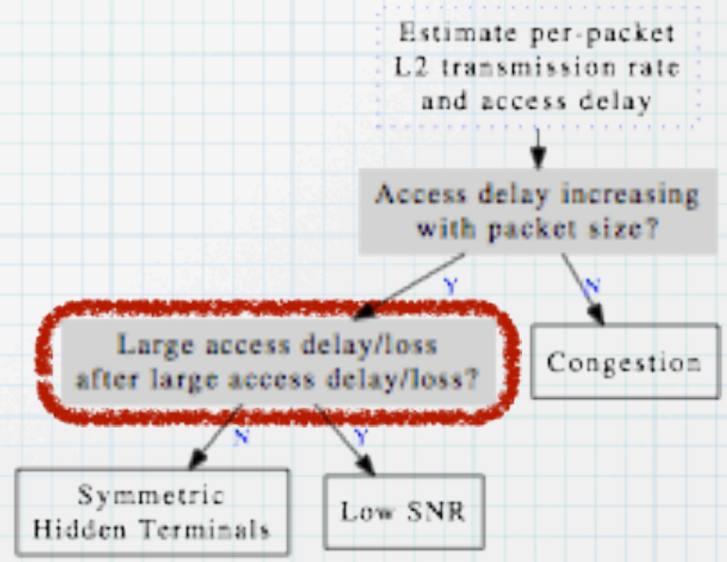
Hidden terminal:

$p_c \approx p_u$



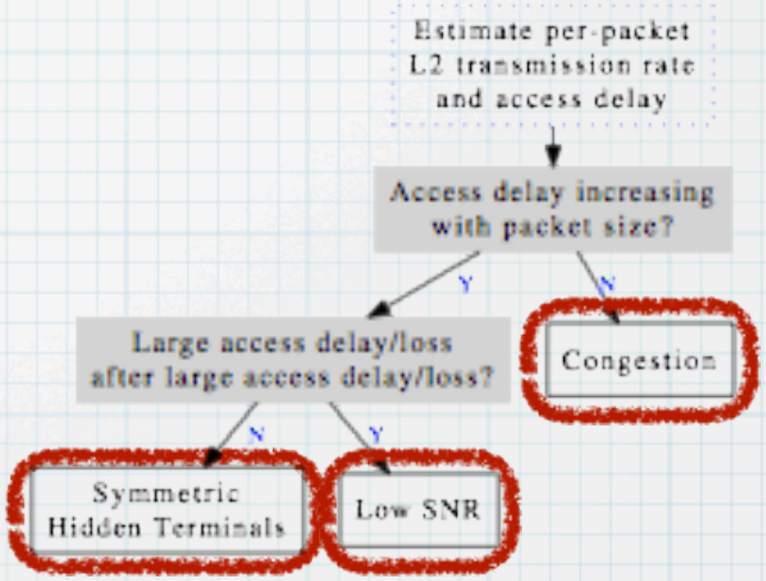
Low SNR:

$p_c \gg p_u$



Summary

* WLAN-Probe: tool for user-level diagnosis of 802.11 pathologies
  * Single 802.11 probing point
  * Commodity NICs
  * No kernel/admin-level changes
* Extensions:
  * wide-area probing for 802.11 diagnosis? ("M-Lab")
  * passive (TCP) inference?



Pythia:
Detection, Localization, Diagnosis of Wide-area Performance Problems

Pythia:
one tool, three objectives

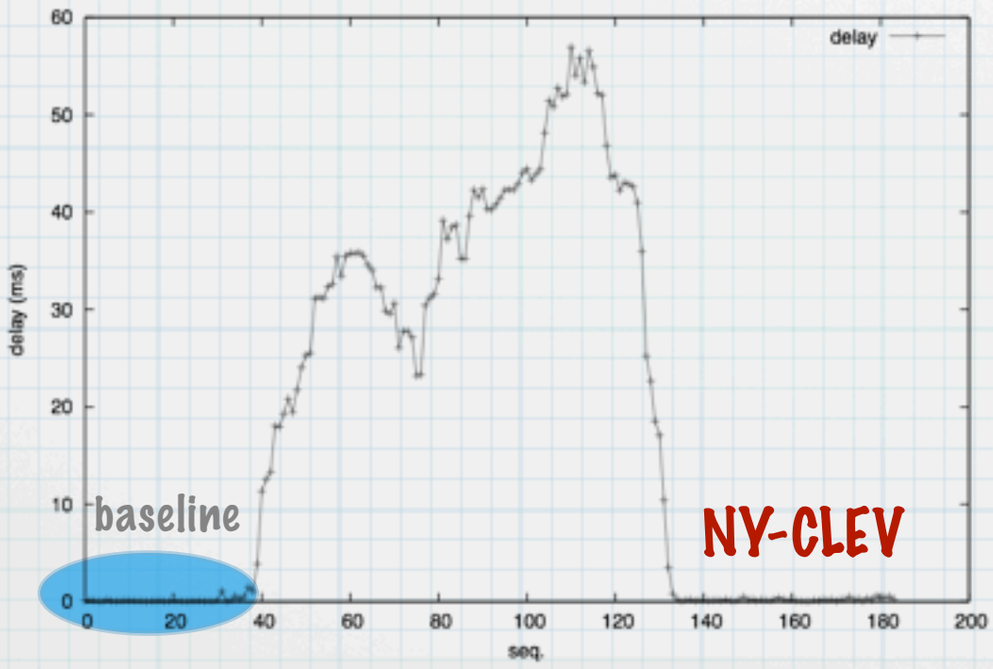
* Data analysis tool (e.g. perfSONAR data)
* Funded by DoE
* Detection:
  "noticeable loss rate between ORNL and SLAC on 07/11/11 at 09:00:02 EDT"
* Localization
  "it happened at DENV-SLAC link"
* Diagnosis
  "it was due to insufficient router buffers"

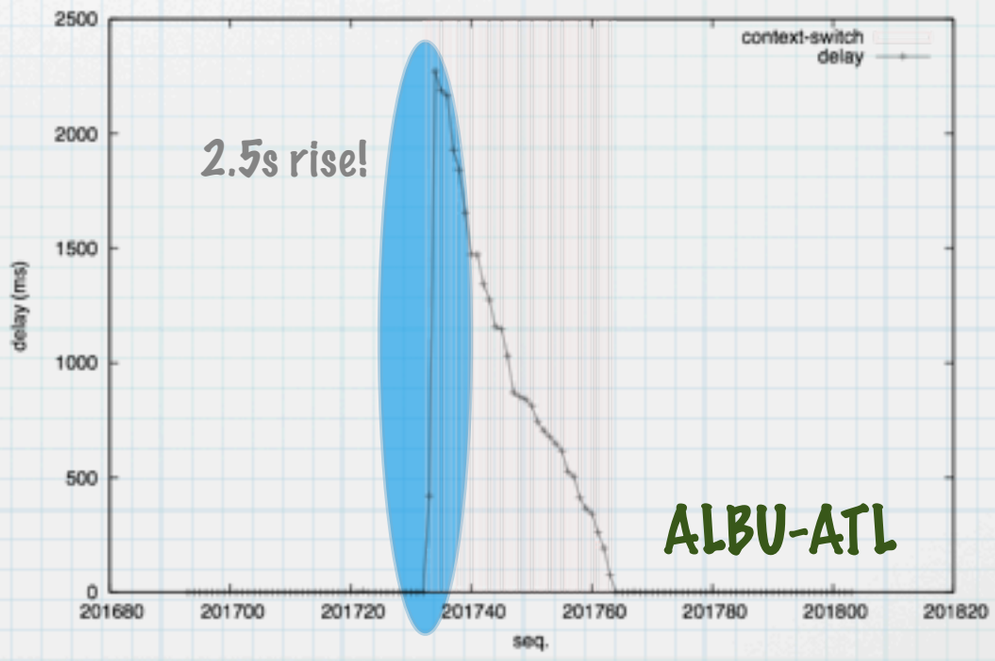
Pythia: Approach

- Existing diagnosis systems mine patterns and dependencies in large-scale network data (e.g., AT&T's G-RCA)
- Can we use domain knowledge?
  - useful in inter-domain diagnosis where data is not available
- Architecture:
  - sensors do full-mesh measurements of network
  - central server computes and renders results
  - Infrastructure: perfSONAR (ESnet & Internet2)

Detection

- First step: "Is there a problem?"
- Look for deviations from baseline
  - Delay: nonparametric kernel density estimates to locate baseline
  - Loss and reordering: empirical baseline estimates

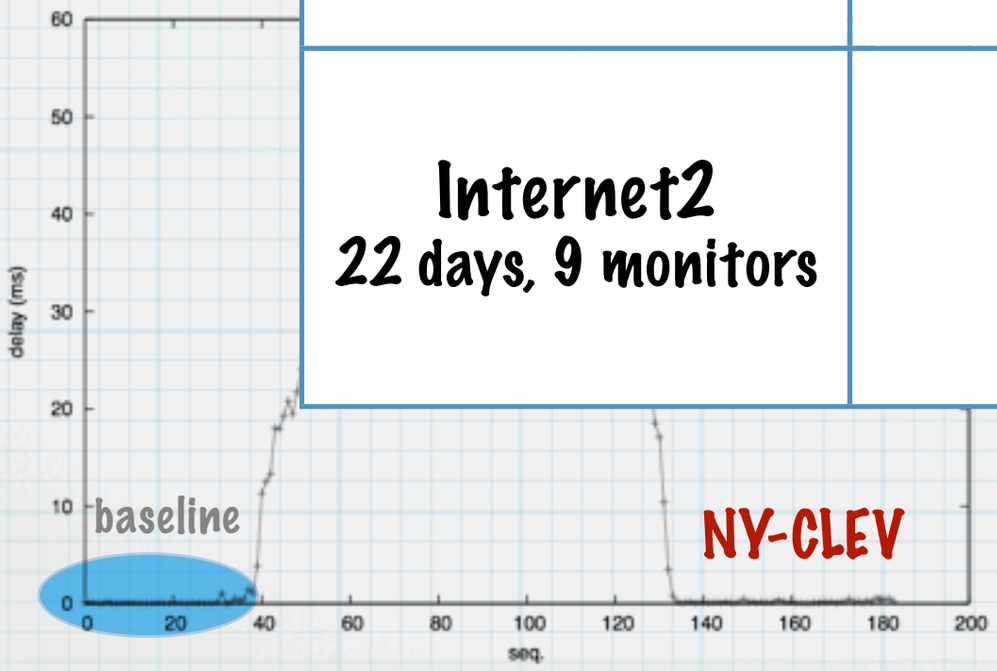


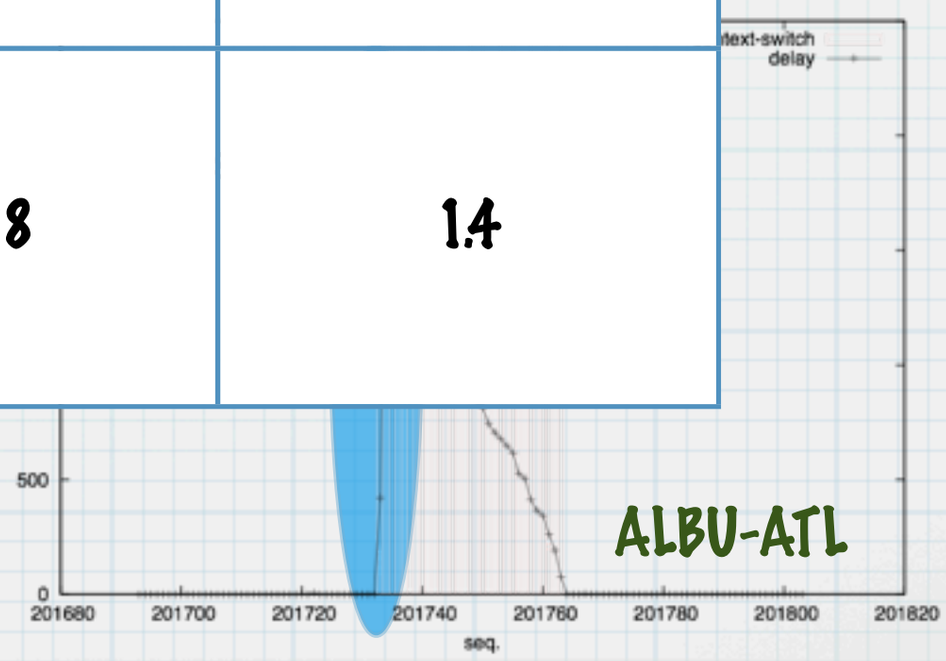


Detection

* First step: "Is there a problem?"
* Look for deviations from baseline
  * Delay: nonparametric kernel density estimates to
  *

	Estimated events	Events / path / day
ESnet 12 days, 33 monitors	933	0.1
Internet2 22 days, 9 monitors	2268	1.4





Diagnosis

* Follow-up to detection:
  "What is the root cause?"
* Diagnosis types:
  * congestion types
  * routing effects
  * loss nature
  * reordering nature
  * end-host effects

Congestion Nature

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Congestion Nature

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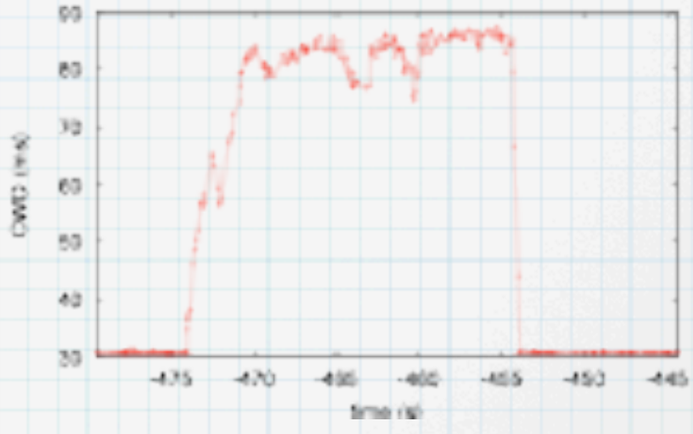
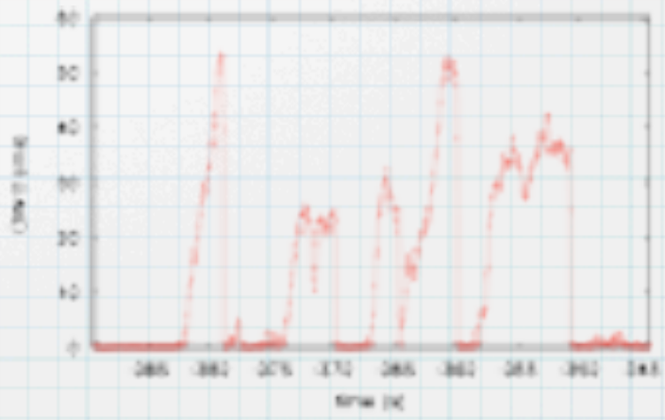
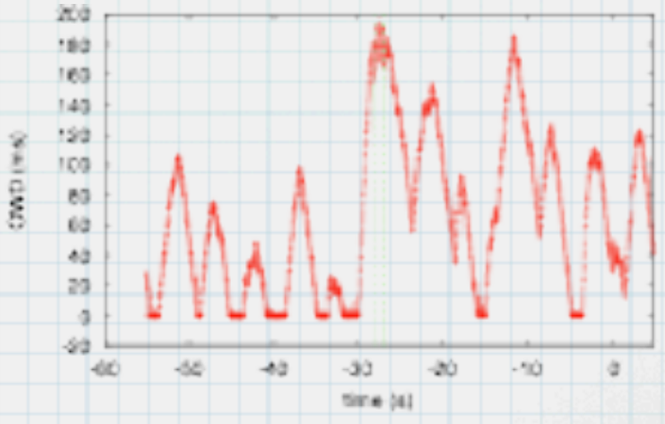
- "Bursty": intermittent queues (high jitter)
- Very small buffer
- Excessive buffer



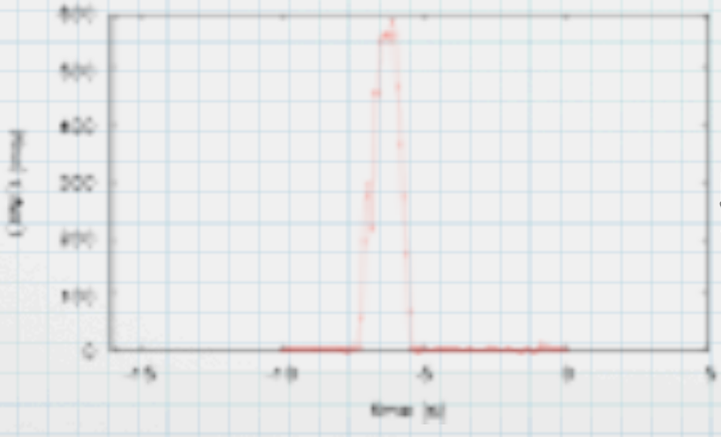
Overload: ESnet



Bursty: PlanetLab



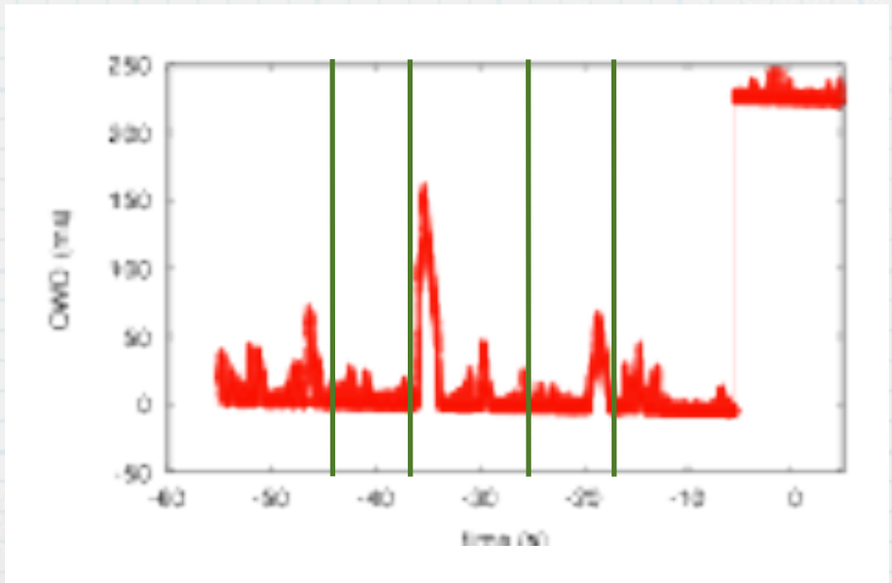
Bursty: Home link

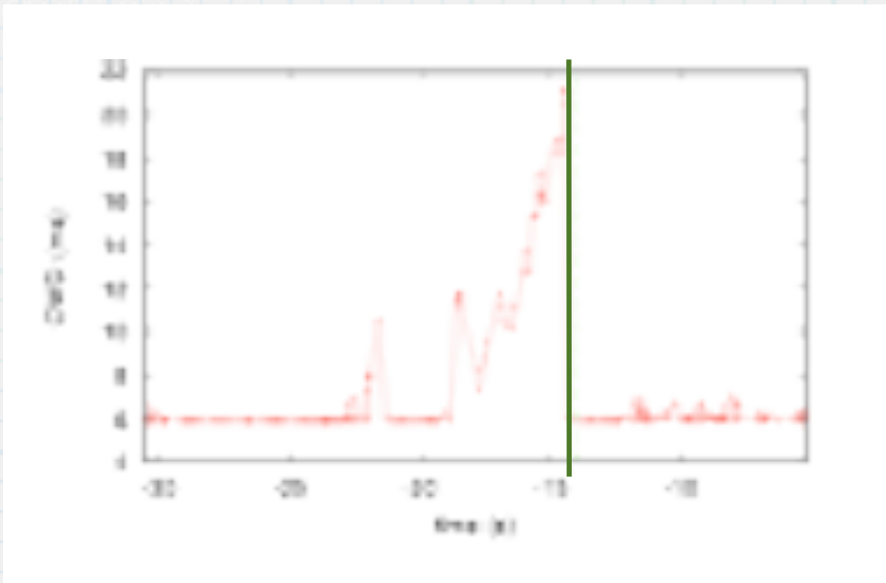


Excessive buffer: Home link

Loss Nature

* Random losses: (majority) losses do not correlate with high delays
* Otherwise: non-random losses





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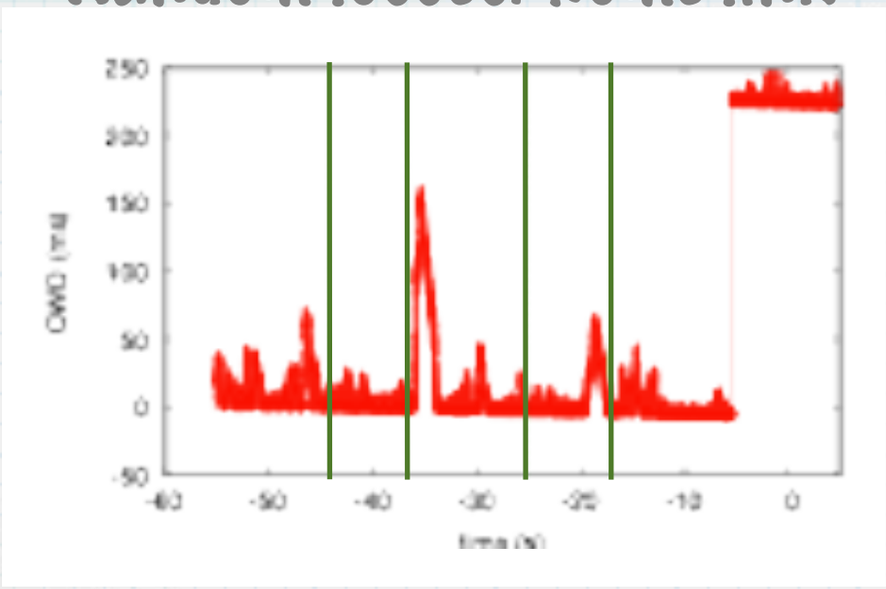
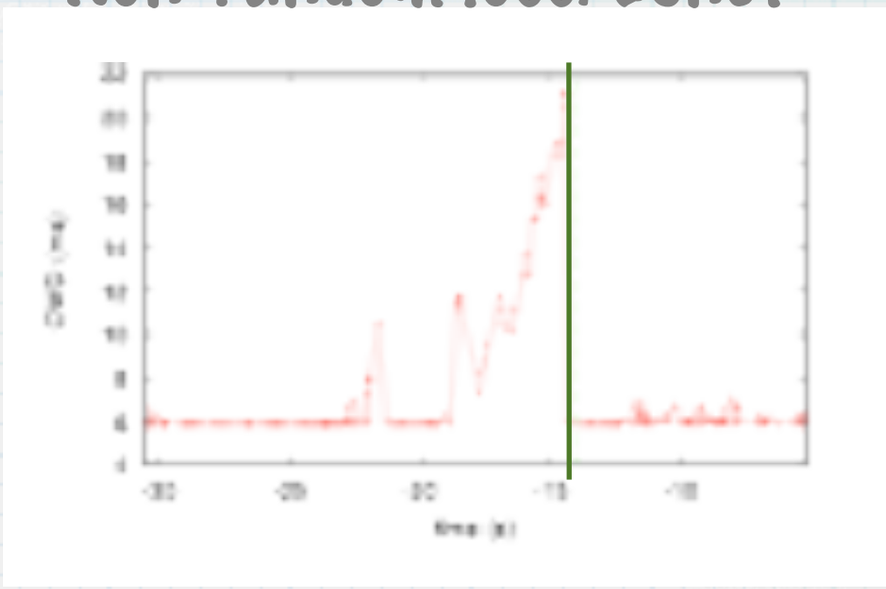
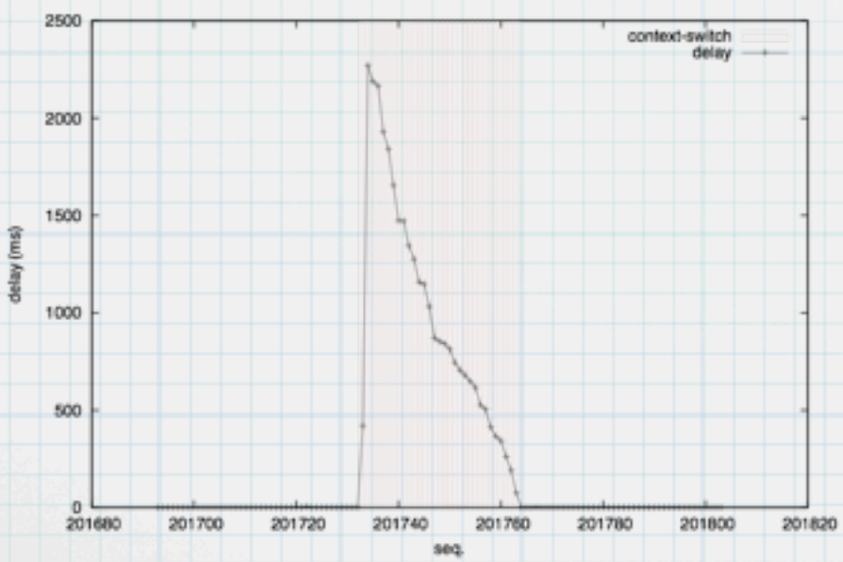


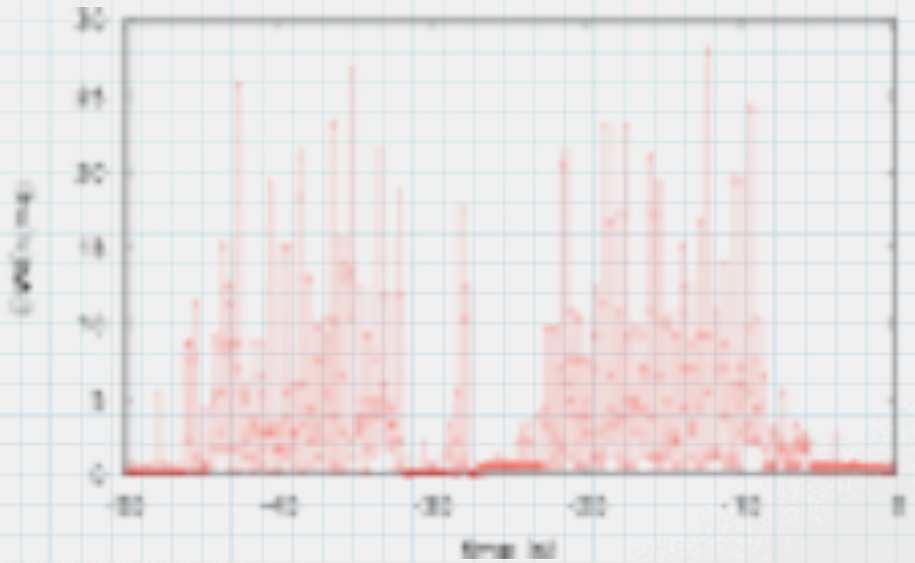
Non-random loss: ESnet



End-host Effects

* Delays and losses induced due to:
  * context switches
  * clock synchronization (NTP)
  * others (e.g., PlanetLab virtualization)





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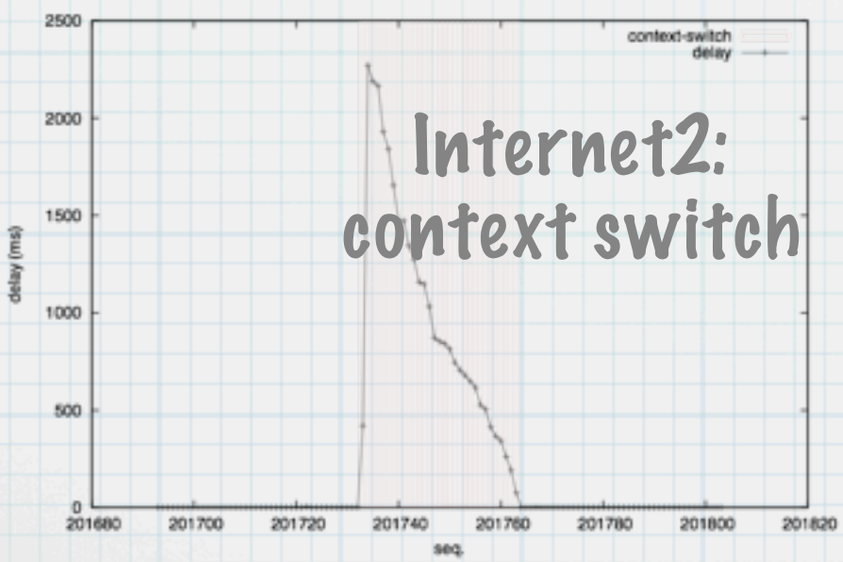
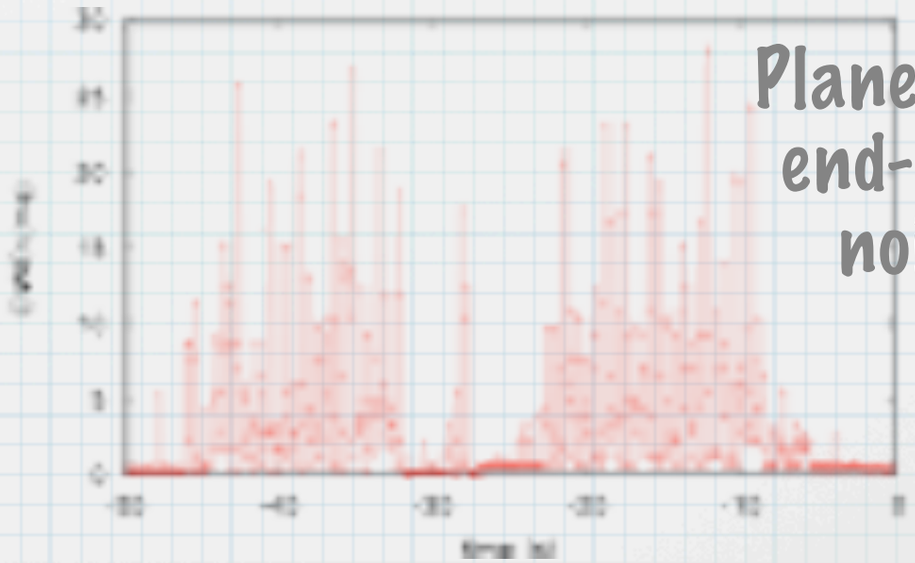


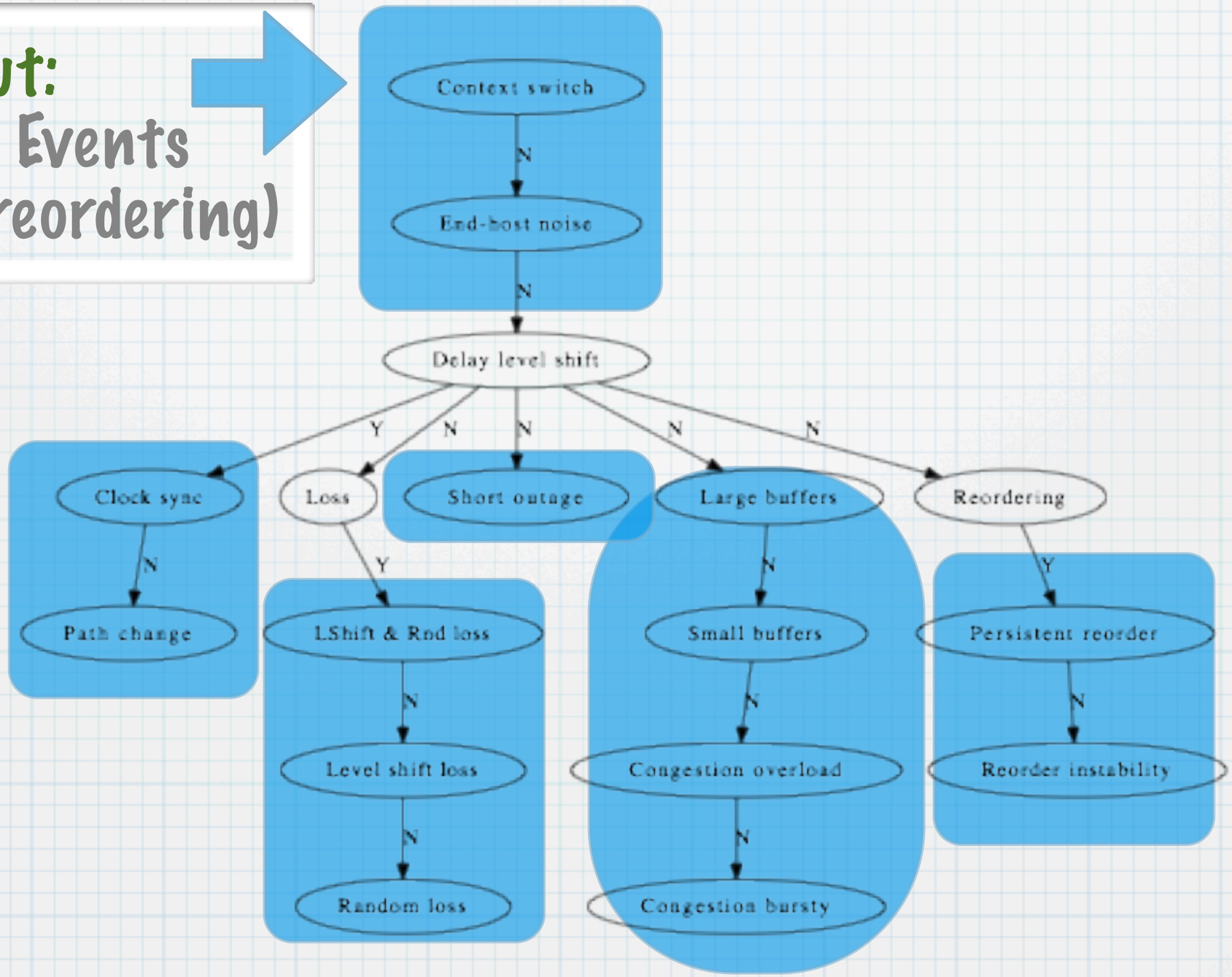
Internet2: context switch



PlanetLab: end-host noise

The Diagnosis Tree

Input:
Detected Events
(delay, loss, reordering)



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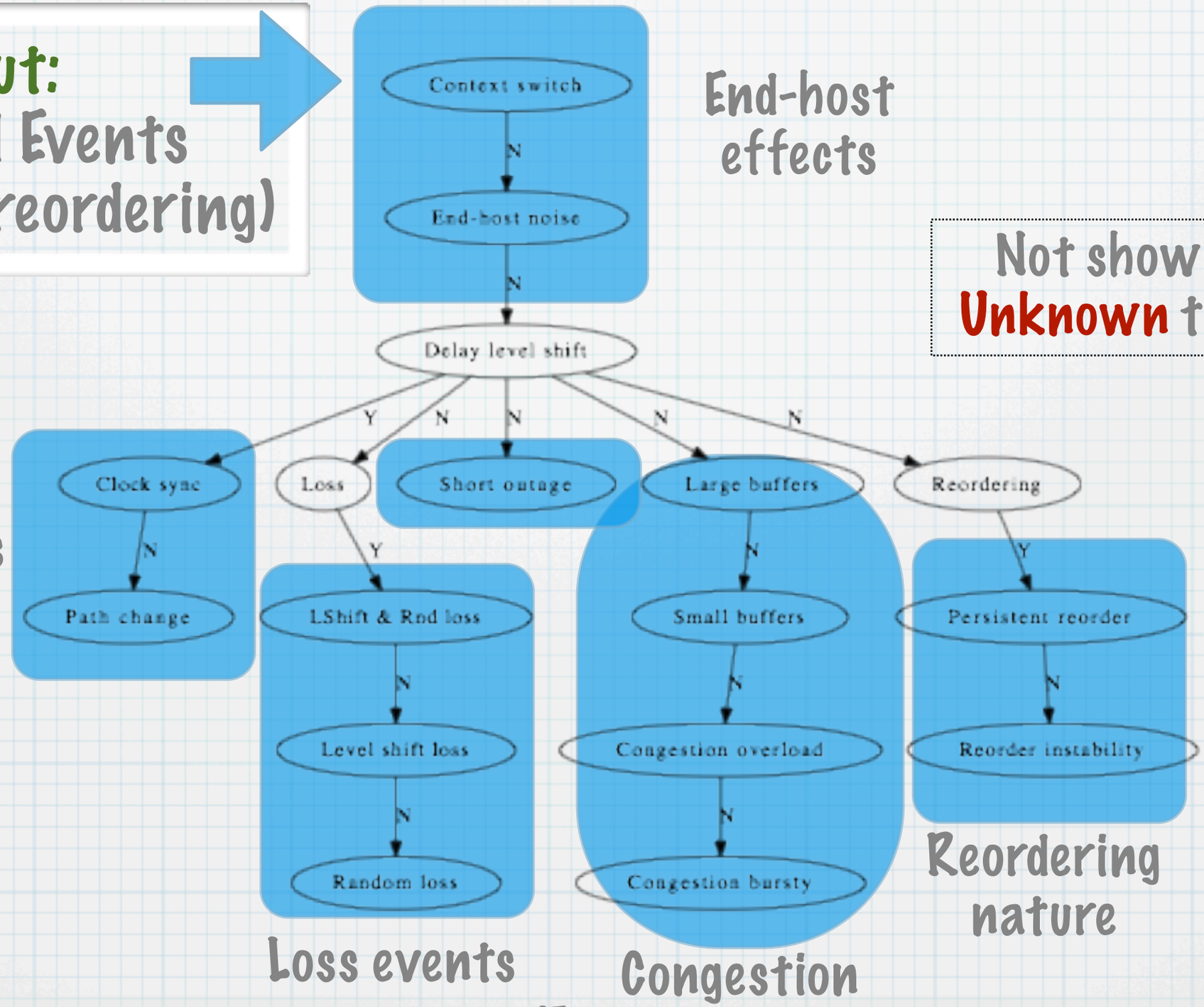


End-host effects

Not shown:
Unknown type

NTP vs. route events

Loss events

Congestion

Reordering nature

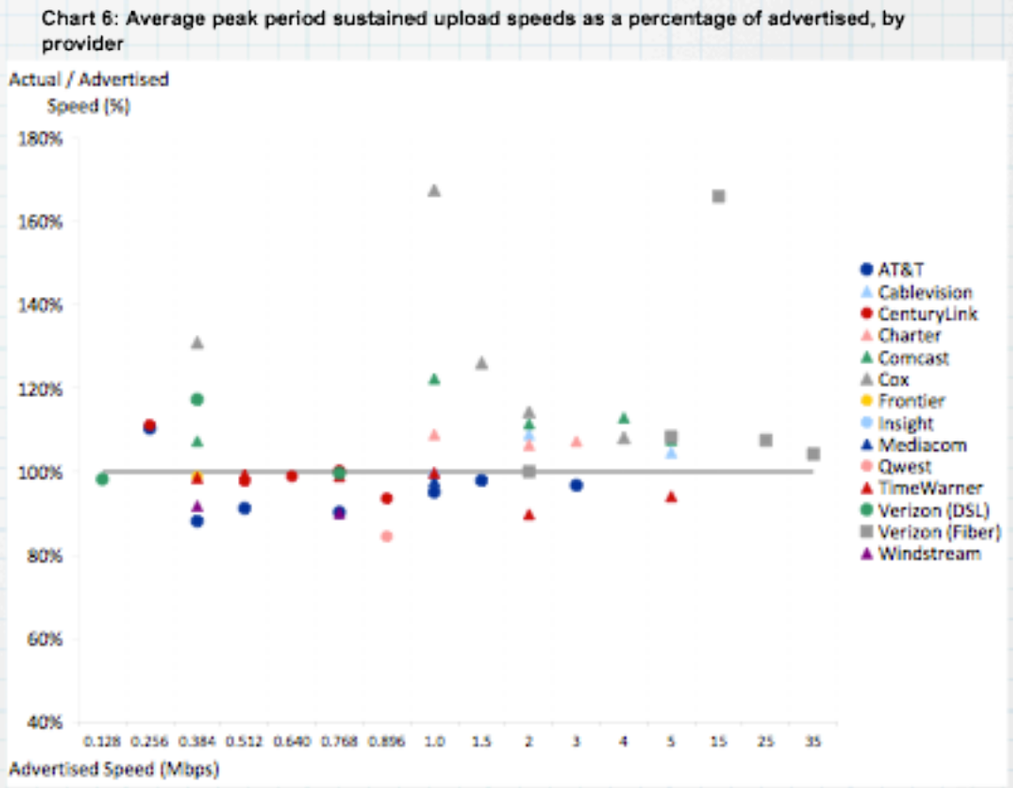
Pythia In-Progress

- More performance problem types...
- Unsupervised clustering to identify unknown events
- Open-source system implementation:
  - Detection, localization, diagnosis
  - Interfacing with data:
    - ESnet, I2, PL-testbed, broadband networks
  - Front-end for operators

ShaperProbe: update

The FCC 2011 report

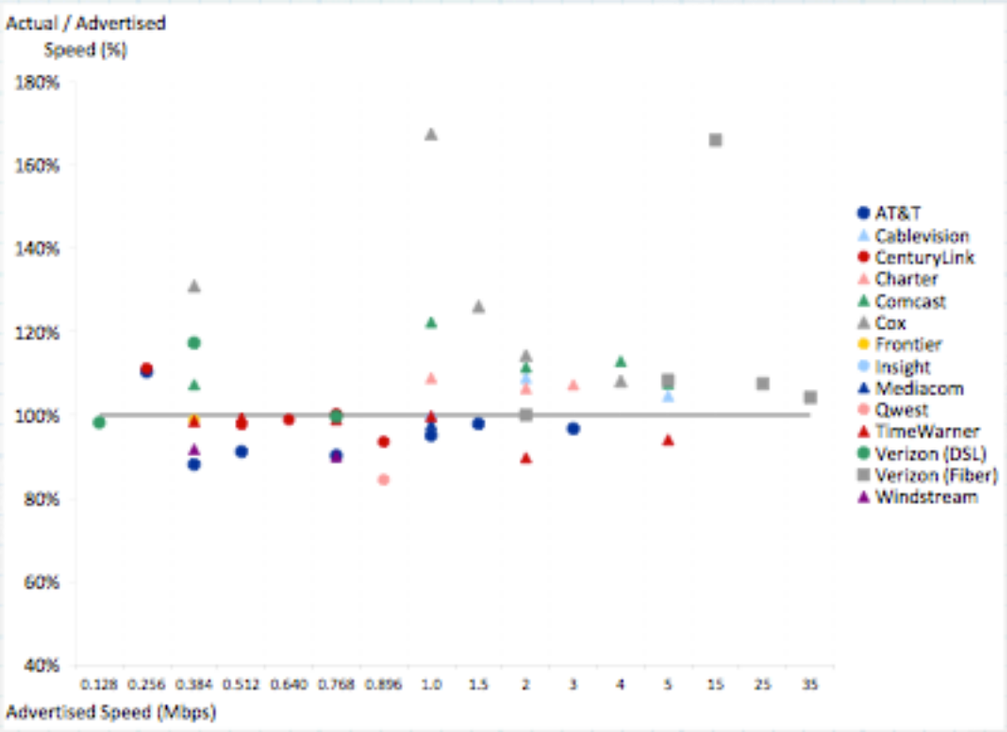
* FCC broadband study (2011) found that: "many cable service tiers exceed 100% of the advertised upstream rate"
  * We revisit this statement
  * FCC/SamKnows measured the sustained rate using a 30s TCP stream
  * If shaping kicks in after 25s, the sustained speed can't be measured



How long should we test?

	Capacity (Mbps)	Shaping rate (Mbps)	Burst duration (s)	Measured/sustained (%)
Comcast upstream	3.5	1	17	100
	5	2	15, 31	100, 250
	9	5.5	26	163
	14.5	10	19	100

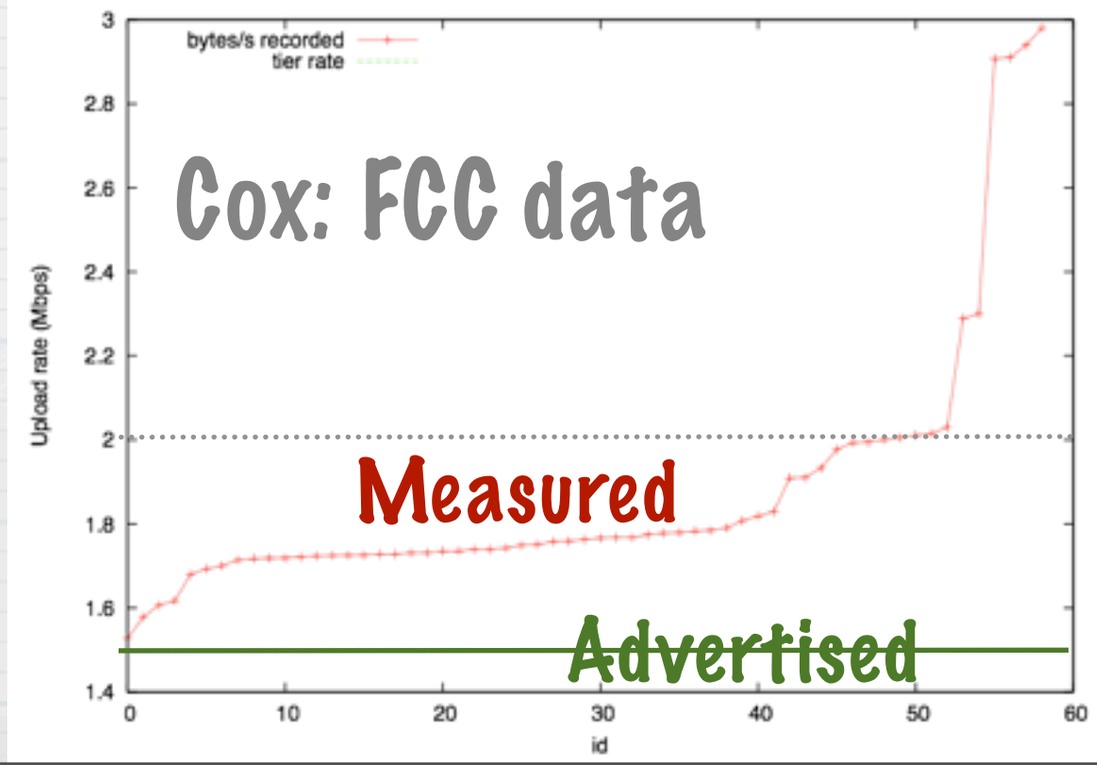
Chart 6: Average peak period sustained upload speeds as a percentage of advertised, by provider

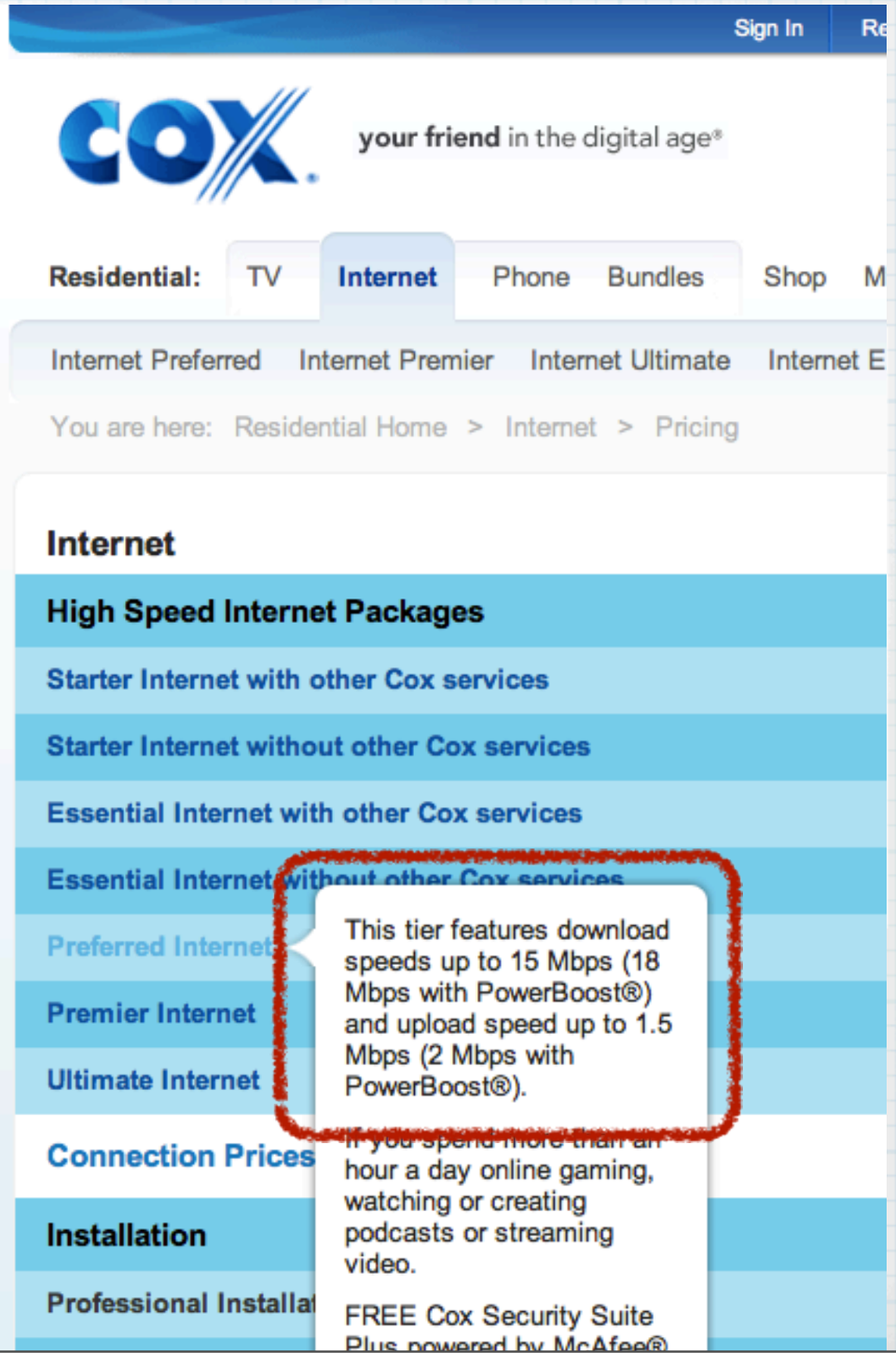


How long should we test?

	Capacity (Mbps)	Shaping rate (Mbps)	Burst duration (s)	Measured/sustained (%)
Comcast upstream	3.5	1	17	100
	5	2	15, 31	100, 250
	9	5.5	26	163
	14.5	10	19	100

	Capacity (Mbps)	Shaping rate (Mbps)	Burst duration (s)	Capacity/sustained (%)
Cox upstream	1.5	2	50	133





Thank You!

Diagnosing: Home Wireless & Wide-area Networks

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Localization

- Follow-up to detection:
  "Which link is bad?"
- Link/path performance levels
  discrete:
  e.g., high delay, medium delay, low delay
- Localization: minimum number of bad links that can explain bad paths
  - use greedy heuristic to solve iteratively

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Internet2 event:
28th Feb 2011, 00:10:51 GMT