End-to-end Performance Diagnosis

Re:
Solicitation of input contributions by IEEE 802.16’s Metrology Study Group <http://ieee802.org/16/sg/met> for IEEE 802.16’s Session #79 of 14-17 May 2012.

Base Contribution:
None

Purpose:
Consideration during discussions of Study Group activity and plans.

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The contributor is familiar with the IEEE-SA Patent Policy and Procedures:

End-to-end Performance Diagnosis

Partha Kanuparththy
Georgia Institute of Technology
This Talk: Tools

* End-to-end userlevel diagnosis of wireless performance problems

* Detailed diagnosis of “speed”
How is it relevant?

Lesson 1: Measure the right metrics

TCP throughput can be sensitive to single loss, and is a complex function of delays, loss rate meaningful? Should allow user to troubleshoot perf.

Lesson 2: Ensure Accuracy and Usability

Measurement methods accurate under typical confounding factors: small form factors, busy OS, ...? Do the tools work without needing OS changes?

Lesson 3: Diagnosis can be detailed

“5 Mbps throughput?” OR “10 Mbps throttled down to 2 Mbps after 7s”?
Detailed Diagnosis of “Speed”
Traffic Shaping/Policing

* Practice of dropping link capacity after some time
  * e.g., “PowerBoost” in cable ISPs
* What is a reasonable performance metric for “speed”?  
  * throughput = 4 Mbps?  
  * capacity = 7 Mbps; and sustained rate = 2 Mbps?

```
Time (s)  | Received rate (Mbps)
----------------------------------
1-8       | 7 Mbps -> 2 Mbps
Upload in 8s: 7 Mbps -> 2 Mbps
```

Tuesday, May 15, 2012
**ShaperProbe Service**

- Hosted on MeasurementLab.org
- Started mid-2009
- 1.5 million runs, 3k users/day; 5,700 ISPs

[Diagram of ShaperProbe Service]

`DiffProbe: Shaper Detection Module`

- Connected to server 38.102.0.111.
- Estimating capacity:
  - Upstream: 5961 Kbps.
  - Downstream: 22003 Kbps.
- The measurement will take up to 2.5 minutes. Please wait.
- Checking for traffic shapers:
  - Upstream: Burst size 3996-4087 KB; Shaping rate: 1045 Kbps.
  - Downstream: Burst size 9077-9726 KB; Shaping rate: 6346 Kbps.
- For more information, visit: http://www.cc.gatech.edu/~partha/diffprobe

Tuesday, May 15, 2012
Hosted on M-Lab
Started mid-2009
1.5 million runs, 3k users/day; 5,700 ISPs

ShaperProbe Service

Some are more accurate than others. There’s a tool called ShaperProbe that you can use, you can find a link to it from here or somewhere, that will give you the most accurate reading IMO.

ShaperProbe is actually meant to detect any shaping on your line, however because of that it runs tests for a longer time than any test site I know, resulting in a highly accurate reading.

I do know that I sustain ~2.8 MB/s via torrent or usenet when I’ve tried that to test. I haven’t found a reliable single-connection test as of yet (except for shaperprobe).

Yes the best way is for a large download going past the boost so above is my example. I have also found that shaperprobe seems to do a good job estimating both the boost and sustained levels.

Traffic Shaping with ShaperProbe

5,700 ISPs

Tuesday, May 15, 2012
Case-study: Comcast

* About 30k runs (Late 2009 – May’11)

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Tuesday, May 15, 2012
Home Wireless
Userlevel
Performance Diagnosis
Home Wireless
Userlevel
Performance Diagnosis

802.11 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, ...)

![Diagram of Home 802.11 Networks](image)
802.11 Performance Problems

Wireless clients see problems:
802.11 Performance Problems

- Wireless clients see problems:
  - Low signal strength (due to distance, fading and multipath)
802.11 Performance Problems

* Wireless clients see problems:
  * Low signal strength (due to distance, fading and multipath)
  * Congestion (due to shared channel)
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- Wireless clients see problems:
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  - Hidden terminals (no carrier sense)
802.11 Performance Problems

- Wireless clients see problems:
  - Low signal strength (due to distance, fading and multipath)
  - Congestion (due to shared channel)
  - Hidden terminals (no carrier sense)
  - Non-802.11 interference (microwave, cordless, ...)

The testbed is housed in the College of Computing at Georgia Tech.

In future work, we will conduct a more extensive evaluation of our measures with reverse-path responses. The measurements will allow us to distinguish between pathologies; further, we can estimate them with user-level measurements.

User-level active probing has been used to estimate wireless access delay because it captures important properties of the link layer delays which allow us to predict interference. Instead, with WLAN-probe, hidden terminals in the network are specific to MadWiFi's conflict graphs.

The proposed diagnostics are based on a certain component of a probing packet's One-Way Delay (OWD), referred to as the first element of the OWD.

The experiments demonstrate that to the extent of our knowledge, hidden terminals in the part of our WLAN may be nearby (e.g., in other home networks, and expand the set of diagnosed pathologies. User-level active probing has been used to estimate interference. Instead, with WLAN-probe, hidden terminals in the network are specific to MadWiFi's conflict graphs.

The proposed diagnostics are based on a certain component of a probing packet's One-Way Delay (OWD), referred to as the first element of the OWD. This component captures the following delay components: a) a (variable) backoff, b) the transmission delay of potential retransmissions, and d) certain constant delays (DIFS, SIFS).
Why not measure throughput?

Why not “upload speed = 5 Mbps” and “download speed = 7 Mbps”?

- congestion: 7 Mbps
  hidden terminal: 0.3 Mbps!

- allows user to better understand & troubleshoot connection
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
WLAN-Probe

* We diagnose 3 performance pathologies:
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We diagnose 3 performance pathologies:

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Figure 1: System architecture.
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
Life of 802.11 Packet

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Life of 802.11 Packet

* Delays in a busy channel:
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  - random backoffs

* Unavoidable variable delays:
  - TX-delay(s) (based on L2 TX-rate)
  - 802.11 ACK receipt delay

* Usually implemented in NIC firmware

* Can we measure these delays?
  - Yes!
Access Delay

- busy-wait
- re-TXs
- backoffs
- TX-delay
- ACKs
Access Delay

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

rate adaptation!
Access Delay

Captures channel “busy-ness” and channel bit errors

excludes 802.11 rate modulation effects

\[ d = \text{OWD} - (\text{TX delay}) \]

first L2 transmission

d = \text{OWD} - (\text{TX delay})
Access Delay

- Capture channel "busy-ness" and channel bit errors
- Excludes 802.11 rate modulation effects
- \[ d = \text{OWD} - (\text{TX delay}) \]
- First L2 transmission

rate adaptation!
Access Delay: TX delay

- \( d = \text{OWD} - (\text{TX delay}) \)
- TX-rate?
  - send 50-packet train with few tiny packets
  - use packet pair dispersion to get TX-rate:
    \[
    r_{i,1} = \frac{s_i}{\Delta_i - \Delta_{\text{tiny}}} \text{ current busy-wait delays}
    \]
  - Estimate a single rate for the train: rates remain same across train!
Access Delay: TX delay

* $d = OWD - (TX \text{ delay})$

* 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

  * Estimate a single rate for the train: rates remain same across train!

![](chart.png)
Diagnosis Tree

Estimate per-packet L2 transmission rate and access delay

Access delay increasing with packet size?

Large access delay/loss after large access delay/loss?

Symmetric Hidden Terminals

Low SNR

Congestion
Size-dependent Pathologies

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

Low signal strength
Hidden terminals

Congestion

Payload size (B)

Access delay (ms)

Access delay increasing with packet size?

Estimate per-packet L2 transmission rate and access delay

Large access delay/loss after large access delay/loss?

Congestion

Symmetric Hidden Terminals

Low SNR
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

Estimate per-packet L2 transmission rate and access delay

Access delay increasing with packet size?

Large access delay/loss after large access delay/loss?

Congestion

Symmetric Hidden Terminals

Low SNR
Hidden Terminals

Define two measures:

\* \( p_u = P [ \text{high delay or L3 loss} ] \)

\* \( p_c = P [ \text{neighbor is high delay or L3 loss} \mid \text{high delay or L3 loss} ] \)

Hidden terminal:

\* \( p_c \approx p_u \)
Hidden Terminals

Hidden terminal: 
\[ p_c \approx p_u \]

Low SNR: 
\[ p_c \gg p_u \]

Ratio: \[ p_c / p_u \] sufficient to diagnose hidden terminals.

Estimate per-packet L2 transmission rate and access delay

Access delay increasing with packet size?

Large access delay/loss after large access delay/loss?

Symmetric Hidden Terminals

Low SNR

Congestion
Thank You!

partha AT cc.gatech.edu

* Lesson 1: Measure the right metrics

* Lesson 2: Ensure Accuracy and Usability

* Lesson 3: Diagnosis can be detailed