Measurements close to users

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Network performance disruptions are frustrating

For users

For ISPs
Home networks can cause performance disruptions

- Cross-traffic competes for bandwidth
- Large buffers and heavy uploads increase delays
- Poor WiFi increases jitter and reduce bandwidth
  - Poor placement of access point
  - Interference from other access points
  - Contention from other devices
  - Non-Wifi interference (e.g., microwaves, baby monitors)
Goal

Assist users to diagnose performance problems in the home network

- Automatic detection: Is there a problem?
  - Focus on performance disruptions that affect users

- Problem identification: where is the problem?
  - More detailed diagnosis when problem is local
Outline

- User experience of network performance
  - Measuring network performance close to users
  - Correlating with user experience

- Home network performance: Home vs. Access
  - Measurement vantage point: end-host vs. gateway

- Fathom: browser-based measurement platform
Approaches to measure performance close to users

- Active probing
  - Based on issuing probes, analyzing response

- Passive analysis of user’s traffic
  - Tap incoming and outgoing traffic: tcpdump, pcap
  - Monitor status of TCP connections
RTT from active probes: ping

probe
ICMP
echo request
d
m
reply
ICMP
echo reply
t0
RTT
m
d
t1
probe
reply
RTT from passive measurements: tcptrace
### Other end-to-end performance metrics

<table>
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<tr>
<th>Metric</th>
<th>Active</th>
<th>Passive</th>
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<td>Loss</td>
<td>ping/iperf</td>
<td>TCP retransmissions</td>
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<td>Throughput</td>
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<td>Delay variation/jitter</td>
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<td>Available bandwidth</td>
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<tr>
<td>Capacity</td>
<td>ShaperProbe iperf UDP</td>
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- More metrics
  - IETF IP Performance Metrics Working Group

- More tools
  - [http://www.measurementlab.net/](http://www.measurementlab.net/)
## Summary: passive vs. active

### Passive
- No need to inject traffic
- Measures performance experienced by users
- Measures destinations that don’t respond to probes

- Privacy concerns
- Collection overhead
- Only measures paths with traffic

### Active
- No need to tap user’s traffic
- Measure performance of paths even without traffic
- Often used for diagnosis

- Not direct measure of user experience
- Probing overhead
  - Cover a large number of paths
  - Continuous measurements
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Challenges in measuring user perception

- User perception varies
  - Per user, per environment, per application
  - For a given user according to external factors
  - Controlled environment versus field

- Can’t ask frequent user feedback
  - At most ~10 per day
  - Orders of magnitude more network measurements (every millisecond)
Approaches to obtain user feedback

- Offline: out-of-bad feedback
  - Interviews, diaries
  - Pro: detailed feedback
  - Con: infrequent feedback; hard to correlate with network metrics

- Online: Integrated in measurement tool
  - System triggered, user triggered
  - Pro: more frequent feedback; automation is easier
  - Con: feedback can be harder to interpret
Online user feedback

- Which questions to ask?
  - Easy to fill, not to annoy users
  - Enough information to interpret results

- When to ask the questions?
  - User triggered: depends on user
  - System triggered: Experience sampling mechanism
    - Cover diverse levels of network performance
Example: HostView

- A data collection tool for laptops (Mac OS / Linux)
- Mixed methodology
  - Network traces
  - Application process names
  - Machine metrics
  - User feedback
- Deployment (Nov 2010 – Feb 2011)
  - 40 users (14 countries)
  - Most users ran tool for one month
HostView: User feedback

- **System Triggered feedback**
  - Experience sampling methodology (ESM)
  - Triggered based on state of machine
  - 5 short questions about network performance
  - At most 3 times a day

- **User Triggered feedback**
  - “I’m annoyed” button 😞
  - Same questions as in ESM
  - Can trigger as often as user wants
HostView: Example question

4. Did you experience any of the following problems, in the last five minutes? (Click all that apply)

- [ ] Can't connect to some sites or services
- [ ] Poor voice or audio quality
- [ ] Slow download or upload
- [ ] Slow browser
- [ ] Poor video quality
- [ ] Any other problem(s):
- [ ] None
User vs. network reporting

- **User perspective**
  - Good/poor performance according to the user

- **Network and system perspective**
  - Good/poor performance according to network metrics

**Question:** Do these co-occur?
Can’t connect to some sites or services

![Graph showing RTT and TCP RST/TCP RETR over time in minutes.](image-url)
Everything is good!
Summary: correlating user feedback with network performance

- Hard to get feedback from users
  - Many network performance samples without feedback
  - Users are diverse in how they report a problem

- Raw network metrics alone are not enough
  - Not all outliers affect the user perception
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What is the speed of my access link?

Home Network: AT&T DSL

6 Mbps Down, 512 Kbps Up

access link

ISP Network

speedtest.net: 4.4 Mbps, 140 Kbps
Netalyzr: 4.8 Mbps, 430 Kbps

End host measurements are affected by confounding factors
Gateway better captures speed of access link

Home Network: AT&T DSL
6 Mbps Down, 512 Kbps Up

speedtest.net: 4.4 Mbps, 140 Kbps
Netalyzr: 4.8 Mbps, 430 Kbps
Gateway: 5.6 Mbps, 460 Kbps

Gateway can account for confounding factors
Gateway deployments

- **SamKnows**
  - Active measurements: throughput, delay, web performance, etc.
  - FCC deployment: ~10,000 gateways

- **BISmark**
  - OpenWRT router modified to perform active/passive measurements
  - Georgia Tech deployment: ~100 gateways
Interpreting throughput results

Different techniques measure different aspects of throughput
Summary: Gateway vs. end-devices

- **Home gateway**
  - Ideally placed between home devices and Internet
  - But, have limited resources and deployment is harder

- **Instrument end-devices**
  - Observe poor user experience
  - But, have limited view of home network and development is harder
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End-host measurements are challenging

- Measurement from end-hosts are vital
  - Researchers to understand Internet
  - Practitioners to diagnose user problems

- Hard to deploy measurements
  - Developers: Portability, safety
  - Users: need to install new software
A browser-based measurement platform

- Why browser?
  - Flexibility, deployability
  - Ubiquity of browser

- Fathom: Firefox extension
  - Measurement API in JavaScript
  - Web page performance
  - System performance
  - Active measurements