Locating Performance Bottlenecks in Home Networks

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Problem: Service Calls are Costly

- The cost of a service call to an ISP is $9–25
  - "Truck rolls" cost considerably more
- As many as 75% of these calls are caused by problems *within the home network*
- **Can we help the user help themselves?**
  - **How to determine whether the problem is the ISP or the home wireless network?**

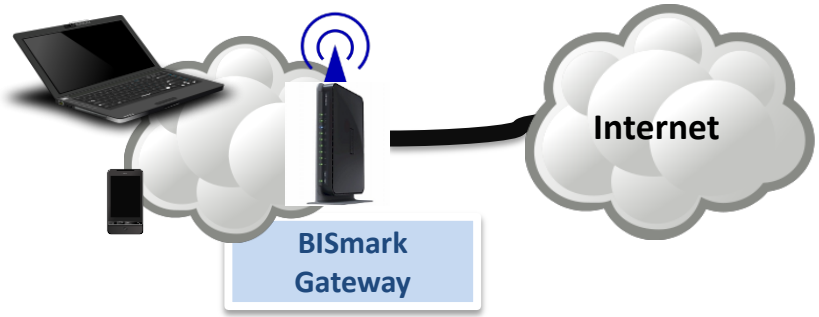
Causes of Problems Inside the Home

- Bad wireless connection
- Poor placement of access point
- Interference from other access points and devices
- Contention from other devices
- Cross-traffic on the wireless network
- Non-Wifi interference (baby monitors, etc.)

Challenges

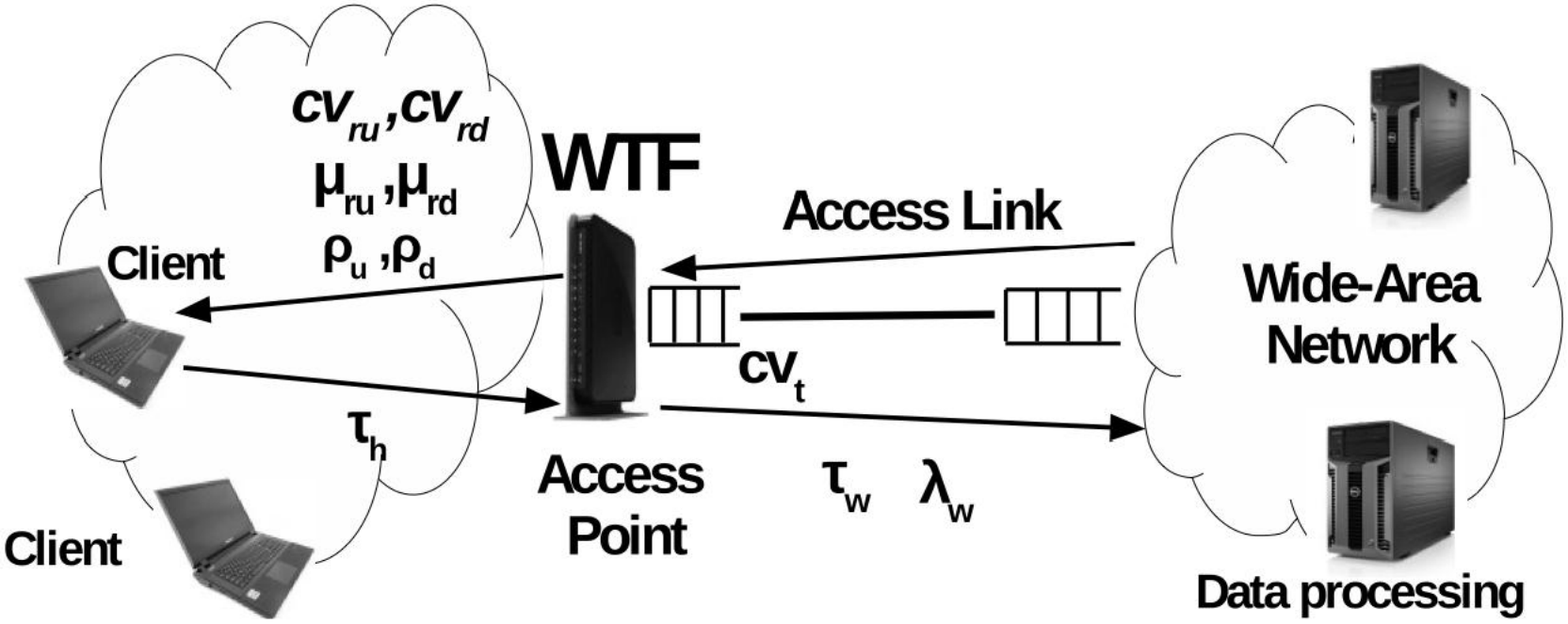
- Active measurements are invasive, inaccurate
  - Wireless performance is too variable
  - The probe traffic itself disrupts the wireless network (interference, contention)
- Conditions are dynamic
- Performance characteristics depend on vantage point

Approach: Deploy on the Gateway



- Advantages
  - "Demarcation point" between the home wireless network and the access link
  - Can observe all traffic passing through the router
- Disadvantages
  - Limited resources for traffic capture and analysis
  - Deployment is more difficult

Overview of Parameters Measured



- Coefficient of variation of packet interarrival times
- Wireless retransmission rates (both directions)
- Wireless bitrates (both directions)
- Round-trip time between client and access point
- Wide-area packet loss rate and round-trip time

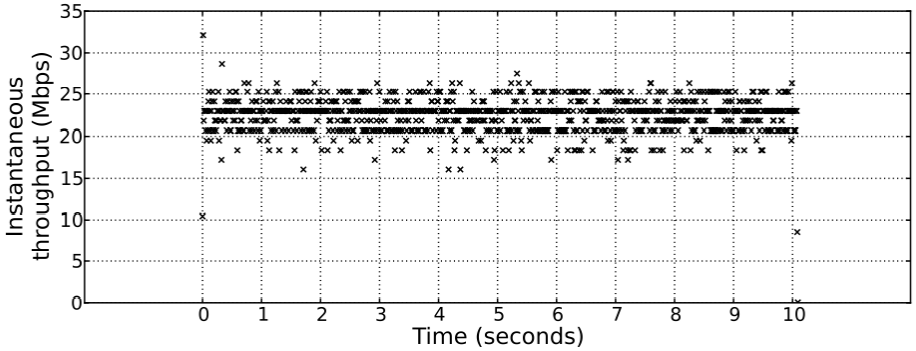
General Approach

1. Identify **access network bottlenecks**
2. Identify **wireless network pathologies**
3. Identify **wide-area pathologies**

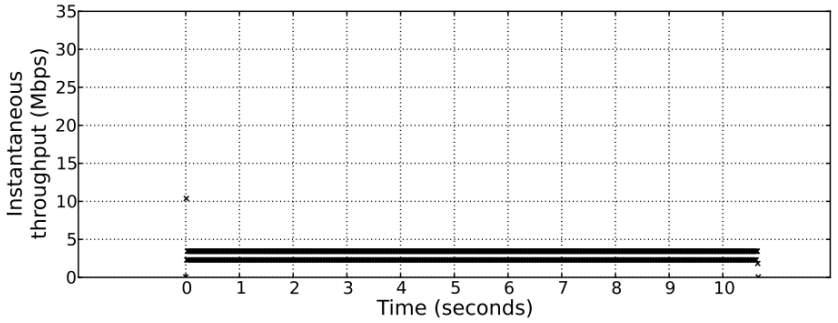
Identifying Wireless Bottlenecks

- Measure **instantaneous throughput**
  - When wireless link is the bottleneck, throughput is more variable
  - Caused by variability in packet interarrival times
- Measure **coefficient of variation of packet interarrival time**

Wireless Link Bottleneck



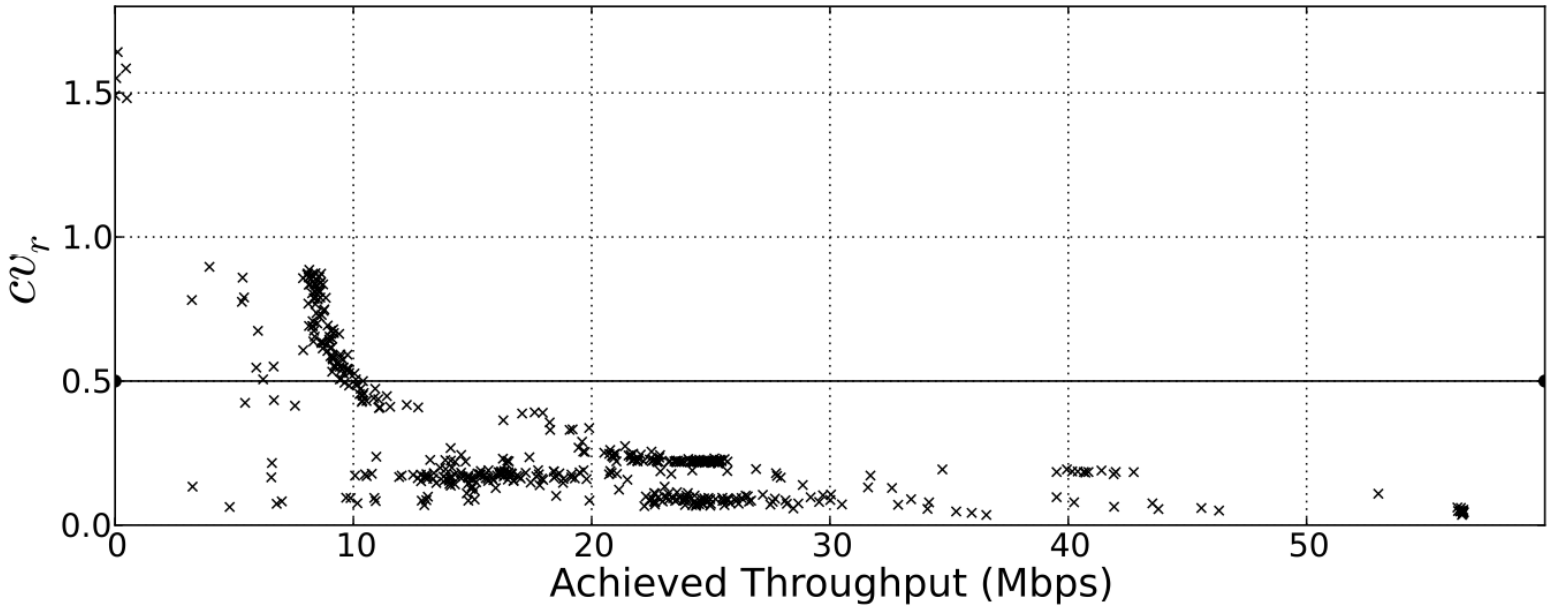
Access Link Bottleneck



Accuracy is near 100% for a wide range of values, across many network types.

Identifying Wireless Pathologies

- Variable bitrate correlates with low achieved throughput



Parameter Settings

Parameter	Threshold	Conclusion
cv_t	≤ 0.8	Access link bottleneck.
cv_r	≤ 0.5	Possible poor wireless.
μ_r	≤ 0.5	Possible poor wireless.
ρ_u,ρ_d	≥ 0.1	Possibly lossy wireless.
τ_h	≥ 15 ms	Possible contention in wireless.
τ_w	≥ 100 ms	High latency.
λ_w	≥ 0.02	Loss in the wide area.

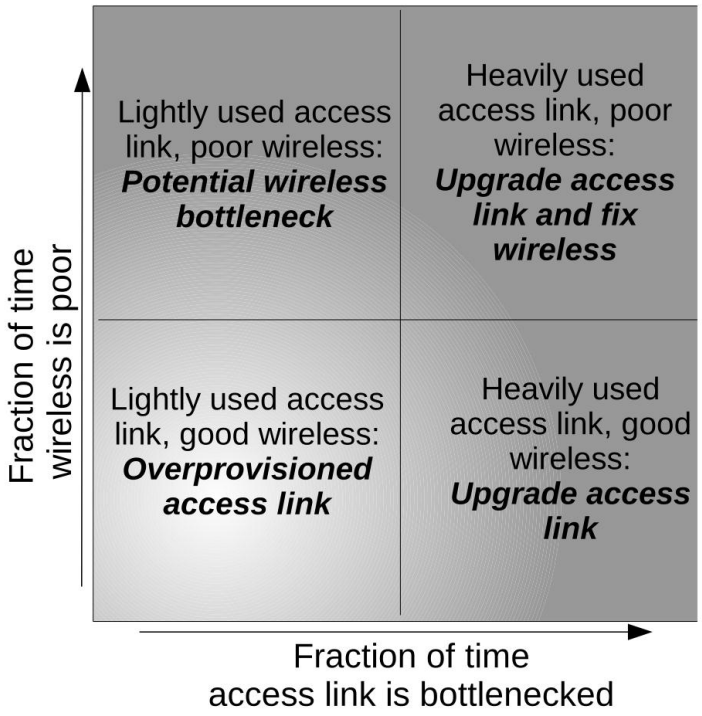
- Smooth packet arrivals on access link indicate upstream bottleneck
- High RTTs between client and AP suggest contention
- Smooth packet arrivals, bitrate variation, and retransmissions indicate poor wireless channel

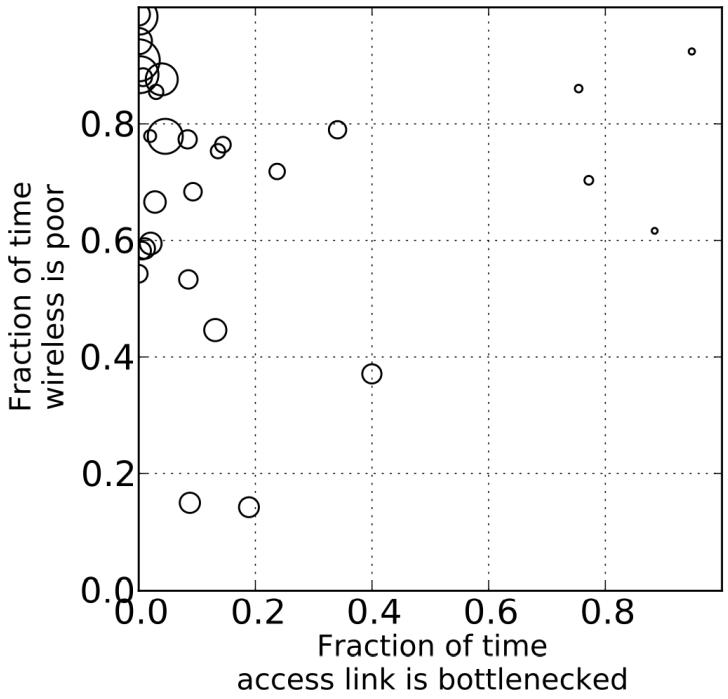
Other Wireless Pathologies

- Low normalized average bitrate
- High TCP Round Trip time between client and access point
  - Indicates possible contention in wireless

Main Takeaway

Once downstream throughput exceeds about 10 Mbps, bottlenecks are typically inside the home.

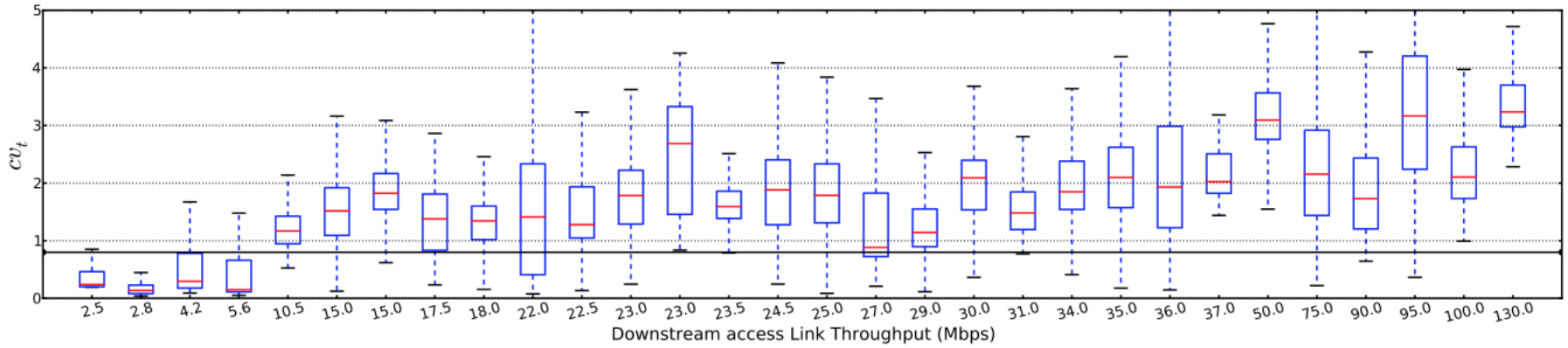




Exploring Performance Across Homes

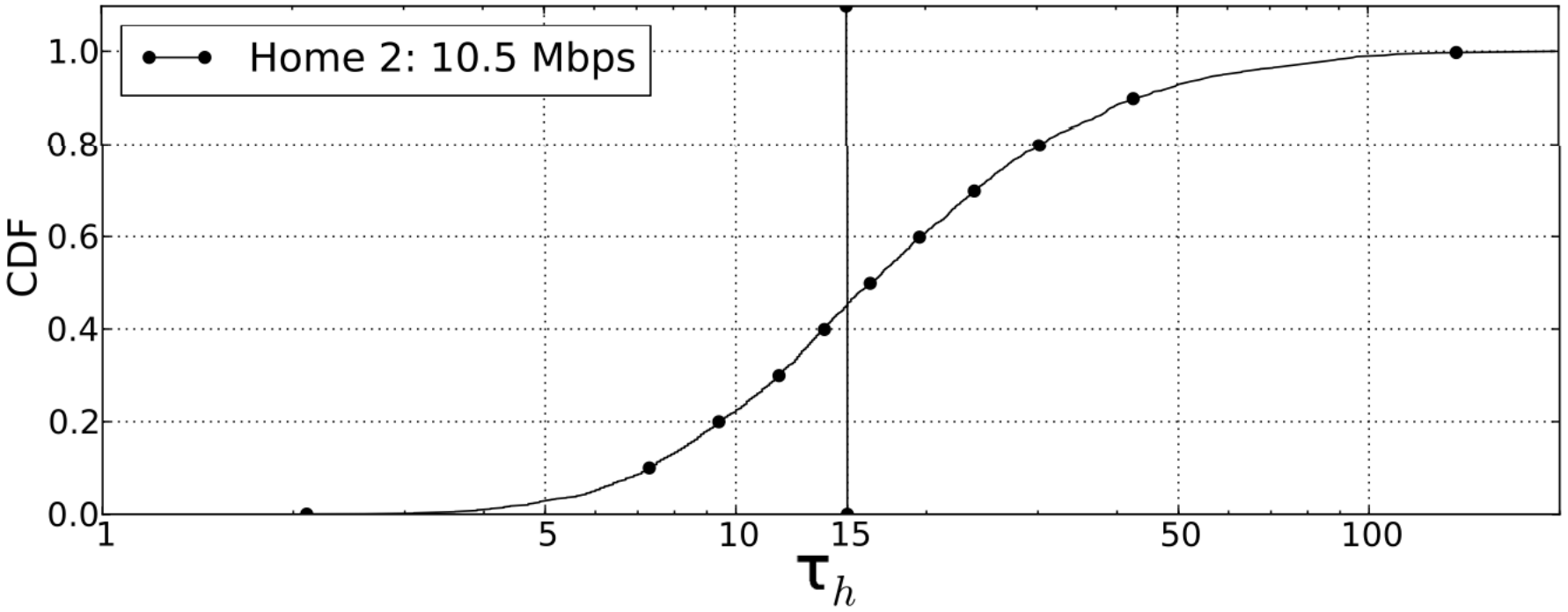
Once downstream throughput exceeds about 10 Mbps, bottlenecks are typically inside the home.

Coefficient of variation in packet interarrival times across each home, as a function of throughput. Higher values mean wireless bottleneck.



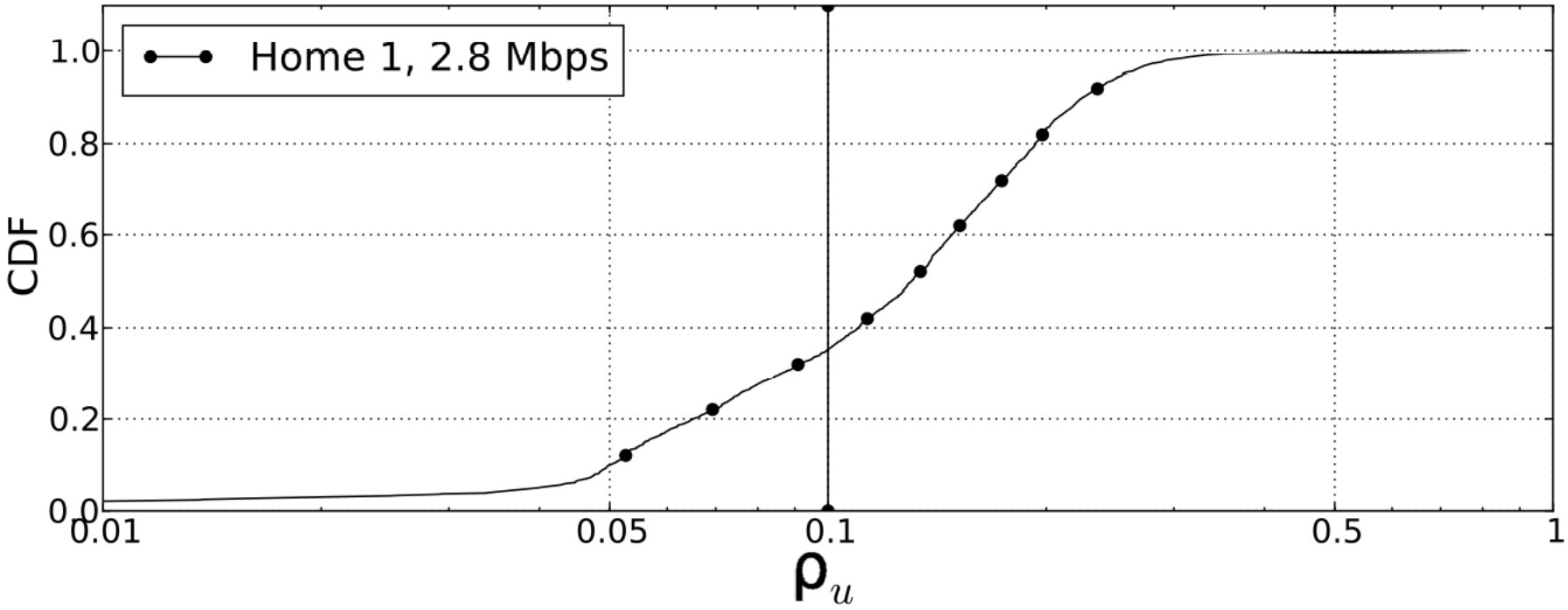
Case Study: High In-Home Latency

RTT between the client and the AP can be high. Often caused by contention.



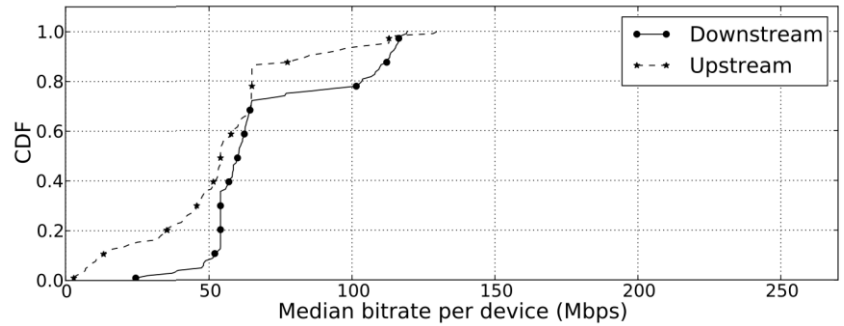
Case Study: Retransmissions

Excessive retransmissions can occur.
In this home, nearly half of frames had at least a 10% retransmission rate.



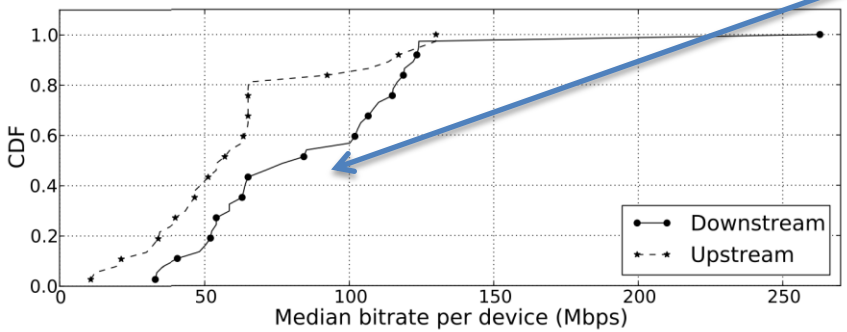
Effect of 2.4 vs. 5 GHz Channels

- Number of devices connected, access points visible (and how this affects performance)
- **Example:** Higher median bitrates on 5 GHz channels (possibly due to less contention)



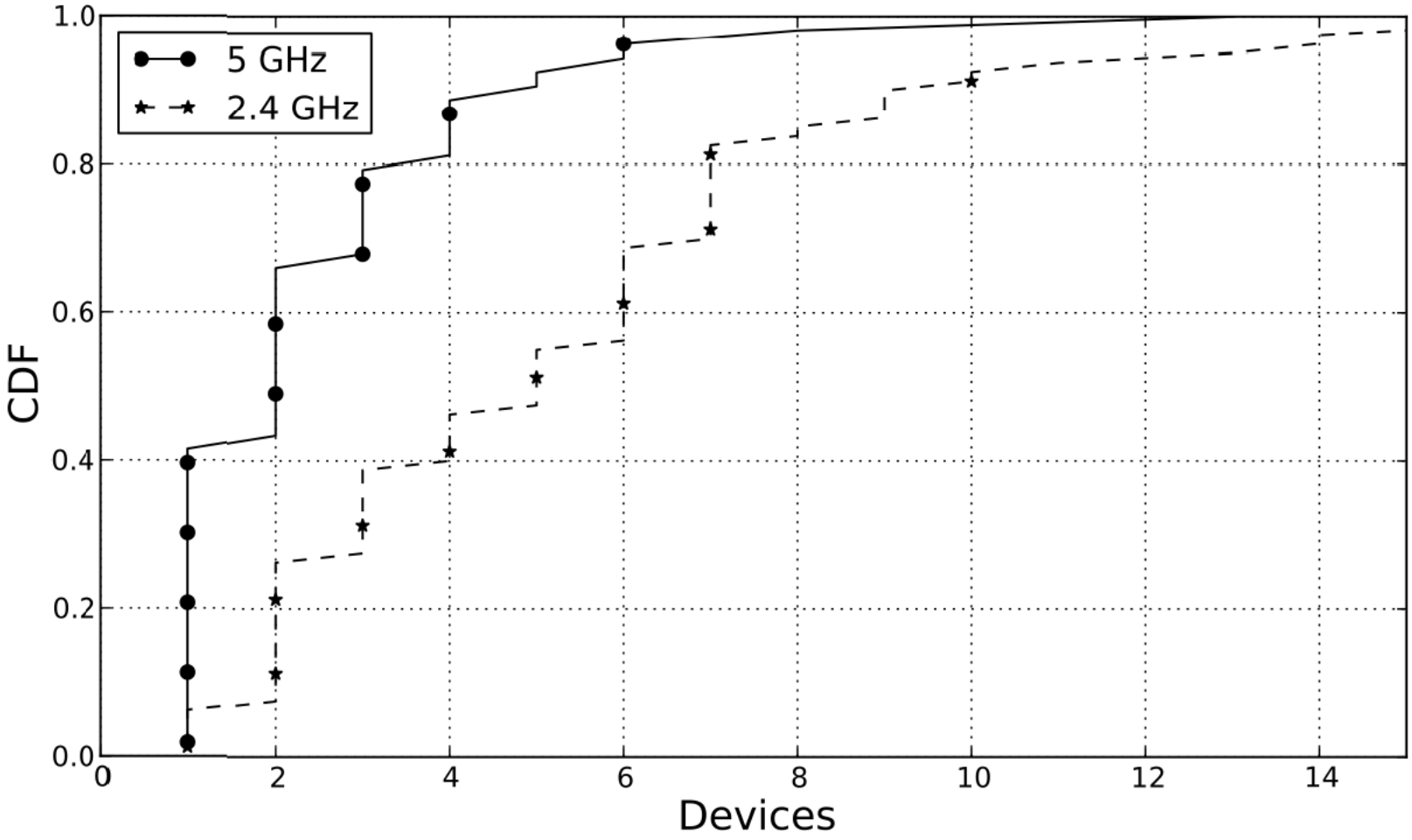
2.4 GHz

Devices on the 5 GHz channels see higher bitrates!

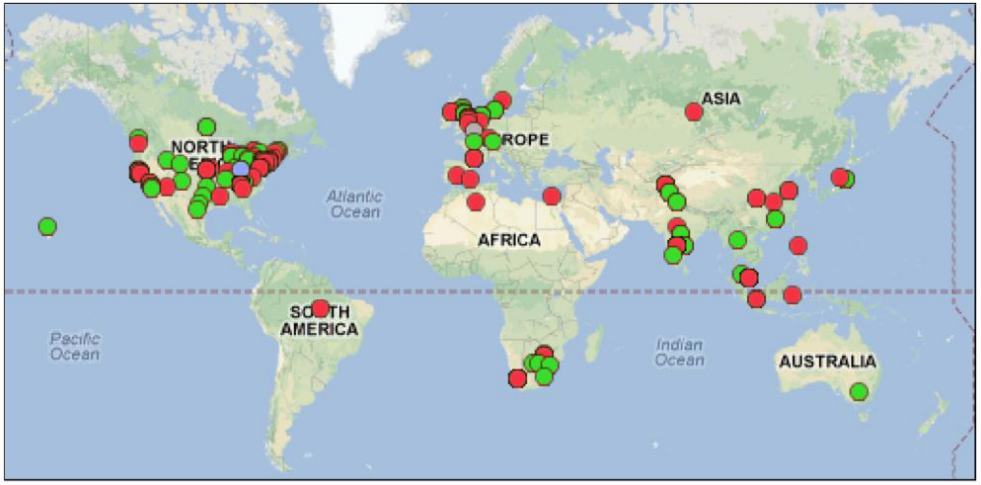


5 GHz

Possible Explanation: More Devices in 2.4 GHz



Deployment Status and Next Steps



- Deployed on 100+ routers across the BISmark testbed
- Currently only runs in “sampled” mode
  - Collects packet traces for 15 seconds every 5 minutes
  - Uploads to server for offline analysis
- Online mode is currently being developed
- **Possible next steps**
  - Implement online version
  - More statistical rigor behind some of the thresholds

Conclusion

- Home network users experience many performance problems in home networks
  - Many of these problems are with the home wireless network, *not with the ISP*
- We have built and deployed an open source, router-based tool to distinguish access link bottlenecks from wireless bottlenecks
  - Ultimately, hopefully reduced service calls