Performance Analysis of the Intertwined Effects between Network Layers for 802.11g Transmissions

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Outline

- ***Motivation***
- **Previous Work**
  - **Analytic Models**
  - **Measurement Studies**
- **Experiments**
  - **Tools and Setup**
  - **Experimental Design**
- **Results and Analysis**
- **Conclusions and Future Work**

Motivation

- Previous research has studied WLAN performance through analytic modeling, simulation and measurement.
- However, the conclusions drawn have not always been precise and the results have focused on one protocol layer (primarily the data link layer).
- Important Question:

Is Quality of Service (QoS) a realistic goal over WLAN's?

- We are interested in "refining" how one application running over a Wireless LAN (WLAN) can impact another application.
- The interaction between protocol layers can yield results that can significantly impact performance when multiple applications run over a WLAN.

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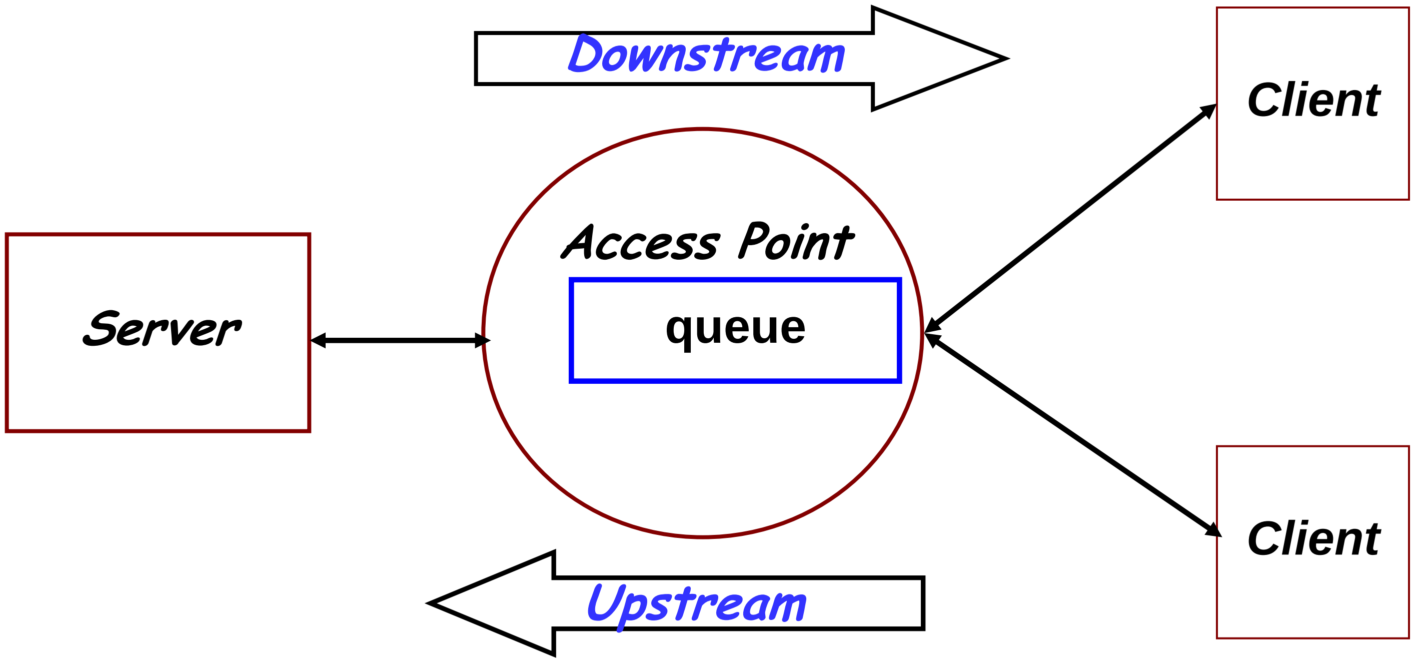
Analytic Models of 802.11

- [Cali et al. 98] "IEEE 802.11 Wireless LAN: Capacity Analysis and Protocol Enhancement"
  - Models early 802.11, i.e., no dynamic rate adaptation.
  - Models the "ideal" channel: no transmission errors, no hidden terminals.
- [Bianchi 2000] "Performance Analysis of the IEEE 802.11 Distributed Coordination Function"
  - Uses the same assumptions as Cali, but emphasizes the "saturation" throughput such that the transmission queue of each wireless node is never empty.
- [Heuss et al 03] "Performance Anomaly of 802.11b"
  - Employs analytic equations based on simplified version of Bianchi including no multiple collisions (no retries) and hosts alternate transmissions.
  - Focuses on dynamic rate adaptation effect.
  - *Conclusion: A single slow wireless node brings all wireless nodes down to its throughput level.*
  - Simulate and measure, but measurement uses only upstream UDP and TCP.
    - Note: TCP results do not match very well.

Generic WLAN with AP



Measurement Studies of 802.11

- [Pilosof et al. 03] "Understanding TCP fairness over Wireless LAN"
  - Predominantly simulation, but includes one set of measurement results to show that TCP upstream dominates over TCP downstream with background UDP traffic that makes buffers available at the AP the critical resource.
- [Aguayo et al. 04] "Link-level Measurements from an 802.11b Mesh Network"
  - Perform early morning measurements of Roofnet where there is one sender at a time.
  - Conclude there is not a strong correlation with link distance and SNR with link level loss rates and that an important cause of intermediate loss rates is multi-path fading.

Measurement Studies of 802.11

- [[Bai and Williamson 04] "The Effects of Mobility on Wireless Media Streaming Performance"
  - Create their own AP device to vary queue size.
  - Downstream measurements of UDP videos show WLAN supports easily two fixed clients receiving 1Mbps video clips with AP queue < 30 buffers.
  - When one client becomes mobile, it goes through "bad" locations and frames get discarded, rate adaptation moves to 1 Mbps, AP queue backlogs and overflows!!
  - When one client fixed and one client mobile, mobile client kills performance of fixed client because the MAC-layer queue fills with frames from poorly-connected client. The AP queue is the bottleneck.
- [Yarvis et al. 05] "Characteristics of 802.11 Wireless Networks"
  - Consider: transmission rate, transmission power, node location, house type.
  - Conduct measurements in three homes with link layer retransmissions disabled.
  - Discover: wireless performance can be quite asymmetric, node placement can be a key factor, no correlation with physical distance.

802.11 Physical Layer

- *'Adjust transmission rate on the fly'*

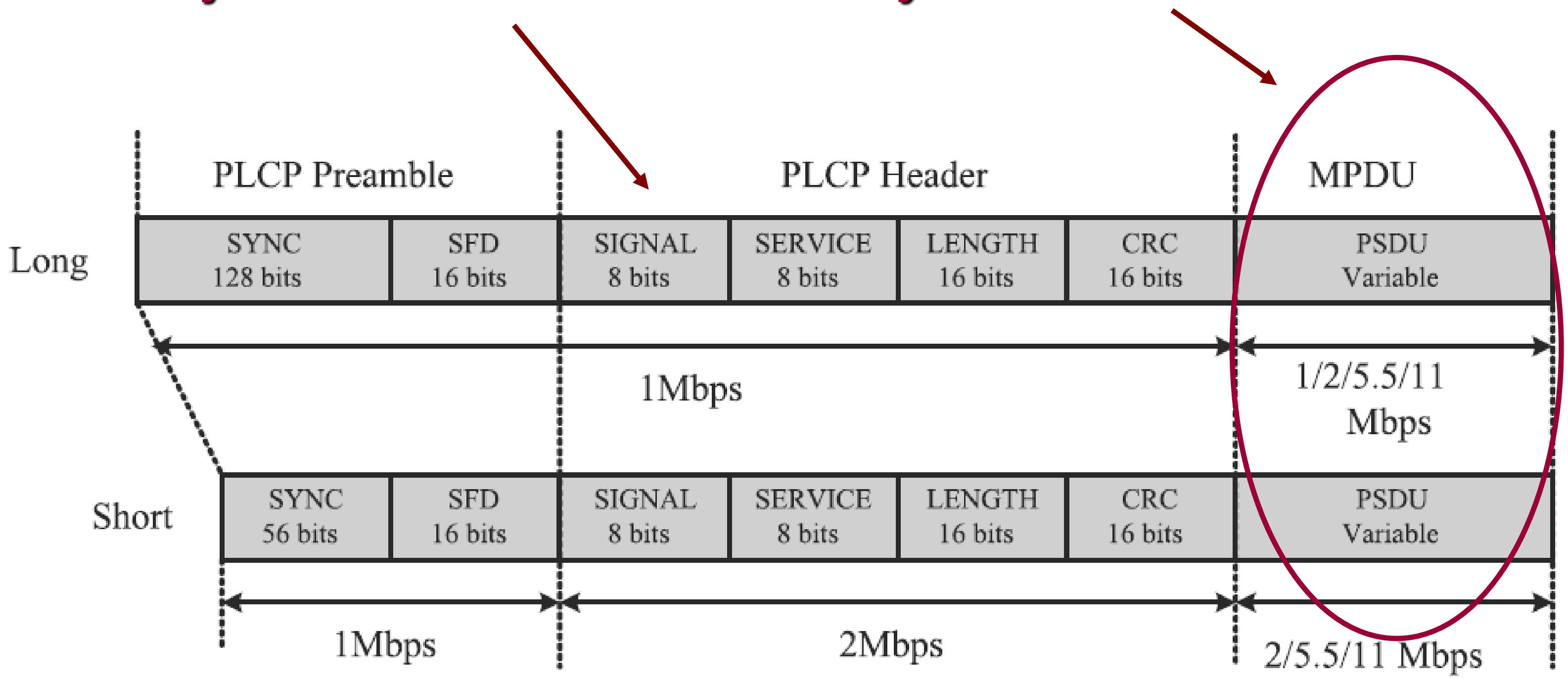


Fig. 2 IEEE 802.11b HR/DSSS PHY framing structure.

[N. Kim]

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Tools & Experimental Setup

Wireless Signal Strength

Good Location: >= -70dBm

Bad Location: <= - 75dBm

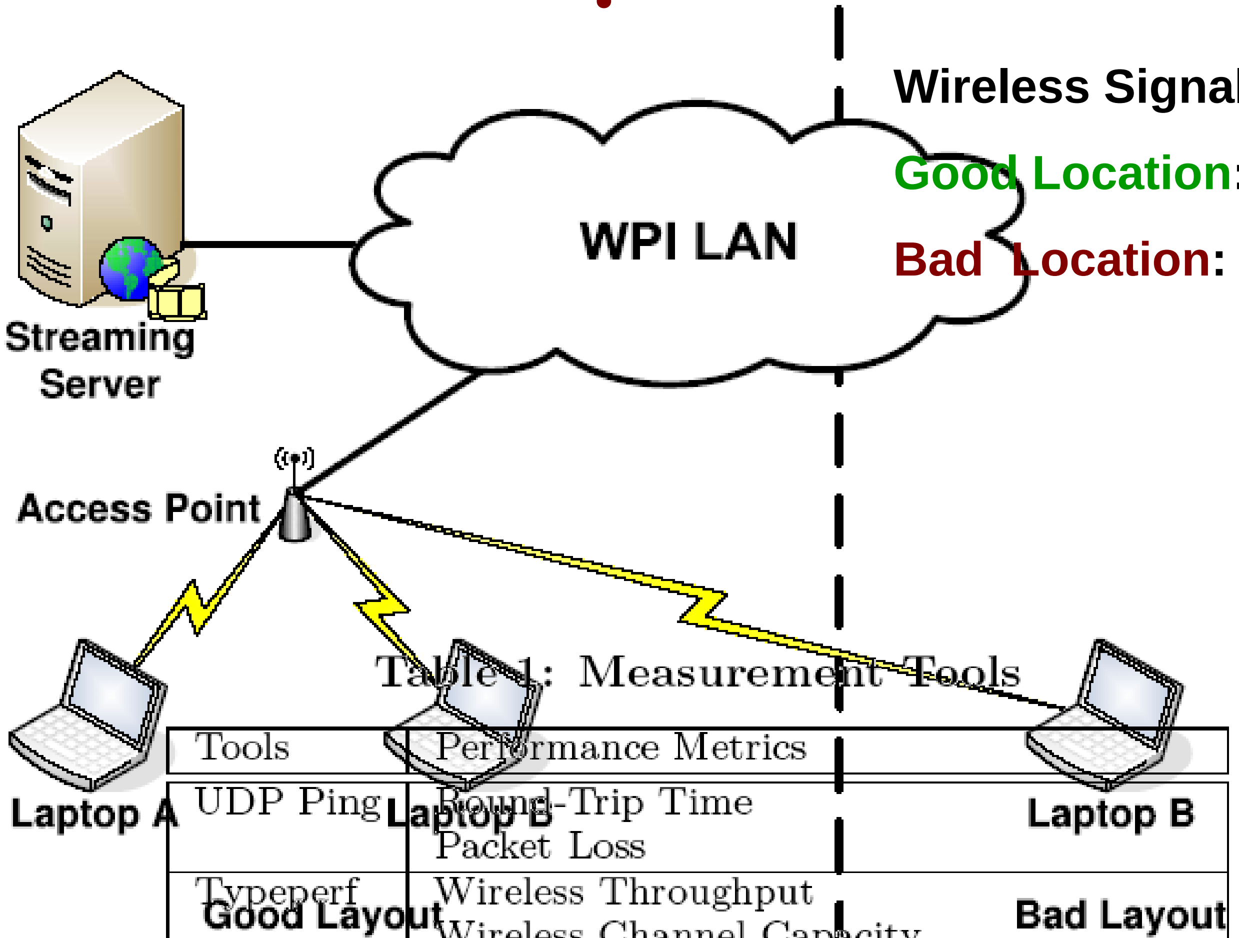


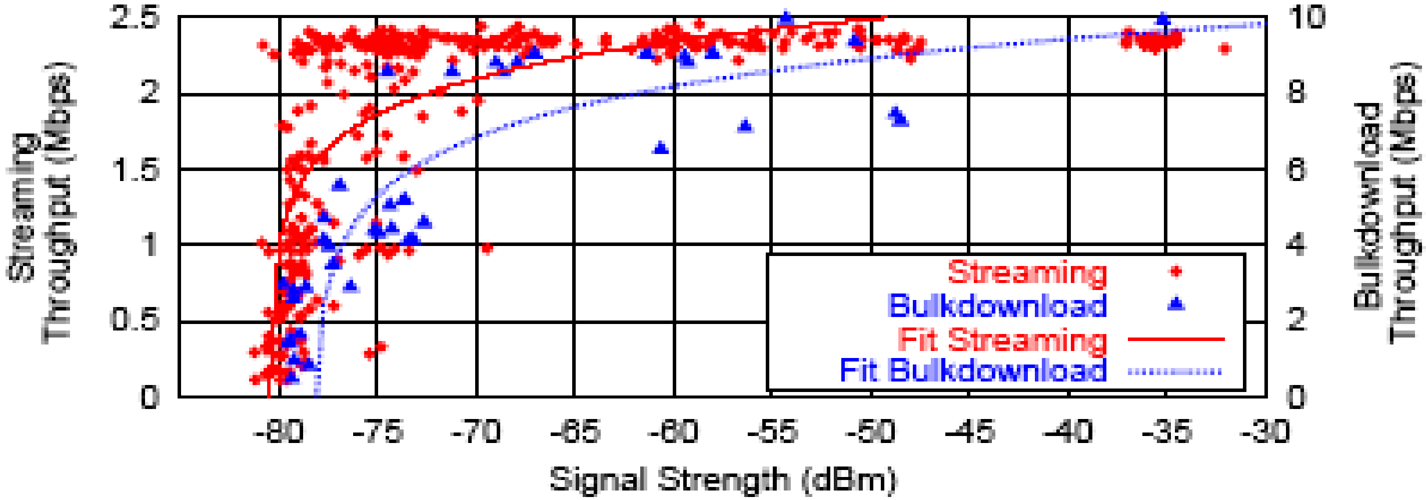
Table 1: Measurement Tools

Tools	Performance Metrics
UDP Ping	Round-Trip Time Packet Loss
Typeperf	Wireless Throughput Wireless Channel Capacity
WRAPI	Wireless Frame Retries Received Signal Strength Indicator (RSSI)

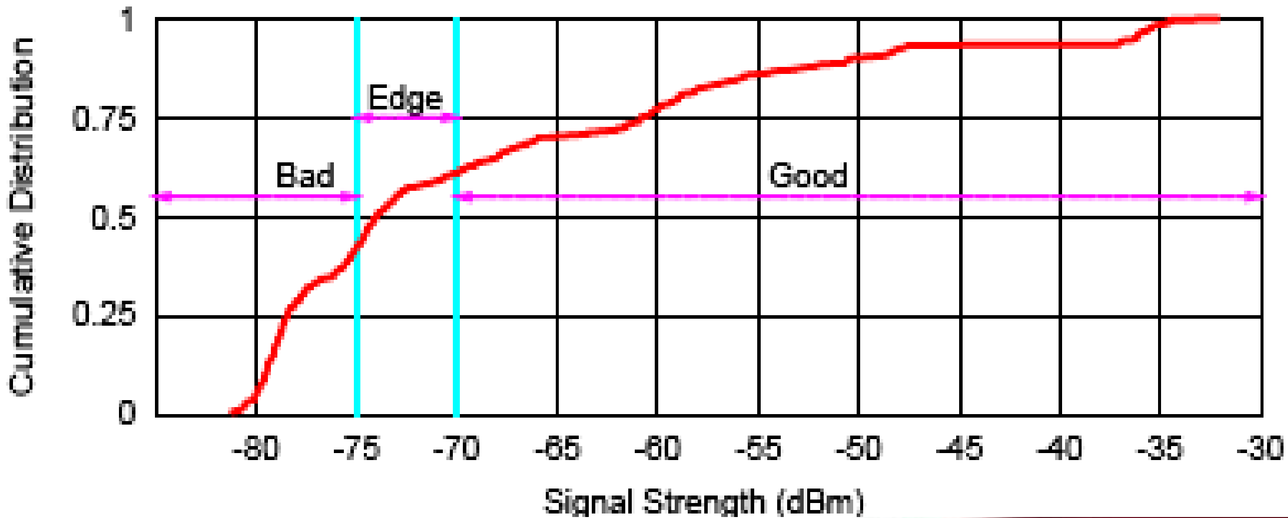
Figure 1: Measurement Setup

Signal Strength Analysis

•*Fig.2.*



•*Fig.3.*



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Experiments

Table 2: Experiment Cases

Case	Host A	Host B	
	Good Location	Good Location	Bad Location
1	TCP Download	-	-
2	TCP Download	TCP Download	-
3	TCP Download	-	TCP Download
4	TCP Download	-	UDP Stream
5	TCP Download	-	TCP Stream
6	TCP Download	TCP Stream	-
7	TCP Download	UDP Stream	-
8	-	-	TCP Stream
9	-	-	UDP Stream

Streaming Video Characteristics

Length : 2 minutes **Encoding bit rate: 5Mbps**

Resolution: 352 x 288 **Frame Rate : 24 fps**

Video Frames

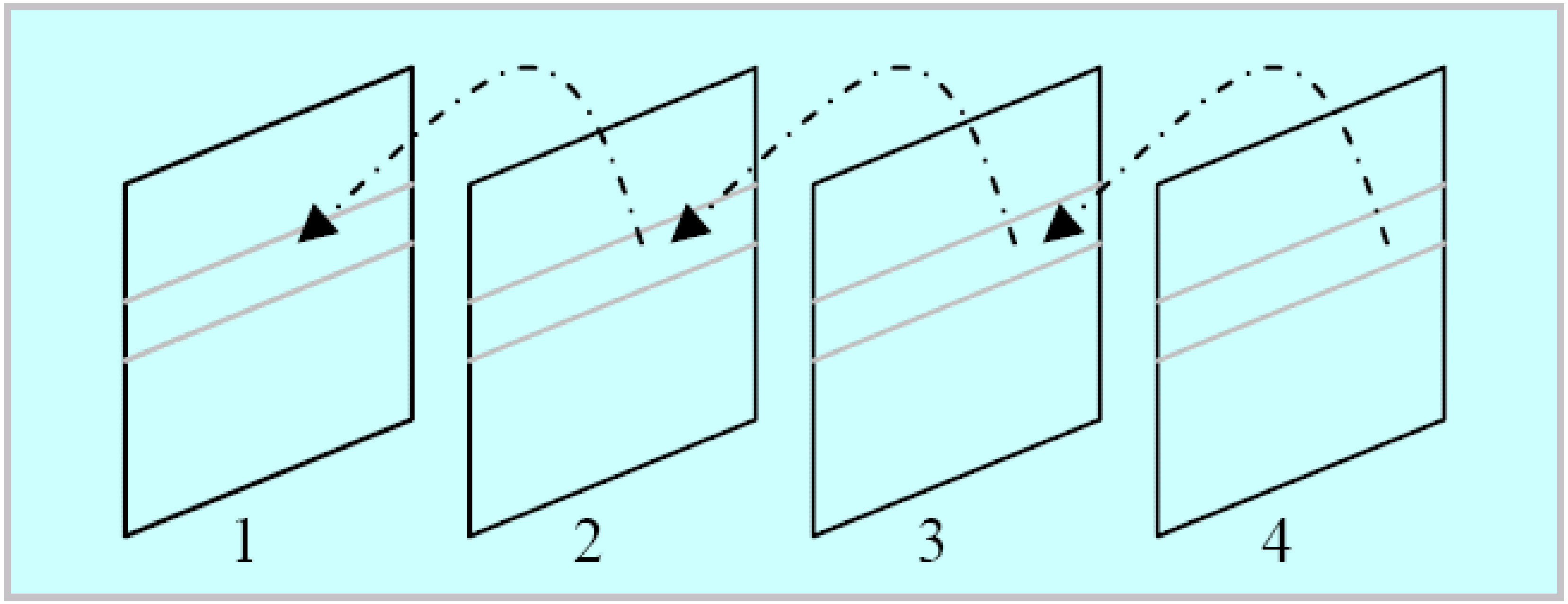
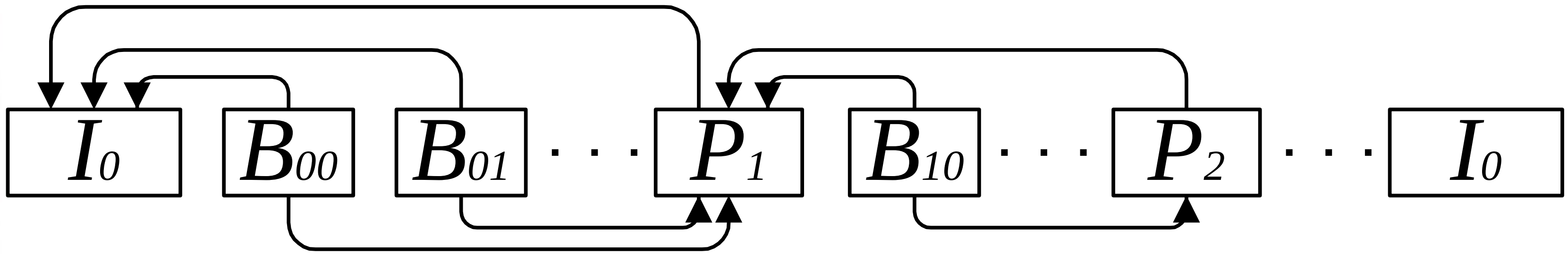


Fig. 3 Illustration of a reference chain, where each square represents a video frame, and each rectangle represents a GOB

MPEG

- Group Of Pictures (GOP)
  - IBBPBBPBBPBBIBBPBBPBBPBBI…
- Frame types are of different sizes
- This creates VBR video transmissions



Experimental Design

- The two laptops are positioned in “exactly” the same location with the same physical orientation and at locations known for little wireless traffic.
- All experiments were conducted at night to minimize motion (from people).
- Although the videos stream for two minutes, our analysis uses data between the 50-100 second interval.
- Each experiment was repeated three times.

Consistency Test

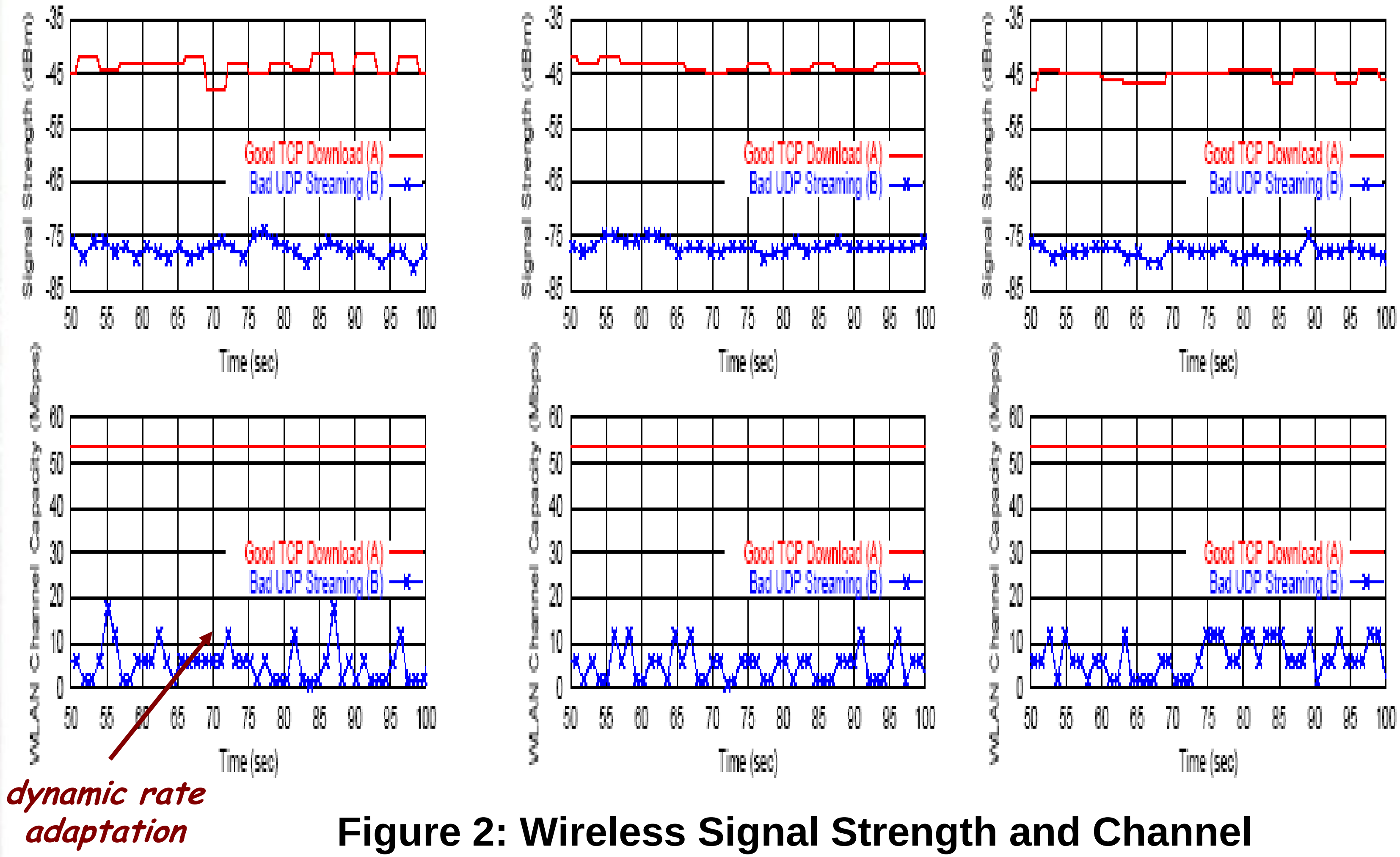


Figure 2: Wireless Signal Strength and Channel Capacity for Three Separate Runs

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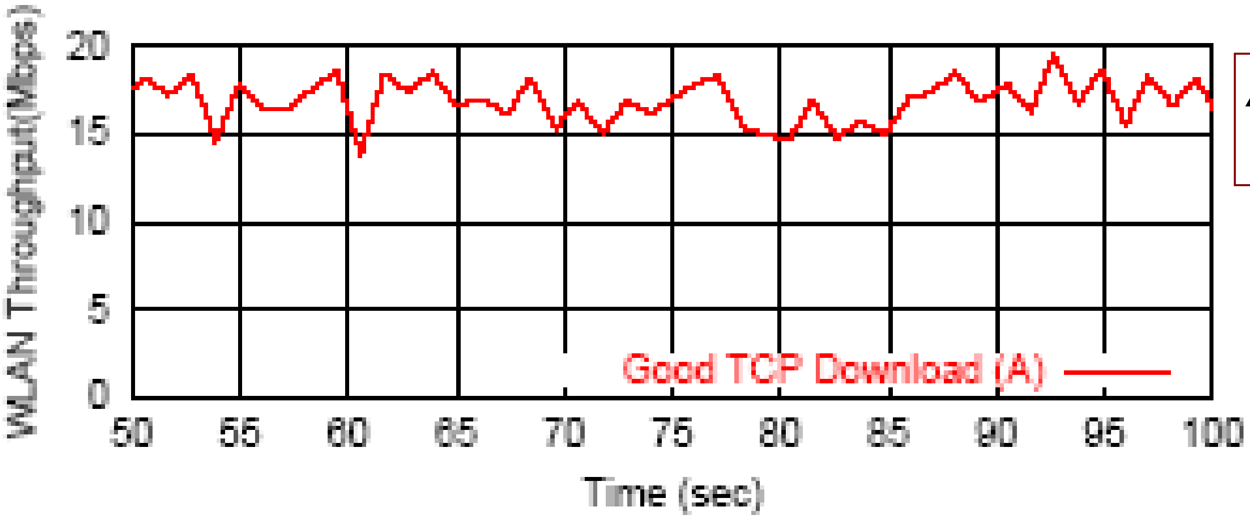
A Single TCP Download



Average throughput 18.8 Mbps

Fig 3a TCP Download to a Good Location

802.11 Performance Anomaly

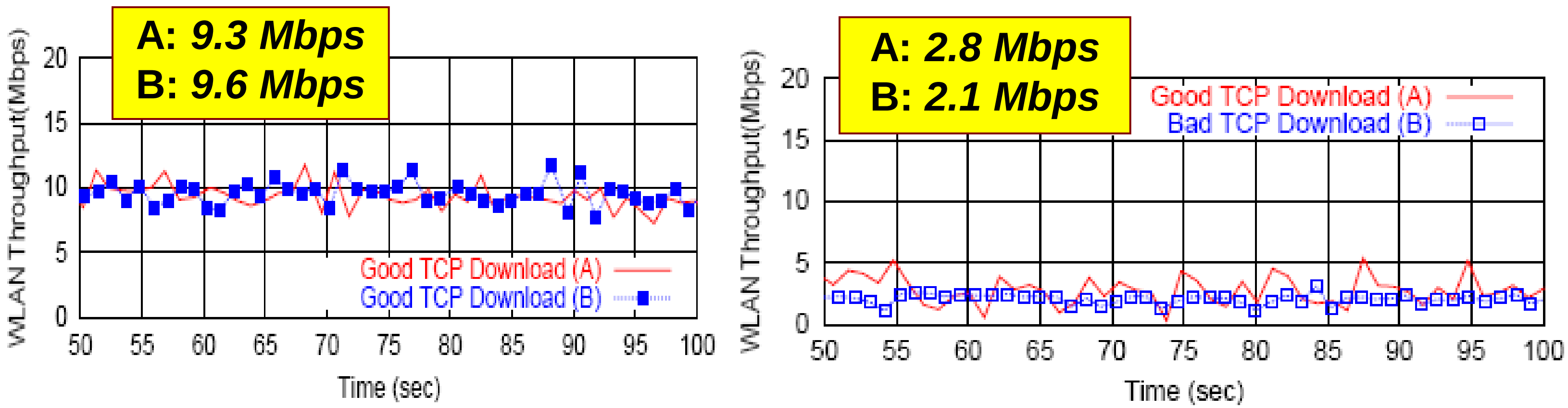


Fig 3 TCP Throughput Comparison

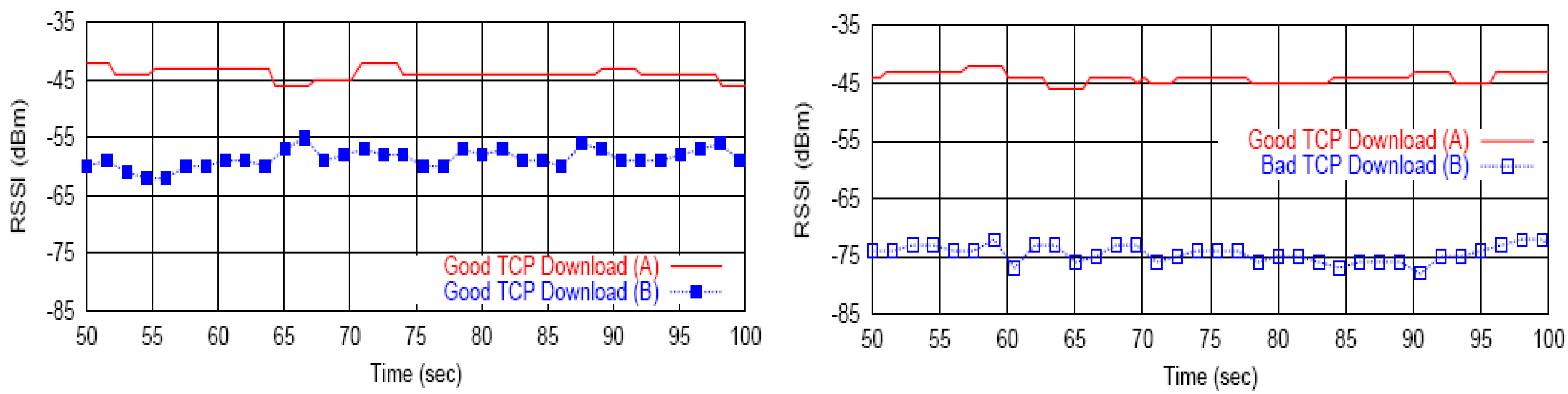


Fig 4 Wireless Received Signal Strength Indicator Comparison

TCP Download Channel Capacities

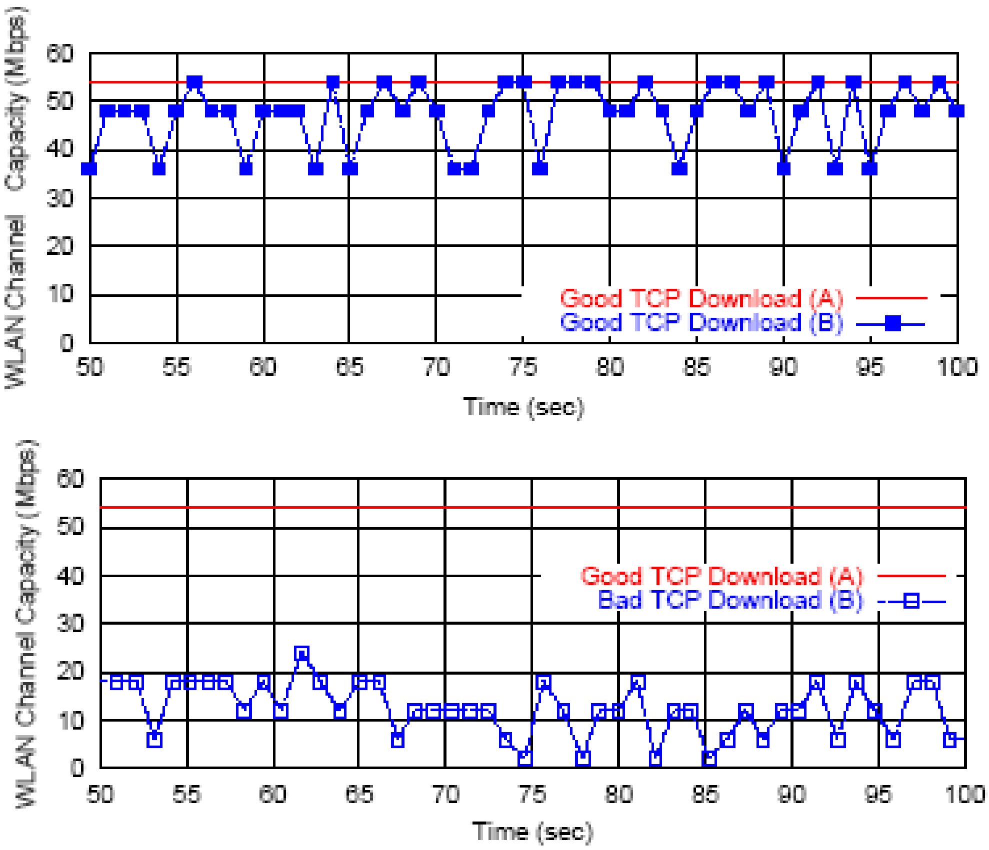
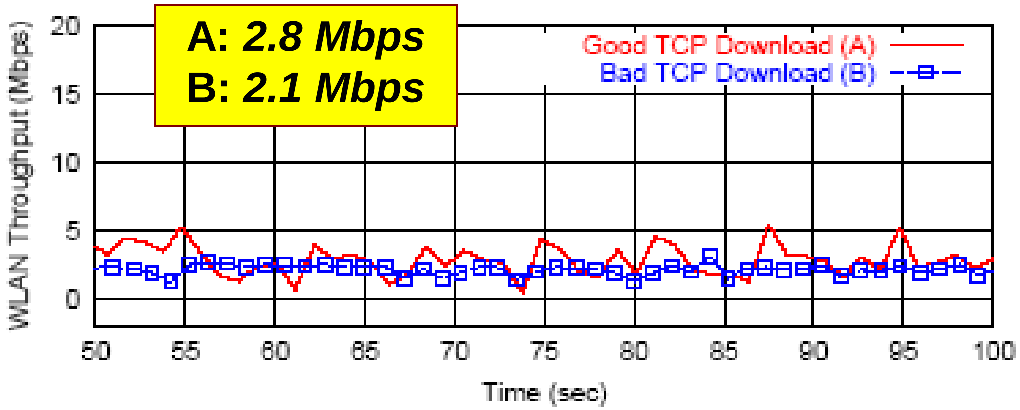
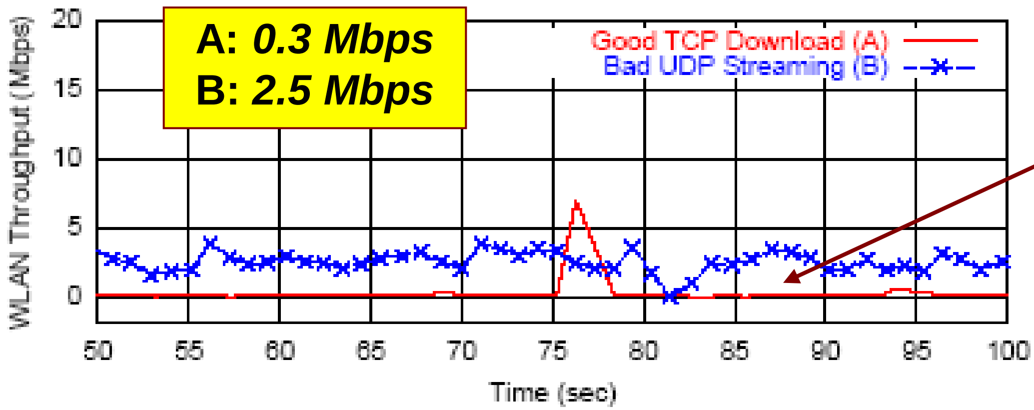


Figure 5: Channel Capacity Impacted by Location

Bad UDP Stream





UDP stream kills TCP download!!

Figure 6: Throughput Impacted by Location and Application

Frame Retries and Packet Loss

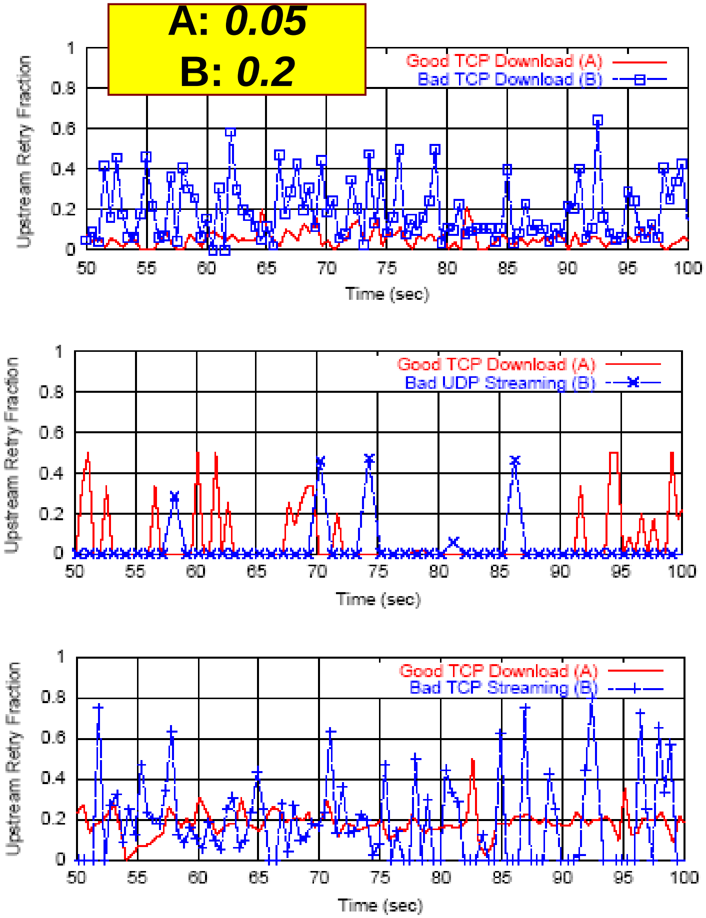


Figure 7: Wireless Layer Retry Fraction

AP queue causes high packet loss

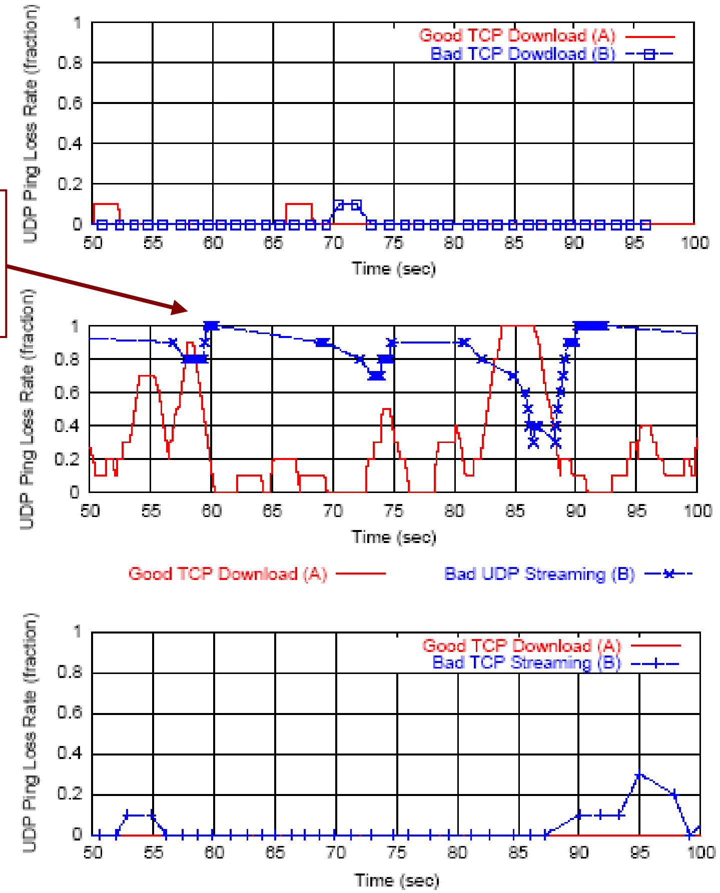
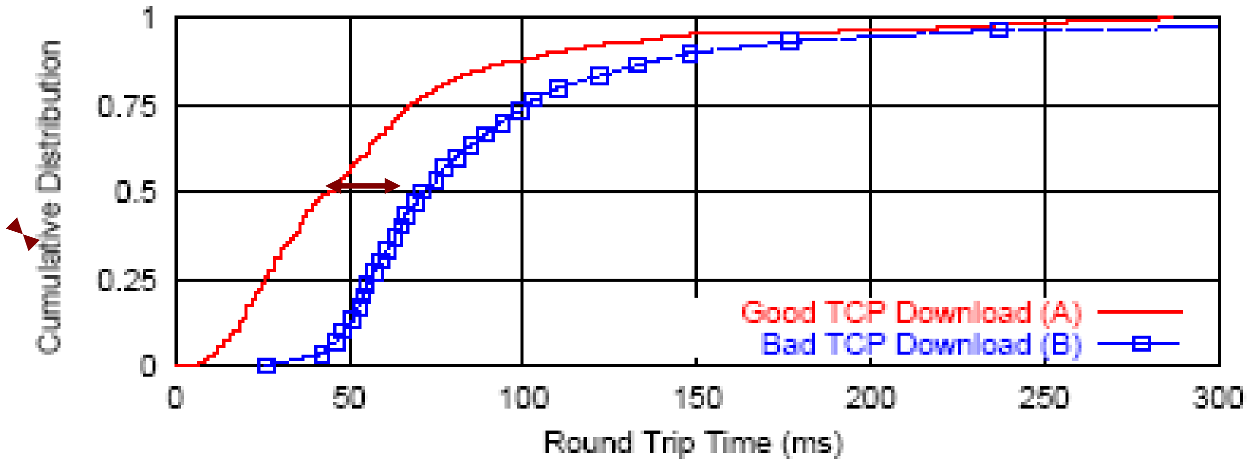
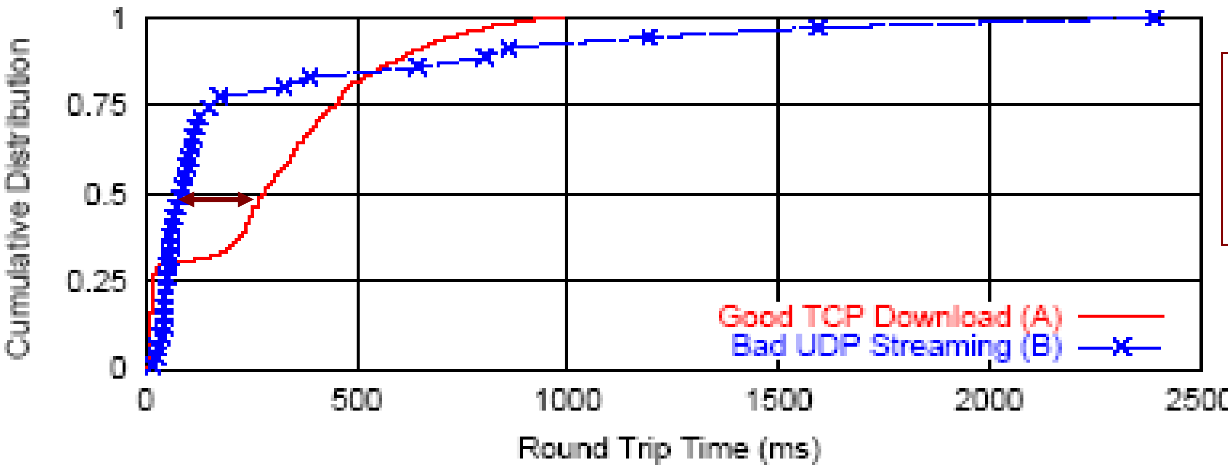


Figure 8: UDP Ping Loss Fraction

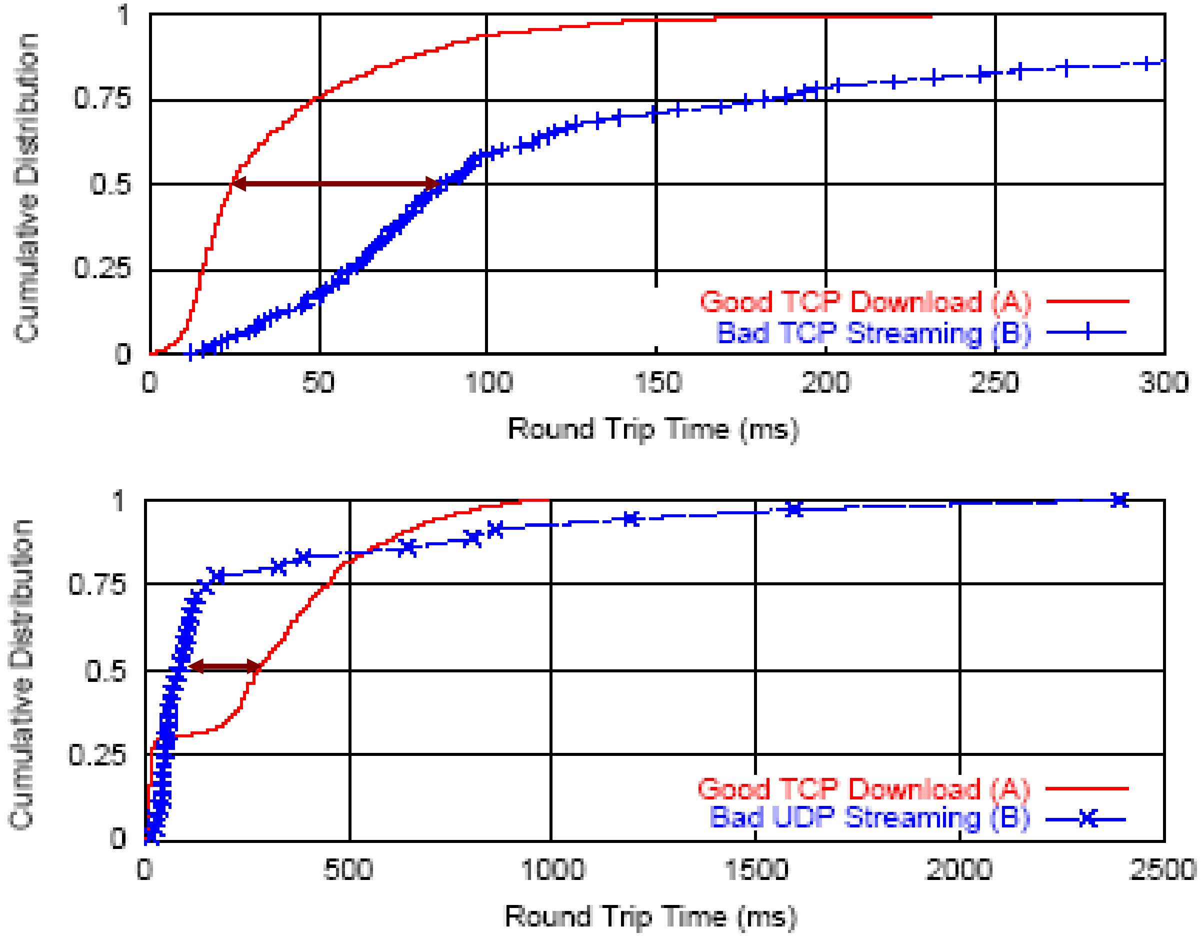
Round Trip Times





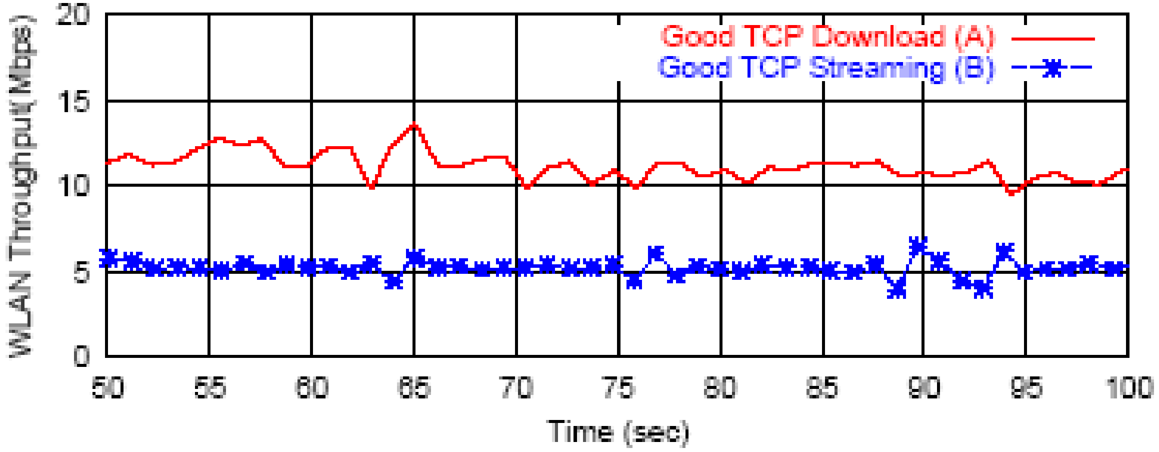
large UDP RTT's

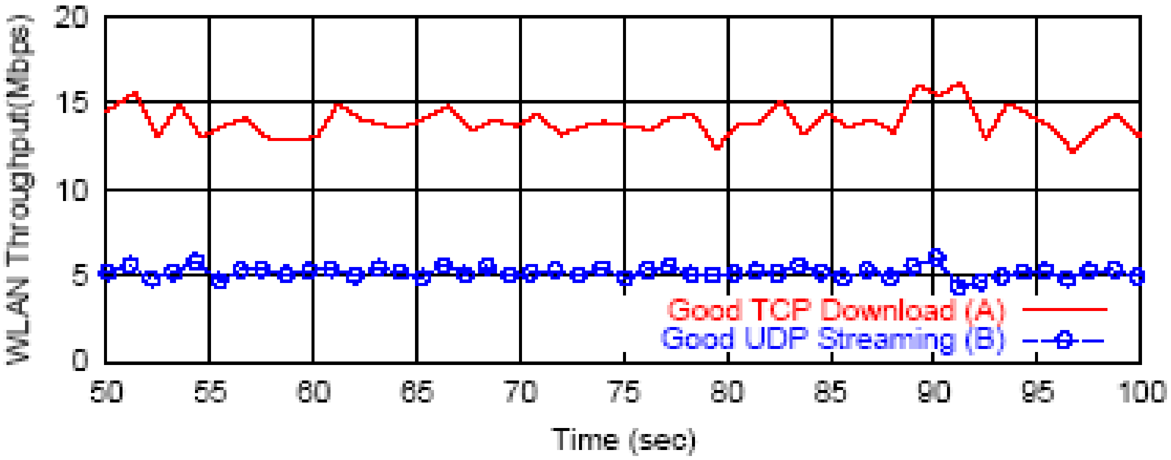
Round Trip Times



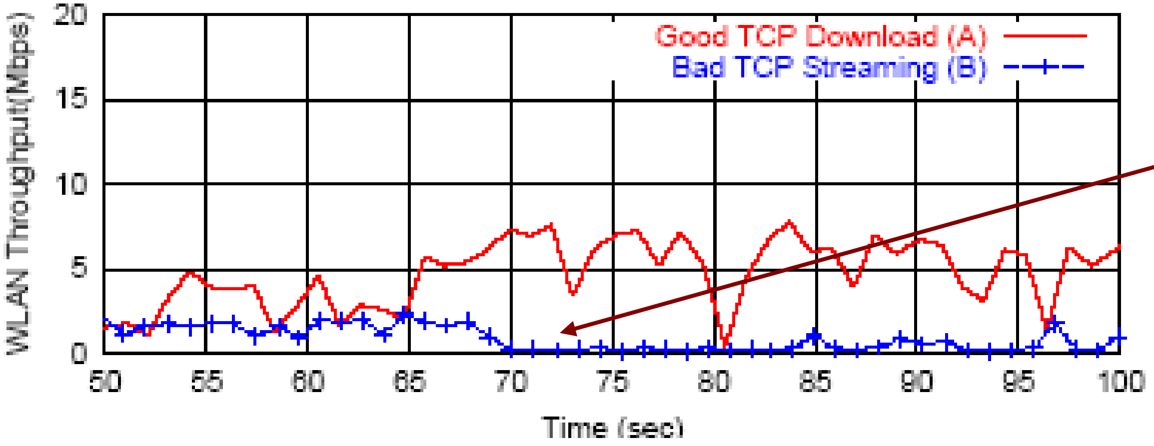
TCP does not fill the AP Queue.

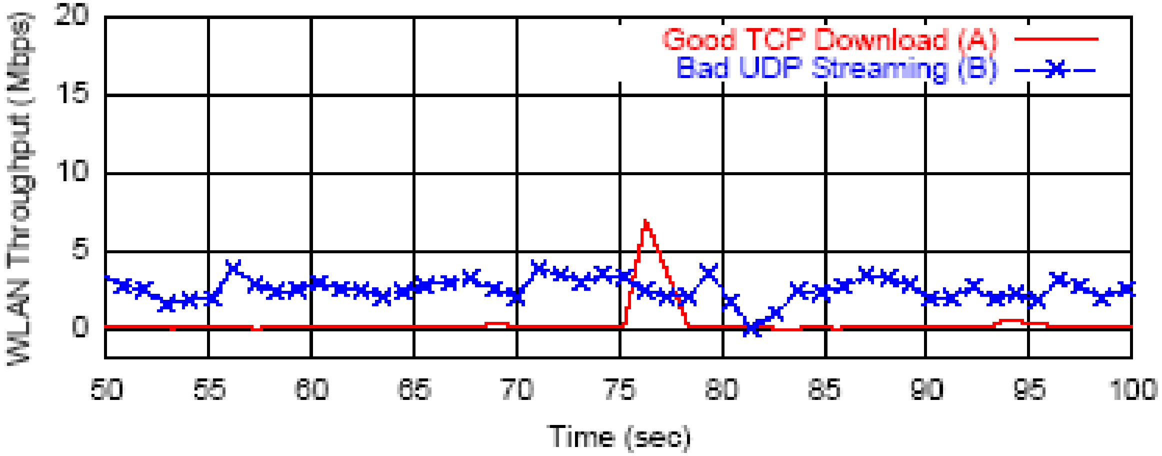
Good Streaming





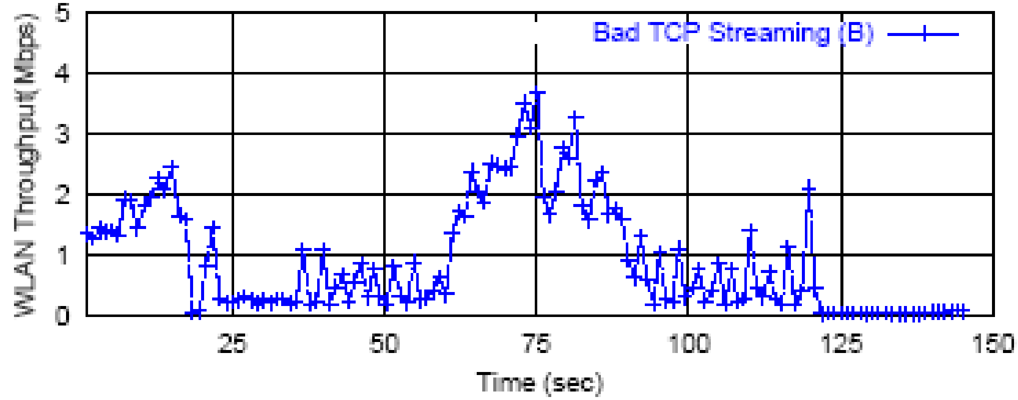
Bad Streaming

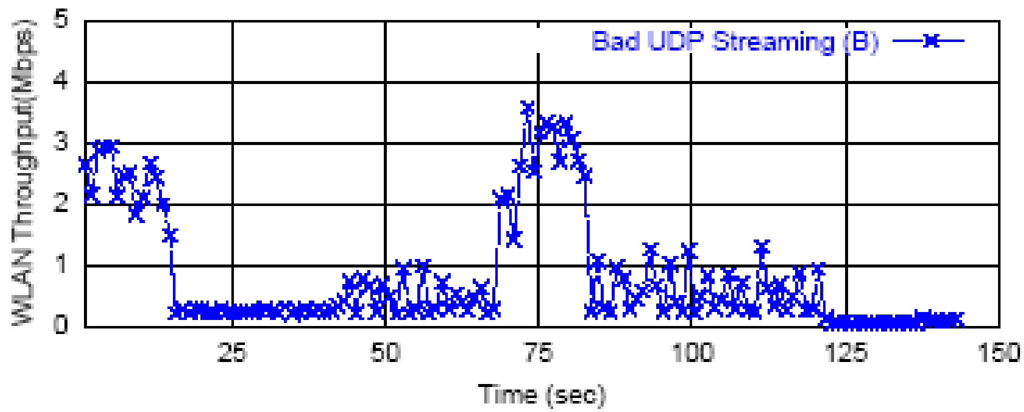




TCP streaming adjusts to bad location

Single Bad Streams





Conclusions and Future Work

- Application behavior impacts WLAN performance of concurrent applications.
- The choice of Transport Protocol impacts performance over a WLAN.
- Just modeling the data link channel misses interwined effects of the AP network layer queuing.
- We need to get 'inside' the AP to understand the queuing in both the upstream and downstream direction.
- Is there a way for streaming application to get "hints" about the wireless data link layer?

Thank You!

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