Measurement-Based Analysis of the Performance of several Wireless Technologies

R. Cosma[a], A. Cabellos-Aparicio[b], J. Domenech-Benlloch[c], J. Gimenez-Guzman[c], J. Martinez-Bauset[c], M. Cristian[a], A. Fuentetaja[d], A. López[b], J. Domingo-Pascual[b], J. Quemada[d]

a. Technical University of Cluj-Napoca, Romania
b. Universitat Politècnica de Catalunya, Barcelona, Spain
c. Universidad Politécnica de Valencia, Spain
d. Universidad Politécnica de Madrid, Spain

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Agenda

I. Introduction
II. Layer 3 Parameters
III. Measurement Methodology
IV. Experimental Results
V. Conclusions and Future Work

I. Introduction

- Events with major implications for the Internet:
  - The advent of broadband connections (DSL, Cable Modems, Wireless Access)
  - The rapid evolution of Wireless Technologies
- The current paradigm shift:
  - High Bandwidth
  - Low Delay
  - *Extended Area of Service*
  - *Mobility*

Present Solutions

- IEEE 802.11 (WiFi)
  - Reduced costs
  - Maximum theoretical debits of 54 Mbps (.g)
  - Short-range coverage / low mobility
- UMTS / HSDPA
  - 3G Technology: Mobility issues have been solved
  - Standards that enhance the Data Rates
- IEEE 802.16 (WiMAX)
  - New Infrastructure
  - Mobility support in 802.16e
  - Economical benefits

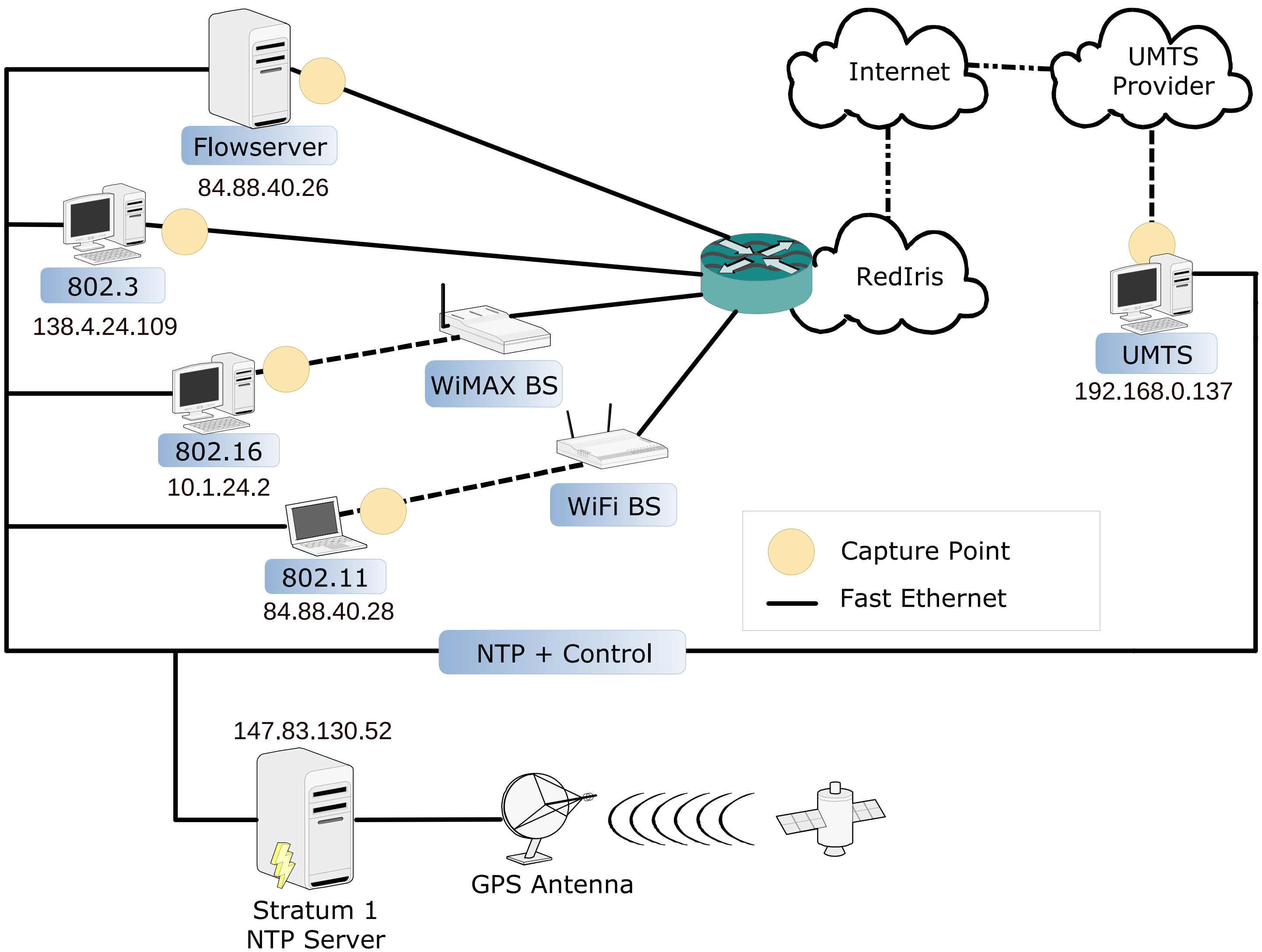
II. Layer 3 Parameters

- Standard metrics for the performance of Internet data delivery services:
  - One-way Delay (OWD)
  - Interpacket Delay Variation (IPDV)
  - Packet Loss Ratio (PLR)
- Relevance:
  - Performance of Transport Layer protocols
  - Performance of Interactive/Real-time applications
  - Insights on the dynamics and effectiveness of Layer 2 protocols/implementations.

III. Measurement Methodology

1. Deployment and configuration of the test-bed scenario
2. Clock Synchronization
3. Generating the Probe Traffic
4. Capture of Test Traffic at the relevant nodes
5. Extraction of Layer 3 Metrics from the capture files

Testbed Scenario



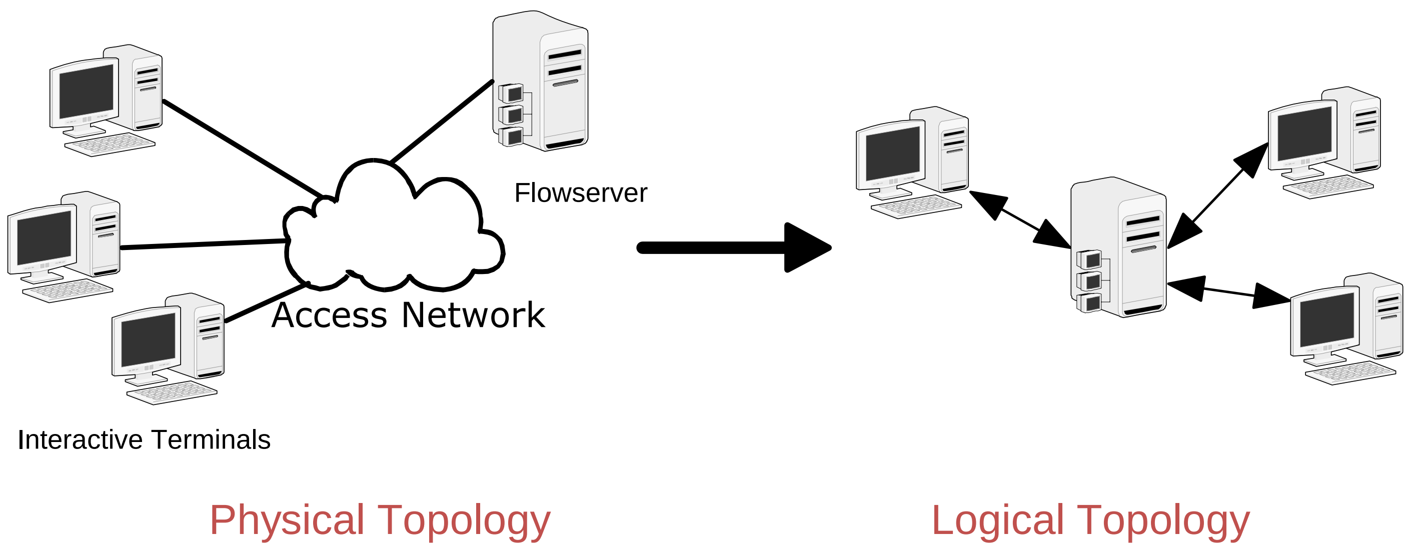
Clock Synchronization - NTP

- The Network Time Protocol
  - Hierarchy-based Architecture (Stratum Levels)
  - Time source differentiation algorithms
  - Information combining (agreement) algorithms
- NTP Dedicated Network
  - Separate Network Interfaces
  - Stratum 1 Servers
  - GPS-based Time Source
  - High accuracy

Test traffic - Isabel

- Why did we use a videoconferencing application?
  - Simultaneous traffic generation for all the clients
  - UDP advantages
  - Different nature of Audio and Video flows
- Isabel:
  - High modularity
  - Appropriate logical topology

Test traffic - Isabel



- Each client sends its data to the *flowserver.*
- Flow multiplexing takes place at the *flowserver*.

Traffic Capture - Wireshark

- Requirements:
  - Timestamping
  - Capture file format
- Wireshark:
  - Platform-independent operation
  - Advanced GUI
  - PCAP file format

Layer 3 Metrics Extraction

- Implementation:
  - Perl programming language
  - Net::Pcap wrapper
- Functionality:
  - Synchronization checking
  - RTP flows listing
  - Packet matching algorithm for metric extraction

IV. Experimental Results

- Structure:
  - Statistical descriptors of central tendency and variability: min, max, mean, median, standard deviation
  - Histogram and CDF plots for OWD/IPDV
  - Variation of metrics with respect to packet size
- Objectives:
  - Empirical evaluation of link performances
  - Influence of Layers 1 & 2
  - Link behavior when subject to CBR/VBR traffic

Test traffic overview

Link/SSRC	Flow		Packets	Flow size (Mbytes)	Throughput (kbps)
Ethernet (2800)	Up	Audio	32261	9.04	78.15
		Video	22805	16.38	142.59
UMTS (2799)	Up	Audio	-	-	-
		Video	19117	13.29	115.62
WiFi (2798)	Up	Audio	32864	9.21	78.39
		Video	20470	14.37	122.37
WiMAX (2797)	Up	Audio	22429	6.28	54.26
		Video	21005	15.08	129.64

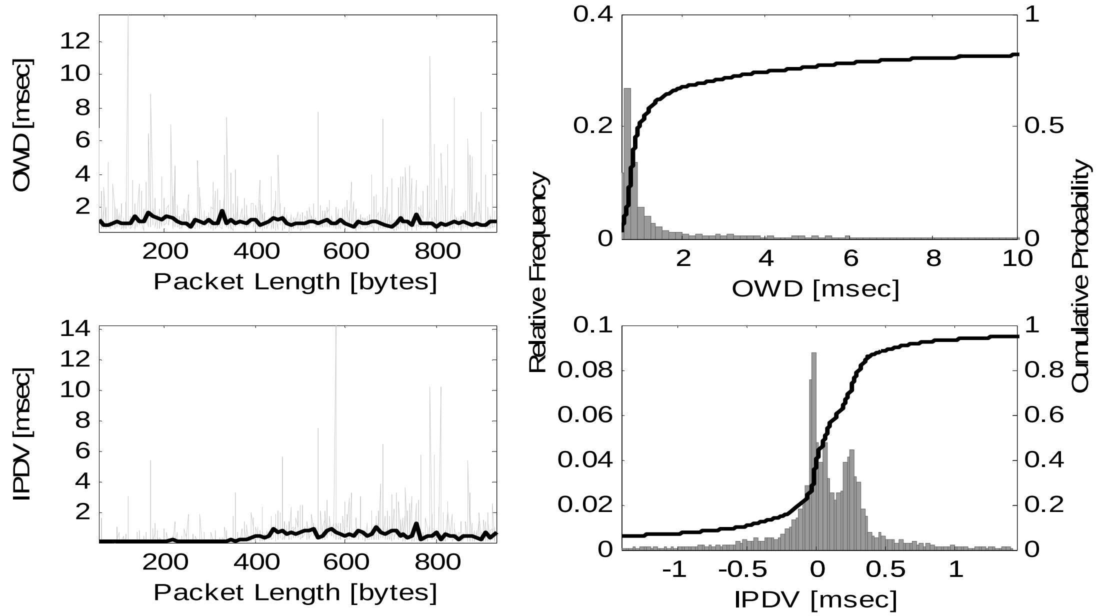
Results - WiFi

- Statistical parameters

Metric (ms)		Max	Mean	Median	Min	Dev	PLR
Video Up	OWD	20.373	4.677	1.003	0.550	7.128	0.034%
	IPDV	1.443	0.400	0.064	-3.416	2.143	
Audio Up	OWD	3.320	1.081	0.587	0.400	1.777	0%
	IPDV	0.982	0	0.015	-2.039	1.488	
Video Down	OWD	2.849	1.278	0.895	0.516	2.072	0.879%
	IPDV	0.686	0	0.059	-1.773	1.487	
Audio Down	OWD	1.824	0.895	0.602	0.511	1.616	0.38%
	IPDV	0.607	0	0.018	-1.571	1.406	

- Maximum OWD values due to ARQ mechanism
- Well-centered IPDV distributions
- Uplink / Downlink asymmetry due to channel access mechanism

Results – WiFi Uplink



- Metrics variation with packet size:
  - OWD: unaffected
  - IPDV: increased values for packet sizes > 400 bytes

Results - WiMAX

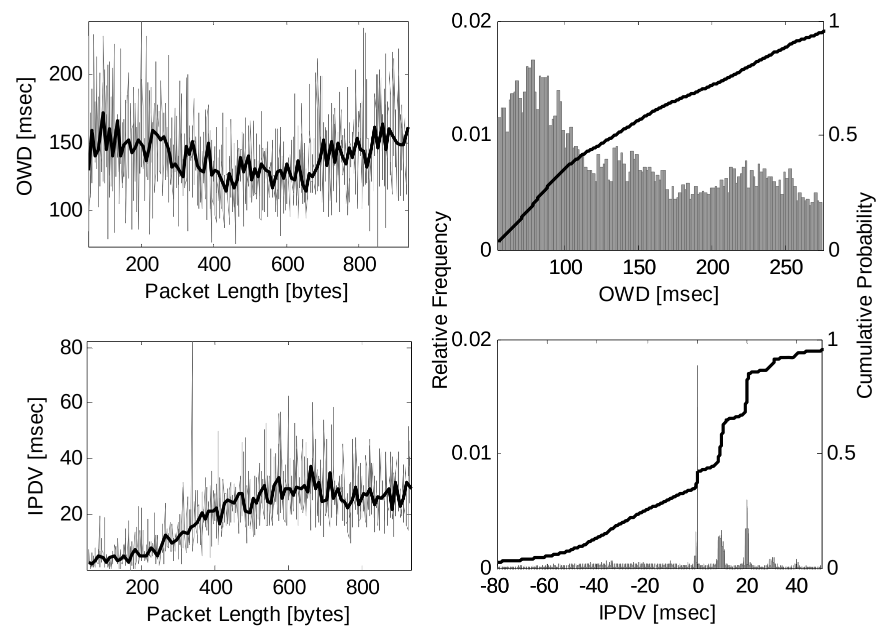
- Statistical parameters

Metric (ms)		Max	Mean	Median	Min	Dev	PLR
Video Up	OWD	275.118	150.672	134.998	54.056	77.686	10.621%
	IPDV	49.587	0	8.933	-80.051	35.005	
Audio Up	OWD	244.949	107.593	81.300	42.960	67.957	3.237%
	IPDV	39.185	400 μs	4.616	-62.378	27.819	
Video Down	OWD	158.730	78.567	67.192	55.251	34.513	6.54%
	IPDV	10.160	-0.300	0.570	-22.082	9.540	
Audio Down	OWD	104.967	68.058	62.121	54.322	23.135	0.857%
	IPDV	8.691	0	0.275	-16.799	8.514	

- Asymmetries:
  - Uplink / Downlink – different power amplifier gains for MS and BS
  - Audio (CBR) / Video (VBR)
- High Packet Loss Ratios:
  - Experimental MS equipment at Valencia

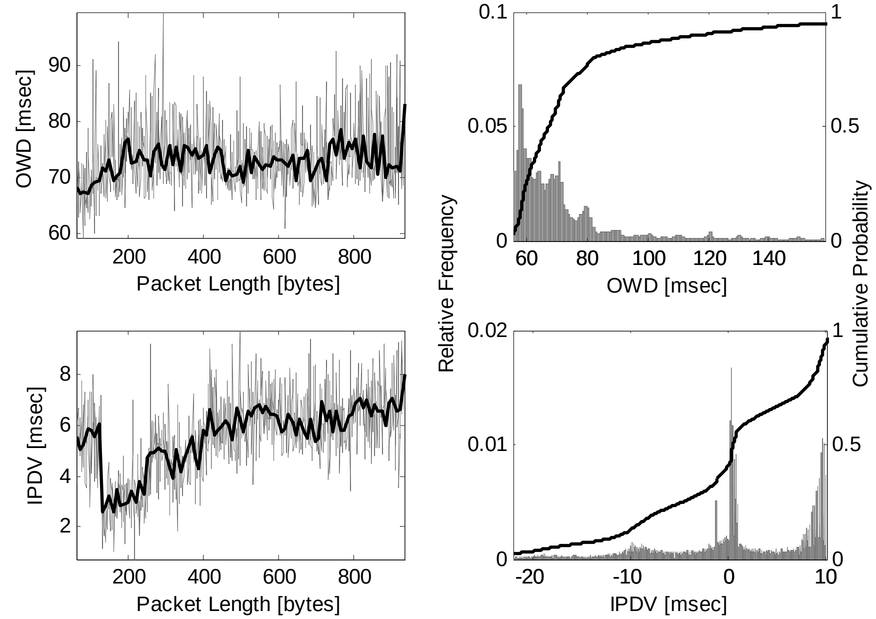
Results – WiMAX Uplink

- Optimal packet length: ~500 bytes.
- Discrete nature of IPDV distribution:
  - Frame size: 5ms
  - TDD
  - ARQ mechanism
- Multiple retransmissions



Results – WiMAX Downlink

- IPDV unstable with small packet sizes
- Discrete nature of IPDV
- Less frame retransmissions than Uplink



Results – UMTS/HSDPA

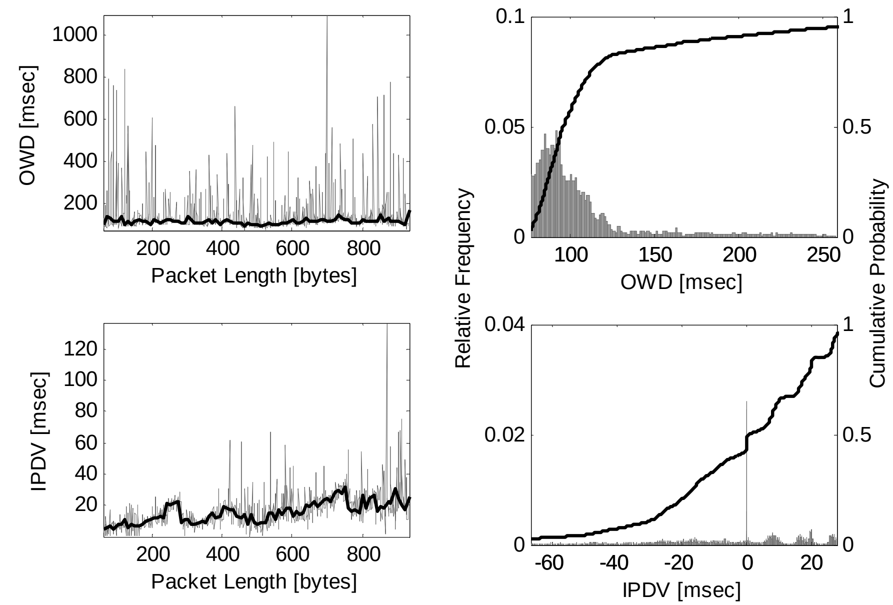
- Statistical parameters

Metric (ms)		Max	Mean	Median	Min	Dev	PLR
Video Up	OWD	258.251	153.877	95.385	75.903	103.481	0.250%
	IPDV	27.792	-0.258	1.058	-66.573	30.228	
Video Down	OWD	98.176	74.2441	67.500	50.047	43.524	0.242%
	IPDV	11.751	0	1.825	-22.244	15.349	

- Special setup imposed by the maximum *uplink* bandwidth
- High maximum values due to congestion in the provider's network
- IPDV distributions better than WiMAX
- Efficient ARQ mechanisms

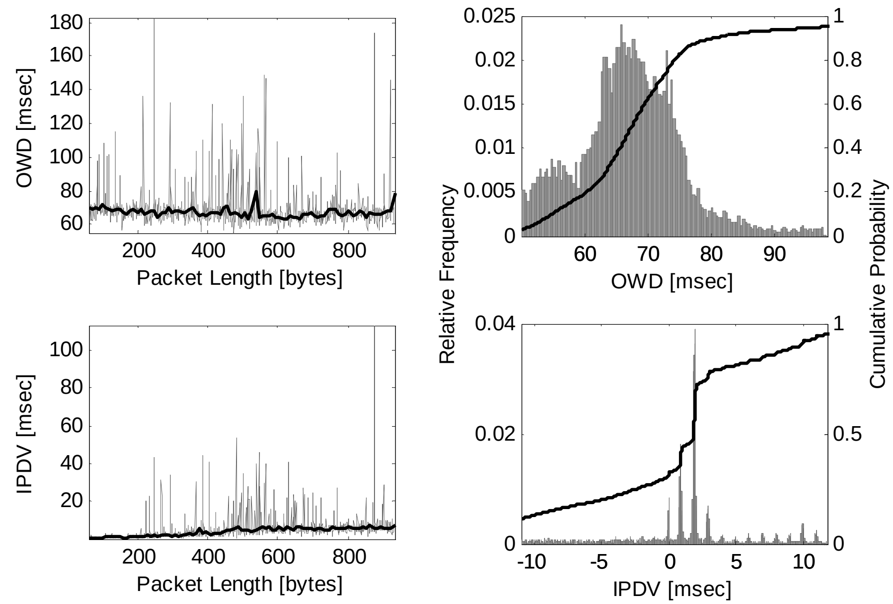
Results – UMTS Uplink

- Metric variation with packet size:
  - OWD stable
  - IPDV less stable, increasing
- Discrete IPDV nature:
  - Link temporization at RLC layer
  - Loss recovery in integer number of TTIs



Results – UMTS Downlink

- Lower OWD values
- IPDV and OWD stable with packet size
- HSDPA effects on IPDV discretization:
  - TTI limited to one radio frame
  - Reduced radio frame duration duration



V. Conclusions

- Simple methodology for extracting Layer 3 Metrics for heterogeneous networks
- WiFi:
  - Good stability of metrics in respect to packet size
  - Extreme values caused by ARQ mechanism
  - Uplink / Downlink asymmetry due to the radio channel disputing algorithm
- WiMAX:
  - High PLR – experimental equipment
  - Uplink / Downlink asymmetry
  - IPDV discretization due to ARQ mechanisms
- UMTS / HSDPA:
  - Efficient retransmission schemes
  - HSDPA effects on Downlink metrics
- Better values for metrics associated with CBR (Audio) traffic

V. Conclusions

	WiFi	WiMAX	UMTS
OWD	Best	Medium	Worst
IPDV	Best	Worst	Medium
PLR	Best	Medium	Best
Throughput	Best	Best	Medium
Range/Mobility	Worst	Medium	Best

- Best (green)
- Medium (orange)
- Worst (red)

V. Future Work

- Development of a system for *fingerprinting* wireless links:
  - Based on the nature of OWD & IPDV distributions
  - Network Layer could infer the access link w/o employing cross-layering techniques
- Extending the Perl application:
  - Real-time mode
  - Capture and processing of traffic other than RTP over UDP