Wireless Test Results Booklet

University of Michigan, Ann Arbor

This booklet presents testing results for major wireless standards, IEEE 802.11 a/b/g (Wi-Fi) and IEEE 802.15 (Bluetooth), conducted at the Engineering Research Center for Reconfigurable Manufacturing Systems at the University of Michigan. The clients and access points used for experimentation were provided by ABB, Phoenix Contact and Siemens.

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NSF Engineering Research Center for Reconfigurable Manufacturing Systems

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Executive Summary

The purpose of booklet is to present results of testing major wireless standards, IEEE 802.11 A/B/G (Wi-Fi) and IEEE 802.15 (Bluetooth). The tests were conducted at the Center for Reconfigurable Manufacturing Systems at the University of Michigan (UM). The clients and access points used for experimentation were provided by Phoenix Contact, Siemens and ABB.

Section 1 contains the results of distance and interference experiments for the Phoenix Contact Bluetooth devices as performed in an outdoor environment. The results of testing the Bluetooth devices at low transmit powers for two packet sizes (60 bytes and 1024 bytes) have also been documented in this section. Sections 2 and 3 present the findings for Phoenix Contact 802.11 devices for interference testing conducted outdoors for 802.11G and 802.11A protocols respectively. Section 4 documents the interference testing for 802.11B protocol along with the distance testing results for all three 802.11 (A,B,G) protocols with respect to time delay performances. Section 5 contains details of the interference test setup for ABB WISA base station and sensor pad and section 6 presents the results for indoor and outdoor transmit power tests as well as distance results of distance tests for two types of Siemens WLAN client devices.

The test results were organized in tables and illustrated by scatter plots and histograms using the Report Generator[1] software developed at UM. The tables in the reports provided by the Report Generator illustrate the performance results in terms of total packets, lost packets, average time delay, standard deviations in delay, maximum delay and minimum delay. All lost packets were ignored for statistical purposes. Microsoft Office EXCEL 2007 and MATLAB R2009a were also used to generate plots for the collected data. The test setups for each experiment type are briefly explained at the beginning of each section.

Extensive testing was conducted to address the following key challenges in implementation of wireless automation:

- Interoperability and coexistence of protocols
- Communication jitter and packet loss
- Standardized test plan to characterize and bench mark networks and wireless devices

[1] Report Generator (c) 2008 ERC-RMS University of Michigan

Section 1

Test Results for Phoenix Contact Bluetooth

This section contains results for the following experiments:
-Outdoor distance tests
-RF interference tests
-Low power tests

In the outdoor distance tests, the distance was set at 30 m and the noise power range was from 0 dBm to -60 dBm.

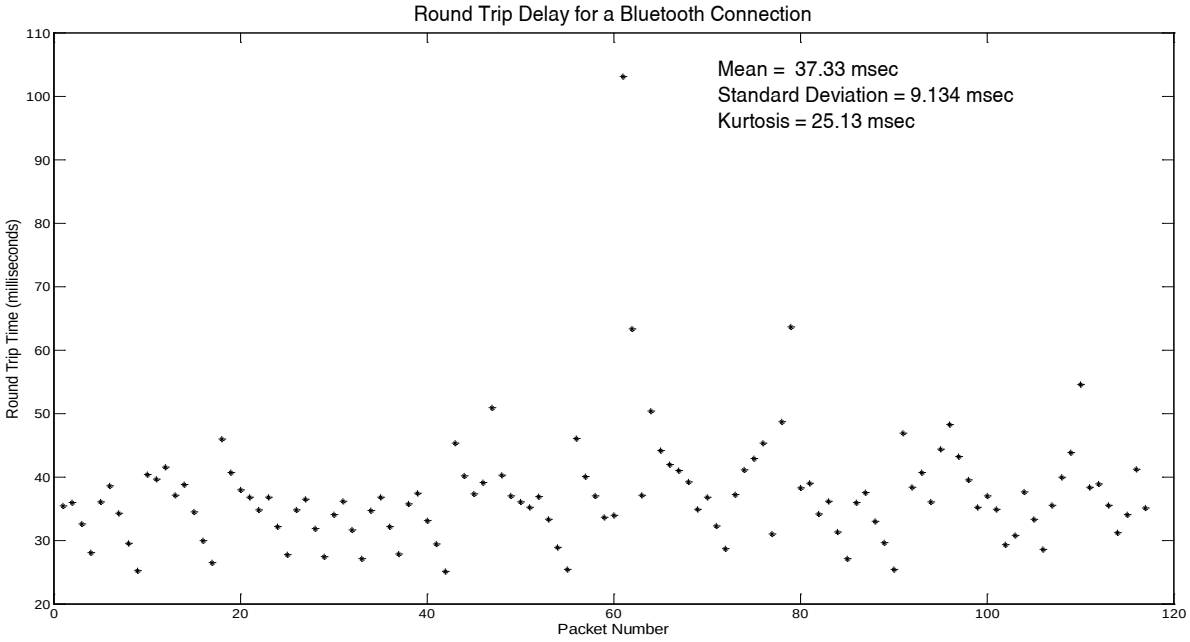
Noise Power (dBm)	Distance (m)	Mean (msec)	Std. Deviation (msec)	No. of Packets Lost
No Noise	30	45.70	9.66	1/478
-30	30	47.04	12.00	1/481
-40	30	45.95	9.46	1/485
-45	30	46.02	9.68	1/479
-50	30	47.14	11.51	1/481
-55	30	47.59	16.55	1/481
-60	30	45.08	9.39	1/482

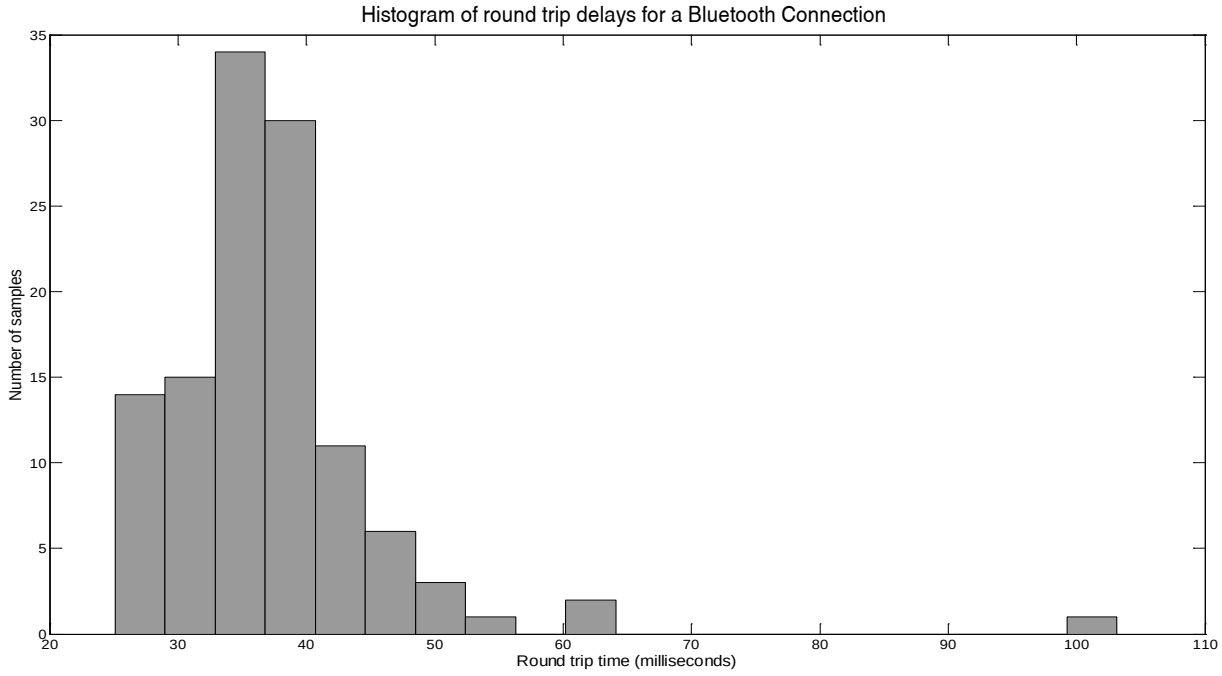
Please note that occasionally one packet is erronously marked as lost when data is captured by our test software. It appears this is connected with how we initialize the embedded capture software and due to synchronization issues when using two computers in coordination. This error occurs in about 30% of the tests conducted and has never resulted in more than one packet reported as lost.

We recommend that the reader disregard reports of single packet lost and for tests with several packets lost consider that the actual numberlost may be lower by one.

Bluetooth: Baseline Test

The Bluetooth client was connected to a laptop and the access point was placed next to the client. Packets were 'pinged' from the laptop to the access point and the Wireshark program was used to capture packet transmission data. The data presented here has been plotted on Matlab. All lost packets in these tests were ignored for statistical purposes. The mean and standard deviation formulae are consistent with the rest of the report



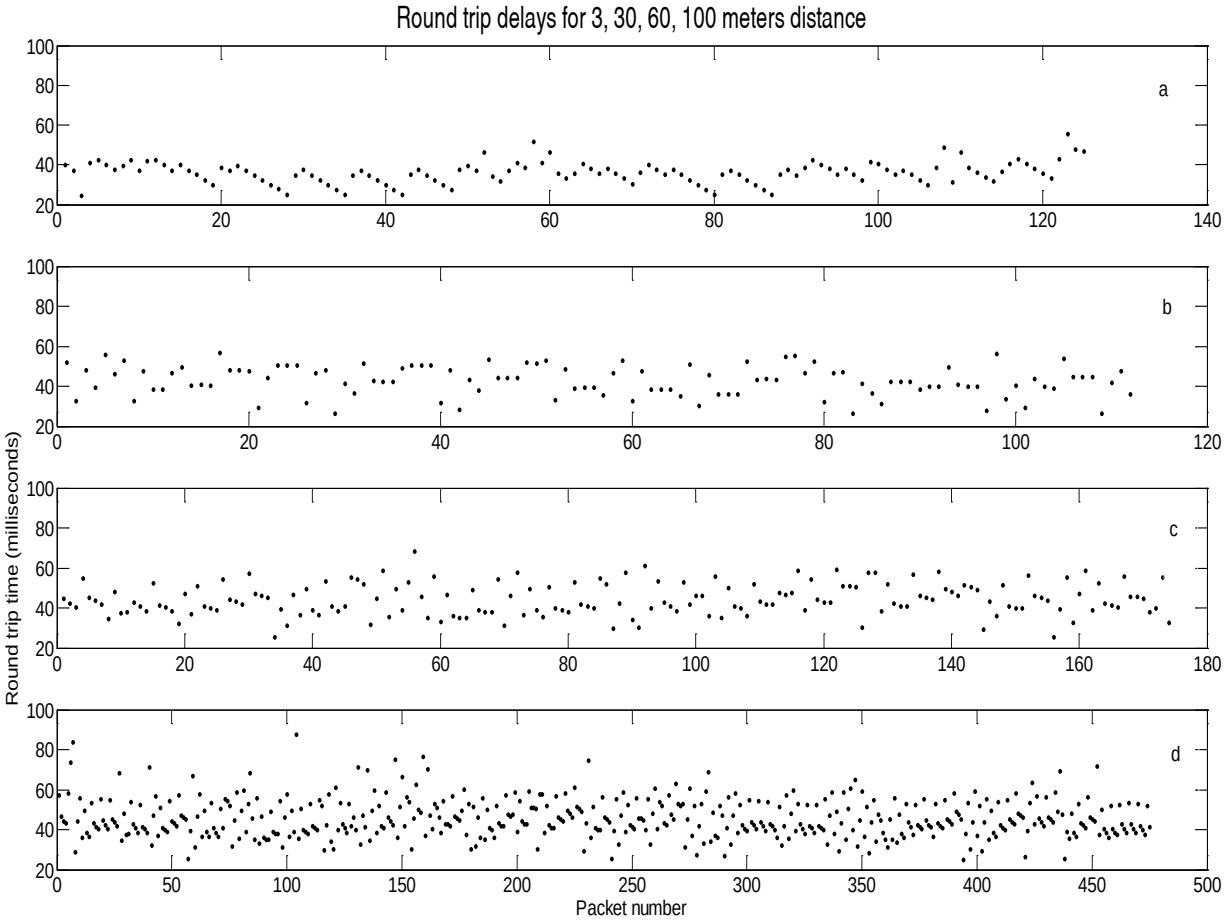


Bluetooth: Distance tests

This test was conducted in an outdoor environment. The BT client was connected to a laptop and the access point was placed x distance away for each test, where x = 3, 30, 60, 100m. Packets were 'pinged' from the laptop to the access point and the Wireshark program was used to capture packet transmission data.

Subplot 'a' : Distance=3m
Subplot 'b' : Distance=30m
Subplot 'c' : Distance=60m
Subplot 'd' : Distance=100m

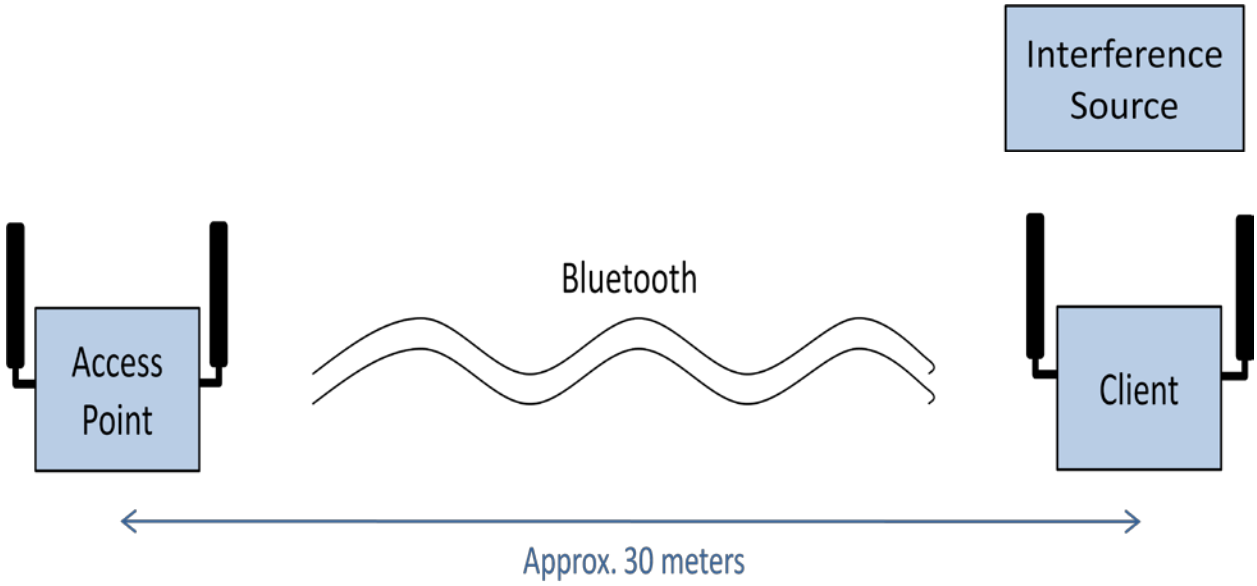
The plots on this section show different packet number axes because the experiments were conducted on run time rather than on packet numbers.



Bluetooth: Interference tests

The Bluetooth client and AP were placed approximately 30m apart and a signal generator (Rohde and Schwarz SMJ-100A) was used as an interference source (Fig 1). The interfering signal was an 802.11b transmission set to modulate at 2.441 GHz.

Figure1: Interference test setup for Bluetooth



Report:PHX-BT10-100-XX-2-SW-Baseline

Experimented by Jeehong Yang and Wajiha Shahid

University of Michigan

2008-07-24 14:46:02

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Phoenix Contact Bluetooth AP
Channel	N/A
Signal Power	-30
Noise Power	No Noise
Distance	30
Comments	Noise signal was centered at 2.441 GHz modeling Wireless LAN 802.11b.

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
Histogram Data Size (bytes)	45

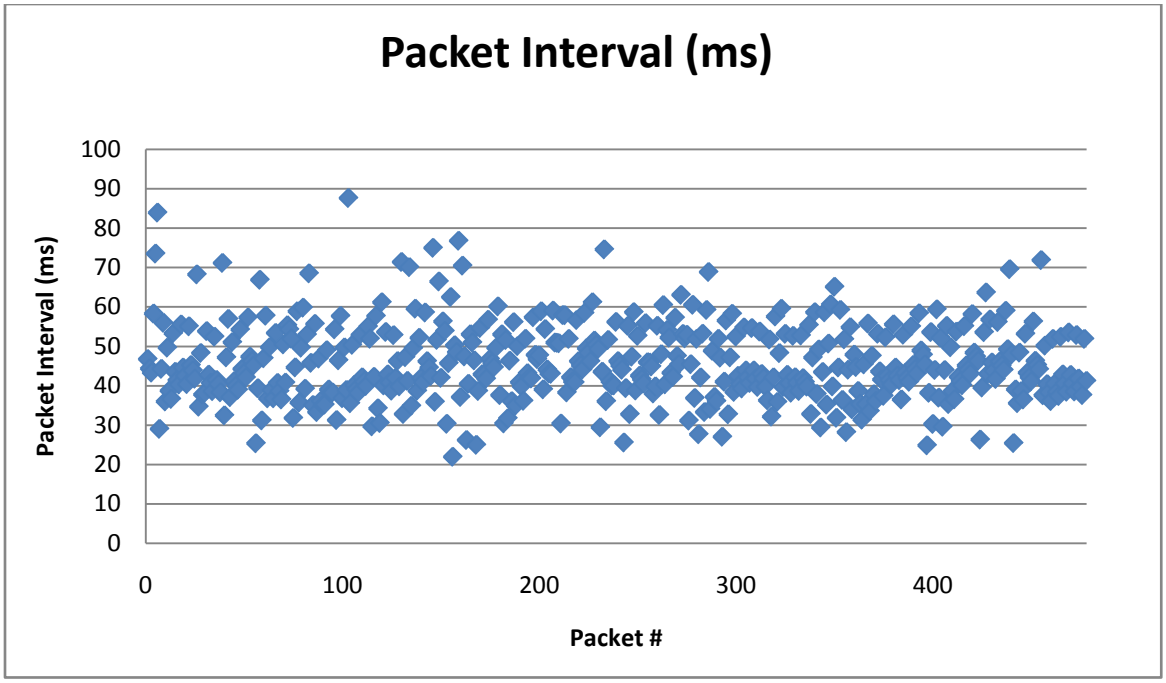
Results

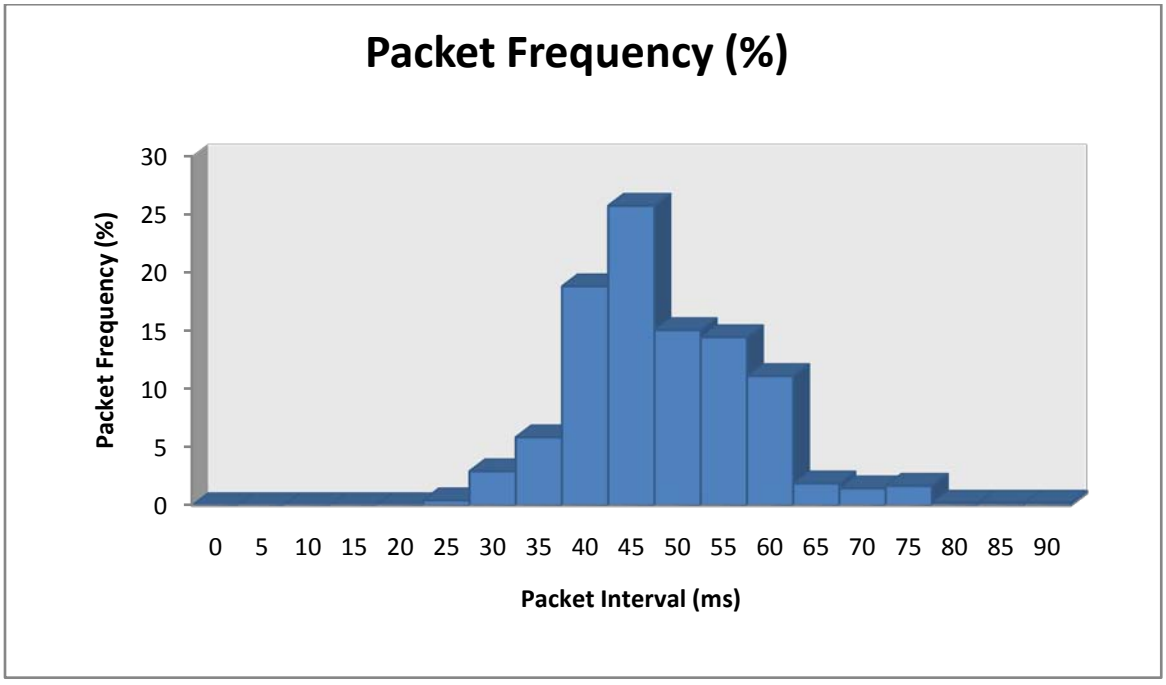
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	478	N/A	N/A	N/A
# Lost Packets	1			
Average (ms)	45.70		+/-10%	
Std. Deviation (ms)	9.66		+/-10%	
Min (ms)	21.98		+/-10%	
Max (ms)	87.64		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
100
90
80
70
60
50
40
30
20
10
0
0
100
200
300
400
Packet #


Packet Frequency (%)
Packet Frequency (%)
30
25
20
15
10
5
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90
Packet Interval (ms)

Report: PHX-BT10-100-30-2-SW, Noise

Experimented by Jeehong Yang and Wajiha Shahid

University of Michigan

2008-07-24 14:46:00

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Phoenix Contact Bluetooth AP
Channel	N/A
Signal Power	-30
Noise Power	-30
Distance	30
Comments	Noise signal was centered at 2.441 GHz modeling Wireless LAN 802.11b.

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	45

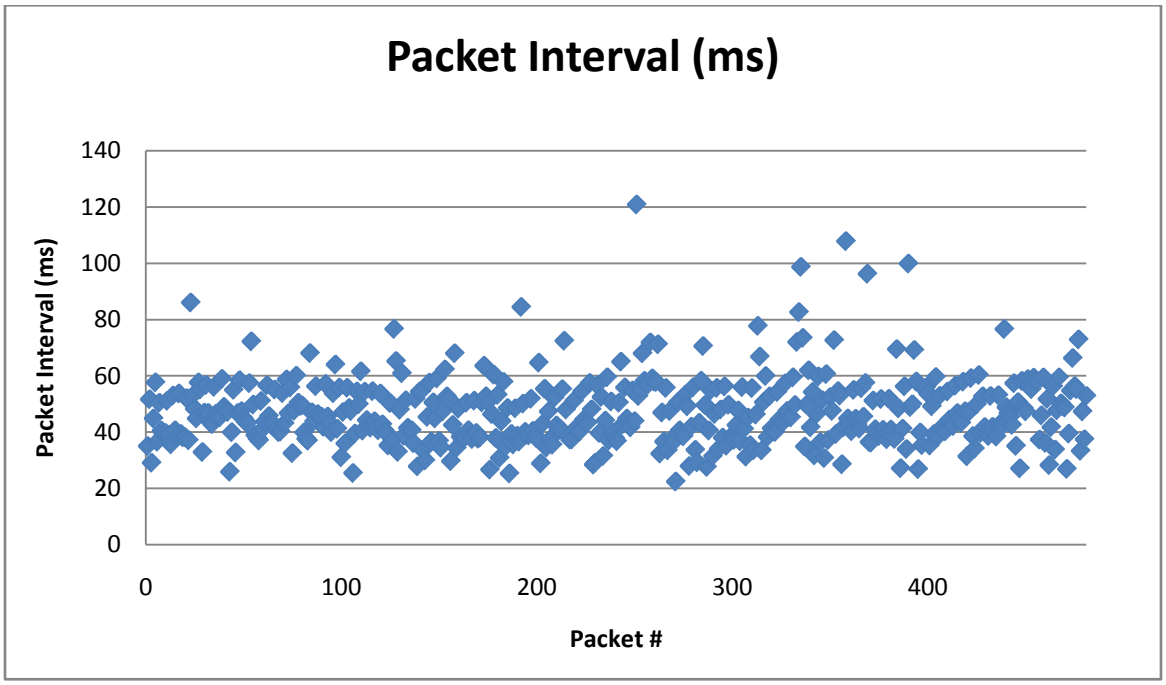
Results

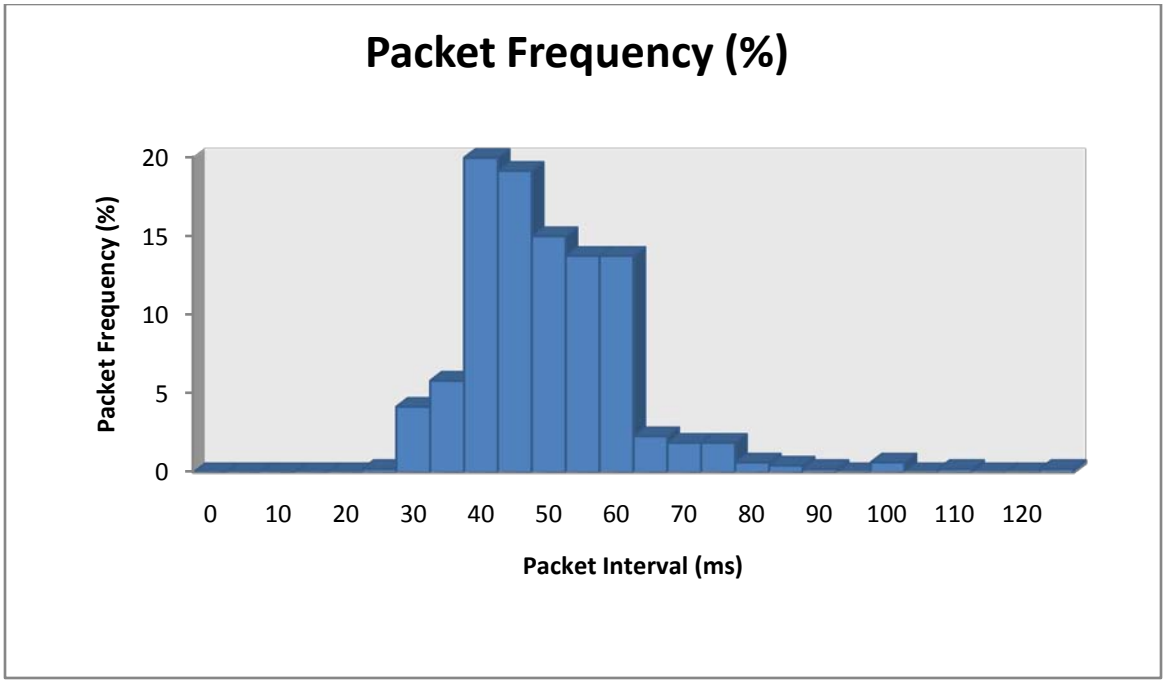
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	481	N/A	N/A	N/A
# Lost Packets	1			
Average (ms)	47.04		+/-10%	
Std. Deviation (ms)	12.00		+/-10%	
Min (ms)	22.43		+/-10%	
Max (ms)	120.82		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
140
120
100
80
60
40
20
0
0
100
200
300
400
Packet #


Packet Frequency (%)
Packet Frequency (%)
20
15
10
5
0
0
10
20
30
40
50
60
70
80
90
100
110
120
Packet Interval (ms)

Report: PHX-BT10-100-45-2-SW, Noise

Experimented by Jeehong Yang and Wajiha Shahid

University of Michigan

2008-07-24 14:45:57

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Phoenix Contact Bluetooth AP
Channel	N/A
Signal Power	-30
Noise Power	-45
Distance	30
Comments	Noise signal was centered at 2.441 GHz modeling Wireless LAN 802.11b.

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	45

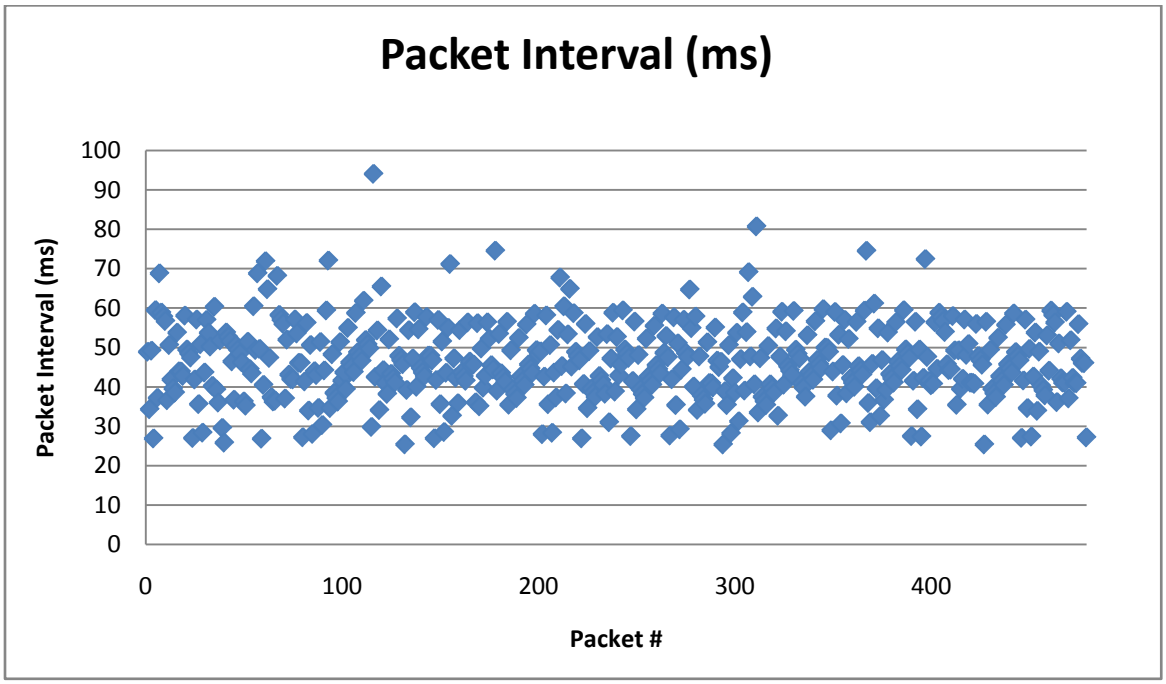
Results

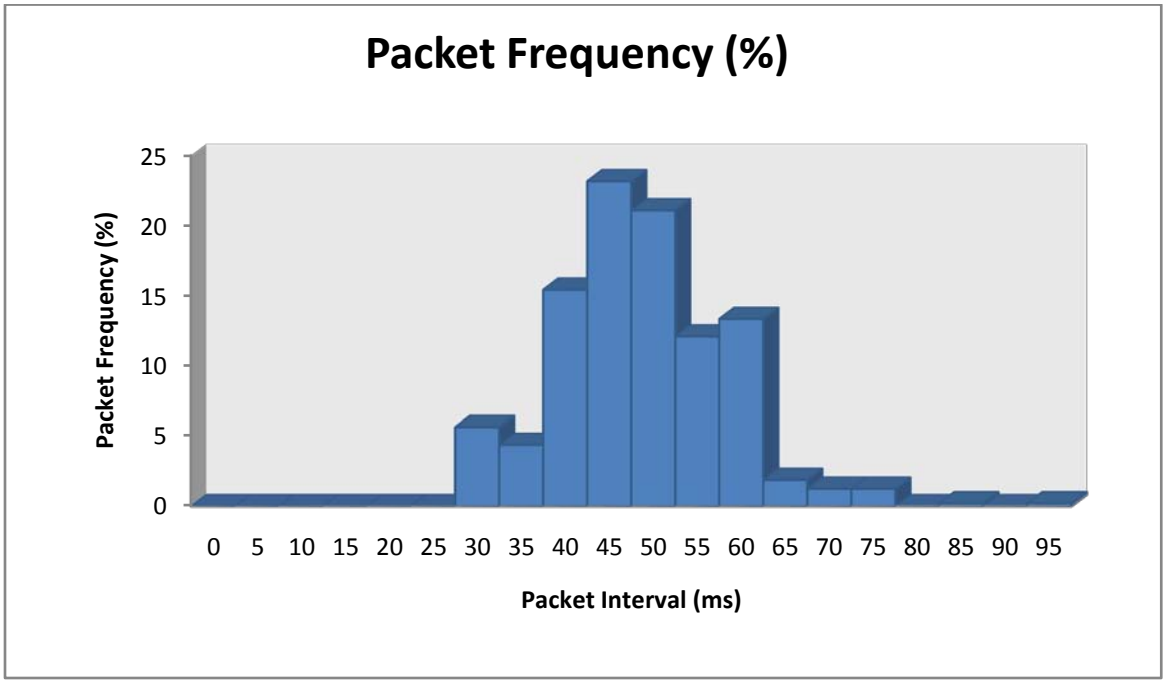
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	479	N/A	N/A	N/A
# Lost Packets	1			
Average (ms)	46.02		+/-10%	
Std. Deviation (ms)	9.68		+/-10%	
Min (ms)	25.38		+/-10%	
Max (ms)	94.07		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
100
90
80
70
60
50
40
30
20
10
0
0
100
200
300
400
Packet #


Packet Frequency (%)
Packet Frequency (%)
25
20
15
10
5
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
Packet Interval (ms)

Report: PHX-BT10-100-50-2-SW, Noise

Experimented by Jeehong Yang and Wajiha Shahid

University of Michigan

2008-07-24 14:46:01

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Phoenix Contact Bluetooth AP
Channel	N/A
Signal Power	-30
Noise Power	-50
Distance	30
Comments	Noise signal was centered at 2.441 GHz modeling Wireless LAN 802.11b.

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	45

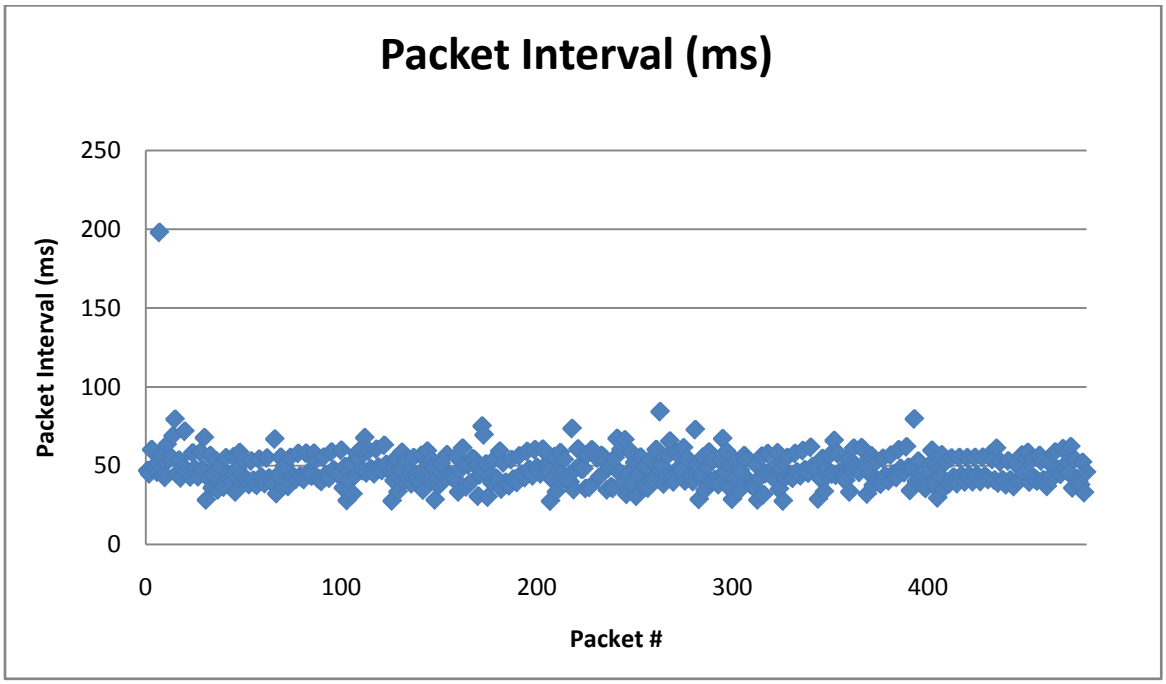
Results

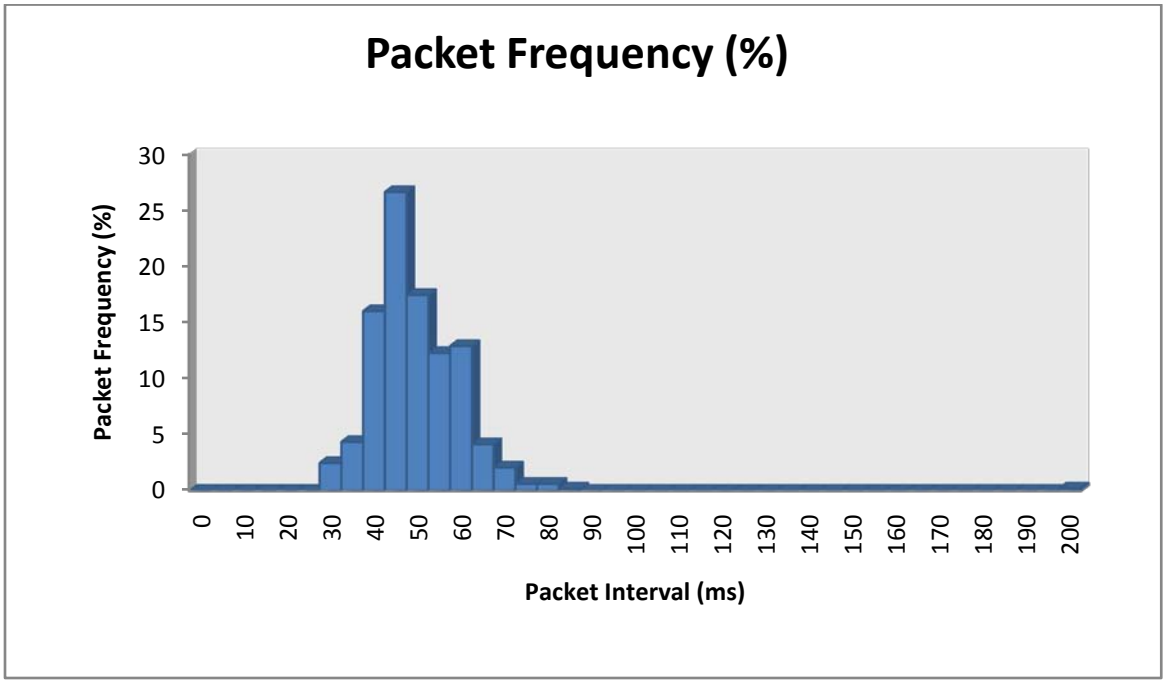
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	481	N/A	N/A	N/A
# Lost Packets	1			
Average (ms)	47.14		+/-10%	
Std. Deviation (ms)	11.51		+/-10%	
Min (ms)	27.40		+/-10%	
Max (ms)	197.97		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
250
200
150
100
50
0
Packet Interval (ms)
0
100
200
300
400
Packet #


Packet Frequency (%)
30
25
20
15
10
5
0
Packet Frequency (%)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Packet Interval (ms)

Report: PHX-BT10-100-55-2-SW, Noise

Experimented by Jeehong Yang and Wajiha Shahid

University of Michigan

2008-07-24 14:45:58

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Phoenix Contact Bluetooth AP
Channel	N/A
Signal Power	-30
Noise Power	-55
Distance	30
Comments	Noise signal was centered at 2.441 GHz modeling Wireless LAN 802.11b.

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	45

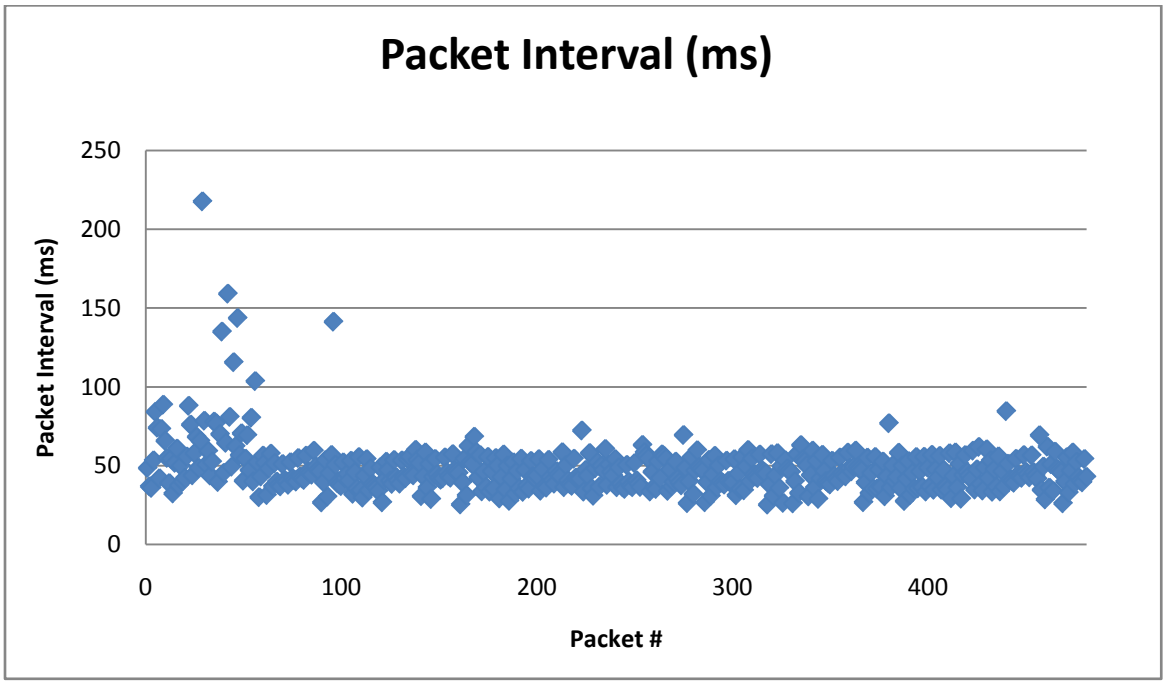
Results

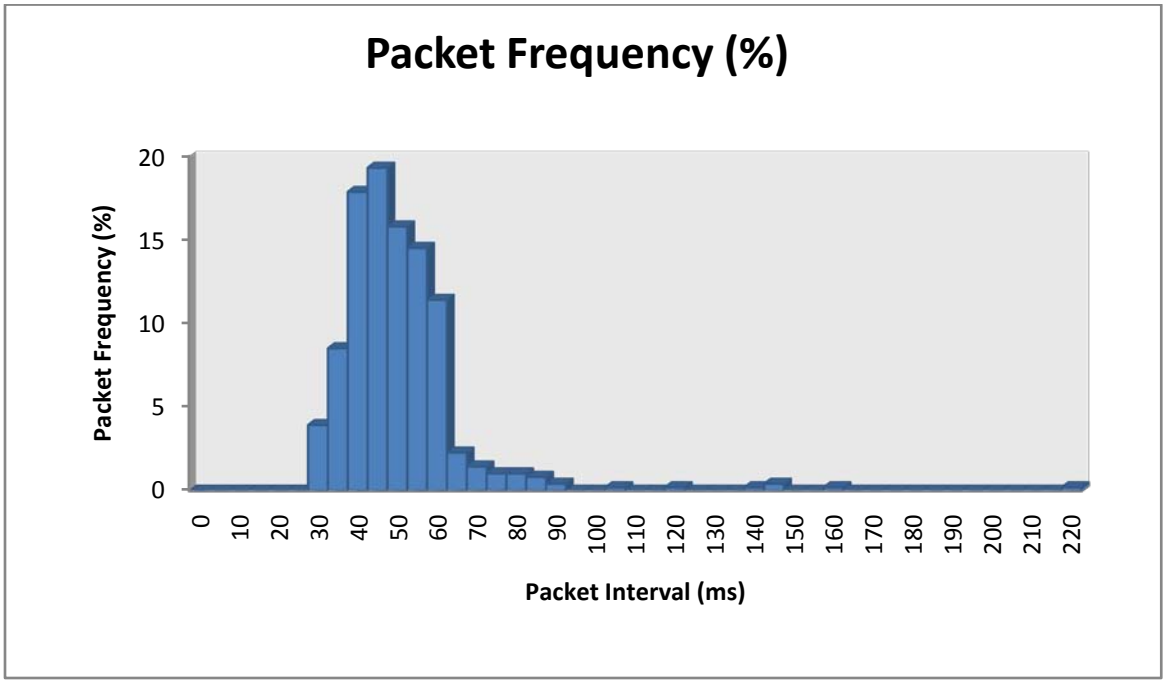
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	481	N/A	N/A	N/A
# Lost Packets	1			
Average (ms)	47.59		+/-10%	
Std. Deviation (ms)	16.55		+/-10%	
Min (ms)	25.29		+/-10%	
Max (ms)	217.67		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
250
200
150
100
50
0
0
100
200
300
400
Packet #


Packet Frequency (%)
Packet Frequency (%)
20
15
10
5
0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
Packet Interval (ms)

Report: PHX-BT10-100-60-2-SW, Noise

Experimented by Jeehong Yang and Wajiha Shahid

University of Michigan

2008-07-24 14:46:01

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Phoenix Contact Bluetooth AP
Channel	N/A
Signal Power	-30
Noise Power	-60
Distance	30
Comments	Noise signal was centered at 2.441 GHz modeling Wireless LAN 802.11b.

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	45

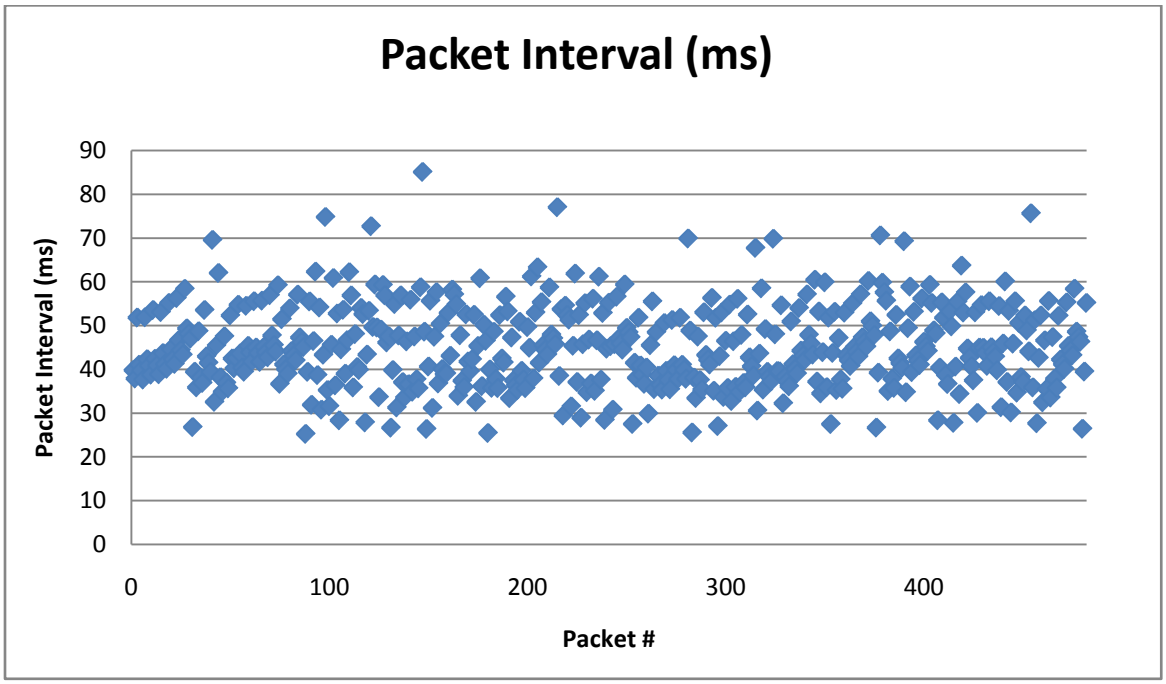
Results

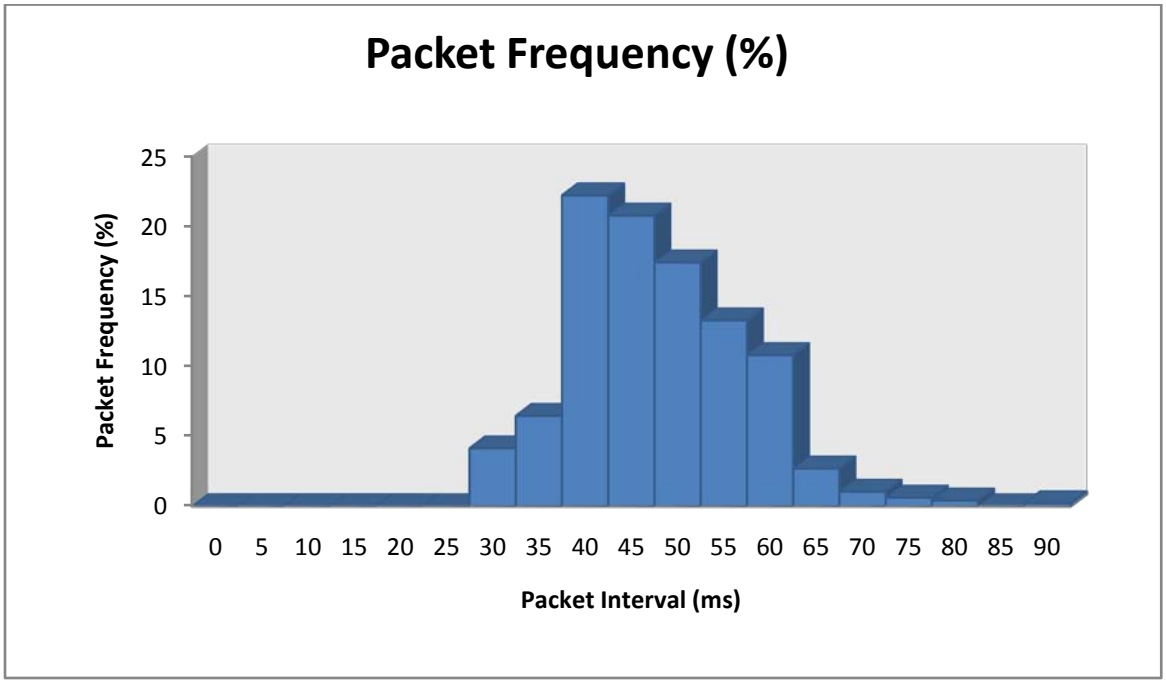
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	482	N/A	N/A	N/A
# Lost Packets	1			
Average (ms)	45.08		+/-10%	
Std. Deviation (ms)	9.39		+/-10%	
Min (ms)	25.26		+/-10%	
Max (ms)	85.12		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
90
80
70
60
50
40
30
20
10
0
0
100
200
300
400
Packet #


Packet Frequency (%)
Packet Frequency (%)
25
20
15
10
5
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90
Packet Interval (ms)

Report: PHX-BT10-100-40-2-SW, Noise

Experimented by Jeehong Yang and Wajiha Shahid

University of Michigan

2008-07-24 14:46:01

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Phoenix Contact Bluetooth AP
Channel	N/A
Signal Power	-30
Noise Power	-40
Distance	30
Comments	Noise signal was centered at 2.441 GHz modeling Wireless LAN 802.11b.

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	45

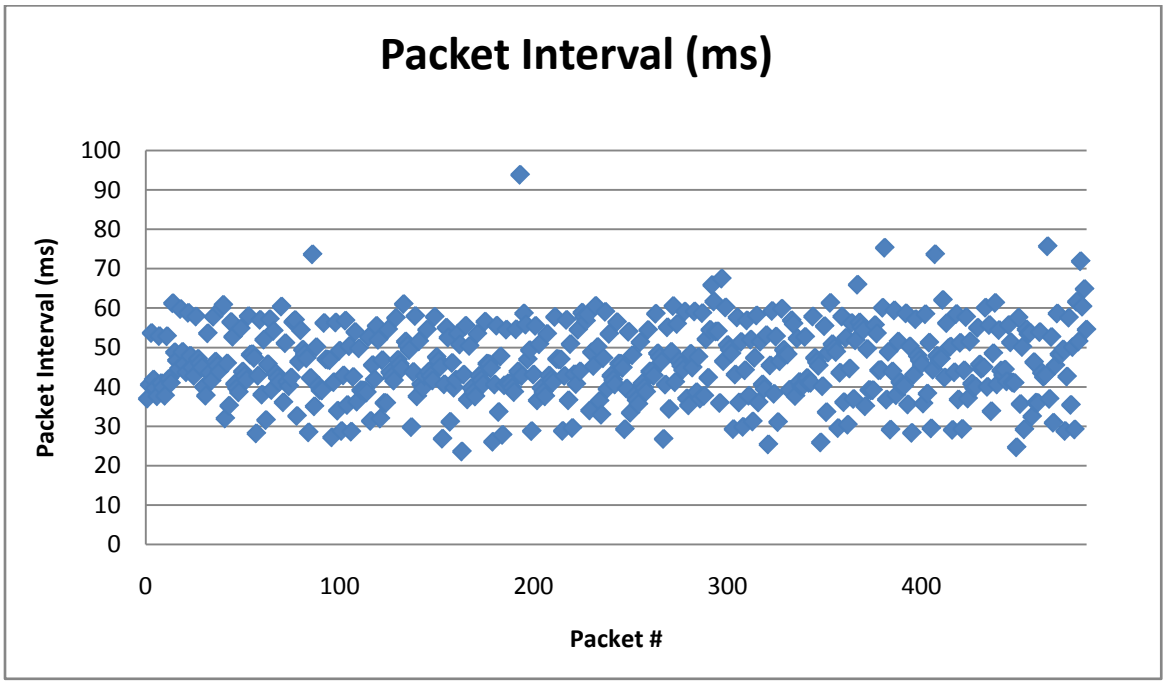
Results

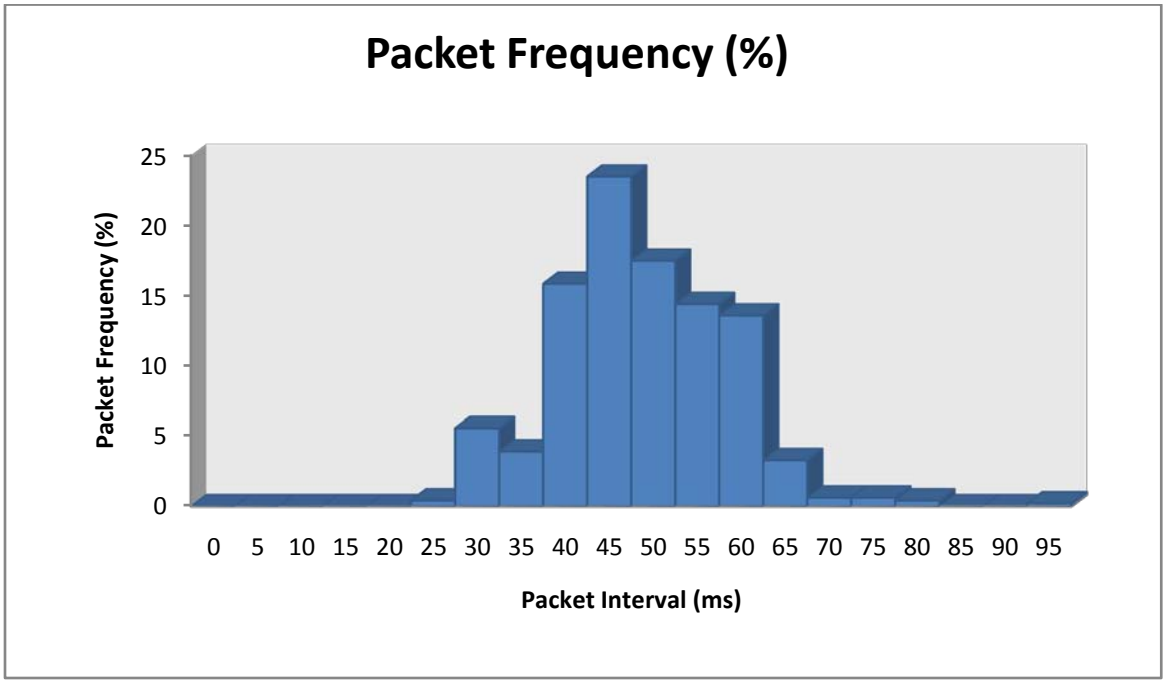
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	485	N/A	N/A	N/A
# Lost Packets	1			
Average (ms)	45.95		+/-10%	
Std. Deviation (ms)	9.46		+/-10%	
Min (ms)	23.59		+/-10%	
Max (ms)	93.85		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
100
90
80
70
60
50
40
30
20
10
0
0
100
200
300
400
Packet #

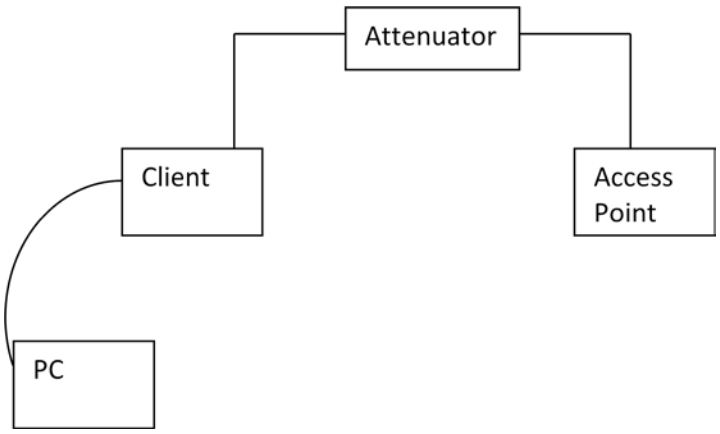

Packet Frequency (%)
Packet Frequency (%)
25
20
15
10
5
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
Packet Interval (ms)

Bluetooth: Low Power Testing

The goal of these tests was to determine the point where the packets begin experiencing a sharp rise in round trip times as the power decreases.

The PC was connected to the client via an ethernet cable and coaxial cables were used to connect the client and the access point (Fig 2). The bluetooth device transmission power was fixed at 1 dBm and attenuation (-15, -16, -19, -20 dB respectively for each test) was added. Finally, data packets were 'pinged' from the PC. This experiment was conducted for ping packet sizes of 60 and 1024 bytes. A schematic of the test is shows in Figure 2.

Figure 2: A schematic for the low power testing procedure



Network Device Test Report: NoAttenuationAdded-60Bytes-BT.txt

Experimented by Wajiha

University of Michigan

2009-03-04 09:59:12

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Phoenix Contact Bluetooth
Channel	-
Signal Power	1
Noise Power	-
Distance	-
Comments	

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	-
HistogramData Size (bytes)	60

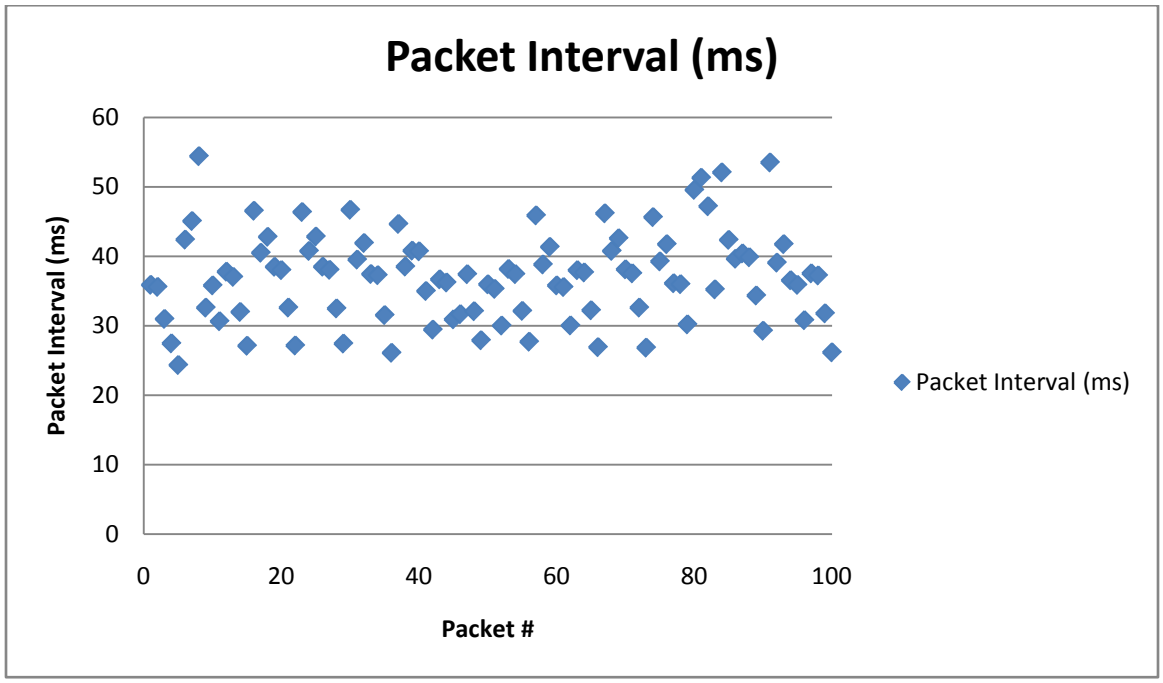
Results

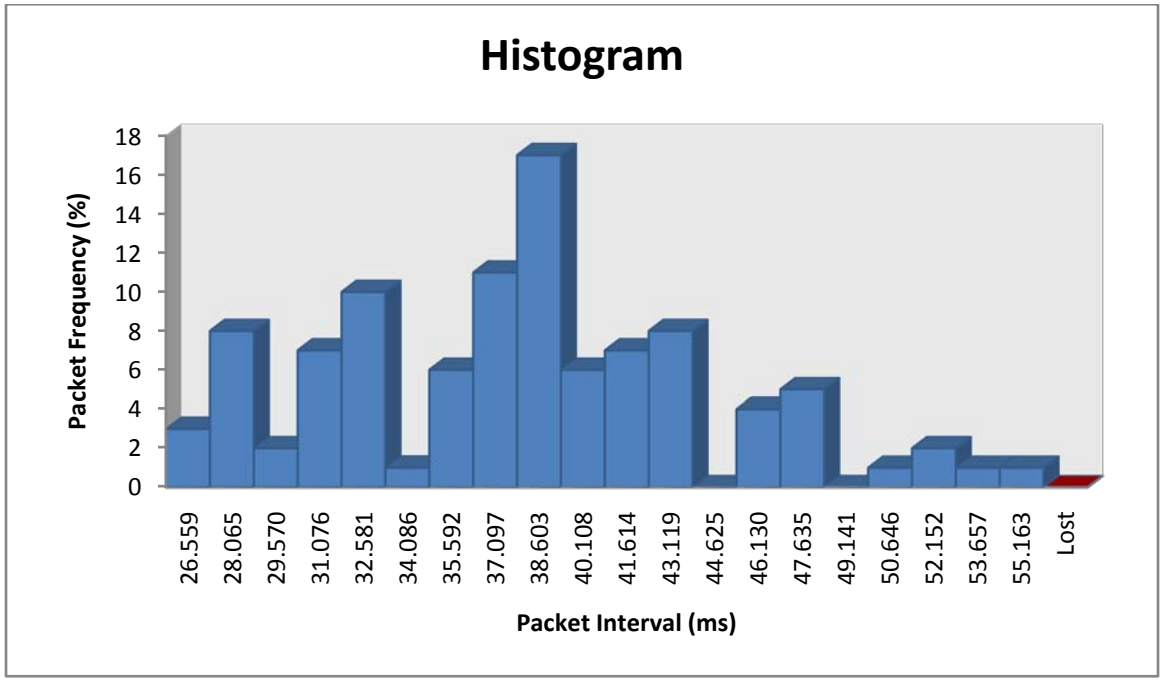
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	100	N/A	N/A	N/A
# Lost Packets	0			
Average (ms)	37.059		+/-10%	
Std. Deviation (ms)	6.46		+/-10%	
Min (ms)	24.301		+/-10%	
Max (ms)	54.410		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
60
50
40
30
20
10
0
0
20
40
60
80
100
Packet #
Packet Interval (ms)


Histogram
Packet Frequency (%)
18
16
14
12
10
8
6
4
2
0
26.559
28.065
29.570
31.076
32.581
34.086
35.592
37.097
38.603
40.108
41.614
43.119
44.625
46.130
47.635
49.141
50.646
52.152
53.657
55.163
Lost
Packet Interval (ms)

Network Device Test Report: Att=-16dBm,60Bytes-BT,TransmitPower=1dBm.txt

Experimented by Wajiha

University of Michigan

2009-03-04 09:59:12

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Phoenix Contact Bluetooth
Channel	-
Signal Power	1
Noise Power	-
Distance	-
Comments	

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	-
HistogramData Size (bytes)	60

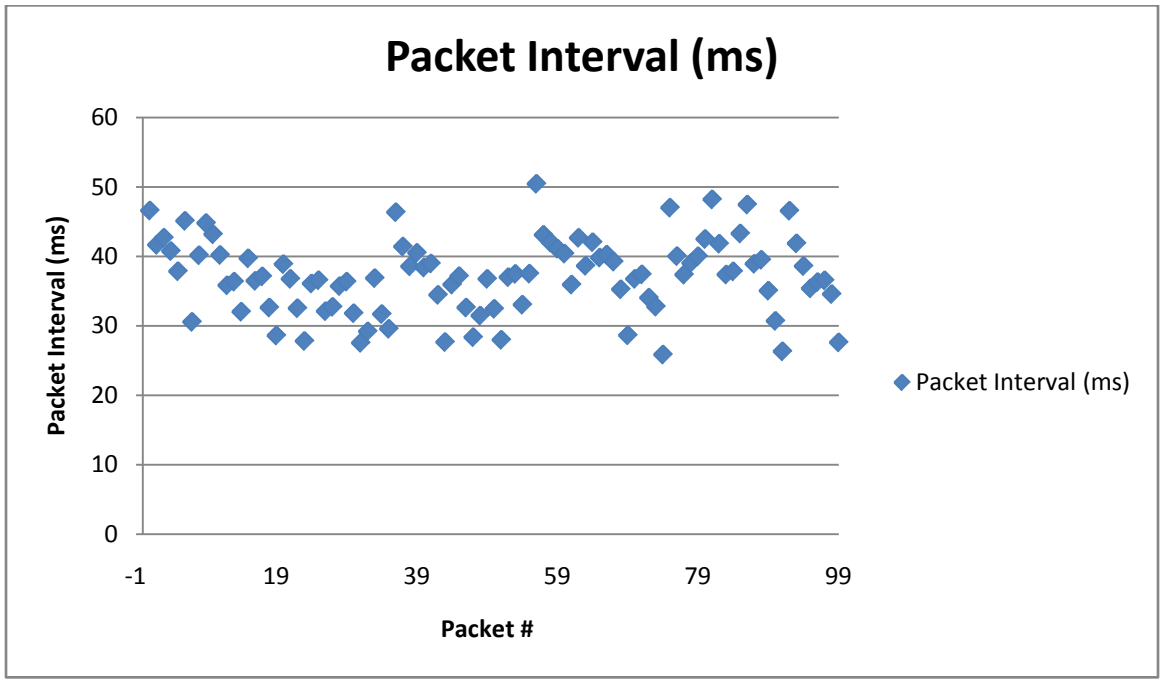
Results

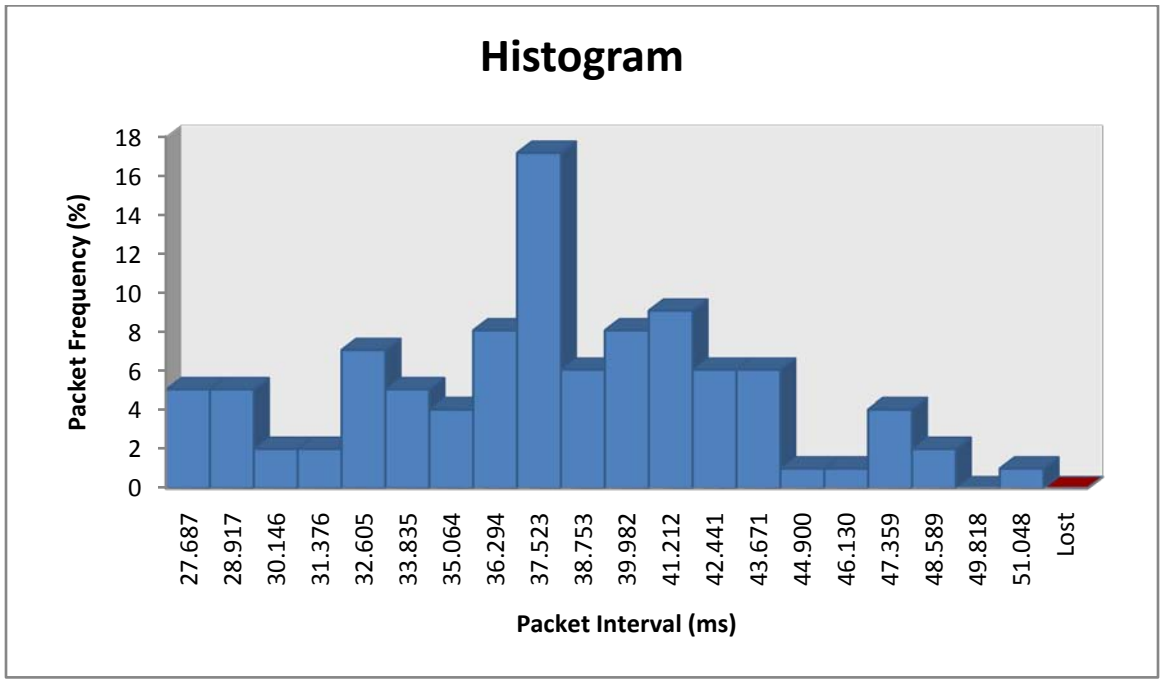
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	99	N/A	N/A	N/A
# Lost Packets	0			
Average (ms)	37.106		+/-10%	
Std. Deviation (ms)	5.35		+/-10%	
Min (ms)	25.843		+/-10%	
Max (ms)	50.433		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
60
50
40
30
20
10
0
Packet Interval (ms)
-1
19
39
59
79
99
Packet #
Packet Interval (ms)


Histogram
18
16
14
12
10
8
6
4
2
0
Packet Frequency (%)
27.687
28.917
30.146
31.376
32.605
33.835
35.064
36.294
37.523
38.753
39.982
41.212
42.441
43.671
44.900
46.130
47.359
48.589
49.818
51.048
Lost
Packet Interval (ms)

Network Device Test Report: Att=-18dB-60Bytes.txt

Experimented by Wajiha

University of Michigan

2009-03-04 09:59:12

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Phoenix Contact Bluetooth
Channel	-
Signal Power	1
Noise Power	-
Distance	-
Comments	

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	-
HistogramData Size (bytes)	60

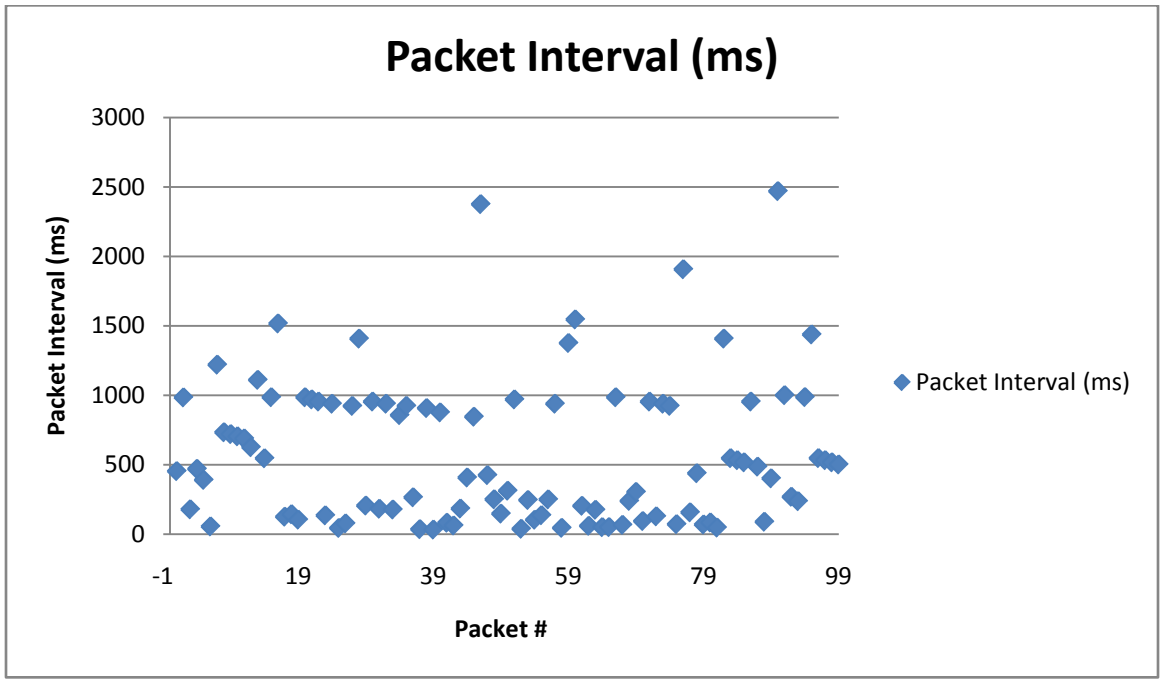
Results

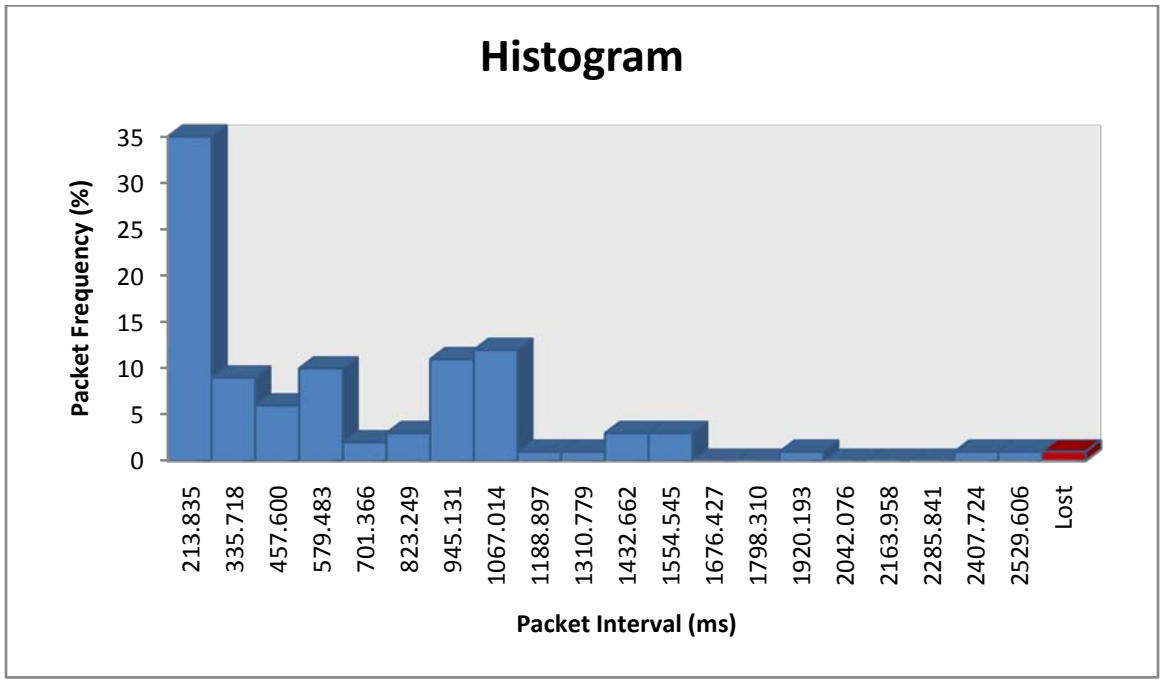
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	100	N/A	N/A	N/A
# Lost Packets	1			
Average (ms)	570.962		+/-10%	
Std. Deviation (ms)	515.95		+/-10%	
Min (ms)	31.011		+/-10%	
Max (ms)	2468.665		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
3000
2500
2000
1500
1000
500
0
Packet Interval (ms)
-1
19
39
59
79
99
Packet #
Packet Interval (ms)


Histogram
35
30
25
20
15
10
5
0
Packet Frequency (%)
213.835
335.718
457.600
579.483
701.366
823.249
945.131
1067.014
1188.897
1310.779
1432.662
1554.545
1676.427
1798.310
1920.193
2042.076
2163.958
2285.841
2407.724
2529.606
Lost
Packet Interval (ms)

Network Device Test Report: Att=-19dB-60Bytes.txt

Experimented by Wajiha

University of Michigan

2009-03-04 09:59:12

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Phoenix Contact Bluetooth
Channel	-
Signal Power	1
Noise Power	-
Distance	-
Comments	

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	-
HistogramData Size (bytes)	60

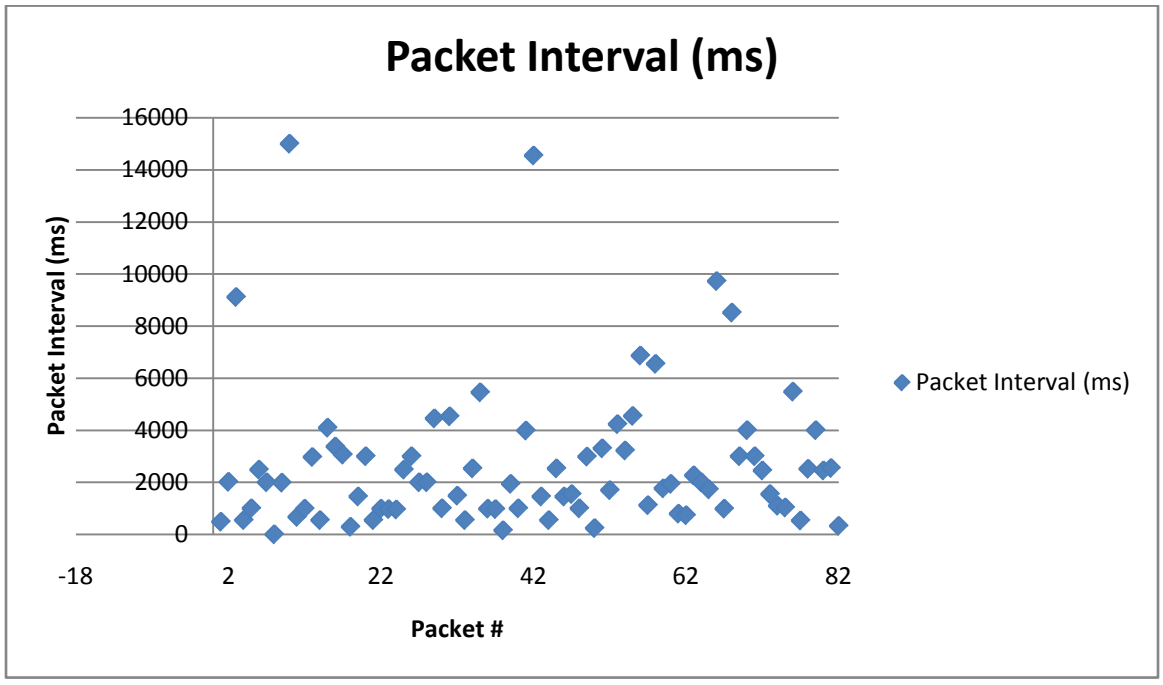
Results

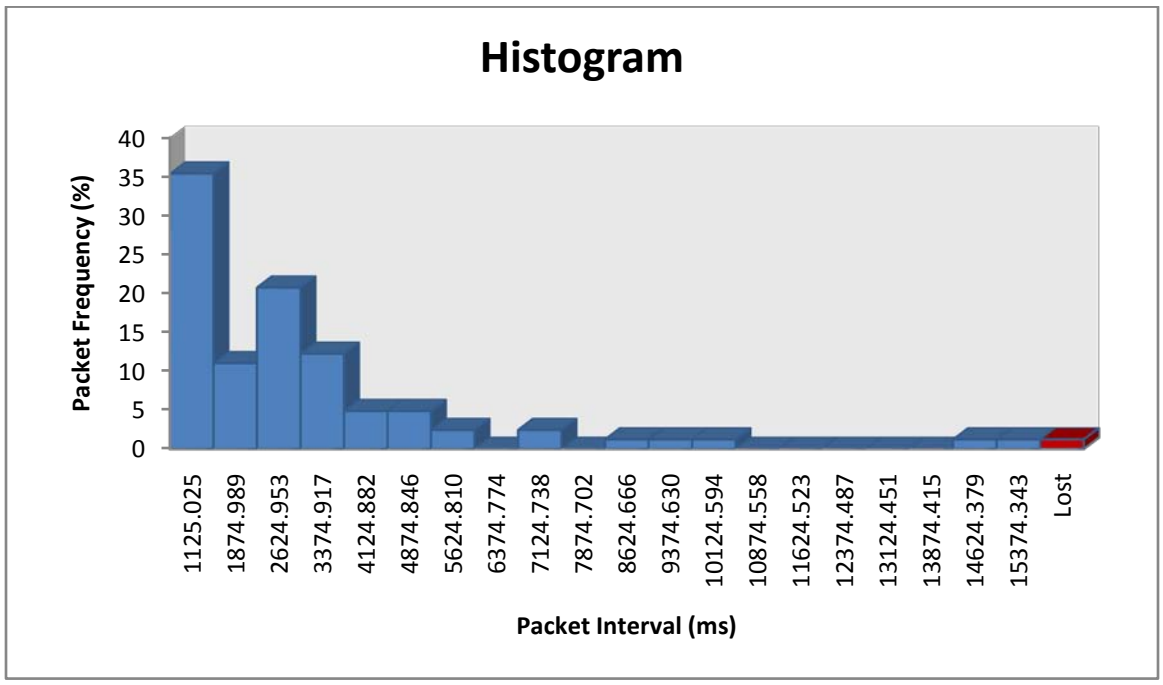
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	82	N/A	N/A	N/A
# Lost Packets	1			
Average (ms)	2758.53		+/-10%	
Std. Deviation (ms)	7516685.132		+/-10%	
Min (ms)	0.079		+/-10%	
Max (ms)	14999.361		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
16000
14000
12000
10000
8000
6000
4000
2000
0
Packet Interval (ms)
-18
2
22
42
62
82
Packet #
Packet Interval (ms)


Histogram
40
35
30
25
20
15
10
5
0
Packet Frequency (%)
1125.025
1874.989
2624.953
3374.917
4124.882
4874.846
5624.810
6374.774
7124.738
7874.702
8624.666
9374.630
10124.594
10874.558
11624.523
12374.487
13124.451
13874.415
14624.379
15374.343
Lost
Packet Interval (ms)

Network Device Test Report: NoAttenuationAdded,1024Bytes-BT,TransmitPower=1dBm.txt

Experimented by Wajiha

University of Michigan

2009-03-04 09:59:12

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Phoenix Contact Bluetooth
Channel	-
Signal Power	1
Noise Power	-
Distance	-
Comments	

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	-
HistogramData Size (bytes)	1024

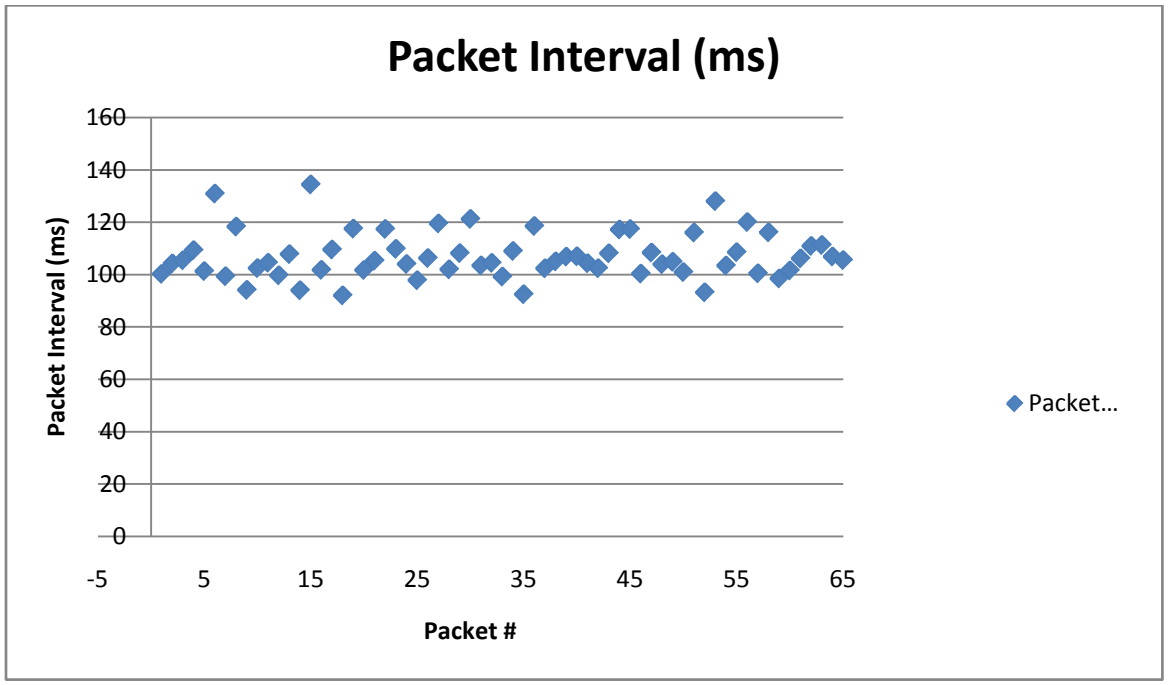
Results

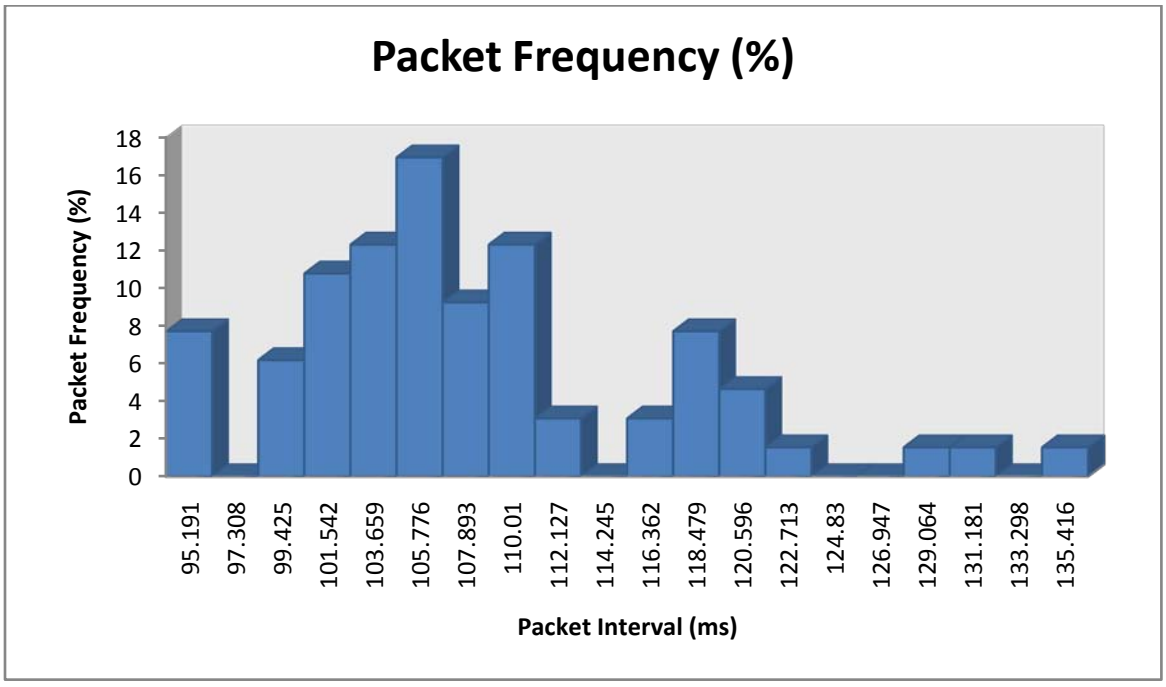
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	65	N/A	N/A	N/A
# Lost Packets	0			
Average (ms)	107.100		+/-10%	
Std. Deviation (ms)	8.80		+/-10%	
Min (ms)	92.015		+/-10%	
Max (ms)	134.357		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
160
140
120
100
80
60
40
20
0
Packet Interval (ms)
-5
5
15
25
35
45
55
65
Packet #
Packet…


Packet Frequency (%)
18
16
14
12
10
8
6
4
2
0
Packet Frequency (%)
95.191
97.308
99.425
101.542
103.659
105.776
107.893
110.01
112.127
114.245
116.362
118.479
120.596
122.713
124.83
126.947
129.064
131.181
133.298
135.416
Packet Interval (ms)

Network Device Test Report: Att=-16dB-60Bytes.txt

Experimented by Malvika

Student - UoM

2009-02-12 15:17:19

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Bluetooth Access Point Modbus TCP-Ethernet/IP-ProfiNet
Channel	-
Signal Power	1
Noise Power	-
Distance	-
Comments	

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	200
HistogramData Size (bytes)	1024

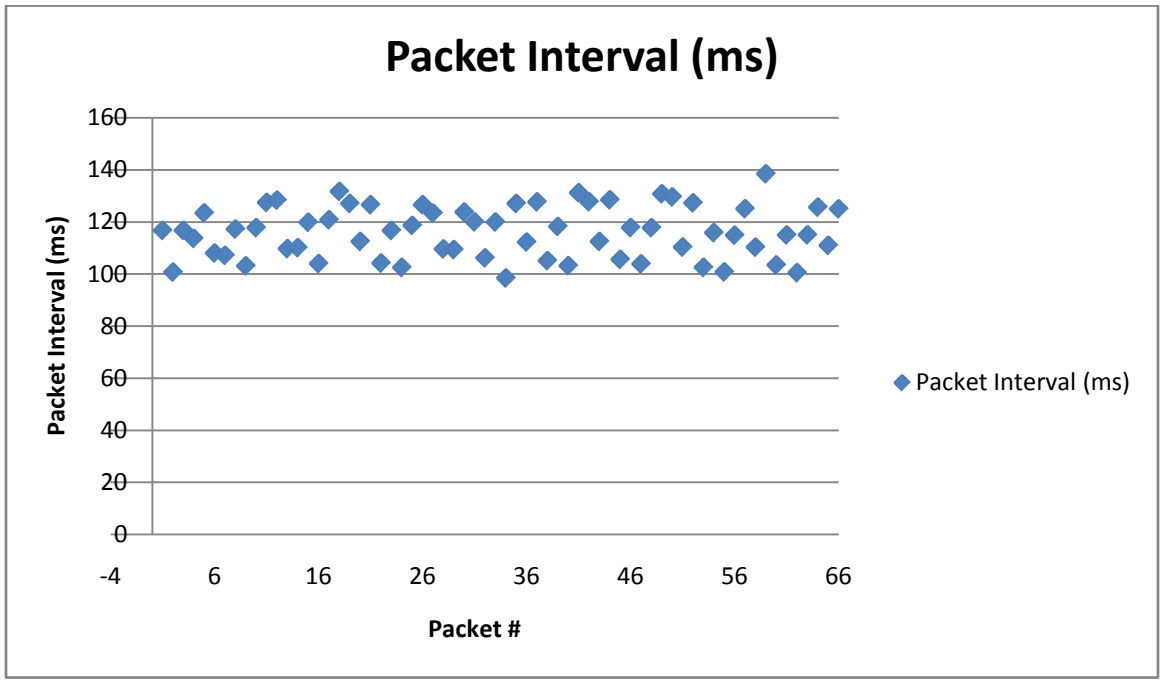
Results

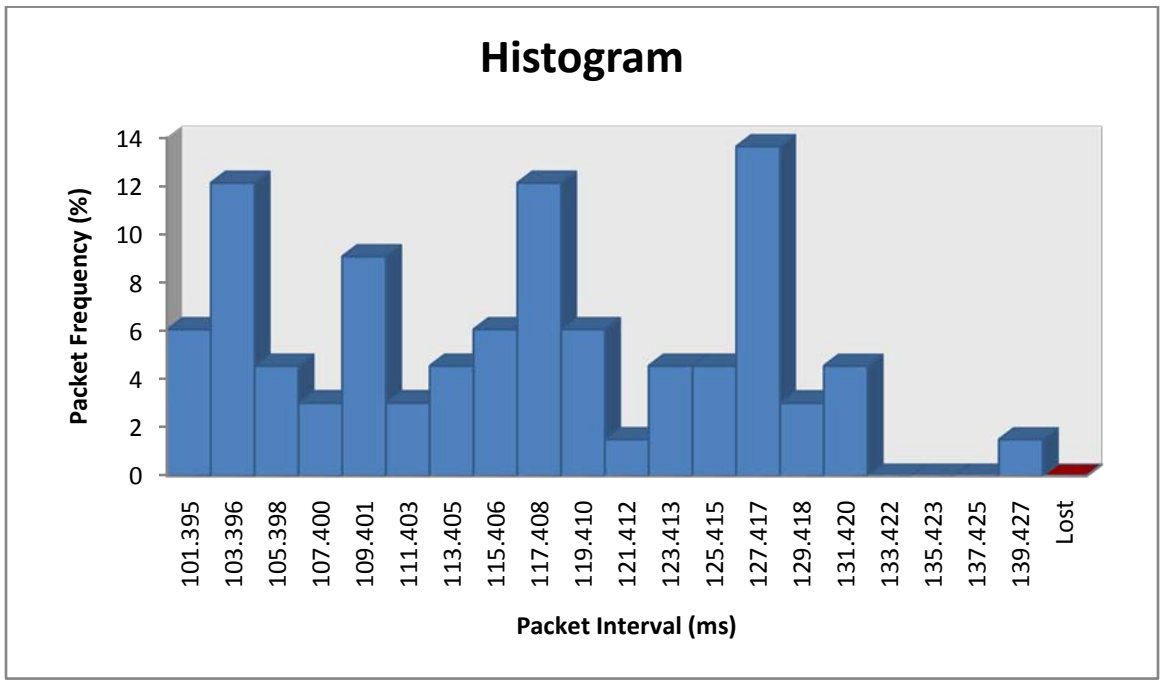
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	66	N/A	N/A	N/A
# Lost Packets	0			
Average (ms)	116.045		+/-10%	
Std. Deviation (ms)	9.83		+/-10%	
Min (ms)	98.392		+/-10%	
Max (ms)	138.426		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
160
140
120
100
80
60
40
20
0
Packet Interval (ms)
-4
6
16
26
36
46
56
66
Packet #
Packet Interval (ms)


Histogram
14
12
10
8
6
4
2
0
Packet Frequency (%)
101.395
103.396
105.398
107.400
109.401
111.403
113.405
115.406
117.408
119.410
121.412
123.413
125.415
127.417
129.418
131.420
133.422
135.423
137.425
139.427
Lost
Packet Interval (ms)

Network Device Test Report: 1024 bytes Att=-17dB.txt

Experimented by Wajiha

University of Michigan

2009-03-04 09:59:12

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Bluetooth Access Point Modbus TCP-Ethernet/IP-ProfiNet
Channel	-
Signal Power	1
Noise Power	-
Distance	-
Comments	

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	-
HistogramData Size (bytes)	1024

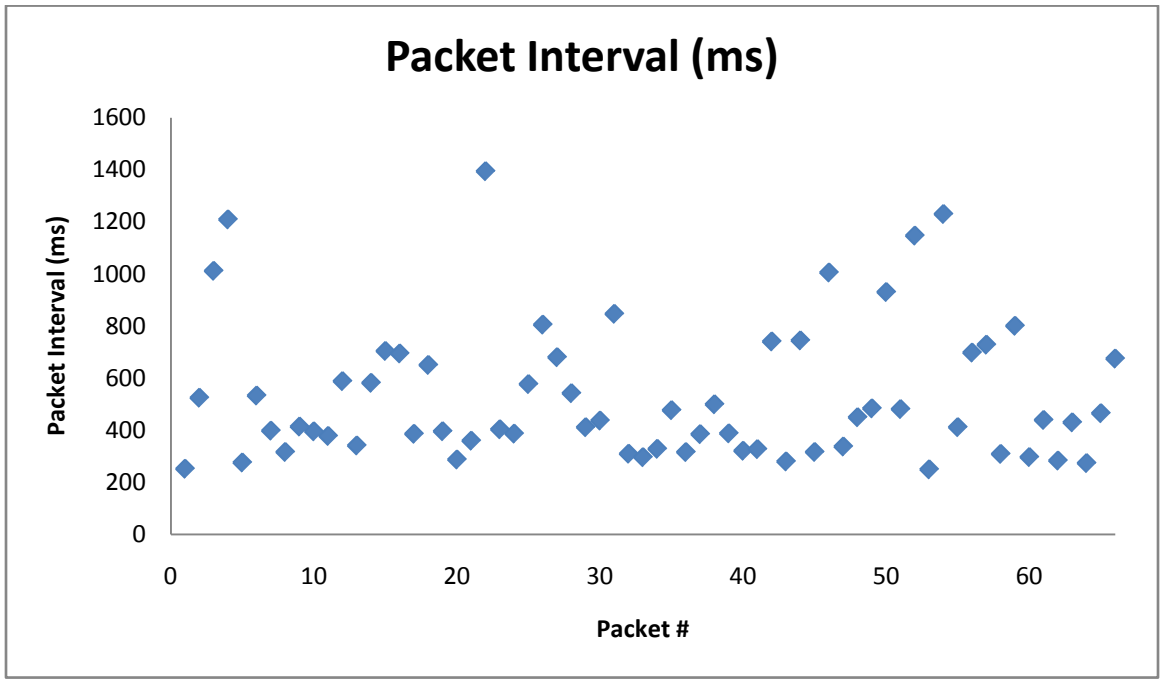
Results

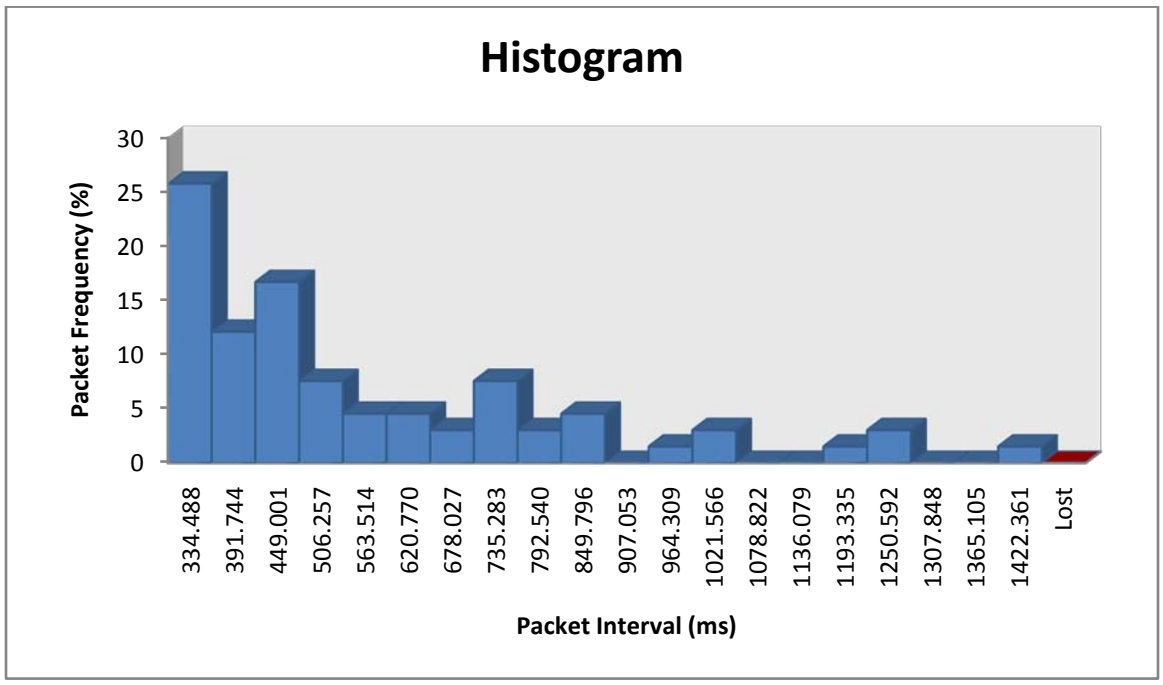
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	66	N/A	N/A	N/A
# Lost Packets	0			
Average (ms)	529.920		+/-10%	
Std. Deviation (ms)	264.11		+/-10%	
Min (ms)	248.603		+/-10%	
Max (ms)	1393.733		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
1600
1400
1200
1000
800
600
400
200
0
0
10
20
30
40
50
60
Packet #


Histogram
Packet Frequency (%)
30
25
20
15
10
5
0
334.488
391.744
449.001
506.257
563.514
620.770
678.027
735.283
792.540
849.796
907.053
964.309
1021.566
1078.822
1136.079
1193.335
1250.592
1307.848
1365.105
1422.361
Lost
Packet Interval (ms)

Network Device Test Report: 1024 bytes at -18 dbNew.txt

Experimented by Wajiha

University of Michigan

2009-03-04 09:59:12

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Bluetooth Access Point Modbus TCP-Ethernet/IP-ProfiNet
Channel	-
Signal Power	1
Noise Power	-
Distance	-
Comments	

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	-
HistogramData Size (bytes)	1024

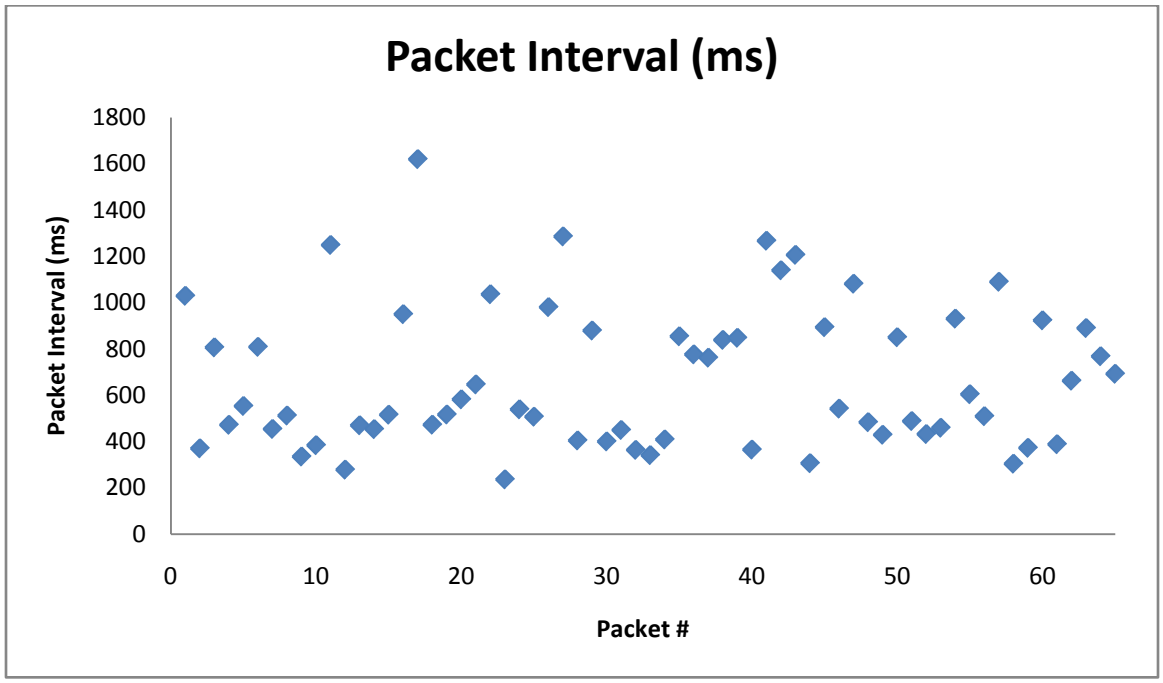
Results

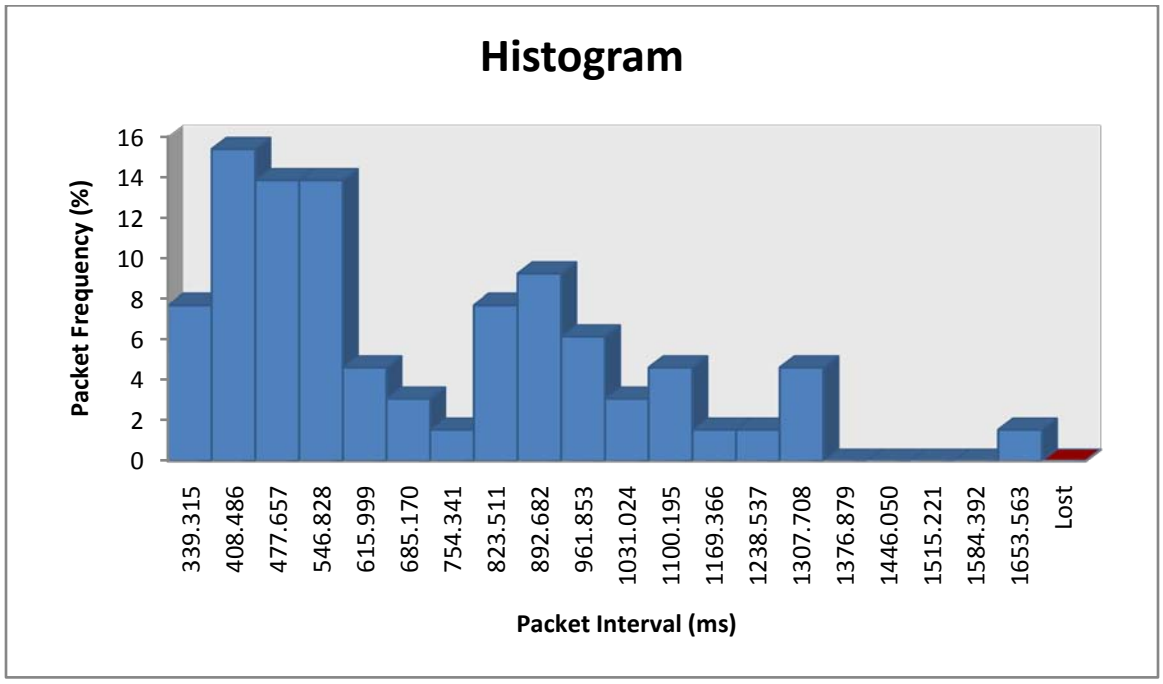
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	65	N/A	N/A	N/A
# Lost Packets	0			
Average (ms)	667.950		+/-10%	
Std. Deviation (ms)	305.48		+/-10%	
Min (ms)	235.558		+/-10%	
Max (ms)	1618.978		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
1800
1600
1400
1200
1000
800
600
400
200
0
0
10
20
30
40
50
60
Packet #


Histogram
Packet Frequency (%)
16
14
12
10
8
6
4
2
0
339.315
408.486
477.657
546.828
615.999
685.170
754.341
823.511
892.682
961.853
1031.024
1100.195
1169.366
1238.537
1307.708
1376.879
1446.050
1515.221
1584.392
1653.563
Lost
Packet Interval (ms)

Network Device Test Report: 1024 bytes at Att=-20 db.txt

Experimented by Wajiha

University of Michigan

2009-03-04 09:59:12

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Bluetooth Access Point Modbus TCP-Ethernet/IP-ProfiNet
Channel	-
Signal Power	1
Noise Power	-
Distance	-
Comments	

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	-
HistogramData Size (bytes)	1024

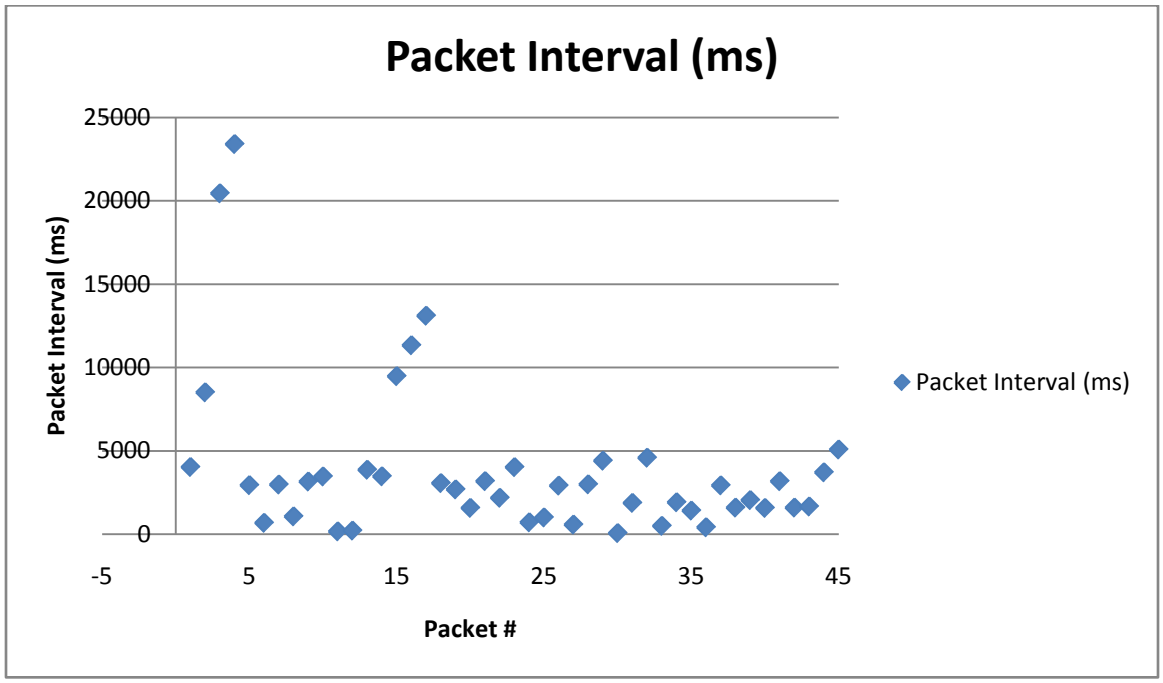
Results

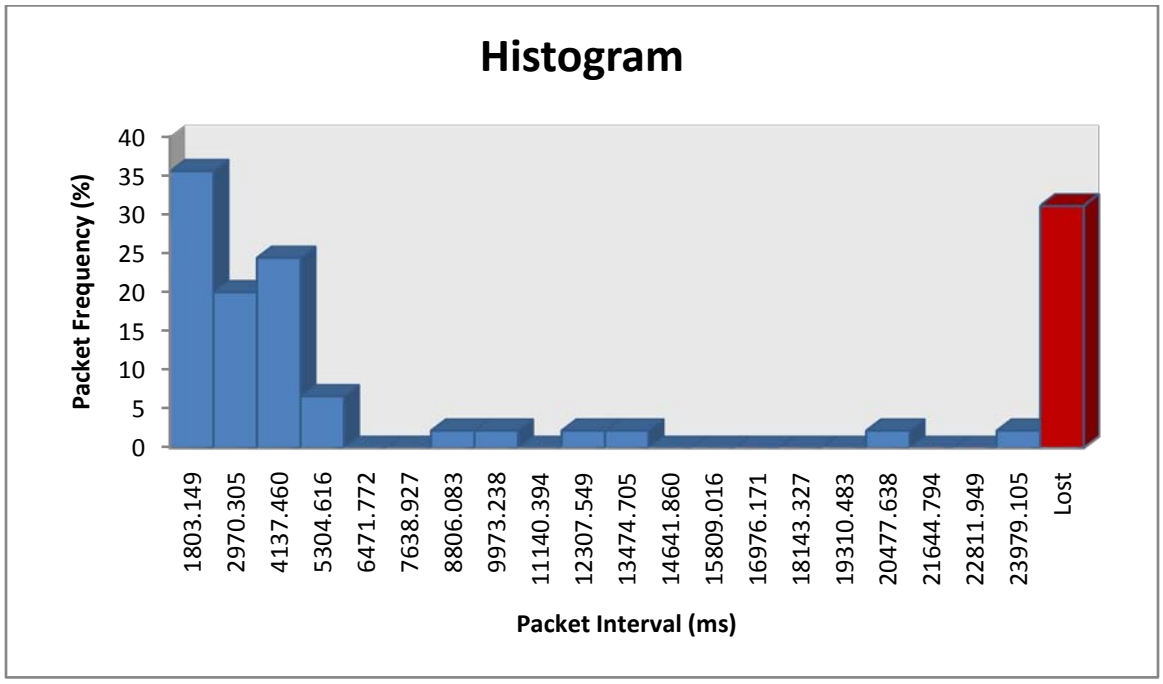
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	45	N/A	N/A	N/A
# Lost Packets	14			
Average (ms)	3893.871		+/-10%	
Std. Deviation (ms)	4812.33		+/-10%	
Min (ms)	52.416		+/-10%	
Max (ms)	23395.527		+/-10%	

Post-experiment Comments

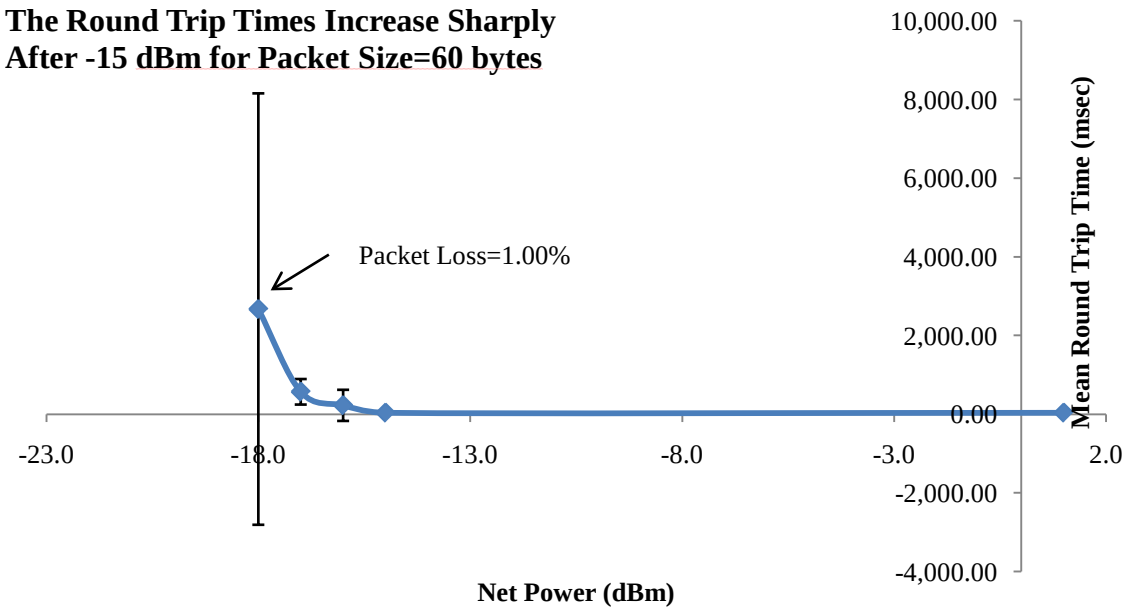
Post-experiment comments can be added here.

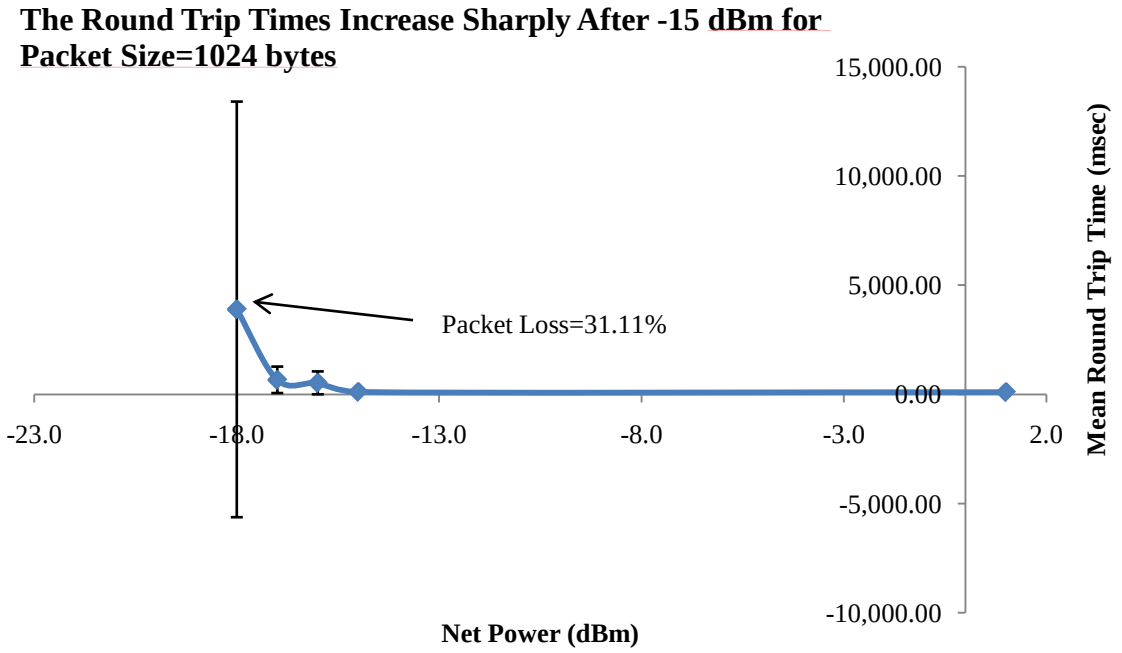
Graphs


Packet Interval (ms)
25000
20000
15000
10000
5000
0
-5
5
15
25
35
45
Packet Interval (ms)
Packet #
Packet Interval (ms)


Histogram
40
35
30
25
20
15
10
5
0
Packet Frequency (%)
1803.149
2970.305
4137.460
5304.616
6471.772
7638.927
8806.083
9973.238
11140.394
12307.549
13474.705
14641.860
15809.016
16976.171
18143.327
19310.483
20477.638
21644.794
22811.949
23979.105
Lost
Packet Interval (ms)

Round Trip Times Vs Power for 60 Bytes and 1024 Bytes





In these tests, the net power was reduced until there was more than 1% packet loss for 60 byte packets; this limit was hit at -18dBm. Illustrating how the size of packets affects system robustness at low signal power, we show here that at -18dBm the packet loss is 31.11%.

Section 2

Test Results for Phoenix Contact 802.11g

This section contains results for the following experiment:
-RF interference tests

The test setup was similar to the Bluetooth interference test setup (Figure 1 pg 10).

Noise Power	Distance	Std. Deviation	Average	Packets Lost
No noise	100	6.65	6.65	1/372
-45	100	151.01	52.14	34/393
-50	100	10.74	12	1/372
-55	100	5.99	6.85	1/368
-60	100	5.87	7	1/369

Report:PHX-W11G-100-XX-2SW-Baseline

Experimented by Jeehong Yang and Wajiha Shahid

University of Michigan

2008-07-23 19:14:50

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Phoenix Contact Wireless 802.11g
Channel	6 (2.437 GHz)
Signal Power	-30
Noise Power	No noise
Distance	100
Comments	Noise model: 802.11g sweeping noise centered at 2.437GHz.

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	1024

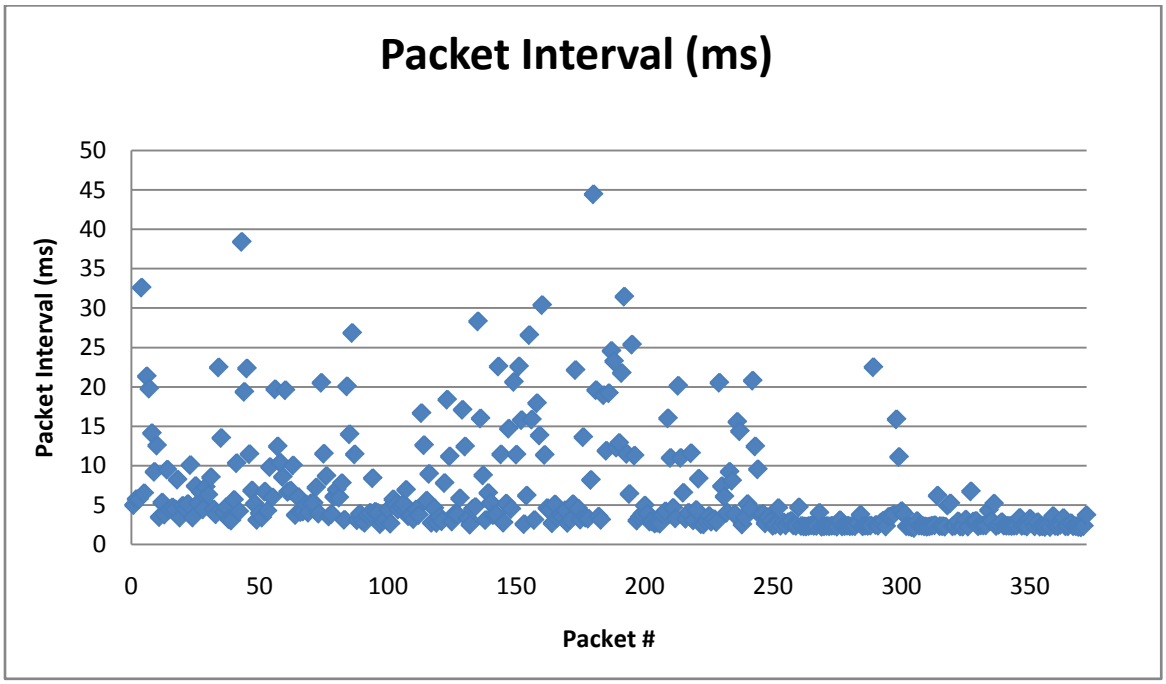
Results

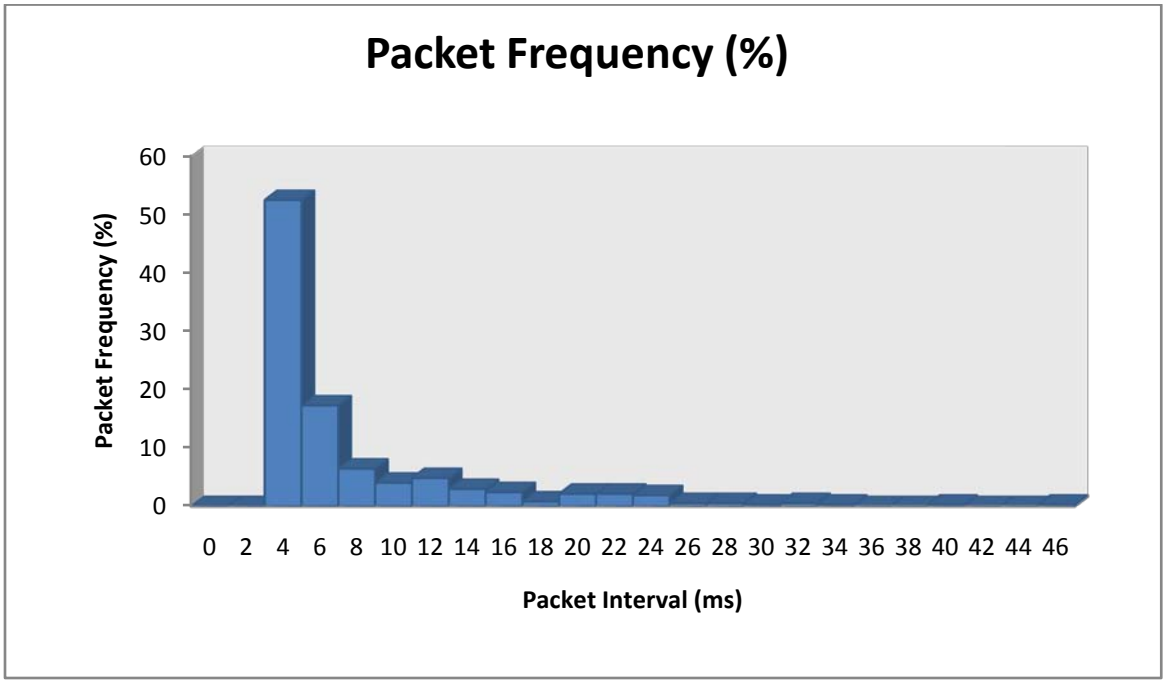
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	372	N/A	N/A	N/A
# Lost Packets	1			
Average (ms)	6.65		+/-10%	
Std. Deviation (ms)	6.55		+/-10%	
Min (ms)	2.07		+/-10%	
Max (ms)	44.45		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
50
45
40
35
30
25
20
15
10
5
0
0
50
100
150
200
250
300
350
Packet #


Packet Frequency (%)
Packet Frequency (%)
60
50
40
30
20
10
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46
Packet Interval (ms)

Report: PHX-W11G-100-45-2-SW, Noise

Experimented by Jeehong Yang and Wajiha Shahid

University of Michigan

2008-07-23 19:14:57

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Phoenix Contact Wireless 802.11g
Channel	6 (2.437 GHz)
Signal Power	-30
Noise Power	-45
Distance	100
Comments	Noise model: 802.11g sweeping noise centered at 2.437GHz.

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	1024

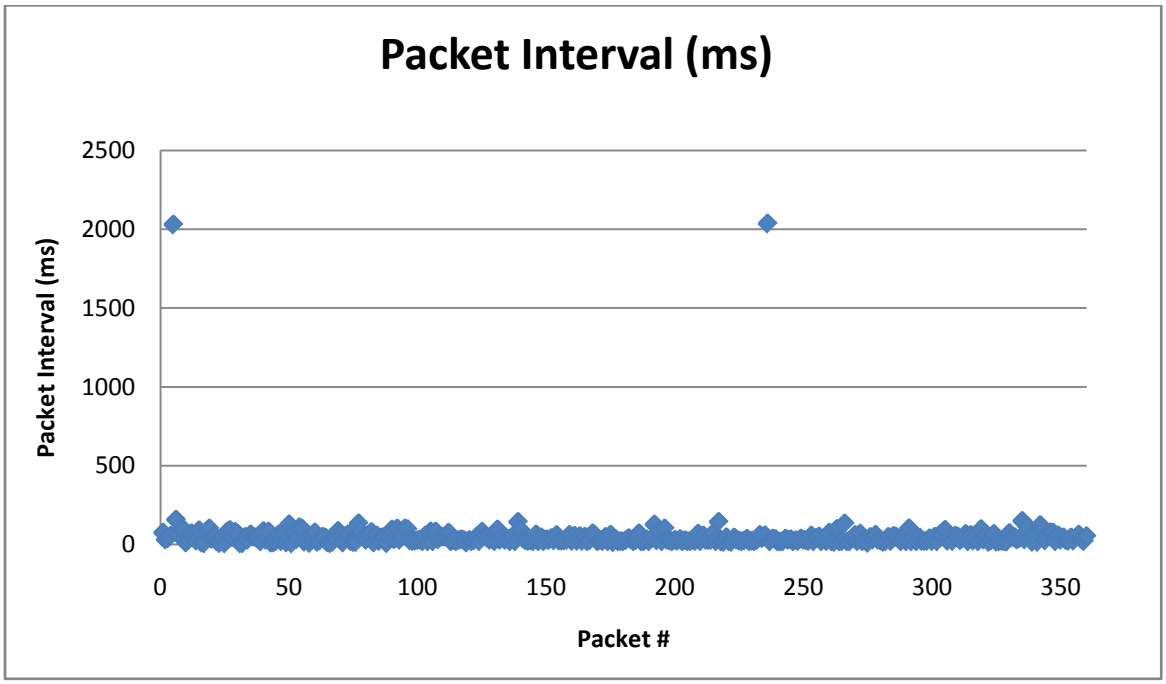
Results

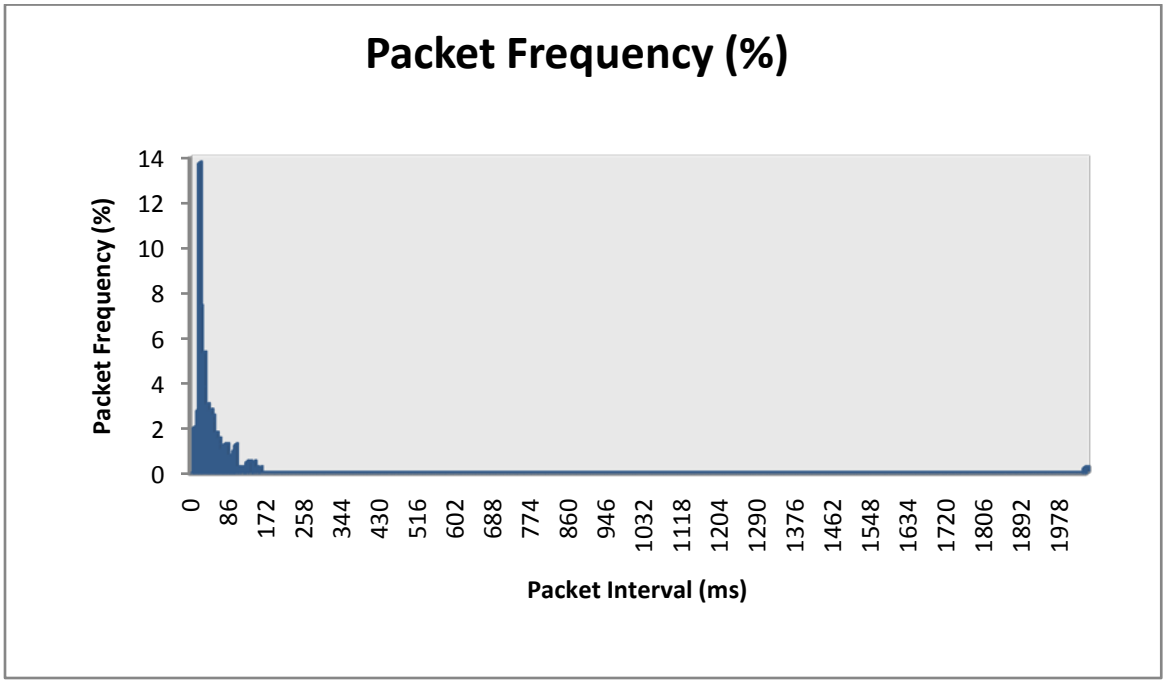
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	393	N/A	N/A	N/A
# Lost Packets	34			
Average (ms)	52.14		+/-10%	
Std. Deviation (ms)	151.01		+/-10%	
Min (ms)	6.35		+/-10%	
Max (ms)	2037.77		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
2500
2000
1500
1000
500
0
0
50
100
150
200
250
300
350
Packet #


Packet Frequency (%)
Packet Frequency (%)
14
12
10
8
6
4
2
0
0
86
172
258
344
430
516
602
688
774
860
946
1032
1118
1204
1290
1376
1462
1548
1634
1720
1806
1892
1978
Packet Interval (ms)

Report: PHX-W11G-100-50-2-SW, Noise

Experimented by Jeehong Yang and Wajiha Shahid

University of Michigan

2008-07-23 19:14:57

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Phoenix Contact Wireless 802.11g
Channel	6 (2.437 GHz)
Signal Power	-30
Noise Power	-50
Distance	100
Comments	Noise model: 802.11g sweeping noise centered at 2.437GHz.

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	1024

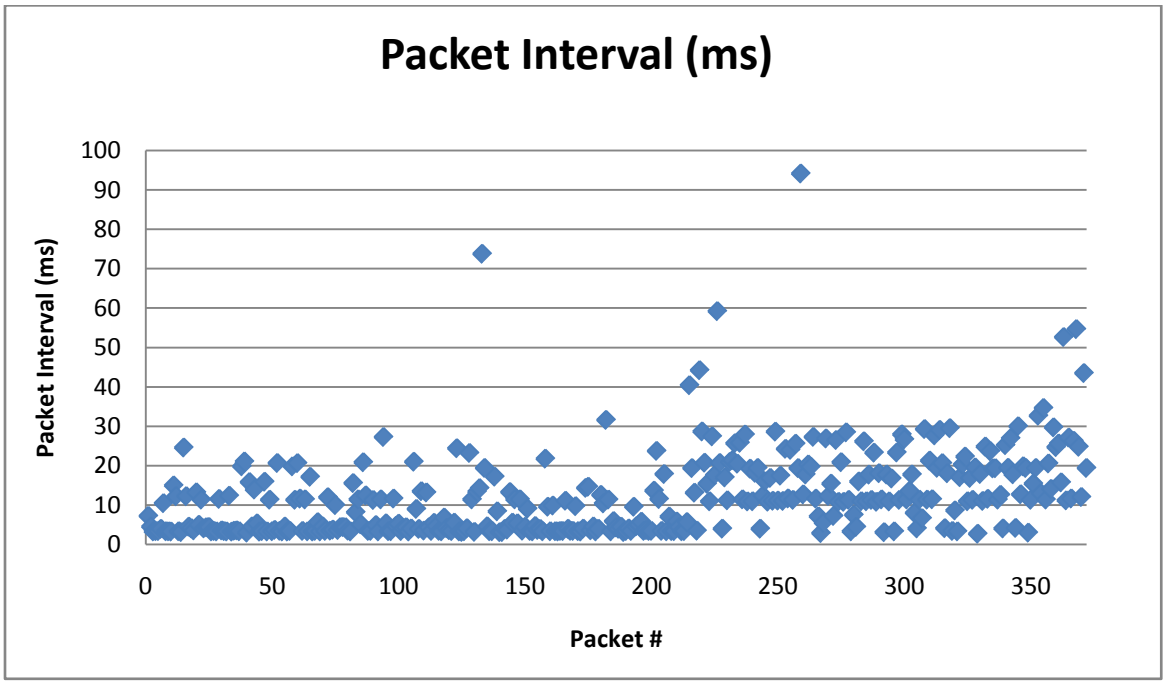
Results

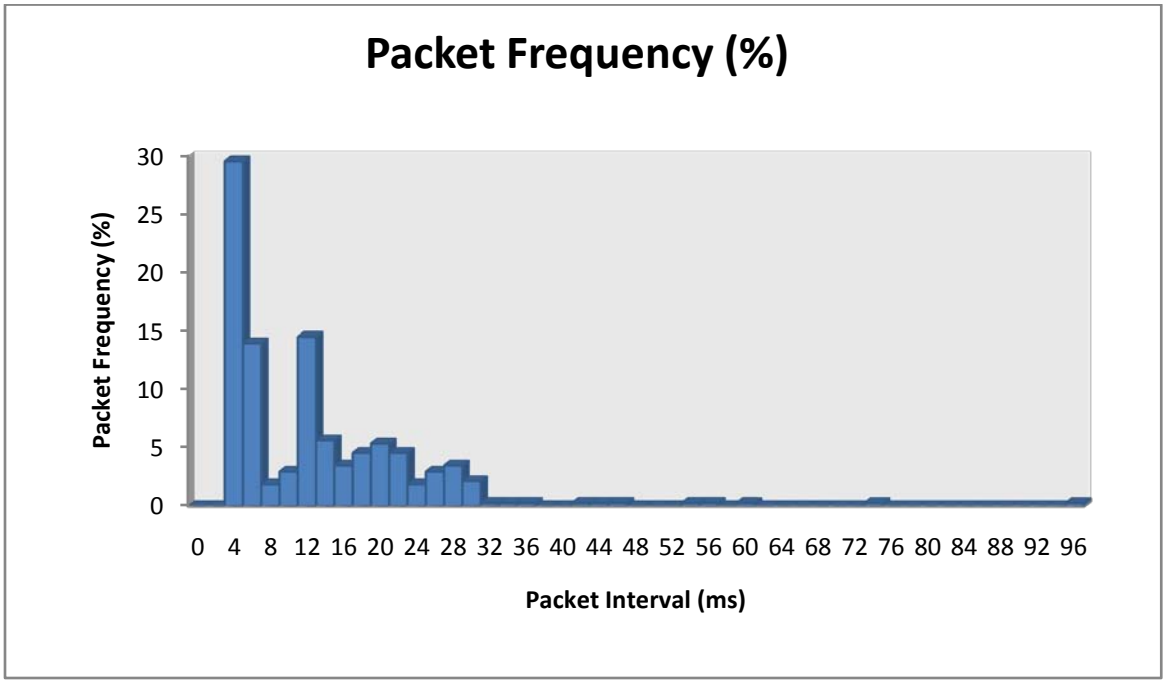
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	372	N/A	N/A	N/A
# Lost Packets	1			
Average (ms)	12.00		+/-10%	
Std. Deviation (ms)	10.74		+/-10%	
Min (ms)	2.70		+/-10%	
Max (ms)	94.14		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
100
90
80
70
60
50
40
30
20
10
0
0
50
100
150
200
250
300
350
Packet #


Packet Frequency (%)
Packet Frequency (%)
30
25
20
15
10
5
0
0 4 8 12 16 20 24 28 32 36 40 44 48 52 56 60 64 68 72 76 80 84 88 92 96
Packet Interval (ms)

Report: PHX-W11G-100-55-2-SW, Noise

Experimented by Jeehong Yang and Wajiha Shahid

University of Michigan

2008-07-23 19:14:57

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Phoenix Contact Wireless 802.11g
Channel	6 (2.437 GHz)
Signal Power	-30
Noise Power	-55
Distance	100
Comments	Noise model: 802.11g sweeping noise centered at 2.437GHz.

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	1024

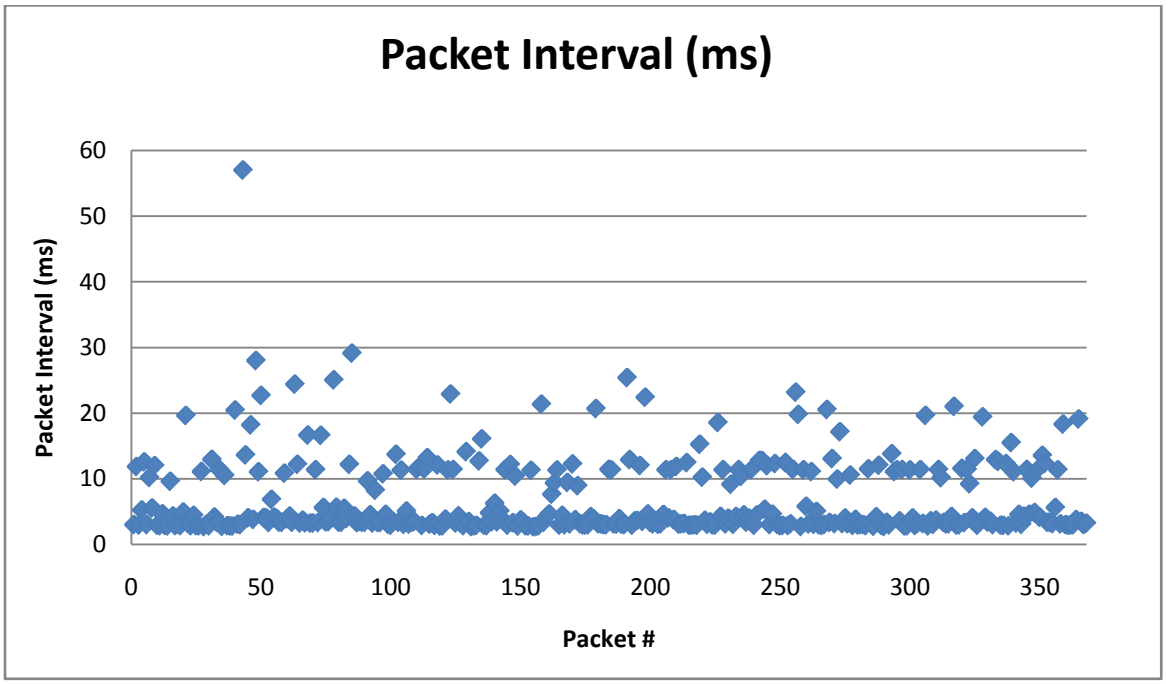
Results

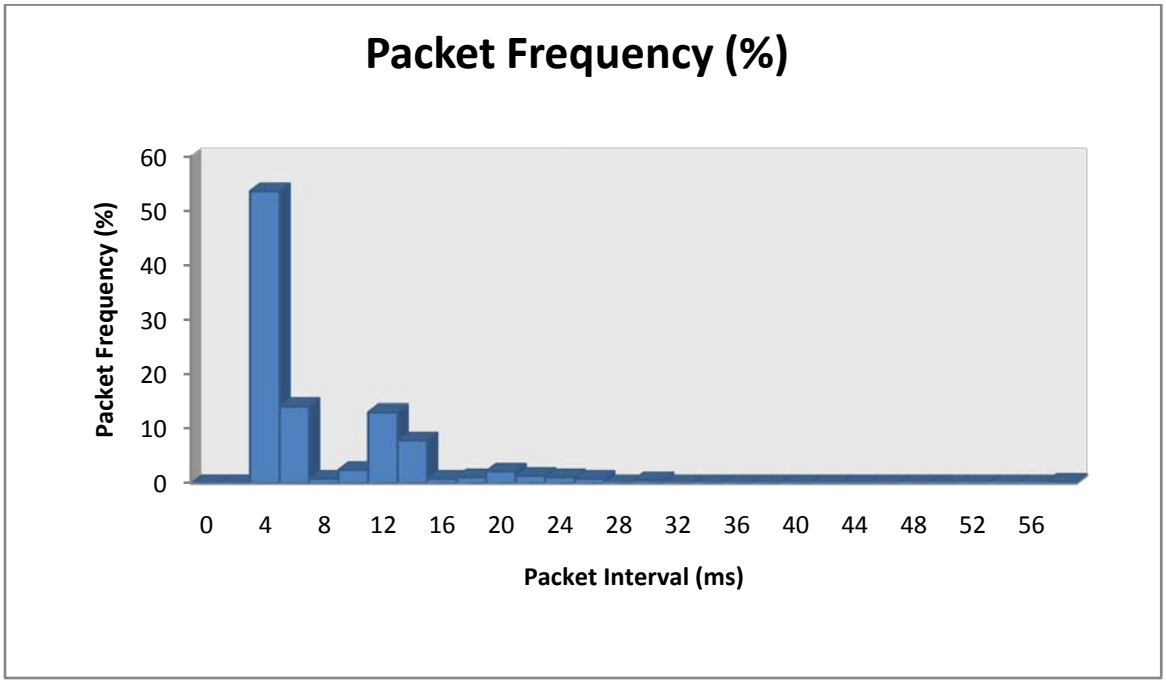
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	368	N/A	N/A	N/A
# Lost Packets	1			
Average (ms)	6.85		+/-10%	
Std. Deviation (ms)	5.99		+/-10%	
Min (ms)	2.71		+/-10%	
Max (ms)	57.03		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
60
50
40
30
20
10
0
0
50
100
150
200
250
300
350
Packet #


Packet Frequency (%)
Packet Frequency (%)
60
50
40
30
20
10
0
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
Packet Interval (ms)

Report: PHX-W11G-100-60-2-SW, Noise

Experimented by Jeehong Yang and Wajiha Shahid

University of Michigan

2008-07-23 19:14:58

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Phoenix Contact Wireless 802.11g
Channel	6 (2.437 GHz)
Signal Power	-30
Noise Power	-60
Distance	100
Comments	Noise model: 802.11g sweeping noise centered at 2.437GHz.

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	1024

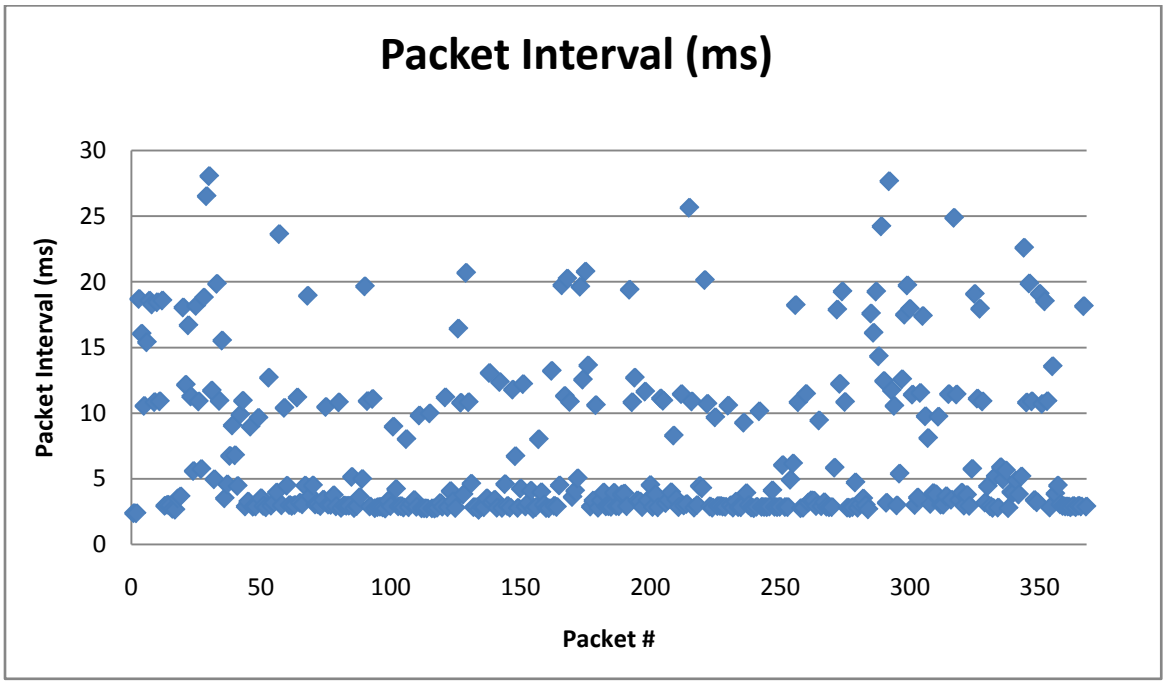
Results

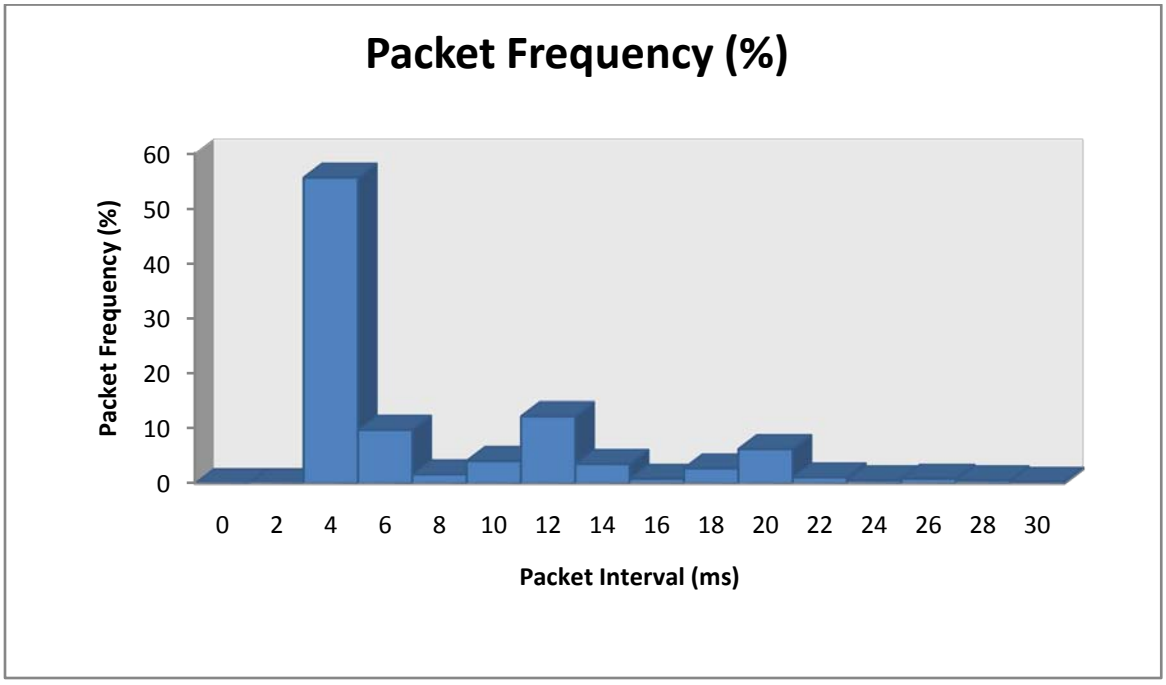
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	369	N/A	N/A	N/A
# Lost Packets	1			
Average (ms)	7.00		+/-10%	
Std. Deviation (ms)	5.87		+/-10%	
Min (ms)	2.36		+/-10%	
Max (ms)	28.05		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
30
25
20
15
10
5
0
0
50
100
150
200
250
300
350
Packet #


Packet Frequency (%)
Packet Frequency (%)
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
Packet Interval (ms)

Section 3

Test Results for Phoenix Contact 802.11a

This section contains results for the following experiments:
-RF interference tests

The test setup was similar to the Bluetooth interference test setup (Figure 1 pg 10).

Noise Power (dBM)	Distance (m)	Standard Deviation	Mean	No. of Packets Lost
No Noise	100	1.96	3.27	1/369
-40	100	34.41	20.81	44/383
-45	100	3.35	5.30	6/367
-50	100	2.17	3.73	1/363
-55	100	2.74	4.21	1/363
-60	100	2.43	3.91	1/367

Report:PHX-W11A-100-XX-2SWBaseline

Experimented by Jeehong Yang and Wajiha Shahid

University of Michigan

2008-07-23 19:24:55

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Phoenix Contact Wireless 802.11a
Channel	52 (5.26 GHz)
Signal Power	-40
Noise Power	No Noise
Distance	100
Comments	Noise model: 802.11a sweeping noise centered at 5.26GHz.

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	1024

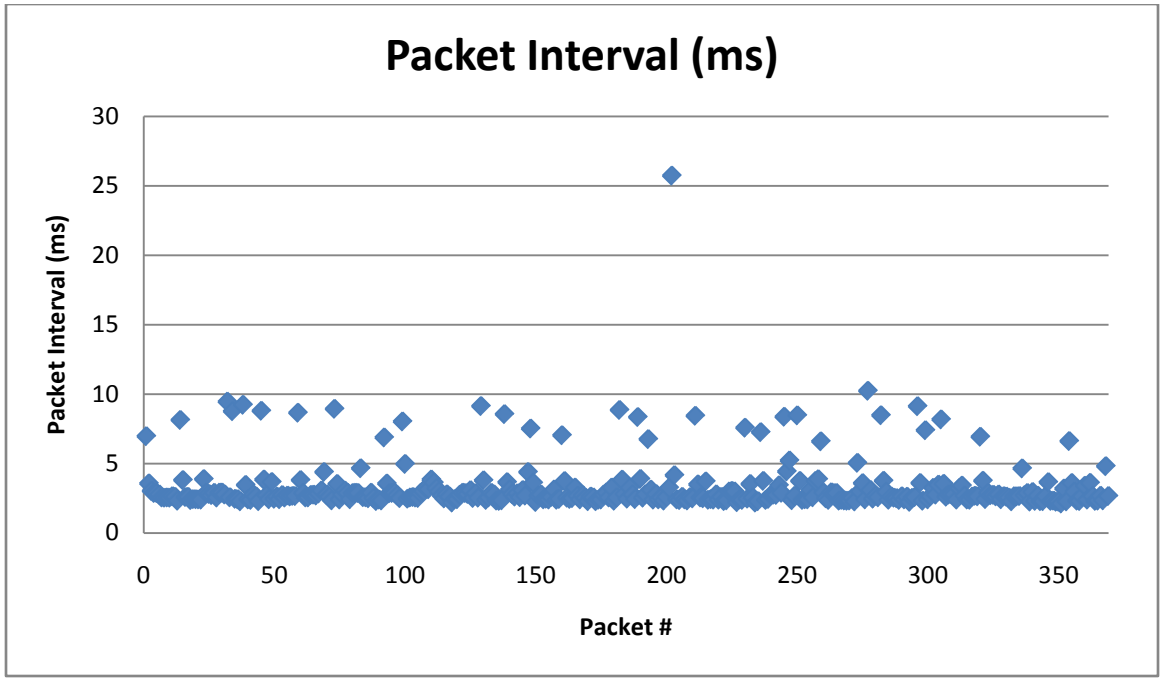
Results

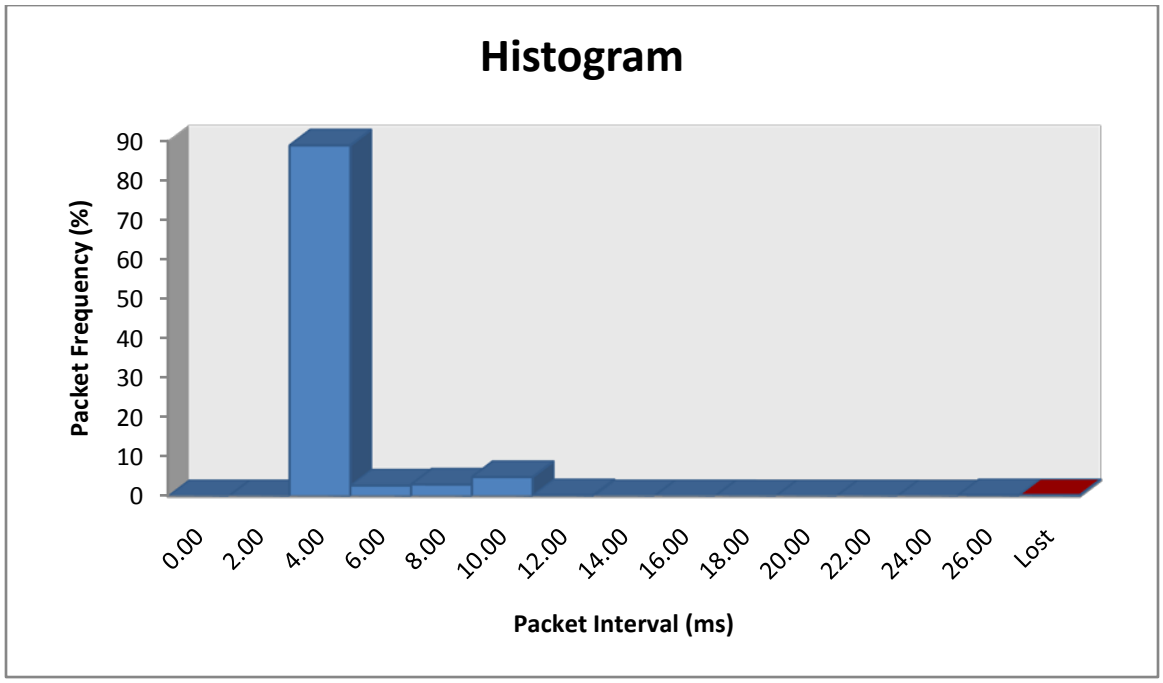
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	369	N/A	N/A	N/A
# Lost Packets	1			
Average (ms)	3.27		+/-10%	
Std. Deviation (ms)	1.96		+/-10%	
Min (ms)	2.11		+/-10%	
Max (ms)	25.73		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
30
25
20
15
10
5
0
0
50
100
150
200
250
300
350
Packet #


Histogram
Packet Frequency (%)
90
80
70
60
50
40
30
20
10
0
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
22.00
24.00
26.00
Lost
Packet Interval (ms)

Report: PHX-W11A-100-40-2-SW, Noise

Experimented by Jeehong Yang and Wajiha Shahid

University of Michigan

2008-07-23 19:24:57

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Phoenix Contact Wireless 802.11a
Channel	52 (5.26 GHz)
Signal Power	-40
Noise Power	-40
Distance	100
Comments	Noise model: 802.11a sweeping noise centered at 5.26GHz.

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	1024

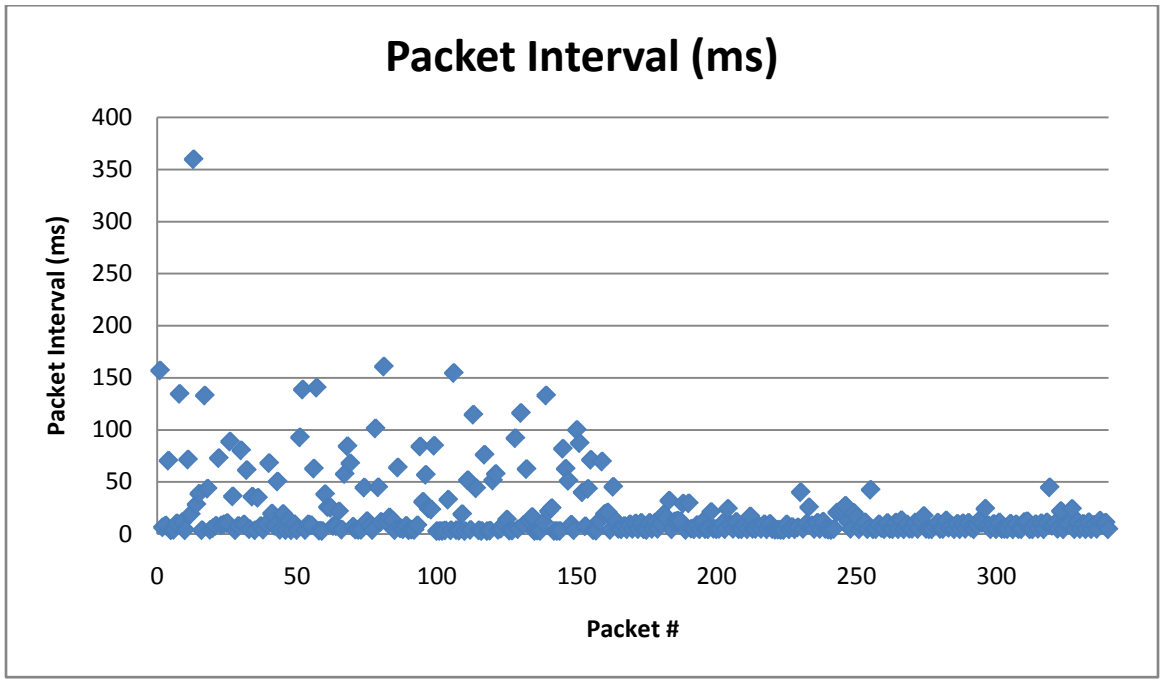
Results

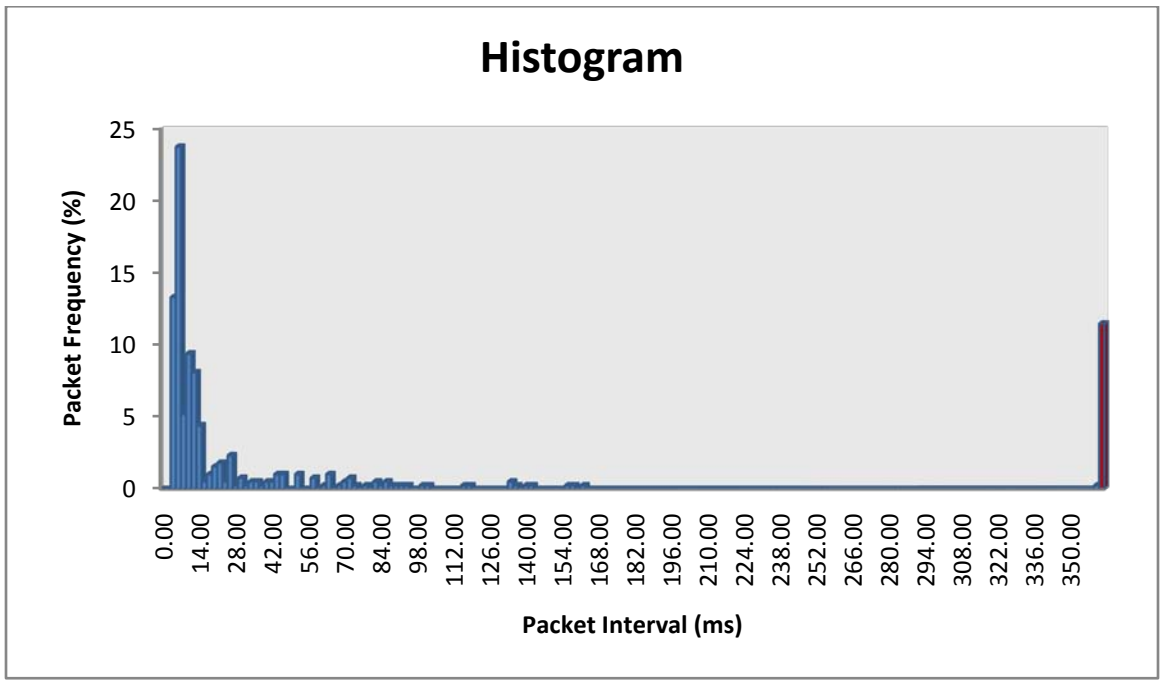
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	383	N/A	N/A	N/A
# Lost Packets	44			
Average (ms)	20.81		+/-10%	
Std. Deviation (ms)	34.41		+/-10%	
Min (ms)	2.84		+/-10%	
Max (ms)	359.63		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
400
350
300
250
200
150
100
50
0
0
50
100
150
200
250
300
Packet #


Histogram
Packet Frequency (%)
25
20
15
10
5
0
0.00
14.00
28.00
42.00
56.00
70.00
84.00
98.00
112.00
126.00
140.00
154.00
168.00
182.00
196.00
210.00
224.00
238.00
252.00
266.00
280.00
294.00
308.00
322.00
336.00
350.00
Packet Interval (ms)

Report: PHX-W11A-100-45-2-SW, Noise

Experimented by Jeehong Yang and Wajiha Shahid

University of Michigan

2008-07-23 19:24:58

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Phoenix Contact Wireless 802.11a
Channel	52 (5.26 GHz)
Signal Power	-40
Noise Power	-45
Distance	100
Comments	Noise model: 802.11a sweeping noise centered at 5.26GHz.

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	1024

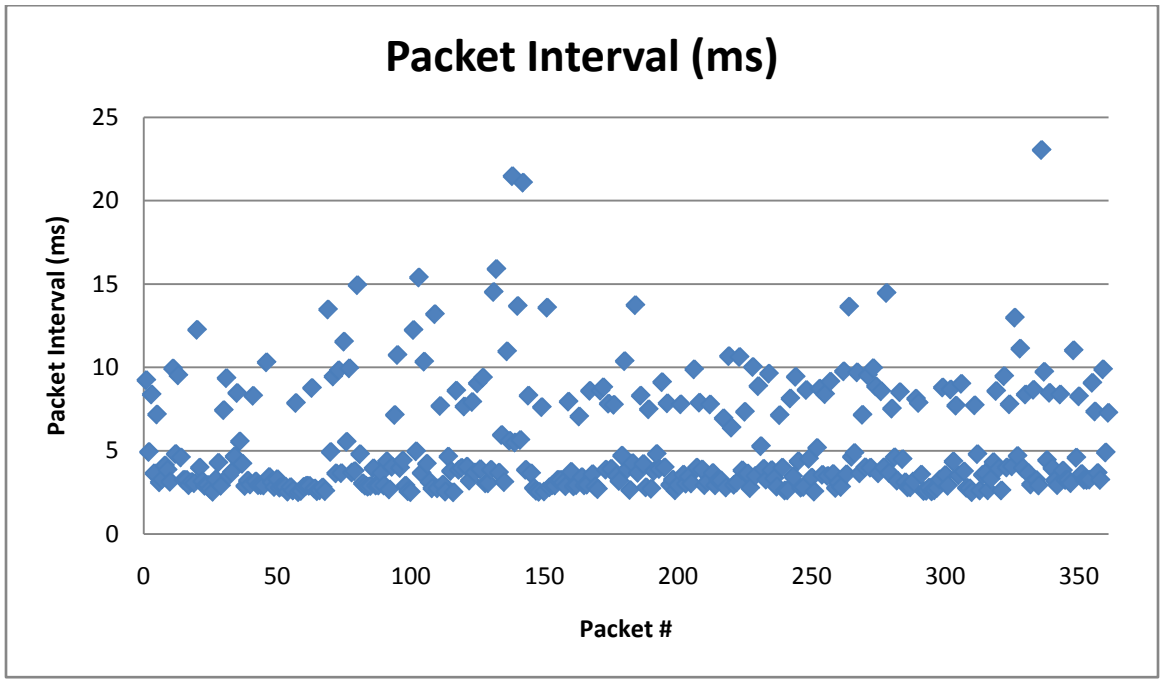
Results

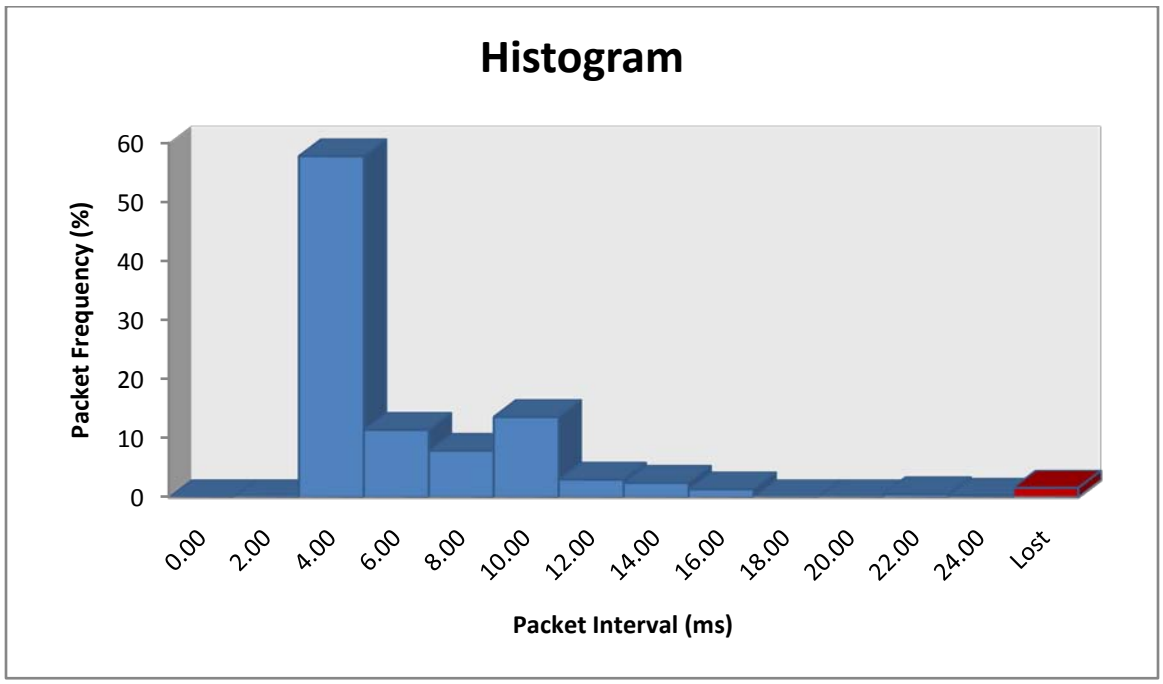
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	367	N/A	N/A	N/A
# Lost Packets	6			
Average (ms)	5.30		+/-10%	
Std. Deviation (ms)	3.35		+/-10%	
Min (ms)	2.49		+/-10%	
Max (ms)	23.03		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
25
20
15
10
5
0
0
50
100
150
200
250
300
350
Packet #


Histogram
Packet Frequency (%)
60
50
40
30
20
10
0
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
22.00
24.00
Lost
Packet Interval (ms)

Report: PHX-W11A-100-50-2-SW, Noise

Experimented by Jeehong Yang and Wajiha Shahid

University of Michigan

2008-07-23 19:24:59

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Phoenix Contact Wireless 802.11a
Channel	52 (5.26 GHz)
Signal Power	-40
Noise Power	-50
Distance	100
Comments	Noise model: 802.11a sweeping noise centered at 5.26GHz.

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	1024

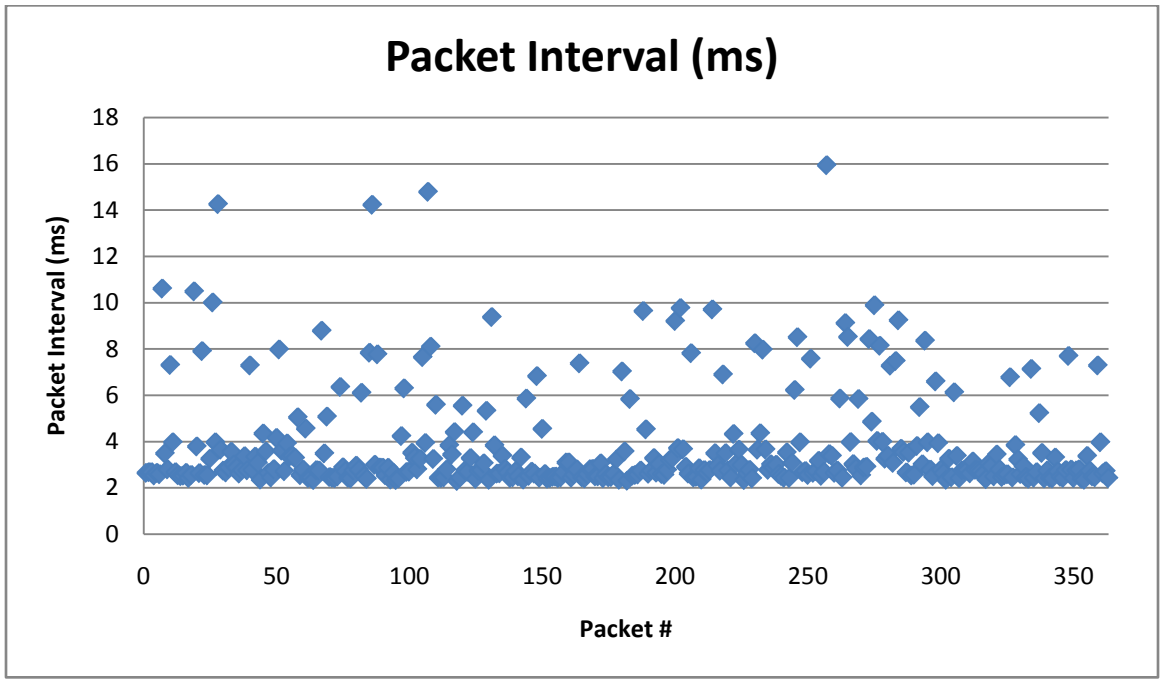
Results

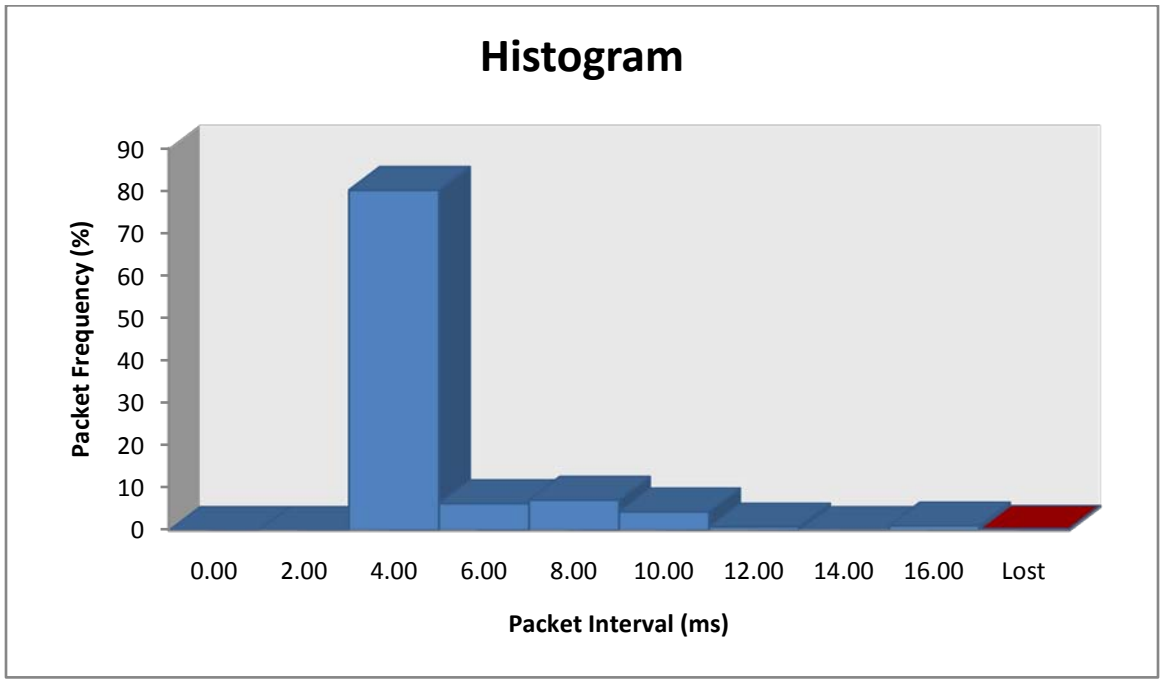
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	363	N/A	N/A	N/A
# Lost Packets	1			
Average (ms)	3.73		+/-10%	
Std. Deviation (ms)	2.17		+/-10%	
Min (ms)	2.29		+/-10%	
Max (ms)	15.93		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
18
16
14
12
10
8
6
4
2
0
0
50
100
150
200
250
300
350
Packet #


Histogram
Packet Frequency (%)
90
80
70
60
50
40
30
20
10
0
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Lost
Packet Interval (ms)

Report: PHX-W11A-100-55-2-SW, Noise

Experimented by Jeehong Yang and Wajiha Shahid

University of Michigan

2008-07-23 19:25:01

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Phoenix Contact Wireless 802.11a
Channel	52 (5.26 GHz)
Signal Power	-40
Noise Power	-55
Distance	100
Comments	Noise model: 802.11a sweeping noise centered at 5.26GHz.

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	1024

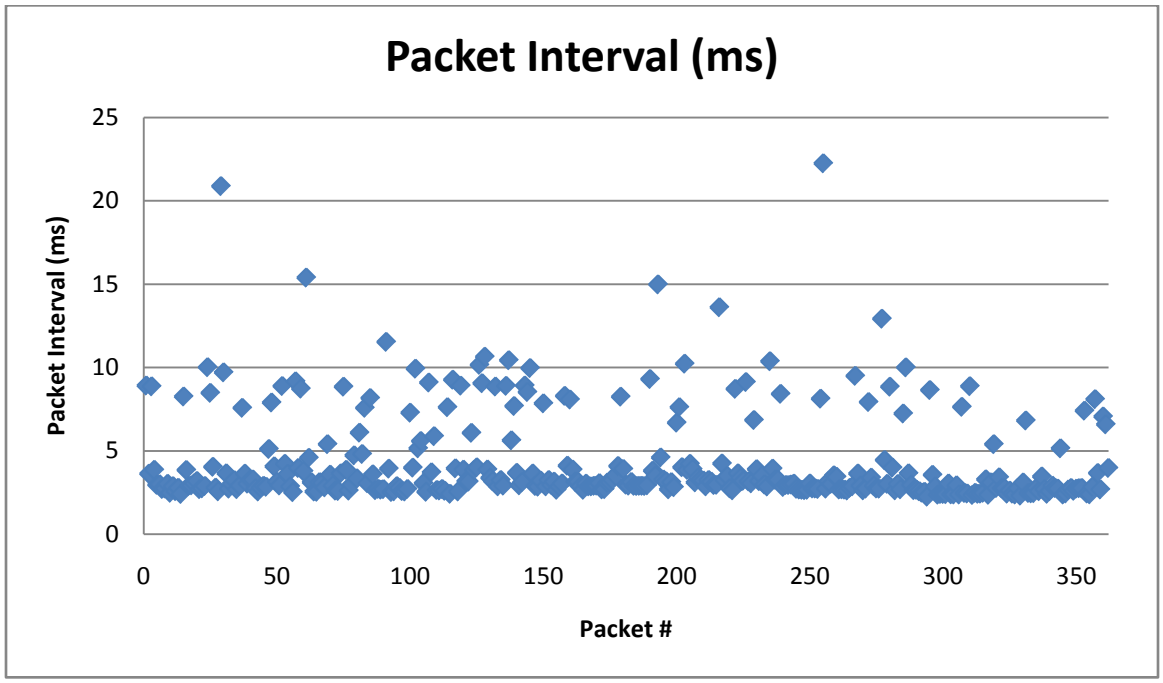
Results

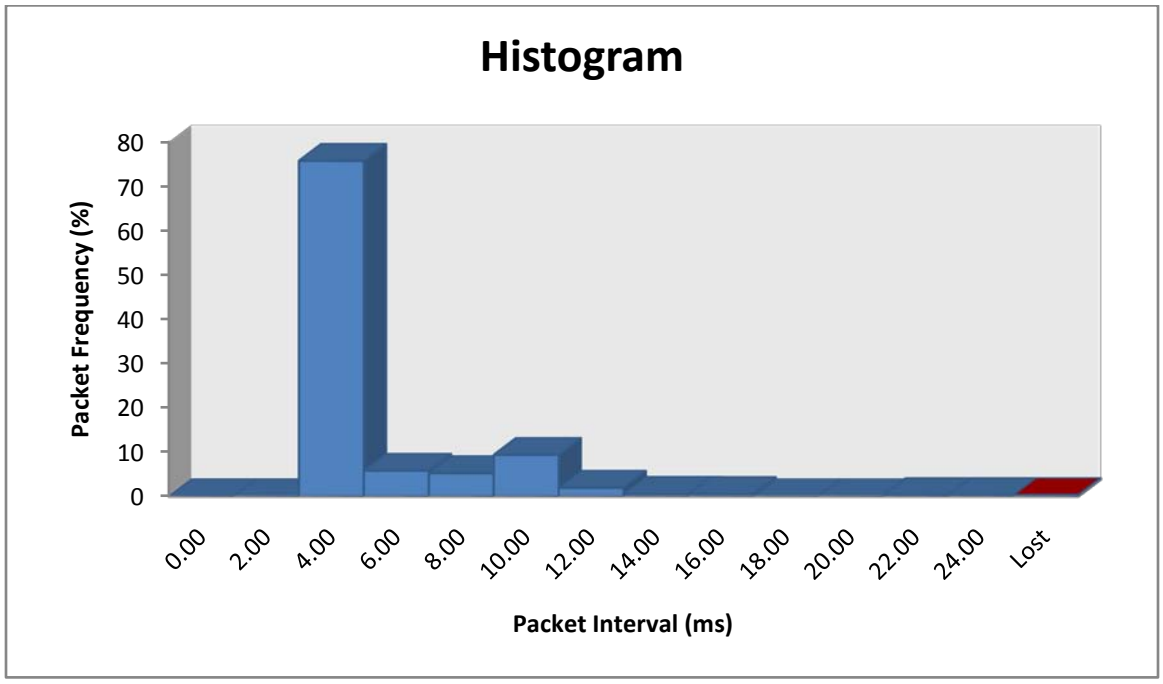
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	363	N/A	N/A	N/A
# Lost Packets	1			
Average (ms)	4.21		+/-10%	
Std. Deviation (ms)	2.74		+/-10%	
Min (ms)	2.24		+/-10%	
Max (ms)	22.25		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
25
20
15
10
5
0
0
50
100
150
200
250
300
350
Packet #


Histogram
Packet Frequency (%)
80
70
60
50
40
30
20
10
0
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
22.00
24.00
Lost
Packet Interval (ms)

Report: PHX-W11A-100-60-2-SW, Noise

Experimented by Jeehong Yang and Wajiha Shahid

University of Michigan

2008-07-23 19:25:02

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Phoenix Contact Wireless 802.11a
Channel	52 (5.26 GHz)
Signal Power	-40
Noise Power	-60
Distance	100
Comments	Noise model: 802.11a sweeping noise centered at 5.26GHz.

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	1024

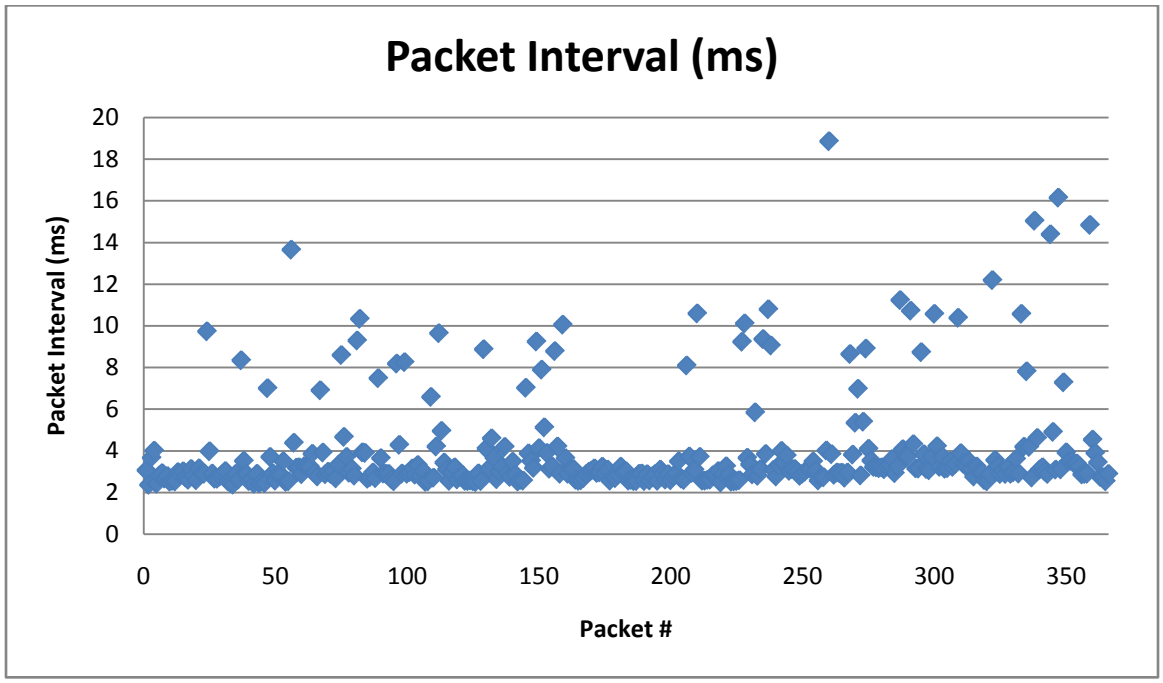
Results

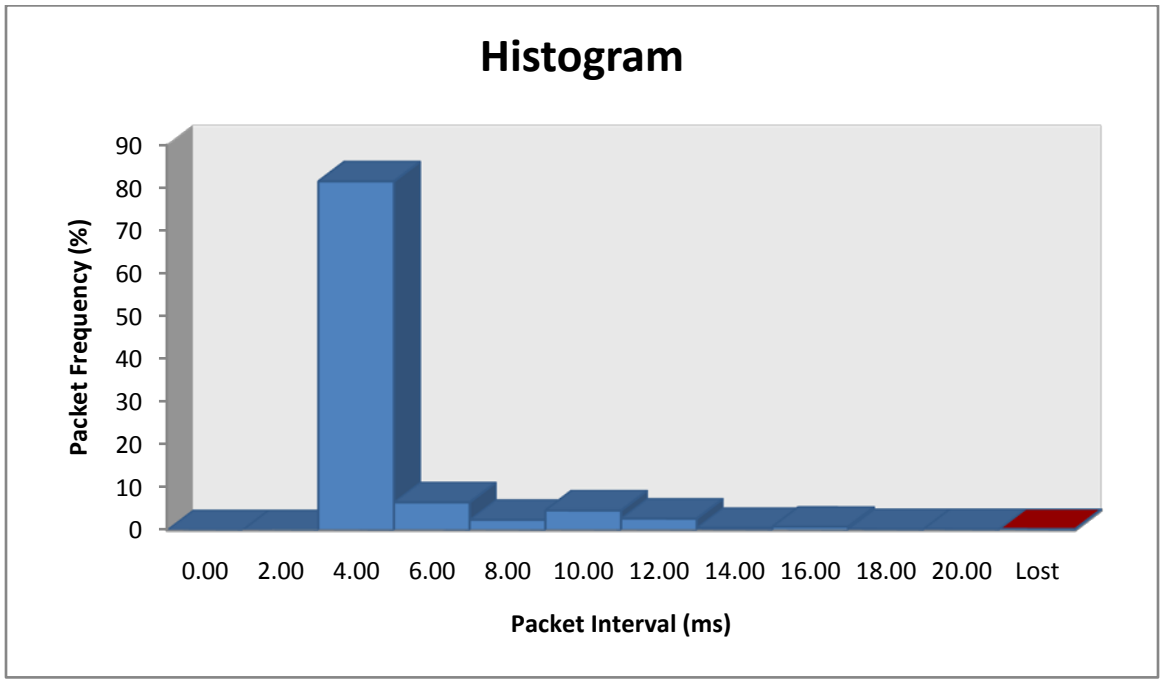
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	367	N/A	N/A	N/A
# Lost Packets	1			
Average (ms)	3.91		+/-10%	
Std. Deviation (ms)	2.43		+/-10%	
Min (ms)	2.36		+/-10%	
Max (ms)	18.86		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
20
18
16
14
12
10
8
6
4
2
0
0
50
100
150
200
250
300
350
Packet #


Histogram
Packet Frequency (%)
90
80
70
60
50
40
30
20
10
0
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
Lost
Packet Interval (ms)

Section 4

Test Results for Phoenix Contact 802.11b

This section contains results for the following experiments:
-RF interference tests

The interference test setup was similar to the Bluetooth interference test setup (Figure 1 pg 10).

Noise Power	Distance (m)	Standard Deviation	Mean	No. of Packets Lost
No Noise	100	2.37	3.33	0/388
-55	100	-44.89	63.29	38/481
-65	100	38.54	44.83	33/460

Report: PHX-W11B-100-XX-2-SW

Experimented by Jeehong Yang and Wajiha Shahid

University of Michigan

2008-07-24 15:04:30

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Phoenix Contact Wireless 802.11a
Channel	7 (2.442 GHz)
Signal Power	0
Noise Power	No Noise
Distance	100
Comments	Noise model: 802.11b sweeping noise centered at 2.442 GHz.

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	128
HistogramData Size (bytes)	1024

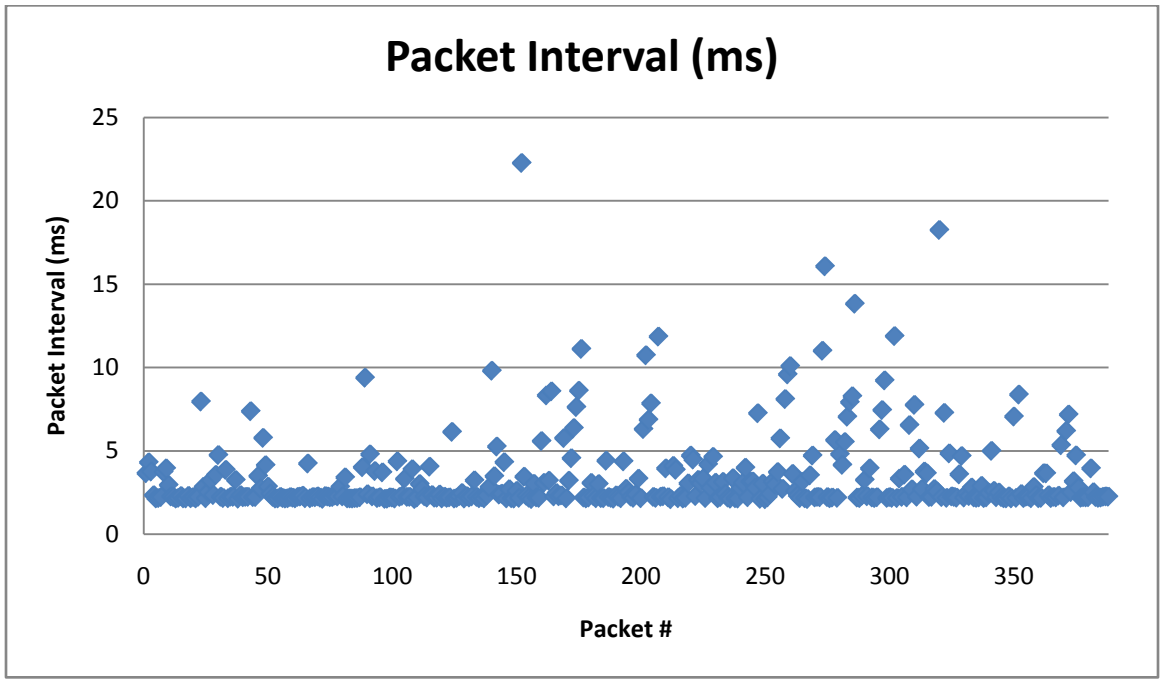
Results

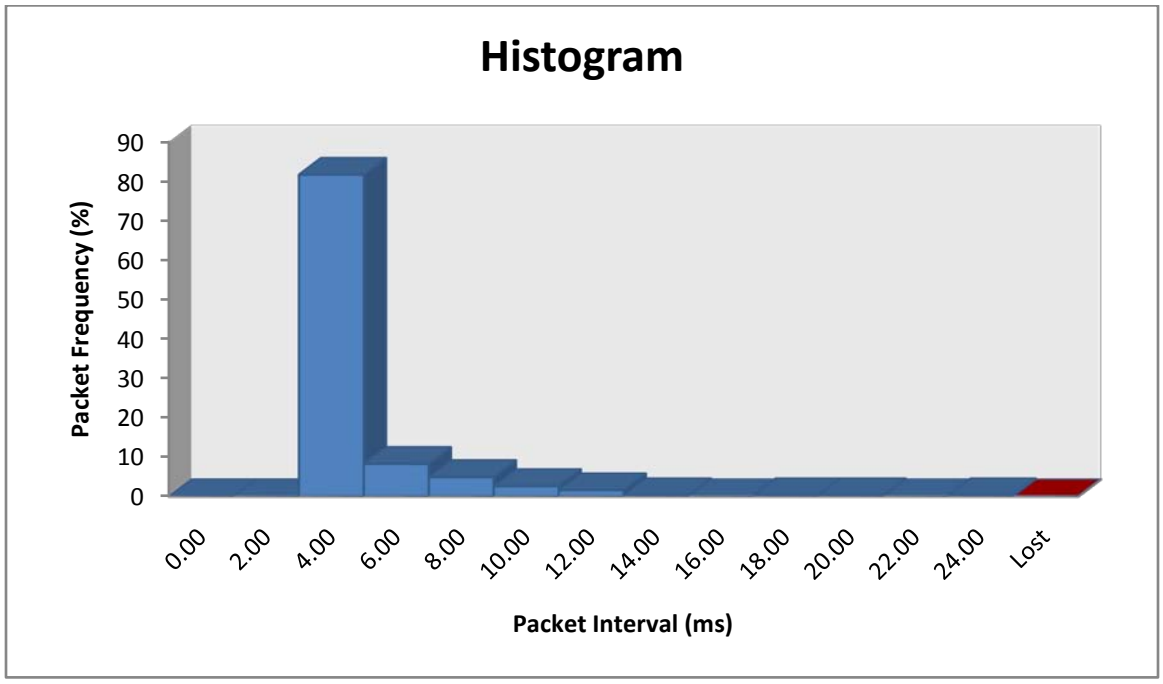
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	388	N/A	N/A	N/A
# Lost Packets	0			
Average (ms)	3.33		+/-10%	
Std. Deviation (ms)	2.37		+/-10%	
Min (ms)	2.08		+/-10%	
Max (ms)	22.26		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
25
20
15
10
5
0
0
50
100
150
200
250
300
350
Packet #


Histogram
Packet Frequency (%)
90
80
70
60
50
40
30
20
10
0
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
22.00
24.00
Lost
Packet Interval (ms)

Report: PHX-W11B-100-65-2-SW, Noise

Experimented by Jeehong Yang and Wajiha Shahid

University of Michigan

2008-07-24 15:04:06

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Phoenix Contact Wireless 802.11a
Channel	7 (2.442 GHz)
Signal Power	0
Noise Power	-65
Distance	100
Comments	Noise model: 802.11b sweeping noise centered at 2.442 GHz.

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	128
HistogramData Size (bytes)	1024

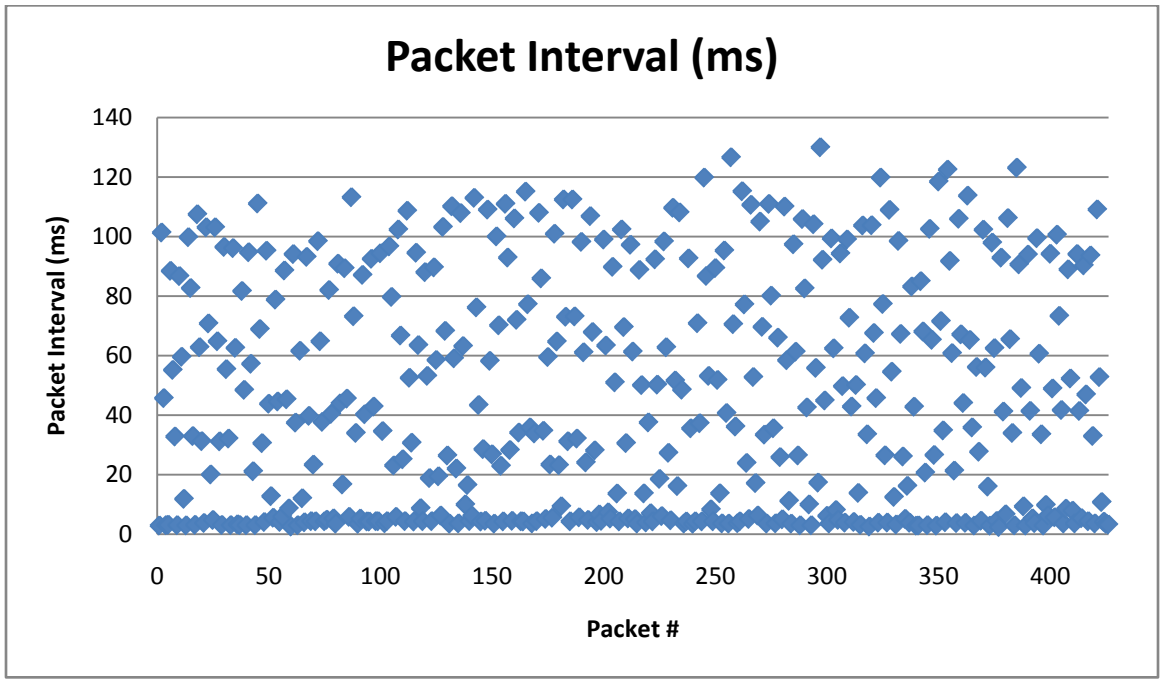
Results

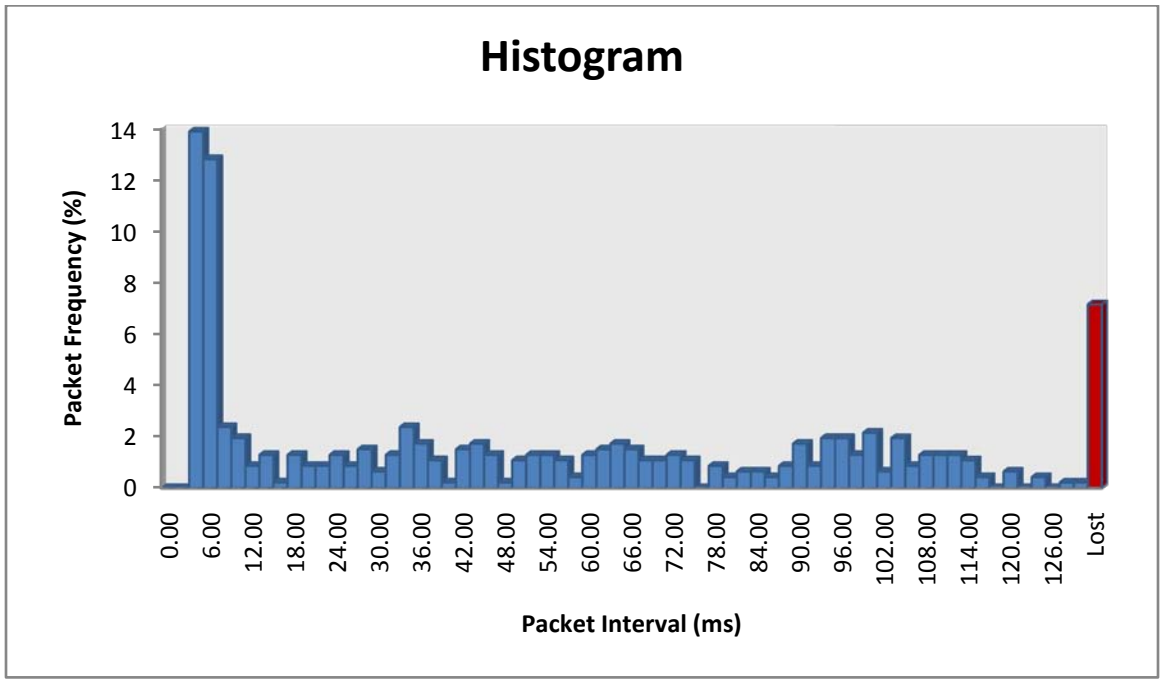
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	460	N/A	N/A	N/A
# Lost Packets	33			
Average (ms)	44.83		+/-10%	
Std. Deviation (ms)	38.54		+/-10%	
Min (ms)	2.29		+/-10%	
Max (ms)	129.96		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
140
120
100
80
60
40
20
0
0
50
100
150
200
250
300
350
400
Packet #


Histogram
Packet Frequency (%)
14
12
10
8
6
4
2
0
0.00
6.00
12.00
18.00
24.00
30.00
36.00
42.00
48.00
54.00
60.00
66.00
72.00
78.00
84.00
90.00
96.00
102.00
108.00
114.00
120.00
126.00
Lost
Packet Interval (ms)

Report: PHX-W11B-100-55-2-SW, Noise

Experimented by Jeehong Yang and Wajiha Shahid

University of Michigan

2008-07-24 15:02:53

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Phoenix Contact Wireless 802.11a
Channel	7 (2.442 GHz)
Signal Power	0
Noise Power	-55
Distance	100
Comments	Noise model: 802.11b sweeping noise centered at 2.442 GHz.

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	128
HistogramData Size (bytes)	1024

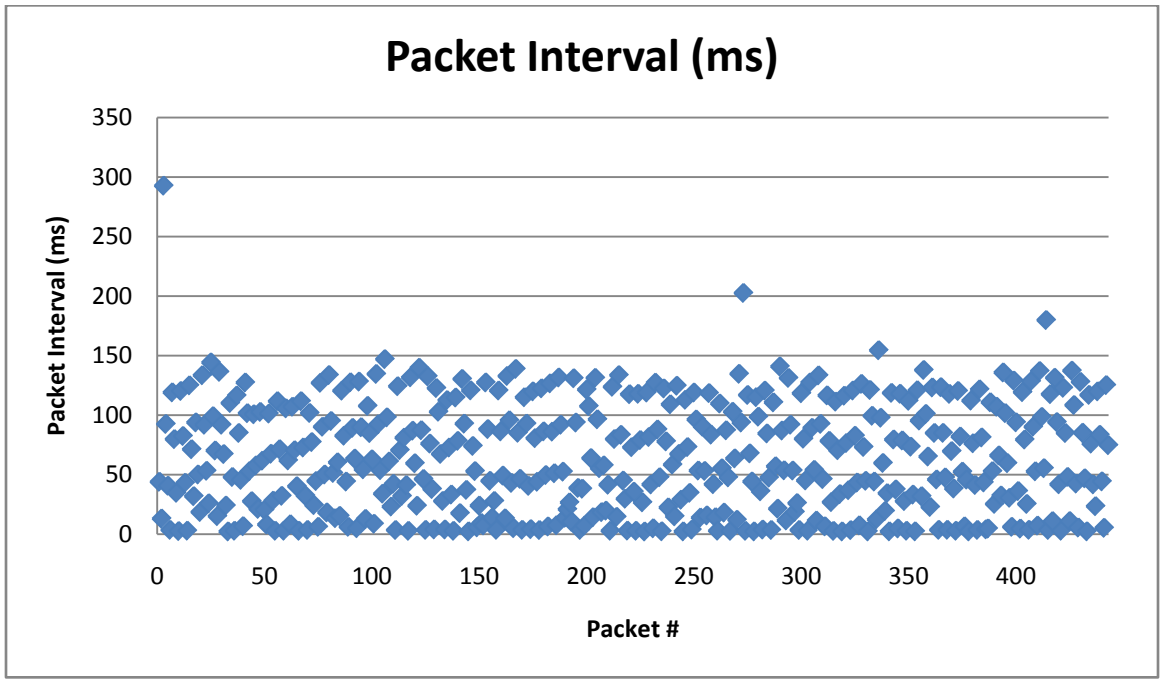
Results

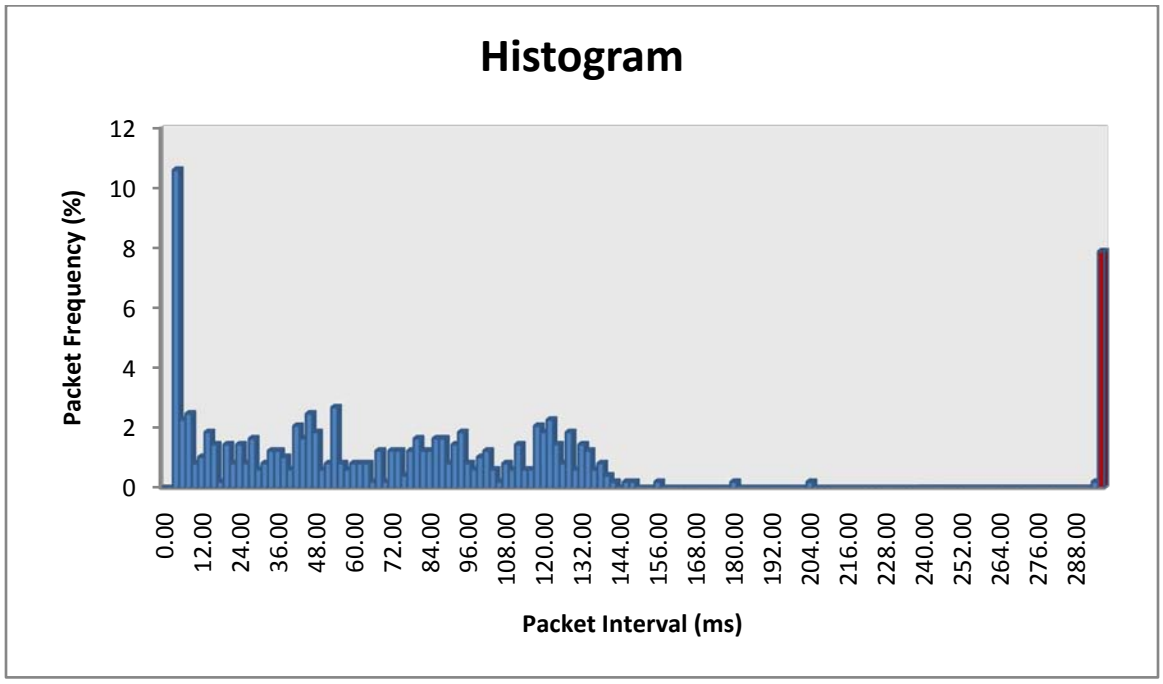
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	481	N/A	N/A	N/A
# Lost Packets	38			
Average (ms)	63.29		+/-10%	
Std. Deviation (ms)	45.89		+/-10%	
Min (ms)	2.22		+/-10%	
Max (ms)	292.59		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
350
300
250
200
150
100
50
0
0
50
100
150
200
250
300
350
400
Packet #


Histogram
Packet Frequency (%)
12
10
8
6
4
2
0
0.00
12.00
24.00
36.00
48.00
60.00
72.00
84.00
96.00
108.00
120.00
132.00
144.00
156.00
168.00
180.00
192.00
204.00
216.00
228.00
240.00
252.00
264.00
276.00
288.00
Packet Interval (ms)

Section 5

Test Results for ABB WISA

This section contains results for the following test:
-RF interference tests
-RF range tests

The combined interference and range test results are as follows:

Noise Power (dBM)	Distance (m)	Standard Deviation	Mean	No. of Packets Lost
-60	3	4.46	41.454	0/5000
No Noise	5	4.84	41.468	0/5000
0	5	5.09	41.794	0/5000
20	5	5.23	41.888	0/5000
-30	5	5.06	41.663	0/5000
No Noise	20	6.26	41.840	0/5000
0	20	19.83	45.880	0/5000
10	20	18.88	45.645	0/5000
20	20	43.76	58.151	0/5000
-30	20	8.42	42.034	0/5000
-60	20	4.95	41.639	0/5000
No Noise	25	41.43	54.989	0/5000
-30	25	155.05	146.380	0/5000
-60	25	57.16	63.215	0/5000

Additional comments:

- The distance/range experiments conducted at the ERC/RMS were outside the operating limits of WISA. This explains the consistent occurrence of outliers at roud trip times greater than 150 ms. Discussion with ABB confirmed that WISA is designed for operation within a short range to allow a high node density to minimize interference from other equipment. To extend the range capabilities of current WISA devices, ABB recommends adding a low cost RF amplifier to the transmitting connector of the WDIO module. ABB is also working to develop a built-in option for range extensions for the latest versions of WISA/WSAN/WIO link devices.

- ABB emphasized that outliers in distance tests between 100-200 ms can be related to a WISA device's fail safe mode, which is triggered when the WDIO/Base station detects a connections fault on one of the devices. The WDIO/Base station loses connection during this mode only if a downlink parameter cannot be delivered within 8 tries or 18 ms on air. The WDIO/Base station then attempts to reconnect again after 100 ms. An outlier of approximately 500 ms can be observed if a signal was unable to be transmitted within 8 retries. In this case, the field device will indicate an error message, which must be acknowledged.

- ABB explained that depending on the Devicenet speed, a time delay of 40 ms with the current FieldBus Plug at the bus connection was within the WISA device range.

- ABB also confirmed that tests indicating delays with a time spacing of approximately 10 ms can be associated with the PLC scan/update cycle. This can be verified by taking measurements in the normal program loop[2].

[2] Comments in this section have been added as per the email of Mr. Guntram Scheible (guntram.scheible@de.abb.com) to Dhananjay Anand of ABB dated 4th November 2009.

ABB WISA: Interference Test Setup

The tests presented here were conducted in a radio environment reflecting a practical use case. First, a radio propagation model was built based on measurements taken at a FORD-ACH test facility. The laboratory in the Manufacturing Research Center and the University of Michigan was verified against the model as having similar radio propagation characteristics in the ISM band. More information about the propagation characteristics is available in *D. M. Anand, J. R. Moyne, and D. M. Tilbury. Performance evaluation of wireless networks for factory automation applications. In Proceedings IEEE-CASE, 2009.*

The test setup consisted of an ABB WDIO base-station connected to a PLC over Devicenet. The PLC was programmed to cyclically set and reset an IO line on a wireless sensor pad (WDP) and capture round trip times for 5000 set+reset events.The WDIO base-station and the WDP wireless sensor pad communicated over an ABB WISA link.

The experiment (fig 3 and 4) was conducted for 5m (with a clear line of sight between the I/O module and the sensor pad), 20m (with 1 partition between the module and the sensor pad) and for 25m (with 2 partitions between the module and the sensor pad).

Figure3: Test setup with the I/O module

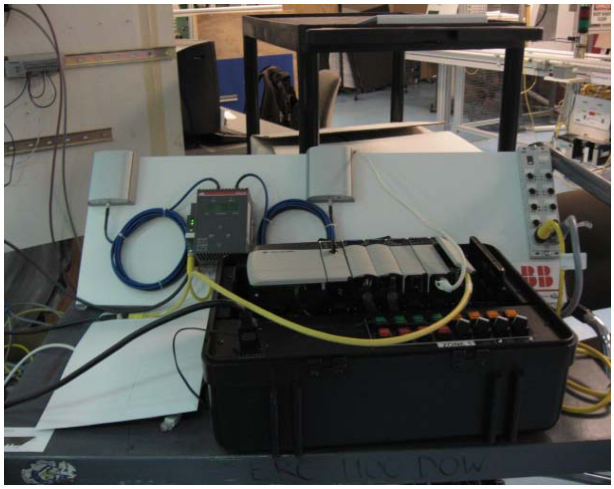
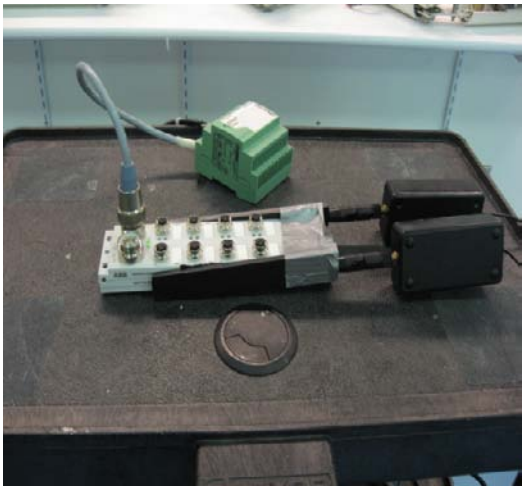


Figure4: Test setup with the sensor pad



Network Device Test Report: No RF.COT

Experimented by Wajiha Shahid and Jeehong Yang

University of Michigan

2009-09-14 16:14:50

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	ABB WISA
Channel	-
Signal Power	-
Noise Power	NONE
Distance	5m
Comments	

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	-
HistogramData Size (bytes)	-

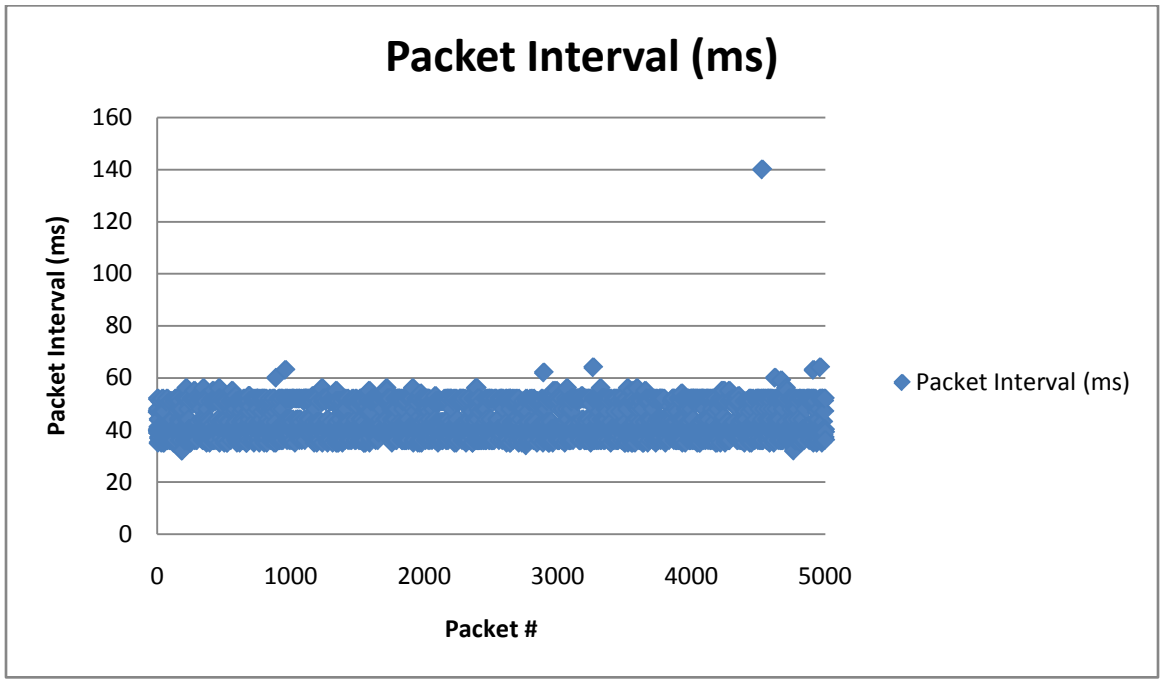
Results

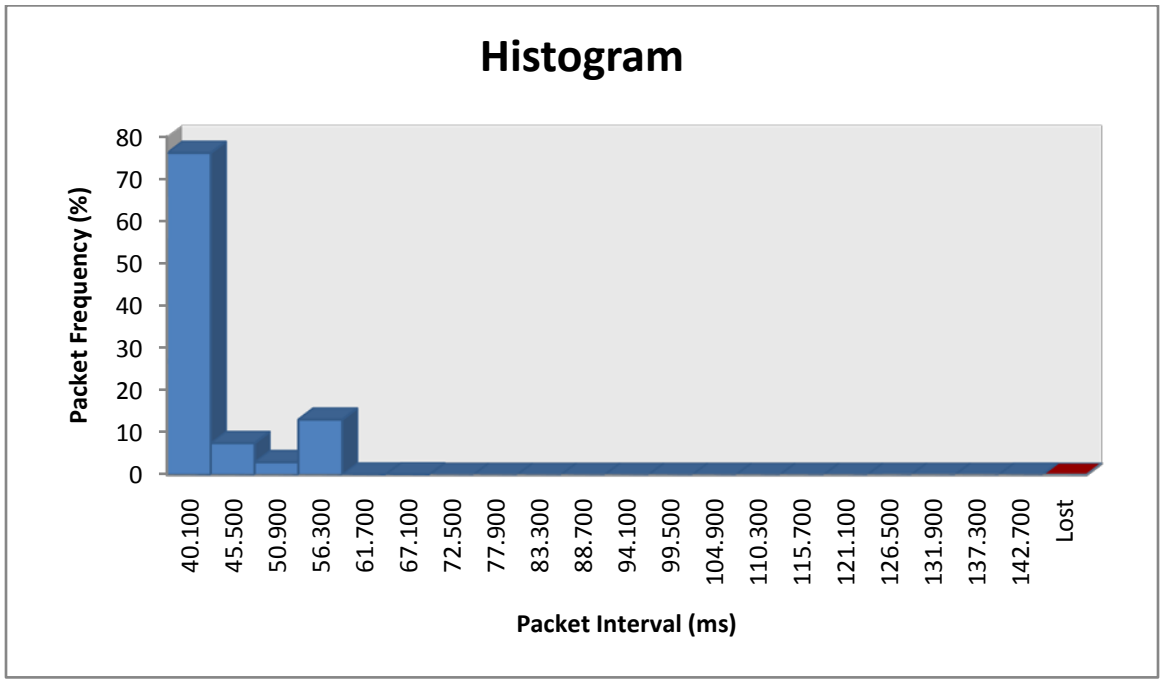
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	5000	N/A	N/A	N/A
# Lost Packets	0			
Average (ms)	41.468		+/-10%	
Std. Deviation (ms)	4.84		+/-10%	
Min (ms)	32.000		+/-10%	
Max (ms)	140.000		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
160
140
120
100
80
60
40
20
0
Packet Interval (ms)
0
1000
2000
3000
4000
5000
Packet #
Packet Interval (ms)


Histogram
80
70
60
50
40
30
20
10
0
Packet Frequency (%)
40.100
45.500
50.900
56.300
61.700
67.100
72.500
77.900
83.300
88.700
94.100
99.500
104.900
110.300
115.700
121.100
126.500
131.900
137.300
142.700
Lost
Packet Interval (ms)

Network Device Test Report: RF = 0dBm.COT

Experimented by Wajiha Shahid and Jeehong Yang

University of Michigan

2009-09-14 16:14:50

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	ABB WISA
Channel	-
Signal Power	-
Noise Power	0dBm
Distance	5m
Comments	

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	1024

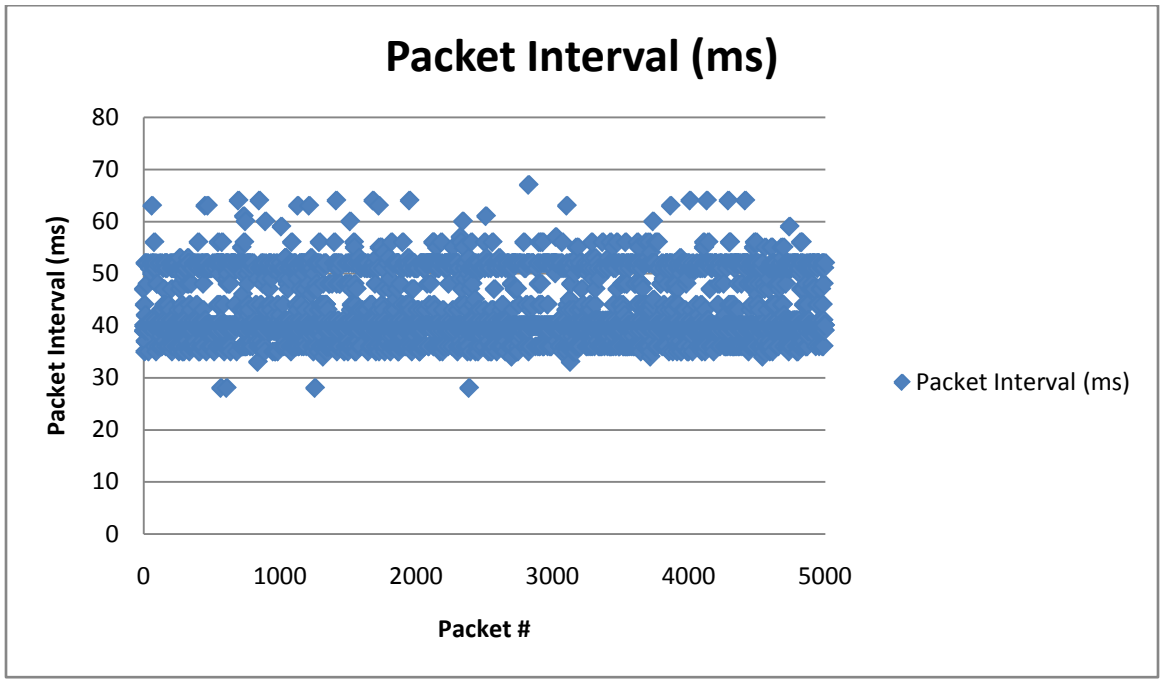
Results

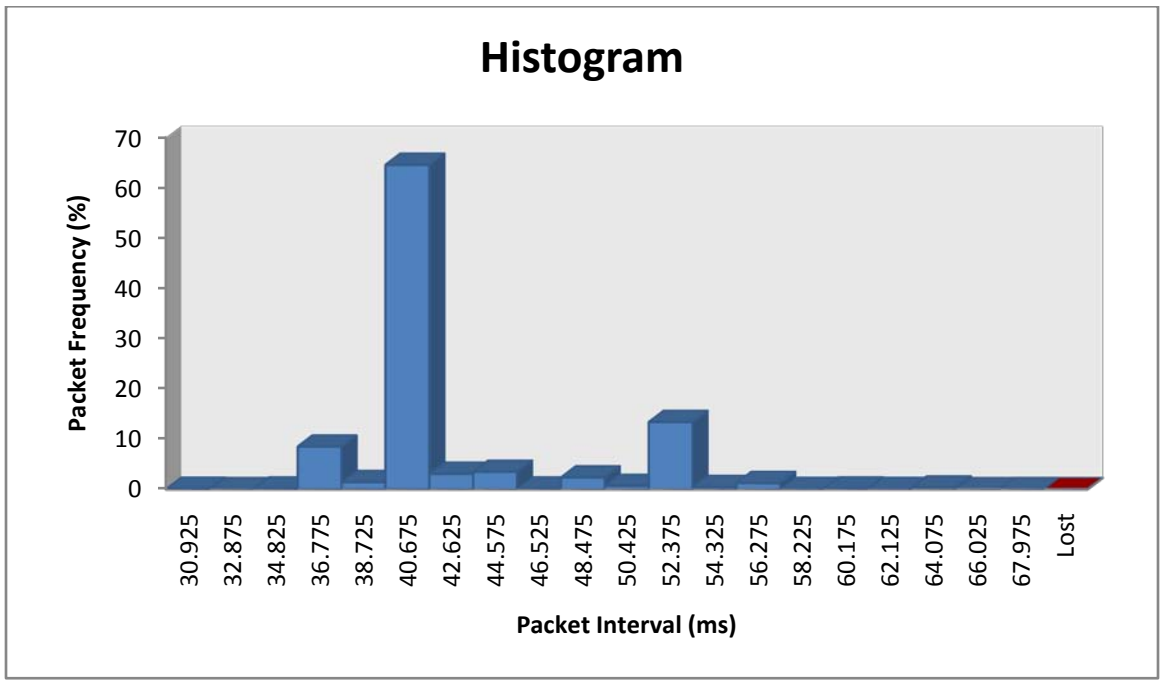
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	5000	N/A	N/A	N/A
# Lost Packets	0			
Average (ms)	41.794		+/-10%	
Std. Deviation (ms)	5.09		+/-10%	
Min (ms)	28.000		+/-10%	
Max (ms)	67.000		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
80
70
60
50
40
30
20
10
0
0
1000
2000
3000
4000
5000
Packet #
Packet Interval (ms)


Histogram
Packet Frequency (%)
70
60
50
40
30
20
10
0
30.925
32.875
34.825
36.775
38.725
40.675
42.625
44.575
46.525
48.475
50.425
52.375
54.325
56.275
58.225
60.175
62.125
64.075
66.025
67.975
Lost
Packet Interval (ms)

Network Device Test Report: RF = 20 dBm.COT

Experimented by Wajiha Shahid and Jeehong Yang

University of Michigan

2009-09-14 16:14:50

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	ABB WISA
Channel	-
Signal Power	-
Noise Power	20dBm
Distance	5m
Comments	

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	1024

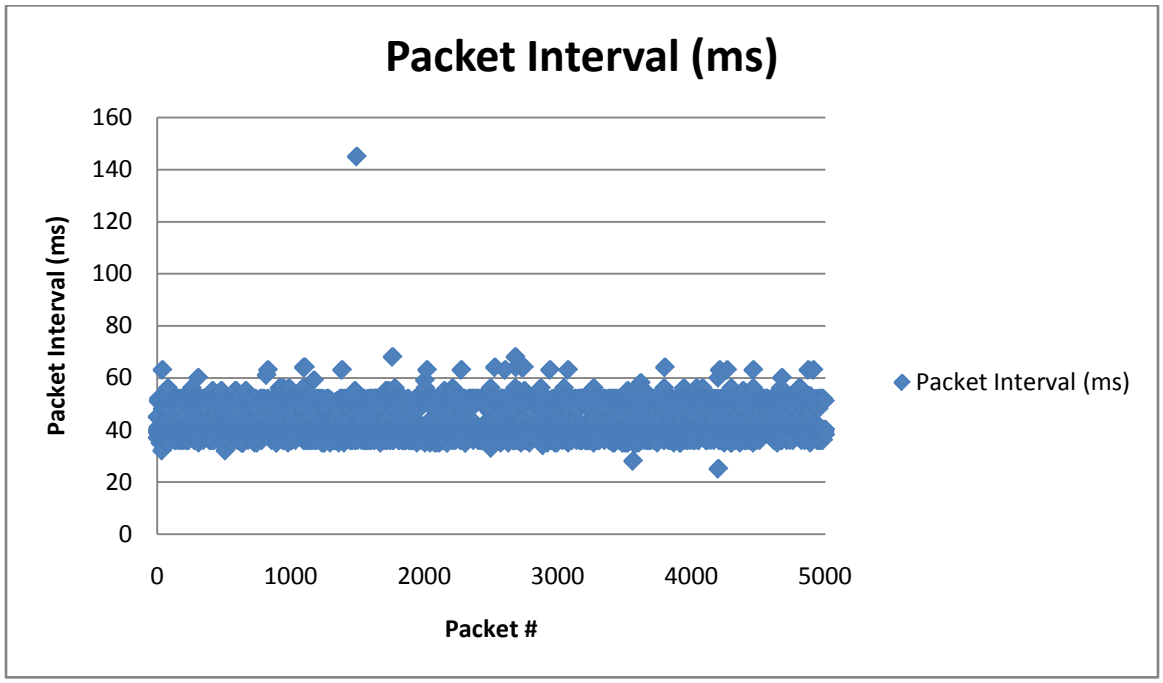
Results

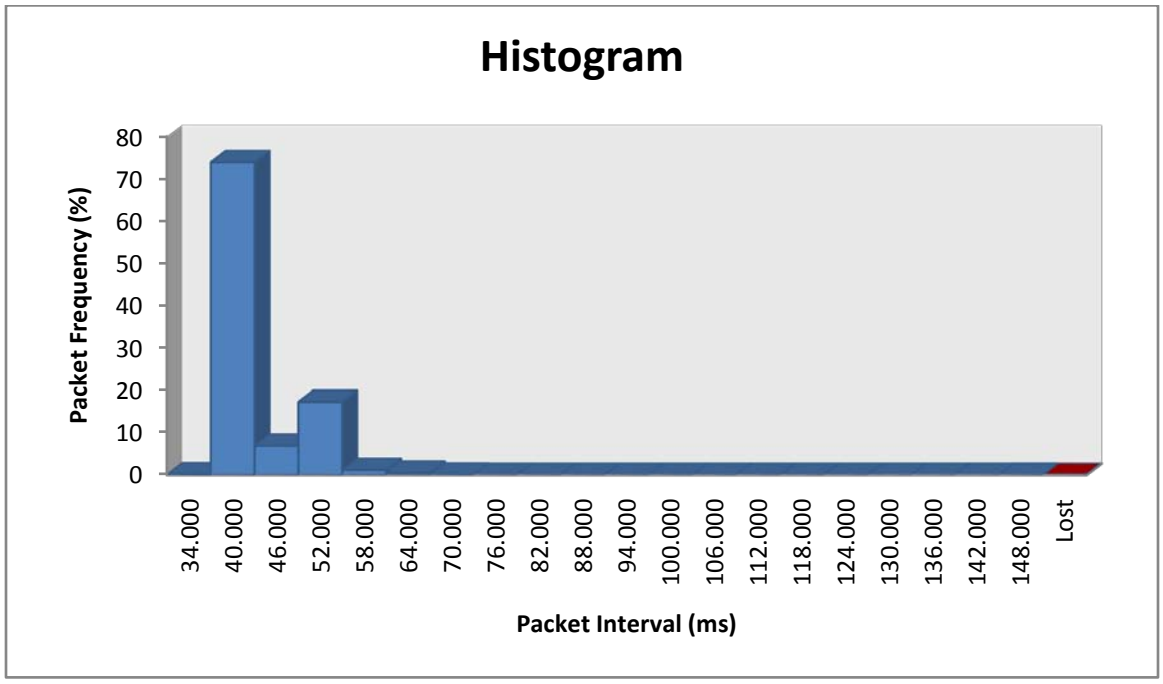
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	5000	N/A	N/A	N/A
# Lost Packets	0			
Average (ms)	41.888		+/-10%	
Std. Deviation (ms)	5.23		+/-10%	
Min (ms)	25.000		+/-10%	
Max (ms)	145.000		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
160
140
120
100
80
60
40
20
0
Packet Interval (ms)
0
1000
2000
3000
4000
5000
Packet #
Packet Interval (ms)


Histogram
80
70
60
50
40
30
20
10
0
Packet Frequency (%)
34.000
40.000
46.000
52.000
58.000
64.000
70.000
76.000
82.000
88.000
94.000
100.000
106.000
112.000
118.000
124.000
130.000
136.000
142.000
148.000
Lost
Packet Interval (ms)

Network Device Test Report: RF = -30 dBm.COT

Experimented by Wajiha Shahid and Jeehong Yang

University of Michigan

2009-09-14 16:14:50

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	ABB WISA
Channel	-
Signal Power	-
Noise Power	-30dBm
Distance	5m
Comments	

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	1024

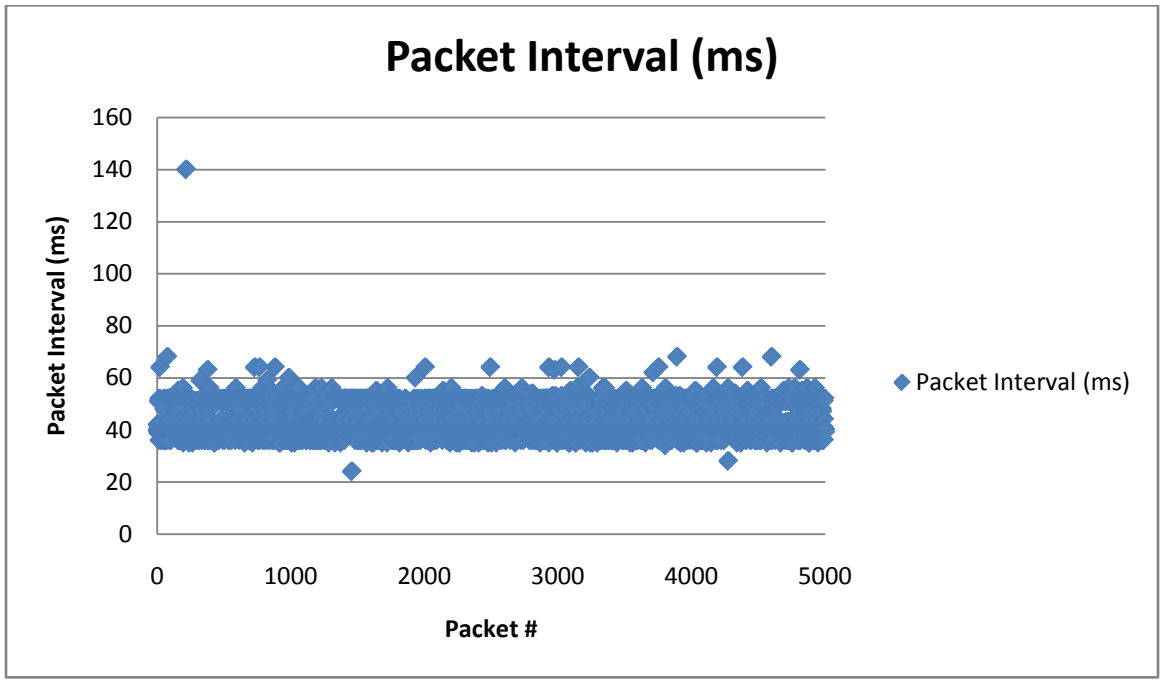
Results

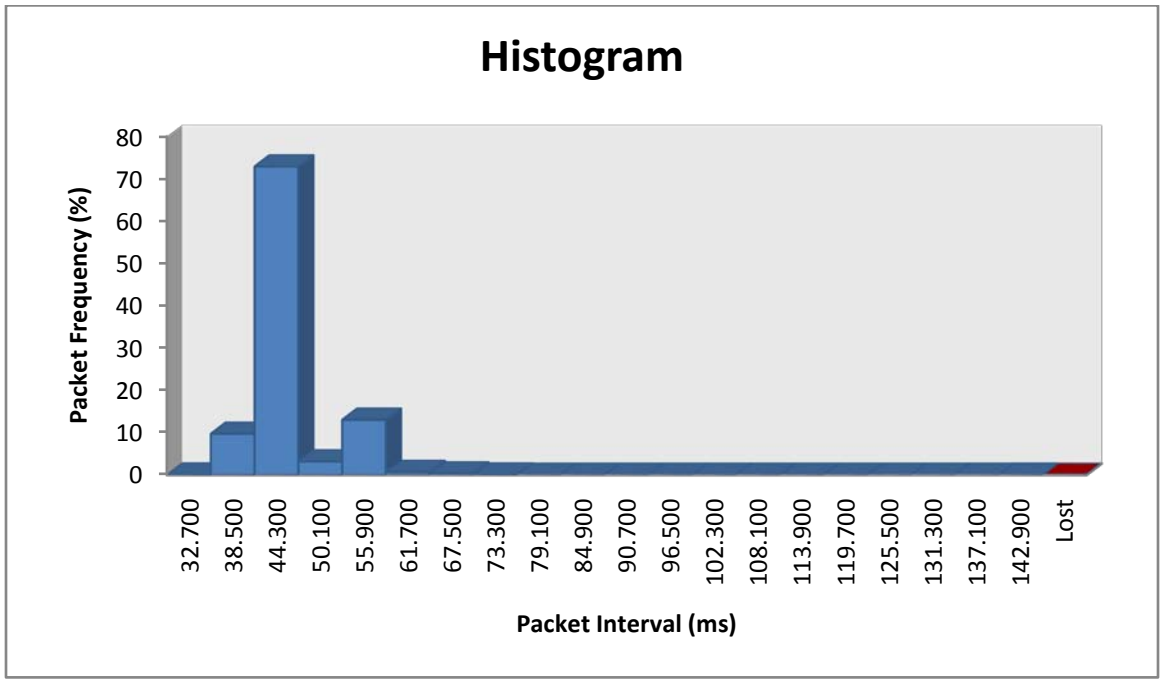
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	5000	N/A	N/A	N/A
# Lost Packets	0			
Average (ms)	41.663		+/-10%	
Std. Deviation (ms)	5.06		+/-10%	
Min (ms)	24.000		+/-10%	
Max (ms)	140.000		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
160
140
120
100
80
60
40
20
0
Packet Interval (ms)
0
1000
2000
3000
4000
5000
Packet #
Packet Interval (ms)


Histogram
80
70
60
50
40
30
20
10
0
Packet Frequency (%)
32.700
38.500
44.300
50.100
55.900
61.700
67.500
73.300
79.100
84.900
90.700
96.500
102.300
108.100
113.900
119.700
125.500
131.300
137.100
142.900
Lost
Packet Interval (ms)

Network Device Test Report: RF = -60 dBm.COT

Experimented by Wajiha Shahid and Jeehong Yang

University of Michigan

2009-09-14 16:14:50

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	ABB WISA
Channel	-
Signal Power	-
Noise Power	-60dBm
Distance	3m
Comments	

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	1024

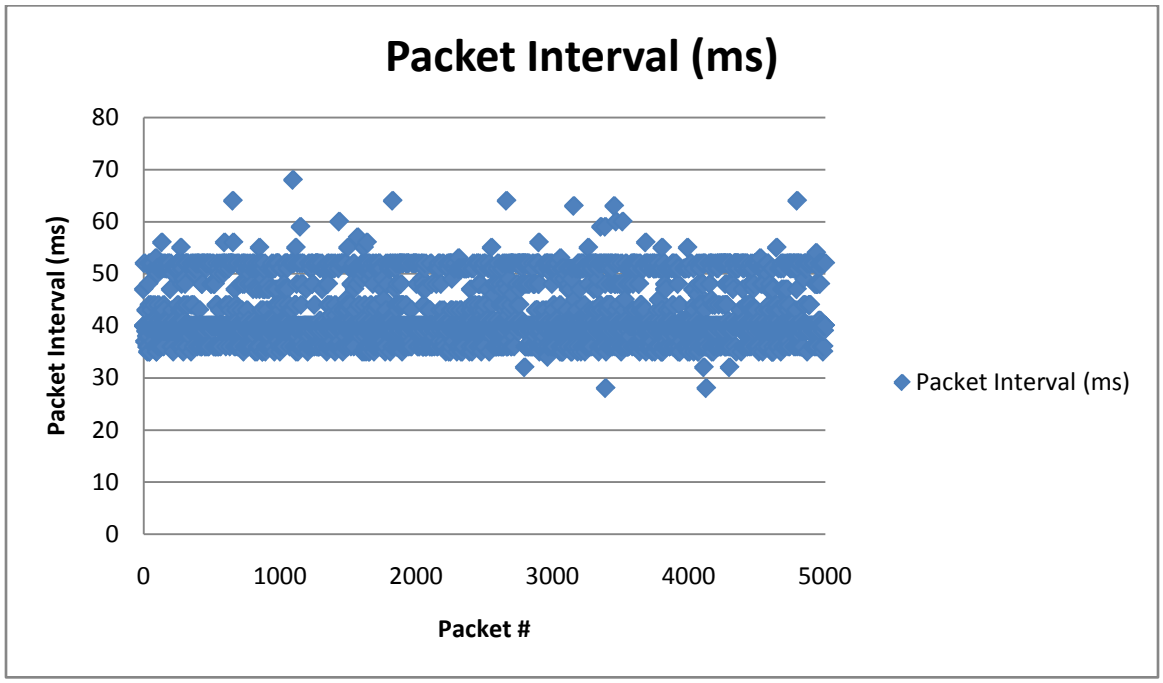
Results

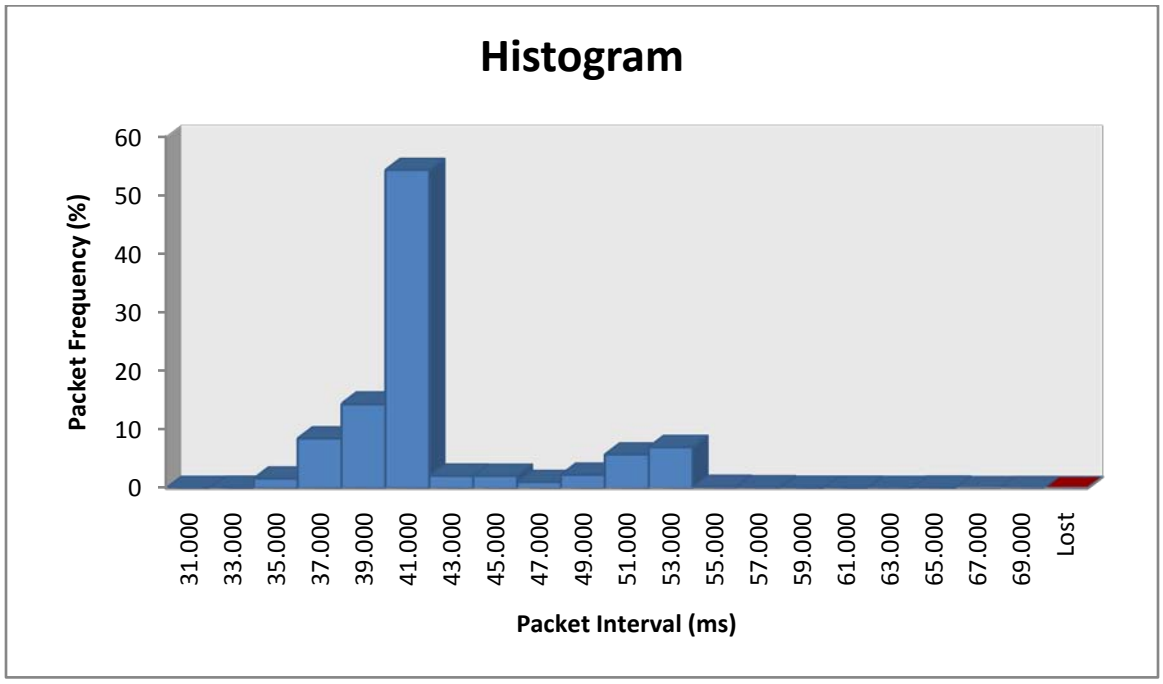
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	5000	N/A	N/A	N/A
# Lost Packets	0			
Average (ms)	41.454		+/-10%	
Std. Deviation (ms)	4.46		+/-10%	
Min (ms)	28.000		+/-10%	
Max (ms)	68.000		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
80
70
60
50
40
30
20
10
0
0
1000
2000
3000
4000
5000
Packet #
Packet Interval (ms)


Histogram
Packet Frequency (%)
60
50
40
30
20
10
0
31.000
33.000
35.000
37.000
39.000
41.000
43.000
45.000
47.000
49.000
51.000
53.000
55.000
57.000
59.000
61.000
63.000
65.000
67.000
69.000
Lost
Packet Interval (ms)

Network Device Test Report: No RF.COT

Experimented by Wajiha Shahid and Jeehong Yang

University of Michigan

2009-09-14 16:14:50

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	ABB WISA
Channel	-
Signal Power	-
Noise Power	None
Distance	20m
Comments	

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	1024

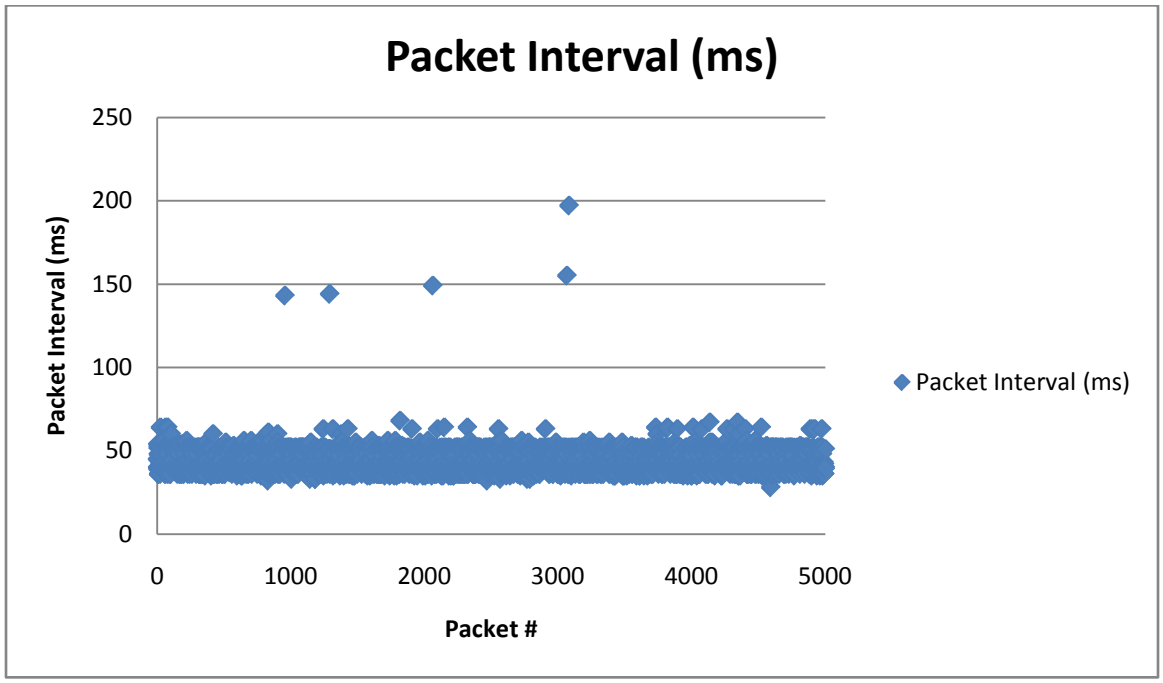
Results

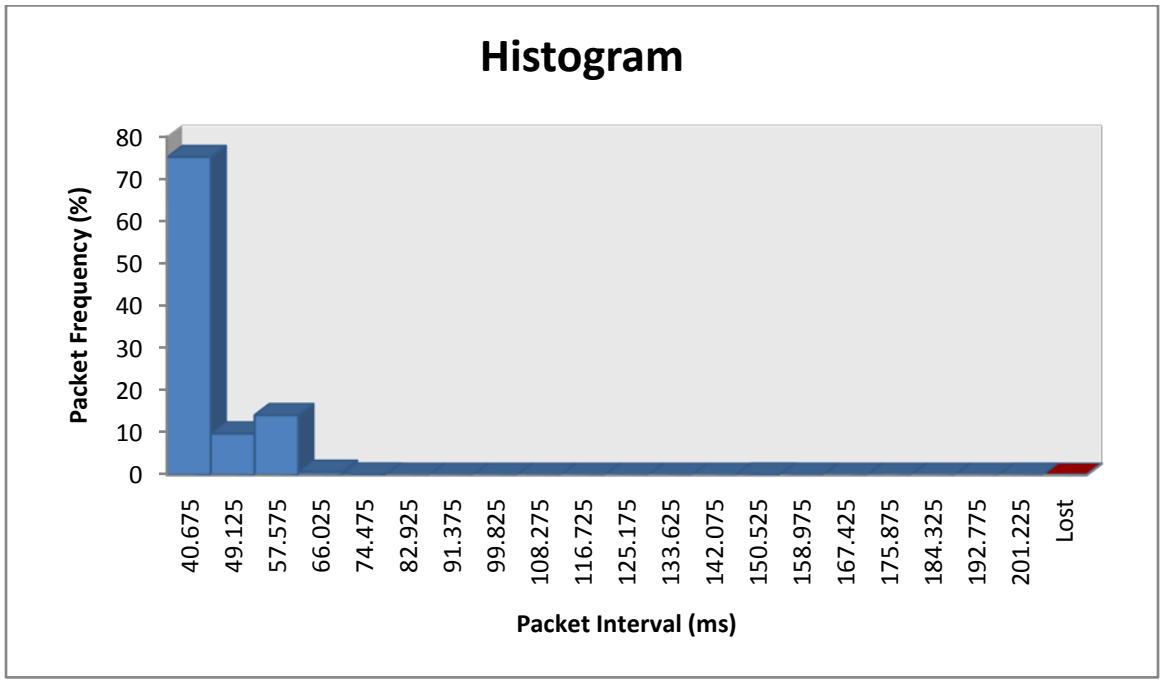
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	5000	N/A	N/A	N/A
# Lost Packets	0			
Average (ms)	41.840		+/-10%	
Std. Deviation (ms)	6.26		+/-10%	
Min (ms)	28.000		+/-10%	
Max (ms)	197.000		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
250
200
150
100
50
0
Packet Interval (ms)
0
1000
2000
3000
4000
5000
Packet #
Packet Interval (ms)


Histogram
80
70
60
50
40
30
20
10
0
Packet Frequency (%)
40.675
49.125
57.575
66.025
74.475
82.925
91.375
99.825
108.275
116.725
125.175
133.625
142.075
150.525
158.975
167.425
175.875
184.325
192.775
201.225
Lost
Packet Interval (ms)

Network Device Test Report: RF = 0dBm.COT

Experimented by Wajiha Shahid and Jeehong Yang

University of Michigan

2009-09-14 16:14:50

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	ABB WISA
Channel	-
Signal Power	-
Noise Power	0dBm
Distance	20m
Comments	

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	1024

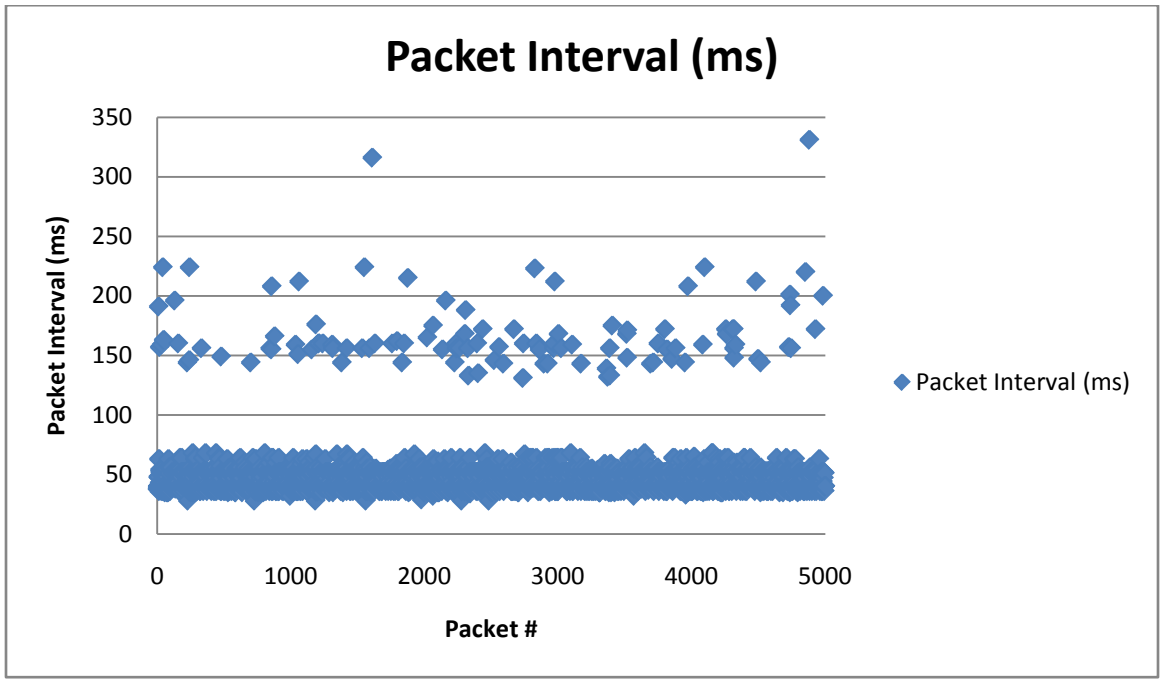
Results

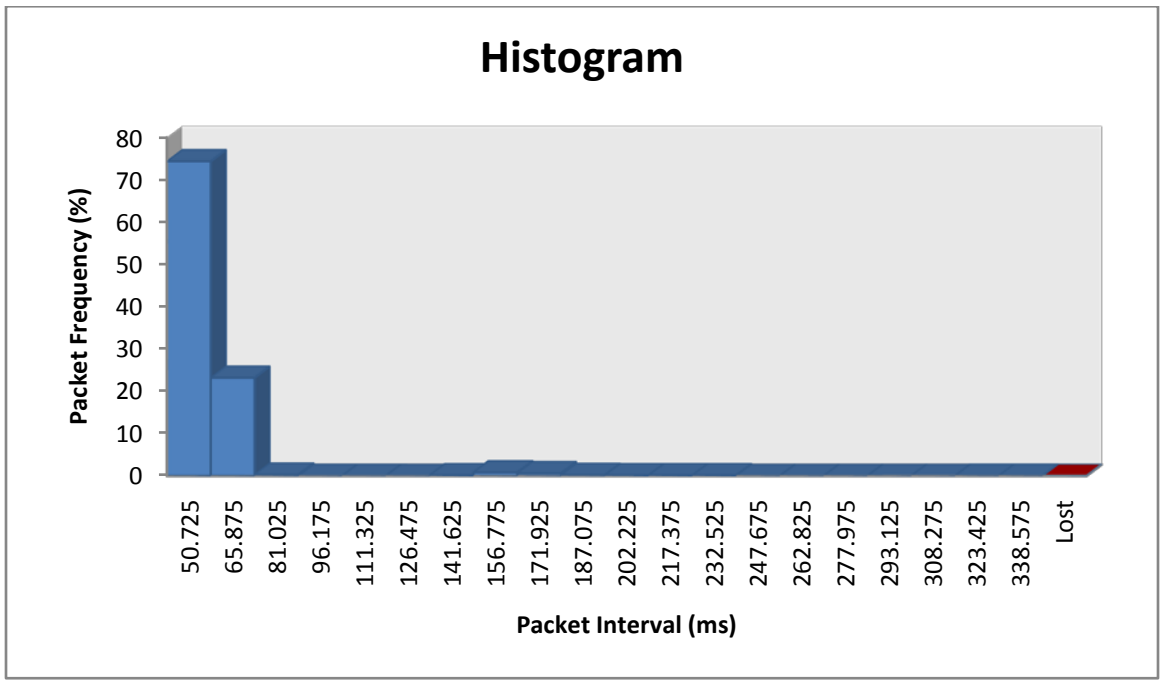
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	5000	N/A	N/A	N/A
# Lost Packets	0			
Average (ms)	45.880		+/-10%	
Std. Deviation (ms)	19.83		+/-10%	
Min (ms)	28.000		+/-10%	
Max (ms)	331.000		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
350
300
250
200
150
100
50
0
0
1000
2000
3000
4000
5000
Packet #
Packet Interval (ms)


Histogram
Packet Frequency (%)
80
70
60
50
40
30
20
10
0
50.725
65.875
81.025
96.175
111.325
126.475
141.625
156.775
171.925
187.075
202.225
217.375
232.525
247.675
262.825
277.975
293.125
308.275
323.425
338.575
Lost
Packet Interval (ms)

Network Device Test Report: RF = 10 dBm.COT

Experimented by Wajiha Shahid and Jeehong Yang

University of Michigan

2009-09-14 16:14:50

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	ABB WISA
Channel	-
Signal Power	-
Noise Power	10dBm
Distance	20m
Comments	

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	1024

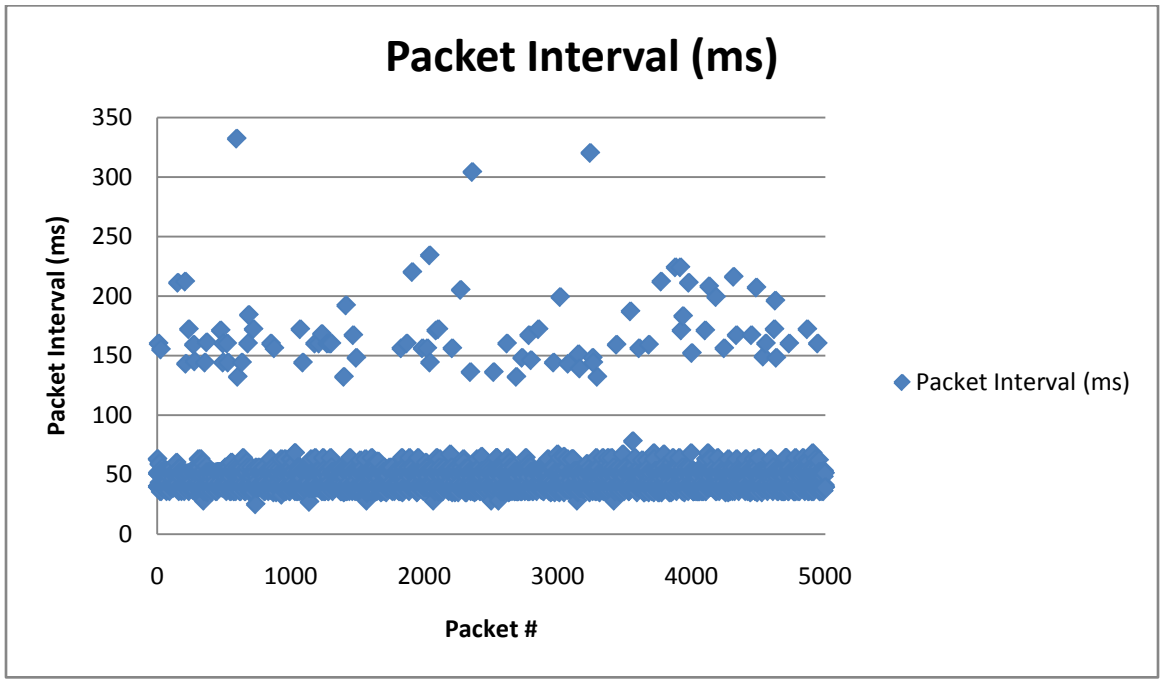
Results

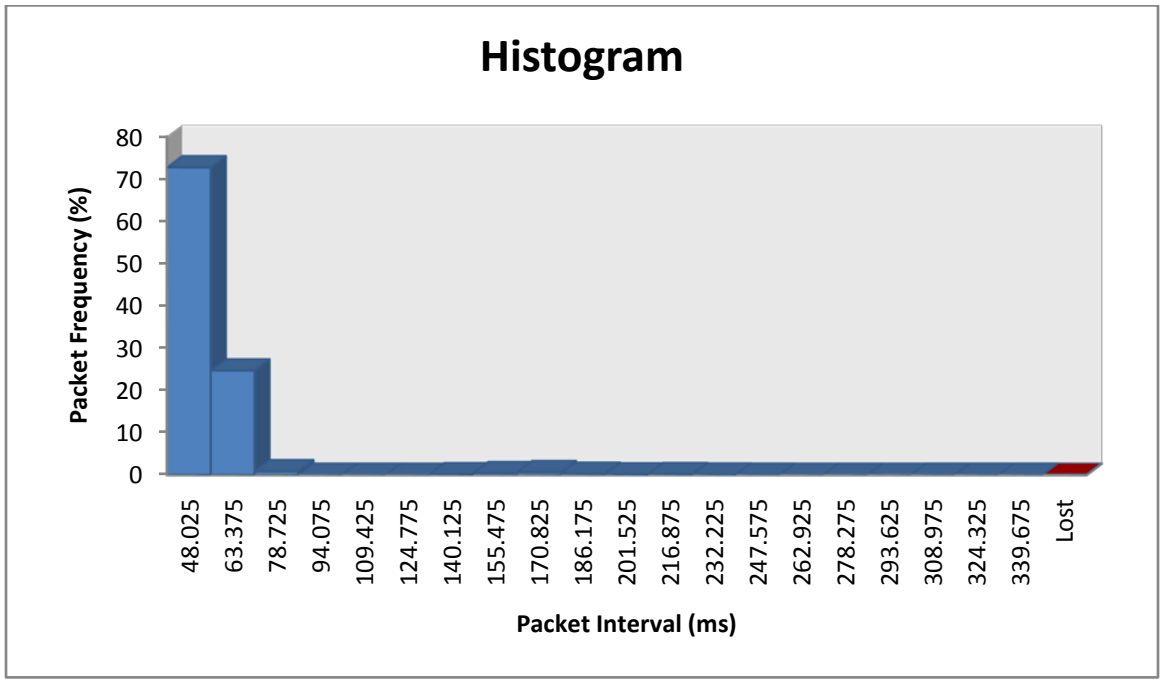
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	5000	N/A	N/A	N/A
# Lost Packets	0			
Average (ms)	45.645		+/-10%	
Std. Deviation (ms)	18.88		+/-10%	
Min (ms)	25.000		+/-10%	
Max (ms)	332.000		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
350
300
250
200
150
100
50
0
0
1000
2000
3000
4000
5000
Packet #
Packet Interval (ms)


Histogram
Packet Frequency (%)
80
70
60
50
40
30
20
10
0
48.025
63.375
78.725
94.075
109.425
124.775
140.125
155.475
170.825
186.175
201.525
216.875
232.225
247.575
262.925
278.275
293.625
308.975
324.325
339.675
Lost
Packet Interval (ms)

Network Device Test Report: RF = 20 dBm.COT

Experimented by Wajiha Shahid and Jeehong Yang

University of Michigan

2009-09-14 16:14:50

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	ABB WISA
Channel	-
Signal Power	-
Noise Power	20dBm
Distance	20m
Comments	

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	1024

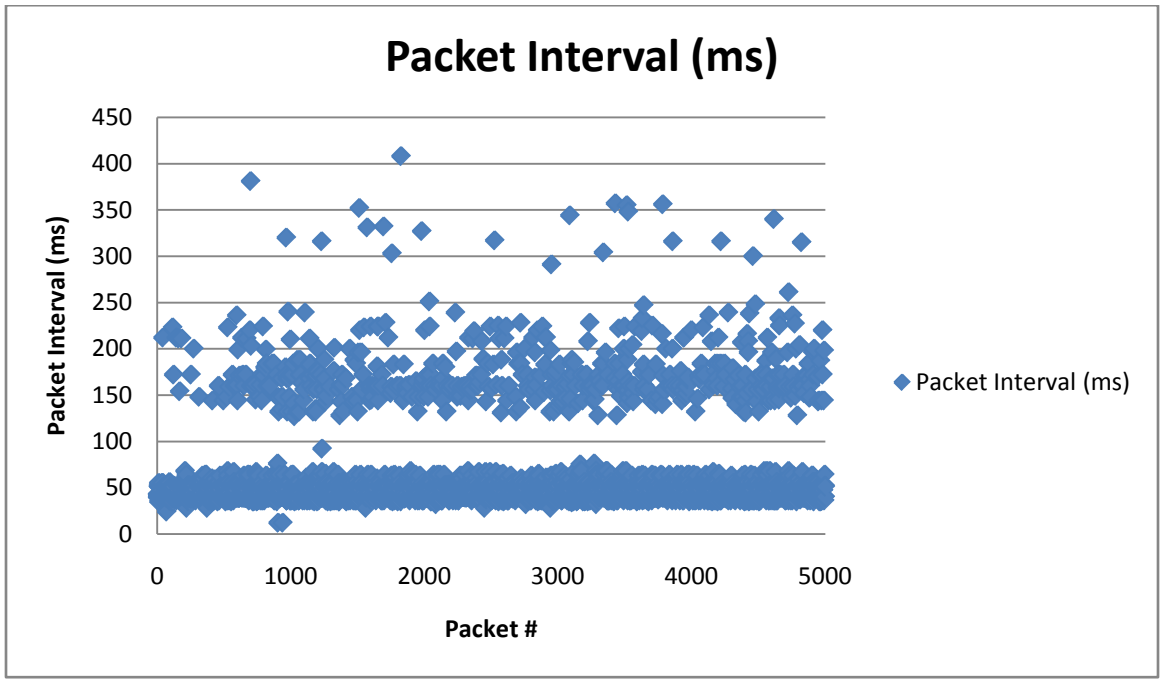
Results

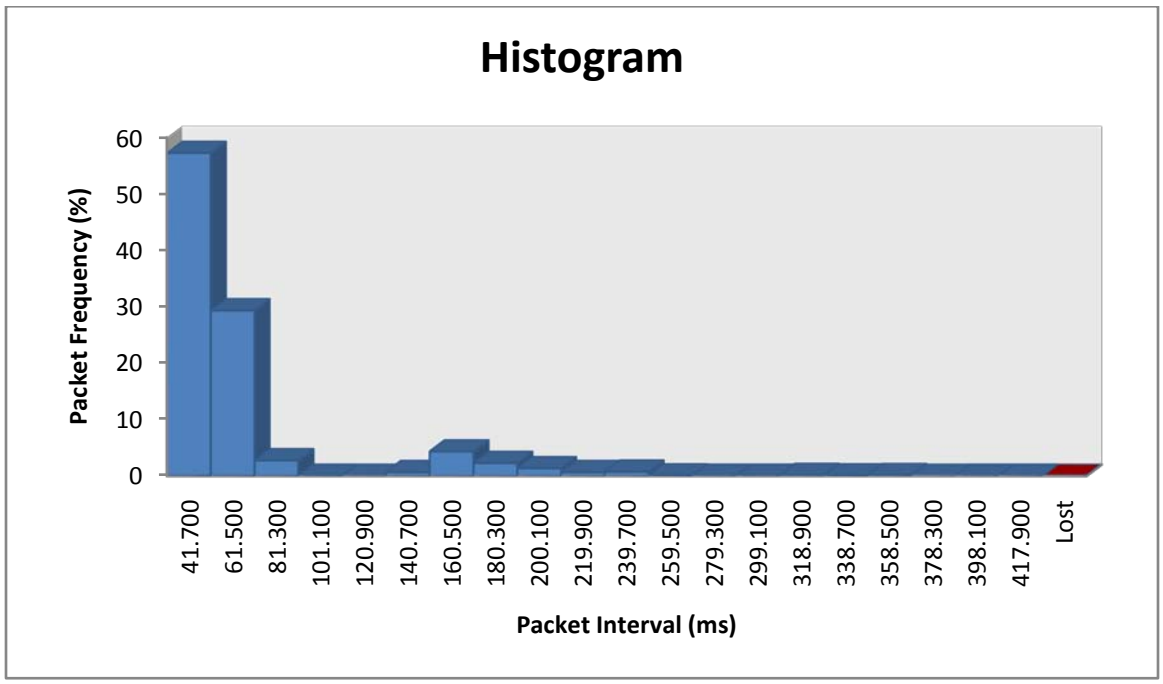
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	5000	N/A	N/A	N/A
# Lost Packets	0			
Average (ms)	58.151		+/-10%	
Std. Deviation (ms)	43.76		+/-10%	
Min (ms)	12.000		+/-10%	
Max (ms)	408.000		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
450
400
350
300
250
200
150
100
50
0
0
1000
2000
3000
4000
5000
Packet #
Packet Interval (ms)


Histogram
Packet Frequency (%)
60
50
40
30
20
10
0
41.700
61.500
81.300
101.100
120.900
140.700
160.500
180.300
200.100
219.900
239.700
259.500
279.300
299.100
318.900
338.700
358.500
378.300
398.100
417.900
Lost
Packet Interval (ms)

Network Device Test Report: RF = -30 dBm.COT

Experimented by Wajiha Shahid and Jeehong Yang

University of Michigan

2009-09-14 16:14:50

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	ABB WISA
Channel	-
Signal Power	-
Noise Power	-30dBm
Distance	20m
Comments	

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	1024

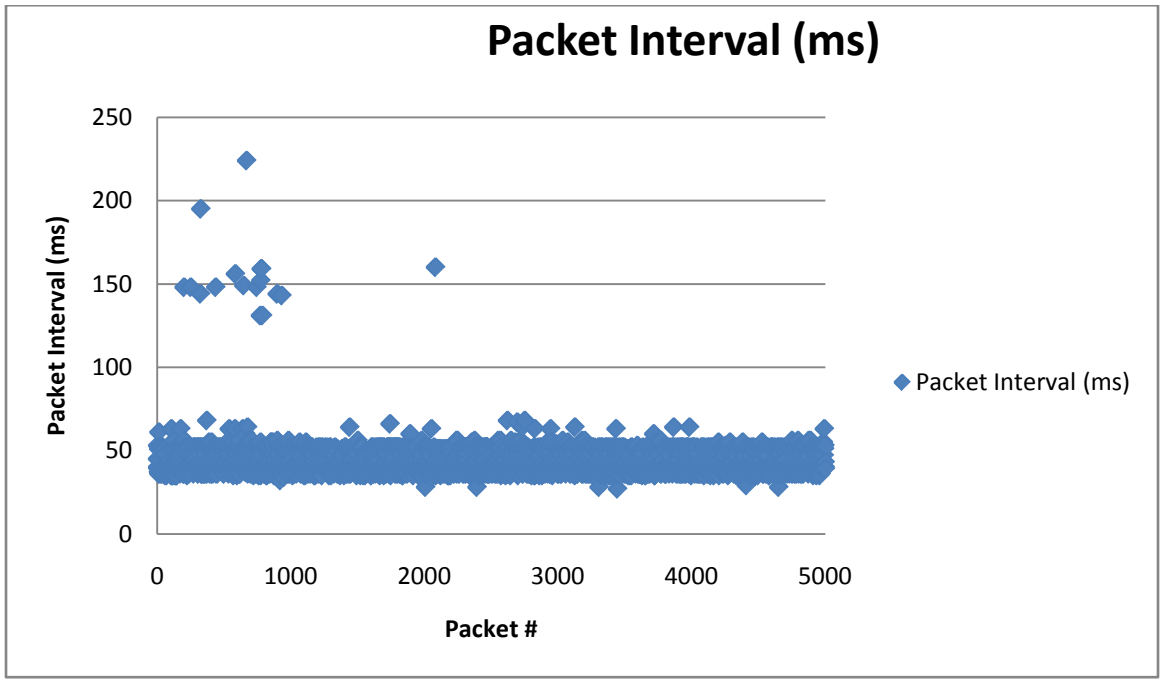
Results

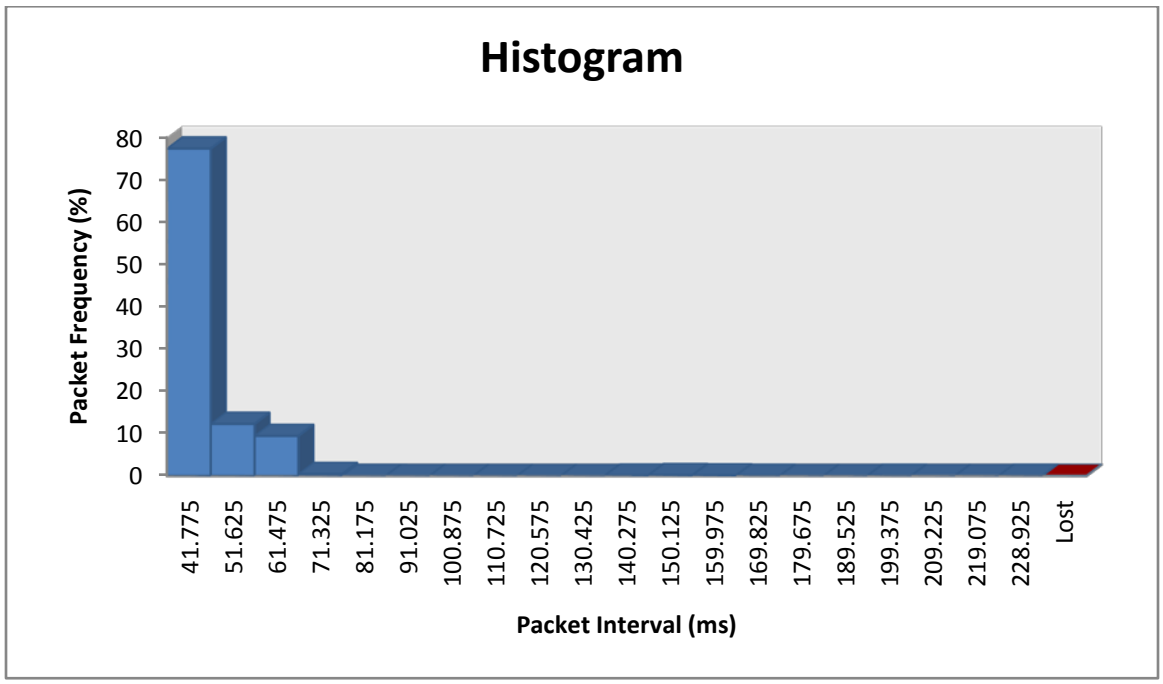
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	5000	N/A	N/A	N/A
# Lost Packets	0			
Average (ms)	42.034		+/-10%	
Std. Deviation (ms)	8.42		+/-10%	
Min (ms)	27.000		+/-10%	
Max (ms)	224.000		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
250
200
150
100
50
0
Packet Interval (ms)
0
1000
2000
3000
4000
5000
Packet #
Packet Interval (ms)


Histogram
80
70
60
50
40
30
20
10
0
Packet Frequency (%)
41.775
51.625
61.475
71.325
81.175
91.025
100.875
110.725
120.575
130.425
140.275
150.125
159.975
169.825
179.675
189.525
199.375
209.225
219.075
228.925
Lost
Packet Interval (ms)

Network Device Test Report: RF = -60 dBm.COT

Experimented by Wajiha Shahid and Jeehong Yang

University of Michigan

2009-09-14 16:14:50

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	ABB WISA
Channel	-
Signal Power	-
Noise Power	-60dBm
Distance	20m
Comments	

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	1024

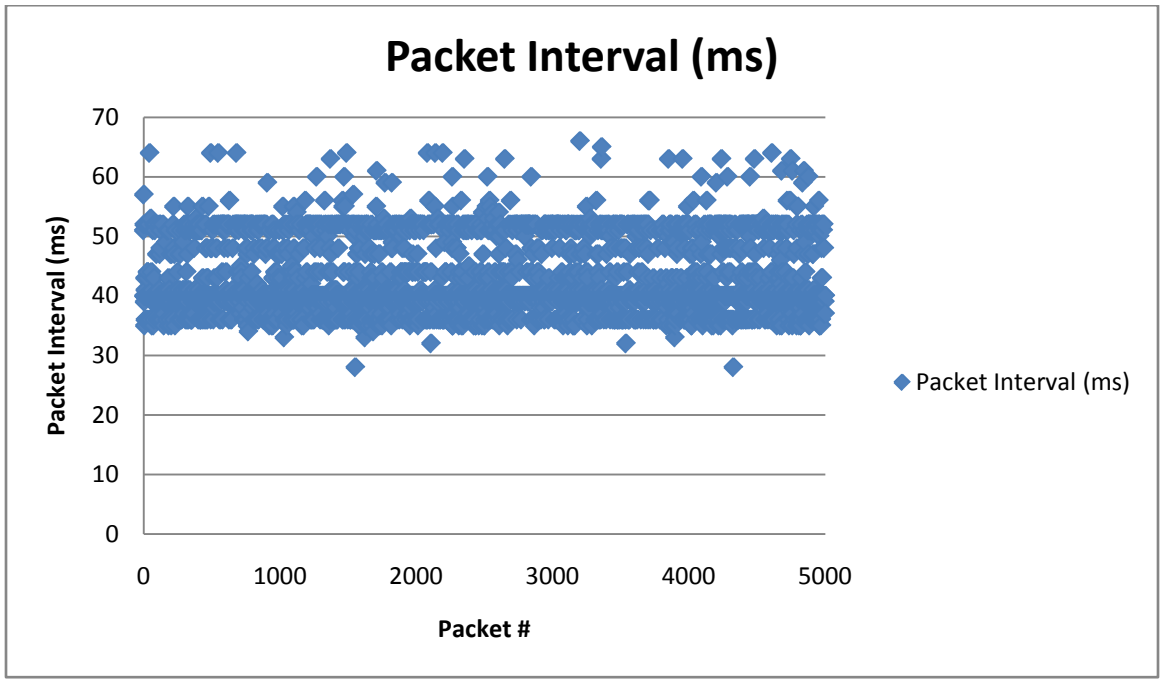
Results

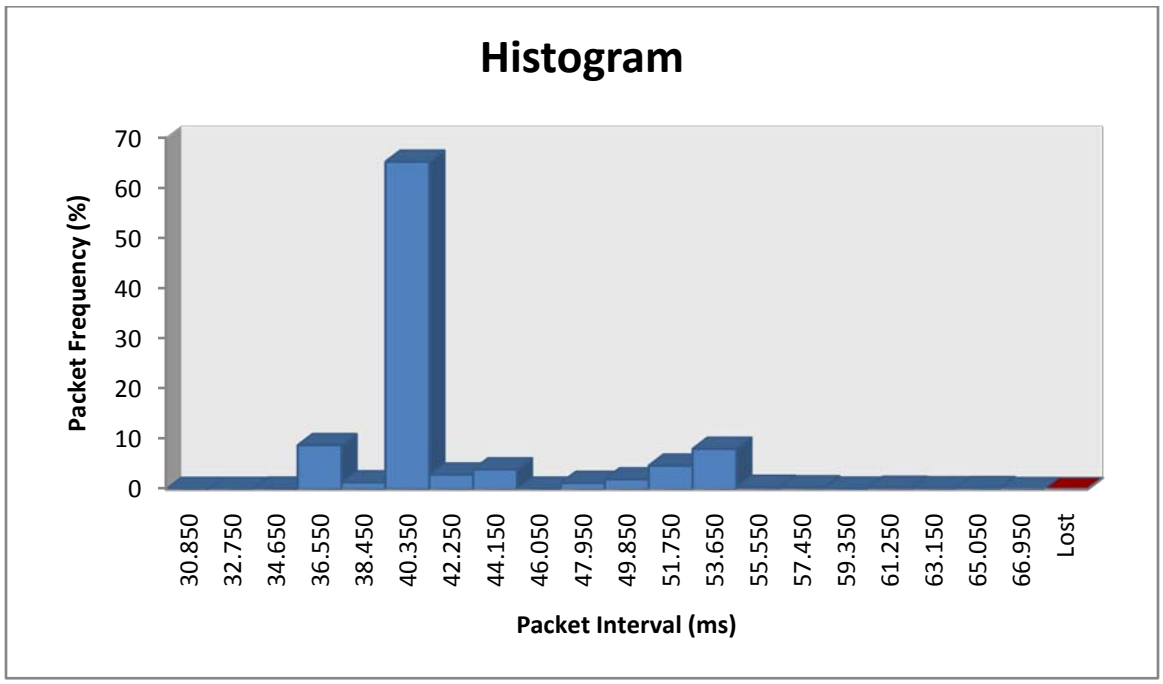
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	5000	N/A	N/A	N/A
# Lost Packets	0			
Average (ms)	41.639		+/-10%	
Std. Deviation (ms)	4.95		+/-10%	
Min (ms)	28.000		+/-10%	
Max (ms)	66.000		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
70
60
50
40
30
20
10
0
Packet Interval (ms)
0
1000
2000
3000
4000
5000
Packet #
Packet Interval (ms)


Histogram
70
60
50
40
30
20
10
0
Packet Frequency (%)
30.850
32.750
34.650
36.550
38.450
40.350
42.250
44.150
46.050
47.950
49.850
51.750
53.650
55.550
57.450
59.350
61.250
63.150
65.050
66.950
Lost
Packet Interval (ms)

Network Device Test Report: No RF.COT

Experimented by Wajiha Shahid and Jeehong Yang

University of Michigan

2009-09-14 16:14:50

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	ABB WISA
Channel	-
Signal Power	-
Noise Power	None
Distance	25m
Comments	

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	1024

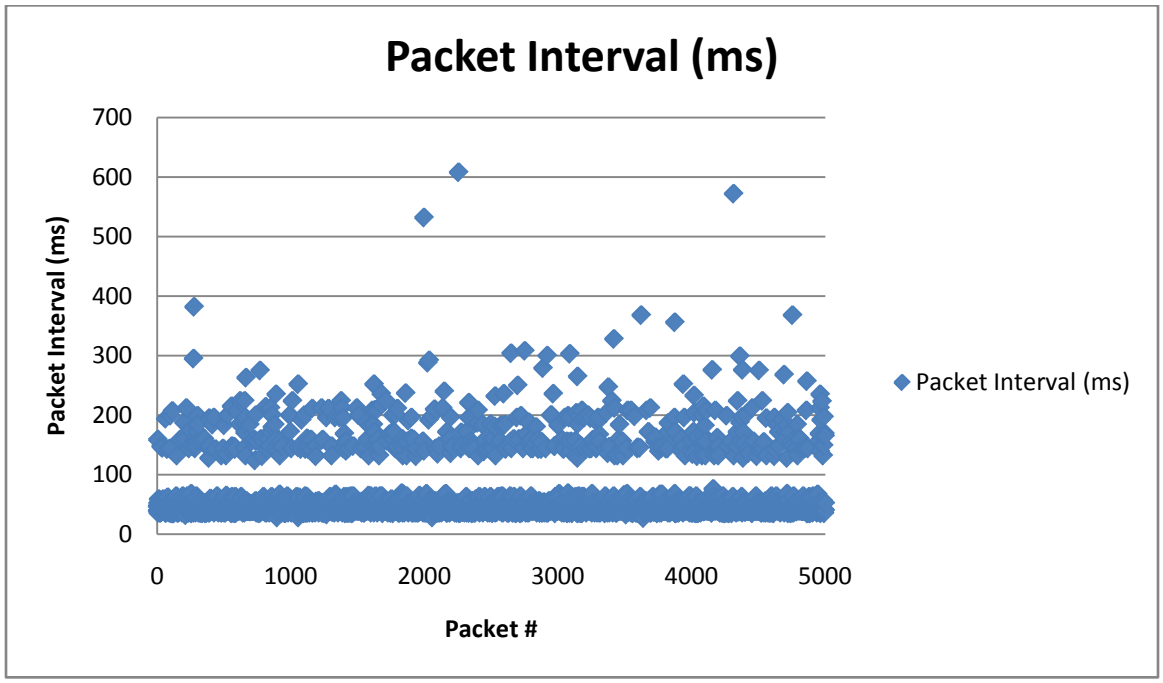
Results

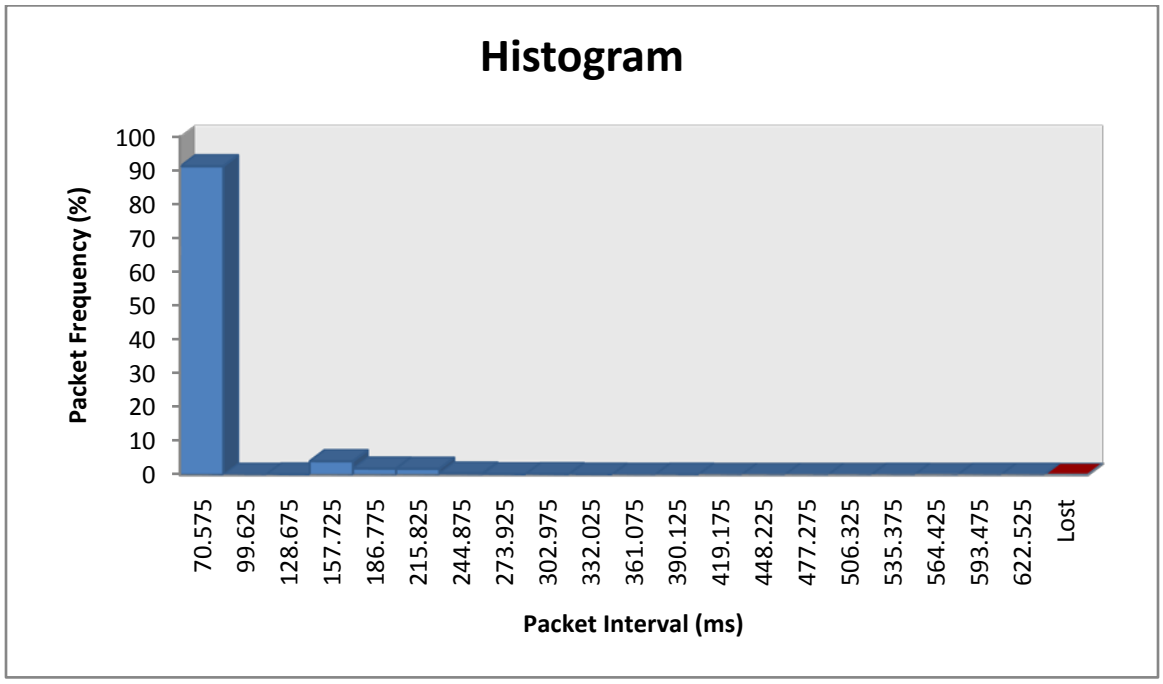
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	5000	N/A	N/A	N/A
# Lost Packets	0			
Average (ms)	54.989		+/-10%	
Std. Deviation (ms)	41.43		+/-10%	
Min (ms)	27.000		+/-10%	
Max (ms)	608.000		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
700
600
500
400
300
200
100
0
0
1000
2000
3000
4000
5000
Packet #
Packet Interval (ms)


Histogram
Packet Frequency (%)
100
90
80
70
60
50
40
30
20
10
0
70.575
99.625
128.675
157.725
186.775
215.825
244.875
273.925
302.975
332.025
361.075
390.125
419.175
448.225
477.275
506.325
535.375
564.425
593.475
622.525
Lost
Packet Interval (ms)

Network Device Test Report: RF = -30 dBm.COT

Experimented by Wajiha Shahid and Jeehong Yang

University of Michigan

2009-09-14 16:14:50

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	ABB WISA
Channel	-
Signal Power	-
Noise Power	-30dBm
Distance	25m
Comments	

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	1024

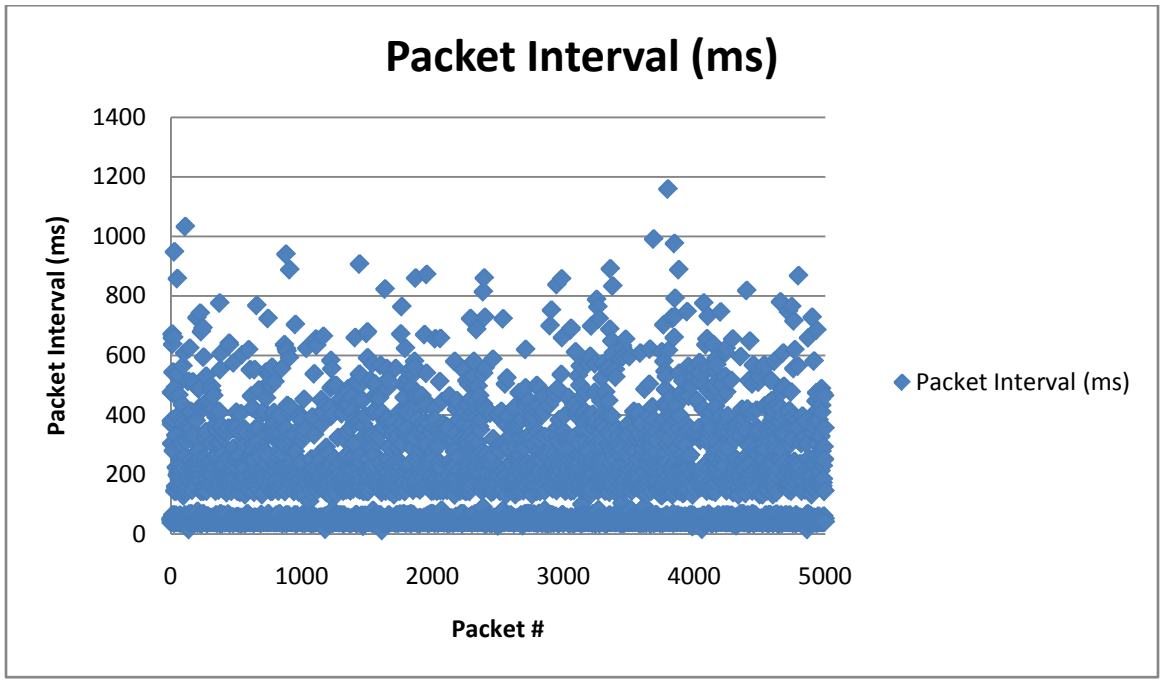
Results

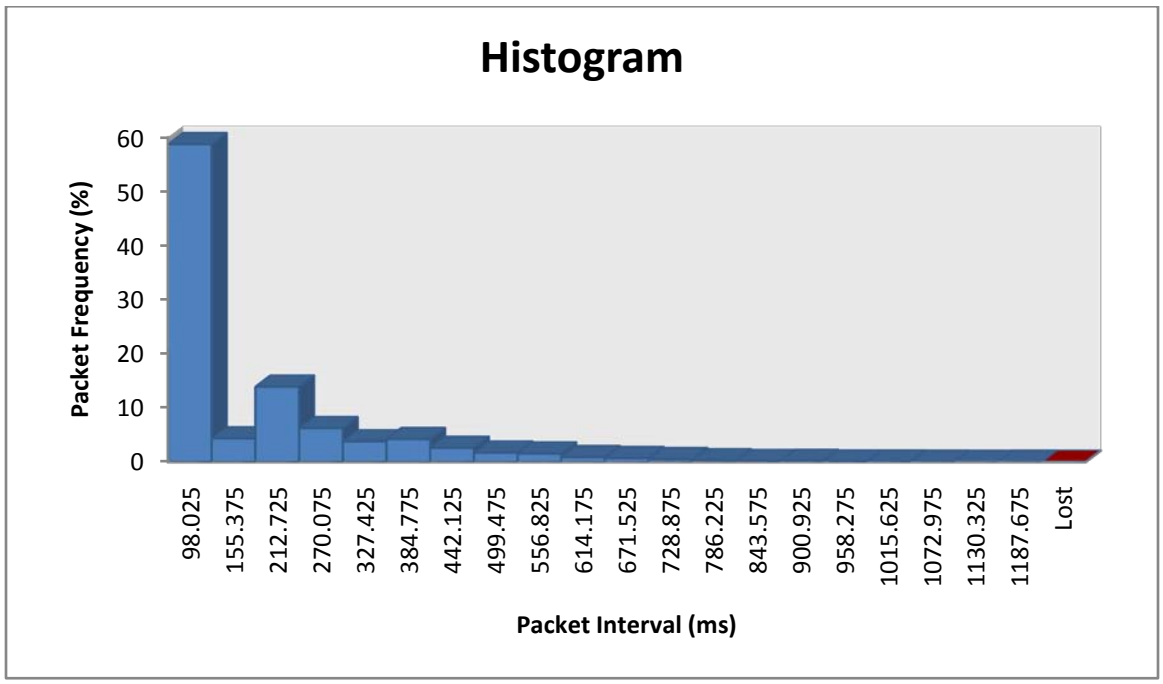
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	5000	N/A	N/A	N/A
# Lost Packets	0			
Average (ms)	146.380		+/-10%	
Std. Deviation (ms)	155.05		+/-10%	
Min (ms)	12.000		+/-10%	
Max (ms)	1159.000		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
1400
1200
1000
800
600
400
200
0
Packet Interval (ms)
0
1000
2000
3000
4000
5000
Packet #
Packet Interval (ms)


Histogram
60
50
40
30
20
10
0
Packet Frequency (%)
98.025
155.375
212.725
270.075
327.425
384.775
442.125
499.475
556.825
614.175
671.525
728.875
786.225
843.575
900.925
958.275
1015.625
1072.975
1130.325
1187.675
Lost
Packet Interval (ms)

Network Device Test Report: RF = -60 dBm.COT

Experimented by Wajiha Shahid and Jeehong Yang

University of Michigan

2009-09-14 16:14:50

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	ABB WISA
Channel	-
Signal Power	-
Noise Power	-60dBm
Distance	25m
Comments	

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	1024
HistogramData Size (bytes)	1024

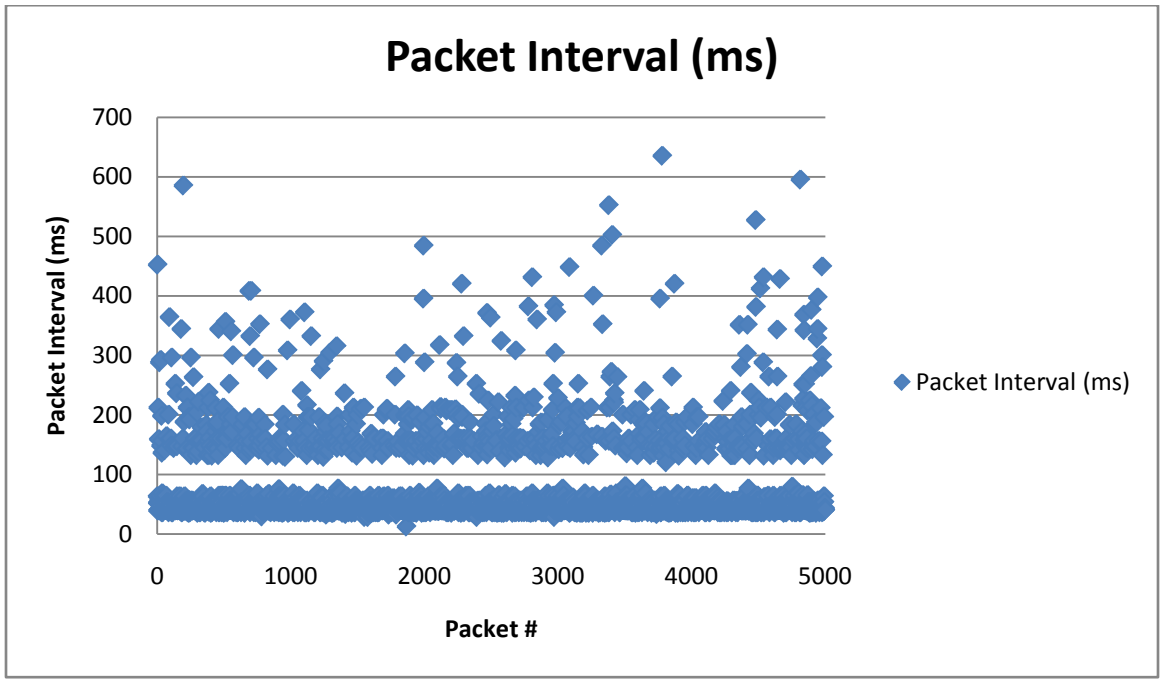
Results

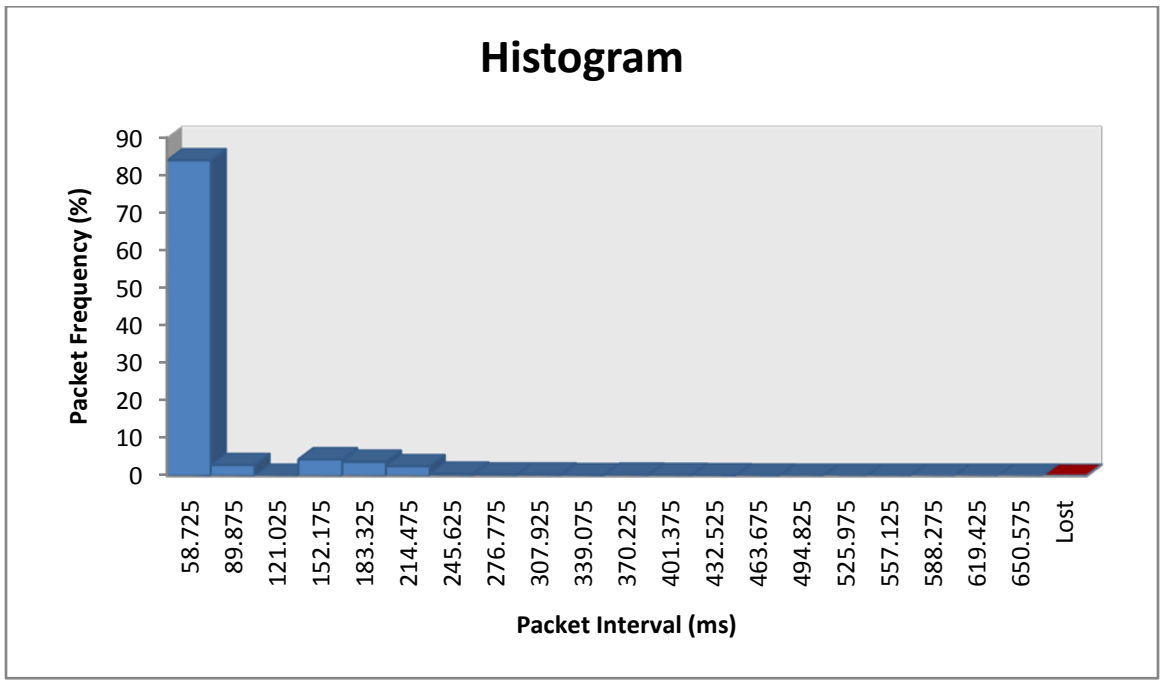
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	5000	N/A	N/A	N/A
# Lost Packets	0			
Average (ms)	63.215		+/-10%	
Std. Deviation (ms)	57.16		+/-10%	
Min (ms)	12.000		+/-10%	
Max (ms)	635.000		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
700
600
500
400
300
200
100
0
Packet Interval (ms)
0
1000
2000
3000
4000
5000
Packet #
Packet Interval (ms)


Histogram
90
80
70
60
50
40
30
20
10
0
Packet Frequency (%)
58.725
89.875
121.025
152.175
183.325
214.475
245.625
276.775
307.925
339.075
370.225
401.375
432.525
463.675
494.825
525.975
557.125
588.275
619.425
650.575
Lost
Packet Interval (ms)

Section 6

Test Results for Siemens 802.11 WLAN

This section contains results for the following tests:
-Indoor transmit power test
-Distance test 8dBm and 20 dBm
-Outdoor transmit power test

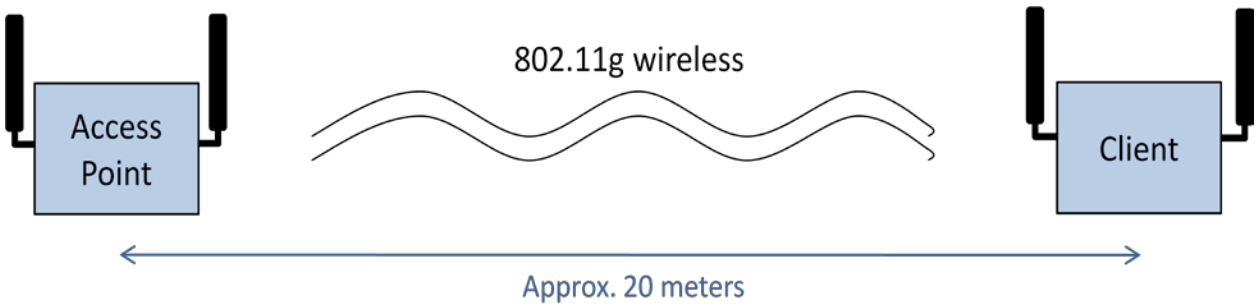
Results for outdoor transmit power test at 0m distance and 0 dBm noise power are as follows:

Transmit Power (dBm)	Standard Deviation	Mean	No. of Packets Lost
8	5.30	5.415	0/246
11	3.47	5.081	0/250
14	2.02	4.094	0/140
17	4.63	4.631	0/230
20	2.09	4.069	0/250

Indoor Transmit Power Testing

The access point and the client were placed 20m apart within line of sight of each other. Next, an operating channel was chosen to minimize the effects of potential interference from the presence other wireless networks in the vicinity of the testing area. Standard antennas which came with devices were used. The indoor laboratory environment was characterized by several machines/surfaces which acted as signal reflecting sources.

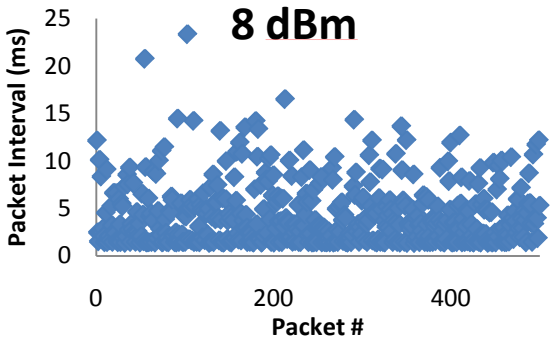
During the course of the test, the transmit power for on the client and AP was altered in intervals of 3 dBm, between the range of 20 dBm (Full Power) to 8 dBm (1/16 Power). The following is a schematic of the experiment setup.

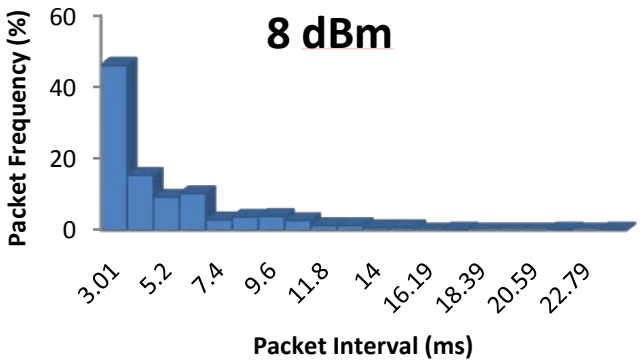


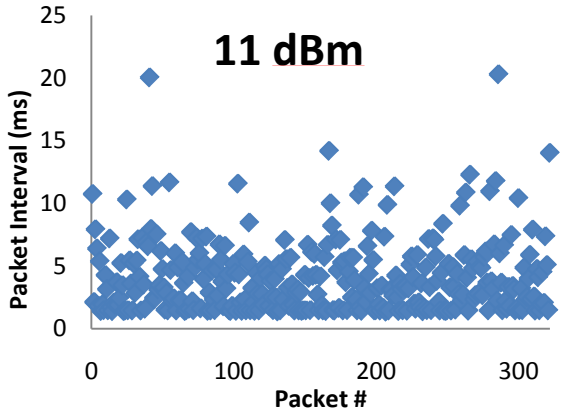
The time delay characteristics observed in both clients are listed in the table below:

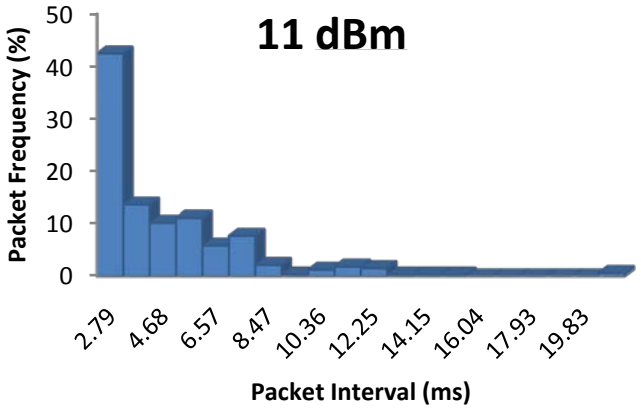
	W746-1PRO				**W747-1RR**			
Noise (dBm)	Average (msec)	Standard Deviation (msec)	Minimum (msec)	Maximum (msec)	Average (msec)	Standard Deviation (msec)	Minimum (msec)	Maximum (msec)
20	4.06	3.17	1.38	20.07	6.63	19.70	1.09	22.87
17	4.23	2.82	1.36	15.25	4.10	3.13	1.08	12.58
14	4.24	2.80	1.39	19.79	3.49	2.87	1.09	16.15
11	4.06	2.90	1.36	20.30	3.63	2.71	1.09	13.84
8	4.25	3.21	1.36	23.34	3.87	3.05	1.02	17.50

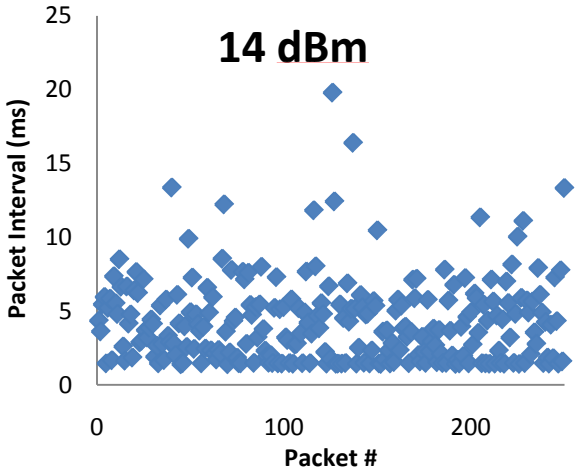
Transmit Power: Client W746-1PRO

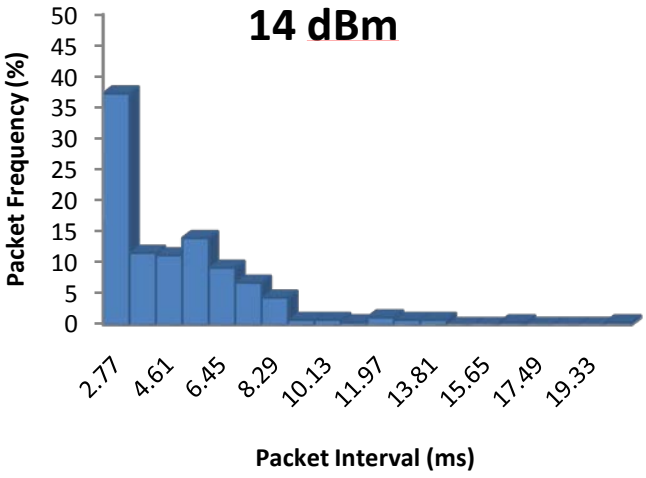




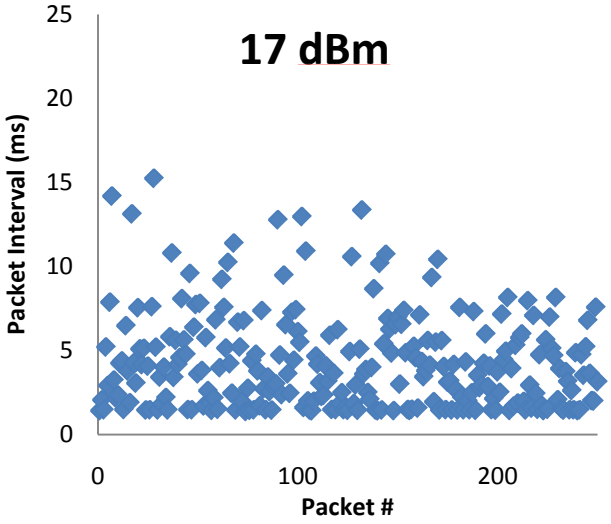


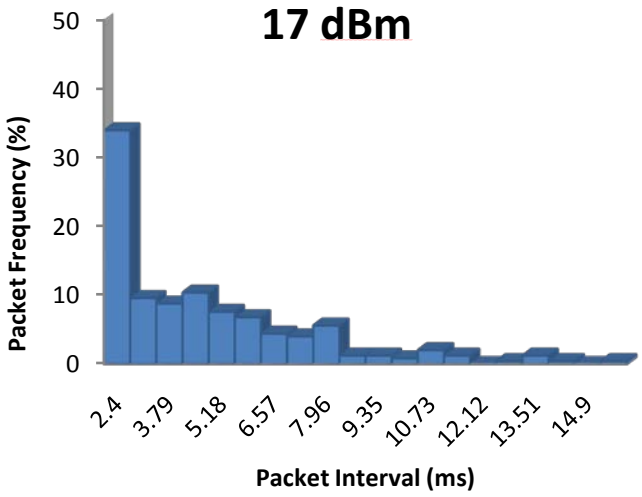


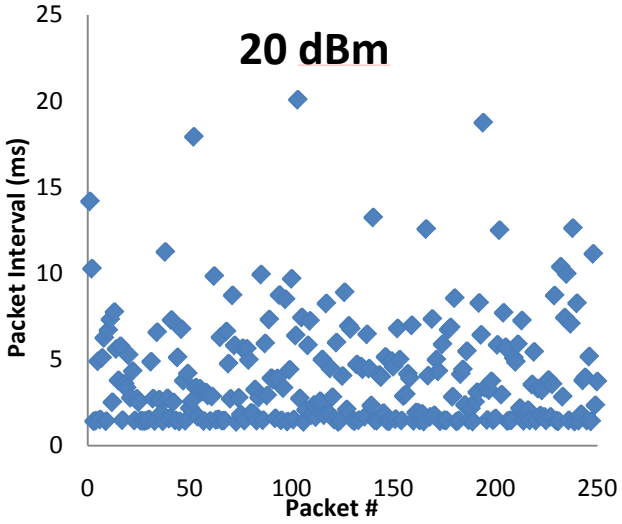


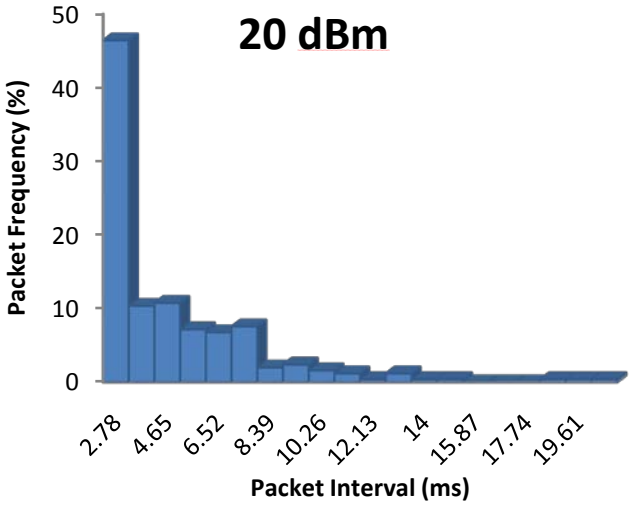


Transmit Power: Client W746-1PRO

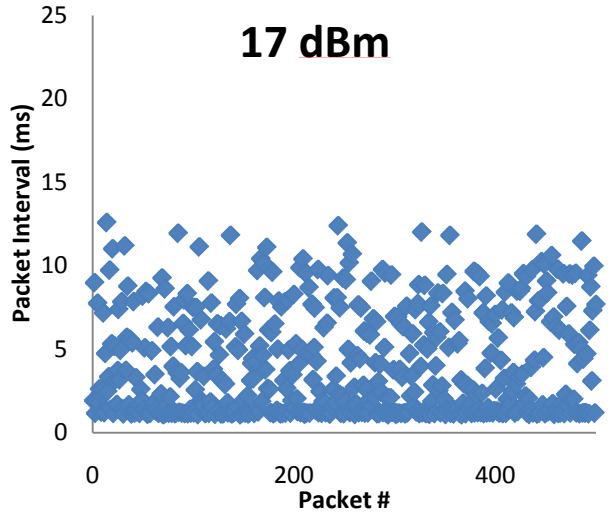


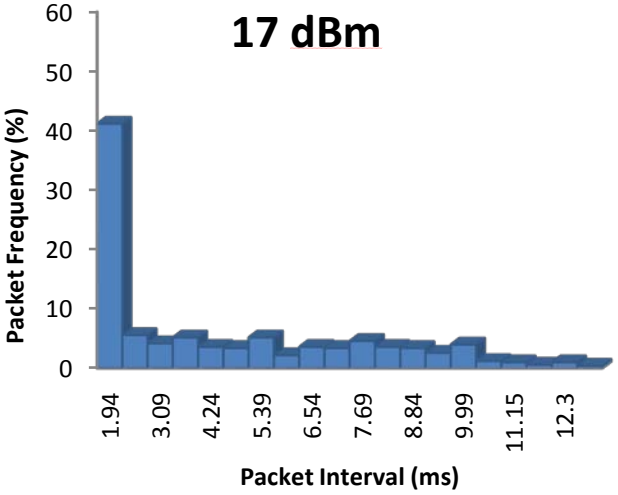


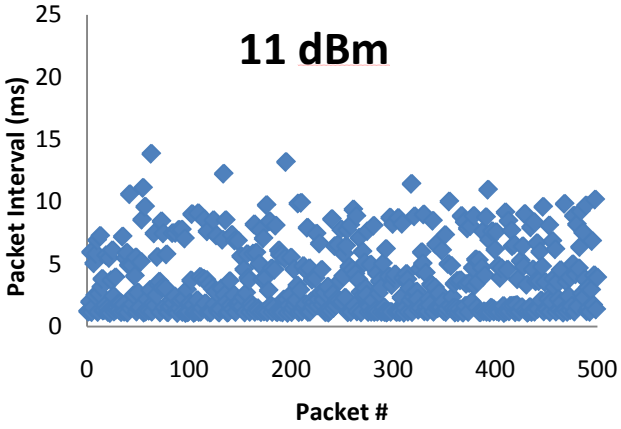


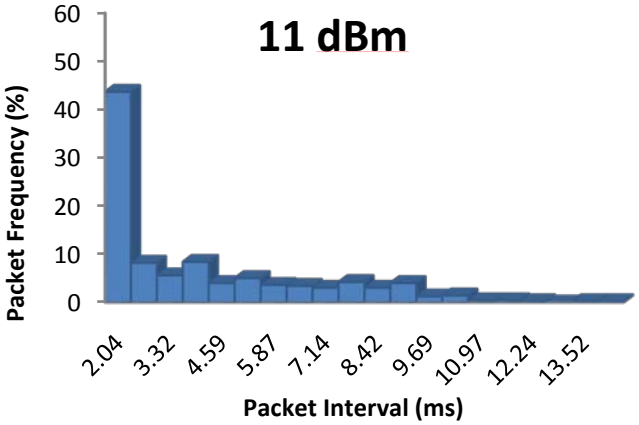


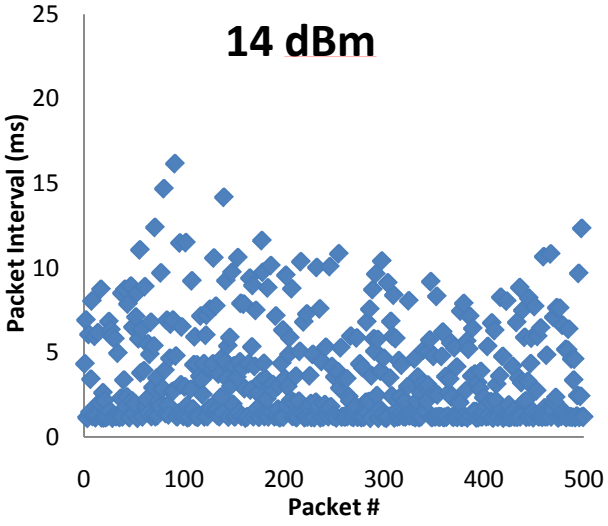
Transmit Power:Client W747-1RR

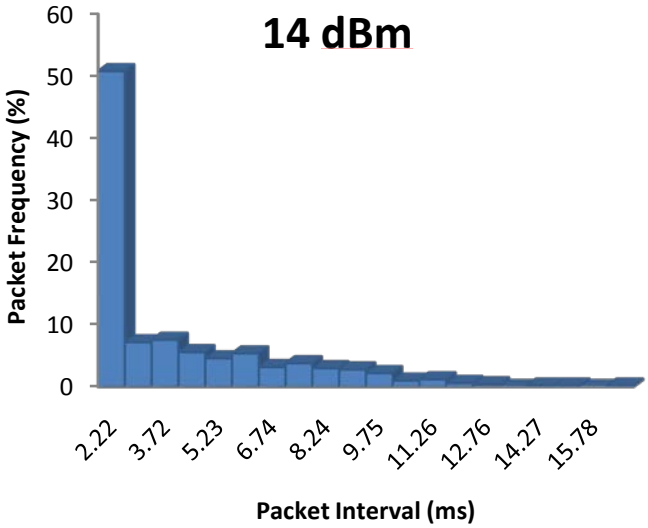




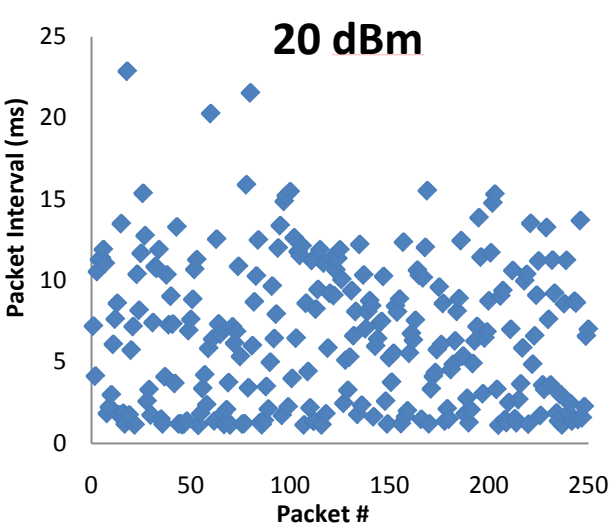


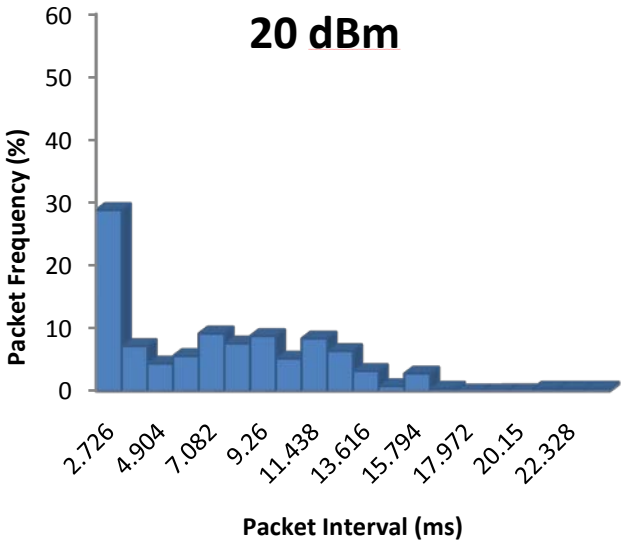






Transmit Power:Client W747-1RR





Transmit Power: Outdoors Testing

The purpose of the outdoor testing was to reduce interference from indoor wireless networks and to replicate the same test environments every day.

As baseline tests, the devices were placed next to each other and their power settings were varied between 8dBm and 20 dBm. The client W747-1RR was then tested at 8dBm (lowest power setting) and at 20 dBm (highest power setting) at distances ranging from ~10m to ~55m.

The schematics below illustrate the two configurations of the distance tests to due to the length limitation of the extension cords used.

Figure5: Test setup for distance testing of less than 20m

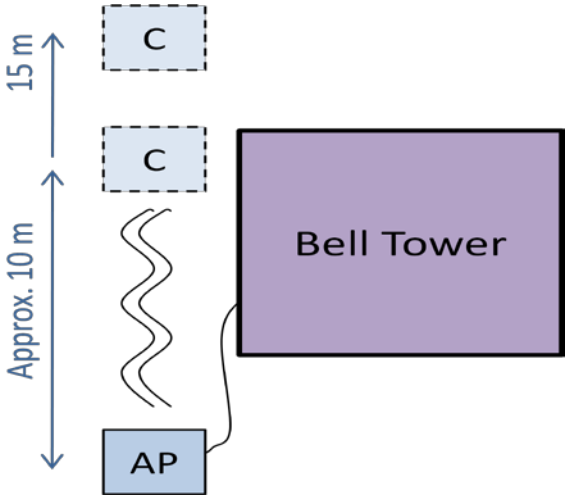
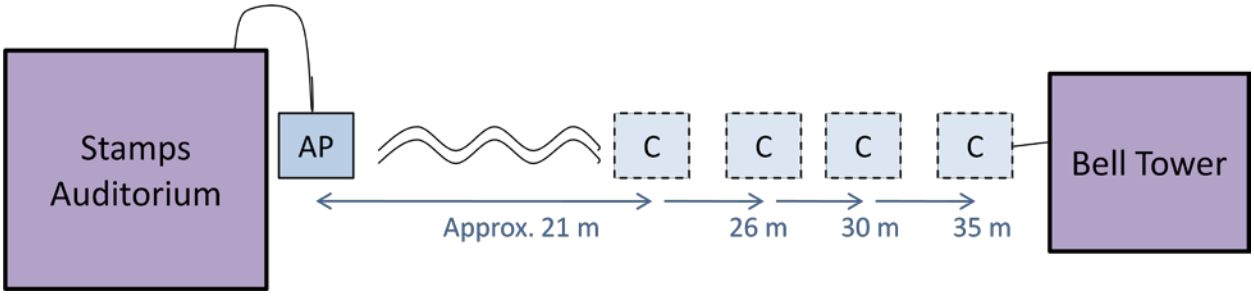


Figure6: Test setup between two buildings for distance testing greater than 20m



Network Device Test Report: Transmit Power = 8 dBm, Outdoor Baseline

Experimented by Katie Olson and Wajiha Shahid

University of Michigan

2008-10-28 15:50:12

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Scalance WLAN
Channel	6
Transmit Power	8 dBm
Noise Power	0
Distance	0
Comments	

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	100
HistogramData Size (bytes)	1024

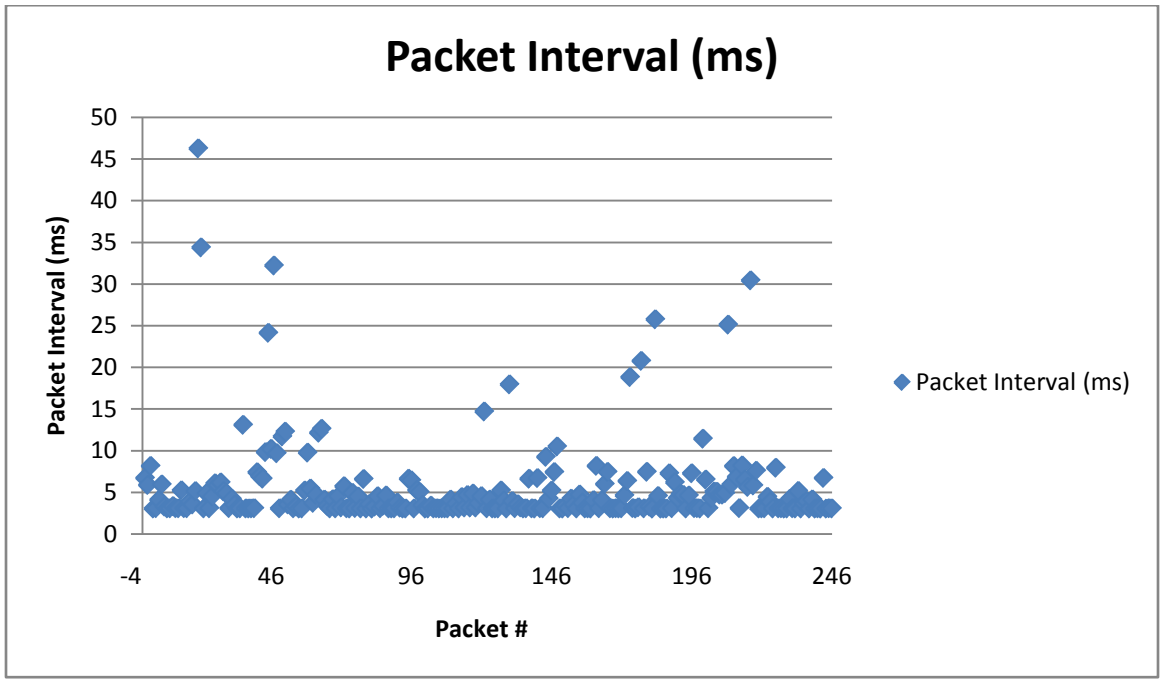
Results

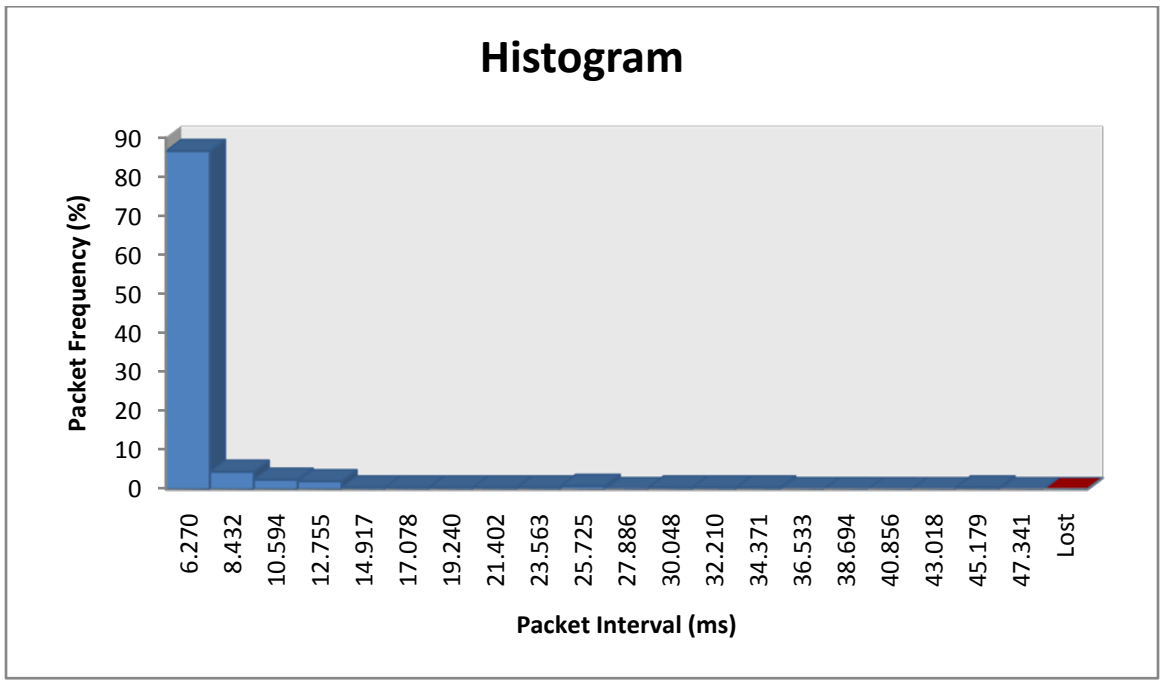
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	246	N/A	N/A	N/A
# Lost Packets	0			
Average (ms)	5.415		+/-10%	
Std. Deviation (ms)	5.30		+/-10%	
Min (ms)	3.028		+/-10%	
Max (ms)	46.260		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
50
45
40
35
30
25
20
15
10
5
0
-4
46
96
146
196
246
Packet #
Packet Interval (ms)


Histogram
Packet Frequency (%)
90
80
70
60
50
40
30
20
10
0
6.270
8.432
10.594
12.755
14.917
17.078
19.240
21.402
23.563
25.725
27.886
30.048
32.210
34.371
36.533
38.694
40.856
43.018
45.179
47.341
Lost
Packet Interval (ms)

Network Device Test Report: Transmit Power 11dBm, Outdoor Baseline

Experimented by Katie Olson and Wajiha Shahid

University of Michigan

2008-10-28 15:47:47

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Scalance WLAN
Channel	6
Device Power	11 dBm
Noise Power	0
Distance	0
Comments	

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	100
HistogramData Size (bytes)	1024

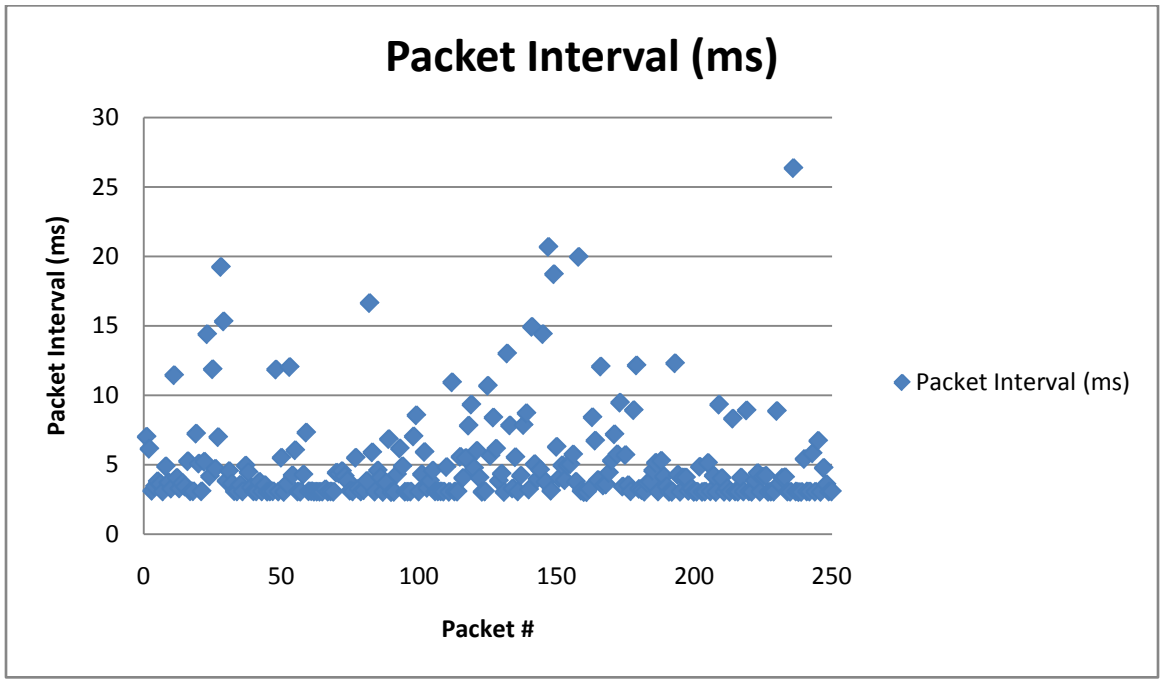
Results

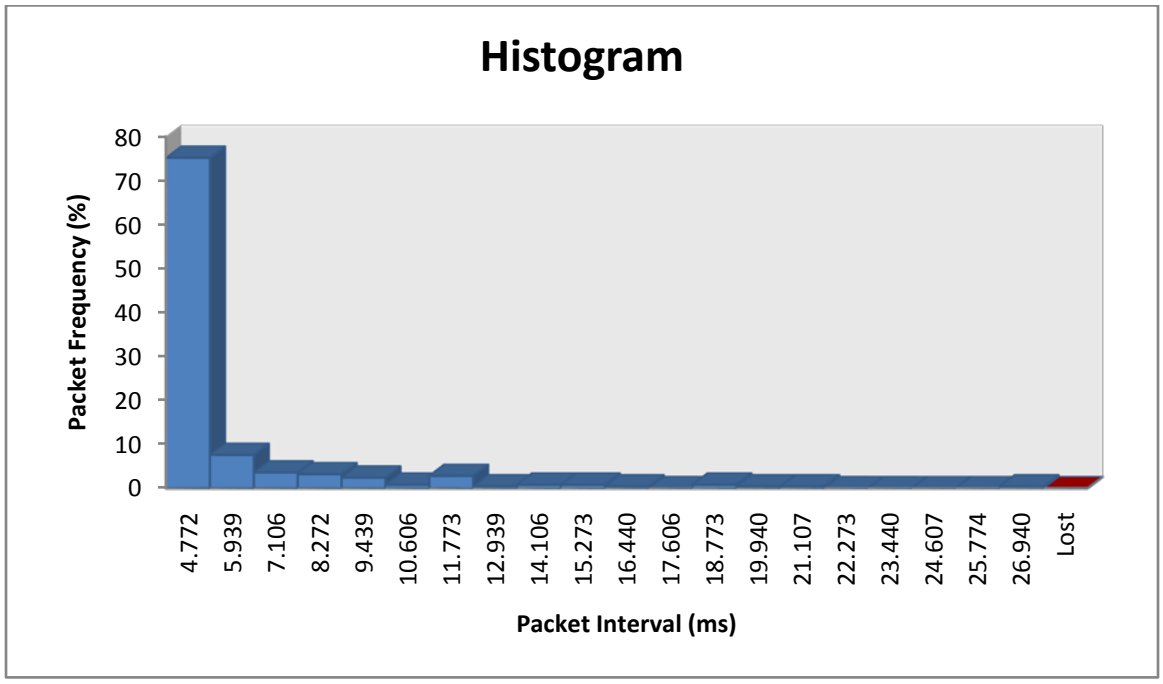
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	250	N/A	N/A	N/A
# Lost Packets	0			
Average (ms)	5.081		+/-10%	
Std. Deviation (ms)	3.47		+/-10%	
Min (ms)	3.022		+/-10%	
Max (ms)	26.357		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
30
25
20
15
10
5
0
0
50
100
150
200
250
Packet #
Packet Interval (ms)


Histogram
Packet Frequency (%)
80
70
60
50
40
30
20
10
0
4.772
5.939
7.106
8.272
9.439
10.606
11.773
12.939
14.106
15.273
16.440
17.606
18.773
19.940
21.107
22.273
23.440
24.607
25.774
26.940
Lost
Packet Interval (ms)

Network Device Test Report: Transmit Power = 14 dBm, Outdoor Baseline

Experimented by Katie Olson and Wajiha Shahid

University of Michigan

2008-10-28 15:45:57

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Scalance WLAN
Channel	6
Transmit Power	14
Noise Power	0
Distance	0
Comments	

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	100
HistogramData Size (bytes)	1024

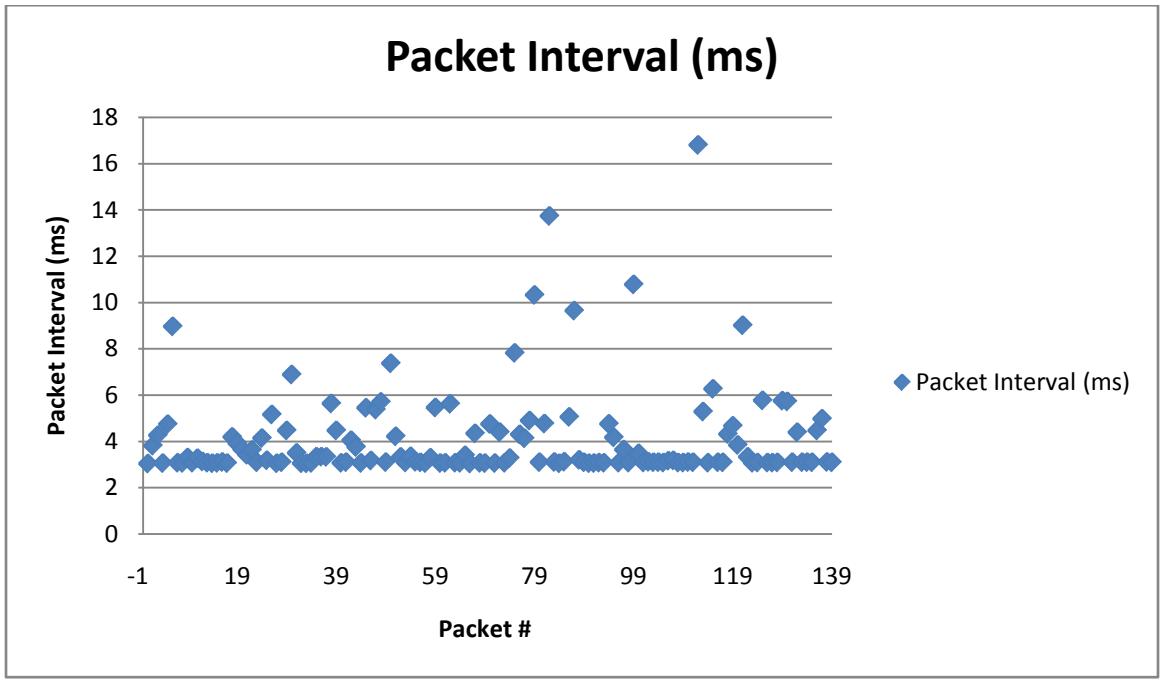
Results

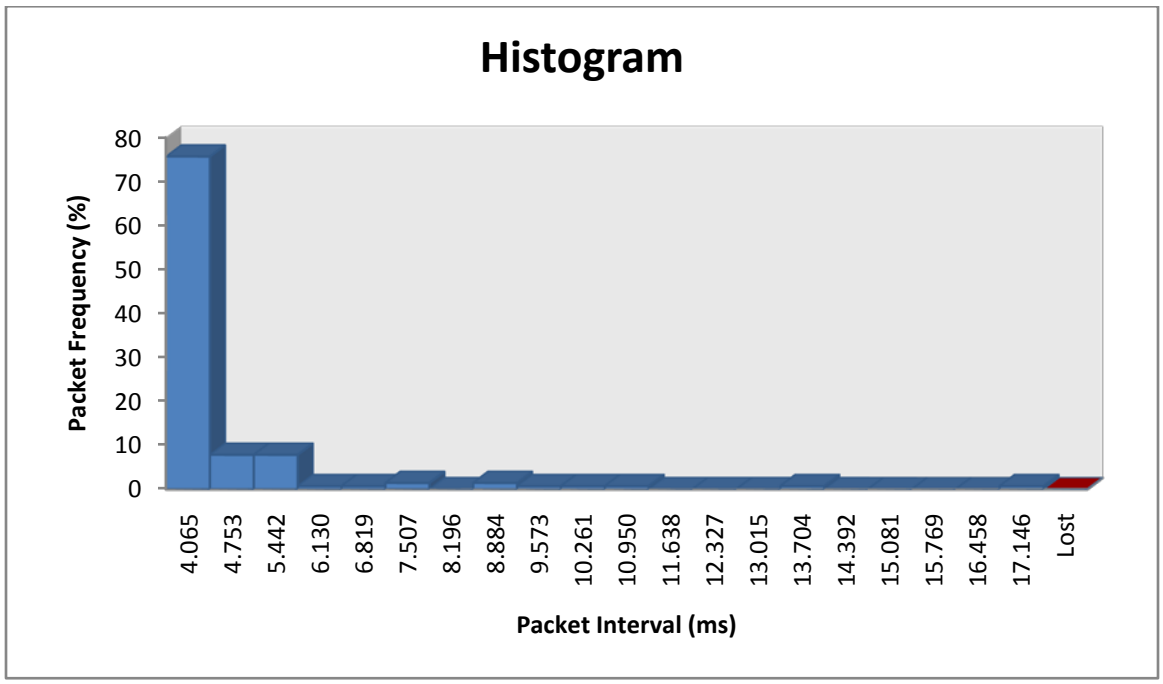
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	140	N/A	N/A	N/A
# Lost Packets	0			
Average (ms)	4.094		+/-10%	
Std. Deviation (ms)	2.02		+/-10%	
Min (ms)	3.032		+/-10%	
Max (ms)	16.802		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
18
16
14
12
10
8
6
4
2
0
-1
19
39
59
79
99
119
139
Packet #
Packet Interval (ms)


Histogram
Packet Frequency (%)
80
70
60
50
40
30
20
10
0
4.065
4.753
5.442
6.130
6.819
7.507
8.196
8.884
9.573
10.261
10.950
11.638
12.327
13.015
13.704
14.392
15.081
15.769
16.458
17.146
Lost
Packet Interval (ms)

Network Device Test Report: Transmit Power = 17 dBm, Outdoor Baseline

Experimented by Katie Olson and Wajiha Shahid

University of Michigan

2008-10-28 15:42:05

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Scalance WLAN
Channel	6
Transmit Power	17
Noise Power	0
Distance	0
Comments	

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	100
HistogramData Size (bytes)	1024

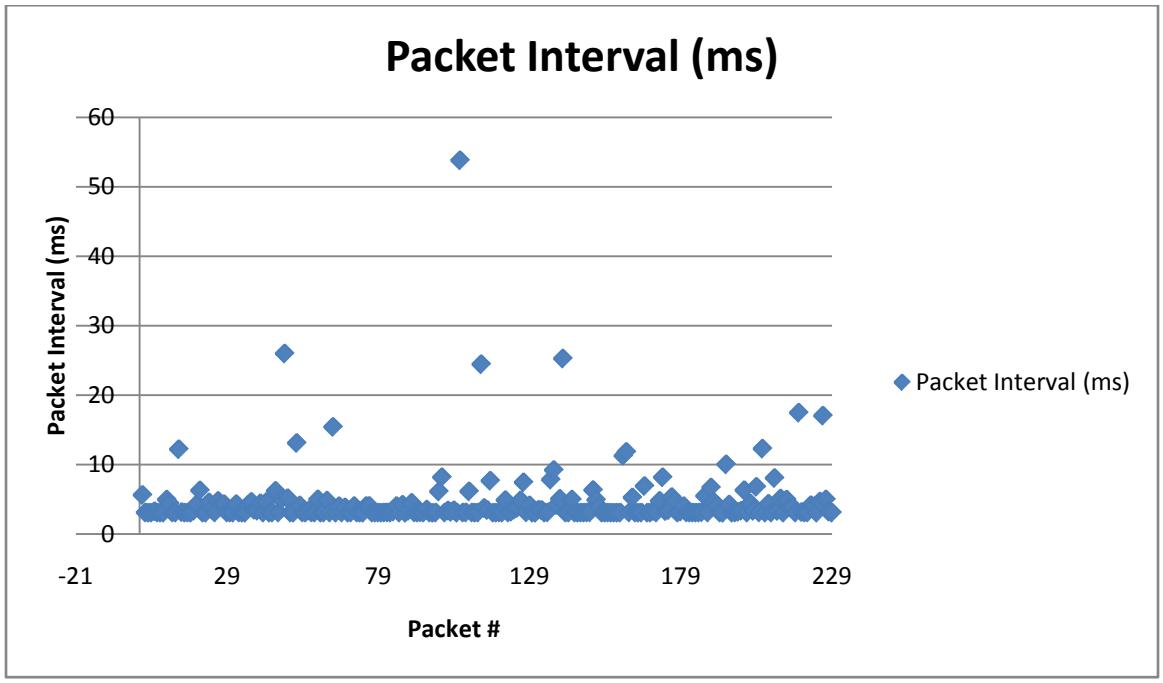
Results

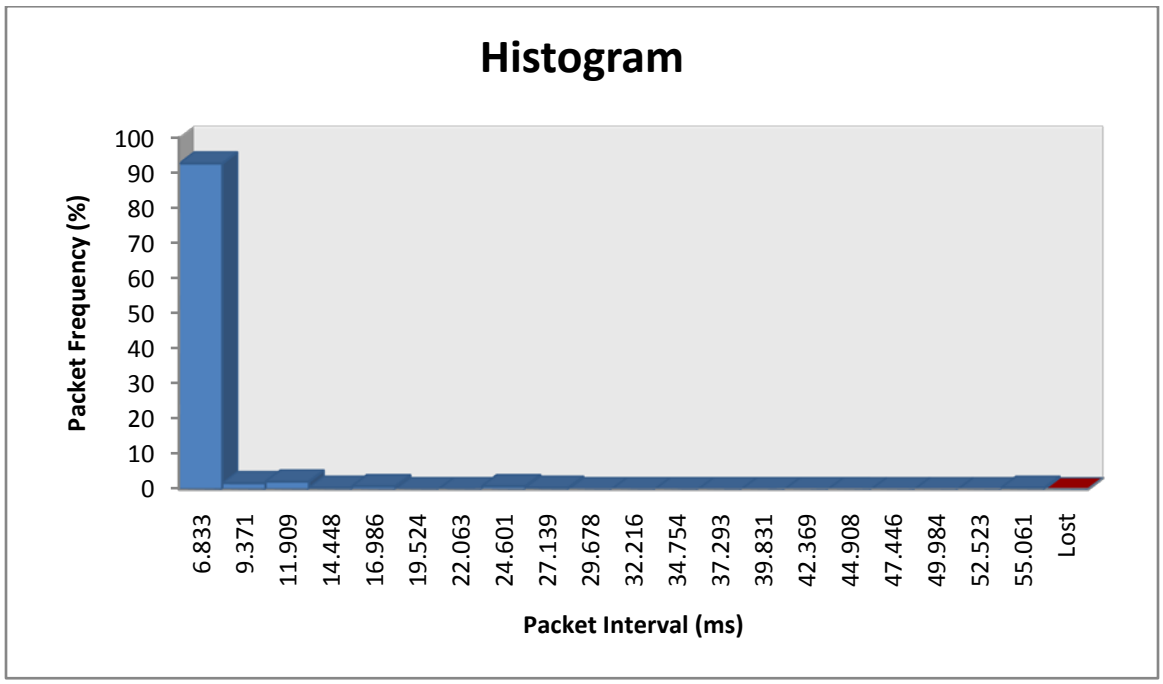
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	230	N/A	N/A	N/A
# Lost Packets	0			
Average (ms)	4.631		+/-10%	
Std. Deviation (ms)	4.63		+/-10%	
Min (ms)	3.025		+/-10%	
Max (ms)	53.792		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
60
50
40
30
20
10
0
Packet Interval (ms)
-21
29
79
129
179
229
Packet #
Packet Interval (ms)


Histogram
100
90
80
70
60
50
40
30
20
10
0
Packet Frequency (%)
6.833
9.371
11.909
14.448
16.986
19.524
22.063
24.601
27.139
29.678
32.216
34.754
37.293
39.831
42.369
44.908
47.446
49.984
52.523
55.061
Lost
Packet Interval (ms)

Network Device Test Report: Transmit Power = 20 dBm, Outdoor Baseline

Experimented by Katie Olson and Wajiha Shahid

University of Michigan

2008-10-28 15:34:07

Test #1 - Baseline (no background traffic)

Background Traffic

None

Experiment Parameters

Parameter	Value
Device Name	Scalance WLAN
Channel	6
Transmit Power	20
Noise Power	0
Distance	0
Comments	

Connection Parameters

Parameter	Value
Requested Packet Interval (ms)	100
HistogramData Size (bytes)	1024

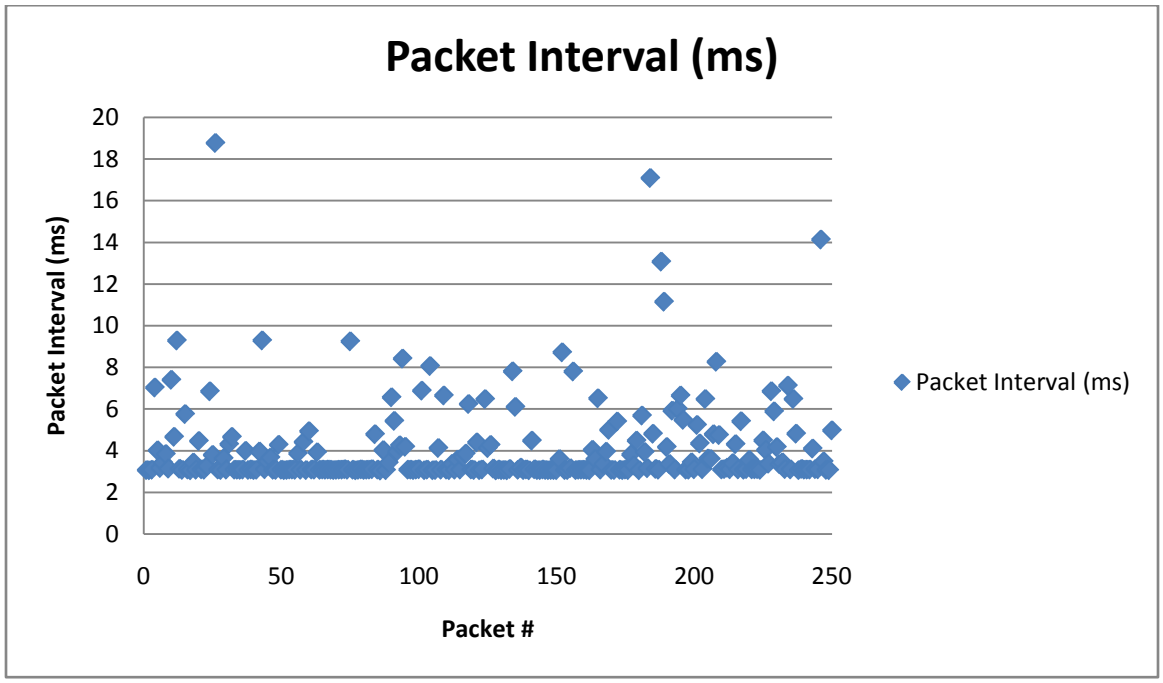
Results

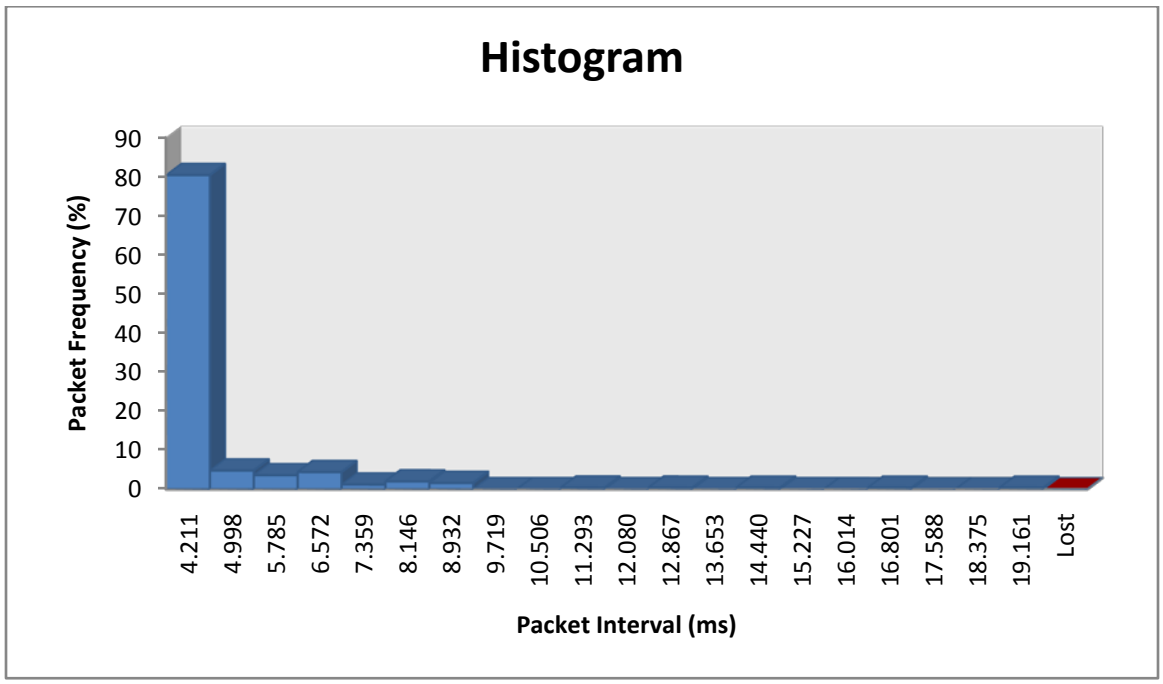
Info	Value	% of Mean	Pass Criteria	Pass / Fail
# Total Packets	250	N/A	N/A	N/A
# Lost Packets	0			
Average (ms)	4.069		+/-10%	
Std. Deviation (ms)	2.09		+/-10%	
Min (ms)	3.031		+/-10%	
Max (ms)	18.768		+/-10%	

Post-experiment Comments

Post-experiment comments can be added here.

Graphs


Packet Interval (ms)
Packet Interval (ms)
20
18
16
14
12
10
8
6
4
2
0
0
50
100
150
200
250
Packet #
Packet Interval (ms)


Histogram
Packet Frequency (%)
90
80
70
60
50
40
30
20
10
0
4.211
4.998
5.785
6.572
7.359
8.146
8.932
9.719
10.506
11.293
12.080
12.867
13.653
14.440
15.227
16.014
16.801
17.588
18.375
19.161
Lost
Packet Interval (ms)

Distance Testing: Summary

The following tables summarizes the mean round trip time delays of the distance testing conducted at 8 dBm and 20 dBm respectively for distances ranging from 5m till 55m.

Table1: Round trip time delays for testing at 8dBm

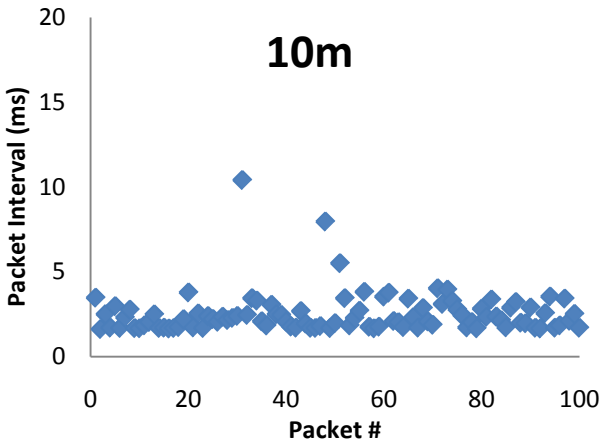
Distance (m)	Round Trip Times (msec)
15	2.50
21	4.42
26	4.71
30	5.55
35	8.12

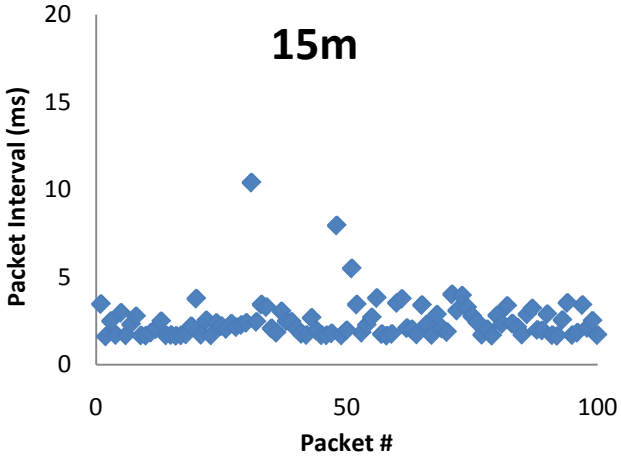
Table2: Round trip time delays for testing at 20dBm

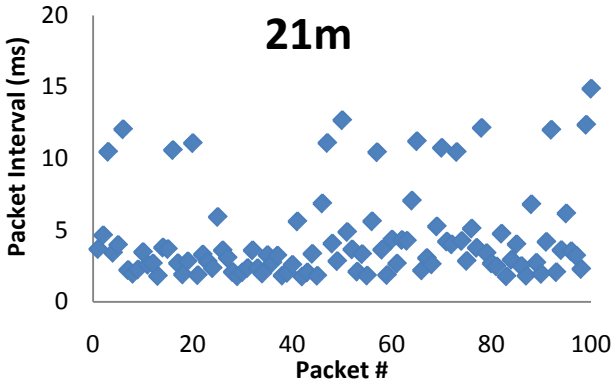
Distance (m)	Round Trip Times (msec)
5	2.14
15	3.59
25	5.35
40	3.70
47	8.18
55	10.94

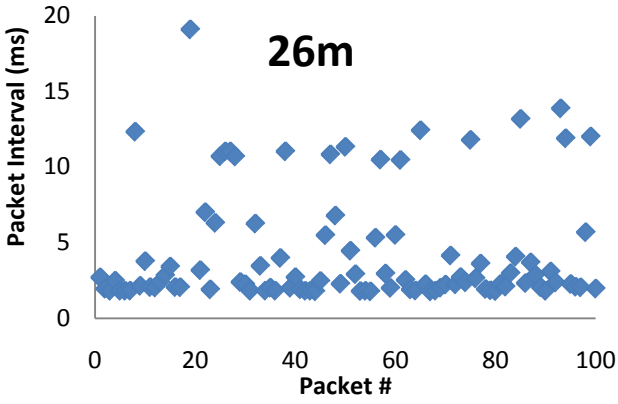
Distance Testing

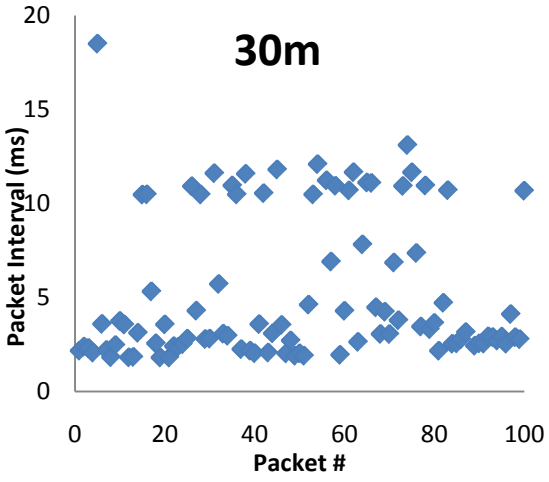
Transmit Power:Client W747-1RR,8dBm

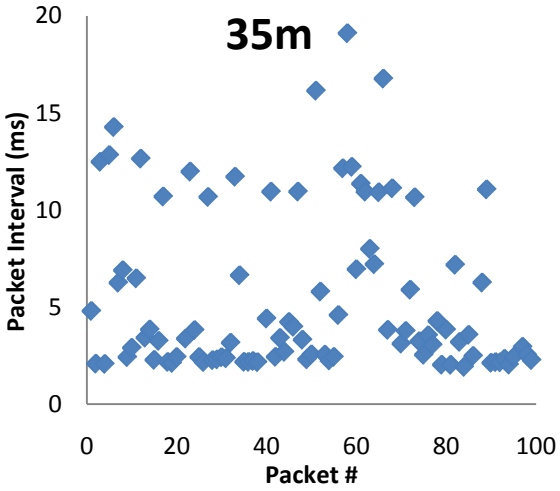






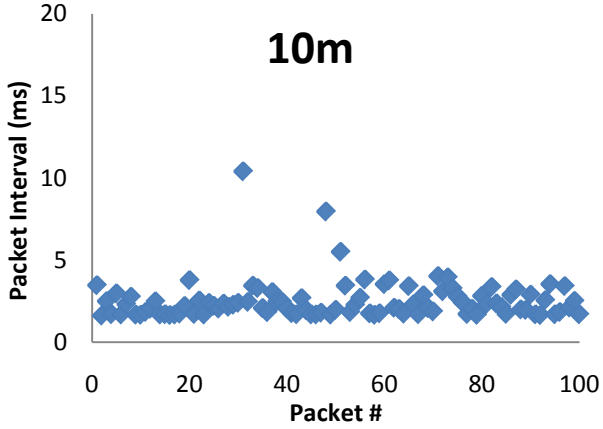


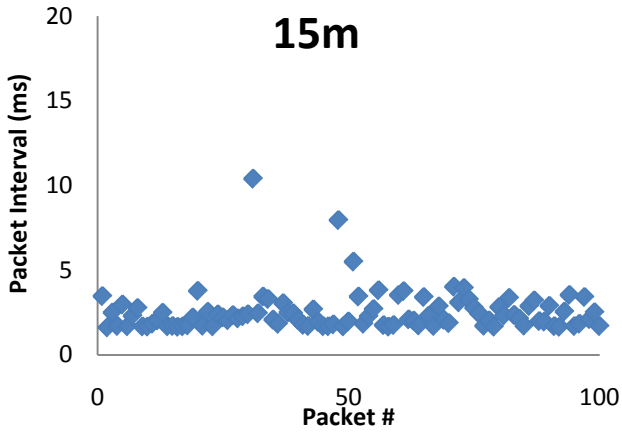


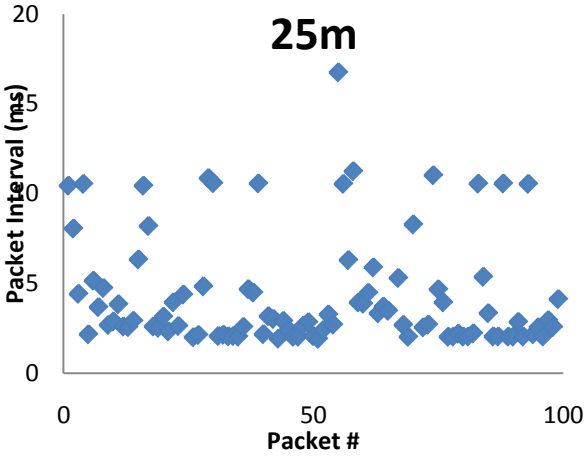


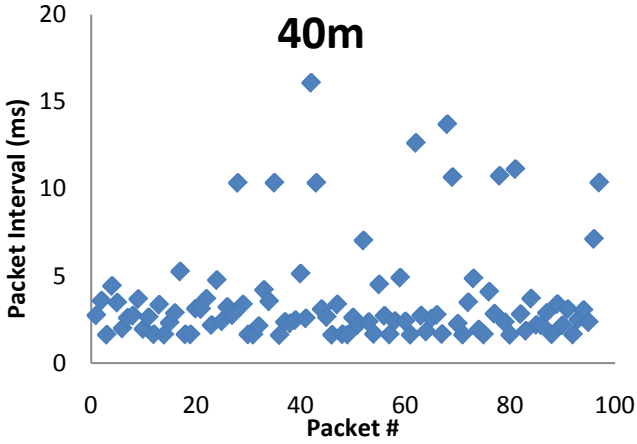
Distance TestingTransmit Power

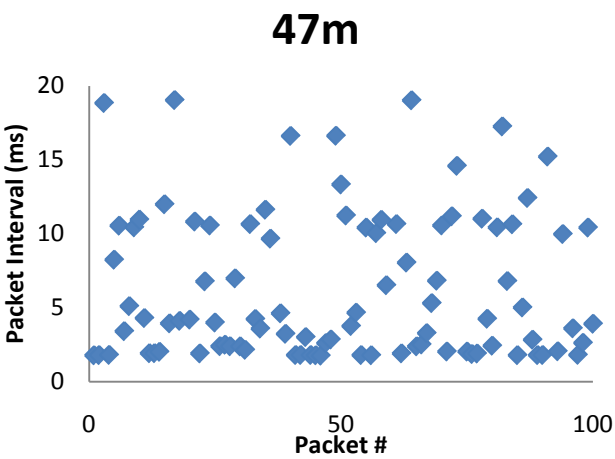
Client W747-1RR,20dBm

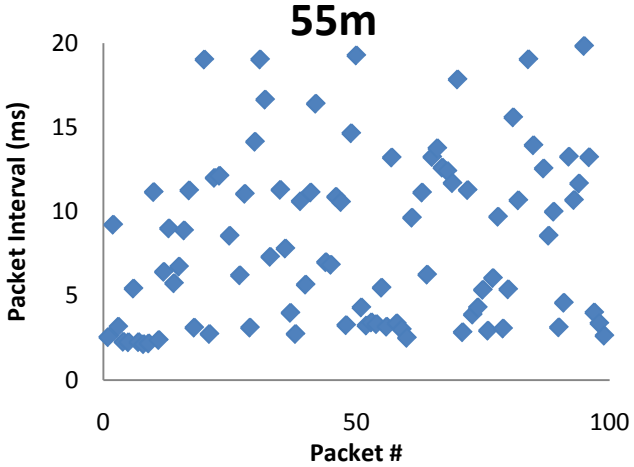












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