Uplink Performance of TCP/UDP Protocol on IEEE 802.11/g Wireless Network Category: Networks

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Abstract

This paper studies wireless network performance in an outdoor environment. Experiments are conducted on an infrastructure mode of IEEE 802.11b/g wireless LAN, using a wireless-enabled server, and one wireless client, and a wireless network analyzer tool. The experiments focus on the TCP/UDP performance and network throughput achievable in the wireless outdoor environment. This paper discusses results of static performance of the wireless network, Received signal Strength (RSSI), response time and throughput values parameters. These parameters estimate the behavior and characteristics of the network. The two transport layer protocols, TCP and UDP are used in these measurements with IP as network layer protocol. The measurements are taken with the help of AMG WiFi Manager which is developed by the researcher and NetIQ Chariot tools.

Key word: Received Signal Strength, Response time, throughput, wireless performance

1. Introduction

Two exciting and highly popular Internet technologies are the World Wide Web and wireless networks. The Web has made the Internet available to the masses, and wireless technologies have revolutionized networks, by freeing users from the constraints of physical wires. A natural step in the wireless evolution is the convergence of these technologies to form the "wireless Network": the wireless classroom, the wireless campus, the wireless office, and the wireless home [1, 2, 3, 4]. Interestingly, the same technology that allows machine and laptops to be mobile (i.e., wireless network cards) also enables the deployment of wireless clients and servers. This paper studies the feasibility of static performance of the wireless network in outdoor networks. The paper reports measurements from AMG WiFi Manager which is developed by the researcher and NetIQ Chariot tools usage in an outdoor environment at the University of Saurashtra in May-June 2008. We designed and deployed an 802.11b/g compliant experimental wireless network on Saurashtra University Campus Road.

Our experiments focus on the TCP/UDP uplink performance and network throughput achievable in an infrastructure mode of wireless network environment, and the impacts of factors such as Received signal Strength (RSSI), response time and throughput values parameters [5], uplink behavior at 200 meters to 1000 meters with different distance locations, The results show satisfactory performance in the wireless outdoor network, with throughput ranging from 1-5 Mbps, depending on the distance and outdoor obstacles and workload. The bandwidth is shared fairly amongst TCP connections, and user response times are acceptable.

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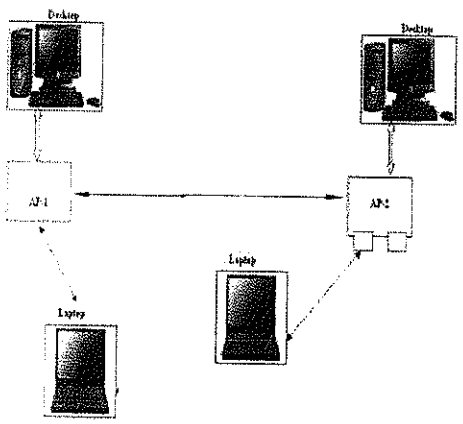
2. Experimental Wireless Data Network Setup

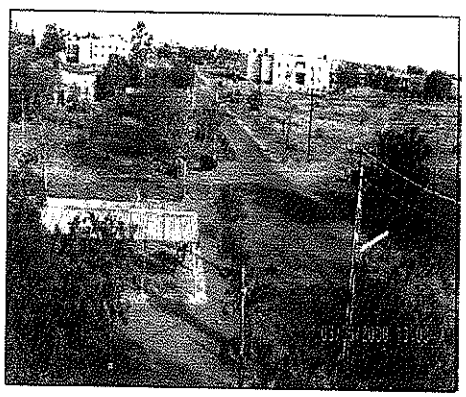
We designed and deployed an 802.11b/g [6, 12] compliant experimental wireless network on Saurashtra University Campus Road. This part discusses the experimental network design and architecture, and describes site details and network components.

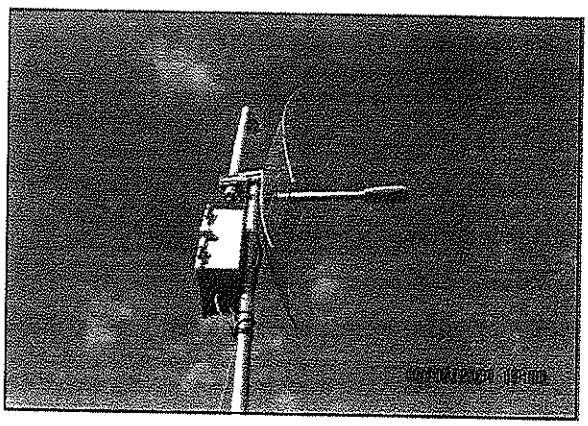
2.1 Network Architecture

Our designed network features a wireless backbone with a linear topology, and two different nodes stretched over the road length (approximately 2KM). While Aerial distance measured through GPS System from Computer department to opponent site is 0.6204Km. The department GPS Position is Latitude N 220 17.563 Longitude E 0700 44.654 and opponent site GPS Position is Latitude N 220 16.960 and Longitude E 0700 44.677. The network is based on IEEE 802.11b/g wireless LAN [11–15] standard, and is equipped with two Wireless Access Points (WAPs).



The designed network is built on two distinct nodes. The nodes are numbered as 1, and 2 starting from the Department of computer science and moving towards the South defining point to point architecture [16]. Each node consists of an access point which has the capability to handle Wi-Fi Clients simultaneously. The access points along the road provide access network coverage. The following picture shows the Department of Compute Science Road on which the experimental wireless network is being set up.





2.2 Network Equipment

The network interfaces one access point along the road. The access points are connected to Desktop nodes via straight Ethernet cables. Each access point is equipped with D-Link access point DWL-3200 AP [7], 24 dBi 120° sector antennas and 3600 Omni directional antennas. All backbone antennas are installed at an approximate height of 40 feet (12.2 meters), whereas most of the access network antennas are installed at an approximate height of 30 feet (9.1 meters) from ground level. A computer is connected to first access point using cross over Ethernet

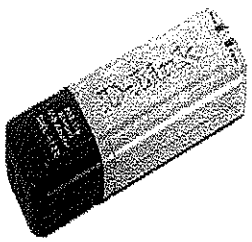
cable. One and sometimes two laptops are used for collecting network performance measurements. AMG Wifi Manager Software is being developed by researcher and NetIQ Chariot software tools are used for the data collection.

iii. Wireless Access Points

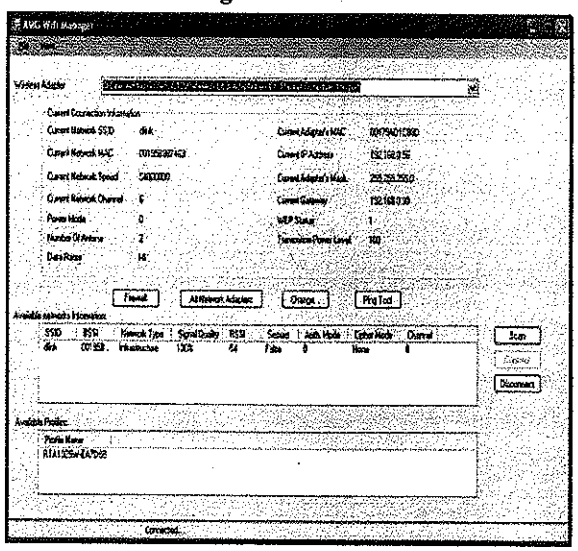
I have been using D-Link access point DWL-3200 AP [7] in our network. Similar to network router it is also equipped with 10/100 Base-T Ethernet (IEEE 802.3) interface with power over Ethernet.

iv. WiFi Client

I have been using D-Link [7] USB PC Cards as wireless client in our laptops and network infrastructure including backbone desktop. The same card can be used as WiFi wireless client for access point applications and delivers data rates up to 54 Mbps.

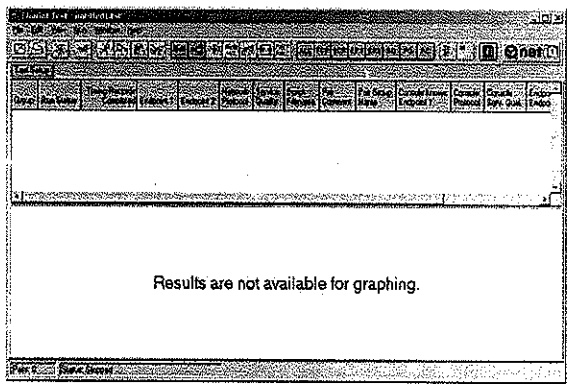


v. AMG WiFi Manager



This manager is totally developed by the researcher. This software tool enables us to measure and record wireless link signal quality, RSSI, signal and noise levels and number of messages received at different data rates over the link. We used this software tool extensively to measure wireless link quality and wireless Received Signal Strength Indicators (RSSI).

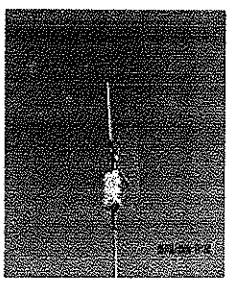
vi. Chariot TM



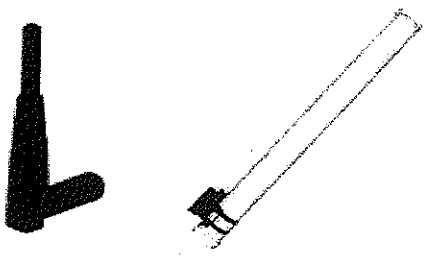
The NetIQ [8] Chariot software tool is being used to measure our network performance. This tool allows us to test system performance including throughput, response time, streaming tests etc. with various network layer, and transport layer protocols such as IP, Mobile IP, IPSec, TCP, UDP, RTP etc. The tool has several application scripts including MPEG Video, FTP, File Transfer and many others. These applications can be used to test network performance under specific conditions.

vii. Antennas

We are using following 2.4 GHz, 3 dBi [7] Magnetic Vehicle Mount Omnidirectional antenna from D-link. 2.4 GHz 12 dBi 120° [7] antennas were used for access network 2.4 GHz 12 dBi 360° [7] omni directional antennas were used for access network



Fixed Computer



We have a computer with an Intel P-IV with 2.4GHz processor to the first network using approximately 100 feet crossover Ethernet cable. The computer is equipped with 1 GB RAM and Microsoft Windows XP-Sp3 operating system.

viii. Laptops

We are in need of two laptops for our network performance measurement purposes. Currently I have only one laptop. The Dell latitude [9] 830 laptop is equipped with Intel Pentium core 2 Due Processor 2.0 GHz CPU, 4 GB RAM and Microsoft Windows Vista operating system. This laptop is installed with NetIQ Chariot and AMG Wifi Manager Software tools, which were used to measure network performance. This laptop is used throughout to measure network performance.

3. Network Performance Results & Analysis

This part discusses static performance of the network, Received Signal Strength (RSSI), response time and throughput values parameters. These parameters estimate the behavior and characteristics of the network. The two transport layer protocols, TCP and UDP are used in these measurements with IP as network layer protocol. The measurements are taken with the help of AMG WiFi Manager and NetIQ Chariot tools.

As discussed in the previous part, the experimental network consists of an 802.11b/g compliant wireless backbone. The backbone is implemented by connecting D-Link 3200AP with Wireless directional antennas in a linear fashion. This backbone serves the purpose of distribution system (DS), and transfers data among various nodes statically. Following is a summary of average Received Signal Strength (RSSI) of backbone links.

3.1 Average RSSI of Backbone Links

Link No. Channel No. Average RSSI **1 6 -85.60** These measurements are taken with the help of AMG WiFi Manager. The backbone RSSI values give us an insight into network performance. The better the RSSI the better the network performance may be.

3.2 End-user Wireless Link SNR and Coverage

This section discusses network coverage and RSSI for stationary users on the road (from AP-1 to the road end) and only AP-1 is used to provide network access. Hence, in this configuration, the network has only one active access point i.e. AP-1. This section of the road is relatively straight but with significant changes in the elevation at various sections on the road. All of these measurements are taken by AMG WiFi Manager, which can record end-user RSSI and the data rate. The end-user wireless link is defined as the link between the wireless access point and the laptop. All of the following results are based on 50 times averages taken over multiple readings at a particular place. The measurements are taken at static locations along the road moving on the southbound lane. The access point (AP-1) and Laptop's RSSI plot with distance is shown in following Figure. The RSSI curves represent average RSSI values measured at every 200 meters starting from location of AP-1.

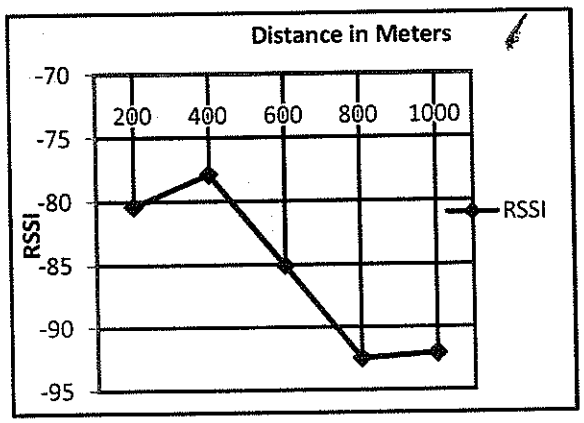


Figure1: Average RSSI at AP-1 and Laptop

RSSI	Meters
-80.4	200
-77.9	400
-85.1	600
-92.5	800
-92.1	1000

Meters	Signal Quality
200	41%
400	34%
600	31%
800	10%
1000	14%

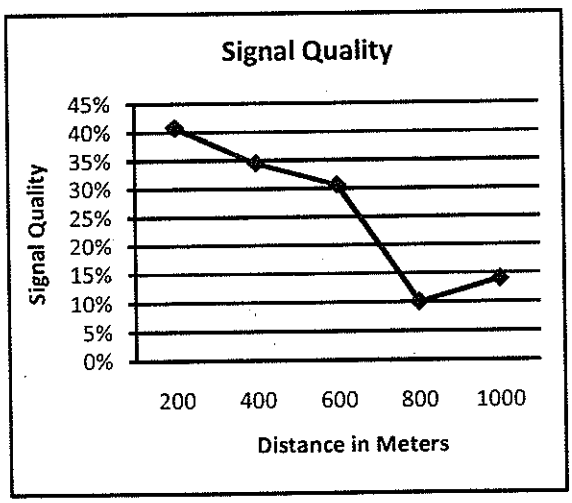


Figure 2: Laptop's Average Received Signal Quality

3.3 Network Delays

This section presents and discusses network latency results recorded with the help of NetIQ Chariot and AMG WiFi Manager. Chariot helps us testing the network response time under different testing conditions and the AMG WiFi Manager helps us recording the local wireless link RSSI. I have used the Laptop 1 throughout these measurements. The latency test is performed by Chariot from different locations on the road to the Desktop using TCP/IP and UDP/IP protocols. Chariot sends a data file of 100 bytes from Laptop 1 to Desktop and requests for a reply of 100 bytes in response. This transfer is performed 50 times in order to calculate the accurate value for this test.

3.3.1 TCP Analysis Results

Response time test is performed from different locations on the road using TCP as transport layer protocol. The TCP Default Send Size for all of TCP tests is 32767 bytes. The test is run on network's uplink (wireless link from Laptop 1 to Desktop) and downlink (wireless link from Desktop to Laptop 1) simultaneously (and in some cases separately) to get a fair idea about network delays in both the directions. Since the data size is only 100 bytes in each test, it is unlikely that the simultaneous testing saturate the network. Hence running a full-duplex test is safe and reliable from network performance measurement point of view.

While Connected to AP-1

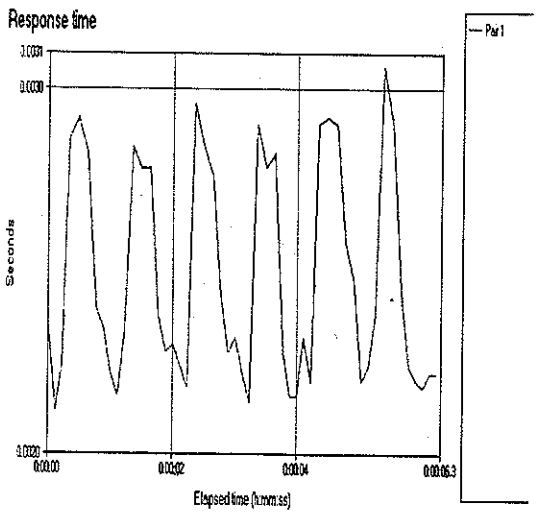
The test is run while connected to AP-1 at a static location with reasonable RSSI and Signal Quality. Some of the test details are given below.

200 Meters

- Laptop RSSI : -85.6
- Frequency Channel #: 6
- Pair 1: Uplink
  - Average Response Time: 2 ms
  - Bytes Sent By Laptop: 250,000
  - Bytes Received By Laptop: 250,000

Response Time

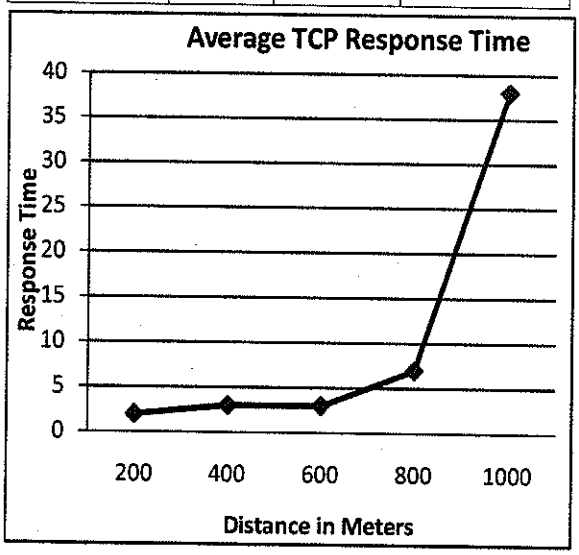
Group / Pair	Response Time Average	Response Time Minimum	Response Time Maximum	Response Time 95% Confidence Interval	Measured Time (secs)	Relative Precision
All Pairs	0.002	0.002	0.003			
Pair 1	0.002	0.002	0.003	0.000	6.198	3.416
Totals:	0.002	0.002	0.003			



The following table shows the total data collection at different locations with its summary.

Table: Average TCP Response Time Summary

Laptop Connected To	Laptop RSSI	Distance (Meters)	Average Response Time (ms)
AP-1	- 80.41	200	2
AP-1	- 77.90	400	3
AP-1	- 85.10	600	3
AP-1	- 92.49	800	7
AP-1	- 92.08	1000	38



3.3.2 UDP Analysis Results

The response time test as described earlier is related with TCP as transport layer protocol. The UDP Default Send Size is 8183 bytes for all the tests mentioned with UDP in this document.

While Connected to AP-1

The full-duplex UDP response time test is run on the network while connected to AP-1. Some of the test details and results are given below.

200 Meters

- Laptop RSSI:
  -85.6
- Frequency Channel #:
  6
- Pair 1: Uplink
  - Average Response Time:
    15 ms
  - Bytes Sent By Laptop:
    10,000,000
  - Bytes Received By Laptop: 10,000,000

Response Time

Group/ Pair	Response Time Average	Response Time Minimum	Response Time Maximum	Response Time 95% Confidence Interval	Measured Time (Secs)	Relative Precision
All Pairs	0.148	0.115	0.727			
Pair 1	0.148	0.115	0.727	0.014	14.847	9.280
Totals:	0.148	0.115	0.727			

The below table show the summery of data for TCP versus UDP data which was collected with laptop with different locations with distance.

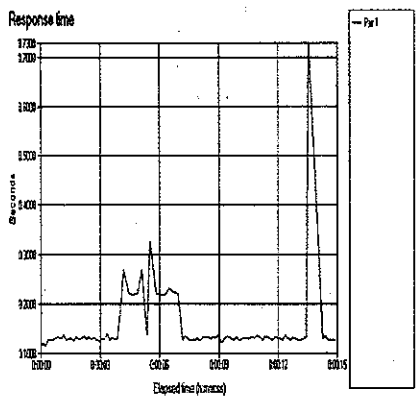
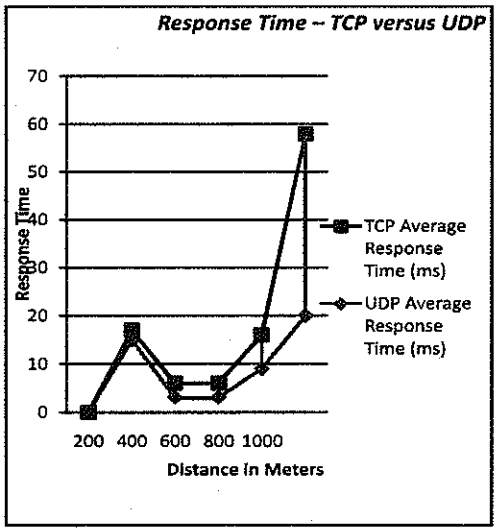


Table: Response Time – TCP versus UDP Summary

Laptop Connected To	Laptop RSSI	Distance (Meters)	UDP Average Response Time (ms)	TCP Average Response Time (ms)
AP-1	-80.41	200	15	2
AP-1	-77.90	400	3	3
AP-1	-85.10	600	3	3
AP-1	-92.49	800	9	7
AP-1	-92.08	1000	20	38



3.4 Throughput Test

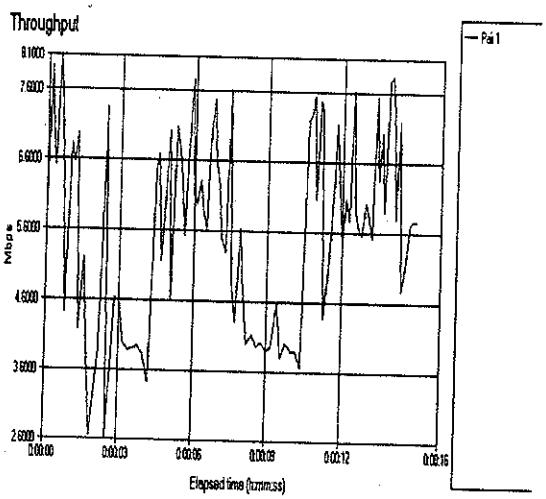
Throughput test is run by Chariot. This test sends a data file of 100,000 bytes from source host to destination host and records the time it takes to be received by it. This practice is repeated 100 times and the results are averaged later on to get a reliable measure of network throughput [17]. This test is performed with TCP/IP protocol stack while connected to access points along the road with reasonable RSSI.

3.4.1 TCP Analysis Results While Connected to AP-1

200 Meters Throughput

The test details are given below.

Group /Pair	Average (Mbps)	Minimum (Mbps)	Maximum (Mbps)	Throughput 95% confidence Interval	Measured Time (Secs)	Relative Precision
All Pairs	5.323	2.623	8.081			
Pair 1	5.346	2.623	8.081	0.298	14.966	5.581
Totals:	5.323	2.623	8.081			

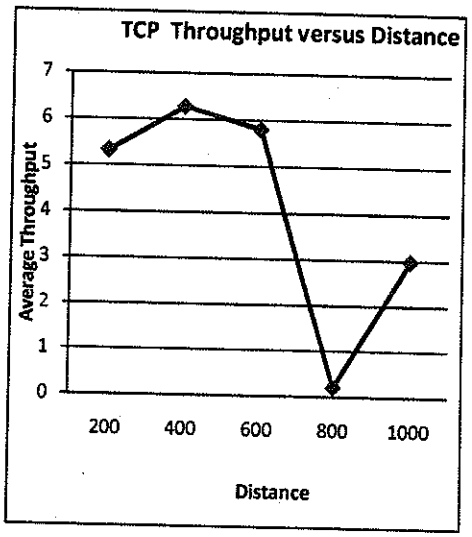


- Average Uplink Throughput:
  5.323Mbps
- Average Response Time:
  150 ms
- Average RSSI at Laptop:
  -80.41
- Total Bytes Sent by Laptop:
  10,000,000
- Total Bytes Received by Laptop:
  100
- Frequency Channel #:
  6

The following table shows the summery of the TCP throughput test performed at different locations.

Table: Uplink TCP Throughput Test Summary

Lap top Connected to	Lap top RSS I	Average Throughput (Mbps)	Response Time (ms)	Distance (Meters)
AP - 1	-80.41	5.323	150	200
AP - 1	-77.9	6.276	127	400
AP - 1	- 85.1	5.801	137	600
AP - 1	-92.49	0.200	300	800
AP - 1	-92.08	2.973	269	1000



3.4.2 UDP Analysis Results

Chariot is used to perform streaming test running on UDP/ IP protocol stack. The UDP is best-effort connectionless protocol and can be used to estimate a network's saturated throughput. Chariot sends streaming file at a rate of 10-Mbps from source host to destination host and repeats the practice 100 times in this test. The average results provide us an estimate of the network's saturated

throughput, or in other words the maximum data rate that it can support with UDP/IP protocol stack.

While Connected to AP-1

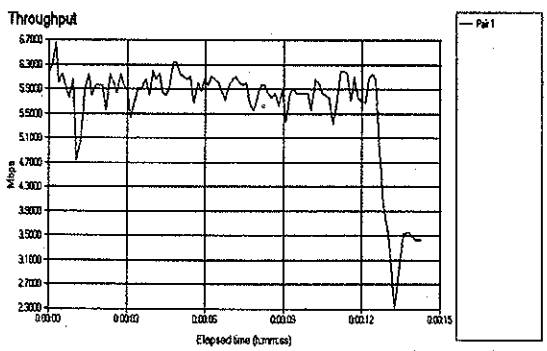
200 Meters

The test results and some details are shown as follows.

- Average Uplink Throughput: 5.603Mbps
- Average RSSI at Laptop: - 80.41
- Total Bytes Sent by Laptop: 10,000,000
- Total Bytes Received by Laptop: 10,000,000
- Frequency Channel #: 6

Datagram (Endpoint 1)

Group / Pair	Total Datagrams Sent by E1	Duplicate Datagrams Sent by E1	Total Datagrams Received by E1	Duplicate Datagrams Received by E1	Datagrams Lost. E1 to E2
All Pairs	1,301	0	1,301	0	0
Pair 1	1,301	0	1,301	0	0
Totals:	1,301	0	1,301	0	0



The following table shows the uplink UDP streaming test at different location with different distance level.

Uplink UDP Streaming Test Summary

Laptop Connected To	Laptop RSSI	Average Throughput (Mbps)	Max Consecutive Lost Diagrams	Distance (Meters)
AP - 1	-80.41	5.603	0	200
AP - 1	-77.9	4.542	6	400
AP - 1	-85.1	4.761	2	600
AP - 1	-92.49	0.271	23	800
AP - 1	-92.08	2.973	4	1000

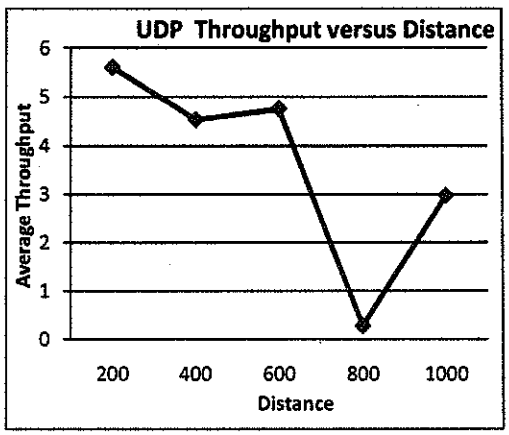


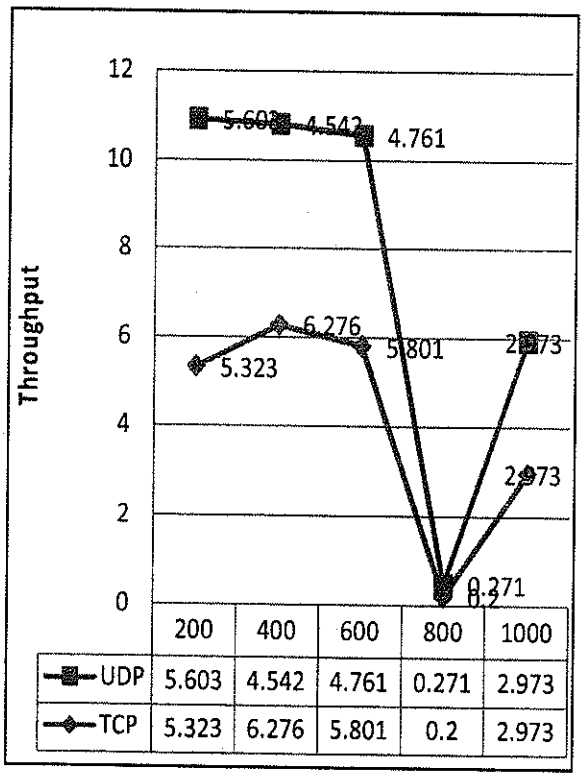
Figure: Uplink UDP Streaming Throughput versus Distance

Uplink Throughput - TCP versus UDP

The following Figure shows a comparison of TCP throughput and UDP saturated streaming throughput versus number of hops. Since TCP is a connection-oriented transport layer protocol with congestion control capabilities, it deals with the network data loss and

latency issues better than UDP. It, however, requires handshaking all the time with the host destination to address network congestion and data loss issues more intelligently. UDP, on the other hand, is a best-effort, [10] connectionless protocol that has no way of confirming a packet delivery or loss and, hence, is not treated as a reliable transport layer protocol. The UDP streaming throughput gives us an idea of network's saturation. TCP throughput, therefore, comes out to be less than that with UDP.

Uplink Throughput - TCP versus UDP



	200	400	600	800	1000
UDP	5.603	4.542	4.761	0.271	2.973
TCP	5.323	6.276	5.801	0.2	2.973

4. Conclusions

In this paper, Department of Computer Science Road's experimental wireless network's static performance is discussed. It clarifies that wireless coverage and end-user data rate depends on site details in addition to location of the antenna and the type used. An RSSI value of -85 11 Mbps data rate between end-user and an access point down the road. An RSSI of -94 or less may cause data loss along the road. Better results can be obtained by using 200 to 600 meters than 800 to 1000 meters and hence 200 to 600 meters should be used for laptop for performance measurement. The uplink exhibit different throughputs due asymmetric design and no of trees on the road. The average response time of the TCP is practically same increases almost linearly with increasing distance. On the other hand, the average response time of the UDP is a little different for the directions and increases more with increasing distance. The total average response time of the UDP is a little more than that of TCP. The average TCP throughputs in the directions degrade almost linearly with increasing distance but with different rates and at 400 meters it give more better throughput. The UDP streaming throughput is used to measure the saturated throughput of the network, which is almost similar to TCP throughput.

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Author's Biography

Dr. Atul Gonsai has completed his Graduation in Bachelor of Business Administration (BBA) and Master degree in Master of Computer Applications (MCA) then completed his Ph.D. work in Computer Networking. He has been awarded Career Award for Young Teachers from AICTE- New Delhi. He is working as Assistant Professor in Department of Computer Science Saurashtra University Rajkot after completing his MCA from the same Institute in April 2000. He has written 35 research paper and 3 paper submitted for conference for acceptance. His research interest encompasses performance tuning of computer networks, wireless networks, High performance networking etc. He has taken part in 13 national and 8 international conferences and seminars. He is DCNI D – link Certified Network Integrator from D-link India Goa. He has published 4 books and is also writing one book on Computer Networking, which is not yet published. He is maintaining and handling MCA computer Labs and Saurashtra University Library Networking. He is life Member of ISTE New Delhi.