COMP9336 MOBILE DATA NETWORKING

HANDS ON ASSIGNMENT,SEMESTER 2,2017

Experimental Study of an Enterprise-Wide Wireless Lan (UNSW)

REPORT

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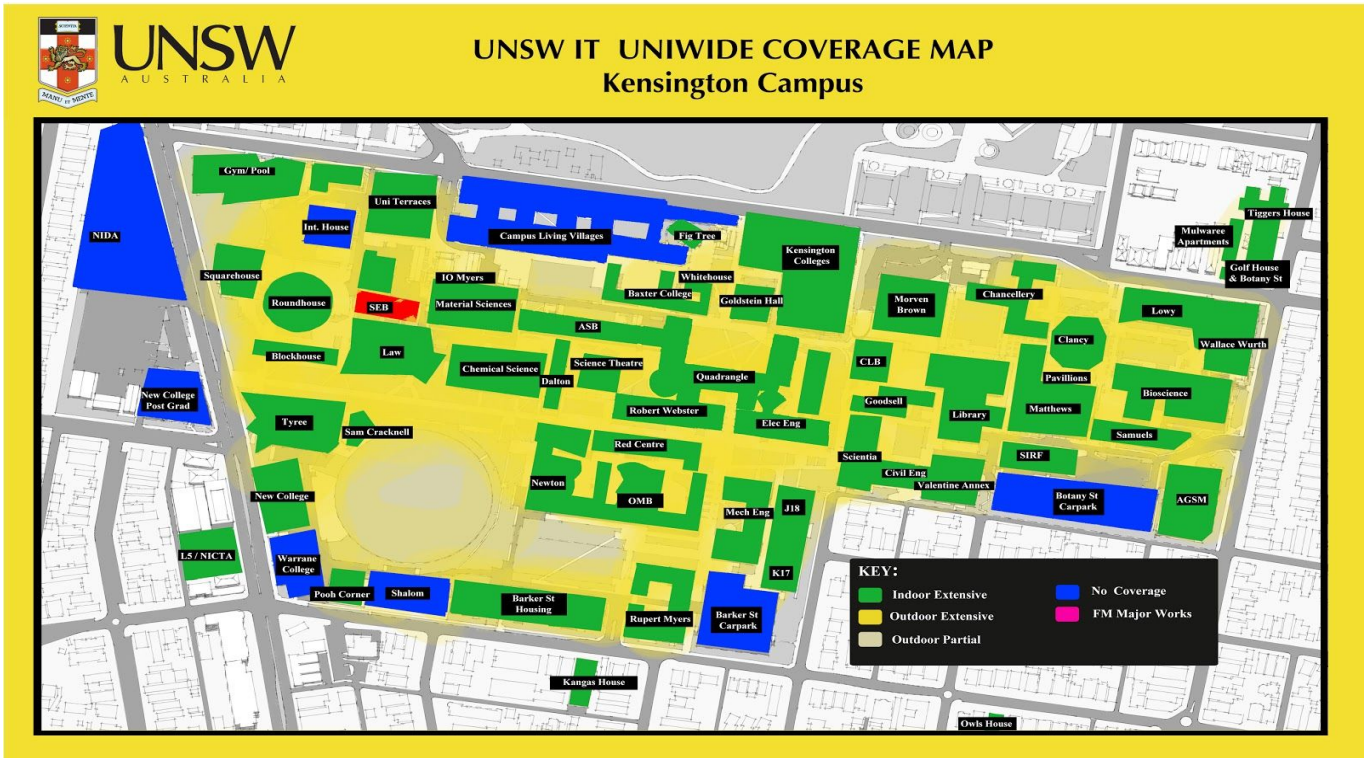
Overview of the Project :

The main motivation and intention of this project is to estimate the performance of an Enterprise-wide wireless LAN mainly focussing on UNSW Sydney Campus-wide wireless LAN namely "UniWide" which has about 5200 Access Points(AP) till date deployed over the entire campus to provide reliable and good wireless connectivity to the users. UNSW completely rely on secure wireless networking rather than physical cables to connect the users to the internet.This project aims to find out the true performance of Uniwide by performing a survey and analysing Link Layer and looking into Mobility-related performance by measuring data while moving from one location to another within the campus by roaming across various APs and checking out Layer 4 Connectivity(TCP Connectivity), Layer 3 Handoff also known as IP handoff delay,Layer 2 Handoff also known as L2 handoff delay.The values are conducted across multiple locations across the campus since it is difficult to predict the true performance of UniWide at every single location of the campus based on survey performed on one location due to the fact that any network will not be designed uniformly and varies based on the number of users, data traffic, available resources,maintenance, costs etc..

Here is the UNSW Wifi Coverage map of UNSW Kensington Campus in Sydney taken from UNSW main website:



Requirements : Mobile(testing device)Android Version 5+,Android Studio

Background of the Project :

Estimating the performance of the network is required for any small scale to large scale networks .It is more important in case of large scale of networks where the cost,usage and participating crowd are in large scale and guaranteed performance is expected of these networks. Specifically when it comes to networks that are deployed in Banking sector,education sector etc where the performance should be consistent at all times and at all locations and provide the same performance to every single user. For example be it a case where a banking customer is processing a transaction where significant data rate and related connections should be kept at high for successful completion of the transaction or consider the case where students enrollment open in Universities such as UNSW and thousands of students wish to enrol for a particular course but only few students will be successful due to the fact that even though all students prepare to enrol few students have good data rate and

signal and others who don't have enough end up losing which is not fair and the university fail to give equal wireless connectivity to all students and i feel they are not fair enough in this aspect .

Hence, estimating the performance of a network gives us a chance to study bit more about the network and possible areas of improvements by increasing the number of Access Point(AP)s or increment in bandwidth ,throughput etc.With increasing usage of users everyday,monitoring the performance is must in any organisation and making changes to the network has become common thing today

Approach toward the Problem :

Having clearly explained the brief overview of the project,I have divided the project into two phases based on the network OSI layer classification as Link Layer Analysis which includes protocol standards,signal strength,data rates and AP coverage density for a given specific location and Mobility Layer Analysis majorly focussing on Layer 4(TCP) connectivity when switching between APs, Layer 3 Handoff(IP handoff) and L2 handoff recording changes in APs.To find this significant changes I have developed an Android app which enables us to perform the above said analysis and identifies required changes when switching between APs.

I have conducted the survey calculating various parameters based on design required to estimate the performance of UNSW network using my mobile at several locations and found several fascinating facts which is not expected and more of expected things as well.Let’s see how a university such as UNSW is able to provide how good/bad to their students/visitors in the upcoming pages.

Link Layer Analysis:

As we all know that Link layer is the lowest layer in the Internet Protocol Suite and it implements the communication protocol necessary for host to link to its directly connected network.The performance metrics that are being considered as a part of this project are being explained below based on the practical calculations made.To find out how good your network is giving the best to you can be assessed based on the following 4 parameters which truly makes significant effect towards performance of the network.

They are as follows:

1.802.11 protocol available
2.Signal Strength
3.Data rate
4.AP Density

1.802.11 Protocol available:

Uniwide uses a series of protocols based on IEEE 802.11 standards (a/b/g/n/ac) to connect its users to the internet.During the course of my survey,I found various protocols available at various frequency bands such as 2.4Ghz and 5Ghz bands which can be observed from the below sample observations in Figure 1.

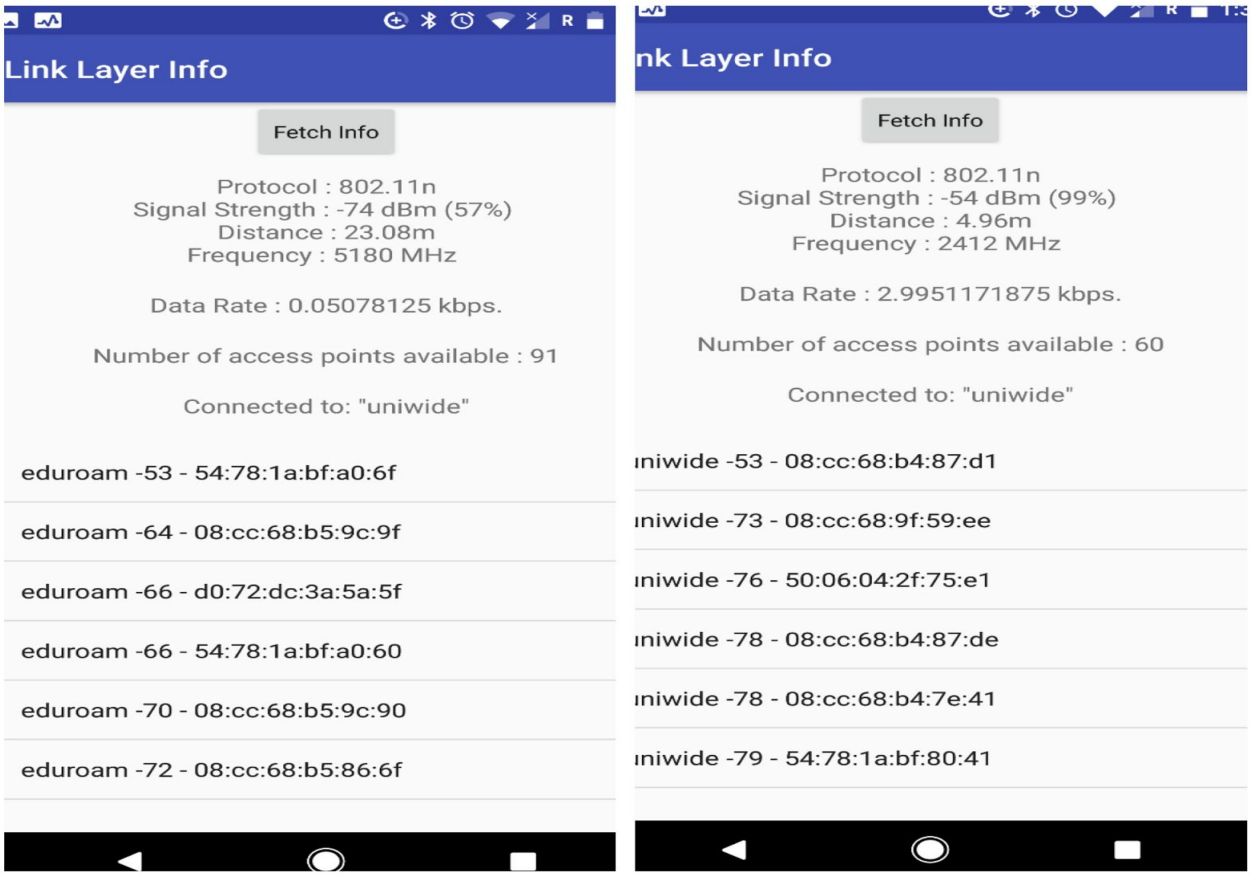


figure.1

Apart from the frequency bands the various protocols that I found are 802.11a,802.11b,802.11g,802.11n,802.11ac which are the WiFi standards given by IEEE.From this it can be concluded that UNSW network covers all the available Wifi standards.Students/Guests accessing the UNSW wireless network(**uniwide**) should have their device configured to be compatible with any of these which I am sure most of the devices today has and hence thereby I conclude that 100% every user with any type of device should be able to access UNSW network without any problem.The available protocols are shown below.

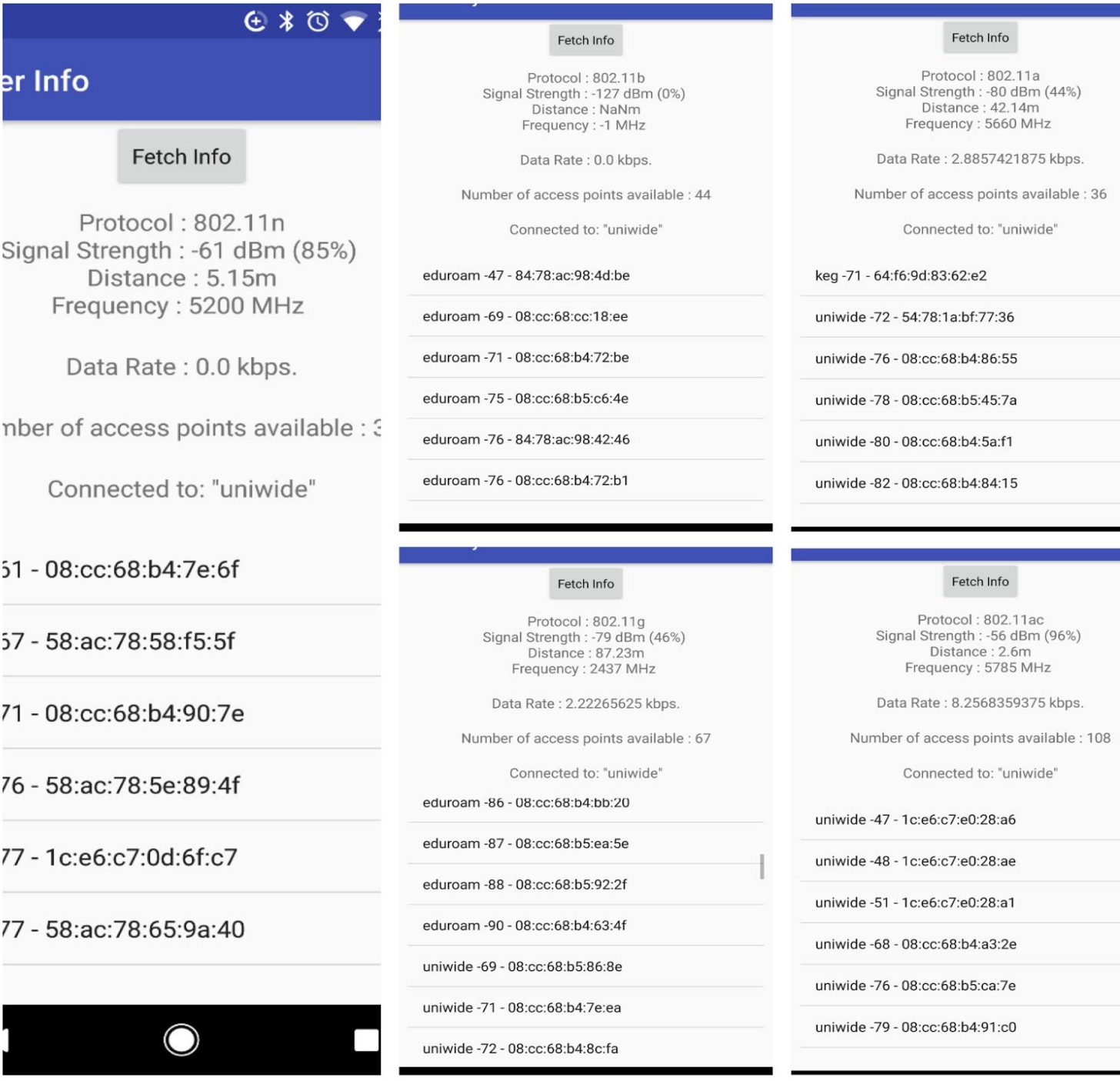
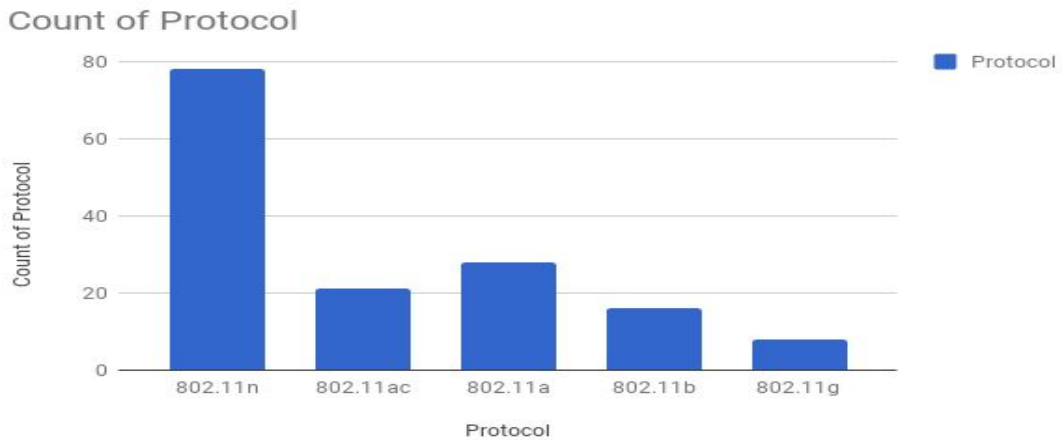

er Info
Fetch Info
Protocol : 802.11n
Signal Strength : -61 dBm (85%)
Distance : 5.15m
Frequency : 5200 MHz
Data Rate : 0.0 kbps.
nber of access points available : 3
Connected to: "uniwide"
51 - 08:cc:68:b4:7e:6f
57 - 58:ac:78:58:f5:5f
71 - 08:cc:68:b4:90:7e
76 - 58:ac:78:5e:89:4f
77 - 1c:e6:c7:0d:6f:c7
77 - 58:ac:78:65:9a:40
Fetch Info
Protocol : 802.11b
Signal Strength : -127 dBm (0%)
Distance : NaNm
Frequency : -1 MHz
Data Rate : 0.0 kbps.
Number of access points available : 44
Connected to: "uniwide"
eduroam -47 - 84:78:ac:98:4d:be
eduroam -69 - 08:cc:68:cc:18:ee
eduroam -71 - 08:cc:68:b4:72:be
eduroam -75 - 08:cc:68:b5:c6:4e
eduroam -76 - 84:78:ac:98:42:46
eduroam -76 - 08:cc:68:b4:72:b1
Fetch Info
Protocol : 802.11a
Signal Strength : -80 dBm (44%)
Distance : 42.14m
Frequency : 5660 MHz
Data Rate : 2.8857421875 kbps.
Number of access points available : 36
Connected to: "uniwide"
keg -71 - 64:f6:9d:83:62:e2
uniwide -72 - 54:78:1a:bf:77:36
uniwide -76 - 08:cc:68:b4:86:55
uniwide -78 - 08:cc:68:b5:45:7a
uniwide -80 - 08:cc:68:b4:5a:f1
uniwide -82 - 08:cc:68:b4:84:15
Fetch Info
Protocol : 802.11g
Signal Strength : -79 dBm (46%)
Distance : 87.23m
Frequency : 2437 MHz
Data Rate : 2.22265625 kbps.
Number of access points available : 67
Connected to: "uniwide"
eduroam -86 - 08:cc:68:b4:bb:20
eduroam -87 - 08:cc:68:b5:ea:5e
eduroam -88 - 08:cc:68:b5:92:2f
eduroam -90 - 08:cc:68:b4:63:4f
uniwide -69 - 08:cc:68:b5:86:8e
uniwide -71 - 08:cc:68:b4:7e:ea
uniwide -72 - 08:cc:68:b4:8c:fa
Fetch Info
Protocol : 802.11ac
Signal Strength : -56 dBm (96%)
Distance : 2.6m
Frequency : 5785 MHz
Data Rate : 8.2568359375 kbps.
Number of access points available : 108
Connected to: "uniwide"
uniwide -47 - 1c:e6:c7:e0:28:a6
uniwide -48 - 1c:e6:c7:e0:28:ae
uniwide -51 - 1c:e6:c7:e0:28:a1
uniwide -68 - 08:cc:68:b4:a3:2e
uniwide -76 - 08:cc:68:b5:ca:7e
uniwide -79 - 08:cc:68:b4:91:c0

figure.2



2.Signal Strength :

As we all know that the performance of a wireless network connection depends greatly on strength of the Wifi signal which determines the data rate available on a particular link.This is an indication of the range that a particular access point has throughout any given area.From this we can say that the range a particular AP has control over can be determined by the signal strength.We can partly say that signal strength is inversely proportional to distance.

During my survey over the campus i was able to find several places where signal strength is close 99% and there are places where signal strength is 0 which elucidates that there are several regions which are not covered in the campus and people looking for connectivity in these regions have to move to some other places for connectivity.One interesting example found during my survey can be seen in figure.3 below.

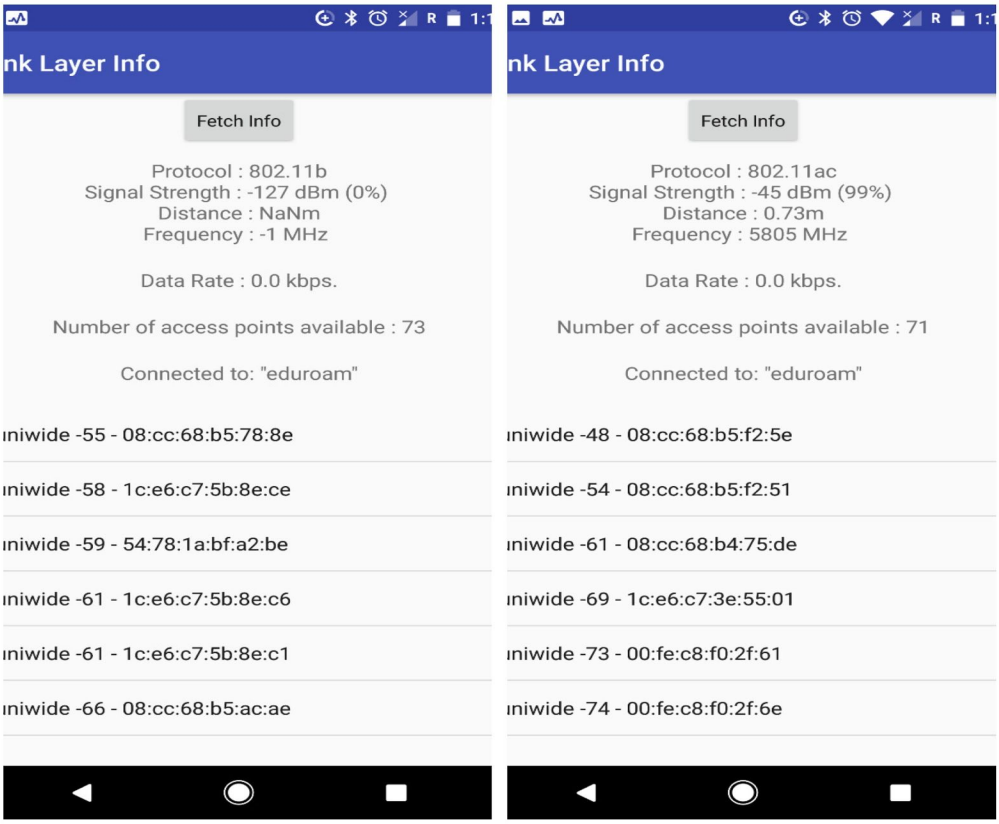
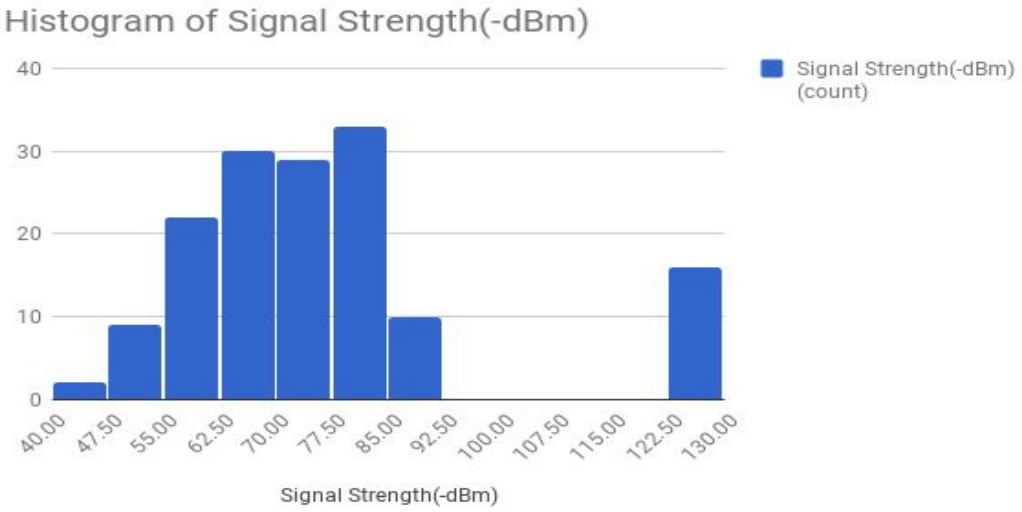
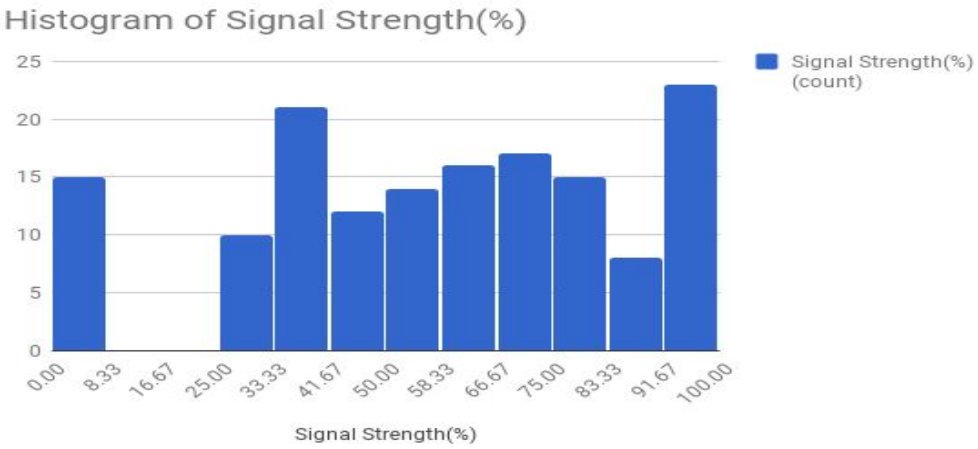


Figure.3(recorded at Matthews Theatre Food Court,UNSW)





The above example was taken in Matthews Theatre Food Court ground floor where maximum usage is expected and I could find a place where the location was surrounded by about 70-90 APs around but none of them were able to cover this particular location and from my research i observed that this might be due to improper placement of APs/none of the APs were able to reach out to this place.Apart from this there are places where signal strength is about 99% and each place has varying signal strength between 0-100.From this it can be concluded that proper planning can be made to cover each and every location with the resources we have or else we can try to increase the capacity of the APs to cover wider ranges.

3.Data Rate :

Starting with the fact that any wireless network is a shared service between all users connecting between all users connecting to a particular access point,users experience varying data rates.Different possible data rates are found across the campus and keep changing over the time based on the number of users,data traffic and available bandwidth,signal strength etc..The best and worst case scenarios observed are presented below in figure.4.UNSW provides data rates varying from minimum of 8Kbps to upto 300Mbps to its users has been found during my survey.Having said that the maximum data rate that can be reached is upto 600 Mbps and minimum can go upto 0 Kbps in ideal cases which are the lower and upper limits of Uniwide.

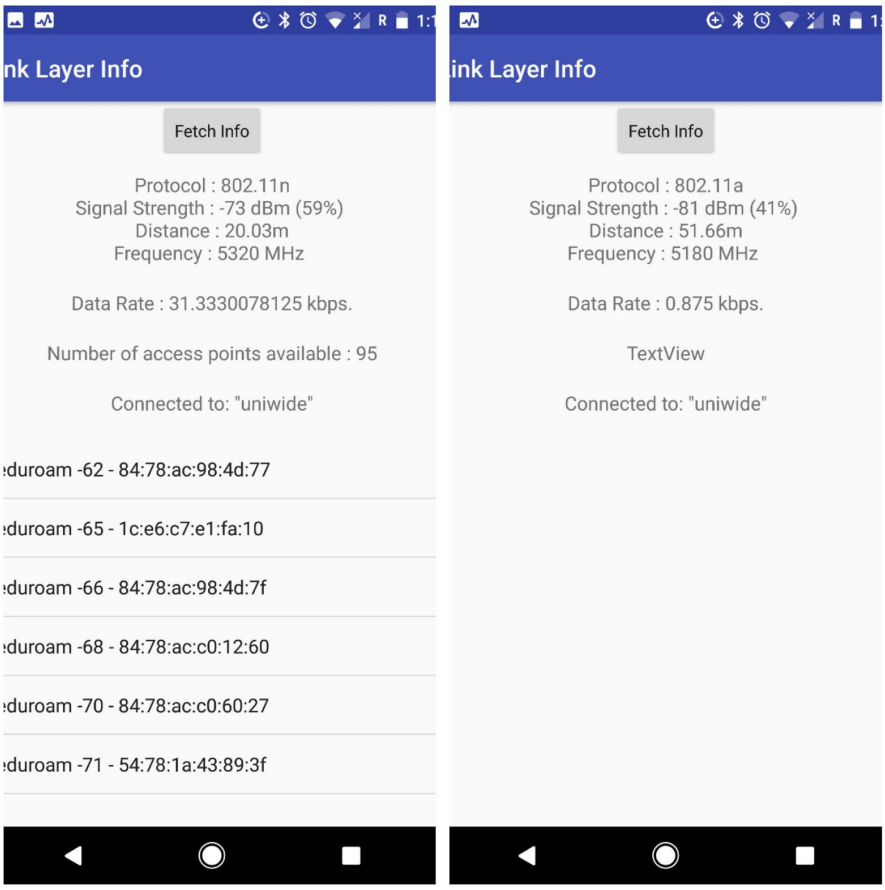
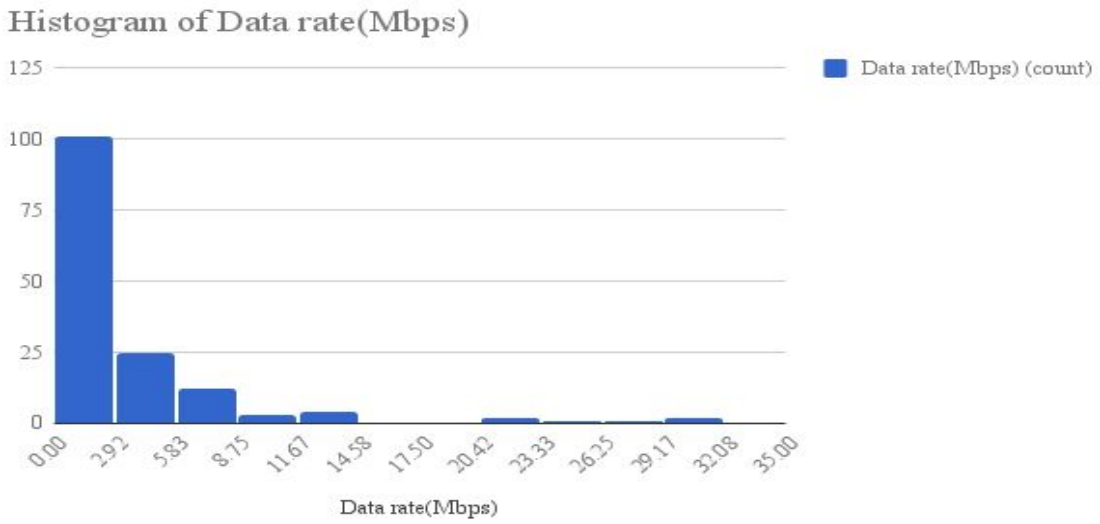


Figure.4(recorded highest at UNSW Business School and lowest at Subway,UNSW)



One more important observation that can be made from the below figures is that whenever a particular location is experiencing low data rates(<11Mbps) 802.11b protocol can be seen and in case of date rates where data rates are > 100Mbps 802.11n protocol can be seen.

4.AP Density:

UNSW network(Uniwide) consists of several access points(APs) also called as hotspots at various locations across the campus.These access points uses radio frequency to communicate with our devices(mobile,tables/laptop etc).Recent studies proved that the performance of the network or throughput of the system is characterised by the number of interfering access points rather than the number of clients in one sense which proves that there is need to focus on the number of APs covering a particular location.

Though there are about 5200 APs covering the entire campus they are not evenly distributed over the entire campus which is proved in my survey which is one of the major factors for unfair network resource allocation to the users.The highest number of APs covering any specific location recorded is 169 near UNSW Business School and most fascinating fact is that I was able to find a place in Library which was covered by only one AP when talking about worst case.As we all know that Library is one of the most popular places in the University expecting thousands of students hanging around and one AP covering a particular location resembles poor planning in such a place.The best and worst case scenarios are presented in below Figure.5

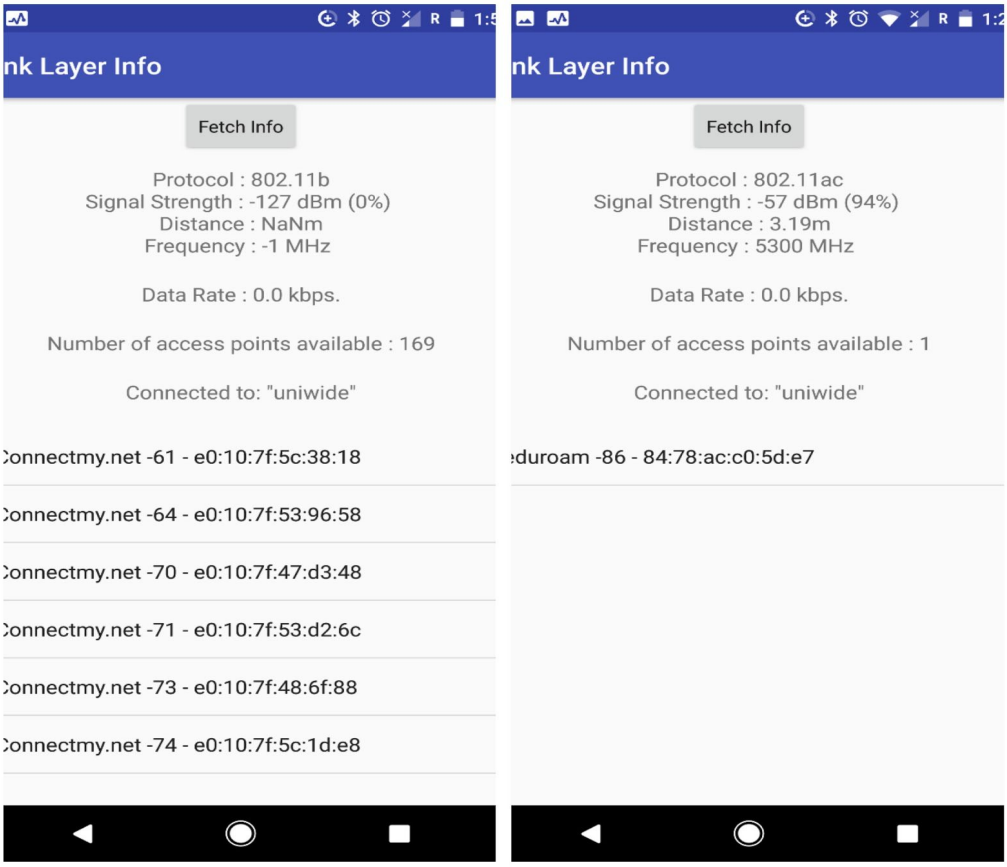
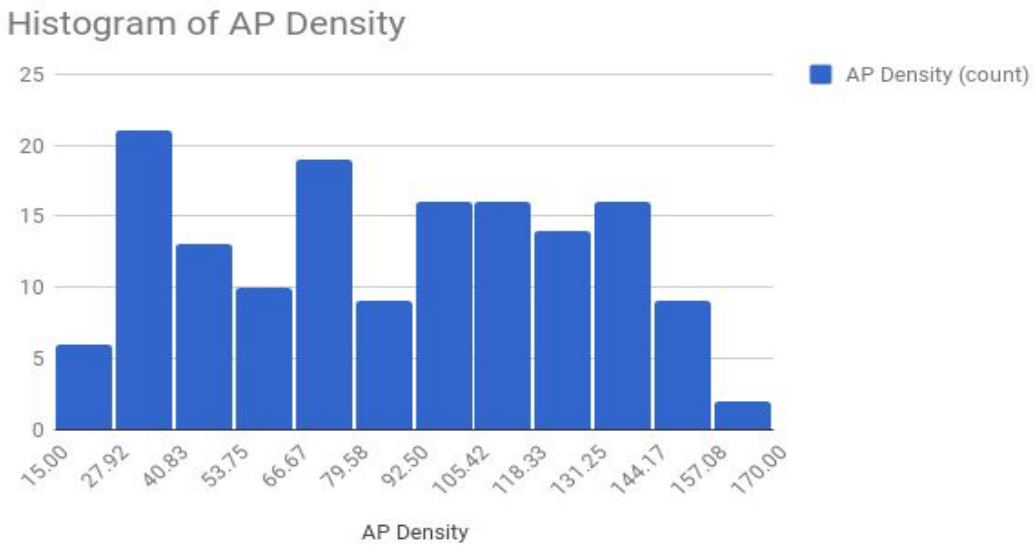


Figure.5(recorded highest at Quadrangle Food Court and lowest at UNSW main Library)



Details of Various APs discovered across Campus

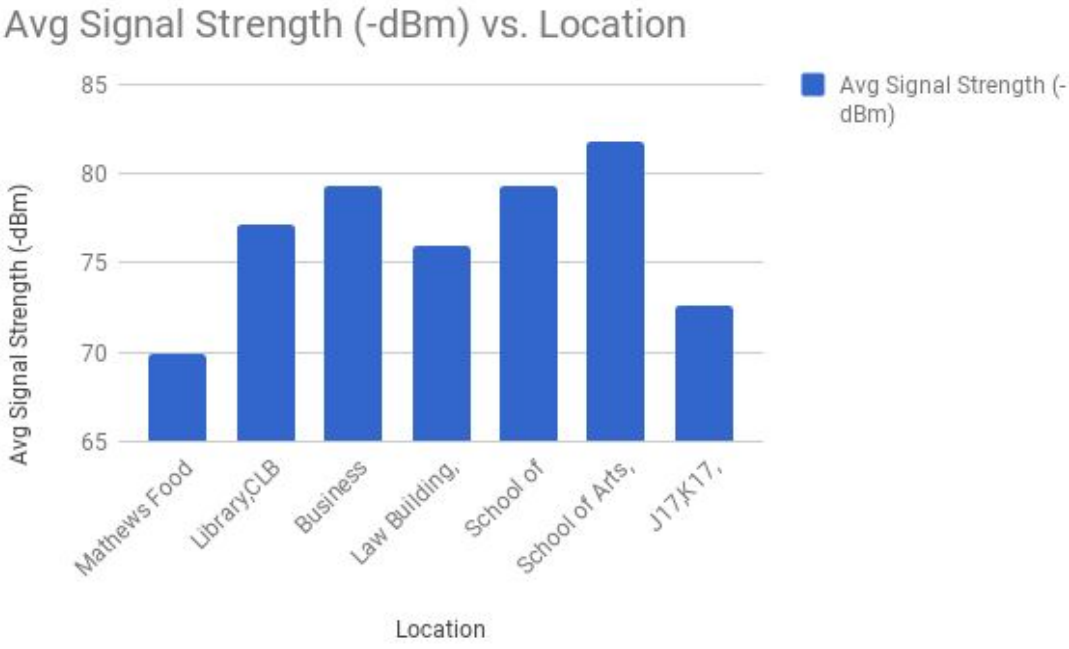
AP name	AP address	Physical Location discovered
eduroam-53	08:cc:68:b5:fa:6f	Mathews Theratre Food Court
eduroam-63	08:cc:68:b4:75:d0	Bees Building
Global_Students-74	1c:e6:c7:5b:8e:c3	UNSW Gate9
eduroam-66	84:78:ac:98:4d:7f	Library Ground Floor
eduroam-60	58:97:1e:b2:3D:c7	Library Second Floor
eduroam-64	d0:c7:89:c6:56:c0	Postgrad Study Room,Library
Global_Students-56	08:cc:68:cc:30:72	Quadrangle Building
eduroam-62	08:cc:68:b5:c0:3f	Quad Food Court
eduroam-56	1c:e6:c7:f0:16:90	UNSW B-School
Global_students-66	08:cc:68:b4:c8:9b	Chemistry Building
Gloabl_Students-47	7c:0e:ce:d2:ca:c2	Michael Couch Innovation Center
eduroam-47	84:78:ac:98:4d:be	UNSW LAw Library
uniwide-63	84:78:ac:c0:35:27	UNSW Law Building Floor1
uniwide-68	1c:e6:c7:0d:56:bf	UNSW main walkway
uniwide-61	08:cc:68:b5:98:30	Tyree Building

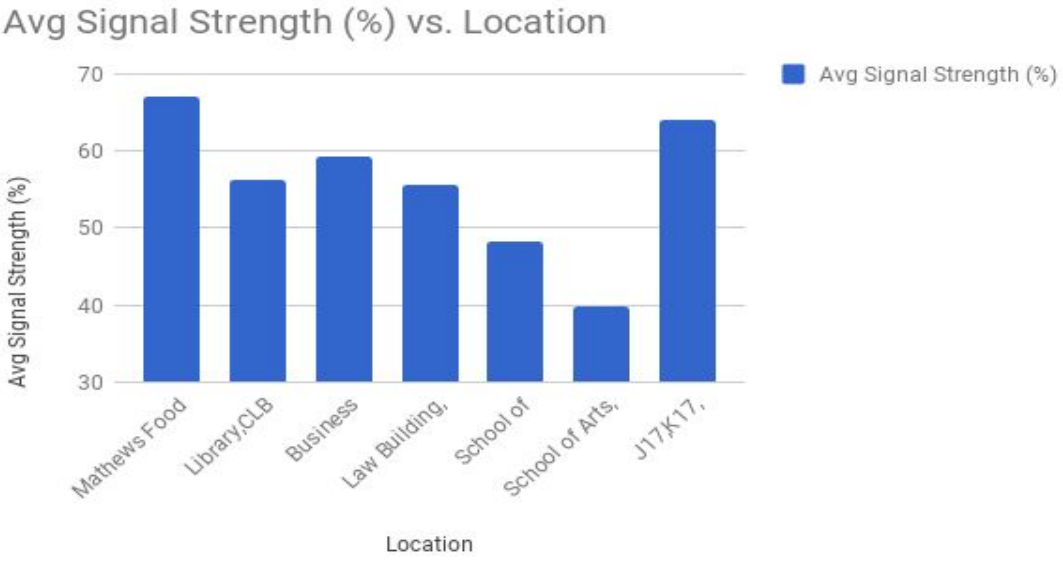
uniwide-52	08:cc:68:b4:6f:ff	UNSW Entrance,Anzac Parade
eduroam-65	d0:72:dc:53:5e:a1	UNSW Round House
Connectmy.net-68	24:c9:a1:6b:dB:08	School of Computing
eduroam-73	1c:e6:c7:3e:61:c6	UNSW play ground
Gloab_students-65	7c:0e:ce:dc:5d:04	Physics Building
Global_Students-64	d0:72:dc:53:5d:44	CSE Car park
Global_Students-81	54:78:1a:bf:77:33	Barker st,Car Park
uniwide-72	54:78:1a:bf:77:36	K17 Ground Floor
eduroam-62	08:cc:68:b4:e4:8f	K17 Level1
eduroam-79	F4:4e:05:23:61:40	J17 Lift
eduroam-61	08:cc:68:b5:8d:f1	Electrical Building
uniwide-47	1c:e6:c7:e0:28:a6	UNSW Arts Building
uniwide-79	08:cc:68:b4:91:c0	Old CSE Building
Connectmy.net-72	24:c9:a1:6f:8d:88	UNSW Civil Building
Global_Students-78	f0:9e:63:14:76:a4	Old CSE Building Labs
eduroam-70	08:cc:68:b5:9c:90	Robert Webster Building
ArcWireless_guest-57	00:26:18:dc:1d:cab	ARC Student Office
eduroam-61	54:78:1a:bf:a0:67	Electrical Building
eduroam-47	08:cc:68:b4:a1:1e	CSE Building level 3
eduraom-47	1c:e6:c7:e0:28:a7	Coffee on Campus
uniwide-47	1c:e6:c7:e0:28:ae	CSE Level4

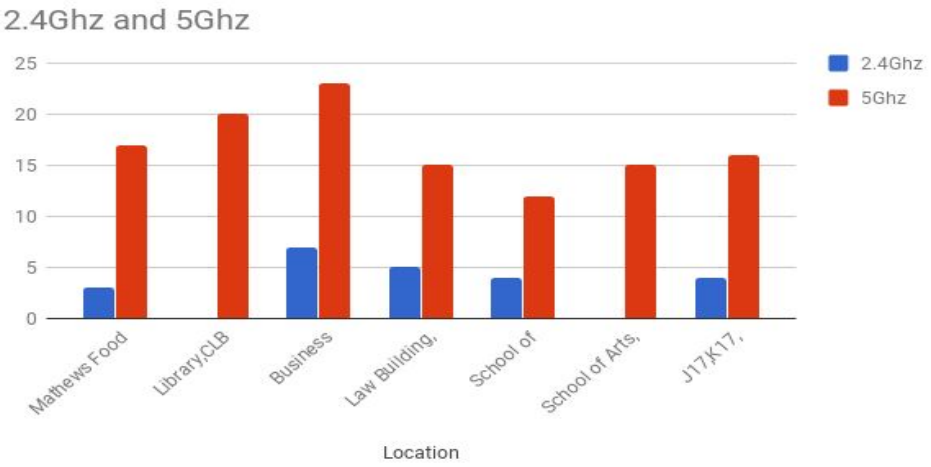
Summary of Link Layer Analysis :

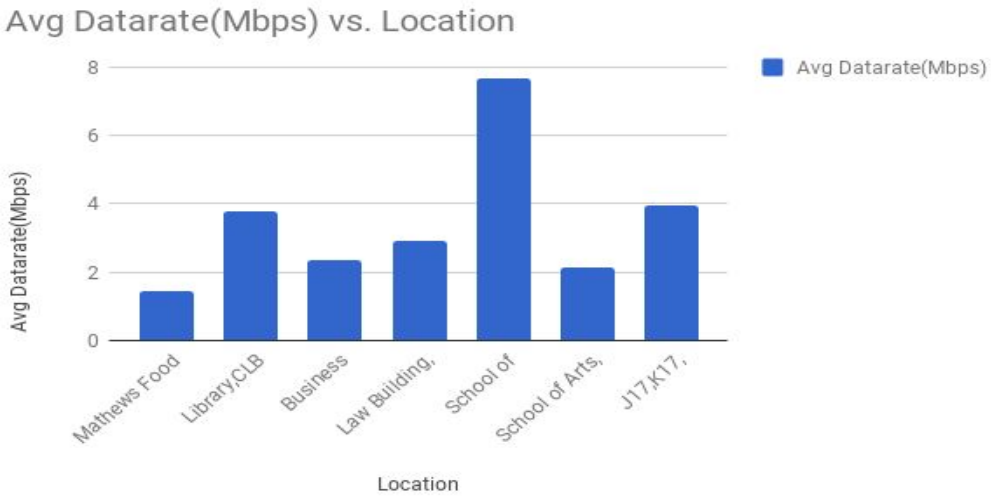
In this section I would like to conclude few facts based on the above calculated parameters across all locations at UNSW by normalizing the individual values to see the over all performance and how good or how bad in a specific location.

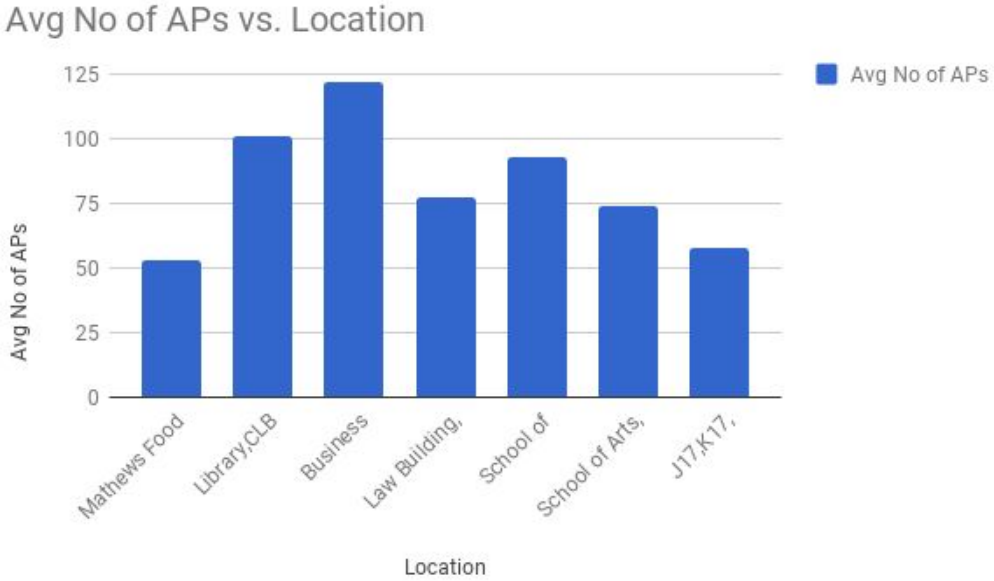
The recording captured across the campus


Avg Signal Strength (-dBm) vs. Location
Avg Signal Strength (-dBm)
85
80
75
70
65
Avg Signal Strength (-dBm)
Mathews Food
Library,CLB
Business
Law Building,
School of
School of Arts,
J17,K17,
Location


Avg Signal Strength (%) vs. Location
Avg Signal Strength (%)
70
60
50
40
30
Avg Signal Strength (%)
Mathews Food
Library,CLB
Business
Law Building,
School of
School of Arts,
J17,K17,
Location


2.4Ghz and 5Ghz
25
20
15
10
5
0
2.4Ghz
5Ghz
Mathews Food
Library,CLB
Business
Law Building,
School of
School of Arts,
J17,K17,
Location

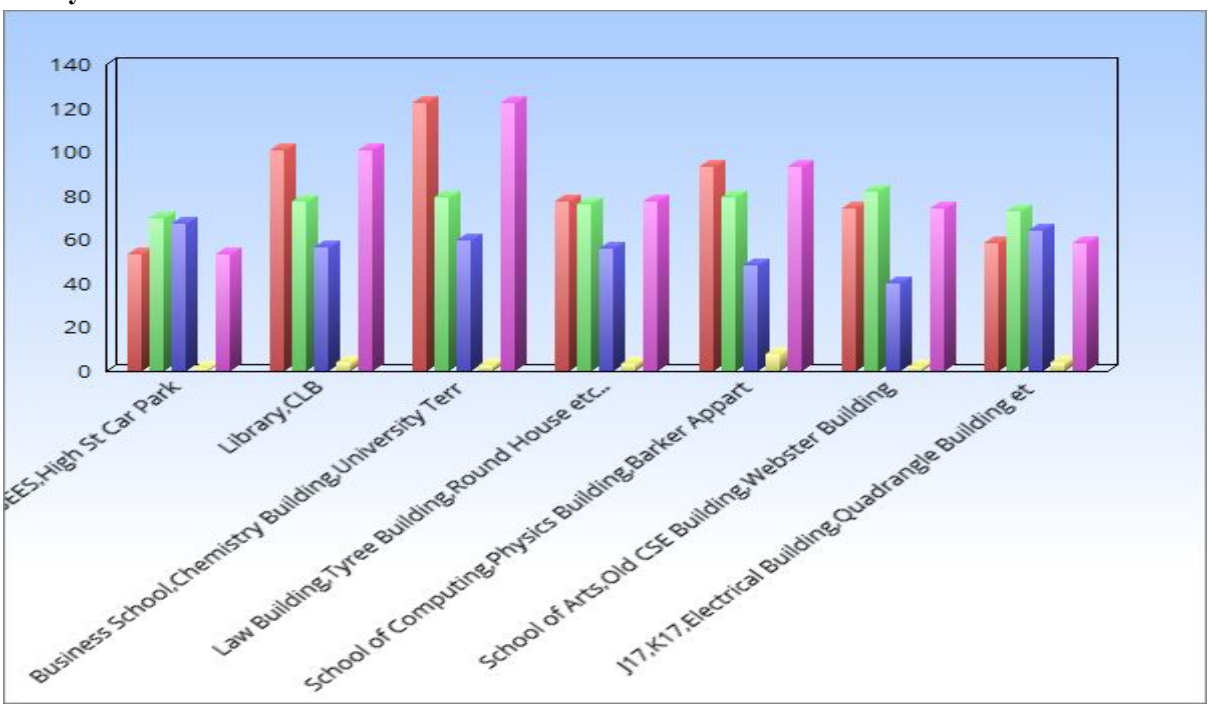

Avg Datarate(Mbps) vs. Location
8
6
4
2
0
Avg Datarate(Mbps)
Avg Datarate(Mbps)
Mathews Food
Library,CLB
Business
Law Building,
School of
School of Arts,
J17,K17,
Location


Avg No of APs vs. Location
125
100
75
50
25
0
Avg No of APs
Avg No of APs
Mathews Food
Library,CLB
Business
Law Building,
School of
School of Arts,
J17,K17,
Location

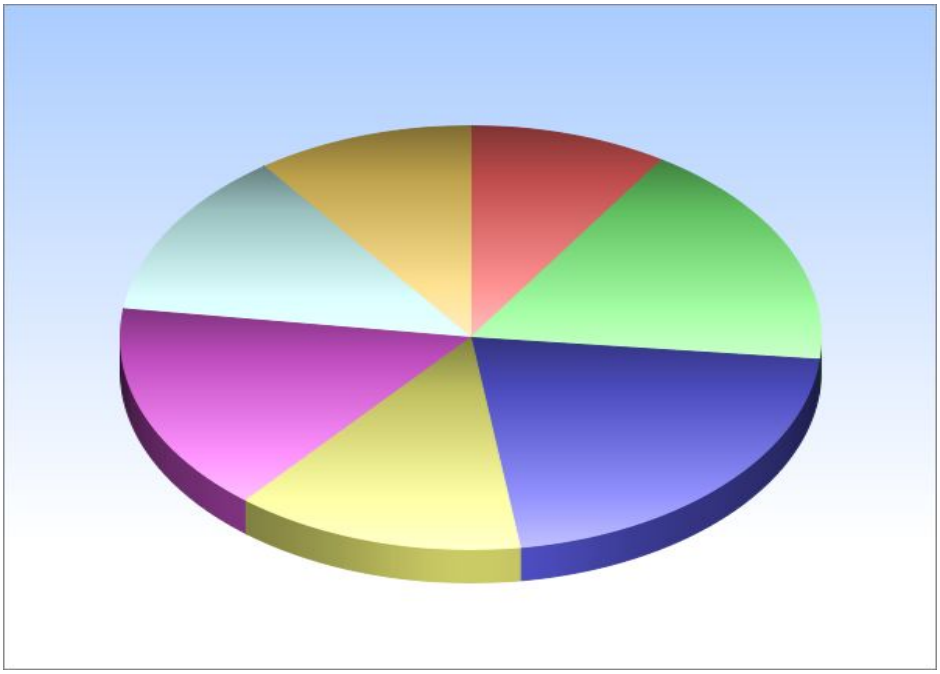
From the above graphs it can be seen that :

- **Average signal strength is reasonably good and same covering all locations with avg value close to about 67% which is quite good enough to decent experience to its users.**
- **Most of the locations are accessed across 5Ghz band and sometime 2.4Ghz band can also be seen and in most cases 802.11n protocol standard is observed to provide good data rates.**
- **Avg data rates observed is around 7-8 Mbps which is very high as per the current standards and is outperforming around School of Computing Sciences and art building surroundings.**
- **Avg number of APs covering given any location inside the campus is about 60+ which is good enough to meet the requirements but interesting thing is that AP density is more than 100 surrounding in UNSW business and Law buildings.**

When we talk about overall performance of uniwide in a particular location the below graph will explain clearly.



Though there are discrepancies in the values equilibrium is maintained throughout and this made UNSW network one of the outstanding ones which can be seen from below pic chart.



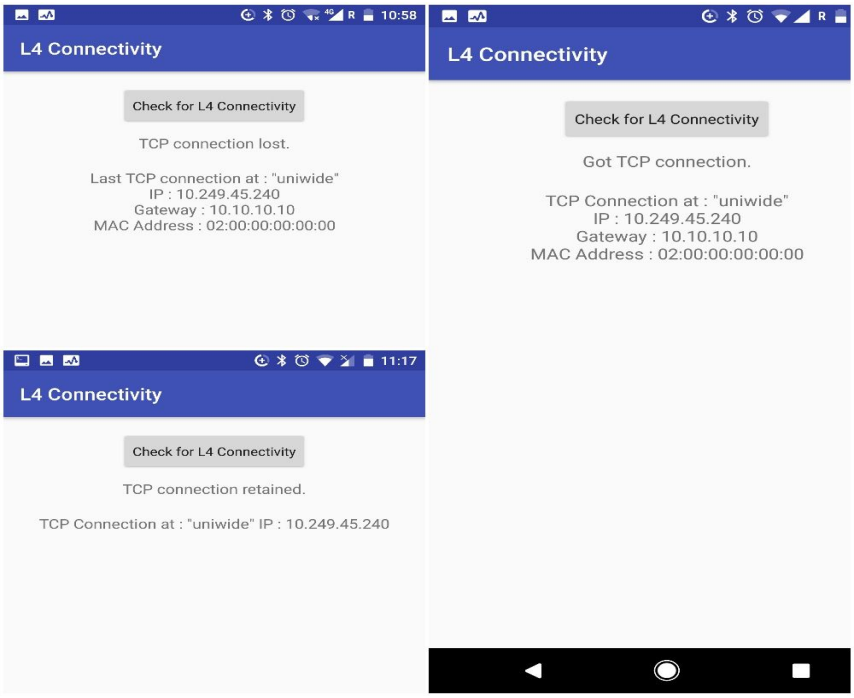
Mobility Analysis :

Today's communication is completely moved onto mobile systems from static systems and mobility management is one of the major challenges in wireless communication.None of us wanted to stick to a place just to get connected with Internet and this made our life easier.AS we keep moving in the background several things happen and we mainly focus on the TCP connectivity,IP handoff and L2 handoff which are the major factors that help us estimate the performance of any network.In our process of estimating Uniwide performance we consider these 3 factors.The behaviour of the above mentioned factors are calculated with the support of the android app developed by me to verify the functionality and estimate the behaviour.Lets take a look on each of these factors in detail.

1.L4 Connectivity :

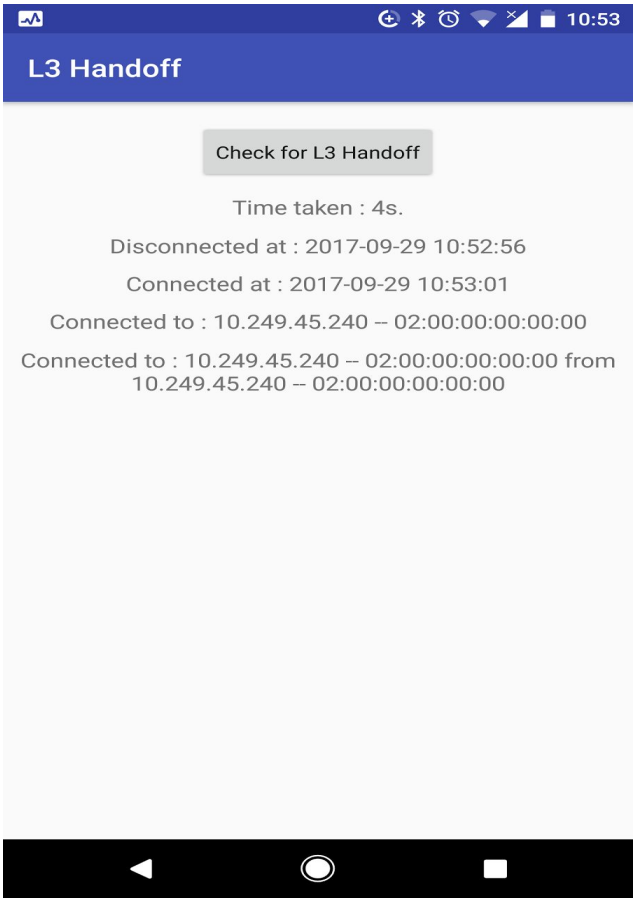
L4 Connectivity can also be rephrased as Layer 4 connectivity or TCP connectivity.It is important that we look into TCP connectivity because TCP is responsible for end to end delivery to our messaged and plays a key role in successful communication.The behaviour of TCP when we keep moving from one location to another,the access point we are connected to also changes and how the connectivity behaves is what we are looking for in this section.

I have setup a server in my laptop running and developed a client model using Android Studio which enables me to connect to the server.During this process I have an active TCP connection opened and remains opened until disturbed possibly due to change of ports/IP address/close of connection.Our task is to find out the status of this particular TCP connection when we keep changing APS or locations which automatically changes AP that we are connected to since single AP cant cover entire campus which is a know fact.Few interesting facts were found during my survey.In most cases connection was lost due to change of IP address/port number in which case I have to reconnect my client to the server and open another new TCP connection.But interestingly I found few cases where the existing TCP connection retained in spite changing my location and AP.These results are shown below.



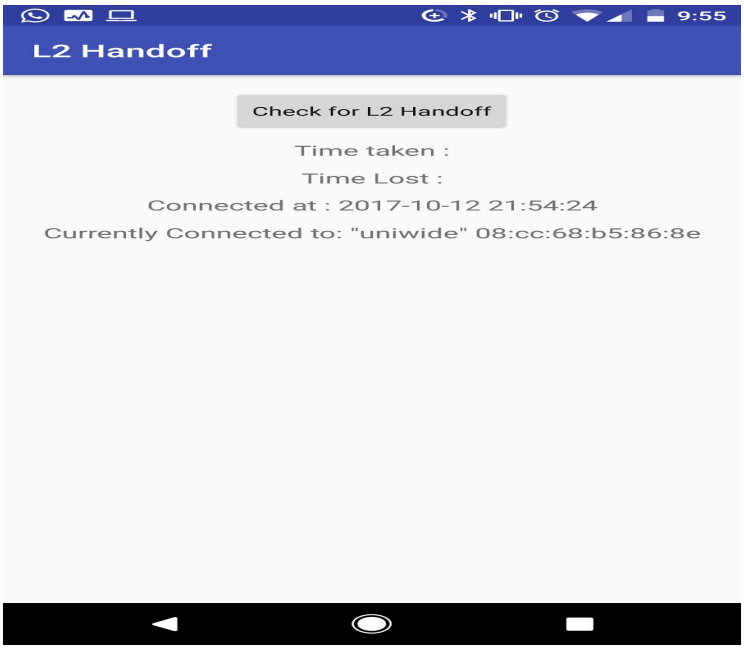
2.L3 handoff :

L3 handoff also known as layer 3 handoff or IP handoff.Our main aim in this task is to find the changes in IP address whilst moving from one location to another changing APs along the way and possibly looking to find out if there are cases where the IP address is retained or changes when TCP connection is retained or changed.And fascinating part of this is that both cases have been identified which are presented in the below snapshots.



3.L2 handoff :

In this section our aim is to find out the changes in AP when moving from location to another location and recording the changes in AP and the time at which the connection is lost and the time at which new connection is obtained can be seen below.



Please check the below github link to find the apk and code details regarding the project and progress in the commits throughout the development of the project.
https://github.com/kmr0877/Performance-of-Enterprise-Wide-Wireless-LAN

Please find the below google drive link to find all the observations recorded during the survey.

https://photos.app.goo.gl/ZE568icFCdbz5M3r1

Please contact on z5124393@student.unsw.edu.au if you face any issues accessing the link

References :

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