INDOOR AND OUTDOOR WIRELESS LOCAL AREA NETWORK DESIGN IN CST CAMPUS

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ABSTRACT

The growing number of students in college demands effective and reliable internet services as it is vital source of information for a student. Through the survey conducted and the general scenario of the users, it is found that the existing WLAN service doesn't suffice the users in the campus. The survey was aided by distributing survey questionnaires to get general views about the existing WLAN system. To have a strong justification to the views, WLAN survey software, Ekahau Heat Mapper is used to get the idea of channel assigned to different APs, coverage area given by APs, location of APs in buildings and find the flaws in the old WLAN design which has lead to inefficient Wi-Fi network. This paper gives the solution to the existing problems stated by proposing a new WLAN design. The new design is achieved through numerous surveys taken using software and hand held calculations. Through our design an efficient WLAN with good coverage area and non-interfering channels is achieved which will lead to a reliable internet service in the campus.

***Keywords:** WLAN, SSID, AP, Link Budget, Channel assignment*

1. INTRODUCTION

Wireless internet is one of the latest technologies that have come in the field of communication. It allows users to share a high-speed Internet connection among multiple computers without being tethered to wires or wall jacks. This project is aimed to design a WLAN which will provide an efficient coverage concentrating on the user density. Present scenario of Wi-Fi network in the campus is found to be unreliable from the survey done. It was found to be set up in an assumption basis without a proper design by randomly placing the access points. To tackle the above stated problems we have approached it through various means to find a solution. It includes surveying and analyzing the result for the network coverage of each of the access points.

The specifications of the equipments being used for deploying WLAN is taken into consideration. An analysis is done whether the positions of APs, channels assignments and specification of equipments used are appropriate or not. By finding the flaws of currently deployed WLAN, a new WLAN is designed which overcomes most of the problems associated with the already existing network.

2. METHODOLOGY

2.1 SOFTWARE SURVEY

A thorough site survey was done to study about existing networks. The site survey was done in Ekahau HeatMapper. It is a free software tool for quick and easy coverage mapping of Wi-Fi (802.11) networks (Anon, The Ekahau · Heat Mapper, 2012). It's an easy-to-use tool that shows, on a map, the wireless network coverage. It also locates all access points and provides a real-time view of all access points and their configurations (Anon, 2012). It uses built-in wireless network adapter, therefore, all only a Windows-based laptop with wireless is required. AutoCAD was used to make floor plans of the buildings. These floor plans were uploaded in the Ekahau HeatMapper and survey was done accordingly (Anon, 2012). The software is easy to use but requires an exact map or floor plan to find out the proper network coverage.

Table1. Colour representation of signal strength

Colour representation of Signal strength	Signal strength	Remarks
	-48dBm to -40dBm	Outstanding
	-56dBm to -48dBm	Excellent
	-64dBm to -56dBm	good
	-72dBm to -64dBm	Fair
	-80dBm to -72dBm	poor
	-88dBm to -80dBm	No coverage

The different signal strength in dBm is represented by different colours. Strongest is represented by dark green and signal strength depreciates as shown in the above table.

2.2 SURVEY OF INDOOR NETWORK

For convenience of site survey of indoor wireless network, hostel block A is considered. The following Figure1 shows the coverage area of AP located in block A with SSID AML.

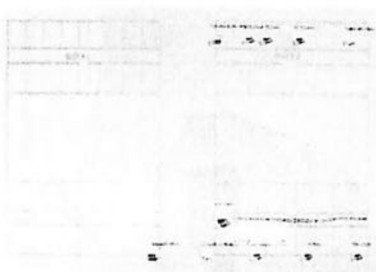

Figure1. Coverage area of AML AP

This existing location of the AP was found to be interfering with the signals from other block and more over the signal from this block seemed to be going out to other unwanted areas rather than being available within the block. The rooms located at the extreme ends of the block received very week signal and poor network coverage.

The above figure Figure2 shows one of the many overlapping of signals from access points of different hostel blocks.

Channel used and SSIDs are represented in the following figure.

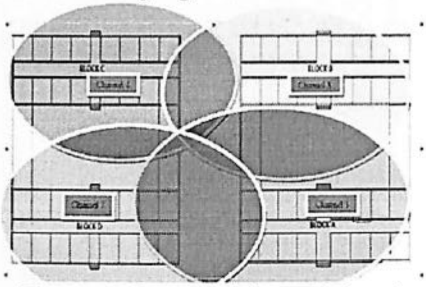

Figure2. Over lapping of signals

For example SSID for AP in block B is represented by BML and its channel is 8. Likewise the same is indicated for different blocks. Table2 shows the channels assigned to the APs, SSIDs and current positions of the APs.

Table2. Positions of APs in different hostel blocks

Block	Floor	Side of Placement	Channel
A	Ground(G)	Right side (R)	9
	Middle(M)	Left side (L)	3
	Top(T)	Right side(R)	2
B	Ground(G)	Left side(L)	No AP
	Middle(M)	Right side(R)	8
	Top(T)	Right side(R)	11
C	Ground(G)	Left side(L)	No AP
	Middle(M)	Right side(R)	4
	Top(T)	Left side(L)	4
D	Ground(G)	Right side(R)	6
	Middle(M)	Left side(L)	7
	Top(T)	Left side(L)	2
E	Ground(G)	Right side(R)	11
	Top(T)	Left side(L)	6
	Top(T)	Middle(M)	No AP
	Top(T)	Right side(R)	2

2.3 SURVEY OF OUTDOOR NETWORK

2.3.1 READING BARS INDICATED ON LAPTOP:

For outdoor network survey the bars indicated on laptop was used to estimate the coverage areas given by the two existing outdoor antenna access points i.e. ECE AP and Work Shop AP. Both the antennas in use are Vertical Array Omni-directional antenna operating at 2.4 GHz with peak gain of 12 dBi. The coverage of the two antennas placed for outdoor WiFi coverage is shown in the following:

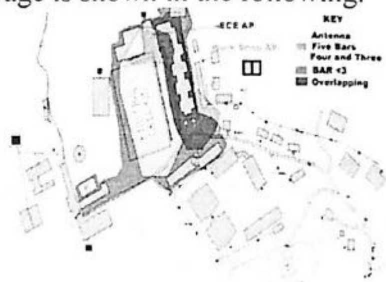

Figure3. Coverage area of ECE AP and Workshop AP

2.3.2 NETWORK SURVEY WITH NETSURVEYOR

Another network surveying tool NetSurveyor was used to check the signal strength at a particular distance was used. It is an 802.11 (WiFi) network discovery tool (Anon, NetSurveyor Professional, 2010). It gathers information about nearby wireless access points in real time and displays it in a useful way. The data is displayed using a variety of different diagnostic views and charts (Jeriah, 2011). With the help of NetSurveyor the strength of beacon signal in outdoor and channel used was determined.

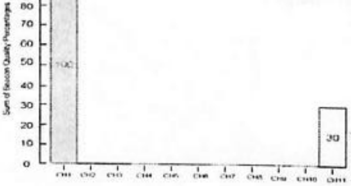

Figure4. Graph Plotted from Netsurveyor

The chart above shows the strength of beacon signal and channel used indicated in the NetSurveyor. Some spots were chosen in a college map and accordingly survey was done by going to the chosen spots and taking snap shots of the results indicated in the software. These spots were later analyzed and an approximate coverage map was drawn in AutoCAD.

3. FINDINGS FROM SURVEY

3.1 INTERFERENCE OF THE WI-FI SIGNALS

One of the most common root causes for having slow and unstable wireless network connections is interference (Balanis, 2011). Most of the Wi-Fi signals from different APs in the hostel area were found to be overlapping. The channels assigned for these different APs were done on a random basis and there are definitely lots of interference taking place which lead to the poor connectivity of the network. Overlapping of signals in Figure2 shows high interference as the channels assigned were overlapping channel to each other (C.A.Rusen, 2012). The existing channel assignments of APs in each hostel block are shown in Figure5. The current position of the APs is such that some of the rooms at far end don't fall within its coverage area. The locations of APs in each block are clearly given in Table2.

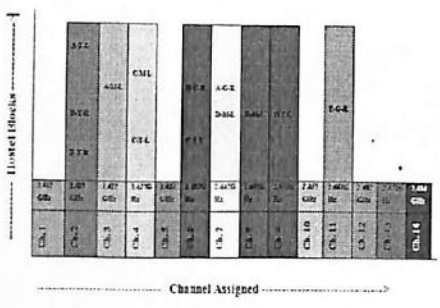

Figure5. Existing channel assignments

3.2 OUTDOOR ANTENNA COVERAGE

The survey conducted infers that current location of the outdoor Omni-directional antenna leads to wastage Wi-Fi signals. The signal is found to be going out of college boundary, especially from ECE AP, as it is located near to the college boundary on top of lecture theatre. The position of this AP is clearly indicated in Figure3. The signal was found to be covering more of the areas where user density was minimum and didn't give enough where the user density was maximum. The signals going out of the campus were obviously wasted and were of no use to anyone. This problem has to be rectified by designing an efficient outdoor wireless network.

3.3 RESEARCH THROUGH QUESTIONNAIRES

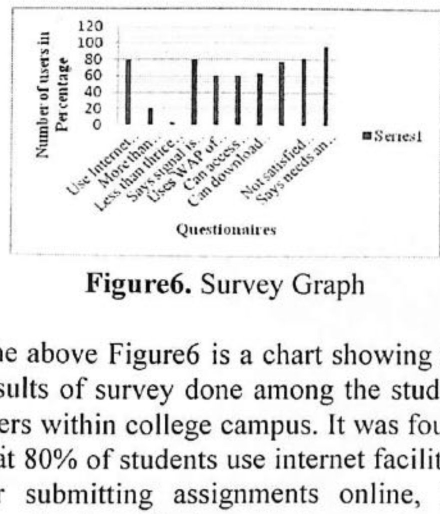

Figure6. Survey Graph

The above Figure6 is a chart showing the results of survey done among the student users within college campus. It was found that 80% of students use internet facilities for submitting assignments online, for downloading lecture notes and for browsing purposes. Only few numbers of students were found to be using it less frequently. Majority of students were found to be saying that the signal is not strong enough and not satisfied with internet speed. Only 50% to 60% were able to access College Web mail and VLE (Virtual Learning

Environment) with ease but the rest were having tough time in loading. It was also found that despite having Access Points in their own block; most of the students were found to be using the AP from other blocks to have access to internet. Over 95% of students feel that there needs to be an improvement in network connectivity for better signal strength and faster browsing.

4. DESIGN OF NEW WIRELESS NETWORK

4.1 INDOOR WIRELESS NETWORK DESIGN

4.1.1 RELOCATION OF AP AND ASSIGNING NEW SSIDS:

As discussed earlier the position of AP inside a building affected the coverage area. The previous locations of APs are shown in Table 2.

In the new indoor network design the positions of APs are brought to the centre of each block as shown in Figure7.

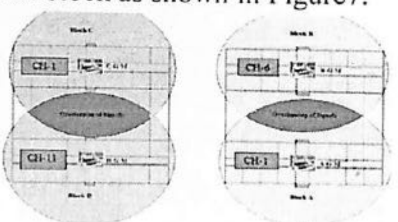

Figure7. New channel and SSID assignment

The SSIDs of APs has also been changed to AGM from AGR. Like all other APs which were located on the left and right of the building were brought to centre of the building to have an efficient and uniform coverage area.

4.1.2 CHANNEL ASSIGNMENT:

After placing an AP to a correct position, a right channel assignment has to be done to have a non-interfering wireless network. In Figure5 the channels assigned to the nearby APs fall under the overlapping channels and these has been changed as shown in Figure7. The new channel assignment eliminates the signal interference between the nearby APs as non-overlapping channels have been assigned to nearby APs in the new design (Rappaport, 2002).

4.1.3 IMPLEMENTED DESIGN:

The Figure8 shows the new location of access point in hostel block. In newly designed Wi-Fi network in different blocks, the access points will be located in the centre whereby the network coverage becomes more effective compared with the previous one with the APs located at the corners as shown in Figure1 and Table2.

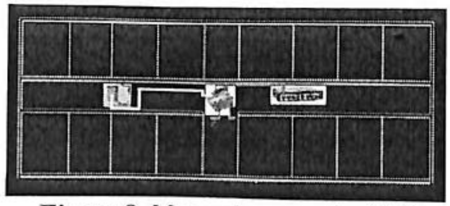

Figure8. New placement of AP

This Figure9 shows the coverage of newly designed Wi-Fi network in hostel blocks. The access point known as A-M-M located at the centre of the building floor shows the further improved network coverage in the area. Comparing with the previous location of access point now we can access the better coverage as shown in the Figure9. With this design everyone in the particular area can have the high speed internet facility.

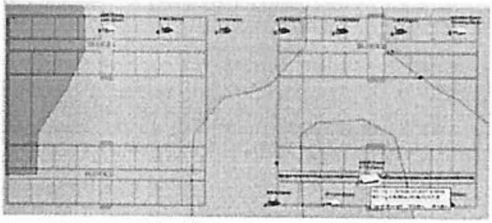

Figure9. Coverage of AMM

4.1.3 LINK BUDGET CALCULATION:

To verify whether the new design is feasible or not a link budget is calculated. Link budgeting gives the power that can be received by the receiver (Korowajczuk, 2011). In our calculation a receiver has been considered as laptop at the last room of the hostel and transmitter as AP in the middle of hostel block as shown in Fiugure10.

$FSPL = 92.45 + 20LogF + 20Log10d$ -------- *(i)* (Bijgewerkt, 2005).

FSPL = Free Space Path loss in decibels

F = frequency in GHz

dB = decibels

d = distance in kilometres

Here in our calculation the distance is taken between the laptop in the furthest room in a block from the Access Point. The distance was found to be 16.15 m.

- **Calculation of Free Space Path Loss**

Parameters required are as follows:

Frequency = 2.4 GHz

Distance = 16.15 m = 0.01615 Km

Now,

$Lp = 92.45 + 20log\ (2.4) + 20log\ (0.01615)$

$= 64.22\ dBm$------------------- *(ii)*

- **Calculation of Link Budget**

We have considered link in the following three stages:

The transmitting end: which consist of AP, cable and the antenna?

The middle bit: This is considered the distance between the AP and laptop.

The receiving end: The receiver is considered as laptop which supports IEE 802.11 a/b/g.

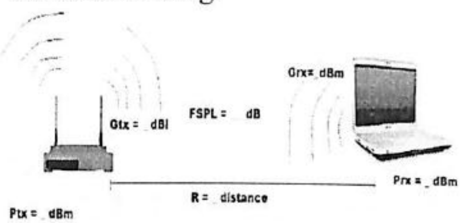

Figure10. Link budget between AP and a Laptop

Link budget

$= Ptx - LL + Gtx + FSPL - LL + Grx - Prx$ -------- *(iii)* (Bijgewerkt, 2005)

Ptx = Output power of transmitter in dBm

LL = Antenna and cable losses at transmitter in dB

Gtx = Transmitter Antenna Gain in dBi

FSPL = Free Space Loss--> propagation loss in dB (negative number)

LL = Antenna and cable losses at receiver in dB

Grx = Receiver antenna gain in dBi

Prx = Receiver sensitivity in dBm (negative number)

Specification of Antenna in Laptop:

Gain/Grx = 2 – 9 dBi (Taking mean value for calculation 5.5 dBi as per gain given in Table 3 of Appendix)

Receiver sensitivity/ Grx -72 dBm

LL = 3 dBm (normal value)

Specification of access point antenna as per the data sheet:

Ptx = 15 dBm
LL = 3 dBm
Gtx = 7 dBi
According to (ii) we have FSPL = 64.23 dBm
Now,
Using equation (iii)
Link Budget = 15 – 3 + 7 - 64.23 – 3 + 5.5 + 72
= 29.93 dB

However the above signal won't be available in practical applications because sufficient amount of signal will be blocked by the concrete walls. A single concrete wall will block around 4dBm of signal, which means that from a total of 29.93 dB only 25.93 dB signals would be available at the other end. As the signal propagates to further distances it will get attenuated and eventually a point will be reached where there would be no signal at all. However after subtracting the signal loss through walls the received signal level at the receiver is found to be greater than the receiver sensitivity of -72 dBm (Korowajczuk, 2011). Therefore the new wireless network is feasible.

4.2 OUTDOOR WIRELESS NETWORK DESIGN

4.2.1 FEASIBLE ANTENNA FOR CST OUTDOOR WLAN:

The proposed outdoor antenna to be installed for new Outdoor Network is a 120° sector antenna. Using this type of antenna more clients can be supported because using 2 sectors with 2 Access Points, the number of clients can be doubled in a given area (Rappaport, 2002). The gain of proposed antenna is 14dBi which is much higher than the currently installed Omni-directional antenna with 12dBi. Moreover the signal from the sector antenna won't radiate its signal to unwanted areas as in case of the Omni antenna. The proposed antenna will have fewer retries and fewer packets lost as the signal will be focused in the desired area enhancing signal strength to a great extent (Balanis, 2011). Interference can be eliminated because a sector antenna is directional and usually has good front-to-back (F/B) ratio, it can reduce or eliminate interference from sources that are behind the sector antenna (Anon, Omni Antenna vs. Directional Antenna, 2007).

4.2.2 DESIGN OF OUTDOOR WI-FI NETWORK WITH PROPOSED ANTENNA:

As per the new outdoor network design the proposed antenna is to be placed on top of the bachelor's quarter. Two sector antennas with 120° horizontal beam width are enough to cover the main areas where there should be Wi-Fi coverage. As they are directional antenna the coverage will be in a particular direction depending on the beam width. The approximate coverage of the two sector antenna is shown in Figure 10. As per the network survey the existing outdoor antenna doesn't provide sufficient coverage and moreover it covers only certain area where other area is left without signal. The green arcs in the Figure 10 represent signals from one sector antenna faced towards the ground and lab areas. The other one is aligned towards the staff area and self catering hostel area, signal is represented by pink arcs. Hostel area has its own indoor network coverage; therefore two sector antenna doesn't need to cover this area. However the signals from these sector antennas should not interfere with the indoor hostel network. The position of the antennas can be aligned manually and adjusted so that the signals from the proposed antenna don't go towards the hostel area, which is clearly shown in Figure 10. (Aragon-Zavala, 2007)The figure also shows that using two 120° sector antenna covers most of the probable position of user in the campus.

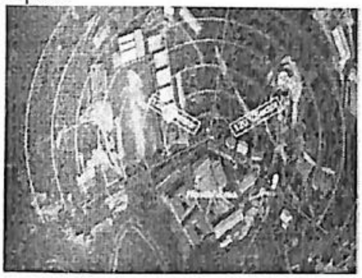

Figure10. Approximated Coverage Area of Proposed Antenna

- **Calculation of Link Budget**

Before calculating a link budget first of all Free Space Path Loss is calculated as follows:

Free Space Path Loss Calculation

$FSPL = 92.45 + 20LogF + 20Logd$ (Bijgewerkt, 2005)

FSPL = Free space path loss in decibels

F = frequency in GHz

d = distance in kilometers

Parameters required are as follows:

Frequency = 2.4 GHz

Distance = 0.288 Km

Now,

$FSPL = 92.45 + 20log\ (2.4) + 20log\ (0.288) = 89.24\ dB$

- **Calculation of Link Budget**

$Link\ budget = Ptx - LL + Gtx - FSPL - LL + Grx + Prx$ (Bijgewerkt, 2005)

Parameters are:

Receiver sensitivity/Grx = -72 dBm, LL = 3 dB, Ptx = 13.010dBm, Gtx = 14dBi, FSPL = 89.24dB, Grx = 4.5dBi and Receiver sensitivity in dBm (negative number) = (-72dBm)

$Link\ Budget = 13.010 - 3 + 14 - 89.24 - 3 + 4.5 + 72 = 8.27\ dBm$

As stated earlier the RSL (received signal lever) at the receiver is found to be 8.27 dBm from the calculation. Therefore the network is suitable for deployment as new outdoor network design in CST campus.

5. CONCLUSION AND FUTURE SCOPE

With the technology advancing now and then, having good internet connectivity is of utmost importance to keep on track with the changing technology. Internet is the humungous source of information in today's world. In our campus too as a small part of the big world, we have aimed to make the wireless local area network a better one for the future generations. The research carried out brought out lot of loopholes that are prevailing in current WLAN setup in our campus. As the number of students increase every year accessing internet from the hostel and residential area has become a great challenge for the college to increase the bandwidth and have an effective connectivity. Currently a bandwidth of 6 Mbps has been deployed. To have an efficient use of this provided bandwidth a good WLAN should be in place, with proper design. The "Design of indoor and outdoor Wi-Fi network in CST campus" was done successfully. The indoor network was designed by doing network coverage survey using Ekahau Heatmapper and NetSurveyor. The software that we used gave us enough information to do Radio Frequency prediction and design the network accordingly. After a tedious work of survey and calculations we were able to complete our WLAN design.

Through our findings we are pretty much sure that the new WLAN design that we have proposed would be a good wireless local area network solution. We hope that our design will be accepted by the IT department and implemented accordingly. We sincerely believe that much of the current prevailing problems will be solved.

6. ACKNOWLEDGMENT

We offer our sincere gratitude to the lecturers and management of College of Science and Technology, Royal University of Bhutan, Royal Government of Bhutan for providing us with this great opportunity of doing our bachelor degree project on "Design of Indoor and Outdoor Wi-Fi Network in CST campus". We are provided with all the basic facilities such as internet facilities and free access to library and all the necessary materials required for surveying and verification of the designed network. Only with the help of all these facilities we could accomplish this project successfully.

We are really grateful to Mr. Tandin Wangchuk for his full support, clear ideas and constructive feedbacks which really helped us during research and while designing networks. We are very much thankful to Mr. Mahendra Rai, our ICT Associate for his valuable time which he spent with us during our project and helping us even during off hours.

Lastly, we would not forget to thank all our friends for their kind supports and valuable feedbacks which really helped us to accomplish this project.

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