11-1-2009

# Key Issues that apply to Wireless Local Area Networks (WLANs) Technology from a Study of the Chinese Campuses and UK Equivalent

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wireless networks, WLAN, WiFi, WiMAX, campus networks, China, OPNET

**Disciplines**
Computer Engineering | Signal Processing

**Comments**
This paper was presented at the Fifth Collaborative Research Symposium on Security, E-Learning, Internet and Networking (SEIN 2009), 26-27 November 2009, which was held in Darmstadt, Germany. It was published by the University of Plymouth and the symposium proceedings are available at http://www.cisnr.org

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## 1. Introduction

Access to University on-line resources and the Internet has changed dramatically over the last few years. Technology has developed to allow students to have desktops at home or in their dormitory rooms. Laptops have become a daily necessity, and more and more students bring laptops to lectures and tutorials. This provides a challenge to network managers to ensure the availability of access to the Internet and Intranet everywhere on campus all times of day and night. An important tool to enable this is the availability of faster connections provided by wireless networks.

Additionally most university faculties are trying to find methods to integrate the laptop into the classroom and have them engage in student learning and teaching. Wireless technology is ideal to provide this type of access due to the convenience of being relatively quick and cheap to install. At present IEEE 802.11 (WiFi) provides a solution since wireless networks have been installed into school classrooms and libraries where students can access network anywhere on campus (Olsen, 2002). For

example, *"the utilisation of technology to build a student-centred environment where active learning is the core approach to acquiring concepts processes and attitudes that become lifelong habits in each student's life"*. (e-Scholar, 2007).

The general availability of Wireless Access Points provides simple connections to the existing infrastructure to be made without resorting to extensive building wiring and the resultant unavailability of rooms. Figure 1 shows the typical infrastructure.

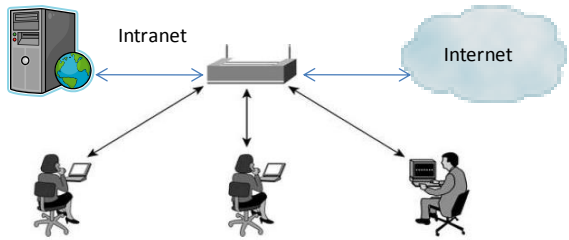


**Figure 1: Typical WLAN Access**

However, with the increase in the number of wireless users some issues associated with the wireless LAN are introduced. For example the availability of a useable signal between the user and the access point is not always predictable since it is dependant on a number of issues such as distance and terrain. As the number of wireless users increases the WLAN quality of service (QOS) decreases and eventually the wireless connection can become unusable. This problem is expounded since users at the extremes of the physical coverage of the Access Point reduce the speed of the connection to gain improved signal strength resulting in all users experiencing a drop in the bandwidth to the Access Point. At present in an open network there is no automatic solution to these problems.

As the size of the network increases in terms of campus size and number of users the above problems have a greater effect on the usability of the WLAN. This paper investigates the effects of physical coverage area, number of likely users, bandwidth usage, user applications and difference in sizes of files caused by different International languages and investigates how new technologies could address these issues.

## 2. Case study

### 2.1. Area of Wireless Network Coverage

First of all, the coverage of the wireless network must be considered, because it is a key point in the wireless network. It is necessary to know how much area will be covered by the signal, and therefore how many base stations are required. Typical antenna for 802.11b and 802.11g, the most commonly available WiFi technology at present, are omni-directional and can only reach approximately 70 metres. Therefore, careful thought needs to be given to the area the wireless network needs to cover and which standards are used.

2.1.1. Within a building

Many of the problems associated with the design of a WLAN are associated with the physical constraints of the buildings that need to be networked. For example in the library building of Glyndŵr University which is of fairly modern construction, the wireless service is the best in the whole campus area, 6 Access Points are distributed on the 4 floors. Figure 2 shows the location and the signal coverage from the Access Points. Red diamonds indicate the position of the Access Points and the colouring surrounding them indicate the strength of the signal, green is excellent ~ -60dB, yellow is acceptable ~ -70 dB, brown is ~ -85 dB which is the limit of acceptable signal. It can be seen that since it is mostly an open office environment there is a very good overall coverage. The sighting of the Access Points is an important decision that needs to be made in advance of the installation which sometimes is not easily made. (Bacqueville D. 2005)

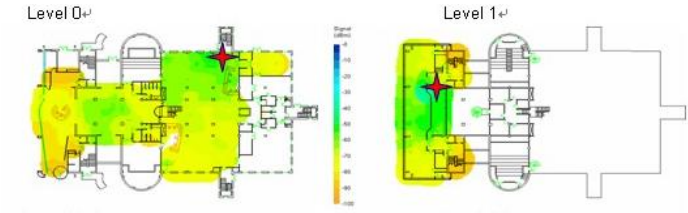


**Figure 2: Wireless reception within a building**

2.1.2. Campus Wide Considerations

Having investigated the issues associated with the internals of buildings it is then necessary to consider campus wide issues. Figure 3 shows the typical spread of wireless hotspots in buildings around a city University campus, it is an approximate map of the wireless hotspots of the University of Bristol, all hotspots support 802.11a, b, g (University of Bristol, 2009). It can be seen that the buildings are wide spread and separated by roads producing difficulties in providing high speed access.

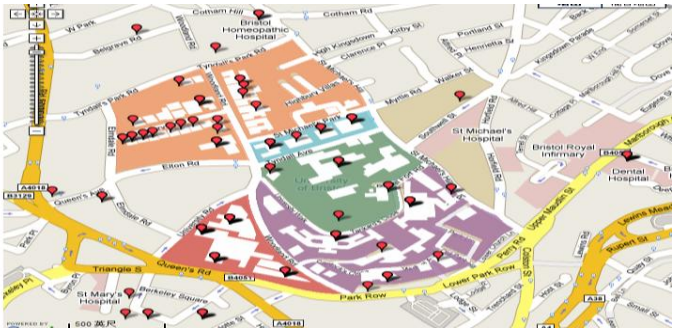


**Figure 3: Wireless map of University of Bristol 2009**

WiFi can not be used for the interconnection of the buildings due to the distances involved and so either wireless line of sight or wired connections have to be designed into the network for the infrastructure connection.

## 2.2. Investigation of Chinese Campuses

In China, the wireless network application of the Northeast Normal University is a typical case. This has 2 campuses, the main campus, and the other is Jingyue. There are approximately 26,000 users on the campus network, provided for by approx 22,000 computer network connections most of which are cabled connections. The take up of WiFi network access is not very high only about 2% of the total connections are made this way. Wireless provision has been made using two kinds of Access Points, one for outdoor usage and another with larger capacity for indoor connection. These two devices support 802. 11a/b/g and the maximum speed achievable is 54Mbit/s. (Li Xianglong and Liu Xiaolong, 2007)

The wireless campus network offers the service for the staff/teachers/lecturers and the students, and have Portal authentication to prevent the illegal use of the wireless network with a timer system is in place to limit the user access.

### 2.2.1. Size of Campuses and Number of students

There are many differences between Chinese universities and British universities, and this is even more pronounced in the campus wireless network application.

#### 2.2.1.1. Physical size of campus in China

Most of the Chinese universities have a large campus, because they have 2 or more campuses in the same city; campuses are even extended into different areas. A report from the Ministry of Education of China shows the amount of newly added area of school building in 2007 is 57 $km^2$, and the floor area under construction is 49$km^2$ in the 1900 higher educational institutions in China. The Vice-minister of the Ministry of Education of China, Yuan Guiren said *"in 2000, there were 5.56 million students in our university; however, until 2005 this number has achieved 15.62 million. During 5 years have increased enrolment 10million students in university. However this number of the students will reach 20million until 2010."* So this clearly shows the rate of expansion in higher education is enormous (Ministry of Education of the People's Republic of China, 2007)

Most of the Chinese students live in student dormitories on the campus, which are also available for staff. On the campuses there are a lot of residents and so the number of network users is much greater than British campuses.

#### 2.2.1.2. Features of Chinese campus

On the campuses, the wireless zones are only in the main buildings, they do not offer the campus wide wireless services e.g. Northeast Normal University has 11 base stations in two campuses. Wireless technology has been introduced and tested in the campus network for a few years e.g. Peking University started to build a wireless

network in 2002. However, the majority of universities are just starting their wireless network plan. In Chinese university campuses the number of laptops is still low.

| University | Peking University | Shanghai Jiao Tong | University of Leeds | University of Warwick |
|---|---|---|---|---|
| Staff | 16,073 | 7,901 | 8,000 | 5,168 |
| Students | 29,617 | 50,225 | 30,500 | 16,646 |
| Size $Km^2$ | 2.6 $Km^2$ | 3.5 $Km^2$ | 4.9 $Km^2$ | 2.9 $Km^2$ |
| % wireless coverage | 8.5% | 40% | 30% | 25% |

**Table 1: WLAN implementation in sample universities in UK & China**

Table 1 illustrates the difference in sizes between Chinese and UK universities. There are a lot of faculties, staff, and students in the university, and the size of campus is also very large to cater for the numbers. Most wireless local area networks that are installed in the campus networks use the IEEE 802.11 standard. In 2007, Peking University started the construction of the second phase of the wireless network, hoping to satisfy the demand by teaching and scientific research. At present approximately 800 pieces of wireless network equipment has been deployed in the campus. The Peking University wireless network coverage is widespread, and supports the teaching, the scientific research, the office work, the public classroom, the convention centre and the student's dormitories and public areas. The total coverage reaches 72 areas and supports IEEE 802.11a/b/g. At present, in Peking University, the daily average users of the wireless network reaches 3000 people (Shang qun, 2008). Figure 4 shows the wireless usage by area which is dominated by the general areas.

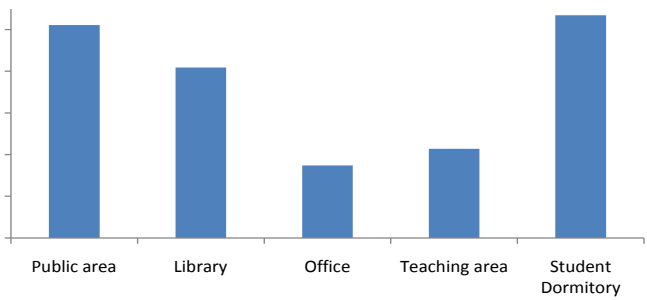


**Figure 4: Wireless Network usage by location for Peking University (2008)**

2.2.2. Features of British Campuses

In the UK, universities campuses are mostly located in the same city/town. The wireless zones covers most areas, even in some instances the entire campus e.g.

Glyndŵr University. In British university campuses the population of laptops is at a high level and most of students and staff live off campus.

# 3. Wireless technology

When designing a wireless network as with wired networks it is necessary to investigate the bandwidth requirements. This will help find a suitable position for Access Points.

## 3.1. Area of Wireless Network Coverage

First of all, the coverage of the wireless network must be considered, because it is a key point in the wireless network. The reason is that we need to know how much area will be covered by the signal, and how many base stations are needed. Typical distances covered by 802.11b and 802.11g are 70m and the range of the 802.11n is increased to 100m, however this is fairly new technology and many laptops and PDAs do not support this standard. To calculate how many base stations would be required it is necessary to do a site survey to identify the distances involved and suitable positions for the installation of Access Points. This will then give an indication of the costs of the wireless network.

## 3.2. Bandwidth Requirement of the Network

The bandwidth requirement is a very important factor in the whole network, because of the range of applications people require. However, in the university campus network, the http/text application still plays an important role. Therefore only website pages models are used to design the bandwidth requirement of the network and to carry out the tests.

## 3.3. WiFi

Most laptops, PDAs etc come with WiFi facilities already installed so this is an obvious choice as a link into the network. To this end most University campuses along with many coffee shops, restaurants, and libraries provide this type of access.

### 3.3.1. IEEE802.11 Standards

In 1997, the initial 802.11 standard was approved. This has set the standard for WiFi which utilizes the unallocated frequency in the 2.4GHz band or the 5GHz band. This specifies a set of standards 802.11a, 802.11b, 802.11g and the latest 802.11n. Each of these standards has different characteristics and reflects the improvement in technology. The current standard is 802.11g which is backward compatible. (Jim Geier, 2004).

In 2003 the IEEE formed a 802.11 Task Group to develop a wireless standard capable of speeds greater than 100 Mbits/sec. The IEEE 802.11n draft standard was planed to increase data rates and range without the additional power. Each station has multiple streams, Multiple Input/Multiple Output (MIMO) technology providing a high data-rate stream into multiple lower rate streams and then transmits them

simultaneously over the available radios and antennae. This permits a theoretical maximum data rate of 248 Mb/s utilizing two streams. (Cisco, 2009)

3.3.2. WiMAX

WiMAX (Worldwide Interoperability for Microwave Access) is a newer technology and is specified in the IEEE 802.16 standard. It is a broadband wireless access technology that can provide high speed connection to the Internet, with a range of possibly 50km. The IEEE 802.16 committee promoted a point-to-multipoint broadband wireless access standard for systems in the frequency range 10-66 GHz. Both the Media Access Control (MAC) and the physical (PHY) layers are covered by the standard. Also the Task groups made an amendment to expand the specification to cover both the licensed and unlicensed bands in the 2-11 GHz range. Little experience is available with this technology at present since equipment is only now starting to become available so simulations have been used in this investigation.

# 4. Traffic Captures

Clearly there also issues associated with language and character sets used in China and the UK. A network analyser (Wireshark, 2009) has been used to capture the packets from various websites to enable these comparisons to be made. Live captures from the Internet were made followed by offline analysis. To gain a useful comparison it was decided to look at a general website i.e. the BBC news website for the UK and the Chinese equivalent Sina. This was then enhanced by repeating the captures for University websites, Glyndŵr University for the UK and Peking University for China.

## 4.1. BBC captures

A Wireshark capture of one person visiting the BBC website (http://www.bbc.co.uk/ ) provides the breakdown of the individual packets by address, along with the type and size of the packets. Analysing this captured information enables details about the distribution of packet lengths during the recording to be obtained.

## 4.2. Other Websites

A similar recording was made for Sina (http://www.sina.com.cn). The results were analysed and the graph can be seen in Figure 5.

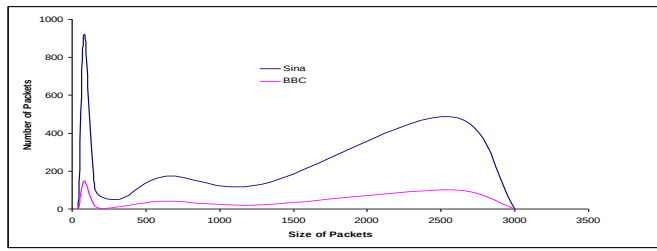


**Figure 5: Comparison of Chinese and British News Websites**

This shows the relationship between the size of the packets received and the quantity. It can be clearly seen that for a similar web site the number of packet received from the Chinese sites is much greater than a UK site, Sina website sends 450% more packets than BBC. Additionally the packet size is also greater; the majority of packets sent from Sina are in the range 1280 to 2560 bytes.

This was then repeated for the University of Peking and Glyndŵr home pages. Figure 6 shows this information for Peking and Glyndŵr Universities. The BBC data was included in the graph to give some indication of the scales. It can also be seen form Figures 5 & 6 that the news websites produce much more information than a University's home page. Again the overall number of packets received from the Chinese website is much larger, about 40% more.

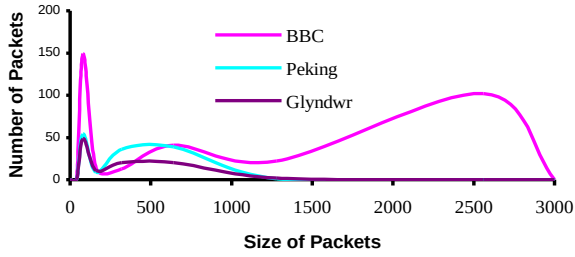


**Figure 6: Distribution of Packet size for University and BBC Websites**

### 4.3. Summary of traffic captures

In summary from the results in Table 2 it can be seen that the size of data from the news websites is much greater than the Universities websites. The times indicated show the actual observed times from Glyndŵr University in the UK, clearly the response times for China are much larger than would be expected if the measurements were carried out locally.

| Website | Count of packet | Time | Size of data |
|---|---|---|---|
| Sina.com.cn | 1864 Packets | 85 secs | 9.7 Mbits |
| BBC | 341 packets | 8 secs | 2 Mbits |
| Peking University | 139 packets | 6 secs | 0.2 Mbits |
| Glyndwr University | 102 packets | 1.2 secs | 0.16 Mbits |

**Table2: The summary of traffic capture**

# 5. Traffic modelling

The data collected in Section 4 was used to create a data model to enable an analysis of the technologies to be carried out. This was done by considering the data as being the equivalent of one person clicking a new page every 60 seconds, so the user will receive a response over a period of one minute.

## 5.1. Extended model for Multi-person

The model assumes that one person uses the wireless network on the campus to visit the same outside website so that a traffic model can be created for a 24 hour period. Each user will receive an update in 60 seconds based on the fact that some of the access will take place during lectures and others outside.

To make the model more realistic it was necessary to estimate the typical number of users on the network over a 24 hour period. This can be seen in Figure 6 which indicates that early in the morning the numbers are low and build up part way through the morning. There is a clear dip during the lunch break followed by a build up during the afternoon which is the typical business model. However since the model is going to be applied to a University campus then this is extended to reflect the usage after 17:00 i.e. the network on campuses peaks during the evening period at a time around 23:00 to midnight. This is supported by Figure 4 which shows the wireless usage for locations around Peking University campus (Shang qun, 2008). Usage in the dormitories, library and public areas was much greater than the teaching areas.

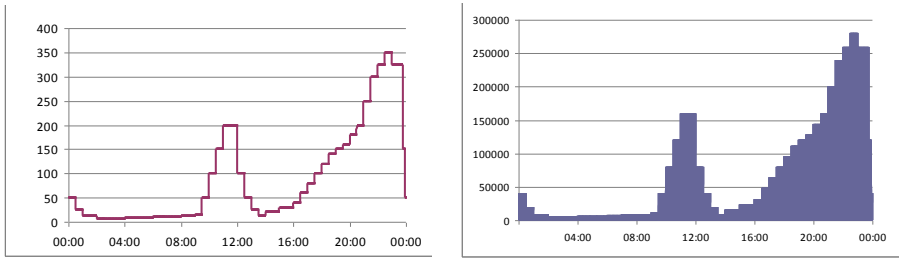


**Figure 4: Number of users & packets by time of day**

If the traffic information gathered in section 4.3 for a single user is applied to the model for the number of users on the network, then the number of packet as a relationship to the time of day can be calculated. The typical outcome can be seen in Figure 6.

# 6. OPNET Modelling

It is necessary to use a modelling tool to analyse the traffic for this investigation. OPNET was chosen since the basic technology infrastructure components are readily available. A number of different infrastructure models were built to investigate the effect of the traffic model (OPNET, 2009).

### 6.1. Wired Model

Firstly a new wired project in OPNET was created as the main scenario shown in Figure 8; this contains models for a typical campus network: the user areas, Intranet and Internet. User areas are modelled as various buildings included as 5 subnets. The Intranet is modelled as a FTP and HTTP server set and the Internet as an IP Cloud with http access.

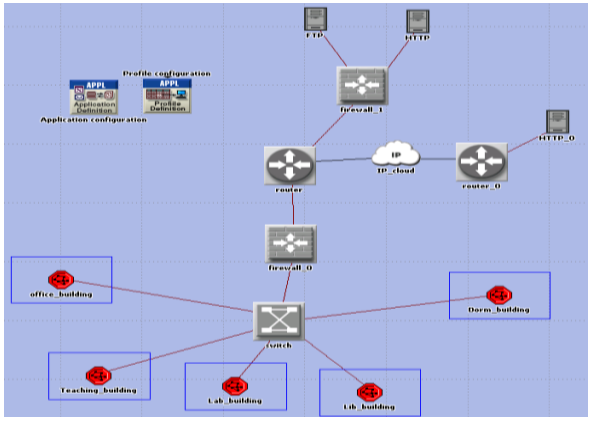


**Figure 5 OPNET model for Wired Network**

### 6.2. IEEE 802.11 Model

A similar model was created for an IEEE 802.11 network and the components were extended to use 802.11g. This enabled the results obtained with the wired model to be compared with the wireless model. This model uses 3 subnets for the simulation, a wireless subnet, Intranet sever subnet and the wired infrastructure. Wireless users can connect to the Access Point and visit outside websites or Intranet servers. Then the traffic model was changed to reflect the high usage in a Chinese campus as seen in Figure 8.

The attributes of the Access Point and workstation were set up in OPNET to reflect the typical devices found on a Campus. The data rates of wireless devices were adjusted to 54Mbps, the highest data rate supported by 802.11g. When running the model with relatively low traffic levels there is no problem since all the traffic sent from the wireless network is received at the Http Internet server and vice versa. This can be seen in Figure 8 where the lines on the graph overlap. However when the traffic levels are increased in line with the model shown in Figure 7 it can be seen from Figure 8 that not all the packets get through. This is because of the bandwidth restriction on the wireless part of the network, since the bandwidth is limited to 54Mbps. The rest of the network has at least 100Mbps. So WiFi has the ability to cover the areas; however the bandwidth is going to be a problem at certain times of the day when the traffic is very high. More access points could be provided in the areas but then this identifies a further problem how to control the users i.e. since client machines choose the SSID of the access point to connect to. Since the users

are mobile it is very difficult to direct the users to particular access points to spread the traffic.

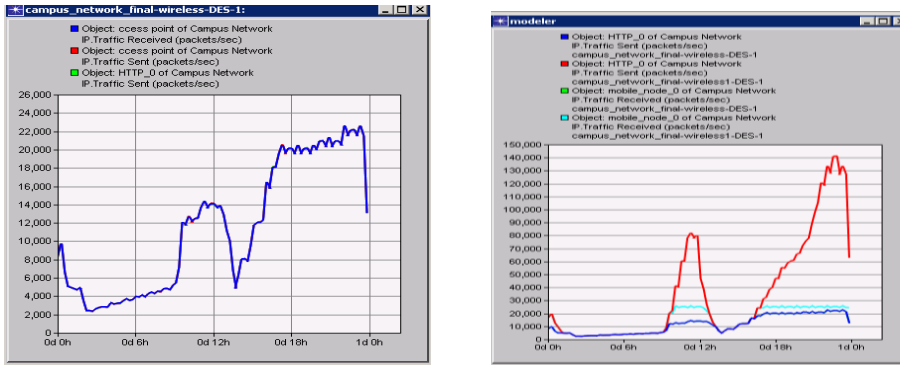


**Figure 6 Results for OPNET simulation of Wireless networks**

### 6.3. Modelling for Wimax

When investigating other technologies using wireless techniques it was found that Wimax is a possible solution to this problem. Based on the campus network, WiMAX was used in the wireless network to replace the WiFi areas in the previous model. Running the high level traffic model with this scenario provides the result shown in Figure 9. Clearly it can be seen that the wireless section has increased the overall bandwidth by 30Mbps.

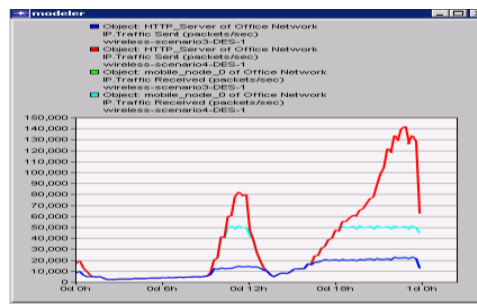


**Figure 7: Wimax results**

However with WiMAX it is possible to cover a much greater area and therefore it is possible that the total number of users could increase.

## 7. Conclusion

This research investigated the typical usage of wireless network on University campuses in the UK and China. It was found that the total number of students on a University campus in China is much larger than that in the UK. Additionally most Chinese students live on the campus. This means that the overall requirement for access to computer networks is greater in China. There is also a drastic planned

increase in the size of the campuses over the next few years. However the usage of laptops and PDAs in the UK far outstrips the numbers used in China but it is anticipated that the numbers in China will increase dramatically over the next 3-5 years. If this is the case then the requirement for network access both wired and wireless will show a similar increase.

At present Universities use WiFi as the means to allow roaming users access to the network. WiFi has a number of limitations associated with coverage area and available bandwidth. At present this does not cause too much of a problem in the UK universities due to the student population and the size of the buildings. If this model was taken to China however it is foreseen that there would be a number of issues that would need to be addressed. The greatest problem is likely to be associated with bandwidth requirements. This paper compared typical websites in the UK and China and found that the content of the Chinese websites resulted in much larger files being transmitted around the network. Typical for similar websites is that the files could be up to 400% larger.

Traffic models were created to simulate the usage by one user and then scaled this by the number of users excepted during different times of the day. This enabled the performance of the wireless network to be investigated. The only way of analyzing this was to use a simulator. The OPNET Modeller was used to create infrastructure models for wired and wireless networks, both WiFi and WiMAX. The traffic model was then used to test out the infrastructure. It was found that the bandwidth available from an IEEE.11g network was a limiting factor in the network. When this was repeated with a WiMAX design then it was found that this was capable of handling a high level of traffic.

Limitations of this study include that it not always possible to obtain reliable information on the network usage on a campus and so the samples reviewed was limited to around 10. The models used were simplistic both for the devices and traffic. In these models only http traffic was considered, many kinds of packets such as, the video, FTP, voice etc were not considered.

Even taking into account all these limitation it does suggest that WiMAX does warrant further investigation.

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