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A Study on High Data Rate WLAN

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***Abstract*— The demands on WLANs for functionality and scalability are growing due to the rapid proliferation of new network devices and applications. Wired communication networks can provide the connectivity and performance but not mobility. WLAN provides the solution for portability with connection of mobility as well as performance. The increased demands for mobility and flexibility in our daily life are demands that lead the development from wired LANs to wireless LANs (WLANs). A wireless LAN is based on a cellular architecture where the system is subdivided into cells, where each cell (called Base service Set or BSS) is controlled by a Base station (called Access point or AP). This paper considers the problem of providing gbps user data-rate in indoor environments. To upgrade the data rate of WLANs, the IEEE presented the IEEE 802.11g standard for providing higher data rates up to 54 Mbps at the 2.4 GHz frequency band. In this paper, performance of IEEE 802.11g standard is described with respect to WLANs.**

***Keywords*— Bandwidth, Security, WLAN, WLAN Standards, AP.**

I. Introduction

As the deployment of Wireless LAN increase well around the globe, it is increasingly important for us to understand different technologies and select the most appropriate one. WLAN systems are a technology that can provide very high data rate applications and individual links (e.g. in company campus areas, conference centers, airports and in libraries) and represent an attractive way of setting up computers networks in environments where cable installation is expensive or not feasible. Wireless LANs can be broadly classified into two categories: ad hoc wireless LANs and wireless LANs with infrastructure**.** In ad hoc networks, several wireless nodes join together to establish a peer-to-peer communication. Each client communicates directly with the other clients within the network. Ad-hoc model is designed such that only the clients within transmission range (within the same cell) of each other can communicate. If a client in an ad-hoc network wishes to communicate outside of the cell, a member of the cell must operate as a gateway and perform routing. They typically require no administration. Networked nodes share their resource without a central server as shown in Fig 1.. In wireless LANs with infrastructure, there is a high-speed wired or wireless backbone. Wireless nodes access the wired backbone through access points. These access points allow the wireless node to share the available network resources efficiently. Prior to communicating data, wireless clients and access points must establish a relationship, or an association. Only after an association is established can the two wireless stations exchange data.

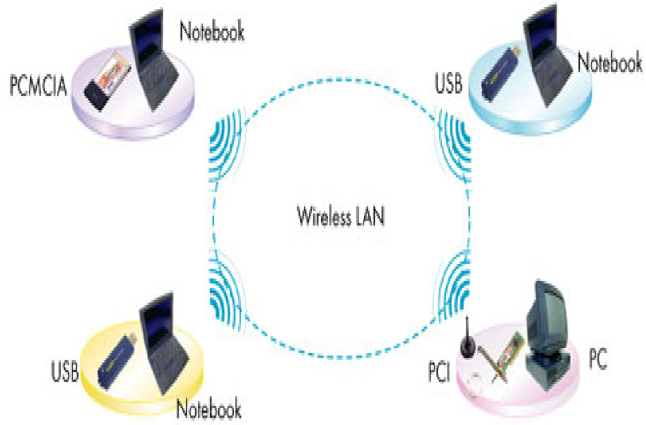

Fig.1 ad hoc wireless LANs

II. WLAN

A WLAN provides wireless network communication over short distance using radio or infrared signals instead of traditional network cabling. It is common for most users today to not only have a primary computing device but also at least one other smart device. Wireless operators have worked hard to accommodate the increased demand for data services over wireless networks as shown in fig.2

They have been forced to consider alternative offload strategies, including wirelessly connecting electronic devices (Wi-Fi). Unfortunately, the majority of smart phones being introduced into the marketplace only support Wi-Fi at 2.4 Gigahertz (GHz), which is rapidly increasing pressure on Wi-Fi designers and administrators to design products for the smallest segment of bandwidth available. Understanding the throughput requirements for this application and for other activities that will take place on the network will provide the designer with a per-user bandwidth goal. Multiplying this number by the number of expected connections yields the aggregate bandwidth that will be required.

A WLAN typically extends an existing wired local area network. WLANs are built by attaching a device called the access point (AP) to the edge of the wired network. Clients communicate with the AP using a wireless network adapter similar in function to a traditional Ethernet adapter. Network security remains an important issue for WLANs. Random wireless clients must usually be prohibited from joining the WLAN. Technologies like WEP raise the level of security on wireless networks to rival that of traditional wired networks.

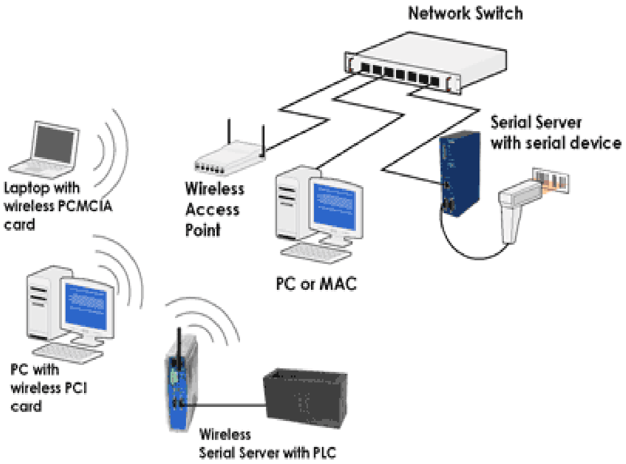

Fig.2 wireless LANs with infrastructure

III. WLAN STANDARDS

Some WLAN standards which we used in our research are:

a) IEEE 802.11
1. 802.11a
2. 802.11b
3. 802.11g
b) HiperLAN1/2
c) Bluetooth

3.1. IEEE 802.11 :

This initial standard specifies a 2.4 GHz operating frequency with data rates of 1 and 2 Mbps. With this standard, one could choose to use either frequency hopping or direct sequence (two non compatible forms of spread spectrum modulation). In late 1999, the IEEE published two supplements to the initial 802.11 standard: **802.11a** and **802.11b (Wi-Fi)**. The 802.11 working group is currently extend data rates in 2.4 GHz band to 54 Mbps using OFDM (orthogonal frequency division multiplexing), which is the **802.11g** standard.

3.1.1 802.11a

This is a physical layer standard in the 5 GHz radio band. It specifies eight available radio channels (in some countries, 12 channels are permitted). The maximum link rate is 54 Mbps per channel; maximum actual user data throughput is approximately half of that, and the throughput shared by all users of the same radio channel. The data rate decreases as the distance between the user and the radio access point increases. The 802.11a standard (High Speed Physical Layer in the 5 GHz Band) specifies operation in the 5 GHz band with data rates up to 54 Mbps. The advantages of this standard (compared to 802.11b, Higher Speed Physical Layer Extension in the 2.4 GHz Band) include having much higher capacity and less RF (radio frequency0 interference with other types of devices (e.g. Bluetooth), and products are just now becoming available throughout 2002.

3.1.2 802.11b

This is a physical layer standard in the 2.4 GHz radio band. It specifies three available radio channels. Maximum link rate is 11 Mbps per channel, but maximum user throughput will be approximately half of this because the throughput is shared by all users of the same radio channel. The data rate decreases as the distance between the user and the radio access point increase. One of more significant disadvantage of 802.11b is that the frequency band is crowded, and subject to interference from other networking technologies, microwaves ovens, 2.4 GHz cordless phones (a huge market), and Bluetooth (Wireless standards Up in the Air). There are drawbacks to 802.11b, including lack of interoperability with voice devices, and no QoS provision for multimedia content. Interference and other limitation aside, 802.11b is the clear leader in business and institutional wireless networking and is gaining share for home applications as well.

3.1.3 802.11g

Defines an additional modulation technique for 2.4 GHz band intended to provide speeds up to 54 Mbps. The different frequencies mean that 802.11a products aren't interoperable with the 802.11b base. To get around this, the IEEE developed 802.11g, which should extend the speed and range of 802.11b so that it's fully compatible with the older systems. The standards operates entirely in the 2.4 GHz frequency, but uses a minimum of two modes 9both mandatory) with two optional modes (Wireless Standards Up in the Air). The obvious advantage of 802.11g is that it maintains compatibility with 802.11b (and 802.11b's worldwide acceptance) and also offers faster data rates comparable with 802.11a. The number of channels available, however, is not increased, since channels are a function of bandwidth, not radio signal modulation.

3.2. HiperLAN1/2

European Telecommunication Standards Institute, ETSI, ratified in 1996 with High Performance Radio LAN (HiperLAN1) standard to provide high speed communications (20 Mbps) between portable devices in the 5 GHz range. Similarly to IEEE 802.11, HiperLAN1 adopts carrier sense multiple access protocol to connect end user devices together. Later, ETSI, rolled out in June 2000, a flexible Radio LAN standard called HiperLAN2, designed to provide high speed access (up to 54 Mbps at PHY layer) to a variety of networks including 3G mobile core networks, ATM networks and IP based networks, and also for private use as a wireless LAN system HiperLAN2 has a very high transmission rate up to 54 Mbps. This is achieved by making use of Orthogonal Frequency Digital Multiplexing (OFDM).

3.3. Bluetooth

Bluetooth is an industry specification for short-range RF-based connectivity for portable personal devices with its functional specification released out in 1999 by Bluetooth Special Interest Group. Bluetooth communicates on a frequency 2.45 GHz, which has been set aside by international agreement for the use of industrial, scientific and medical devices (ISM). One of the ways Bluetooth devices should avoid interfering with other systems is by sending out very weak signals of 1 mill watt. The low power limits the range of a Bluetooth device to about 10 meters, cutting the chances of interference between a computer system and a portable telephone or television.

Fig.3 Bluetooth Technology

IV. WLAN CONCEPTS

4.1 Throughput versus data rate

The data rate of a signal is based on the time it takes to send information and overhead data bits when transmitting. Therefore, the aggregate data rate (throughput) is actually much lower because of delays between transmissions. Data rate mostly affects the delay performance of a WLAN. The higher the data rate, the lower the delay when sending data rates can increase the capability to support a larger number of users. Actual throughput is much better indicator of the performance of a WLAN because it provides an indication of the time it takes to send information. Throughput is the flow of information over time. The throughput is always less than the data rate. Throughput, however, provides a more accurate representation of the delays that users experience because they are concerned with how fast information is sent, not 802.11 frames. It is possible to have a very high 802.11 data rate and still have throughput that is relatively low.

4.2 Data Rate settings

If you need to deploy a high-performance WLAN, consider configuring data rate settings to higher fixed values. This forces operation at a higher specific data rate and avoids transmissions at lower data rates, which would negatively impact overall performance. Just keep in mind, however, that using higher data rate settings will significantly reduce range. As a result, you must configure the data rate settings in client radios (which might not be feasible) to realize benefits of using higher fixed data rate settings to improve performance.

4.3 Signal Coverage

As the basis for providing good performance, it is important to have adequate signal coverage throughout the required coverage areas. In areas that have weak signal coverage, the signal level and corresponding SNR will be relatively low. The 802.11 radios might still be able to decode the signals and successfully communicate, but the data rate may be fairly low.

4.4 Bandwidth Control Mechanisms

To provide consistent performance for all users, it might be necessary to implement bandwidth control mechanisms, which divides the total capacity of the network into smaller sizes made available to each user. For example as shown in Figure 11-13 (case without bandwidth control), a signal user (client device A) may download a very large file that requires a few minutes (or even hours), consuming nearly all the capacity of the network. As a result other users, such as client B and C may have very little if no throughput. This uncontrolled use of the network can aggravate users and significantly reduce the effectiveness of the network. A solution to this is to use bandwidth control and configure the access points (or other applicable components) to provide each user a throughput limit, such as 250 Kbps each. This level of performance based on the total users and utilization of the network, forces user to share total capacity of the WLAN in a manner that ensures sufficient performance for everyone.

V. ISSUES OVER WIRELESS LAN

Since wireless devices need to be small and wireless networks are bandwidths limited, some of the key challenges in wireless networks are:

a) Data Rate Enhancements.
b) Low Power networking
c) Security
d) Radio Signal Interference

5.1 Enhancing Data Rate

Improving the current data rates to support future high speed applications is essential, especially, if multimedia services are to be provided a function of various factors such as the data compression algorithm, interference mitigation through error-resilient coding, power control, and the data transfer protocol. Therefore, it is imperative that manufacturers implement a well thought out design that considers these factors in order to achieve higher data rates.

5.2 Low Power Design

The size and battery power limitation of wireless mobile devices place a limit on the range and throughput that can be supported by a wireless LAN. The complexity and hence the power consumption of wireless devices vary significantly depending on the kind of spectrum technology being used to implement the wireless LAN. Normally, direct sequence spread spectrum (DSSS) based implementations require large and power-hungry hardware compared to frequency hopped spread spectrum (FHSS).

5.3 Security

Mobility of users increases the security concerns in a wireless network. Current wireless networks employ authentication and data encryption techniques on the air interface to provide security to its users. The IEEE 802.11 standard describes wired equivalent privacy (WEP) that defines a method to authenticate users and encrypt data between the PC card and the wireless LAN access point. In large enterprises, an IP network level security solution could ensure that the corporate network and proprietary data are safe. Virtual private network (VPN) is an option to make access to fixed network reliable. Since hackers are getting smarter, it is imperative that wireless security features must be updated constantly.

5.4 Radio Signal Interference

Interference can take on an inward or outward direction. A radio-based LAN, for example, can experience inward interference either from the harmonics of transmitting systems or from other products using similar radio frequencies in the local area. Microwave ovens operate in the S band (2.4 GHz) that many wireless LANs use to transmit and receive. These signals result in delays to the user by either blocking transmissions from stations on the LAN or causing bit errors to occur in data being sent. Newer products that utilize Bluetooth radio technology also operate in the 2.4 GHz band and can cause interference with wireless LANs, especially in fringe areas not well covered by a particular wireless LAN access point.

VI. APPLICATIONS

When computers were first built, only large universities and corporations could afford them. Today we may find 3 or 4 personal computers in our neighbor's house. Wireless LANs have taken a similar path, first used by large enterprises, and now available to us all at affordable prices. As a technology, wirelesses LANs have enjoyed a very fast adoption rate due to the many advantages they offer to a variety of situations.

6.1 Access Role

Wireless LANs are deployed in an access layer role, meaning that they are used as an entry point into a wired network. In the past, access has been defined as dial-up, ADSL, cable, cellular, Ethernet, Token Ring, Frame Relay, ATM etc. as in Fig. 4

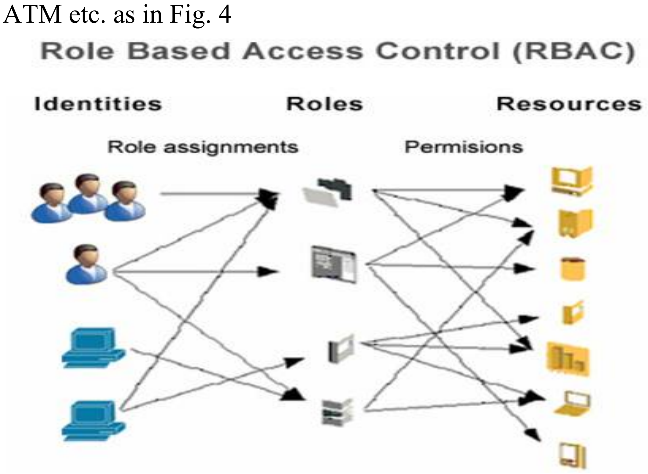

Fig.4 Access Role

6.2 Network Extension

Wireless networks can serve as an extension to a wired network. There may be cases where extending the network would require installing additional cabling that is cost prohibitive. You may discover that hiring cable installers and electricians to build out a new section of office space for the network is going to cost tens of thousands of rupees. Or in the case of a large warehouse, the distances may be too great to use category 5 cable for the Ethernet network in Fig 5.

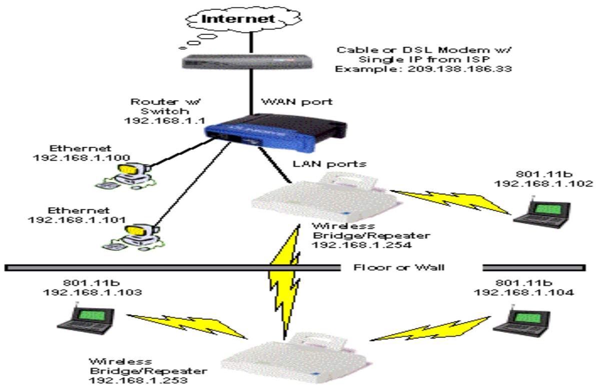

Fig.5 Network Extension

6.3 Building-to-Building Connectivity

In a campus environment, there may be a need to have the network users in each of the different buildings have direct access to the same computer network. Using wireless LAN technology, equipment van be installed easily and quickly to allow two or more buildings to be part of the same network without the expense of leased lines or the need to dig up the ground between buildings. With the proper wireless antennas, any number of buildings can be linked together on the same network. Point-to-multipoint links are wireless connections between three or more buildings, typically implemented in a hub-n-spoke fashion, where one building is the central focus point of the network. This central building would have the core network, internet connectivity, and the server farm as shown in fig. 6

Fig.6 Building to building Connectivity

6.4 Mobility

As an access layer solution, wireless LAN cannot replace wired LANs in terms of data rates (100BT at 100 Mbps versus IEEE 802.11a at 54 Mbps). Wireless connectivity has also eliminated the need for such user devices to be connected using wires that would otherwise get in the way of the users. Some of the new wireless technologies allow users to roam, or move physically from one area of wireless coverage to another without losing connectivity, just as a mobile telephone customer is able to roam between cellular coverage areas. In larger organizations, where wireless coverage spans large areas, roaming capability had significantly increased the productivity of these organizations, simply because users remain connected to the network away from their main workstations as shown in fig. 7

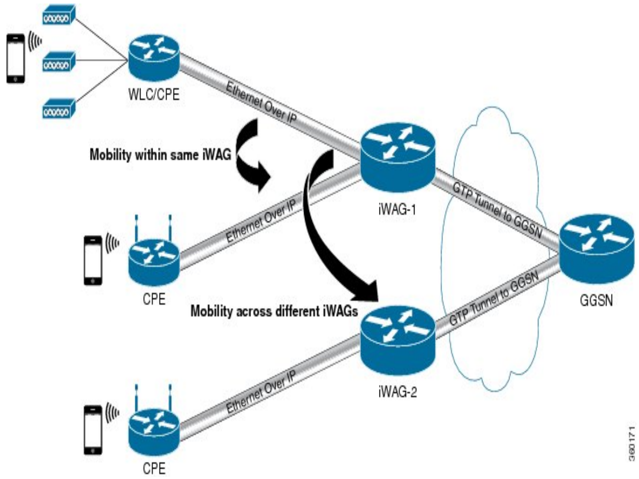

Fig.7 Mobility

VII. ALLOCATION ALGORITHMS

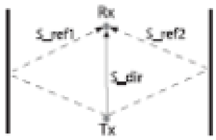

Fig. 8. Signal power consists of direct signal and first order reflections.

Data rate is highly dependent on the signal to interference and noise ratio which can be computed by SINR = S/I+N. where S is the signal, I is the interference and N is the noise. Because of high attenuation of 60GHz, there are only two significant contributions to the received power. One is the direct signal, Sdir, and the other is first order reflection, Sref which is shown in figure 1. These signals reach the user via different paths (by reflecting on different obstructions). For example, in the figure, there are two obstructions that cause two first order reflections Sref1 and Sref2 (dotted line). The signal power at the receiver side becomes Sdir+Sref1+Sref2. In general, it can be calculated using the follow equations:

$$S = S_{dir} + \sum S_{ref} \quad (1)$$

$$S_{dir}[db] = P_t[db] + G_t[db] + G_r[db] - 10log_{10}(\frac{\lambda}{4\pi d})^2 - TL[db] \quad (2)$$

$$S_{ref}[db] = P_t[db] + G_t[db] + G_r[db] - 10log_{10}(\frac{\lambda}{4\pi d})^2 - RL[db \quad (3$$

where Pt is the transmission power, Gt,Gr are the transmitter and receiver antenna gain respectively and TL is the transmission loss if the transmitter and receiver do not have line of sight (LOS). TL depends on the material of the obstruction. If there are multiple obstructions, TL will be the sum of all transmission losses. RL is the reflection energy loss which is also material dependent. Note that interference I is the sum of unwanted energy from all interferes. This unwanted energy reduces the SINR. Let Ijk indicates the interference between uj and uk (if uj and uk are in different frequency channel, Ijk = 0). In this paper, we develop algorithms that dynamically assign users to channel and time slots. The channel as well as time slots can be of variable length. Figure 2 shows an example of an assignment. Multiple users can be assigned to the same channel cp and time slot tp , to form a user set denoted as Ul,p In the example, users u1, u2, u3 are in the set U1,1. Note that different users in the same slot may have a different SINR.

	t1	t2	...
f1	u1,u2,u3	u7	...
f2	u4,u6	u5	...

Fig. 2. Example of an assignment

Next we decide how much bandwidth should be allocated to frequency channels 1 and 2 and the length of the different time slots such that the total throughput is maximized while maintaining 1Gbps rate at each user. Let ri, j be the minimum user data rate in set Ui,j . Then we can calculate the ratio $ratio_{i,j} = \frac{\prod_{k,l} r_{k,l}}{r_{i,j}}$ nd calculate the corresponding time length by $time_{i,j} = \frac{ratio_{i,j}}{\sum_{k,l} ratio_{k,l}}$.To maximize the throughput, we find the set which has the maximum data rate (i.e. sum of data rate of all users in the same set) within the same time slot. Then we calculate the minimum bandwidth required for the remaining sets using $W_{min} = \frac{1Gbps}{rate \times timeLen} \times 640MHz.$ Rate is the minimum data rate of user in the set and timeLen is the assigned time slot length in second. If the bandwidth for some set is b < 640MHz, we reassign the difference (640 − b)MHz to another user set so as to maximize total system throughput.

A. Greedy - SINR threshold based algorithm

In the greedy approach, the idea is that if the total interference at ui initially is large, then ui is more likely to have high interference with other users. On the other hand, if the total interference is small, then we can allocate it with other users in the same frequency channel since it will have less interference. Let r define a SINR threshold - the users' SINR should not fall below this threshold. The following is the algorithm outline:

1) Sort the users in a list by the sum of the interference, i.e. $\sum_j I_{ij}$ for u_i for greedy.
2) Set the current time slot to t1.
3) Set the current frequency channel to c1.
4) Set the current group to g1. Each group is assigned the current time slot and frequency channel.
5) Assume each user i is associated with an interference meter IMi which indicates the interference after the assignment. This value is initially set to zero.
6) Start with the first user up in the list (with smallest total interference value).
7) Pick the antenna (say aij) with the strongest signal. Note that in each time slot, each antenna can only be assigned to M users since M is the number of modules per antenna. If no antenna is available, increment time slot, increment group count and reset the frequency channel. Assign the

current time slot and frequency channel to the current group. Now check the following:

• Pick the first user assigned in the current group (say uk)

• Calculate the SINR > if up is assigned to this group. Note that the interference will be IMp+Ipk.

• Repeat these steps until all users in the group are checked. If all have passed the check, return true, otherwise return false.

8) If the previous step returns true, up is assigned to the current group. Update the all IMi with IMi + Iip for all i in the current group and IMp with the sum of interference with the user in the group. Repeat step 6 until all users are assigned.

9) Otherwise, assign the user to a different group.

10) Increment the current group count.

11) Increment the frequency channel count.

12) Assign up to the current group. Repeat step 6 until all users are assigned.

B. Greedy Dynamic decision based algorithm

The initial list of users is similar to the previous section. However, we do not set a fixed threshold to determine how high SINR should be for each user to be sharing the same channel. Instead, we compare the benefit of putting them in a group or not and pick the best case. For example, assume we only have one frequency channel and two users (ui, uj). Let rsi and rsj be the rate if we assigned them to the same frequency channel be rdi, rdj otherwise. However, in this case, we only have one channel which means they have to be in different time slots. Assume fixed time slot assignment, i.e. the rate is divided by two. rdi will be greater than rsi because of low interference. But rdi/2 > rsi may not be true. We therefore compare the total data rate and pick the best case. Let's define this decision making as F(gi, uk), where gi is the group and uk is the user for whom we need to decide to be in this group or not. It returns 1 if it will be assigned to the same group, otherwise 0.

1) Sort the users in a list by the sum of the interference, i.e. Pj Iij for ui for greedy.
2) Set the current time slot to t1.
3) Set the current frequency channel to c1.
4) Set the current group to g1. Each group is assigned the current time slot and frequency channel.
5) Assume each user i is associated with an interference meter IMi which indicates the interference after the assignment. This value is initially assigned to zero.
6) Start with the first user up in the list (with smallest total interference value).
7) Pick the antenna (say aij) with the best signal. Note that in each time slot, each antenna can only be assigned to M users if M is the number of modules per antenna. If no antenna is available, increment the time slot, increment the group count and reset frequency channel. Assign the current time slot and frequency channel to the current group.
8) If F(g, up) returns 1, up is assigned to the current group. Update all IMi with IMi + Iip for all i in the current group and IMp with the sum of interference with the user in the group. Repeat step 6 until all users are assigned.
9) Otherwise, it is to assigned to a different group.
10) Increment the current group count.
11) Increment the frequency channel count.
12) Assign the up to the current group. Repeat step 6 until all users are assigned.

VIII. Conclusion

A number of wireless LAN standards discussed above for deployment enlisting of others. This paper will help us in understanding the capabilities the WLAN. 802.11a is found to be 3.3 to 4.1 times faster than 802.11b as measured by file transfer times in both ad hoc and infrastructure modes.Our algorithms provide high data rate per user with high bandwidth efficiency for the 60GHz ISM band. Using the special properties of this band, we develop very efficient SDMA algorithms. The algorithms dynamically partition the bandwidth into variable length slots to achieve these high data rates. The experimental results show that the average data rate falls smoothly when the number of users increase, thus showing graceful degradation with loading.

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