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A Robust Analysis of Dual-Band Wireless LAN (4G-WLAN) for Effective Internet Access: A Review Paper

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Abstract

This paper presents the findings of a comprehensive study of dual-band WLAN for internet access. It gives an exposition of the architecture of the 4G-WLAN routers which is a more advanced and the latest technology that uses Adaptive Modulation and Coding (AMC) to dynamically react to channel fluctuations while maintaining bit-error rate targets of the transmission. It also x-rays the part played by the internet service providers (ISP), the access providers (i.e. Dial-up, DSL, Satellite and fibre optics) which are responsible for high data throughput and cost of connection. This paper also discusses the IP addressing methods of the connected devices (i.e. BOOTP and DHCP) which depict the Transmission Control Protocol/Internet Protocol (TCP/IP) of the network. The system clearly provides added convenience of Internet access and the extent of mobility the wireless routers can bring to computer networks and users. This technology provides a platform for future expansion.
Keywords— Dual-Band WLAN, 4G-WLAN Router, AMC, Internet access provider, Data throughput, TCP/IP, Access provider

1.0 Introduction

An application of dual band routers has been suggested in recent years for wireless local area network communications systems in order to overcome the problem of speed and limited channel bandwidth, thereby satisfying an ever growing demand for a large number of users to freely access to the internet. It has been shown by many studies in [1] that when dual band devices are appropriately used for internet access as opposed to single band routers in a wireless communication system, it helps in improving the system performance by increasing channel capacity, speed, range of coverage and efficiency. Wireless mobile communications systems are uniquely identified by “generation” designations, and have sequentially evolved from the first-generation (1G) to the fourth-generation (4G) systems [2]. The 1G systems were marked by analogue frequency modulation and the basic cellular structure of mobile communication hence were used primarily for voice communications.

The 2G systems designed in the 1980s were still used mainly for voice applications but were based on digital technology, including digital signal processing techniques. These systems provided circuit-switched data communication services at a low speed. The competitive rush to design and implement digital systems led again to a variety of different and incompatible standards such as GSM (global system mobile), TDMA (time division multiple access); PDC (personal digital cellular) and CDMA (code division multiple access).These systems operate nationwide or internationally and are today's mainstream systems, although the data rate for users in these system is very limited. There after came another wireless system that goes by the name of 2.5G an "in-between" service that serves as a stepping stone to 3G. The 2.5G system is usually identified as being "fuelled" by General Packet Radio Services (GPRS) along with GSM. It is basically an enhancement of the 2G technologies to provide increased capacity on the 2G RF (radio frequency) channels and to introduce higher throughput for data service, up to 384 kbps. It introduces access to the Internet from mobile devices, whether telephone, PDA (personal digital assistant), or laptop. The 3G systems, made their appearance in late 2002 and in 2003, and were designed for voice and paging services, as well as interactive-media use such as teleconferencing, Internet access, and other services in [1]. The problem with 3G wireless systems is bandwidth, these systems provide only WAN coverage ranging from 144 kbps (for vehicle mobility applications) to 2 Mbps (for indoor static applications). Segue to 4G, the "next dimension" of wireless communication. The 4G wireless uses Orthogonal Frequency Division Multiplexing (OFDM), Ultra Wide Radio Band (UWB), and Millimeter wireless and smart antenna. Data rate of 20Mbps is employed. Mobile speed will be up to 200km/hr. Frequency band is 2-8 GHz and it gives the ability for world-wide roaming to access cell anywhere. However, the demand for higher access speed multimedia communication in today's society, which greatly depends on computer communication in digital format, still seems unlimited. Section 2.0 of this paper briefly discussed the literature review of network specifications and standards mechanism through which WLAN signals are built. The features of the 4G WLAN were explained in section 3.0. Section 4.0 narrates the comparative analysis of the generation’s of the WLAN while section 5.0 clearly explains the configurable architecture of the 4G WLAN. The technologies employed in the 4G WLAN including the smart antennas that operates with Multi-input and Multi-output system were clearly enumerated in section 6.0. The performance analysis of the 4G WLAN and results were stated in section 7.0. Finally, the conclusions are enumerated in section 8.0.

2.0 Literature Review of Network Specifications and Standards

IEEE 802.11

In 1997, the Institute of Electrical and Electronics Engineers (IEEE) in [3] created the first WLAN standard. They called it 802.11 after the name of the group formed to oversee its development. Unfortunately, 802.11 only supported a maximum network bandwidth of 2 Mbps - too slow for most applications. For this reason, ordinary 802.11 wireless products are no longer manufactured.

IEEE 802.11b

IEEE expanded on the original 802.11 standard in July 1999, creating the 802.11b specification. 802.11b supports bandwidth up to 11 Mbps, comparable to traditional Ethernet.

802.11b uses the same unregulated radio signalling frequency (2.4 GHz) as the original 802.11 standard. Vendors often prefer using these frequencies to lower their production costs. Being unregulated, 802.11b gear can incur interference from microwave ovens, cordless phones, and other appliances using the same 2.4 GHz range. However, by installing 802.11b gear a reasonable distance from other appliances, interference can easily be avoided.

- Pros of 802.11b - lowest cost; signal range is good and not easily obstructed
- Cons of 802.11b - slowest maximum speed; home appliances may interfere on the unregulated frequency band.

IEEE 802.11a

While 802.11b was in development, IEEE created a second extension to the original 802.11 standard called 802.11a. Because 802.11b gained in popularity much faster than did 802.11a, some folks believe that 802.11a was created after 802.11b. In fact, 802.11a was created at the same time. Due to its higher cost, 802.11a is usually found on business networks whereas 802.11b better serves the home market.

802.11a supports bandwidth up to 54 Mbps and signals in a regulated frequency spectrum around 5 GHz. This higher frequency compared to 802.11b shortens the range of 802.11a networks. The higher frequency also means 802.11a signals have more difficulty penetrating walls and other obstructions.

Because 802.11a and 802.11b utilize different frequencies, the two technologies are incompatible with each other. Some vendors offer hybrid **802.11a/b** network gear, but these products merely implement the two standards side by side (each connected devices must use one or the other).

- Pros of 802.11a - fast maximum speed; regulated frequencies prevent signal interference from other devices
- Cons of 802.11a - highest cost; shorter range signal that is more easily obstructed.

IEEE 802.11g

In 2002 and 2003, WLAN products supporting a newer standard called 802.11g emerged on the market. 802.11g attempts to combine the best of both 802.11a and 802.11b [3]. The 802.11g supports bandwidth up to 54Mbps, and it uses the 2.4 GHz frequency for greater range. 802.11g is backwards compatible with 802.11b, meaning that 802.11g access points will work with 802.11b wireless network adapters and vice versa.

- Pros of 802.11g - fast maximum speed; signal range is good and not easily obstructed
- Cons of 802.11g - costs more than 802.11b; appliances may interfere on the unregulated signal frequency

IEEE 802.11n

The newest IEEE standard in the Wi-Fi category is 802.11n. It was designed to improve on 802.11g in the amount of bandwidth supported by utilizing multiple wireless signals and antennas (called MIMO technology) instead of one.

802.11n connections should support data rates of over 100 Mbps. 802.11n also offers somewhat better range over earlier Wi-Fi standards due to its increased signal intensity. 802.11n equipment will be backward compatible with 802.11g gear.

- Pros of 802.11n - fastest maximum speed and best signal range; more resistant to signal interference from outside sources
- Cons of 802.11n - costs more than 802.11g; the use of multiple signals may greatly interfere with nearby 802.11b/g based networks.

Apart from these four general-purpose Wi-Fi standards, several other related wireless network technologies exist.

- Other IEEE 802.11 working group standards like 802.11h and 802.11j are extensions or offshoots of Wi-Fi technology that each serves a very specific purpose.
- Bluetooth is an alternative wireless network technology that followed a different development path than the 802.11 family. Bluetooth supports a very short range (approximately 10 meters) and relatively low bandwidth (1-3 Mbps in practice) designed for low-power network devices like handhelds and laptops. The low manufacturing cost of Bluetooth hardware also appeals to industry vendors. You can readily find Bluetooth in the networking of PDAs or cell phones with PCs, but it is rarely used for general-purpose WLAN networking due to the range and speed considerations.
- WiMax also was developed separately from Wi-Fi. WiMax is designed for long-range networking (spanning miles or kilometers) as opposed to local area wireless networking [4].

3.0 Features of a 4G WLAN

This new generation of wireless is intended to complement and replace the 3G systems, below are few features of a 4G WLAN:

- Support for interactive multimedia, voice, streaming video, Internet and other broadband services
- IP version 6.0 based mobile system
- High speed, high capacity and low cost-per-bit
- Global access, service portability and scalable mobile services
- Seamless switching and a variety of Quality of Service-driven services
- Better scheduling and call-admission-control techniques
- Ad-hoc and multi-hop networks (the strict delay requirements of voice make multi-hop network service a difficult problem)
- Better spectral efficiency
- Seamless network of multiple protocols and air interfaces (since 4G will be all-IP, look for 4G systems to be compatible with all common network technologies, including 802.11, WCDMA, Bluetooth, and Hyper LAN).
- An infrastructure to handle pre-existing 3G systems along with other wireless technologies, some of which are currently under development [5].

4.0 Comparative Analysis of Generation's of WLAN

Technology	1G	2G	2.5G	3G	4G
Design Began	1970	1980	1985	1990	2000
Implementation	1984	1991	1999	2002	2010?
Service	Analog voice, synchronous data to 9.6 kbps	Digital voice, short messages	Higher capacity, packetized data	Higher capacity, broadband data up to 2 Mbps	Higher capacity, completely IP-oriented, multimedia, data to hundreds of megabits
Standards	AMPS, TACS, NMT, etc.	TDMA, CDMA, GSM, PDC	GPRS, EDGE, 1xRTT	WCDMA, CDMA2000	Single standard
Data Bandwidth	1.9 kbps	14.4 kbps	384 kbps	2 Mbps	200 Mbps
Multiplexing	FDMA	TDMA, CDMA	TDMA, CDMA	CDMA	CDMA?
Core Network	PSTN	PSTN	PSTN, packet network	Packet network	Internet

Legend:

1xRTT = 2.5G CDMA data service up to 384 kbps
AMPS = advanced mobile phone service
CDMA = code division multiple access
EDGE = enhanced data for global evolution
FDMA = frequency division multiple access
GPRS = general packet radio system
GSM = global system for mobile
NMT = Nordic mobile telephone
PDC = personal digital cellular
PSTN = pubic switched telephone network
TACS = total access communications system
TDMA = time division multiple access
WCDMA = wideband CDMA

5.0 The Architecture of 4G WLAN

The goal of 4G is to replace the current proliferation of core mobile networks with a single worldwide core network standard, based on IP for control, video, packet data, and voice. This will provide uniform video, voice, and data services to the mobile host, based entirely on IPV6 addressing. The layers that constitute the architecture of the 4G WLAN is expressly shown in Fig. 1 below.

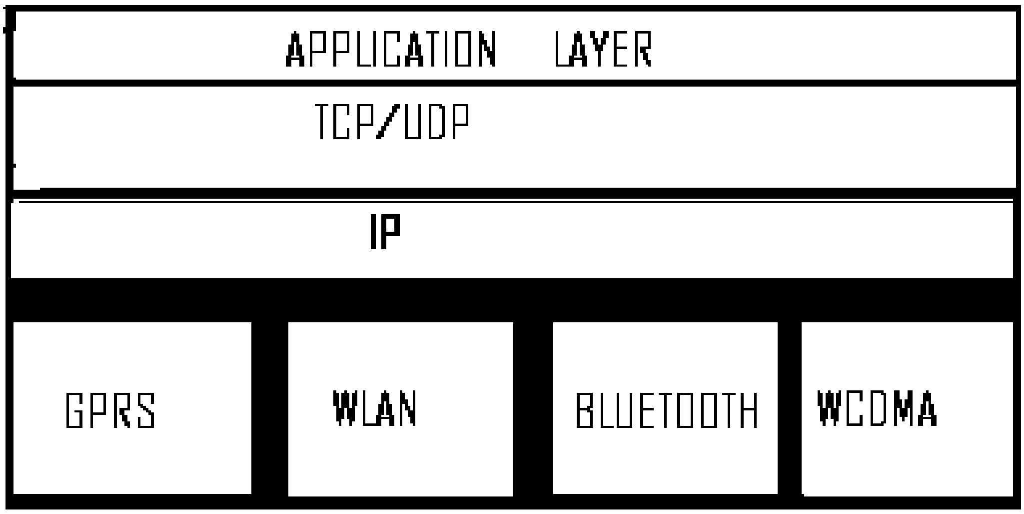

Fig. 1: The Layers of the Architecture of 4G WLAN

The objective is to offer seamless multimedia services to users accessing all IP based infrastructures through heterogeneous access technologies. IP is assumed to act as an adhesive for providing global connectivity and mobility among networks. An all IP-based 4G wireless network has inherent advantages over its predecessors. It is compatible with, and independent of the underlying radio access technology. An IP wireless network replaces the old Signalling System 7 (SS7) telecommunications protocol, which is considered massively redundant. This is because SS7 signal transmission consumes a larger part of network bandwidth even when there is no signalling traffic for the simple reason that it uses a call setup mechanism to reserve bandwidth, rather time or frequency slots in the radio waves. IP networks, on the other hand, are connectionless and use the slots only when they have data to send. Hence there is optimum usage of the available bandwidth. Today, wireless communications are heavily biased toward voice, even though studies indicate that growth in wireless data traffic is rising exponentially relative to demand for voice traffic. Because an all IP core layer is easily scalable, it is ideally suited to meet this challenge. The goal is a merged of data, voice, video and multimedia network [6]. There is absolute perfect convergence with the use of wireless 4G LAN with its internet services.

6.0 Technologies Used in 4G WLAN

A. IP Addressing and DHCP

The Internet is a vast source of information that is continuously updated and accessed via computers and other devices. For a host (device) to connect to the Internet, it is necessary that among other configurations, it must have an Internet Protocol (IP) address [3] & [6]. The IP address is the computer's address on the Internet. A common comparison of an IP address is an individual's telephone number, which is an identifier for people to communicate with the individual. From the late 1980s, configuring a computer to connect to the Internet was a manual process. The protocol Bootstrap Protocol (BOOTP) was the first Transmission Control Protocol/Internet Protocol (TCP/IP) network configuration tool used to prevent the task of having to manually assign IP addresses by automating the process. While the introduction of the BOOTP network protocol was a welcome innovation for network administrators tasked with managing large numbers of computers on a network, it was the first attempt and a new and improved TCP/IP network protocol soon followed. This protocol is called Dynamic Host Configuration Protocol (DHCP). DHCP was not designed as a replacement for BOOTP, but an extension of its functionality.

B. How DHCP Works?

As its name indicates, DHCP provides dynamic IP address assignment. What this means is that instead of having to rely on a specific IP address, a computer will be assigned one that is available from a subnet or "pool" that is assigned to the network. DHCP also extends BOOTP functionality to provide IP addresses that expire. BOOTP indirectly uses a form of leasing that never expired, but the term wasn't actually used until the introduction of DHCP. When DHCP assigns an IP address of version 6.0, it actually leases the identifier to the host computer for a specific amount of time. The default lease is five days, but a network administrator should evaluate their own particular circumstances to determine an appropriate lease [7].

In basic terms, the DHCP lease process works as follows:

- A network device attempts to connect to the Internet.
- The network requests an IP address with the current version 6.0.
- The DHCP server allocates (leases) the network device an IP address, which is forwarded to the network by a router.
- DHCP updates the appropriate network servers with the IP address and other configuration information.
- The network device accepts the IP address.
- The IP address lease expires.
- DHCP either reallocates the IP address or leases one that is available.
- The network device is no longer connected to the Internet.
- The IP address becomes an available address in the network pool of IP addresses with a standing figure of 2^{128}=3.4028 x 10^{38} in [12].

To set up DHCP, you basically need a DHCP - supported client (at least one) and router, and a DHCP server. The client is a computer or other device on a network that requires an IP address and or other network configuration information. The router functions as a forwarding (or routing) agent of IP address requests from the DHCP server. The DHCP server is key infrastructure to the entire operation of the 4GWLAN. It is responsible for allocating, leasing, reallocating, and renewing IP addresses. However, Windows and Linux both support DHCP software [8].

C. Ultra Wide Band

An Ultra Wide Band (UWB) transmitter spreads its signal over a wide portion of the RF spectrum, generally 1 GHz wide or more, above 3.1GHz [2]. The FCC has chosen UWB frequencies to minimize interference to other commonly used equipment, such as televisions and radios. This frequency range also puts UWB equipment above the 2.4 GHz range of microwave ovens and modern cordless phones, but below 802.11a wireless Ethernet, which operates at 5 GHz. Ultra Wide Band equipment transmits very narrow RF pulses, low power and short pulse period, although of wide bandwidth. This means the signal falls below the threshold detection of most RF receivers. Traditional RF equipment uses an RF carrier to transmit a modulated signal in the frequency domain, moving the signal from a base band to the carrier frequency the transmitter uses. Ultra Wide Band is "carrier-free", since the technology works by modulating a pulse, on the order of tens of microwatts, resulting in a waveform occupying a very wide frequency domain. The wide bandwidth of a UWB signal is a two-edged sword. The signal is relatively secure against interference and has the potential for very high-rate wireless broadband access and speed. On the other hand, the signal also has the potential to interfere with other wireless transmissions. In addition, the low-power constraints placed on UWB by the FCC, due to its potential interference with other RF signals, significantly limits the range of UWB equipment (but still makes it a viable LAN technology). One distinct advantage of UWB is its immunity to multi-path distortion and interference. Multi-path propagation occurs when a transmitted signal takes different paths when propagating from source to destination. The various paths are caused by the signal bouncing off objects between the transmitter and receiver for example, furniture and walls in a house, or trees and buildings in an outdoor environment. One part of the signal may go directly to the receiver while another; deflected part will encounter delay and take longer to reach the receiver. Multi-path delay causes the information symbols in the signal to overlap, confusing the receiver, this is known as inter-symbol interference (ISI). Due to the fact that the signal's shape conveys transmitted information, the receiver will make mistakes when demodulating the information in the signal. For long-enough delays, bit errors in the packet will occur since the receiver can't distinguish the symbols and correctly interpret the corresponding bits. The short time-span of UWB waveforms typically hundreds of picoseconds to a few nanoseconds means that delays caused by the transmitted signal bouncing off objects are much longer than the width of the original UWB pulse, virtually eliminating ISI from overlapping signals. This makes UWB technology particularly useful for intra-structure and mobile communications applications, minimizing Signal-to-Noise reduction and bit errors [9].

D. Millimeter Wireless Operation

Using the millimeter wave band (above 20 GHz) for wireless service is particularly interesting, due to the availability in this region of bandwidth resources committed by the governments of some countries to unlicensed cellular and other wireless applications [2]. If deployed in a 4G system, millimeter wireless would constitute only one of several frequency bands, with the 5 GHz band most likely dominant.

Smart Antennas: A smart antenna system comprises multiple antenna elements with signal processing to automatically optimize the antennas' radiation (transmitter) and/or reception (receiver) patterns in response to the signal environment. The configuration of this smart antenna is shown in fig. 2 below. One smart-antenna variation in particular, MIMO (Multi-Input Multi-Output), shows promise in 4G systems, particularly since the antenna systems at both transmitter and receiver are usually a limiting factor when attempting to support increased data rates [3].

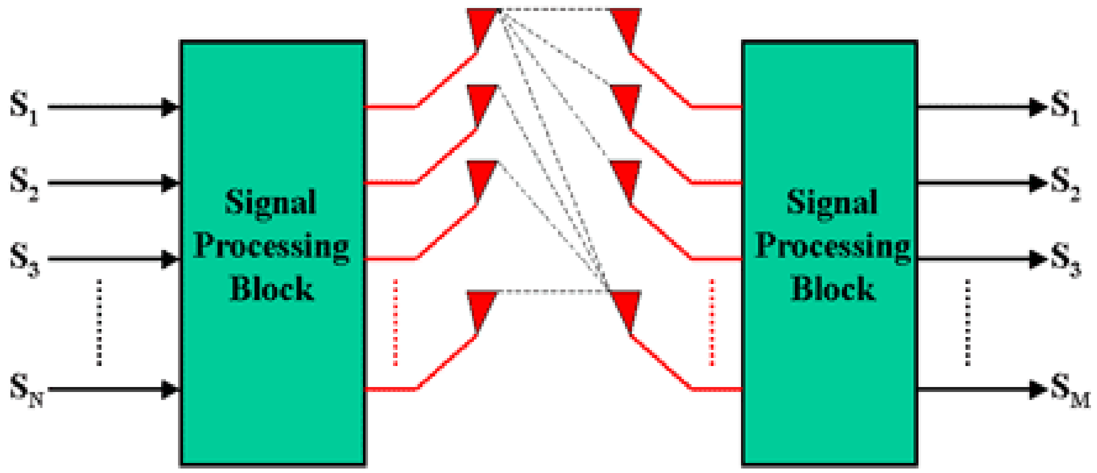

Fig. 2: The Configuration of a Smart Antenna.

MIMO (Multi-Input Multi-Output) is a smart antenna system where 'smartness' is considered at both transmitter and the receiver. MIMO represents Space-Division Multiplexing (SDM)—information signals are multiplexed on spatially separated N multiple antennas and received on M antennas. Figure 2 shows a general block diagram of a MIMO system. Some systems may not employ the signal-processing block on the transmitter side. Multiple antennas at both the transmitter and the receiver provide essentially multiple parallel channels that operate simultaneously on the same frequency band and at the same time. This results in high spectral efficiencies in a rich scattering environment (high multi-path), since you can transmit multiple data streams or signals over the channel simultaneously. Field experiments by several organizations have shown that a MIMO system, combined with adaptive coding and modulation, interference cancellation, and beam-forming technologies, can boost useful channel capacity by at least an order of magnitude.

E. Long Term Power Prediction

Channels to different mobile users will fade independently. If the channel properties of all users in a cell can be predicted a number of milliseconds ahead, then it would be possible to distribute the transmission load among the users in an optimal way while fulfilling certain specified constraints on throughput and delays. The channel time-frequency pattern will depend on the scattering environment and on the velocity of the moving terminal.

In order to take the advantage the channel variability, we use OFDM system with spacing between sub-carries such that no inter-channel interface occurs for the worst case channel scenario (Low coherence bandwidth). A time-frequency grid constituting of regions of one time slot and several sub-carriers is used such that the channel is fairly constant over each region. These time-frequency regions are then allocated to the different users by a scheduling algorithm according to some criterion.

F. Scheduling Among Users

To optimize the system throughput [9], under specified quality of service (QOS) requirements and delay constraints, scheduling will be used on different levels:

Among sectors: In order to cope with co-channel interference among neighbouring sectors in adjacent cells, time slots are allocated according to the traffic load in each sector .Information on the traffic load is exchanged infrequently via an inquiry procedure. In this way the interference can be minimized and higher capacity be obtained. After an inquiry to adjacent cells, the involved base stations determine the allocation of slots to be used by each base station in each sector. The inquiry process can also include synchronization information to align the transmission of packets at different base stations to further enhance performance.

Among users: Based on the time slot allocation obtained from inquiry process, the user scheduler will distribute time-frequency regions among the users of each sector based on their current channel predictions. Here different degrees of sophistication can be used to achieve different transmission goals.

7.0 Performance Analysis of a 4G WLAN

A. Mobility Management

Mobility Management in [8] includes location registration, paging and handover. The Mobile Transceivers (MTs) should be able to access the services at any place possible. The global roaming can be achieved with the help of multi-hop networks that can include the WLANs or the satellite coverage in remote areas. A seamless service (Example: soft handover of the MT from one network to another or from one kind of service to other) is also important. The hand-over techniques should be designed so that they make efficient use of the network (routing) and make sure that hand offs are not done too often. New techniques in location management might be implemented. Each MT need not do location registration every time. They can instead do concatenated location registration, which reports to the network that they are concatenated to a common object. Example: MTs in a train need to re-register only when they get off the train and till the network knows that they are in the train.

B. Congestion Control

Congestion control will be another critical issue in the high performance 4G networks. Two basic approaches can be taken towards the congestion control:

-Avoidance or prevention of the congestion.

-Detection and recovery after congestion.

The avoidance scheme will require the network to suitably implement the admission control (measurement based or pre-computed model) and scheduling techniques.

The detection and recovery would require flow control and feedback traffic management. A conservative approach might be proposed for the 4G systems because of the wide variety of quality of service (QoS) requirements.

C. Quality of Service (QoS)

The 4G-WLAN systems are expected to provide real-time and internet-like services [10]. It is embedded with the fastest network interface card (NIC) that possesses the capability of producing about 8,888.89Mbps throughput and data transmission time of 0.016second while transmitting a data message size of 20MB on the Internet network [11]. The real-time services can be classified into five kinds as follows:

I. Guaranteed: pre-computed delay bound is required for the service. Example voice communication.

II. Productive: Better-than-best-effort is achieved in service.

III. Predictive: Service needs upper bound on end-to-end delay.

IV. Controlled delay: service might allow dynamically variable delay.

V. Controlled load: Service needs resources (bandwidth and packet processing). However, guaranteed and controlled load services are proposed to appear in 4G-WLAN advancement.

8.0 Conclusion

This paper shows that in Wireless networking, the Dual-Band systems are those capable of transmitting on two frequency bands (i.e. 2.4GHz and 5GHz) with network specification of 802.11b and 802.11a while the single band routers work on only one frequency band. The 4G-WLAN routers are proposed to have advancement in their network specifications and will covers a higher frequency range of between 2GHz – 8GHz which is also backward compatible. Hence, the 4G-WLAN technology offers a higher advantage for the internet access requirement of today due to its increased data throughput, speed in multimedia communication and ability to support live streaming, voice and data communication with increased security and automation. Therefore, it is recommended for use as the best source of high speed internet access in today's internet-dependent world.

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