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Performance Issues on the Interoperability between IEEE 802.3 & IEEE 802.11 in Heterogeneous Network Environment

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Abstract: *This paper addresses network computing that seeks to utilize the aggregate resources of many networked computers that can be installed in heterogeneous environment to solve problems of resource allocation, and so on. In doing this, it has to combine the performance from an inexpensive wired local area network (LAN) and wireless local area networks (WLAN) using different operating system, protocols and topologies due to the drawbacks of wired LAN not supporting mobility, quality of services (QoS) in security, and the usage of too many cables. The exchange of data from Wired LAN to Wireless LAN and vice versa is also another main issue to be addressed. The interoperability between the IEEE 802.3 and IEEE 802.11 is done at the data link layer (layer 2) of the OSI model. Network devices like the Switch, Wireless Access Point (WAP), Network Interface Card (NIC) are responsible for this action. Cisco® packet tracer simulation software was used in simulating the IEEE 802.3 and IEEE 802.11 performances in a heterogeneous network environment. The simulation result shows the time-to-live in a local area network to be 128ms while that of the internetwork to be 125ms or less. This makes the LAN data transfer faster than the WLAN, and the information exchange interoperable. This type of network environment is recommended for university campuses and government sectors / ICT agencies.*

Keywords: *performance, interoperability, IEEE standards, heterogeneous network environment*

I. Introduction

In this century, data communications and networking will continue to grow in importance and necessity. This necessity comes with the need for fast and reliable transfer or exchange of data from one node to the other without issues of incompatibility or interoperability problems. Considering the deployment of different brand of computers with different operating systems on different networks topologies with different network protocols all linked or connected together in a common environment to form a heterogeneous networked environment. Standards are required for these situations to augur well. Many network protocols / topologies have been developed and are in use, but the most widely used today are the Local Area Network, which is the Ethernet standard for IEEE 802.3 (Wired LAN), and the Wireless LAN which is the IEEE 802.11 standard.

The Institute of Electrical and Electronics Engineers (IEEE) is a non-profit professional organization founded by a handful of engineers in 1884 for the purpose of consolidating ideas dealing with electro-technology. The IEEE plays a significant role in publishing technical works, sponsoring conferences and seminars, accreditation, and standards development. With regard to Local Area Networks (LANs), the IEEE has produced some very popular and widely used standards. For example, the majority of LANs in the world use network interface cards based on the IEEE 802.3 (Ethernet or Wired LAN) and IEEE 803.11 (WLANs, that is, Wireless LANs) standards.

This paper discusses an overview of the IEEE 802.3 and IEEE 802.11 standards performance and the IEEE 802.3 & IEEE 802.11 interoperability issue in a heterogeneous network environment.

IEEE 802.3 Standards (Ethernet or Wired LAN)

Back in the 1970s at the Xerox Palo Alto Research Center, Dr. Robert M. Metcalf developed a network standard that enabled the sharing of printers to personal workstations [1, 2, 3] . This original system, entitled the "Alto Aloha Network" (later re-named "Ethernet"), was able to transmit data at a rate of 3 Mbps between all connected computers and printers [4]. Later, in 1980 a multi-vendor consortium consisting of DEC, Intel, and Xerox released the DIX Standard for Ethernet. It was through this effort that Ethernet was able to become an open standard for network operations [5]. At the same time, the Institute of Electrical and Electronic Engineers (IEEE) created a group designated the 802 working group to standardize network technologies. This group created standards that they would later number 802.x, where x was the subcommittee developing the particular standard [6]. The subcommittee that developed the standards for the CSMA/CD, functionally very similar to the

DIX Ethernet system, was 802.3. Later in 1985, the official standards were released for the IEEE 802.3. The standards were for Carrier Sensing Multiple Access with Collision Detection access method [6].

Table 1 Communication Standards for IEEE 802.3x

Ethernet Standard	Date	Description
802.3	1983	(10BASE5) 10Mbps over thick coax (AKA Thicknet) with a distance of 500meters. This is based on the CSMA/CD Process.
802.3a	1985	(10BASE2) 10Mbps over thin Coax (a.k.a. Thinnet). With a distance of 185meters. This is based on the CSMA/CD Process.
802.3i	1990	(10BASE T) 10Mbps over twisted pair (UTP or STP). It has a distance of 100meters.
802.3j	1993	(10BASE F) 10Mps over Fiber Optic cable
802.3u	1995	(100BASE-TX) 100BASE-T4, 100BASE-FX Fast Ethernet at 100 Mbps w/auto negotiation
802.3z	1998	(1000BASE-X) Gbps Ethernet over Fiber-Optic at 1 Gbps.
802.3ab	1999	(1000BASE-T) Gbps Ethernet over twisted pair at 1Gbps.

The next category is the 100Mbps Ethernet or "Fast Ethernet". The only functional difference between these two is the speed of data transmission. With a transfer rate of 100Mbps, this system typically uses either Category 5/5e UTP cable or Fiber Optics for the transmission medium [7]. The newest form of Ethernet is the 1Gbps category also known as **GIGABIT ETHERNET**. This technology is functionally similar to the 10 and 100 Mbps technologies, but has subtle differences. The main difference is that the transmission medium for 1Gbps Ethernet is both fiber optic and UTP cable i.e. IEEE 802.3z and 802.3ab [7].

How the IEEE 802.3 (Ethernet) Works

The Ethernet system works with the CSMA/CD standard. CSMA/CD simply means that the computers all have access to the transmission medium, and can send and receive data whenever the network is idle. The benefit of Ethernet is that it has the ability to sense collisions on the network [8]. A collision occurs when two or more machines (nodes) try to send data at the same time. There are sophisticated techniques used to keep this from occurring on a regular basis. When a node on an Ethernet network wishes to send information to another node, it first listens to the network to see if there is network traffic. If the station detects no traffic, it will begin sending the frames of data. These frames will be transmitted throughout the network and ALL nodes on the particular Ethernet segment will receive the frames.

However, only the node for which it was intended will be able to view the contents of the frame [8]. This is done through source and destination addressing. If more and more nodes become active on the network the probability of multiple nodes trying to send information at the same time increases. If two or more nodes send data at the same time a collision will occur. When this happens, the sending station will send out a jam sequence alerting all other nodes that there has been a collision and that any data received should be discarded [9]. The node then waits a period of time and re-sends the frame. A mathematical algorithm termed "**Truncated Binary Exponential Back off** "determines the amount of time the node waits [10].

IEEE 802.11 Standards (WIRELESS LAN)

IEEE 802.11 is a set of media access control (MAC) and physical layer (PHY) specifications for implementing wireless local area network (WLAN) computer communication in the 2.4, 3.6, 5 and 60 GHz frequency bands. They are created and maintained by the IEEE LAN/MAN Standards Committee (IEEE 802). The base version of the standard was released in 1997 and has had subsequent amendments. The standard and amendments provide the basis for wireless network products using the Wi-Fi brand. While each amendment is officially revoked when it is incorporated in the latest version of the standard, the corporate world tends to market to the revisions because they concisely denote capabilities of their products. As a result, in the market place, each revision tends to become its own standard.

Home and business based network installers looking for wireless local area network (WLAN) gear to buy faces an array of choices. Many products conform to the **802.11a**, **802.11b**, **802.11g**, and **802.11n** wireless standards collectively known as Wi-Fi technologies.

Table 2 IEEE 802.11 Standards and Spectrum in summary

Key Standards	Max. Rate	Spectrum (U.S.)	Year
802.11	2 Mbps	2.4GHz	1997
802.11a	54 Mbps	5 GHz	1999
802.11b	11 Mbps	2.4 GHz	1999
802.11g	54 Mbps	2.4 GHz	2003

II. Interoperability Issues Between IEEE 802.3 and IEEE 802.11 Standards

Network Interoperability is the continuous ability to send and receive data between interconnected networks providing the level of quality expected by the end user customer without any negative impact to the sending and or receiving networks. Specifically, network Interoperability is the functional inter working of a service across or between multi-vendor, multi-carrier inter-connections (i.e. node-to-node, or network-to-network) working under normal and stress conditions, and per the applicable standers, requirements, and specifications.

Ideally, the IEEE 802.3 and IEEE 802.11 network standards can't exchange or share data (interoperate) due to the difference in standards and operations. But with the aid of network devices like Layer-2 Switch and Wireless Access Point (WAP), both standards can now interoperate in layer two (2) of the OSI model which is the data link layer. The data link layer groups the bits that we see on the Physical layer into Frames. It is primarily responsible for error-free delivery of data on a hop. The Data link layer is split into two sub-layers i.e., the Logical Link Control (LLC) and Media Access Control (MAC). The Data-Link layer handles the physical transfer, framing (the assembly of data into a single unit or block), flow control and error-control functions. It is responsible for getting the data packaged and onto the network cable. The data link layer provides the network layer (layer 3) reliable information-transfer capabilities.

The main network devices found at the Data link layer are bridge and layer-2 switch or just switch. These devices work at a higher layer than the repeaters or hubs, and therefore are more complex devices. It has some understanding of the data it receives and can make a decision based on the frames it receives as to whether it needs to let the information pass, or can remove the information from the network. This means that the amount of traffic on the medium can be reduced and therefore, the usable bandwidth can be increased. The 802.11 standard defines an integration service (IS) that enables delivery of MSDUs between the distribution system (DS) and the IEEE-802.3 local area network (LAN), via a portal. A simpler way of defining the integration service is to characterize it as a frame format transfer method. The portal is usually either an access point or a WLAN controller.

As a frame moves from a node in 802.3 (Wired network) to another node or client in 802.11 (Wireless network) between a switch and an access point (AP). The 802.3 frames are encapsulated within 802.11 frames i.e. by removing the frame header of the 802.3 frame and replaces it the frame header of the 802.11 for on forward transmission to the wireless client via the Wireless Network Interface Card (WNIC) or (WLAN port). All of the IEEE 802 frame formats share similar characteristics, and the 802.11 frame is no exception. Because the frames are similar, it makes it easier to translate the frames as they move from the 802.11 wireless networks to the 802.3 wired networks and vice versa. Note: the 802.3 Standard Frame has a max. Size = **1,518 bytes**, while the 802.11 standard frame has a max. Size = **2,347 bytes**.

III. Methodology

In this research work, we studied the concept of IEEE 802.3 and IEEE 802.11 performance, and the possibility for their frames to interoperate in layer 2 (Data Link Layer) of the OSI reference model using network components like Bride, Switch, Network Interface Card (NIC) for wired networks and (WLAN) for wireless networks, thereby giving a end-to-end delivery services in a heterogeneous network environment.

We used Cisco Packet Tracer 5.0 network simulation software to carry out the experiment in order to determine the performances of both standards and the effect of their interoperability in heterogeneous network environment experiment. A typical campus enterprise network was simulated having a base station network serving an administrative block and some faculties. A Star-Bus, Star, Hybrid, and Wireless topologies were simulated in a Local Area Networks (LAN), Wireless LANs (WLAN) and Wide Area Network (WAN) fashion using the following network components: 24-ports Cisco catalyst Layer-2 Switch (2950 Series), 5 ports Cisco hub, Linksys Wireless Access Point (WAP), Cisco 2800 Series Routers.

Servers and Personal Computers (PCs) having NIC and Personal Digital Assistant (PDA) / Tablet PC having Wireless NIC.

22-ports out of the 24-ports of the Layer-2 Switch in the Administrative block network were reconfigured to run at Full Duplex and a bandwidth speed of 100Mbps for the Servers and PCs connected, while the other 2-ports were reconfigured to Half Duplex and a bandwidth of 100Mbps and 10Mbps for the Linksys Wireless Access Point (WAP) and the Hub extension network. In the Base Station and Faculties Networks, 23-ports out of the 24-ports of the Layer-2 Switch were reconfigured to run at Full Duplex and a bandwidth speed of 100Mbps for the Servers and PCs connected, while the last port was reconfigured to Half Duplex and a bandwidth of 100Mbps for the Linksys Wireless Access Point (WAP). The Cisco packet tracer software was also modified to capture and measure the Source and destination MAC Addresses, Time To-Live (TTL), TOS, Destination Port, Type, Size and Color of the Frames / Packets. The following protocols were configured for the internal networks: ICMP, ARP, TCP, UDP, SYSLOG, DHCP, while the routing information protocol version 2

(RIPv2) was configured for dynamic routing with the Cisco routers for internetworking between networks, and Encapsulated Point-to-Point Protocol (layer 2 protocol) were configured in the WAN links connecting the routers.

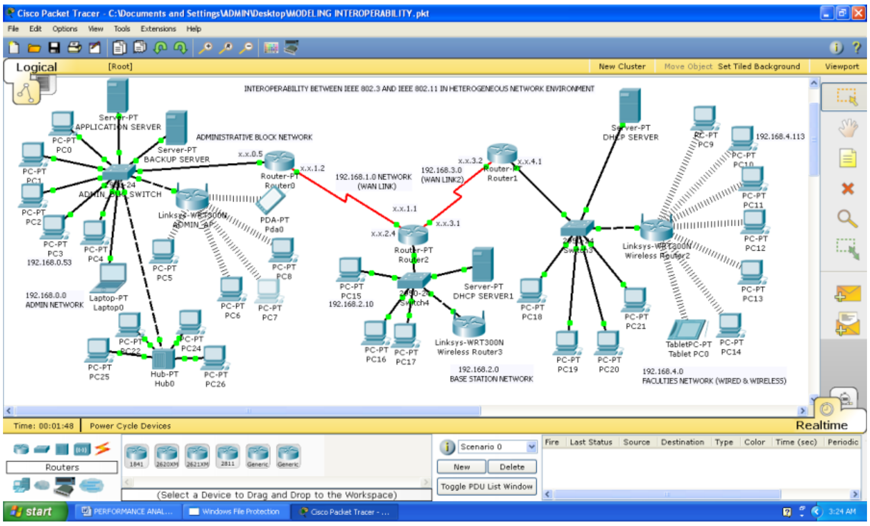

Figure 1 Simulation of a communication network with different network segments, host, protocols and topologies

Communication network of this nature with multiple networks and nodes simulated as shown in Figure 1, illustrates a heterogeneous network environment. The communication network channel is established between three Local Area Networks with multiple wired nodes and wireless clients transferring / exchange of data frames / packets within a particular network and outside the network (Wired and Wireless) along different network media. The transmitting / receiving ends are depicted in the model and the scenario represents a real life campus-wide heterogeneous network environment as a test-bed for this research work.

IV. Results And Discussion

Table 3 Results of pinging between two PCs in IEEE 802.3 (Wired LAN)

USERS	FILE SIZE (Bytes)	Min	Max	Average	TTL
PC0 pings PC1	32	32	62	43	128
PC0 pings PC2	32	31	93	59	128
PC0 pings PC3	32	19	65	40	128
PC0 pings PC4	32	30	94	51	128

Table 3 shows the results obtained from a real time mode simulation of an IEEE 802.3 (Wired Local Area Network) when a user from a node or PC pings another node or PC in the same network. Here, it is observed that each time a node pings another node, 4 packets of 32 byte was transmitted or sent and received using Internet Control Message Protocol (ICMP). The result also shows that the time in milliseconds never exceeded 60ms on the average and the Time-To-Live (TTL) was constantly 128. Time to live (TTL) is a mechanism that limits the lifespan or lifetime of data in a computer or network. TTL can be seen as a timer value included in packets sent over TCP/IP-based networks that tells the recipients how long to hold or use the packet or any of its included data before expiring and discarding the packet or data. TTL may be implemented as a counter or timestamp attached to or embedded in the data. Once the prescribed event count or time span has elapsed, data is discarded. TTL prevents a data packet from circulating indefinitely. The 128 TTL used in the IEEE 802.3 network was meant to improve performance of caching in the IEEE 802.3 network, thereby increasing the actual throughput.

Table 4 Results of pinging between two PCs in IEEE 802.11 (Wireless LAN)

		TIME (in milliseconds)			
USERS	FILE SIZE (Bytes)	Min	Max	Average	TTL
PC5 pings PC6	32	82	174	119	128
PC5 pings PC7	32	70	172	107	128
PC5 pings PC8	32	92	235	128	128
PC5 pings PC9	32	75	173	112	128

Table 4, shows the results obtained from a real time mode simulation of an IEEE 802.11 (Wireless Local Area Network) when a user from a node or PC pings another node or PC in the same wireless local area network. Here, it is observed that each time a node pings another node, 4 packets of 32 byte was transmitted or sent and received using Internet Control Message Protocol (ICMP) over air wave via its antenna. The result shows that the average time in milliseconds never exceeded 130ms, but the Time-To-Live (TTL) was constantly 128. This further shows that though it is having a constant TTL of 128ms when compared to IEEE 802.3 network, but the performance in terms of the actual throughput is less than the IEEE 802.3 network.

Table 5 Results of pinging between two PCs (from IEEE 802.3 to IEEE 802.11)

USERS	FILE SIZE (Bytes)	TIME (in milliseconds) Min	Max	Average	TTL
PC0 pings PC5	32	63	172	102	128
PC1 pings PC6	32	78	190	113	128
PC2 pings PC7	32	90	172	116	128
PC3 pings PC8	32	78	219	124	128

Table 5, shows the results obtained from a real time mode simulation between a node or PC in IEEE 802.3 (Wired Local Area Network) pinging another node or PC in an IEEE 802.11 (Wireless Local Area Network). Here, it is observed that each time a node pings another node as stated, 4 packets of 32 byte was transmitted or sent and received using Internet Control Message Protocol (ICMP) from a wired network through air wave to a wireless network via an access point and it is received by the wireless clients via their antennas. The results average time in milliseconds varies between 102 ms to 124 ms when the pinging was done four consecutive times; while the Time-To-Live (TTL) was constantly 128. This slight variance further shows the level of performance in the interoperability between IEEE 802.3 and IEEE 802.11 on the same network.

Table 6 Results of pinging between two PCs end-to-end across the WAN link

USERS	FILE SIZE (Bytes)	TIME (in milliseconds) Min	Max	Average	TTL
PC0 pings PC19 (Wired LAN)	32	109	156	132	125
PC0 pings PC13 (Wireless LAN)	32	158	187	175	125
PC4 pings PC20 (Wired LAN)	32	140	156	144	125
PC4 pings PC14 (Wireless LAN)	32	168	172	171	125

Table 6, shows the results obtained from a real time mode simulation between a node or PC in IEEE 802.3 / IEEE 802.11 (Wired LAN / Wireless LAN) pinging another node or PC in an IEEE 802.3 / IEEE 802.11 (Wired LAN / Wireless LAN) over an Internetwork. Here, we observed that each time a node pings another node as stated, 4 packets of 32 byte was transmitted or sent and received using Internet Control Message Protocol (ICMP) over the Wide Area Network (WAN) link. The results further shows that the minimum time, maximum time, and the average time in milliseconds were all above 100 milliseconds, while the Time-To-Live (TTL) was constantly 125. This variance in the results when compared to Tables 3, 4, 5 shows the drop in level of performance in terms of the data rate and throughput despite the interoperability between the networks in an heterogeneous network environment.

This drop in performance is as a result of factors like latency, barriers, different protocols / topologies, WAN link, and so on.

V. Conclusion

In this research paper, we presented a model of IEEE 802.3 and IEEE 802.11 network infrastructure and simulated its operations to know the level of performance and interoperability in heterogeneous network environment using Cisco® Packet Tracer simulation software. The model activities were carried out in a real time simulation mode, and the results captured the interactions between a source and destination nodes in a computer network. The simulation results revealed the level of performance in IEEE 802.3 and IEEE 802.11, and the possibility for both of them to interoperate within a network segment or in heterogeneous network environment. The simulation results also show that it is at the data link layer (i.e. layer 2) of the OSI reference model the IEEE 802.3 and IEEE 802.11 interoperate using network component or devices like network interface cards, switch and bridge that can see the frames being sent. Based on the results of the simulation, the maximum time-to-live within a network segment in 128ms when 32 bytes of data packet is sent from one node to another, while in an internetwork, it is 125ms.

VI. Recommendations

The outcome of the simulation has shown the following:

i. That Wired LAN has a higher throughput than Wireless LAN
ii. That Wireless Clients does associate with Wireless Access Point (WAP) in infrastructure mode connected to a wired network in order to make use of network resources.
iii. That both the Wired LAN i.e. IEEE 802.3 and Wireless LAN i.e. IEEE 802.11 can interoperate within the same network segment, internetwork and also in heterogeneous network environment.

We hereby recommend this design for University Campus-Wide Network and for both State and Federal Government Information and Communication Technology agencies for proper bandwidth utilization, efficient allocation of network resources, and effective transmission of data over TCP/IP based computer networks.

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