On the Communication Requirements of IEEE 802.Xxx Standardization: Evaluating Cognition Performance in WLAN

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Abstract: *Reconfiguration Communication System (RCS) intelligently provides interoperating platforms that enable communication with lower standards. Incremental demand for wireless services required justifiable capacity improvement of communication protocols. To ugrade existing wireless systems using APs computational techniques, the operational capability is facilitated flexible scaling and transmission reliability. This paper examines the communication requirements of relevant IEEE standardizations in cognition and interoperations. The impact of larger frame sizes and high delivery rates were examined in Ad-hoc wlan configuration. Using multi-user multiple inputs multiple outputs (MIMO) technology as communication elements in bands below 6GHz, Throughput performance was investigated using enterprise Network Simulator Package (eNSP). A significant reduction in packet errors was recorded in the simulations. This suggests an improved throughput, provided by flexible switching over long-distances. IEEE802.11ac standard implementation confirmed efficient cognition while IEEE 802.22 technology established interoperability techniques during reconfigurations. Protocol amendment to IEEE 802.11a standardization provided higher throughput measure characterized for transmissions below 6GHz traffics. IEEE 802.11af enables multiple multimedia data streaming while co-existence of multiple users on the network guaranteed system scaling. The co-existence of increasingly served users were provisioned by IEEE 8802.16h, while interoperation was facilitated by 802.22 to encourage dynamic resource utilization. Also, dual-stack AP peers in P2P modes provided much flexibility in parameter switching to enable fast handoffs. Support to local network management systems by reconfiguration made entire network scale with reduced latency and resultantly improved throughput performance was attributed to IEEE 802.11ac, 802.11af, 802.16h and IEEE 802.22 standardization implementations.*

Keywords: *IEEE 802.11ac, 802.11af, 802.16h, standardization*

1. Introduction

The application of multiple antennas makes both IEEE 802.11ac and 802.11af standardizations smart, offering data frames to multiple clients through antennas. IEEE 802.11 standard (Wi-Fi) created and maintained by the IEEE LAN/MAN standard committee (IEEE 802.11WG) [1] is currently the most versatile and effective solution in the range of WLAN, introduced in [2]. Both IEEE802.11ac and 802.11af protocols, known as High Efficiency (HE) Wireless Local Area Networks (WLAN) standards were introduced as "The fifth generation of Wi-Fi" in [3] and as improvements over 802.11a generally. IEEE 802.11 6th generation WLAN was drafted to include IEEE 802.16 and 802.22 protocols for cognitive radio networking to deliver greater performances in wireless systems. The main goal of these improvements is to increase throughput achieved by users and the Quality of Service (QoS) capabilities of the network [3].

Evaluation of IEEE 802.11a and 802.11n performances was carried out to compare single-usage MAC-level throughput in [4] while 802.11ac was implemented in enterprise networks in [5]. IEEE 802.11ac and 802.11af standardizations are wireless protocols implemented in received traffic through wirelessly connected APs and clients. Using the throughput metric measurements provided in [4] and in agreement with [6] , an improvement was demanded to enable the IEEE 802.11n protocol to engage in smart computations. Ad-hoc WLANs significantly model mobile clients and terminal devices to transmit and receive traffic over Access Point (APs) using improved standardizations to deliver [7].

Mobile networks use extensive Base Stations (BTSs) and cellular sites to achieve greater coverage while enterprises (including campuses) deploy WLAN models, characterized by various sub-standardizations to ensure suitability in the 'smart campus' infrastructural model required for broadband penetration. Posted in [8], providing various standardizations to impact IEEE 802.11n to support wireless connectivity for Gigabit access through APs, the Wi-Fi alliance defined 802.11ac data rates based on modulation, coding method, spatial streams and guard interval parameters. Technically, IEEE WG offered 802.20 and 802.22 as mobile broadband and wireless access protocols for CR and white space technologies respectively [7] and [8].

Implementation of PHY and MAC layer protocols for broadband access made the trend of network devices' management at the MAC layer very popular. Also, improved latency in cognitive radio technology offered IEEE802.21 as a mid-layer protocol between layer 2 and 3 users to deliver upper layer services. Defined layer 2.5 Media Independent Handover (MIH) enables communication with lower link PHY layer protocols while IEEE802.21 supports seamless communication over wireless technologies through the inclusion of cognitive standardizations [9].

Incremental demand for wireless connections with improved QoS necessitated throughput capacity improvement using wireless protocols. Media access control (MAC) address of Access Points (APs) in IEEE 802.11 defined basic service set (BSS) and extended service set (ESS). To commensurate the proliferation of personal computations and mobility usage, improved transmission performance in a wireless system requires more technical approaches. To fulfill the requirement, improvement is desired in protocol implementation for designed WLAN model to offer improved performance with sustained quality services. With the new amendments made to IEEE 802.11n specifically, Quality of Service (QoS) is sustained.

2. Review of IEEE Standardization

The institute of Electrical and Electronic Engineers (IEEE) is a key standardization organization, which promotes networking technologies via several working groups. The 802 standard committee was established to consist of various definitions and specifications, including IEEE 802.1 (802.X) defined for LAN/MAN architecture. With an emphasis on Internet working and link security, IEEE 802.2 was defined for Logical link control as part of the data-link layer protocol for LAN while IEEE 802.3 and IEEE 802.4 were defined for Ethernet and dominating LAN technology for old Token bus respectively. The LAN technology utilizes token rings over coaxial cables but IEEE 802.5 remained inactive while IEEE 802.6 was defined for Metropolitan Area Networks, using Distributed Queue Dual Bus (DQDB). IEEE 802.7 was defined for the Broadband Technical Advisory Group (TAG) while IEEE 802.8 catered for Fiber-optic TAG as its LAN standard [10].

Other definitions include the IEEE 802.9 for Isochronous LAN Ethernet, which was tagged IsoEnet and IEEE 802.10 for security, specifying key management, access control, and data integrity for both LANs and WANs. IEEE 802.12 was defined for Demand priority but IEEE 802.13 was not used and IEEE 802.14 was defined for Cable data as MAC layer specification for multimedia traffic over hybrid fiber and coaxial networks. Also included is the IEEE 802.15 specification, given to guide Wireless Processor Area network (PAN) as a set of protocols for short-range wireless networks, including Bluetooth (IEEE 802.15.1) and IEEE 802.16 for Broadband wireless access [7]. The PHY and MAC layer protocols for broadband wireless access named Worldwide Interoperability for Multiple Access (WiMax) was based on IEEE 802.16 but IEEE 802.17 and 802.18 were defined for resilient packet ring (RPR) as the protocol to improve resilience for packet data traffic over fiber. IEEE 802.19 defined for TV white spaces and IEEE 802.20 for Mobile Broadband Wireless Access respectively enable the PHY and MAC layer protocols to be implemented for mobile data access. While IEEE 802.22 was defined for cognitive radio (CR), IEEE 802.24 was specified for Vertical Application TAG respectively [7] and [8].

Specifically, IEEE 802.11 defined as a set of protocols for wireless local area networking (WLAN) was operated on 2.4GHz and 5GHz bands but IEEE 802.22 catered for all communications in Wireless Regional Area Networks (WRAN) Broadband access schemes in CR and white Space technologies. Amendment to IEEE802.11a and 802.11n introduced transmission operations below 6GHz for multiple data stream distributions while other amendments enable transmission of 10Mbps over WLAN to eliminate cabling difficulties and costs. Drafted as a cognitive Physical and Media Access Control framework for co-existence of licensed and unlicensed IEEE802.16 applications (users), derived cross-layer standardization were defined for CR as amended specifications in [9].

A study carried out by [6] discussed characteristic features of next generation WLANs based on 802.11n and 802.11ac but IEEE 802.11ac was confirmed to using 5GHz frequency technology to characterize more users at PHY layer [7]. Though 802.11n PHY layer uses the single-input single-output legacy of the single antenna on the channel bandwidth of 20MHz, where clients continue the implementation of 2.4GHz, 802.11ac enable spatial streaming (SS), using multiuser multi-input multiple-output (MU-MIMO) technology to deliver data to multiple clients on frequency spectrum 5GHz simultaneously [7]. However, MIMO technology used OFDM modulation to increase traffic capacity to 40MHz channel in 802.11n. This concept enables dual-band APs' continued use of the 802.11n at 2.4GHz and 802.11ac at 5GHz respectively as discussed in [11].

Duality principle therefore, enables AP configured in peers to offer high performance Wi-Fi networks that are operated for digital transformation era whereby the dual-band configuration allows greater exploitation of qualitative service delivery of multimedia, voice or video services [12]. Through flexible service management control functions, full series Eugenius APs are applicable for constructing cost-effective Wi-Fi networks that engage smart applications to improve user experiences [13]. Generally, APs support dual-stack mode to allow flexible switching while identifying user packets to offer reliable wireless services [14].

3. Experimental Setup

The structural view of the campus/enterprise network is shown in Fig. 1a as viewed with Geographical Information System (GIS) mapping tool. Topology design of the WLAN as a reconfigurable model used in this research consists of 2 units of dual 5GHz APs, configured in peering mode to service 2 clients as shown in fig. 1b. The architecture was enabled to feature the 802.11a (802.11ac and 802.11af) wireless protocols. The structural scenario used the 5GHz AP for continuous transmission of UDP-like traffic to clients while using a single user operational mode.

3.1 Simulation Procedures

AP configuration for transmission was applied without collision using advanced modulation and coding scheme default provisioned in the simulator. Distance between two APs was estimated to capture between 400 and 600metres on the physical surface as shown in the topology design of fig. 1b.

We did a simulation for the ad-hoc WLAN model using two dual-band APs configured and operated in P2P mode. We also assumed Poisson distribution for packet reception at the AP device with a constant packet size of 1MB. Packets are transmitted/sent to the clients as soon as received/generated by the AP.

The transmission was observed over half-day (12hours) to evaluate how AP sends data using the MU-MIMO technique for delivery into multiple clients. The simulation concentrated on the busy hours to examine the throughput capacity of the wireless protocols on the frequency spectrum 5GHz servicing multiple clients at the same time.

Since, the simulation methodology included requirement specifications for Ad-Hoc WLAN modeling, the testing scenario was equipped to function with 802.11n and 802.11ac wireless protocol algorithms. Network configuration included other APs in peering mode too to serve *n* other clients, whereby all APs were expected to participate in transmitting and receiving data simultaneously, demonstrating spatial streaming in the topology design.

Simulation model parameters are included in Table 1 as well as the protocol settings, which are also listed as shown in Table 2.

Table 1. Simulation model and environment

No.	Environment	Variable
1.	Simulator	Enterprise Network Simulator
2.	Operating system	Windows 10
3.	Spatial stream	1-2
4.	Bandwidth	40MHz
5.	Transport Protocol	RIP
6.	Number of clients	1-3
7.	Data Rates	20Mbps

Parameter setting for 802.11n and 802.11ac wireless protocols is shown in Table 2.

Table 2. Parameter setting for protocol implementation

No.	Environment	Variable
1.	TCP protocol	RIP
2.	Spatial stream	1-2
3.	Bandwidth	5GHz
4.	Clients	1-3
5.	Simulation time	5 Seconds
6.	Modulation	The default for dual-band APs
7.	Data rates	20Mbps
8.	MCS	Default for APs

Using eNSP settings and configurations, the behaviour of APs in peering mode for transmission and reception of packets were tested. The simulation began from 8.30am – 6.00pm. Data rates ranging from 1200kbps – 20Mbps were examined. Data source is a client station (Client$_1$) and the data destination is Access Point (AP$_1$ and AP$_2$). Simulation time is 5 – 10 seconds in each half hour. A total of 180 seconds of the simulation were realized.

4. Result and Performance Evaluation

P2P configuration supported concurrent usage of traffic by n clients communicating over programmed interface using various standardizations of Wi-Fi. Simulation scenarios produced outputs of 180 seconds of spatial stream transmissions. Traffic within simulation was achieved in P2P peering mode. Transmission of 1MB packet at various data rates between 1200Kbps – 1950Kbps were achieved. Client receptions over 40MHz bandwidth in default modulation for 5GHz AP were observed.

We therefore plotted data throughput over the simulation period that ranged from 12000Kbps to 19500Kbps at client stations as shown in fig. 3. Fig. 3 showed the minimum required bandwidth was neither below 12Mbps nor above 19.5Mbps. 20Mbps used for evaluation was the amount of purchased traffic/bandwidth currently implemented on campus. Data rate was modeled to fall between available traffic in use.

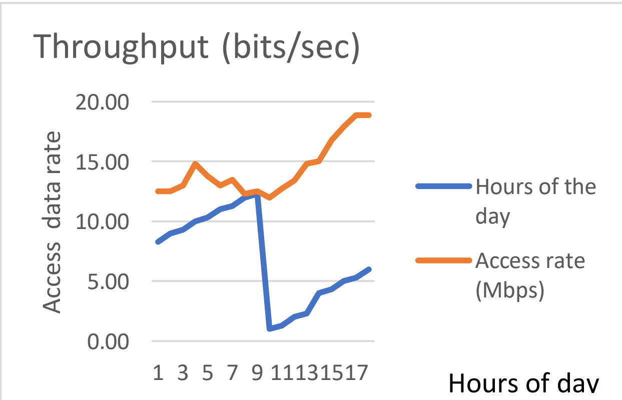

Figure 3: Throughput measure 180 bits/seconds

Data rate significantly dropped at peak (10am and 12noon) but picked up gradually and improved significantly after closing hour (4pm -6pm).

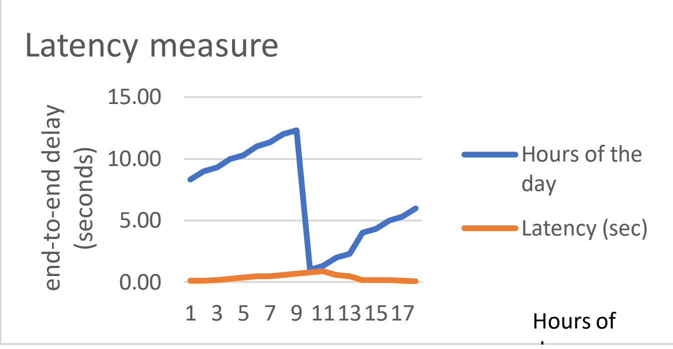

Figure4:Application on P2P link(End-to-End delay)

With large size packets of 1 or 2MB, the insignificant delay was observed in the with minimal packet error detected as shown in fig. 4. Peak period transmission regions (9.30am – 1.30pm) showed slight packet errors, attributed to 40MHz frequency made available using dual-band 5GHz AP in peers while the transmission is enabled to serviced clients simultaneously. Concurrent usage by multiple clients was enabled by spatial streaming traffic.

4.1 Scalability and Extended Services

User Datagram Protocol (UDP) packet implementation resulted in insignificant packet loss as the overall performance of the system was not affected. Also, because UDP is lightweight having smaller overhead and latency than TCP, the improvement in Throughput relied much on an increased level of data traffic in the PHY layer, under MU-MIMO operations in a channel bandwidth of 40MHz, which was provided by the peering APs.

Configured APs were easy to deploy devices, that are managed for greater performance. Demonstration of duality concept using dual-band principle APs in peering enabled the Network Management Centre (NMC) to flexibly control the dual-band traffic configuration. 2.4 and 5GHz Wi-Fi interface 802.11ac and 802.11af were implemented to examine throughput capacity improvement.

Multiple APs extended the capability of WLAN configurations to extend wireless coverage and scale the network system to other areas. Wireless services were extended across the entire campus. Peering APs enabled more concurrent connections by clients.

4.2 Reliability via improved Throughput

The flexible access into the wireless network at nearly all points on campus offer extended services with improved throughput. Transmission reliability was guaranteed as traffics was transmitted to multiple clients on various interfaces, including mobile devices, implementing the various wireless protocols. Efficient interoperation was experienced due to the increased capacity offered. Clients were enabled to use both 802.16h and 802.22 protocols to support planned cognition and reconfiguration.

Service delivery rates were evaluated with various load traffics including multimedia files. SpeedTest() function was run in different scenarios on clients' devices, which were directly communicating with AP_1 or AP_2 nodes in range. Measurements were taken within a basic service set (BSS) and extended service set (ESS) areas across the entire campus.

4.3 Discussions

The duality characteristic of APs used in WLAN enabled the system to deliver better performances in point-to-point (P2P) operational modes than point-to-multipoint (P2MP). Though, simpler to design and cheaper, P2MP configuration was considered not very feasible because the topology design allows a single point of failure. But P2P enables each APs to support hundreds (100) of concurrent users while eliminating a single point of failure. With 2.4GHz APs providing 802.11ac wireless access and 5GHz AP, providing 802.11af wireless access protocol implementations, the ad-hoc WLAN model was offered as an architectural option best suitable for self-organization techniques, which are required in reconfigured systems.

Therefore, AP peering offered a characteristic feature of the basic requirement of cognition because:

(i) Each APs send spatial streams to all clients configured in WLAN and each AP routes featured wireless hubs, providing management control to clients and other AP peers;
(ii) transmission between AP peers extends the capability of WLAN to achieve wider coverage and greater performance in transmission reliability[14];
(iii) peering provided network management flexibility to enable scalability while duality concept provided cognition efficiency required for accurate reconfiguration.

Wireless protocols IEEE 802.11ac and 802.11af provided the enabling environment for efficient cognition while 802.16h and 802.22 respectively supported the co-existence and interoperation of multiple standardizations in reconfigured systems in agreement with [15].

5. Conclusion

With the simulation results, flexible access to wireless services at every point on campus confirmed cognition performance for service extension and good coverage. Improved throughput performance also proved transmission reliability because increasing demand for wireless services for various applications across the entire campus was met. Peering among multiple APs was facilitated to provide the required scalability. Enhanced network services were provided as more users were served appropriately. Multiple APs were configured in P2P peering mode to confirm the duality concept since both 2.4GHz and 5GHz were implemented to enhance performance.

Configured APs spotted at designated locations as displayed in the aerial view shown in fig 1a (appendix) confirmed a structural view of extended WLAN model deployment while the topological view as shown in fig. 1b (appendix) showed peering modes. Improvement in performance was attributed to amendments of the wireless protocols operating within 802.11a family as shown in performance measures (fig. 3 and 4). The improved throughput capacity resulted from the dual-band AP peering technology, which also provided reliable traffic communication to the increasingly served users.

Therefore, IEEE 802.11ac and 802.11af are provisions and standardizations defined for efficient cognition and reconfiguration. Thus, AP peering becoming enabling technologies in RCS, 802.16h technology offered guaranteed support for coexistence for multiple users on the same channel while interoperating with lower IEEE standards. Guaranteed by 802.22 standardization, interoperations were facilitated. These and many other standardizations are ingredients for the reconfiguration technology, which is the underlying implementation used in scaling wireless systems/services. Finally, these standardizations provided support for RCS to enhance spectrum resource utilization. As increased wireless capacity is provided for wider coverage in enterprise settings, improved transmission throughput is guaranteed with AP peers communicating below 6Ghz (2.4 GHz - 5GHz bands).

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Authors Profile

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Appendix

(i) ICT Base Radio (Engenius dual-band AP 2.4/ 5GHz)	(ii) other dual-band APs at spotted points

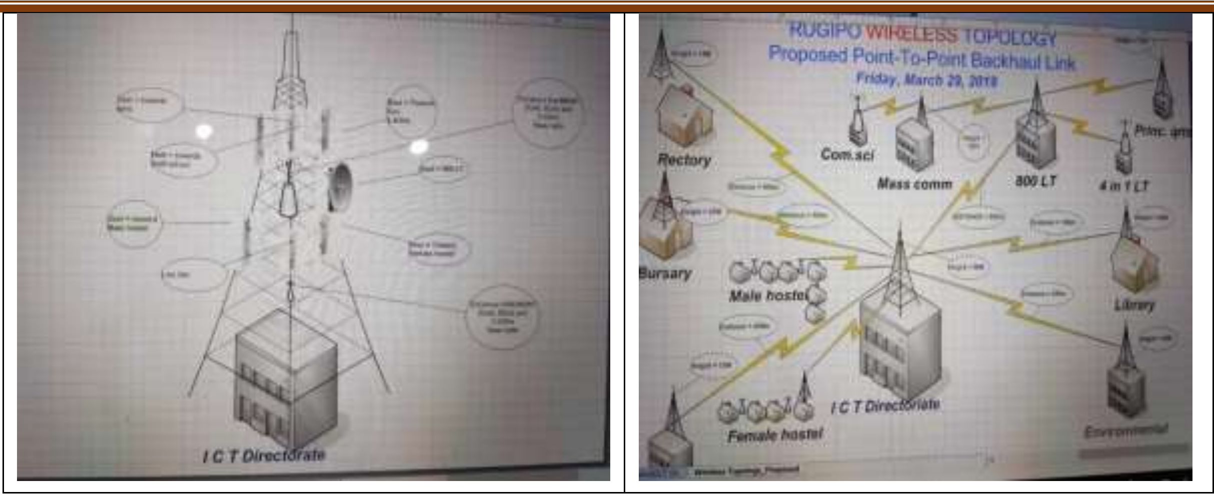

Figure 1a: (i) Overview of configured AP at ICT base and (ii) other APs on Campus (Enterprise)

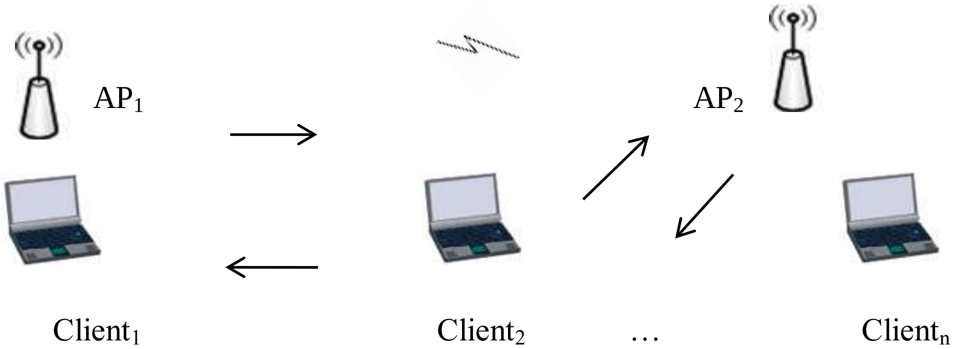

Figure 1b: Scenario (topology) of APs in peering mode