

FRAME AGGREGATION MECHANISM FOR HIGH-THROUGHPUT 802.11N WLANS

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ABSTRACT

IEEE 802.11n Draft is next-generation wireless LAN standard. This article gives detailed description and comparative study of A-MPDU and Two level frame aggregation mechanisms proposed in the latest 802.11n draft standard, which improve extensively the channel efficiency and data throughput. NS 2 simulator is used for simulation of 802.11n WLAN frame aggregation. Simulation results confirm that A-MPDU, and Two level frame aggregation methods improve extensively data throughput. It analyse the performance of each frame aggregation scheme in distinct scenarios, and it conclude that overall, the two-level aggregation can improve throughput performance of 802.11n. Two level aggregation can more effectively deliver data from multiple sources, PDR rate is much higher with much lower delay and Two level aggregation consumed less energy as compared with A-MPDU approach..

KEYWORDS

NS-2 IEEE 802.11N, Frame Aggregation, A-MPDU, Two level aggregation,

1. INTRODUCTION

In the recent years, wireless LAN (WLAN) is most popular for mobile equipment's. Because the equipment cost decreases and the data delivery rate becomes higher. IEEE802.11 WLAN is most popular network in wireless networking, because of its advantages its system possesses such as interoperability, mobility, flexibility, and cost-effective deployment. In July 2002, to achieve higher data rate, IEEE 802.11 standard working group established the High-Throughput Study Group (HTSG). The IEEE 802.11n ("n" represents next- generation) resolution to compose a high-throughput (HT) extension of the current WLAN standard that will increase transmission efficiency, throughput and reduce compulsory overhead. The 802.11n standard offers several advantages over previous wireless LAN technologies.

The most majorable advantages are substantially improved reliability and greater application data throughput. However, the low transmission rate of its medium access control (MAC) and a physical (PHY) layer protocol restrict to support high data rate application. Current WLAN systems having difficulties with the increasing expectations of users and with volatile bandwidth and delay-boundary demands from new higher data rate services, such as high-definition television (HDTV)), file transfer, and online gaming, video teleconferencing, multimedia streaming, voice over IP (VoIP). The major aim of the IEEE 802.11n Task Group (Tgn) is to have maximum data throughput of at least 100 Mb/s. IEEE 802.11n gives recent propositions for PHY which includes multiple input multiple output (MIMO) antennas with orthogonal frequency division multiplexing (OFDM) and various channel binding mechanism.

However, it has been investigated that simply improves the PHY data rate, and it will not be sufficient for enhancing the system throughput. TGn proposed mac enhancement method in latest IEEE 802.11n standard which enhance throughput and improves efficiency. One of the problems with the legacy MAC is the overhead associated with MAC header.[2] One of the efficient ways to reduce the overhead caused by MAC header is to use larger packets. So, aggregating a number of frames together for transmission is becoming popular for high efficient MAC [1].

The throughput performance at the MAC layer can be improved by enhancing mac layer. It can be done by combining several frames before transmission and i.e. frame aggregation. Frame aggregation not only reduces the transmission time for compulsory overheads, but also reduces the waiting time during CSMA/CA (Carrier Sense Multiple Access – Collision avoidance) random backoff period for successive frame transmissions.

This article proposed a highly efficient and flexible frame aggregation scheme, which can substantially improve the channel efficiency. The proposed frame aggregation can occur at two levels, namely the A- MSDU (MAC Service Data Unit) level and A-MPDU Aggregate-MAC Protocol Data Unit level. Besides, the aggregation at each level can be used together or separately.

Table1. 802.11 STANDARDS and specifications

802.11	Freq. (GHz)	Throughput (Mb/s)	Max bit rate (Mb/s)	Modulation	$r_{in.}$ (m)
a	5	23	054	OFDM	~35
b	2.4	04.3	011	DSSS	~38
g	2.4	19	054	OFDM	~38
n	2.4, 5	74	248	OFDM	~70

Hence, this two level aggregation can operate flexibly, based upon the applications and real traffic scenarios. The main aim of this article is to implement the new approach, Two level aggregation for more improved performance and to analyse the performance of each frame aggregation scheme in distinct scenarios, to analyse end to end delay, energy consumption and packet delivery ratio and compare the performance of draft of the IEEE 802.11n A-MPDU aggregation schemes along with the two-level aggregation.

2. IEEE 802.11N

IEEE 802.11 is a set of standards for wireless local area network (WLAN) computer communication, developed by the IEEE LAN/MAN Standards Committee (IEEE 802) in the 5 GHz and 2.4 GHz public spectrum bands. Although the terms 802.11 and Wi-Fi are often used interchangeably, the Wi-Fi Alliance uses the term "Wi-Fi" to define a slightly different set of overlapping standards. The 802.11 family includes over-the-air modulation techniques that use the same basic protocol. The most popular are those defined by the 802.11b and 802.11g protocols, and are amendments to the original standard. Some of the important protocols are

IEEE 802.11n is a proposed amendment to the IEEE 802.11-2007 wireless networking standard to significantly improve network throughput over previous standards, such as 802.11b and 802.11g, with a significant increase in raw (PHY)[1] data rate from 54 Mb/s to a maximum of 600 Mb/s. It is also known as **draft-n**. The 802.11n standard will offer several advantages over previous wireless LAN technologies. The most majorable advantages are substantially improved efficiency and greater application data throughput. However, the low efficiency of its medium access control (MAC)[1] and physical (PHY) layer protocols restricts its applications to support high data rate multimedia services.

3 MAC LAYER OVERHEAD REDUCTION

The PHY enhancements described thus far increase maximum PHY data rate, but would make very inefficient use of the airwaves without the following MAC layer enhancements also utilized by 802.11n.

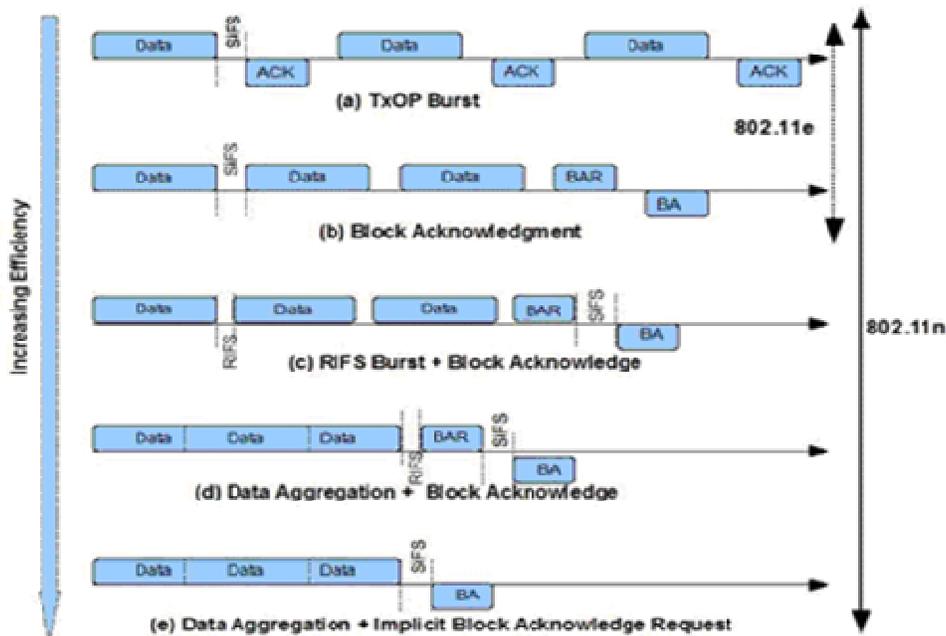


Fig No.1 Block Acknowledgement

3.1. Block Acknowledgement -

Block Acknowledgement reduces the number of ACKs that a receiver must send to a transmitter to confirm frame delivery. Legacy 802.11a/g transmitters expect an (almost immediate) ACK for each non-multicast/broadcast frame. But 802.11n transmitters also accept Block ACKs which confirm receipt of multiple unicast frames. For eg, instead of sending 9 legacy ACKs to confirm frames 1 through 8 and 10, an 802.11n receiver can say the same thing with just one Block ACK.

3.2. Frame Aggregation Mechanism

Aside from the RF improvements, 802.11n has also improved the efficiency of the MAC (Media Access Control) protocol using a single ACK mechanism for multiple frames and ability to aggregate multiple frames into a single transmission.

In 802.11abg, each frame is acknowledged immediately following each transmission. This added robustness comes at a price – no one can transmit a frame while the current sender is waiting for an ACK. 802.11n adds a block ACK (BA) mechanism in which multiple frames can be streamed out and acknowledged by a single frame. This cuts the wait time between frames transmission and allows just the missing frames or frames received in error to be resent by checking a compressed bit map. The transmitter need send only one BA request (BAR) to the receiver. If the receiver acknowledges it, the BA mechanism may be used for the duration of the physical connection (such as between a client and access point). By combining frames together into one larger frame, 802.11n can send multiple frames per single access to the channel

The draft 802.11n specification was crafted with the previous standards with compatibility with more than 200 million Wi-Fi devices which currently in use. An 802.11n access point will communicate with 802.11a devices on the 5-GHz band as well as 802.11b and 802.11g hardware on the 2.4-GHz frequencies. In addition to basic interoperability between devices, 802.11n provides greater network efficiency over what 802.11g offers in mixed mode.

Network efficiency is basically the proportion of the available bandwidth that is used to transmit data as opposed to overhead or protocols used to manage network communications. Wireless environments are much more challenging to orchestrate than wired networks, so there is generally more overhead to ensure that data sent is actually received, and that other clients leave the channel open during transmission. The presence of 802.11b nodes makes communications difficult on the 2.4G-Hz band because the older standard does not recognize OFDM, which is employed by 802.11g and draft-n. This means that if OFDM clients want to communicate in the presence of 802.11b clients, they need to use the older standard's communication protocol at least to protect their higher-rate OFDM transmissions. This drops network efficiency considerably because data packets take far less time to transmit with 802.11g and draft-n than they do under the old 802.11b standard. Some WLAN suppliers, including Broadcom, devised innovative schemes to improve the efficiency and data throughput of mixed 802.11b/g networks.

One of the most important features in the draft-n specification is frame aggregation to improve mixed mode performance. Rather than sending a single data frame, the transmitting end user bundles several frames together. Thus, aggregation improves efficiency by restoring the percentage of time that data is being transmitted over the network,

The main medium access controller (MAC) feature that provides a performance improvement is aggregation. The types of aggregation are defined:

1. Aggregation of MAC Service Data Units (MSDUs) at the top of the MAC (referred to as MSDU aggregation or A-MSDU)
2. Aggregation of MAC Protocol Data Units (MPDUs) at the bottom of the MAC (referred to as MPDU aggregation or A-MPDU)
3. Two level aggregation

3.2.2. A-MSDU Mechanism

In the Aggregated Mac service data units i.e. A-MSDU scheme, multiple MSDUs are bundled to form a MPDU which could consist of multiple sub frames either from multiple sources or for multiple destinations. Fig.2 illustrates the frame format of an A-MSDU. An A-MSDU consists of multiple sub frames (i.e. multiple MSDUs). Each sub frame of an AMSDU has a sub header (Destination address, Source Address, (Length), MSDU, and padding bytes. The size of the MSDU in each sub frame can be different. Different size of MSDUs in each sub frames are aggregated. To make the length of the sub frame in multiple of 4 bytes except for the last sub

frame the padding bytes are appended. All the sub frames are bundled and share a common MAC header and frame check sequence (FCS) which is calculated over all the sub frames and a common MAC header and then appended as the trailer.

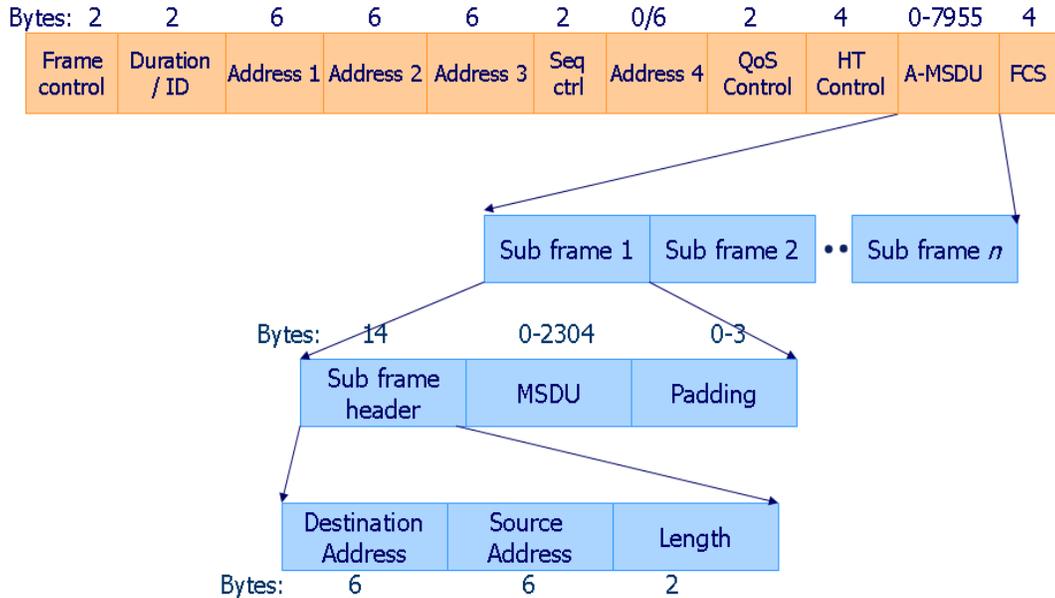


Fig.No. 2 frame format of A-MSDU

By the PHY layer the A-MSDU frame is considered as a single MPDU. Since there is no frame checksum for the individual sub frames, selective retransmission of corrupted sub frames is not possible. Sub frames have the same sequence number and traffic identifier (TID). The maximum length of an A-MSDU frame can be 3839 or 7955 bytes. This capability information is exchanged during the time of association.

The common MAC header contains only source and the access point's (AP's) address in uplink transmissions. Only in the sub headers, the corresponding destination addresses are present., a station can pack MSDUs destined for multiple destinations and send it to the AP in the uplink transmission., the AP can combine multiple MSDUs from various source addresses and send it to a single destination in downlink transmission. An A-MSDU frame cannot be transmitted to multiple end receivers.

3.2.3. A-MPDU Mechanism

Multiple MPDUs with a common PHY header are packed as an A-MPDU which can contain several MSDUs and/or A-MSDUs. The size of each sub frame must be a multiple of 4 bytes except for the last sub frame. Padding bytes are not needed for the last MPDU subframe. To make the length of the sub frame in multiple of 4 bytes, padding bytes are appended same as A-MPDU mechanism. Fig. No. 3 shows the structure of an A-MPDU frame. Each MPDU is prefixed with a delimiter. The delimiter contains MPDU length, cyclic redundancy checks (CRC) and unique pattern. The first four bits in the delimiter are reserved and currently not used. 12 bits MPDU Length subfields are used for representing the length of the current MPDU. Cyclic redundancy check calculation includes reserved and length sub fields. The unique pattern is used to find the next delimiter with minimal computation in case of a corrupted delimiter. In this aggregation mechanism selective retransmission is possible due to the presence of

individual frame check sequence (FCS) for each MPDU. All the MPDUs in an A-MPDU have same traffic identifier (TID) to effectively work with block acknowledgement (BA) mechanism. The maximum length size of an A-MPDU frame is 64 Kbytes. Capability to receive max size of A-MPDU is different for each station and this capability information is announced at the time of network entry process. Even though an A-MPDU frame can have a maximum size of 64 Kbytes, it can aggregate a maximum of 64 MSDUs. This limitation arises because of the use of block acknowledgement mechanism. To overcome this limitation Two level aggregation is proposed, and it can be used where in multiple A-MSDUs each carrying more than one MSDUs are aggregated to form an AMPDU. In this mechanism the size of A-MSDU frame should not exceed 4 KB.

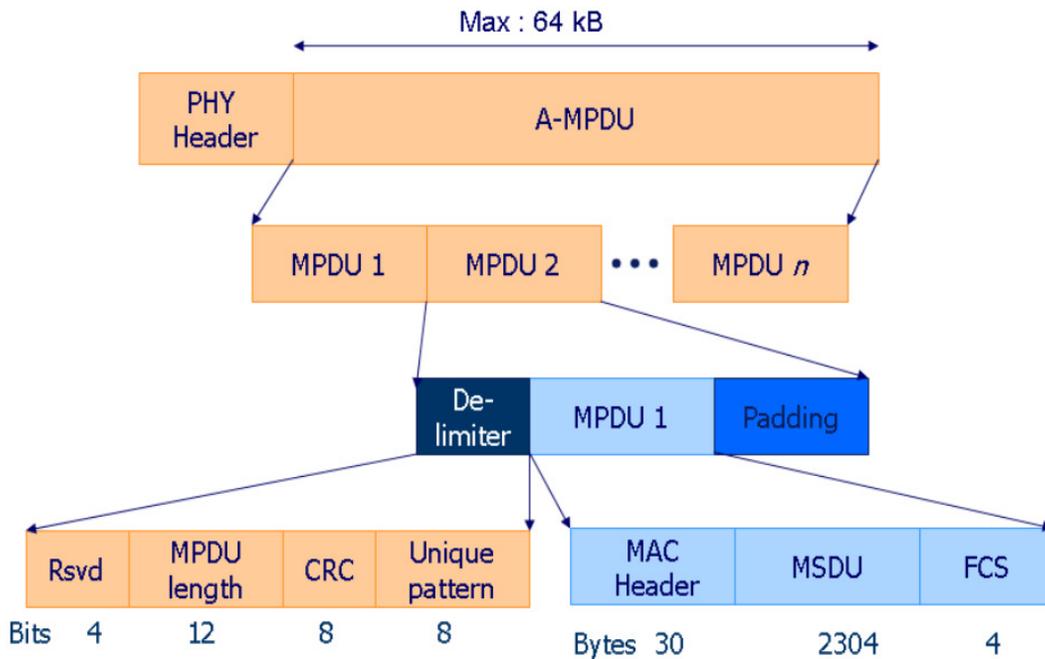


Fig.No. 3 A-MPDU frame format

3.2.4 Two-Level Aggregation

A two-level frame aggregation mechanism comprises a blend of A-MSDU and A-MPDU over two stages. In Fig. 4 it illustrates how this new mechanism can be achieved.

The basic operation is as follows: In the first level, if any MSDUs that are buffered in the A-MSDU provisional storage area justify the A-MSDU constraints explained in the previous related subsection, these data units can be aggregated into a single A-MSDU. If the TIDs are different, all these frames can move to the second level where they will be combined together with any A-MSDUs arises from the first level or other single MSDUs by using A-MPDU aggregation.

However, it must be mentioned that the maximum MPDU length for an A-MPDU data frame is limited to 4095 bytes, and then A-MSDUs or MSDUs with lengths larger than this limitation cannot be transmitted. Conjointly, any frames from an A-MSDU or MSDUs also cannot be included in an A-MPDU. Fig no. 4 illustrates how the two level aggregation mechanism is more efficient in most of the cases than A-MPDU and A-MSDU aggregation operating alone.

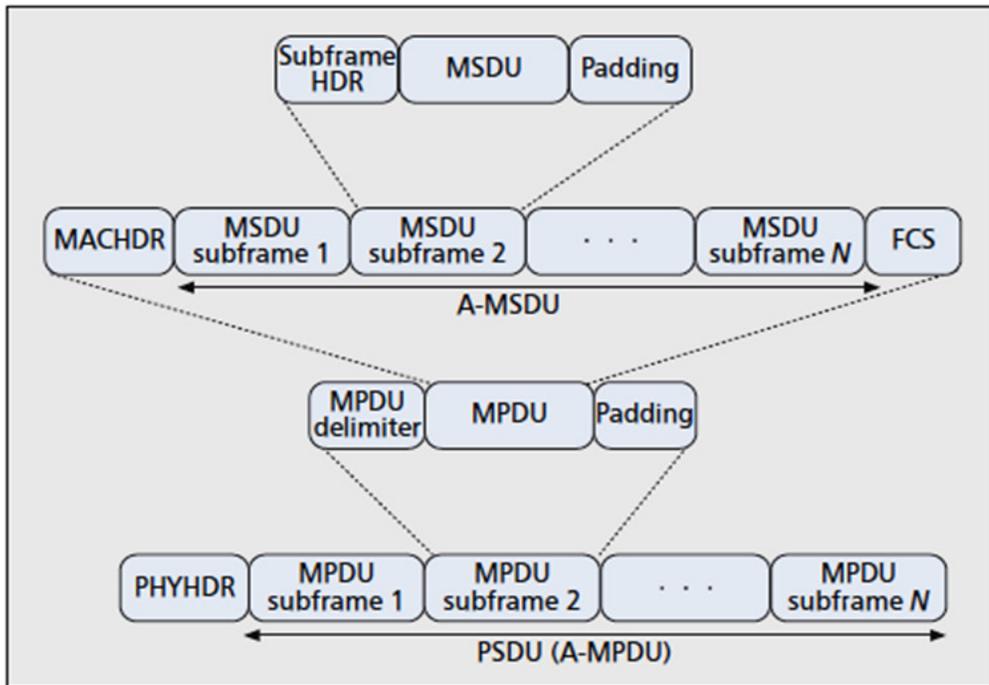


Fig. No. 4: Two Level Aggregation

4. SIMULATION SETUP

In this section, the performance of proposed scheme is evaluated. It compares the performance of the latest draft of the IEEE 802.11n A-MPDU aggregation schemes along with the two-level aggregation. Simulation result shows the different scenario. Proposed scheme is validated using network simulator (i.e. NS2) based on the TCL with the latest 802.11n PHY and MAC enhancements.

Behaviour of a large-scale and complex network system such as Internet at low cost under different configurations of interest and over long period can be predicted by Network simulation software. Many network simulators, such as NS2, Openet, Qualnet, matlab etc., are widely available to simulate network. NS2 is a discrete event simulator written in C++, with an OTcl interpreter as the user interface that allows the input model files (Tcl scripts) to be executed..

The simulator supports a class hierarchy in C++, and a very similar class hierarchy in OTcl. The root of this class hierarchy is the Tcl Object in OTcl. NS2 provides substantial support for simulation of TCP, routing algorithms, queuing algorithms, and multicast protocols over wired and wireless (local and satellite) networks, etc. It is freely distributed, and all source code is available.

NS simulator covers a very large number of applications, protocols, network types, network elements and traffic models. These are called “simulated objects”. The simulator is based on two languages: an object oriented simulator written in C++ and an Otcl interpreter used to execute user’s command scripts. In these scripts, the user can define a particular network topology, the specific protocols and applications that he wishes to simulate and the form of output he wishes to obtain from the simulator.

NS is a discrete event based simulator. The tcl script defines when an event should occur. For example: \$ns at 1.0 “\$ftp start”. When \$ns is a Simulator instance (an event scheduler) and \$ftp

is a FTP application that was set above lower layers (TCP, physical network – topology, delays, etc.) earlier defined by the user in the script.

Trace file result gives event registered at the network. Event is one of: receive (at output of a link), enqueue, dequeue and drop. Time is the time of the event. From node is the input node of the link at which the event occurs and To node is the output node of that link. Pkt. type (tcp, cbr, ...) and size describe the packet. Fid is the link number that the user can set. Src and Dst addr is the source and destination nodes of the packet. Next is the network layer protocol's sequence number (for instance tcp's sequence number) and the last field holds a unique id of the packet in the system. In addition, the user can define a custom trace format to track system parameters that interest him. For example the queues at the input node of links or the window

Simulation has four scenarios. 20 nodes, 30 nodes, 40 nodes and 50 nodes simulations separately with A-MPDU and Two Level Aggregations frame aggregation mechanisms. Each scenario gives analysis of increased number of nodes separately for two frame aggregation mechanism. In 20 nodes scenario, 20 no nodes topology is created with mac value mac/A-MPDU and AODV routing technique. Here the CBR packet size is assumed of 512 Bytes and it is fixed.

This scenario generates trace file namely aodv.tr and nam file namely aodv.nam. Trace file gives the tracing result of topography, and nam file gives the actual animation of 20 nodes topography. Fig no. shows the trace file of scenario 20 nodes with A-MPDU aggregation. Fig no.5 shows the nam file of scenario 20 nodes with A-MPDU aggregation. Similarly different trace files are generated for different scenario. Fig no.6 shows the trace file of scenario 20 nodes with A-MPDU aggregation Awk scripts are used to analysis different parameters (like average throughput, energy, packet data rate, delay) using these tracing results. All analysed results are collected and represented in xgraph tool of Linux.

5. RESULTS

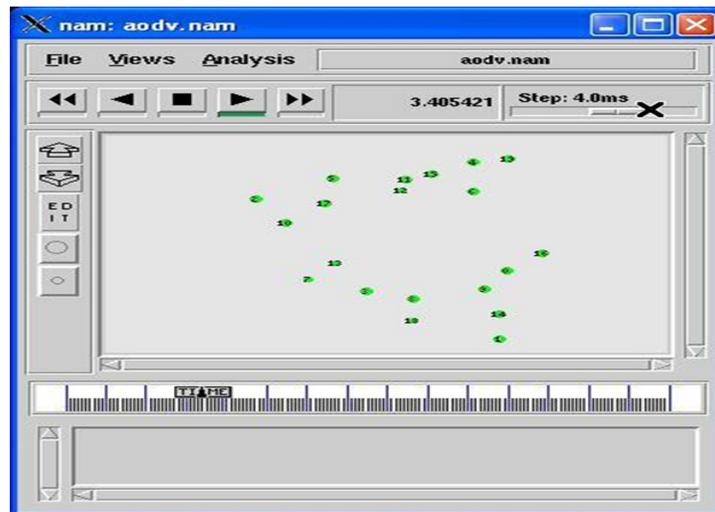


Fig no. 5 Nam file of scenario 20 nodes with A-MPDU aggregation

An A-MPDU aggregation scheme along with the two-level aggregation is compared using different parameters. Following graphs are showing the results for every case in terms of throughput, end to end delay, energy consumption and packet delivery ratio by varying different numbers of nodes on the basis of different parameters.

```

M 0.0 nn 20 x 500 y 500 rp AODV
M 0.0 sc scen-20-test cp cbr-20-test seed 1.0
M 0.0 prop Propagation/TwoRayGround ant Antenna/OmniAntenna
M 2.00000 0 (429.63, 179.83, 0.00), (475.11, 91.76), 0.59
M 2.00000 1 (417.93, 0.59, 0.00), (465.21, 273.35), 2.30
M 2.00000 2 (44.06, 365.45, 0.00), (361.59, 266.92), 8.92
M 2.00000 3 (219.07, 123.48, 0.00), (242.42, 181.90), 1.97
M 2.00000 4 (381.09, 456.97, 0.00), (274.96, 401.43), 1.17
M 2.00000 5 (157.40, 415.56, 0.00), (416.54, 393.43), 9.97
M 2.00000 6 (380.63, 394.48, 0.00), (343.47, 31.50), 9.88
M 2.00000 7 (135.97, 146.46, 0.00), (69.96, 425.13), 7.82
M 2.00000 8 (280.90, 112.32, 0.00), (482.91, 12.76), 7.34
M 2.00000 9 (406.23, 121.77, 0.00), (19.64, 491.89), 9.39
M 2.00000 10 (100.32, 301.22, 0.00), (250.00, 300.56), 0.80
M 2.00000 11 (282.41, 423.03, 0.00), (243.60, 288.58), 8.24
M 2.00000 12 (274.95, 390.16, 0.00), (107.98, 56.50), 4.08
M 2.00000 13 (169.27, 190.99, 0.00), (316.66, 386.82), 6.64
M 2.00000 14 (428.84, 57.28, 0.00), (96.20, 367.04), 9.70
M 2.00000 15 (327.67, 427.65, 0.00), (153.50, 395.64), 7.17
M 2.00000 16 (490.90, 226.13, 0.00), (25.24, 23.02), 5.95
M 2.00000 17 (172.72, 352.57, 0.00), (4.19, 353.24), 9.34
M 2.00000 18 (295.37, 38.23, 0.00), (70.89, 479.76), 9.92
M 2.00000 19 (432.30, 468.62, 0.00), (394.97, 195.61), 2.15
s 2.556838879 1_AGT --- 0 cbr 1000 [0 0 0 0] [energy 1000.000000] ----- [1:0 2:0 32 0] [0] 0 3
s 2.556838879 1_AGT --- 1 cbr 24 [0 0 0 0] [energy 1000.000000] ----- [1:0 2:0 32 0] [1] 0 3
N -t 2.556954 -n 14 -e 999.999200
N -t 2.556954 -n 9 -e 999.999200
    
```

Fig no.6 Trace file of scenario 20 nodes with A-MPDU aggregation.

5.1. Packet Delivery Ratio

Fig. No 6 shows the packet delivery ratio as the function parameter of increasing number of nodes. The ratio of the data packets delivered to the destinations to those generated by the CBR sources is known as packet delivery ratio [32]. The rate of increase of packet delivery ratio for A-MPDU is much lower than for Two level aggregation. Increase in PDR in case of Two level aggregation is due to the large number of frames are received at the sinks.



Fig No. 7 Effect of number of nodes on packet delivery ratio

5.2. Average Delay

The delay includes processing and queuing delay in each intermediate node. Average Delay measures the average one way latency observed between transmitting an event and receiving it at each destination. Ideally, Average Delay should have a rather constant value. Figure 8 shows the average delay observed as a function of network size. Increasing rate of the average delay in Two level aggregation is low as compared to that of the A-MPDU due to its second stage aggregation approach in Two level. Average delay of A-MPDU technique is 1 sec at 20 nodes while average delay of Two level aggregation is minimal at 20 nodes compared with A-MPDU

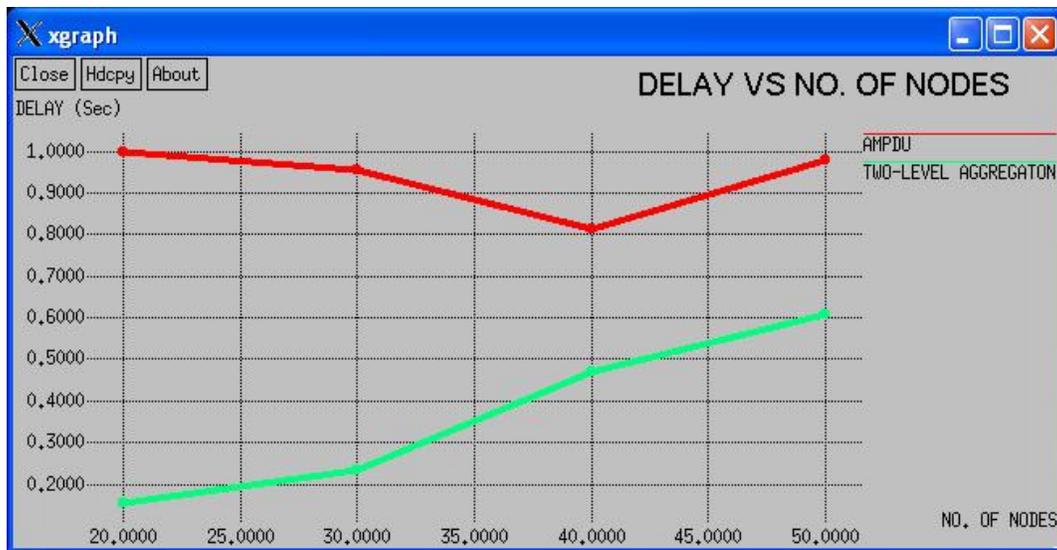


Fig No. 8 Effect of number of nodes on average delay

5.3 Energy Consumption

Fig. No 9 shows the average energy consumed by nodes during the simulation for A-MPDU as well as Two level aggregation scenario. Average energy consumed by A-MPDU technique is 50 Joules, and it's steady for increasing no of nodes. But energy consumed by Two level aggregation technique is 10 joules at 10 nodes and it's slowly increased as numbers of nodes are increased. And at 50 nodes it is only 30 Joules. Simulation result shows that average energy is consumed by Two level aggregation is less than A-MPDU.

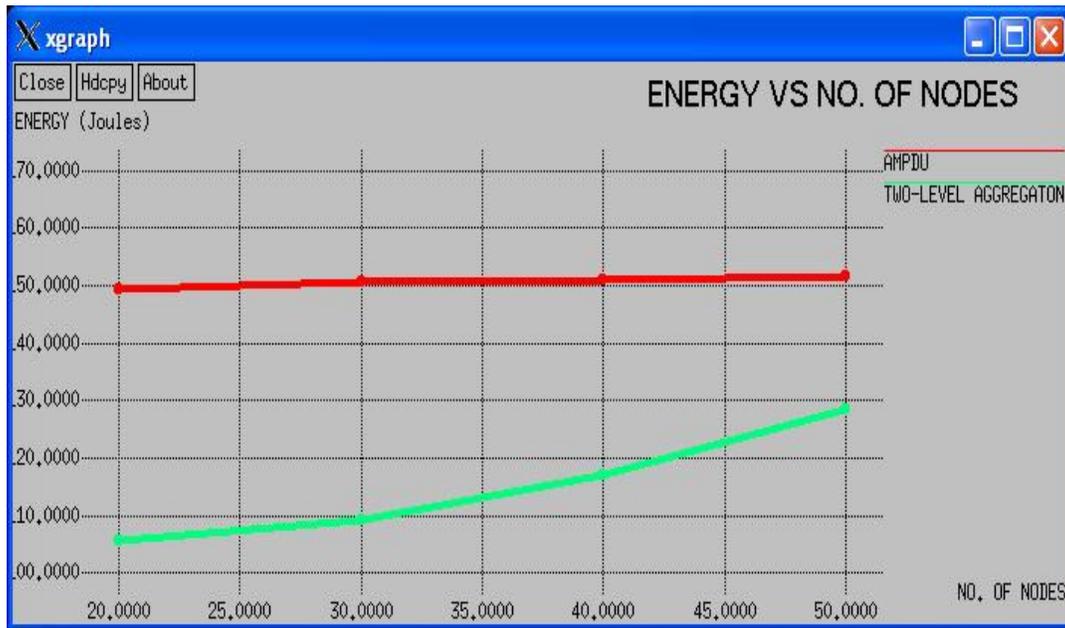


Fig No. 9 Effect of number of nodes on Energy consumed by different scenario

5.4 Throughput

The throughput is the maximum rate at which MAC layer can transmit packets from senders to receivers without packet loss. MAC throughput performance of the schemes increases with an increase of the overload of channel. However, after channel is saturated, the throughput of the A-MPDU scheme is fluctuated. This behaviour is characterized as normal because of channel saturation, meaning the resources are limited to the impending demand. Fig No. 10 shows MAC throughput performance by A-MPDU and Two level aggregation schemes at increasing number of nodes. As number of nodes increases the throughput two-level aggregation is increases exponentially. Throughput achieved by the two-level aggregation is higher than the A-MPDU aggregation scheme. And it is 12Kbps at 50 nodes while throughput of A-MPDU aggregation is fluctuated.

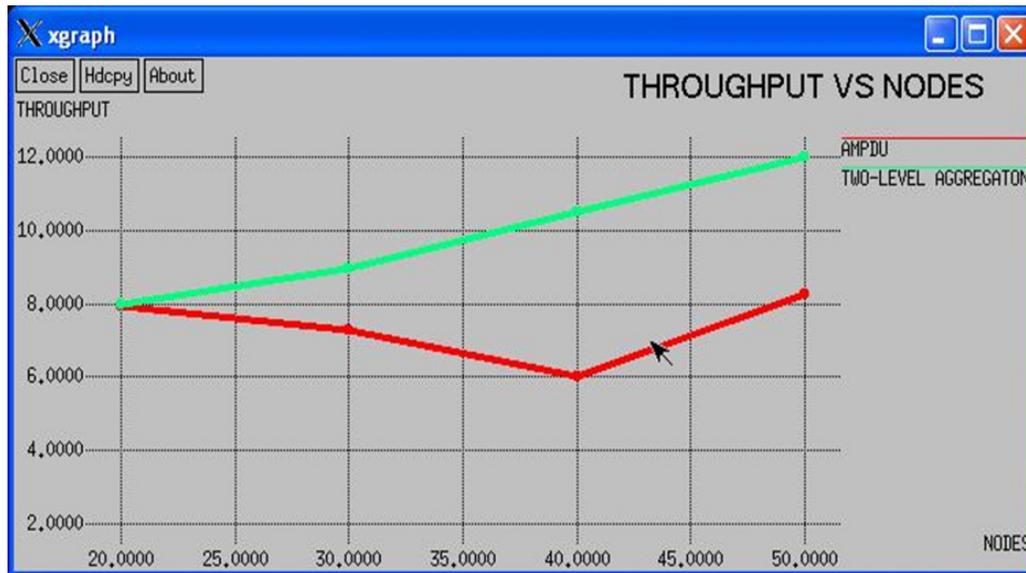


Fig. No. 10 Impact of number of nodes on MAC throughput of different scenario

6. CONCLUSIONS

This report gives detailed information about latest IEEE 802.11 draft. Different standards of IEEE 802.11 draft are explained with their parameter comparison. Here it gives detailed information of latest IEEE 802.11n WLAN draft. This report explained different techniques which enhance physical as well as MAC layer of IEEE 802.11N amendment. For physical enhancement, MIMO, OFDM, Channel bonding techniques are used. This report highlighted different problems in PHY enhancement, and it resolved by MAC enhancement. In MAC enhancement several mechanisms are explained. From which frame aggregation scheme is proposed in the latest IEEE 802.11n draft. Several frame aggregation mechanism are explained, namely A-MSDU, A-MPDU, and the combined two-level aggregation.

Intensive and detailed study of aggregation techniques and comparison of the performance of the two mechanisms A-MPDU and two level aggregation by network simulator (ns2) was done. The simulation results of comparison have been presented in the form of graphs. Simulation results of this project demonstrated that due to second level aggregation mechanisms large numbers of frames are aggregated in two level aggregation. Two level aggregation can more effectively deliver data from multiple sources PDR rate is much higher with much lower delay and less energy consumption as compared with A-MPDU approach.

As more number of frames are delivered effectively in two level aggregation, rate of increasing data throughput is much higher as compared to A-MPDU aggregation mechanism.

Future work includes comparison between these scenario with additional parameters such as packet size, fragment size and random node mobility. It also includes investigating of the optimal frame size to maximize the throughput of current 802.11n draft; optimal frame size will depend on BER (bit error rate).

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