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Performance Evaluation of Bonding Techniques at Wireless 802.11n

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Abstrak

Tuntutan akan throughput bandwidth yang tinggi, mendorong Point to Point wireless agar menyediakan bandwidth lebih untuk berbagai macam aplikasi seperti layanan waktu-nyata multimedia. Kami melakukan riset dengan tesbed eksperimen pada topologi Point to Point menggunakan wireless 802.11n dalam lingkungan LAB. Tujuannya ialah untuk mempelajari performa yang akan diraih oleh teknik Interface Bonding dan Channel Bonding. Kami mengusulkan proses dan disain eksperimen untuk mengevaluasi performa teknik tersebut. Beberapa parameter seperti delay, jitter, data loss rate dan throughput diterapkan di protokol TCP/UDP dengan ukuran paket dan arah arus trafik yang berbeda. Hasil dari eksperimen menunjukan bahwa Channel Bonding memiliki peningkatan throughput yang signifikan. Akan tetapi, hasil Interface Bonding jauh dari harapan, kami menemukan performanya jauh lebih rendah dari singgle normal link. Sebagai hasil penemuan, kami analisis hal itu disebabkan oleh Media Independent Interface (MII), dan Scheduling Algorithm tidak dapat berfungsi dengan baik pada koneksi Point to Point menggunakan wireless 802.11n.

Kata kunci: *channel bonding, interface bonding, point to point, wireless 802.11n*

Abstract

Demands for high throughput bandwidth, encourage Point to Point wireless to serve more bandwidth for many kind application such as real-time multimedia services. We conduct research with testbed experimental at Point to Point topology use wireless 802.11n in LAB environment. The aim is to studying the performance that would be achieved by Interface Bonding and Channel Bonding techniques. We proposed experiment process and design to evaluate the performance of those techniques. Several parameters such as delay, jitter, data loss rate and throughput applied on TCP/UDP protocols with different Packet Sizes and Directional Traffic Flows. The results experiment showed that Channel Bonding has significant throughput improvement. However, the Interface Bonding results are far from expectation, we found that the performance is least than single normal link. As our finding we analyze it caused by Media Independent Interface (MII), and Scheduling Algorithm unable to work properly at wireless 802.11n using Point to Point connection.

Keywords*: channel bonding, interface bonding, point to point, wireless 802.11n*

1. Introduction

Point to Point (PtP) wireless connection allow separate place that use infrastructure mode and configured as wireless bridge to be interconnected. Point to point link is a topology that designed for connect two desktop computers or connect entire local area network [1]**.** The implementation of this configuration is suitable for many conditions such as for low cost technology and capable of making separate place at long range interconnected [2]. Even there has been another alternative of local communication [3], wireless is still the most popular implementation for local communication [4].

Wireless 802.11n, is the latest draft from wireless 802.11 that have enhancement in its technology that already improve the theoretical bandwidth, from 54 Mbps (802.11g) become 135 Mbps (802.11n draft 2.0). The improvement of wireless 802.11n also given capability MIMO to use multiple transmitter and receiver achieve high throughput in single channel spectrum 20 MHz [4], [5].

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Nowadays with the ever growing demand for high throughput bandwidth, Point to Point wireless connection should be able to serve more bandwidth for many kind applications such as real-time multimedia services [6]. The Requirement of throughput improvement on network connection, lead some techniques to achieve more bandwidth. Interface Bonding that already implement on wire Ethernet and Channel Bonding are two techniques that expected capable to improve throughput.

Channel Bonding is mechanism that proposed by TGn Sync [5],[7], these given possibility wireless 802.11n to double the bandwidth throughput. In Channel Bonding, several close channels are bonded into a wideband. It will caused the transmissions band is enlarge, then the packet transmission would increase which leads to the reduction of packet transmissions time [8].Operate Channel Bonding in IEEE 802.11n needs to implement on High Throughput (HT) Green-field mode [9]. It used to activate the stations that capable to run on Channel Bonding. There are several research discuss the Channel Bonding technique such as in [10], where the performance of Channel Bonding on IEEE 802.11n would reduce significantly when get interference from single active IEEE 802.11g link, and their work also show that wide band of Channel Bonding can potentially larger the number of interferers. In [8], they made comparative analysis research of performance Channel Bonding with Multi Channel CSMA and [11] made comparative analysis with Single-channel 802.11.

Another technique to achieve more throughputs is using Linux Bonding also known as Interface Bonding. This technique could aggregate multi link interfaces become as a single logical links, where this technique is already used at Ethernet technology [12] and has been has been standardized as IEEE 802.3ad [13], where the kernel libraries and classes with detail explanation could be seen at [12], [14]. Aggregating the bandwidth of multiple physical communications into a single link to reach higher capacity is a common approach to be used for increasing the network performance. Because bandwidth offered by the multiple interfaces can be aggregated to improve quality or support demanding applications that need high bandwidth [15]. There has been some previous research on aggregating multiple wireless links that have looks for aggregate multiple IP link. In [16], the research is focus to present an adaptive approach to inverse multiplexing reliable transport protocols in wide-area wireless access network (WWAN) environments. While in [17], provide the research to aggregate the bandwidth of multiple IP links by splitting a data flow across multiple network interfaces at the IP level. It is applicable to connectionless (UDP) flows as well as for striping the data flow in a TCP connection across multiple IP links. In [15], the research is able to utilize all available bandwidth on wireless 802.11g that applied in unstable wireless environment. Meanwhile, [18] has able to aggregate three wireless links, into one logical link that only achieve maximal improvement throughput on UDP, but instability occur on TCP side.

This paper provide specific information regarding the implementation Interface Bonding and Channel Bonding techniques at Point to Point wireless 802.11n connection, since there has been no specific research that evaluate the performance of Interface Bonding at Point to Point wireless 802.11n connection and there is no any comprehensive information about comparative performance between Interface Bonding and Channel Bonding on Point to Point wireless 802.11n. We proposed experiment process and design, where several parameters are applied to measures the performance those techniques.

2. Proposed Experiment Process and Design

The research study was conducted at Lab environment that might be still has interference with other wireless devices, since we cannot control the interference. The signal strength of wireless devices is set in strong signal condition during experiment. The testbed experiment is use D-ITG [19] to generate traffic at end to end nodes. D-ITG also used to measures Delay, Jitter, and Data Loss Rate with Round Trip Time RTT mechanism. Moreover, to measures Throughput we use traffic monitoring in router devices that accessed via Winbox, with One Way Delay OWD mechanism. We using Mikrotik ROS v5.2 to make standard PC works as router that would able to provide Interface Bonding and Channel Bonding at Point to Point links used wireless 802.11n, where the wireless adapter uses chipset Atheros AR-92xx with two MIMO Spatial Antenna.

2.1 Experiment Process

This part describes our propose evaluation model to evaluate the performance of bonding technique as showed at Figure 1. We start from setting of wireless modes at router such as establish Point to Point connection with single link normal wireless mode used 20 Mhz bandwidth or applied Interface Bonding with round-robin mode that bond two wireless card with 20 MHz bandwidth each link or configure Channel Bonding with 40 MHz bandwidth.

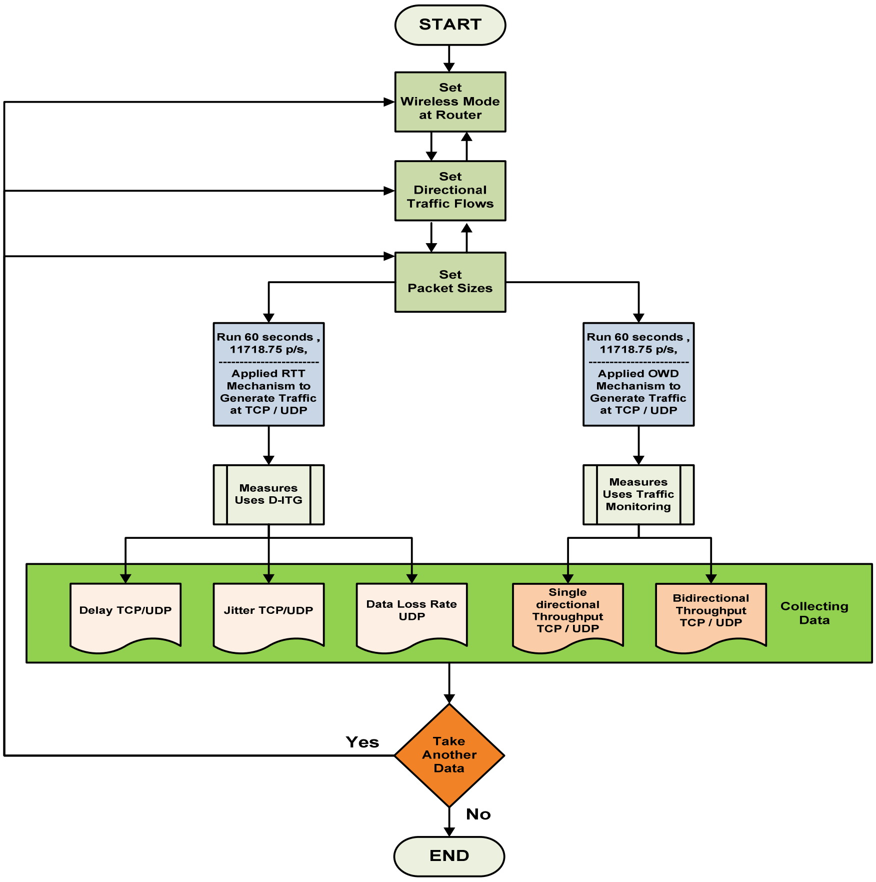

Figure 1. Proposed scheme of experiment process

We set different directional traffic flows that consist with single and bidirectional traffic flows, where this configuration only used to collect the throughput that applied OWD mechanism to generate the traffic. In single directional traffic flows, we only set client PC that able to send traffic at one direction used One Way Delay mechanism (OWD), where the server only receive the traffic that send by client. Otherwise, in bidirectional traffic flow; we prepare the server and client to be able to send traffic at same time used OWD mechanism. Where the server only sent constant 64 bytes traffic unlike client that could send traffic with different packet sizes.

The configuration of directional traffic flows is skipped when we want to collect the results of RTT delay, jitter and data loss rate, where RTT is combination of forward and reverse measurements. Packet Sizes on the experiment are defined on D-ITG. In this experiment testbed, 13 different packet sizes (64, 128, 256, 384, 512, 640, 768, 896, 1024, 1152, 1280, 1408, and 1536) are applied used constant payload size. The data rates that would be pump during experiment each cycles is set as default 11718.75 p/s and the duration is 60 seconds.

After setting and configuration done, we split the process to run the testbed experiment to generate traffic with OWD mechanism or RTT mechanism. After that, the traffic that generates used RTT will measure by D-ITG to provide performance data of Delay, Jitter and Data Loss Rate. The traffic that generates used OWD will measure by Traffic Monitoring in

Mikrotik router that accessed using Winbox from Monitoring PC to provide performance of single directional throughput and bidirectional throughput.

2.2. Network Design

This part describes our proposed network design that used to evaluate the Bonding techniques during experiment. The Network design for experiment testbed consist with five computers, where one computer used as remote monitoring PC that used to measures the throughput in single direction or bidirectional flows. The other two computer used as router that installed with Mikrotik ROS and two computers left used at end-to-end nodes, which connected by a 1GBps directly to each Mikrotik ROS. One computer at end sides is acting as client that responding to sent data, decoding log files and recording results. The other one computer acts as a server, responding to received data. All PC have same specification uses Intel Pentium D 3.2 Ghz, with 2 GB RAM except PC monitoring uses Intel Pentium i7 1.67 GHz with 4 GB RAM.

Figure 2 is the proposed network design to study the performance Channel Bonding, where every Mikrotik only have one wireless 802.11n adapters that used 40MHz band and setup as AP-bridge or Station for each side. The proposed network design to study the performance of Interface Bonding could be seen at Figure 3. The different with channel bonding is only at wireless 802.11n adapters, every Mikrotik have two wireless interface cards that used 20MHz band and setup as AP-bridge or Station for each side. Every router must aggregate two interface become one logical adapter

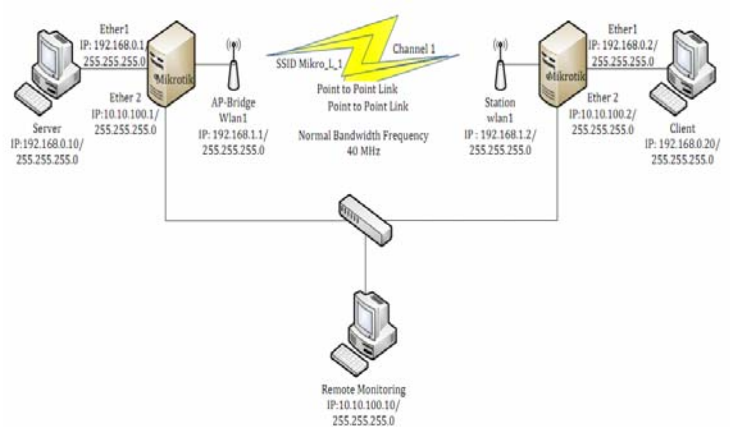

Figure 2. Network design channel bonding

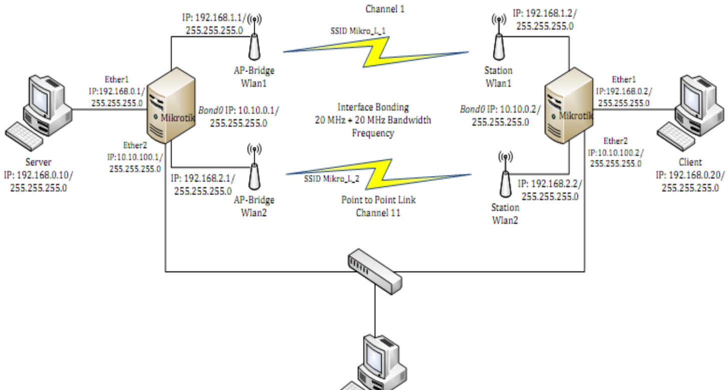

Figure 3. Network design interface bonding

3. Experiment Result

The result in Figure 4, 5, 6 and 7 are showed the throughput performance of Interface Bonding and Channel Bonding that also compared with normal wireless link. In TCP protocol, all the throughput will drop significantly when meet packet size 1536 byte compared with packet size 1408 byte. This condition is occur due to the limitation of MTU at TCP. The results of comparison also showed that if packet size and directional traffic flows influence the throughput of all wireless modes.

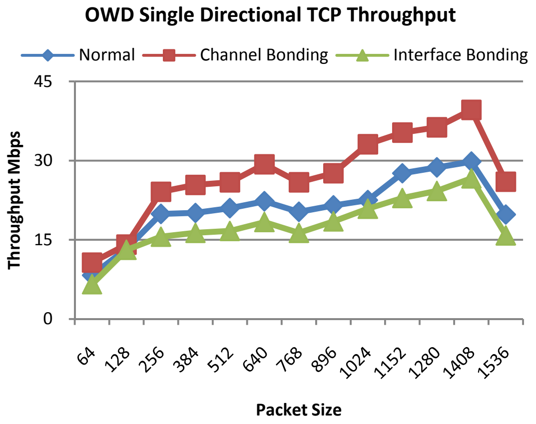

Figure 4. Single directional TCP throughput

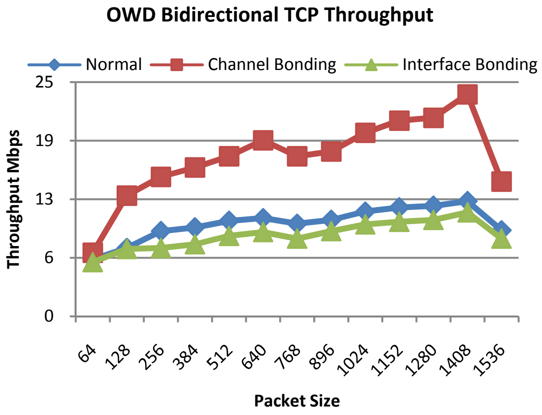

Figure 5. Bidirectional TCP throughput

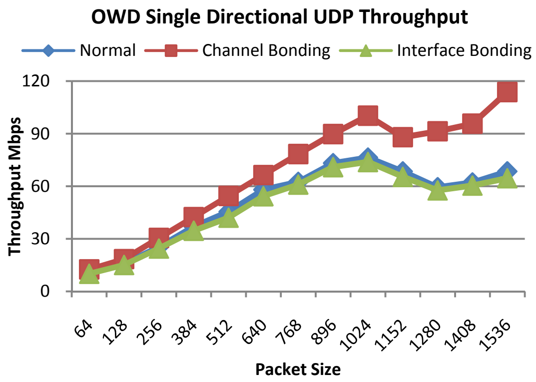

Figure 6. Single directional UDP throughput

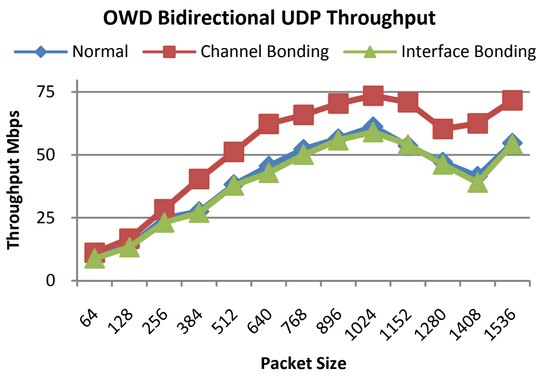

Figure 7. Bidirectional UDP throughput

3.1. TCP / UDP Throughput

The throughput of Channel Bonding is improved when applied this technique at Point to Point Connection. At TCP protocol, the performance single direction and bidirectional traffic flows is increase until 47.11% and 92.68%. Moreover, at UDP also increase until 66.16 and 50.50%.

Otherwise, Interface Bonding technique is showed hasn't improvement, although we bonds two wireless 802.11n, the performance of normal wireless mode with single link is still better. In TCP it drop until 20.48% and 19.78%. Furthermore, the throughput at UDP is drop until 7.39% and 8.12% compared with single link with normal wireless mode.

The performance evaluation of delay, jitter and data loss results are serves in Figure 8 – 16. The results always indicate similar behavior, where the interface bonding has the worst results than single link and channel bonding. The high numbers of delay, jitter and data loss are directly given impact to the degradation of throughput. Beside that, we only has result of data loss rate at UDP protocol, this conditions is occur because TCP is reliable connection protocol that avoids packet loss. This condition resulting D-ITG not detecting any data has been loss at TCP protocol. Therefore, only data loss rate at UDP protocol is collected as showed in Figure 16. The number of Data Loss rate of Channel bonding, is least compared with other. Otherwise, data loss rate at Interface Bonding is increase compared single link with Normal Wireless 8021.11n. The results of data loss rate all connection will increase with the increasing of packet size.

The overall conditions of interface bonding at point to point using wireless 802.11n in this research is contrast with research has been conduct by[15], [18] where the Interface bonding could improve the performance of wireless 802.11b/g event only stable at UDP sides.

3.2. TCP / UDP Delay

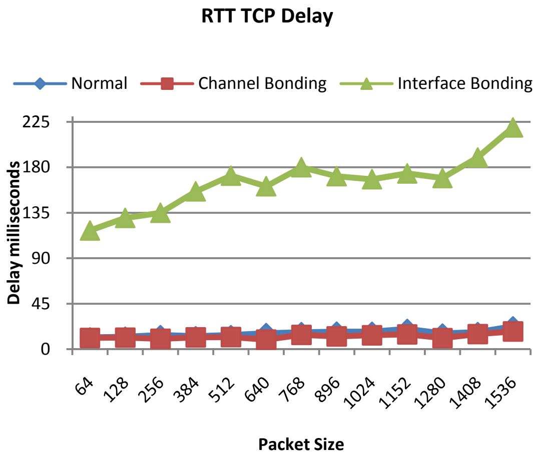

Figure 8. RTT TCP delay

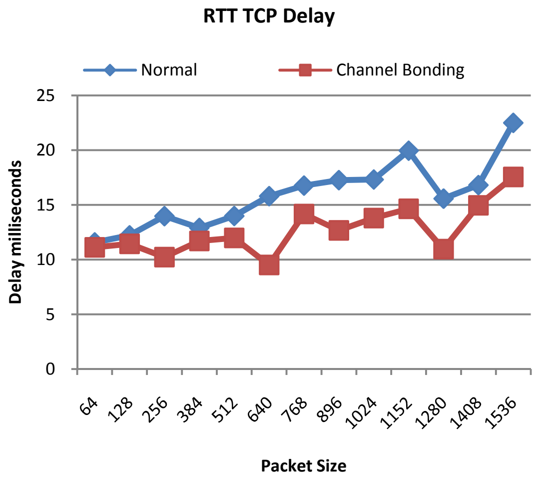

Figure 9. RTT TCP delay

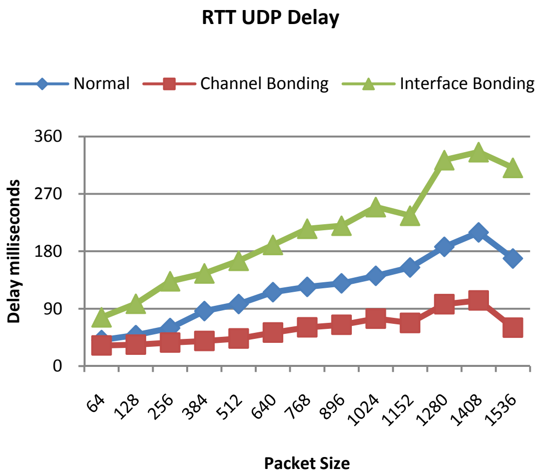

Figure 10. RTT UDP Delay

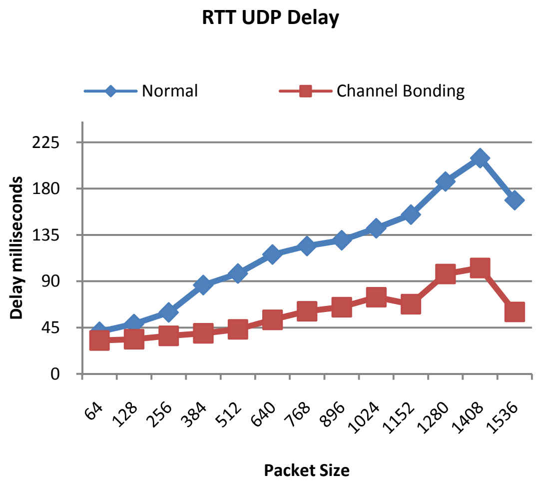

Figure 11. RTT UDP Delay

3.3. TCP / UDP Jitter

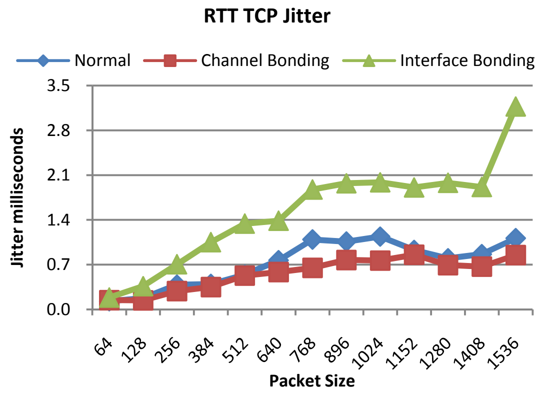

Figure. 12. RTT TCP Jitter

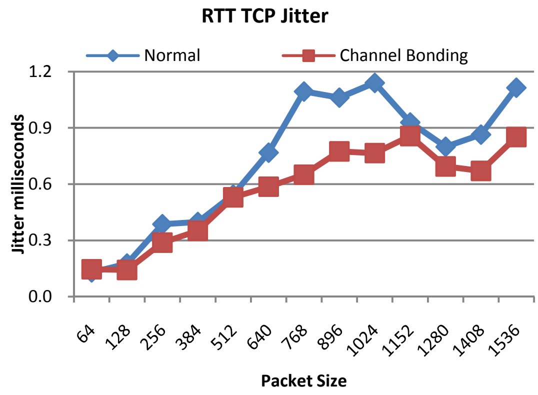

Figure. 13. RTT TCP Jitter

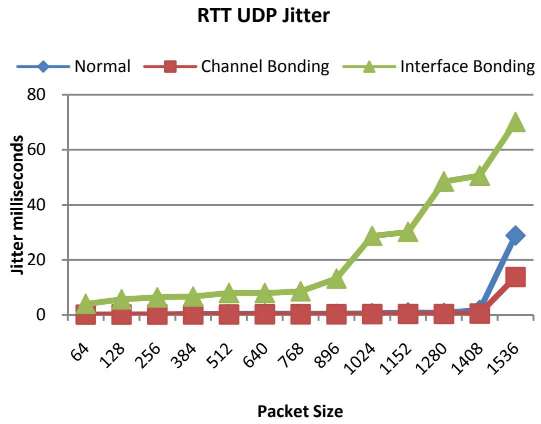

Figure. 14. RTT UDP Jitter

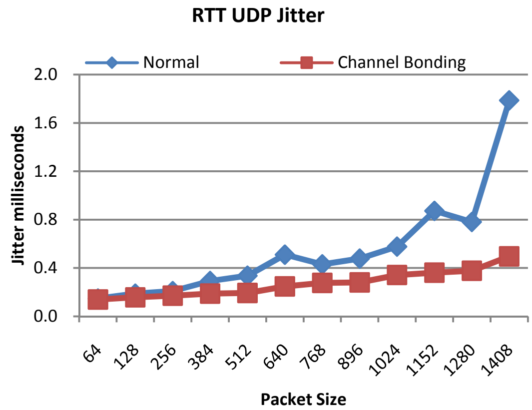

Figure. 15. RTT UDP Jitter

3.4. UDP Data Loss Rate

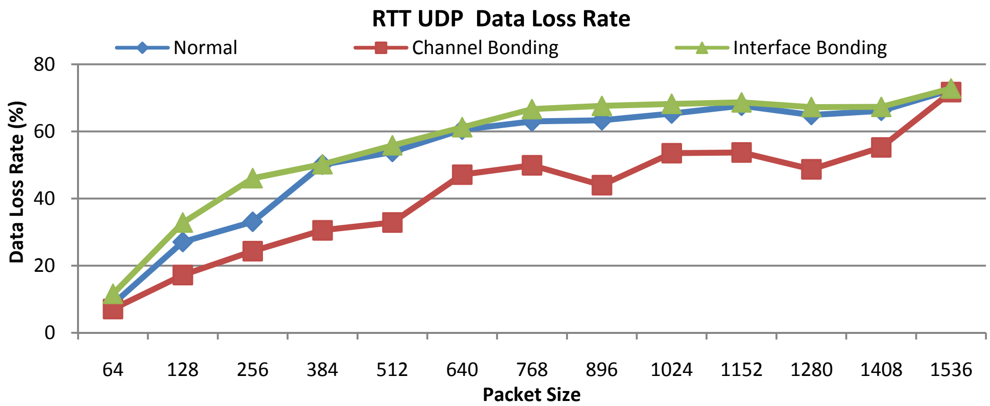

Figure. 16. RTT UDP Data Loss Rate

4. Discussion

The throughput of UDP protocol in this research is always showed higher performance than TCP protocol. UDP is connectionless protocols that not required acknowledgement like at TCP protocol, the speed of UDP protocol in wireless would be higher since the packet that loss will be ignored, because UDP not making retransmission for packet that has been loss.

TCP protocol is connection oriented that used acknowledgment to make sure if all packets are sent. It means, at TCP there is no any data loss rate has been found in this protocol. Since the wireless link is half duplex [20][5] the used of acknowledgement will reduce the throughput performance because it wait until all packet is received that caused at the same time both nodes are requesting to send data and make the process of transferring data alternately. Besides that, refer to [21]*"a network has a maximum transmission unit (MTU), which is the largest packet that can be transported over that physical network. On the Ethernet, the maximum Size is 1500 bytes, which defined as part of the Ethernet standard"*. Therefore, at packet size 1536 bytes the throughput of wireless will drop significantly. It caused the packet that has larger sizes more than 1500 bytes will be hash in to smaller part to fit with the MTU.

The throughput achievement at bidirectional traffic flows will decrease significantly at all packet sizes that has been generate. The degradation throughput at different directional traffic flow it caused by type of transmission medium wireless. The standard wireless 802.11 used half duplex communication medium access control, where *"Half-Duplex wireless system allow two way communication but subscriber can only transmitted and receive at any given time. Same frequency is used for both transmission and reception, with push to talk feature for enabling transmission only at a time "*[22]. This condition is different with wired Ethernet that applied full duplex communication for transmitting and receive the data. At wired transmission that have data rate 100 Mbps, it is able to transmit 100Mbps and receive 100Mbps at same time because full duplex communication medium [23]. However, since wireless is half duplex, the full speed could achieve when device only sends packet data one direction. When at same time the device required to receive packet data, the degradation speed will occur since at that time the medium access control MAC will manage the medium to able send and receive packet alternately that leads to degradations of throughput. Therefore, at bidirectional traffic flows the throughput of wireless link will decreased since both stations are sent and receive packet at same time. The mechanisms that manage half duplex medium access control at wireless are described as standard at IEEE 802.11e [20].

The overall result at this experiment showed that Channel Bonding has significant throughput improvement than Interface Bonding when applied at Point to Point connection used wireless 802.11n. These results could achieve, because Channel Bonding capable to maximizing available bandwidth resources of wireless 802.11n when applied at Point to Point connection for throughput improvement by wider the bandwidth spectrum from the standard 20 MHz become 40 MHz. Since the bandwidth, transmission is enlarge it make packet transmission rate increase and leads to the reduction of packet transmission time [8]. The result from experiment also showed if delay and latency of Channel Bonding is always less than condition of Normal wireless mode at all protocol and all conditions, which affecting to higher throughput achievement.

The performance of Interface Bonding at point to point connection that used wireless 802.11n is not showed improvement performance compared with normal wireless mode, since the performance of throughput, delay, jitter, and data loss rate of single wireless link still better than Interface bonding. The results of performance Interface Bonding at this experiment are contrast, when we compare with experiment that has been done at[15][18]. The different results in this experiment, is also caused by different platform technology and topology that affecting different result of experiment. At that research using wireless 802.11 b/g that implement in standard infrastructure topology without bridging two LAN segment, otherwise the platform Linux and driver that used to be implement as router are different. Moreover, we identified the problems of degradations throughput that occur in Interface Bonding is caused by kernel that not work properly at Point to Point connection use wireless 802.11n. Since the kernel cannot maximize the available bandwidth of each interface wireless 802.11n, the throughput of Interface Bonding is less than single link wireless interface. Main parts at kernel that leads to degradations performance of Interface Bonding are caused by Media Independent Interface that cannot be used for wireless adapter and Scheduling Algorithm that not work properly.

As consideration Media Independent Interface cannot be used at wireless interface to identified wireless link, it makes ARP interval is set as default 100ms. The consequence using default ARP to detect link, it will flooding the wireless link with their broadcast packet every 100ms, besides that when link failure is occur before 100ms the kernel cannot detect it and assume link is always on. Refer to [14]if the kernel will be unable to detect link failures, and will assume that all links are always available. The conditions will likely result in lost packets, and resulting degradation of performance. Another effects that occur since MII cannot work properly, refers to [13]in case the kernel cannot detect MII at wireless device, the data rate at ethool.c would be set as default 100 Mbps. It means the kernel will detect the data rates of wireless constant at 100 Mbps. This conditions affecting the actual speed rate that applied at wireless device at that time cannot detected, since the speed rate of wireless device is different with speed rate of wired Ethernet, the scheduling algorithm will send the packet data constant without care the actual data rates of physical devices. This condition will caused increased the delay, because buffer effect will occur at wireless devices if data rates are below than default speed that set by ethool.c. Another problems caused by kernel that applied scheduling algorithm to split and distribute packet. Refer to [13]algorithm Round Robin will split packet that transmit in sequential order from the first available slave through the last. It means the number of packet that split, will be sent with same amount sequentially to all interfaces. Based on[24] "*In Round Robin, traffic packets are scheduled to each link in a round-robin manner, and it is suitable for homogeneous and stable links such as wired*". Since the wireless link is unstable, we analyze the possibility of link failure is more often and data rates on each link could different even uses same physical devices. Round Robin scheduler will always send the packet data sequentially with same amount without cares with actual data rates each links or event the link is failure that will caused high data loss. Therefore Round Robin algorithm is not sufficient to be implemented at wireless link.

The impact of Media Independent Interface (MII) and Scheduling Algorithm that unable to work properly affecting the number of delay, jitter and data loss rate of Interface Bonding increase significantly compared with normal single link wireless then leads to degradation of throughput.

5. Conclusion

Our proposed experiment process and design has been able to evaluating the performance of Interface Bonding and Channel Bonding while applied at point to point wireless 802.11n. It caused UDP protocols are connectionless, which is not required acknowledgement like TCP protocol that make throughput of UDP protocol in wireless would be higher, due to the no retransmission for packet that has been loss. TCP is reliable connection that avoids packet loss, this condition affecting no any data loss rate at TCP protocol.

Channel Bonding has significant throughput improvement when applied at Point to Point connection. These achievements caused by Channel Bonding capable to maximizing available bandwidth resources of wireless 802.11n by wider the bandwidth spectrum, the affect to enlargement of bandwidth transmission make packet transmission rate increase and leads to the reduction of packet transmission time. On the other hands, Interface Bonding cannot maximize the performance of wireless 802.11n at point to point connection, in fact it has lower performance than single link. These conditions were caused by Media Independent Interface and Round Robin scheduling algorithm unable to work properly at Point to Point connection that used wireless 802.11n. The enhancements of MII are required as suggestion of futures work to make Interface Bonding able to detect link failure when occur in wireless and detect the actual data rates that available at wireless 802.11n. Besides that, the improving Scheduling Algorithm also needed to make algorithm that able to splitting packet data, and distributed the packet data based on the capacity of link and level of signal strength wireless 802.11n adapter that implement at Point to Point connection. For the further work, an enhancement of MII and scheduling algorithm that fully supports to be implementing at interface bonding for wireless 802.11nreqiured.

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