Robust Header Compression with Load Balance and Dynamic Bandwidth Aggregation Capabilities in WLAN

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Abstract

The vigorous development of WLAN in recent years has introduced various kinds of WLAN techniques and research subjects been brought up. The development of WLAN in recent years has deeply involved in our life. Besides of applying in home and office, IEEE 802.11 is also used in medium to long distance wireless transmission. Therefore we proposed a “Traffic Splitter Gateway Mechanism” that utilizes the link aggregation method in combination with RoHC to flexibly switch channels and utilize the wireless resources more efficiently in WLAN.[1]

Keywords: IEEE 802.11, link aggregation, Traffic Splitter Gateway, WLAN, RoHC.

1 Introduction

The vigorous development of network in recent years, surfing the internet, becomes a daily routine for everyone. The deployment of fixed-line network is often limited with transmission distance of 100m by the Ethernet 100BASE-T and the tracking between close buildings via road. One way to solve it is to rent a dedicated line from ISP, but it will cost an unreasonable huge expense. Besides, it is not reasonable to link a computer in the neighbor LAN network through WAN. Moreover, some people proposed the infrared ray transmission, but the biggest problem of it is the low transmission speed and is easily influenced by environment. Laser transmission mode contains certain risk and will be influenced by the climate conditions, in addition, the price and election isn’t available to most people.

Due to the development of WLAN, various kinds of techniques and research subject are unceasingly raised so the problem has a new solution. So far IEEE 802.11g is a very popular transmission protocol, and its transmission rate reaches as high as 54Mbps. Therefore we propose an improvement for the trunking mechanism of IEEE 802.3ad and apply it to Wireless Trunking [1]. We want to set up a wireless trunk and increase bandwidth without changing existing equipment, merge and promote bandwidth of wireless backbone, monitor WLAN transmission condition, and use load balance to allotment of transmission.

In this paper, we will discuss how to build a wireless trunking under the frequency spectrum of unlicensed band designated for wireless network. We use IEEE802.11g to build our wireless environment. By using this standard, we can have 11 available channels. To avoid channel interference, we use as many channel as possible, channel 1, channel 3, channel 5, channel 7, channel 9 and channel 11, by doing so, we can have 192Mbps of bandwidth available. The proposed Traffic Splitter Gateway mechanism can classify the incoming information into 3 types (realtime, non-realtime and general) and then put them in 3 queues. Also, we take the advantage of IEEE 802.3ad to dynamically adjust usage of bandwidth. The proposed mechanism combines IEEE 802.3ad with Robust Header Compression (RoHC) that provides header compression, to efficiently increase the performance of wireless network transmission [2,3,6,7].

The rest of this paper is organized as follows. Section 2 introduces the related works. Section 3 presents Design and implementation. Section 4 introduces the performance evaluation. Conclusions are shown in Section 5.

2 Related Works

In this section we will talk about link aggregation services and Robust Header Compression (RoHC) by explaining relative basic principles, frameworks and applications.

2.1 Link Aggregation Services

The basic concept of IEEE 802.3ad is based on the

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network layer-2 protocol. We turn off the spanning loop function of switch equipments and merge two or more bandwidth together. With the help of trunk link we can set up a virtual logic connection between two DTE that are composed with N full-duplex paths which are in parallel.

Advantage

- Increase Bandwidth
  It can merge many paths into a logic path to raise bandwidth. Theoretically bandwidth will be increased linearly.
- Increase Reliability
  If any entity line is broken down in logic path, it will not affect the connection. The trunk link has the backup function.
- Load Balance
  It can scatter the MAC-client traffic load to each path by using trunk link. When trunk link is settled logically, there is only one line. However as long as one entity line is broken down, the trunk link load balance will shift traffic to the other path. At most four entity lines can be used to form a logic connection at one time.

Disadvantage

- Does not support multi-node
  Basically it only supports connection between two nodes instead of multi-nodes. Figure 1 shows that if multi-node is supported, it will cause the loop problem.
- Does not support different MACs
  The IEEE802.3ad only supports 802.3 series of MAC protocol instead of other network environments.
- Half-duplex model
  The trunking system only supports half-duplex model.
- Does not support links of different speed
  The trunk link doses not support links of different speed. It is not allowed for each DTE to use different speed such as 100Mbps to 10Mbps. Links with the same speed is essential.

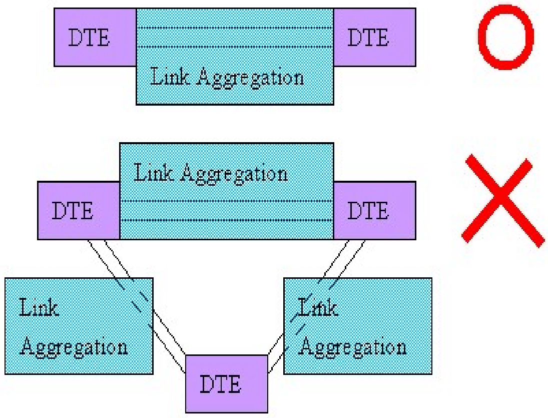

Figure 1 Multi-node connection will have the loop problem

Figure 2 shows the cadre of trunk link. What we propose in this article is based on this cadre and we do not have to correct any cadre and rules. We will set up a Link Aggregation Sub-layer (LAS) as the middle process function with the MAC-client above it and MAC below it. The procedure still follows the original one because LAS functions are used as the communicator. So we focus on the key LAS and make some modifications in order to support wireless trunking and improve transmission efficiency.

IEEE 802.3ad has a set of Beowulf system which the core bonding is based on this opening program. The basic cadre is made from a little correction of the bonding part of Linux core. It also develops a way for managers to conduct management easily, and we use it as a basic frame to design and improve the wireless trunk system. Figure 3 shows that those three network interfaces will be bonded into a large network interface. The MAC of this bonded interface is the one of the first interface. It should be noticed that the program in the core part of Linux is modified under IP layer. The advantage to do so is that we do not have to pay extra attention to the network support when the network interface card is changed. Basically all network interface card should be able to work for this program.

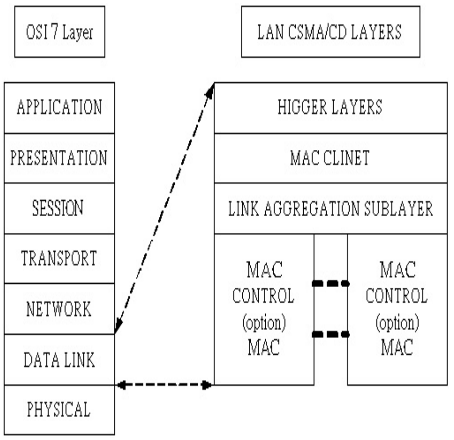

Figure 2 Trunk link framework

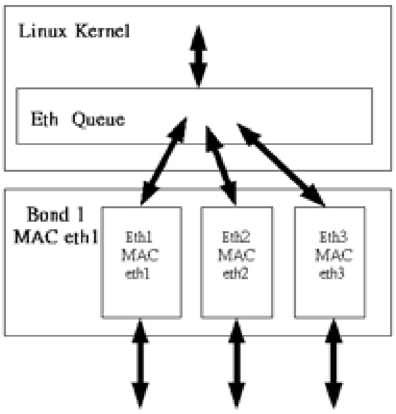

Figure 3 Bonding system Architecture

2.2 Robust Header Compression (RoHC)

In the modern world, the mobile devices are increasing in astonishing both in speed and quantities. Vast users are demanding for more services and most of them are multimedia services. RoHC is a versatile header compression scheme developed by the IETF's RoHC working group and is defined in RFC 3095[4,5]. RoHC provides improved performance over IPHC, and CRTP in high BER and high RTT wireless links, by reducing the impact of context de-synchronization. The RoHC is to keep away from sending redundancies information in header field, this redundancy can be static or dynamic. The static header field can be as Version, Source Address, Destination Address and Flow Label.

As for the operation, it consists of 3 kinds of modes, Uni-directional mode (U-mode), Bi-directional Optimistic mode (O-mode), and Bi-directional Reliable mode (R-mode), as shown in figure 4.

- Unidirectional mode (U-mode)

  There will be no feedback during the entire session, the compressor finite state machines (FSMs) will start by sending few packets will full header, and will pretend the de-compressor's FSMs has received the complete header information and is ready to decompress the compressed packet, it will move to SO state by sending only CID, pretending the de-compressor' s FSM can decompress the compressed packet without problem, since it will be no feedback used, it uses 2 timers that periodically move the compressor's FSMs downward to lower compression state.
- Bidirectional optimistic mode (O-mode)

  In this mode, the feedback is used, only when an unsuccessful decompression occurred.
- Bidirectional Reliable mode (R-mode)

  The feedback channel is used much more frequent, this is used to gain robustness but with the cost of compression rate.

As shown in figure 5, compressor's FSM comprises the Initiation and Refresh (IR) state, First Order (FO) state and Second Order (SO) state. The IR state consists of sending complete and uncompressed header information to the de-compressor. The FO state consists of sending partially compressed header, basically the static field is compressed and dynamic field isn't. The SO state consist of compresses header, it sends only Context ID (CID) alone with payload, and the de-compressor can extract the compresses information without problem.

As for de-compressor's FSM, it comprises of the No Context (NC) state, Static Context (SC) state and Full Context (FC) state. The NC state expresses that the de-compressor's FSM doesn't have any header information, and haven't decompresses successfully any compressed

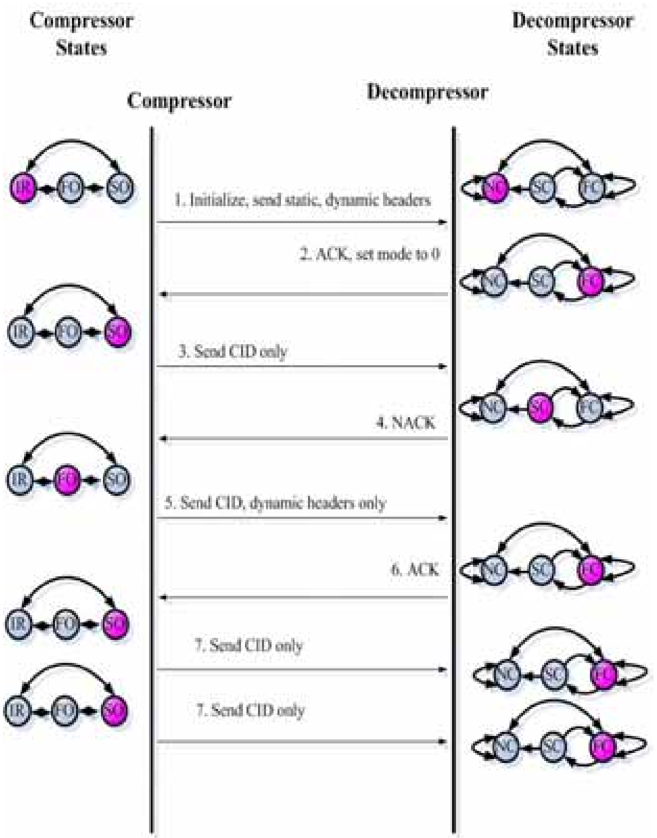

Figure 4 Finite state machines of RoHC Trunk

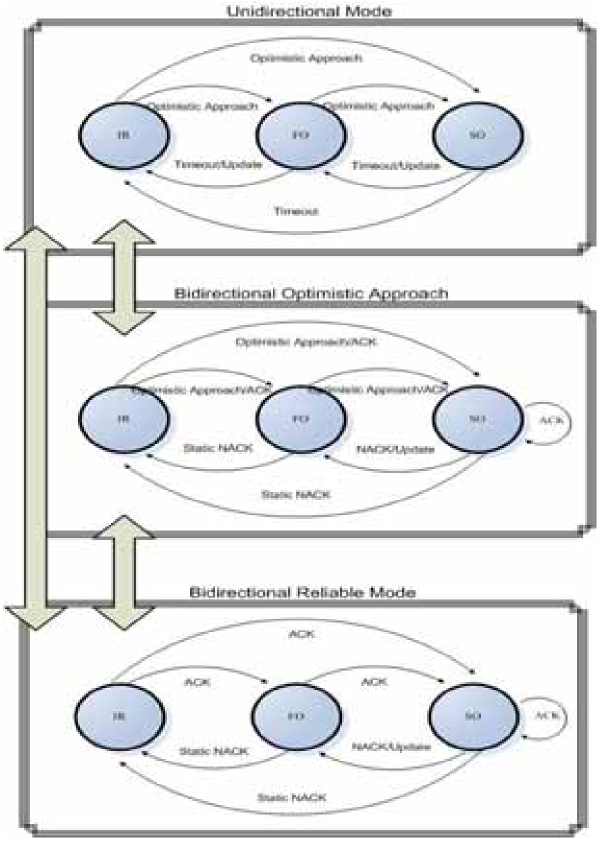

Figure 5 Finite state machines for the ROHC compressor/decompressor

Table 1 Comparison of IEEE802.11 standards

	802.11	802.11a	802.11b	802.11g
Frequency spectrum	2.4GHz	5GHz	2.4GHz	2.4GHz
Data/rate	1or 2Mbps	5,9,12,18,24, 36,48,54 Mbps	1,2,5.5,11 Mbps	6,9,12,15,24 ,36,48,54 Mbps
Modulation	FHSS or DSSS	OFDM	DSSS	OFDM
Transport rate	1.2Mbps	32Mbps	5Mbps	32Mbps
Distance	300-foot	225-foot	300-foot	300-foot
Encryption	Yes	Yes	Yes	Yes
Encryption type	40-bit RC4	40-bit or 104-bit RC4	40-bit or 104-bit RC4	40-bit or 104-bit RC4
Authentication	No	No	No	No
Supply	IEEE802.3	IEEE802.3	IEEE802.3	IEEE802.3

header yet, it will require the compressor to send the complete header information to receive information. The FC state tells that the de-compressor can decompress the compresses header, the compressor only need to send the Context ID with payload, and de de-compressor will try de decompress the packet sent. The last state to be mentioned is SC state, upon un-successful de-compression, the de-compressor's FSM moves to SC state which the compressor sends the packet with dynamic field, and the de-compressor will try to decompress the partially compressed header. If the decompression is unsuccessful, then the de-compressor state will drop backward to FO state, requesting compressor to send the entire header information.

2.3 IEEE 802.11

IEEE 802.11 is a standard formulated by IEEE including 802.11, 802.11a, 802.11b and 802.11g. Table1 shows the comparison of these standards. Nowadays, IEEE 802.11g is very popular and it works at 2.4GHz. At the MAC level we considered both the IEEE802.11 PCF (Point Coordination Function) and DCF (Distributed Coordination Function) phases while the first one is totally managed by the AP, which is coordinated by the different stations that need to transmit data on the shared channel.

Since in WLAN, it cannot detect collisions because of its nature of transmission media, hence it uses CSMA/CA. However the communication protocol also results in low transmission efficiency and excessive overhead.

When media space is free in WLAN, station will wait for a period of time to use the network. At the same time each station will random wait a CP (Contention Period) time to avoid transmitting packages simultaneously. After transmission is completed it will wait a SIFS and send back a ACK to inform the transmission is succeed and does not need to be re-transmitted.

Table 2 Transaction time with packet size of 1500 bytes

	1500-byte MTU TCP Data (μs)	TCP ACK (μs)
DIFS&SIFS	50*1+10*1=60	50*1+10*1=60
802.11 Data	$192+\frac{1542}{1.375}=1313.4$	$192+\frac{82}{1.375}=251.6$
802.11 ACK	$192+\frac{14}{1.375}=203$	$192+\frac{14}{1.375}=203$
Total	1576.4	514.6
Total transaction	2091	

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The figure 6 shows the Wireless Network MAC Frame Header. The PLCP Preamble use 18bytes and PLCP header use 6bytes. It will transmit PLCP header in 1 Mbps. The time to transmit is 72+24=96us.

From table 2, we can observe the transaction time used to convey a TCP content with packet length of 1500 bytes. According to the calculation above, it spent about 2091μs to do so. Therefore, its efficiency is only about 49% if there is no collision happened.

$$\frac{1}{2091*10^{-6}}=\frac{1*10^{6}}{2091}=478.24$$

$$478.24*1500=717360 bytes=700.5468 KB/s=5.4 Mbps$$

$$\frac{5.4}{11}=49\%$$

3 Design and Implementation

Few requirements are needed for Internet load balancing. Every incoming packets will be processed and forwarded by traffic splitter. Therefore, the efficiency of

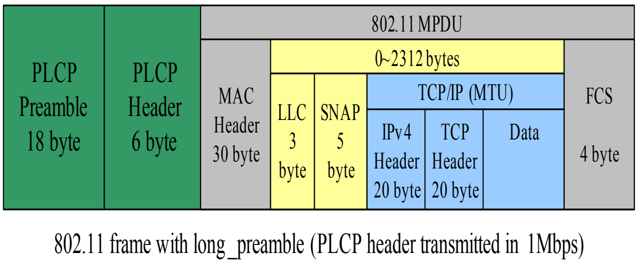

Figure 6 802.11 frame with long preamble traffic splitter should be carefully tweaked, since the poor traffic distribution will lead to un-efficient utilization of bandwidth, it should be working mostly similar to reference model.

When the system works with packets, the FIFO is the main concept of how it works, while a packet of maximum size P_{max} entered the system, not until the data is processed and sent, no more data is allowed to enter the system. We can assume an equation, where $S_i(\tau,t)$ is the amount of information transferred to link ¡ during the period of [τ,t], and C is portion of processed data. As we can see, in FIFO system, while we have a maximum size of packet Pmax, the link *i* and link *j* should send packets with efficiency [7].

$$\left|\frac{S_i(\tau_i t)}{\mu_i} - \frac{S_j(\tau_j t)}{\mu_j}\right| \le \frac{P_{\max}}{\min(\mu_i, \mu_j)}$$

We design a highly efficient mechanism to transmit data by IEEE802.11g. As following, we will introduce the architecture step by step. We deploy 6 Access Points (APs) on each roof of both buildings, using GRID Antennas to improve the transfer range and minimize interference. The bandwidth of 6APs can be combine using link aggregation; user can use their own WiFi equipment, unlicensed, to cut down cost.

In our method, we use three techniques to improve efficiency of the model. Firstly, RoHC provides more bandwidth for wireless transmission and more secured wireless network. If hacker eavesdrop data on wireless network, since we use RoHC compression, they will not be able to decompress the packet. The wireless data transfer rate is less than LAN, we can improve the transfer rate 50% by using RoHC. Secondly, Link aggregation of IEEE 802.3ad technology is used to combine multiple bandwidth of IEEE802.11g and the bandwidth can be adjusted dynamically. Thirdly, we design a flow control gateway, it provide both flow control and ROHC header compression. The proposed system model is shown in figure 7.

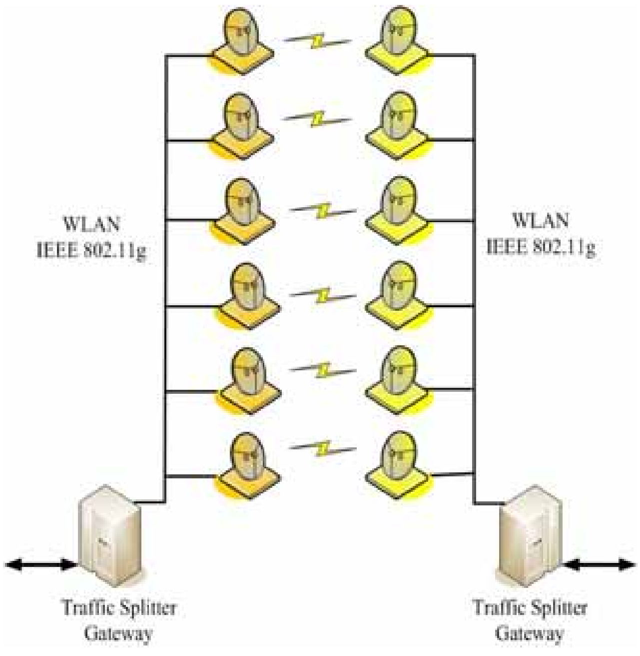

Figure 7 Proposed system model

We'll introduce the working principle of the method. First, we set up 6 APs for each of the two buildings, and using GRID antennas to connect each other. The advantage of using directional antenna that is to raise the transmission power to extend transmission distance and avoiding noise. And, GRID Antennas can limit the receiving degree and avoid been eavesdropped by hackers using wireless environment. In addition, at the rear of the two wireless transmissions we build the Traffic Splitter Gateway, this equipment would play the compression before wireless transfer and load balance.

As the figure 8, we used the 6 channels to dynamic binding bandwidth for backbone, and separated the 6 channels of bandwidth into two groups. One set transmits Header compressor and Trunking, the other one only transmits normal Trunking (Non-RoHC), these two sets bandwidth can be allocated dynamically by Traffic Splitter Gateway, the foregoing transmitting data does not define the mainframe transmitting data, so we will traffic split in Traffic Splitter Gateway, belong to a great deal of transmitting data and the same Flow with source and destination allocate the set including header compressor.

We design two sets Queue space in the Traffic Splitter Gateway, dividedly store 1. A great deal and long time transmitting data, this data suits to make batch of processing. 2. Only several packets in the same flow. The Traffic Splitter Gateway split packets steps as following: It judges source IP, destination IP, and port number in every

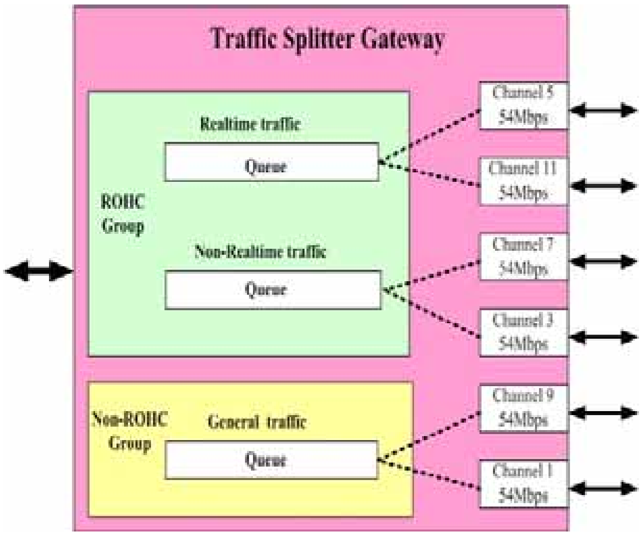

Figure 8 Traffic Splitter Gateway

packet header. About realtime traffic, 5056 (SIP), allocate in realtime queue. Non-realtime traffic, 21 (FTP), allocate in Non-realtime queue. These traffics are allocated 2 channels with each queue and we will use RoHC to compression all packets with a couple queues. In the other set of Queue, only store less and not specific packet.

In Traffic Splitter Gateway, the trunking backbone have six sets which are divided into AP1, AP2, AP3, AP4, AP5 and AP6 and match the six LAN cards in the Traffic Splitter Gateway. The system model is shown in figure 7. In our implementation, these APs were deployed on channel 1, 3, 5, 7, 9, 11.

4 Performance Evaluation

In the simulated environment for the experiment we obtain the experimental parameters by erecting the simulated environment. We have improved the system and analyze the systematic parameters. In the simulated environment, we use two PC to construct Traffic Splitter Gateway and make the connection through access point then take the access points as the segmentation line. While it merged the bandwidth, it takes two wireless paths as the experiment simulated environment.

Then we use the network packet generator software Iperf (http://dast.nlanr.net/Projects/Iperf/) to conduct efficient test toward merging with wireless bandwidth, and through the network monitor software ”Airopeek” with dynamic load balance disposition we can observe the package transmission change in each channel, and adjust the Load Balance disposition condition [16,17,18].

The system throughput is measured using network packet generator hardware SmartBits-SMB600. The wireless frequency Channel 1, 3, 5, 7, 9 and 11 are pre-set to avoid interfere. By the way, we use GRID Antennas to reduce interference.

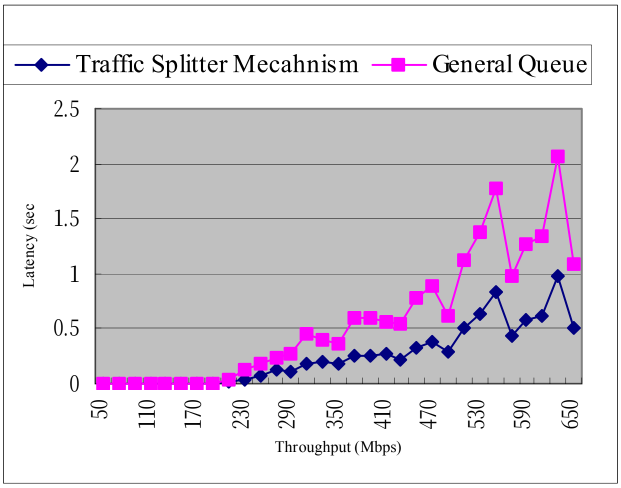

Figure 9 Latency time with load balance

Figure 9 shows latency produced during transmission, by doing comparison of my method and the method that uses trunking technology. Our method will separate the incoming packets into 3 types of services, realtime, non-realtime, and general. It will assign 2 channels for each type of packets initially, each 2 channels can provide 64Mbps of bandwidth, and 6 will be providing 192Mbps bandwidth, and according to the priority of service, we can dynamically modify the bandwidth to perform binding trunking. From figure 9 we can observe that when the transmission has exceeded total bandwidth of 192Mbps, the latency begin to occur.

Figure 10 shows that when we compare the data transmission of ordinary trunking method with the method of RoHC in combination with Trunking, we observe that RoHC can improve the wireless transmission, by reducing the bandwidth wasted to transmit header field and use the saved bandwidth to transmit more payloads, when the type of service belongs to realtime and non-realtime, it will use RoHC to transmit data. By statistic, using this method can increase 31% of transmission rate.

5 Conclusion

This paper discussed how to build a wireless communication tunnel under the frequency spectrum of unlicensed band for wireless network. We use IEEE 802.11g to build the wireless environment. By using this standard, 11 channels are available. In order to avoid the interference, 6 channels are used and 192 Mbps of bandwidth is available. This Traffic Splitter Gateway mechanism can classify the incoming information into 3 types (realtime, non-realtime and general) and then put them in 3 queues.

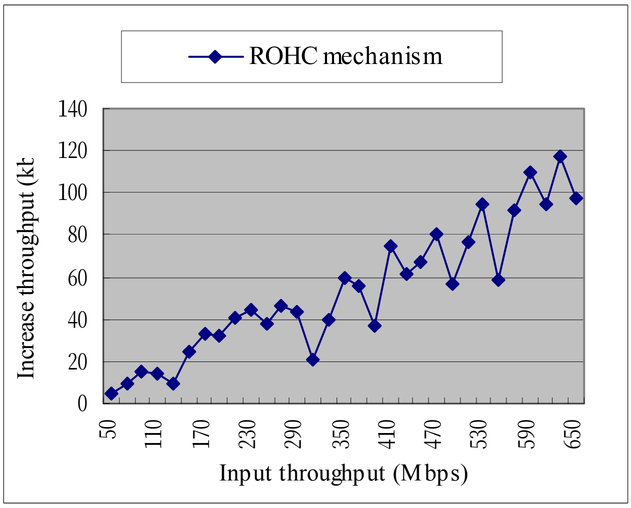

Figure 10 Throughput increase for RoHC mechanism

The mechanism of IEEE 802.3ad was used to dynamically adjust the usage of bandwidth. The proposed approach combines IEEE 802.3ad with RoHC to efficiently increase the performance of wireless network transmission. We improved the bandwidth usage by reducing the wasted bandwidth in header fields. The proposed approach is more robust in the unstable wireless transmission environment and could provide more bandwidth than the currently used standard wireless trunking technology. With a little investment, we can have more bandwidth available. This paper has also provided a scheme to speed up the construction of a wireless trunking architecture and can avoid the complicated setup process for network managers.

Acknowledgment

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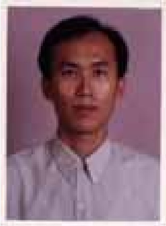
Biographies



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