MAC PROTOCOL FOR WIRELESS COGNITIVE NETWORK

FARAH NAJWA BINTI MOKHTAR

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NIK MOHD ZARIFIE BIN HASHIM
Ketua Jabatan Kejuruteraan Komputer
Fakulti Kejuruteraan Elektronik Dan Kejuruteraan Komputer
Universiti Teknikal Malaysia Melaka (UTeM)
Hang Tuah Jaya,
76100 Durian Tunggal,
Melaka.

Tarikh: 3 MEI 2011

"I hereby declare that this report is the result of my own work except for quotes as cited in the references."

Signature : …….

Author : Farah Najwa Binti Mokhtar

Date : 3rd May 2011

"I hereby declare that I have read this report and in my opinion this report is sufficient in terms of the scope and quality for the award of Bachelor of Electronic Engineering (Computer Engineering) With Honours"

Signature :……

Supervisor : En. Nik Mohd. Zarifie Bin Hashim

Date : 3rd May 2011

Dedicated to my beloved family especially and also to all my friends

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ABSTRACT

Poor link quality that may occur from environment factor such as noise and fading drops the Signal-to-Noise Ratio (SNR) value. This contributes to packet loss during the packet transmission in wireless networks. The objectives of this thesis are to re-design existing MAC protocol to support piggybacking by inserting SNR field in the RTS-CTS frames. It is also to evaluate the protocol performance in terms of average delay and throughput. Non-persistent CSMA has been used as the access protocol and Rayleigh fading channel is chosen as the channel model. As we discovered, WCN with piggybacking mechanism does improve the link quality and hence increase the throughput performance by more than 3 times compared to normal WLAN.

ABSTRAK

Kualiti laluan yang rendah boleh berlaku daripada faktor alam sekitar seperti daripada hingar boleh merendahkan nilai Nisbah Isyarat kepada Hingar (SNR). Ini menyumbang kepada kehilangan paket semasa penghantaran paket dalam rangkaian tanpa wayar. Objektif tesis ini adalah untuk mereka semula protokol MAC sedia ada untuk memuatkan mekanisma sokongan dengan memasukkan ruangan SNR ke dalam rangka RTS-CTS. Ia juga bertujuan untuk menilai pencapaian protokol di dalam purata masa penangguhan dan daya pemprosesan. CSMA bukan persis telah digunakan sebagai protokol akses dan saluran Rayleigh dipilih sebagai model saluran. Seperti yang telah ditemui, WCN dengan mekanisma sokongan telah memperbaiki mutu laluan dan oleh sebab itu, ia telah meningkatkan pencapaian daya pemprosesan lebih daripada 3 kali ganda berbanding WLAN yang normal.

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INTRODUCTION

1.0 Project Background

Wireless network is a network set up by using radio signal frequency to communicate among computers and other network devices. One of wireless networks that is really famous is known as WiFi network or WLAN. Wireless Local Area Networks based on IEEE 802.11 [1] promote significant attention in both the industry and academic, as provide very essential characteristics for example high bandwidth and ease of deployment.This type of network is getting popular nowadays due to easy to setup feature and no cabling involved. Users are able to connect computers anywhere in their home without the need for wires.

The success of the Internet has caused a demand for wireless communications. Moreover packet switching plays important role where it is being applied in almost all technologies. The International Standards Organization (ISO) has defined the fundamental of Open System Interconnection (OSI) to partition computer network design and development areas into seven layers [1].

In this model, a networking system is divided into layers. In each layer, one or more elements implement its functionality. Every elements will communicate directly only with the layer with the nearest layer, and provides facilities for use by the layer above it. Protocol enables an element in one host to interact with other element at the same layer.

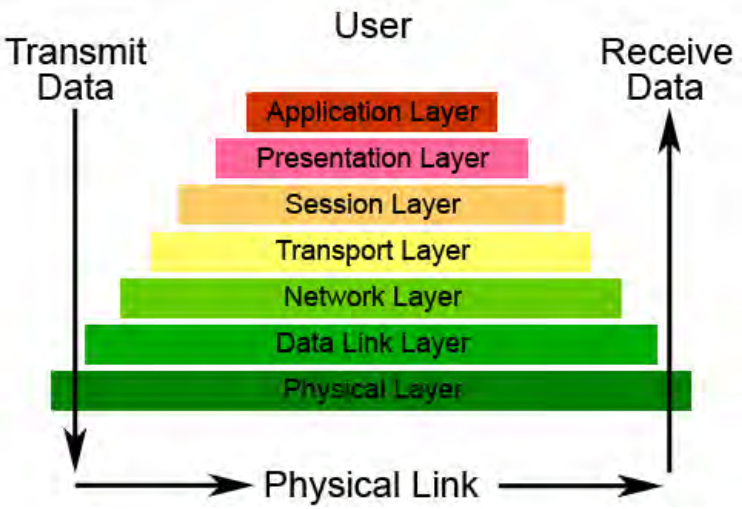

Figure 1.1: OSI Model [2]

The four upper layers are mainly logical and the rest are considered physical. The physical layer of wireless network therefore transmits bits and receives bits in wireless medium, while Medium Access Control (MAC) coordinates the packet transmission using the medium formed by a number of bits [2]. However, this existing MAC protocol does not provide 'smart' protocol for user since it does not have the feedback element to improve the quality of network link. This may contributes to few problems due to poor link quality such as packet loss or collision during the data transmission.

Wireless cognitive network is one of the protocols that can be applied in order to provide reliable link quality so that problems that are mentioned above can be avoided. This cognitive network has several types that are being used in MAC protocol for such as cognitive single channel MAC protocol and also cognitive multichannel MAC protocol [1].

The focus of this thesis is only on the single channel wireless cognitive network solution by modification of the MAC layer. The proposed MAC protocol should provide information of SNR by using piggybacking mechanism. It used CSMA access protocol since the piggybacking mechanism is provided in RTS and CTS frames that only exist in CSMA.

1.1 Problem Statement

Even though wireless network is not a new technology among us, the process of designing and deploying wireless network is still facing many constraints that should be overcome in order to improve the quality of the network. There are various ways to improve the network quality such as prediction of signal propagation based on site-specific information and positioning of access points or routers during planning stage, however, still the performance of the designed wireless network for most of the time is unpredicted [3]. The main reason behind this is may due to the predicted information is non real-time while the wireless link is always changing due to various factors such as movement of objects. Therefore there is a need to provide real-time link quality information to every node in order to improve the network quality.

As a MAC protocol main function is to transfer data between two or more nodes in the network, it is not intelligent or ‘smart’ enough to determine the real-time link quality as well as the real-time throughput of the network. Therefore, this thesis tries to make the network becomes cognitive by piggybacking the information of SNR and throughput so that the communicating nodes know and provide proper responses regarding the given real-time link quality.

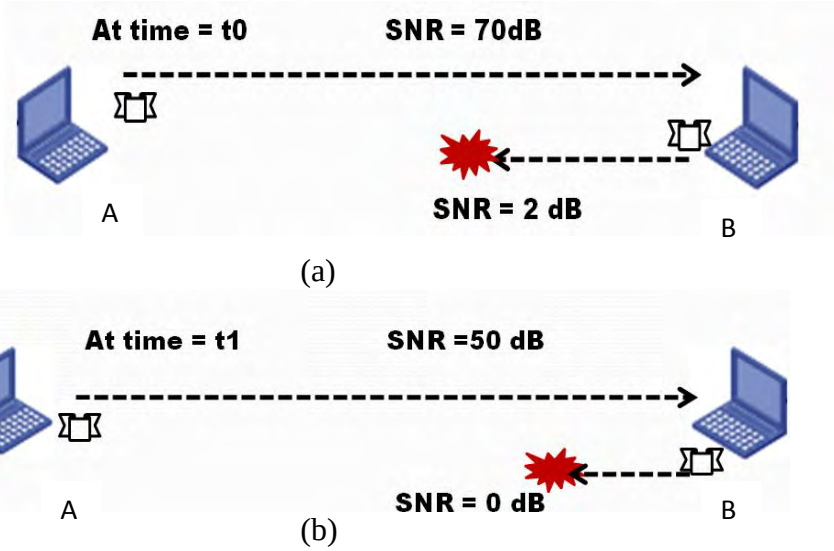

Figure 1.2 (a): Normal WLAN frame transmission at time = t_0 and (b): Normal WLAN frame transmission at time = t_1

In Figure 1.2, the diagram shows the packet transmission in the normal WLAN that can easily contributes to packet loss during the transmission. As can be seen, in (a) at t_0, the SNR is 70 dB but then it is drop to 2 dB. The same situation happened at timet_1 in (b) the SNR also drops at the packet sending from B to A.

Therefore by using cognitive MAC protocol, the link quality can be improved by adjusting the value of power transmission associated with given real-time SNR because the power transmission affects the link quality or in other words, the SNR value is proportional with the value of Transmission Power, P_t.

Figure 1.3: Frame transmission in cognitive network

Figure 1.3 represents the transmission by using improved MAC protocol. As can be observed here, when packet is transmitted from A to B, the SNR value is 70 dB, and the transmission of packet from B to A also has the same SNR value. This is due to cognitive element that has been applied to the MAC protocol. The transmission power, P_t has been increased to higher value that is suitable to increase the value of SNR. It is important to note that P_t is proportional to SNR.

1.2 Objectives

- To re-design non-persistent CSMAwith RTS-CTS protocol to support piggybacking by inserting SNR field in the RTS-CTS frames.
- To evaluate the performance of non-persistent CSMA protocol before and after piggybacking mechanism is applied in terms of average throughput and average delay.

1.3 Scopes of work

The scopes of work of this thesis consists several parts which are divided into three major phases:

- Phase One : Design

This phase consist the basic part of this thesis that includes literature review to the related topic that needed in completing this thesis. For example, the network architecture of wireless cognitive network, the architecture of RTS and CTS packet frame and how to include it in non-persistent CSMA. Also in this phase, the proposed piggybacking algorithm is designed.

- Phase Two : Development

This phase process includes the simulation of the proposed protocol in MATLAB software. This process requires the output of throughput and average delay performances in the form of performance graphs.

- Phase Three : Evaluation

  The final process in this thesis is to provide the performance analysis from the results that has been obtained before. This is the most essential part to determine whether the protocol provides improvement of the link quality or otherwise.

1.4 Contribution of Project

The major contribution of this thesis is the improvement of throughput and average delay where at the end of the thesis, it can be assumed that the throughput has improved from the simulation results while at the same time still produce average delay in the range of existing MAC protocol.

1.5 Thesis Organization

The thesis is organized into five chapters. The first chapter introduces the project background and provides the direction of the work. Followed by the second chapter contains all the theoretical study related to the project. The study includes software or the tools part. Chapter 3 is where the flow of the project is shown using a flow chart. In addition, all the works related to the project will be well explained in this section. The analysis and findings of the results are explained in Chapter 4. Finally, this thesis is concluded in Chapter 5. The future work included in this chapter as well.

CHAPTER II

LITERATURE REVIEW

2.0 Introduction

Literature review can be divided into three parts. The first one is study about the Wireless Cognitive Network. Followed by, the fundamental study of the project such as the understanding of MAC Protocol in WCN. The final part is the study on the piggybacking mechanism that is used in the project. All the literature review parts are essential to give better understanding of the project and to know the limitation and constraints. Finally this chapter will be summarized at the end of this chapter.

2.1 Wireless Cognitive Network

Cognitive according to Cobuild Learner's Dictionary [5] can be defined as '*relating to the mental process involved in knowing, learning and understanding things'*. Cognitive wireless network (CWN) by J. Mitola III [6] is originally considered to improve spectrum utilization and generally considered as a technology to identify the opportunities using the 'spectrum holes' for telecommunications.

In a cognitive network, the collection of elements that construct the network observed the network conditions and then, using the information gained from previous communication with the network, plans, decides and acts on this information.

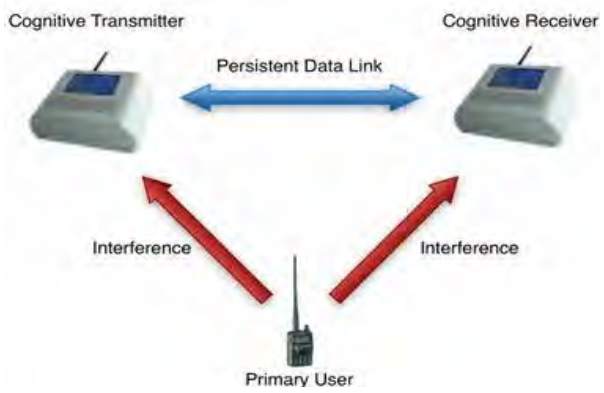

Figure 2.1: Example of Cognitive Communication [7]

It can be consisting of transmitter, receiver, and also user as can be seen in Figure 2.1 above. Cognitive networks are different from other 'intelligent' communication technologies since the actions are taken with respect to the end-to-end goals of a data flow. In addition to the cognitive aspects of the network, a specification language is needed to translate the user's end-to-end goals into a form understandable by the cognitive process *"Cognitive network is a network with a cognitive process that can perceive current network conditions, plan, decide, act on those conditions, learn from the consequences of its actions, all while following end-to-end goals"* [8].

As far as this thesis concern, wireless cognitive network is a closed loop system where it gives essential feedback to the receiver so that it can improve the link quality by increasing element such as transmission power as one of the method to make sure better performance in the wireless network.

2.2 Medium Access Control (MAC) Protocol

MAC layer, sometimes also known as a sub-layer of the Data Link layer, involves the functions and procedures necessary to transfer data between two or more nodes of the network [4]. It is the responsibility of the MAC layer to perform error correction for anomalies occurring in the physical layer. The layer performs specific activities for framing, physical addressing, and flow and error controls responsible for resolving. Conflict may happen among different nodes for channel access. Since the MAC layer has a direct bearing on how reliably and efficiently data can be transmitted between two nodes along the routing path in the network, it affects the Quality of Service (QoS) of the network. The design of a MAC protocol should also address issues caused by mobility of nodes and an unreliable time varying channel [5].

2.3 MAC Protocol in Wireless Cognitive Network

For Medium Access Control (MAC) protocol, which the protocol that coordinates transmission between users that share the same spectrum, the goals of this MAC protocol is to prevent collisions and packet loss while maximizing the throughput and minimizing delay.

The design of MAC is considerably more difficult task in wireless than wired networks [9]. This is due to the fact that in the wireless medium, the signal strength decays causing the medium characteristics to be highly location-dependent. Therefore, mechanism such as CSMA does not work very well because the channel state may be different at the receiver from what is estimated at the receiver.

The main functions of MAC Protocol in Wireless Cognitive Network are:

Observe stage: to sense the environment of network. The environment refers to existing environment of wireless system that has fixed and non-overlapped frequency spectrum. Observe stage also record the usage of the existing systems where there is no usage of cognitive network and make the comparison with and without cognitive network.

Plan stage: check if a temporary link can be used without interfering current users. Temporary link is unused spectrum that may not be used of existing system.

Decide stage: to determine the transmitted power, frequency, duration between two periods which are Contention Period (CP) and Contention-Free-Period (CFP) and schedule the frame transmissions;

Act stage: to perform transmission with synchronize frame distribution. This frame synchronization is used to inform the channel the start time of CFP as well as CP.

This thesis focusing only on CSMA [10] since CSMA has the collision avoidance that listen to the channel before transmitting packet.

2.3.1 Carrier Sense Multiple Access (CSMA) Protocol

In terms of computer networking, Carrier Sense Multiple Access is a part of the data link layer, which is part of how networks and Internet Protocol (IP) addresses work. Carrier Sense Multiple Access, also known by CSMA, is where packets are data bits that are sent over a network [11]. CSMA is a medium access protocol that works as follows:

- When a unit has data to send, it listens to see if the network is busy.
- If the network is not busy, data can be sent.
- If the network is busy, it waits until the network free, then send data.

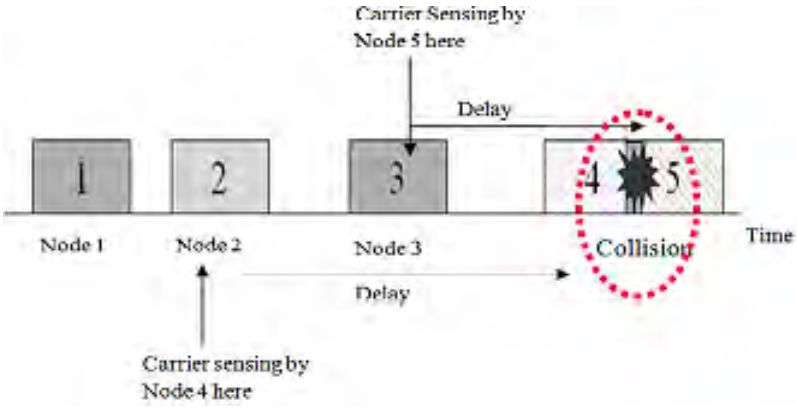

Figure 2.2: CSMA protocol

As shown in Figure 2.2, if node 4 and node 5 can sense the packet transmission at node 2 and node 3, there will be no collision occurs like what already happen at the red circle.

Even though CSMA waits for the line to be clear before transmitting, a collision can still occur. This method is thus often combined with Collision Detection (CD). When a collision is detected, a jam signal will be sent, alerting the receivers of the collision. The data will then be sent again when the line is clear, until either the data is received or a maximum number of attempts are reached. However, the hidden node problem can still occur. Hidden node problem is nodes that are out of range of other nodes that it cannot be reached or sensed.

To resolve the hidden terminal problem, Karn [12] originally proposed the use of Request-to-Send and Clear-to-Send (RTS/CTS) handshaking scheme leading to the Multiple Access Collision Avoidance (MACA) protocol. If a node has a packet to send, it first transmits a RTS packet to request the channel. If available, the receiver replies with a CTS packet. After the sender receives the CTS packet successfully, it proceeds to transmit the actual data packet. Nodes that hear the RTS packet will stop transmission for a long enough period of time to allow the transmitter to receive the CTS packet. Nodes hear the CTS packet will back off for a period of time that is sufficiently enough to allow the receiver to receive the entire data packet [13].