A Simulation Model of IEEE802.11b for Performance Analysis of Wireless LAN Protocols

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Abstract— **The aim of this paper is to provide an overview of the IEEE802.11b simulation model implemented by using OMNet++ simulation framework. The model is suitable for performance evaluation and investigation of wireless networks. There are two main state patterns which are part of the model specifying the CSMA/CA procedure and frame exchange sequences between stations. These are critical major sections of the IEEE 802.11b standard for sharing the communication medium and therefore their accurate modelling is important for simulation based performance analysis of wireless networks. An example network consisting of a mobile station moving through a series of access points is used to demonstrate the model's capabilities. The handover behaviour is consistent with theoretical results and will be used in our further research for testing higher layer performance involving mobility.**

Keywords—**IEEE802.11b, OMNeT++, Simulation**

I. Introduction

COMMUNICATION networks are being highly integrated, and the complexity of their hardware and software architectures is ever increasing. One outcome of this trend is that the performance studies of such integrated networks, and interaction of protocols running on them are becoming extremely difficult. Experimentation on small-scale test beds do not reveal scalability problems, could be very time consuming and costly, and analytical studies may be impossible due to the inadequacy of the mathematical tools neccessary to capture this complexity. One way of overcoming these problems is the application of discrete-event simulation tools for modeling and analysis of telecommunication networks. Within this context, our research group focuses on developing simulation systems for the investigation of performance and scalability of IPv6 and MIPv6 protocols over wired, wireless and cellular access networks. To do our research, we have developed a comprehensive set of simulation models [1]. We have also recently added an accurate model of IEEE802.11b to these models. In this paper, we introduce the structure of the developed model and provide an overview of our ongoing research on wireless networks.

In recent times, we see that wireless access to the Internet is gaining rapid popularity, and supporting data link control layer protocols are being standardized. Among them, IEEE 802.11 [2] Wireless Local Area Network (WLAN) access is the most popular one. Its Working Group was established in the early 90s, to form a specification that provides local area connectivity among devices over the Industrial, Scientific and Medical (ISM) band. After over a decade of development, IEEE802.11 has now matured, and a wide range of manufacturers are now marketing a range of wireless Network Interface Cards (NIC) and Access Points (AP). It is a popular add-on to portable units such as laptops and Personal Digital Assistants (PDA), providing high data rate access. Furthermore, it provides a cheap and convenient means of extending a network without the need of cabling infrastructure and associated expenses. It serves as a good potential candidate to complement future higher layer protocols such as Mobile IPv6 (MIPv6), which we believe will have a very important role in future multi-service and multimedia networks.

The IEEE802.11 model will allow verification of results produced by our test beds and simulation of large-scale IPv6 networks utilizing wireless LAN. The behavior and performance of higher layer protocols and applications involving wireless protocol can be investigated with flexibility and full configuration control. In particular, it will aid our research in mobility management for various protocols operating over the IEEE802.11b mobility framework.

We have chosen OMNeT++ as the simulation environment for the model. The reasons for choosing OMNeT++ can be seen in [1].

In the next section, the overall design of our model is discussed, which includes our approach in obtaining an accurate wireless model. The accuracy of the model is assessed in the following section by comparing performance results obtained from the simulation with a real network. A short section then covers additional support and functionalities that may be added to the model. Finally, a section with some concluding remarks to review the overall discussion is presented.

II. Design of The IEEE 802.11b Model

The IEEE802.11 standard specifies the functionality of the Media Access Control (MAC) sublayer to provide mobility support and data delivery services. These are the aspects we are particularly interested in implementing and modeling accurately. For this reason, we have kept the physical layer model as simple as possible. Our physical layer model provides just the sufficient functionality to allow entities to communicate over the wireless medium without compromising the accuracy of the entire model, hence reducing the simulation time and unnecessary complexity.

A. Physical Medium

The medium is divided into a number of channels specified through a parameter. This is to account for the varying channel numbers that exists in different countries. Each represents a channel within the 2.4GHz band in a Direct Sequence Spread Spectrum (DSSS) System. Each device can only receive or transmit on one channel at a given time.

The signal strength from a STA follows a simple formula as follows:

$$\text{Signal strength} = t/r^2 \quad \text{where}$$
$$t = \text{ transmit power of transmitting station}$$
$$r = \text{ distance from transmitting station}$$

It follows the inverse square law with distance from the transmitting device, while being proportional to the transmission power. This signal strength model allows us to simulate the reception range between two communicating stations. A value known as the receiving power threshold can be set to define the minimum signal power required before an IEEE 802.11b station can process it. Any frames received with a signal reading less than this threshold won't be accepted.

B. MAC Layer

As mentioned earlier, our primary focus is to develop an accurate simulation model of the IEEE 802.11b protocol MAC layer. The implementation of the simulation model is achieved by having two state patterns that dictate the behavior of each IEEE802.11b station under various events. First state pattern represents the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) mechanism. It ensures that each entity shares the wireless medium appropriately. With the help of [3] a state diagram suitable for the model that closely follows the standard was developed.

Another state pattern is required to control the frame exchange allowed on each station. The frames can be restricted depending on the station's current state. Receive Mode is the name given to the class of states and the various types are listed in Table I.

A simulated station can operate in one of the following models:

- Normal IEEE802.11b client
- Monitoring MS - IEEE802.11b client operating in monitoring mode to capture frames on a particular channel
- IEEE 802.11b access point

Operating as a Normal MS, it may switch between the first five Receive Mode listed in Table I depending on the MS's interaction with APs. A state diagram of the relationship between the five modes can be seen in Figure 2. If

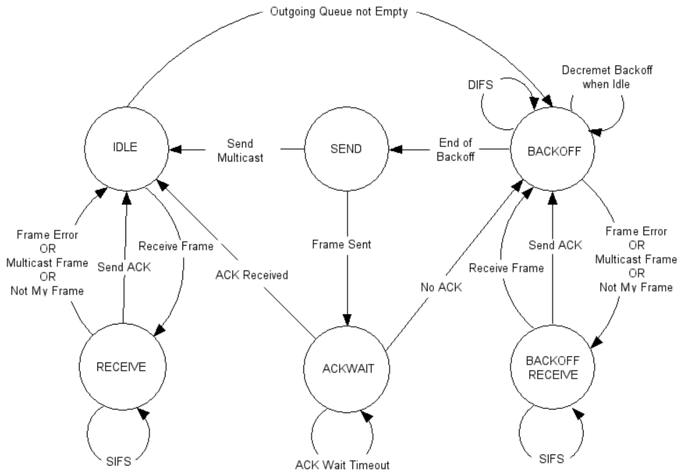

Fig. 1. State diagram of CSMA/CA used in the simulation model

Receive Mode	Description	Frames allowed
Active Scan	Actively probes for surrounding APs	Probe Respons
Passive Scan	Passively discover APs through beacons	Beacon
Authentication	Waiting for authentication response from AP	Authentication, Acknowledge
Association	Waiting for association response from AP	Authentication, DeAuthentication, Association response, ReAssociation response, Acknowledge
Data	Successfully associated with AP, enabling permission to exchange data frames	DeAuthentication, Association response, ReAssociation response, DisAssociation, Data, Beacon, Acknowledge
Monitor	Capture any frames on the current channel	All frames
Access Point	Process frames usually directed to APs	Authentication, Association request, ReAssociation request, Probe request, Data, Acknowledge

TABLE I

LIST OF DIFFERENT RECEIVE MODES

a station operates as a Monitoring MS or AP, its Receive Mode will be Monitor and Access Point respectively. These two Receive Modes cannot switch to others and therefore will persist for the lifetime of the station in the simulation.

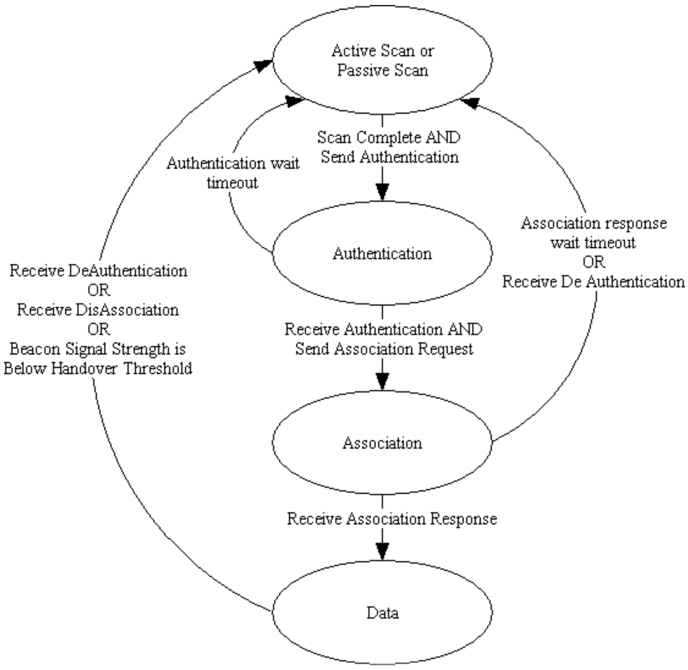

Fig. 2. State diagram of Receive Modes for Normal MS operation

The two state diagrams (discussed above) are important to control each IEEE 802.11b station under various events. This in turn, determines their interactions, enabling communication and sharing of the medium in the wireless network.

III. Wireless Network Simulation Example

This section demonstrates the capabilities and correctness of the model by comparing the handover result with the results of a real implementation reported in [4]. The configuration of the test network is seen in Figure 3.

During the simulation, a MS determines the signal strength of the currently associated AP via the beacon packets received. When the reading reaches below the handover threshold value, a handover is initiated. The threshold is a parameter that can be set easily and should not be less than the receiving power threshold discussed in II.A. If it is larger, the MS will not receive beacons with signal readings to trigger a handover.

According to [5], the handover time obtained in real implementations can vary quite significantly. It all depends on the manufacturer of the client interface and the AP used in combination. They also showed that this variation is due to variations in the probe-wait latency (the time an STA waits on a channel after sending a probe request). In our simula-

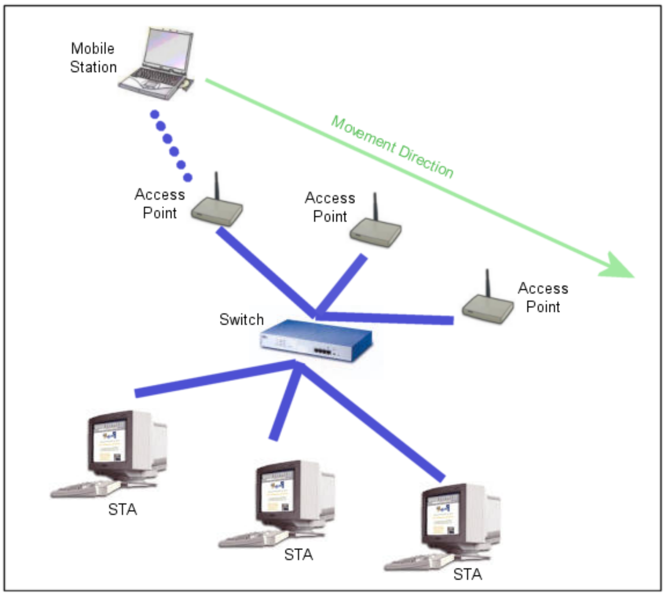

Fig. 3. Test network configuration

tion model, this time can be modified by adjusting a) Probe Response Timeout (PRT) - time to wait for energy after active probe and/or b) Probe Energy Timeout (PET) - time to wait for a probe response after energy detected.

Results from [5] shows that a Cisco station used in combination with a Cisco AP, has a typical PET of 10ms and PRT of 35ms. These are the values used in the simulation in order to compare the results. The handover time can be measured in the simulation by sending a stream of data from the MS to a wired station, while it moves from one AP to another. This is done by using *ping* to send ICMP requests at 15 ms intervals. Missing packets from the data stream due to handover will clearly indicate the delay, as illustrated in Figure 4.

The handover can be seen to last for approximately 220ms. Our model consists of 14 channels, where three APs are within the range of the MS at the time of handover. This means the handover time should theoretically be:

$$\begin{aligned}
\text{Handover Time } &= (Cf \times PET) + (Cap \times PRT) \\
&= ((14 - 3) \times 10\text{ms}) + (3 \times 35\text{ms}) \\
&= 215\text{ms} \quad \text{where} \\
Ct &= \text{ total number of channels} \\
Cap &= \text{ number of channels occupied by APs} \\
Cf &= \text{ number of free channels} = Ct - Cap
\end{aligned}$$

This is consistent with the value obtained from the simulation. Real networks produce a handover time greater than the simulation, because traffic on one channel may crossover to adjacent channels (ie increase Cap). This

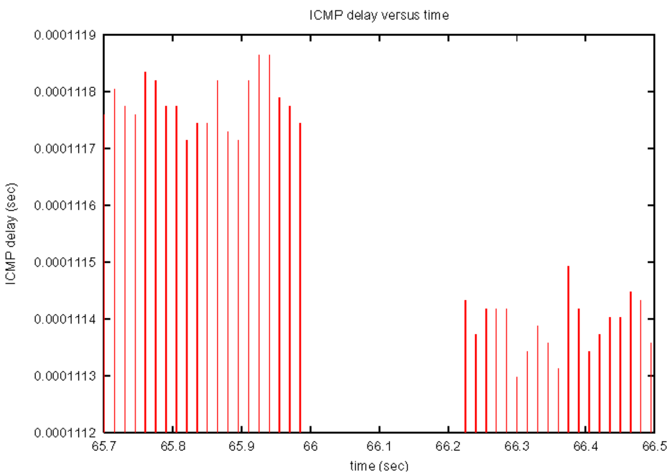

Fig. 4. Graph showing disruption of ICMP stream due to handover

means, a larger number of channels will be detected to be busy during the Probe Energy wait time and therefore the longer Probe Response wait time will apply. In order to obtain a handover delay that accurately follows real implementations, cross talk between channels must be modeled.

It should also be noted that the delay of the ICMP response before and after handover are different. The MS is closer to the AP after the handover compared to the AP before, resulting in a difference in propagation delay.

Further experimental work involving complex networking scenario are being planned which allow an investigation of the effect on handover under increased traffic loads.

IV. Future Additions

The IEEE 802.11b model is still at its early stage, and was developed primarily to investigate MS movement under infrastructure mode. Therefore, a number of attributes is still under consideration and may be implemented at a later date. It includes:

- Ad-hoc mode
- PCF
- WEP
- Multirate support
- Power Save mode
- Fragmentation
- Virtual carrier sense (RTS/CTS exchanges and NAV)

Appropriate mobility models to simulate the movement of MS also need to be developed. Currently movement is done by specifying start and end points, and speed. Having a range of movement algorithms will enable investigations involving many MS moving independently in a network.

V. Conclusion

In this paper we present a brief overview of the IEEE802.11 model implemented under OMNet++ simulation framework. The aim is to achieve an accurate theoretical model allowing performance testing and investigation of wireless networks.

The handover performance obtained in the example network produces a delay we theoretically expected. However, it was slightly different to handover delays obtained in real implementations, mainly due to cross talk between channels.

References

[1] J. Lai, E. Wu, A. Varga, A. Sekercioglu, and G. Egan, "A simulation suite for accurate modeling of ipv6 protocols," *Proceedings of the 2nd International OMNeT++ Workshop*, pp. 2–22, January 2002.

[2] "Information technology - telecommunication and information exchange between systems - local and metropolitan area networks - specific requirements - part 11: Wireless lan medium access control (mac) and physical layer (phy) specifications," IEEE Standard, Tech. Rep., 1999.

[3] T. Khattab, M. El-Hadidi, and H. Mourad, "Analysis of wireless csma/ca network using single station superposition (sss)," *International Journal of Electronics and Communications (AE)*, vol. 56, March 2002.

[4] N. Montavont and T. Noel, "Handover management for mobile nodes in ipv6 networks," *IEEE Communications Magazine*, vol. 40, no. 0163-6804, pp. 38–43, 2002.

[5] A. Mitra, M. Shin, and W. Arbaugh, "An empirical analysis of the ieee 802.11 mac layer handoff process," University of Maryland Department of Computer Science, Tech. Rep. CS-TR-4395, September 2002.