Graduate School of Global Information and
Telecommunication Studies, Waseda University

# Abstract of Doctoral Dissertation

Studies on Multiple Access Schemes for
High Performance Wireless Local Area Networks

高能率無線ローカルエリアネットワークにおける多元アクセス方式に関する研究

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# ABSTRACT

In this dissertation, we focus on the new MAC protocol design for high speed data transmission for wireless local area networks. The proposals, mathematical analysis and numerical simulations are demonstrated in chapter 3, 4, and 5. The dissertation presents two new MAC protocols and a mathematical analysis solution of One-ACK protocol. This document summarizes the achievements of this dissertation, discusses some open issues and future development as the following:

1. Chapter 1 provides overview of the current and near future wireless network. This chapter also points out the serious challenging to the wireless transmission protocol. It is foreseen that wireless communication will have to deliver huge amount of data to meet the increasing need of end users. To meet this requirement, new spectrum should be allocated and innovative technologies should be applied. The process of allocating new spectrum is quite slow and may never meet the spectrum requirement of mobile community. Therefore short term solutions may come from new technologies such as: better coding, MIMO, off-loading techniques, etc. The off-loading approach is the most viable technology. Most of the heavy traffic such as huge file downloading, video streaming, etc. should go through high speed wired networks and then only deliver to end user by wireless technologies such as femtocell or WLAN. The simple, highly effective and world-wide deployed WLAN networks is the most suitable solution. Exploring such capability is the active research trend currently. Besides identifying the research topic, this chapter also introduces plan and structure of this dissertation.
2. Chapter 2 reviews relevant MAC protocols to the research. MAC protocol study is an old research topic which we can trace back to the very beginning of communication system. However, it is among the most active research areas. Most of the new communication systems come with new MAC protocols. It is therefore impossible to have a comprehensive review of this area. In this dissertation, we only focus on the related schemes, which directly or indirectly influence the final outcome of our effort to design more suitable MAC protocols of high performance wireless networks. Those many wireless MAC schemes have origin from ALOHA protocol, the development of wireless technology recently yield a very diverse wireless MAC scheme family. We, therefore, try to follow the development of each branch to highlight the idea development, performance improvement and major academic achievements. During the course of studying the above mentioned protocols, we paid special attention to the analytic parts. The analytic solution plays a key role in any protocol research as it is an important tool to investigate the behavior of system as a whole. One of the powerful tools for MAC protocol performance analysis is Markov chain

framework. Markov chain analysis has been successfully applied to investigate several MAC schemes. Our achievements based firmly on these analytic solutions.

3. Chapter 3 introduces the Continuous Contention-Assisted Transmission (CAT) MAC protocol for wireless ad-hoc network. The proposal used the idea of token in wired-network to apply to wireless environment. Although originated from wired-network scheme, the proposal differs from token protocol in several aspects. Firstly, not every wireless station can receive token. Secondly, the error prone wireless environment may destroy the token unexpectedly. And finally, wireless network is a highly dynamic network; stations can join and leave the network without prior notification. These characteristics should be included in the wireless version of token scheme. At first, a set of stations in close proximity should form into a group to coordinate transmissions. Ideally all station in group should be within transmission range in order for the token to be handled reliably. The right to transmit frame of a station on shared wireless channel is decided by previously successful receiving station. Giving the right to access channel to station has data in the queue will much reduce its random access effort. If the token is passed to station with no demand for channel access then this token is killed. A new phase of random access begins. Transmissions are organized distributedly to reduce conflict among group. In low traffic network, the CAT protocol behaves as random access protocol. When traffic increases, transmissions of stations are quickly scheduled to eliminate unnecessary collisions. Direct result of this proposal is the increase of group throughput. The proposal is suitable for small networks which stations are closed enough to be efficiently organize into non-contending group. The proposed protocol is analysed from mathematical analysis and simulation standpoint. Using Markov chain analysis, the theoretical solution proved the superiority of this proposal. Numerical simulation confirmed the feasibility of CAT protocol in various scenarios. The study in this chapter has only confined in the one group communication. To advance this research trend, several aspects of this protocol need to be studied further, such as: hidden terminal issue, interaction of several groups.

4. Chapter 4 presents the mathematical analysis of one-ACK protocol. One ACK protocol is a very promising candidate for high speed MAC protocol of WLANs. With the demand of large data transmission in high speed network, the major requirement to deliver such huge data is put into the MAC protocol design. Naturally, high speed communication requires big transmission packets. However large frames cannot reliably transmit through wireless channel. Any small error will corrupt the whole frame reception and consequently causes a costly retransmission. The error in wireless channel is busty in nature. Strong error correction code is not enough to counter the adverse effect of bad wireless channel. Therefore it is best to

fragment the big packet into smaller ones with optimum size. When error happens during the transmission, the MAC layer can localizes the corrupted parts in the original frame. The MAC layer then decides to retransmit the only fragments that have been corrupted by channel. The idea reduces much of unnecessary retransmission of large frames. Furthermore, One-ACK organizes retransmission of corrupted fragments so as to reduce overhead. The protocol had only been investigated by simulation in NS-2 previously. It is needed a concrete mathematical proof to complete the proposal. In this chapter, we presented an analytic solution with erroneous wireless channels are included. Retransmission policy is also incorporated into the solution in order to assist the designers. The solution can precisely predict the performance of one-ACK protocol under various simulations setting of retransmission strategies. Several error models can be introduced to the solution to bring it into a wider application.

5. Chapter 5 describes a new MAC protocol design for very high speed transmission wireless network called iLAC. iLAC took a very different approach with conventional MAC protocol designs. Normally, the transmission process is matter to transmitter and receiver alone. This chapter investigates the scenario that many stations involve in the transmission. Even the overhearing stations can actively participate in the scheduling process to avoid future conflict. Generally, the scheduling job is mainly decided by a coordinator node. However in highly dynamic wireless network, installing another management layer is quite costly solution. The coordinator solution will become less efficient in partially connected wireless network. Therefore it is needed distributed coordination scheme to handle the coordination work. We proposed iLAC protocol to address this problem. Neighboring stations are jointly decide transmission time by exchanging information. Transmitting station notifies its next backoff stage setting in the header frames. Overhearing stations know status of the ongoing transmitting station. They adjust their backoff value accordingly to avoid future conflict with that station. Therefore collisions are eliminated efficiently as neighboring stations dynamically schedule transmissions. Coordinating transmission by this scheme reduces wasteful energy significantly due to unproductive colliding transmissions. Mathematical analysis using Markov chain shows excellent agreement with simulations. Using real power consumption measurement data, we show significant improvement in the power consumption structure of stations. In real wireless environment, not all stations can overhear correctly the transmitting frames. The lack of global knowledge of network yields certain level of conflict in transmission. This research topic is currently under investigation.

6. Chapter 6 provides our conclusions on the achievements of this study. We currently investigate other aspect of the proposed MAC protocol. Some of the promising topics are outlined as near future researches.

**List of academic achievements**

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| Articles in refereed journals | o D. C. Hieu, T. Nguonly, S. Shimamoto, Analysis of one-ACK fragmentation MAC protocol for 802.11n under saturated condition, Simulation Journal Vol.2, No.2, pp. 50-56, Jun. 2010, Japan.<br>o D. C. Hieu, A. Masuda, V. H. Rabarijaona, S. Shimamoto, Intelligent Local Avoided Collision (iLAC) MAC Protocol for Very High Speed Wireless Network, IEICE Trans. Commun., vol. E95-B, No. 2, pp. 392-400, Feb. 2012. |
| Presentations at International conferences | o D. C. Hieu, S. Shimamoto, Continuous Contention-Assisted Transmission MAC protocol for Wireless Ad-Hoc Network, Golobecom 2009, pp. 1-6, Nov. 2009. |
| Presentations at domestic conferences | D. C. Hieu, S. Shimamoto, Saturated throughput analysis of CSMA/CA using fixed slot time scheme, Japan Simulation Conference 27th, Jul. 2008.<br>D. C. Hieu, S. Shimamoto, Analysis of the 802.11 DCF in non-saturated condition using fixed slot time scheme, Japan Simulation Conference 28th, Jul. 2009. |