Proposed Multi-channel Ad-hoc Network with Cross-layer Design of MAC and Routing Protocols

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***Abstract*—Ad-hoc network usually employs IEEE 802.11 based wireless LAN with a single channel as wireless links. A multi-hop communication and a single channel interference would cause a transmission performance degradation. The multi-channel technique is effective to improve the transmission performance. This paper proposes the cross-layer design associated with the new multi-channel MAC protocol and the routing protocol suitable for the multi-channel. A network simulation using EXata simulator is executed to evaluate the throughput.**

Keywords—Ad-hoc network; multi-channel MAC; AODV; cross-layer design

I. INTRODUCTION

Ad-hoc network is expected as a low cost and an instantaneous networking technique due to infrastructureless network architecture. This would be useful for an emergency network for a big disaster such as an earthquake, and a low cost tentative network for a big event.

Ad-hoc network employs IEEE 802.11 based wireless LAN(WLAN) and usually uses a single channel interface and a multihop communication. As the number of hops increase, a transmission performance degrades due to a radio interference among wireless links. The effective solution is to use a multi-channel on WLAN[1]. A congestion might decrease on wireless links by using the multi-channel. There are several approaches to the multi-channel architecture. The first approach is to use a single transceiver in order to conform to the current WLAN interface hardware[2,3]. However, the existing MAC protocol, CSMA/CA is implemented for the single channel interface, so new MAC protocols for the multi-channel is required. The second approach is to use multiple transceivers[4]. The third approach is to implement a new physical interface such as CDMA[5].

In this paper we adopt the first approach and propose the cross-layer design associated with the new multi-channel MAC protocol and the new routing protocol based on AODV suitable for the multi-channel MAC. This is a cross-layer approach with MAC and routing protocols. We implement the proposed protocols on EXata[6] and evaluate network characteristics.

II. BASIC IDEA OF PROPOSAL

The proposed idea is to find a route from a source to a destination at first. Then, a channel is assigned onto a link from the source to the next and a data is transmitted, after that the same procedure is executed onto the next link that has been selected by the routing protocol, as a result a communication has been completed from the source to the destination, as shown in Fig.1.

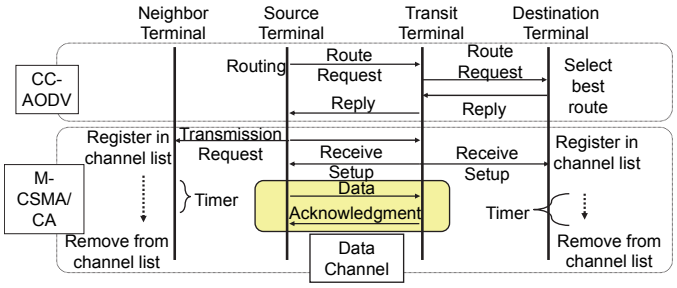

Fig. 1 Basic flowchart of proposed cross-layer scheme for multi-channel Ad-hoc network

CC-AODV(Channel Controlled AODV) is a proposed routing protocol based on AODV, and finds a route using the number of available channels as a routing index. In this scenario, CC-AODV uses a channel assignment information. The channel assignment is done by the MAC protocol, M-CSMA/CA(CSMA/CA for Multi-channel) [7]. A collaboration between the routing and the MAC is essential in this proposal.

A channel list is defined in each node to be accessed from CC-AODV and M-CSMA/CA in order to achieve the cross-layer design, as shown in Fig.2. The channel list holds channels that are reserved by the node itself and are received from other

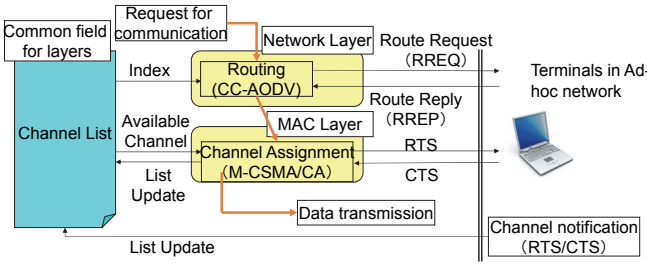

Fig.2 Cross-layer design with CC-AODV and M-CSMA/CA

nodes. When a communication request occurs, the source terminal sends the route request (RREQ) to the destination terminal. A route that has maximum number of available channels is selected by CC-AODV. The detailed CC-AODV is explained in III. This concept is that a route that has maximum number of available channels can give less congestion performance, so that a better performance would be promising. After the routing, an appropriate channel is assigned by M-CSMA/CA for a link-by-link.

N channels are defined on each wireless links. One common dedicated channel is defined as the control channel that is used for a channel advertisement, an assignment and a routing control information. Rest (N-1) channels are the data channel for Data and ACK of MAC transmission. This system is supposed to be a single transceiver and a half-duplex in accordance with an existing IEEE802.11 based WLAN.

III. DETAILED DESIGN OF PROTOCOLS

A. M-CSMA/CA

A channel assignment and a reservation is required for the multi-channel MAC other than a collision avoidance. Following items are added to CSMA/CA;

- Reserved channel advertisement to neighbor nodes using RTS/CTS,
- Channel register and removal on the channel list,
- Shortening of NAV(Network Allocation and Vector).

A timing chart of M-CSMA/CA compared with CSMA/CA is listed in Fig.3.

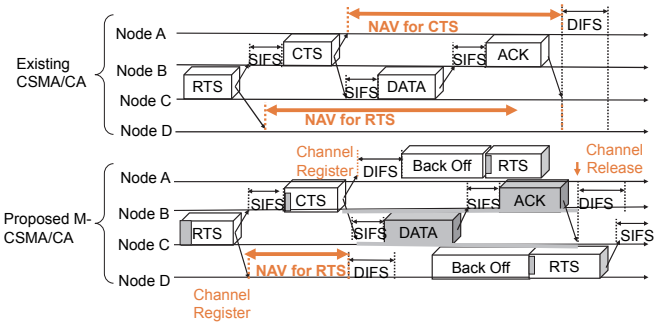

Fig.3 Timing chart of M-CSMA/CA

Each node equips the channel list that holds busy channels of its-self and received on RTS/CTS from neighbor nodes. Then, each node can use any channel without an interference which is not listed in the channel list.

A node C is a source terminal and a node B is a destination terminal, and nodes A and D are neighbor terminals. RTS and CTS are transferred on the common dedicated channel. RTS and CTS are expanded 2 bytes for advertising channels which are reserved by nodes B and C. When nodes A and D receive these channels, they register these channels in their channel lists.

B. CC-AODV

A shortest route is selected in the existing AODV. However a shortest route is selected, if there is no available channel for this route, a packet can't reach to the destination. This suggests that the shortest route is not always the best and a new criteria is required in the multi-channel ad-hoc network.

To avoid such a mismatch, we propose that a route that has more available channels is a better route to decrease the unsuccessful probability of the channel assignment. The minimum number of available channels associated with the route from the source to the destination is the routing index, and the route which has the maximum value of this index is selected. Following items are added to AODV;

- The number of available channels is set on RREQ field,
- Comparison the number of available channels that of the node itself and the value on RREQ in each transit node,
- Route finding procedure according to the received number of available channels.

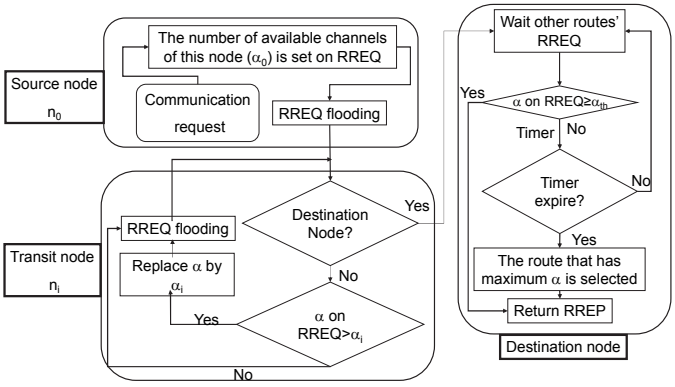

Fig. 4 Flowchart of CC-AODV

The CC-AODV flowchart is shown in Fig.4. The source node calculates the number of available channels (α_0) using its channel list, and set it($\alpha=\alpha_0$) on RREQ(Route Request) field , then floods it. When transit node (n_i) receives the RREQ, it compares α with α_i. If α_i is less than α, replace α by α_i. This process gives RREQ field the minimum number of the available channel associated with this route. The destination node receives RREQs and finds the route whose α is the maximum.

IV. EVALUATION BY SIMULATION

We evaluate the proposed protocol by EXata simulator. First, basic characteristics of M-CSMA/CA is evaluated using AODV, next overall characteristics of M-CSMA/CA with CC-AODV.

A. Evaluation for M-CSMA/CA

A throughput is obtained in a chain topology that nodes are put with 100m intervals. A source signal is UDP and rate is 800kbps, and the routing protocol is AODV. Wireless link is 802.11b. A simulation time is 60s. The number of multi-channels is infinity. The throughput versus the number of hops

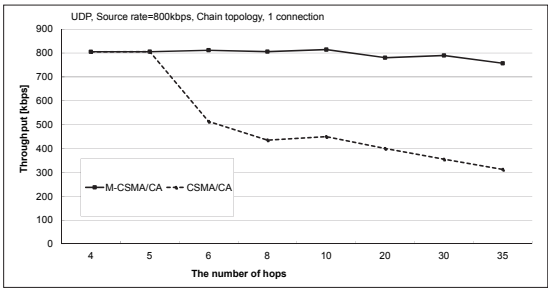

Fig.5 Comparison of throughput in chain topology

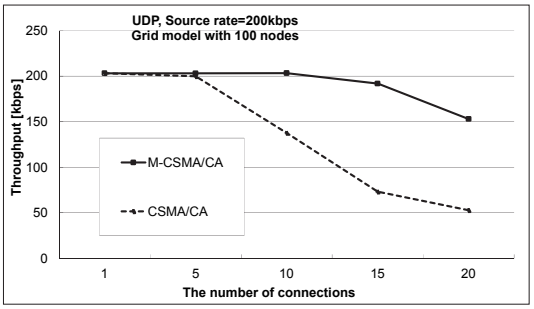

Fig.6 Comparison of throughput versus load traffic

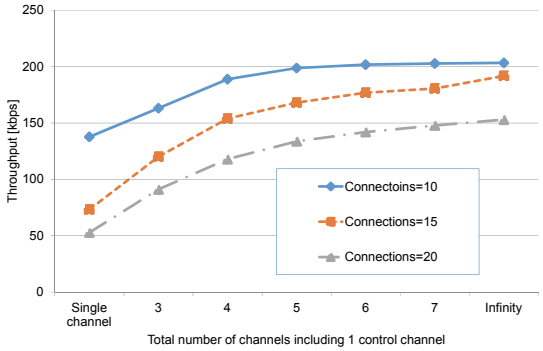

Fig.7 Characteristics of throughput versus the number of channels

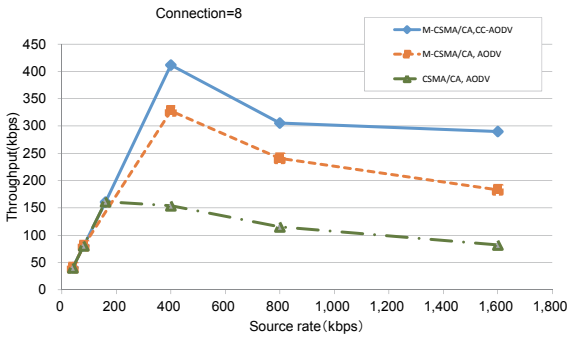

Fig.8 Comparison of throughput for grid model

is shown in Fig.5. As the number of hops increases, M-CSMA/CA can keep higher throughput rather than the single channel (CSMA/CA).

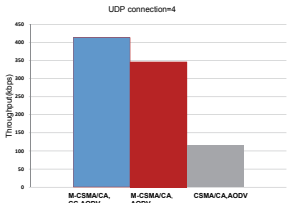

Fig.9 UDP throughput

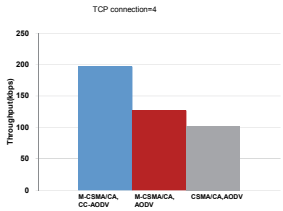

Fig.10 TCP throughput

A more realistic grid model that 100 nodes are put with 100m intervals. The source signal is UDP and 200kbps. In order to examine a load traffic, the average throughput for each connection versus the number of connections is shown in Fig.6. The existing CSMA/CA degrade for more than 5 connections, however M-CSMA/CA can gain good characteristics for 10 connections.

The characteristics of multi-channel systems may be affected by the number of channels. Characteristics of average throughput versus the number of channels is shown in Fig.7. The simulation model is same as that of Fig.6. This show that 5 to 7 channels are sufficient because a confliction on the control data channel may be a bottleneck.

B. Evaluation for CC-AODV and M-CSMA/CA

Next, we evaluate the proposed overall characteristics using CC-AODV and M-CSMA/CA. The simulation model is the grid model. The source signal is UDP. The number of channel is 5. The results are shown in Fig.8. The proposed method (M-CSMA/CA, CC-AODV) gives better performance.

We also evaluate the grid model with 4 UDPs and 4 TCPs. The average throughput for UDP and TCP are shown in Figs. 9 and 10. The proposed scheme obtains better performance.

V. CONCLUSIONS

This paper discussed the multi-channel ad-hoc network, and proposed the cross-layer design of the channel assignment and routing protocols suitable for the multi-channel ad-hoc network. Simulations were executed, and confirmed the better characteristics of the proposed protocols. The comparison with other multi-channel protocols is for further study.

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