Regular Paper

Receiver-prioritized Next Transmission in Multichannel MAC Protocol for Wireless Ad-hoc Networks

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Abstract: Many multichannel MAC protocols for wireless ad-hoc networks have been proposed to enhance the network performance by avoiding contention among adjacent nodes which want to transmit data frames. However, multichannel MAC protocols need channel switching behavior with some time period, therefore frequent channel switching may deteriorate the network performance. In this paper, we propose a new multi-channel MAC protocol called RPNT-MMAC (Receiver-Prioritized Next Transmission in Multichannel MAC) protocol. In RPNT-MMAC protocol, the transmitter and the receiver nodes negotiate the data channel for data frame transmission by exchanging RTS/CTS frame, and if the receiver node already has another data frame to be forwarded to its neighbor node, then it can acquire the right of the next transmission on the same data channel of ongoing transmission procedure and notifies the next transmission's receiver before switching channel. When the node received the notification for the next transmission, it switches to the same data channel at the end of first data frame transmission and receives the data frame. Our proposed method can decrease the frequency of switching channels and improve the network performance such as the packet arrival rate and the end-to-end delay. Moreover, the fairness among data flows can be improved. Network simulation results showed a better performance of our proposed method than the traditional methods.

Keywords: wireless ad-hoc networks, multichannel MAC protocol, receiver-prioritized next transmission

1. Introduction

A wireless ad-hoc network is one of the most promising techniques, which can be constructed by only terminals with a wireless communication function. It doesn't need any infrastructure such as physical cables and wireless access points, therefore wireless ad-hoc networks are much helpful for various situations such as temporal events and disaster situations. Due to the flexibility and autonomy of each node in such networks, developing effective and efficient MAC protocols with a distributed coordination function for wireless ad-hoc networks is one of the most important issues for practical use.

Many research works of MAC protocols for wireless ad-hoc networks are based on IEEE802.11 DCF (CSMA/CA) developed for communication between wireless access point and wireless terminals. Since it has some problems such as interference, hidden terminal and exposed terminal among adjacent nodes which want to transmit data frames, many MAC protocols for wireless ad-hoc networks have been developed to cope with such problems and improve the network performance.

Another technique to enhance the network performance of wireless ad-hoc networks is to employ multichannel MAC protocols [1], in which several adjacent transmitter nodes use different channels without any overlap to transmit data frames. This means that they can transmit data frames simultaneously without any interference, and the number of frame collisions can be also decreased. Therefore, multichannel MAC protocols can have better network performance than MAC protocols using a single channel.

Well, many multichannel MAC protocols need to take some time period to switch from one channel to another channel before and after transmitting data frames, and it may cause a deterioration of the network performance if the channel switching delay is much longer than we expected. For example, the authors of Ref. [2] estimate the channel switching time as several milliseconds by some experiments with note PCs. These values aren't so short that we can ignore. Though many traditional approaches of multichannel MAC protocol have been already proposed, many of them didn't consider the channel switching delay or only consider the small channel switching delay. Therefore, the multichannel MAC protocols with considering the effect of channel switching delay should be developed for practical use.

One of the simple ways to reduce the effect of channel switching delay is to decrease the number of channel switching for data frame transmission. In this paper, we propose a new multichannel MAC protocol called RPNT-MMAC (Receiver-Prioritized Next Transmission in Multichannel MAC) protocol, in which the receiver node of a data frame on a data channel can acquire the right for the next transmission of one data frame on the same data channel. The receiver node of the next transmission switches to the same data channel on which the first data frame transmission is executed at the end of the first transmission, and the first receiver can then transmit the data frame to the second receiver node. By this procedure, our method can decrease the number of channel switching, and as a result, the communication performance such as the packet delivery ratio and the packet transmission delay can be improved.

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The remainder of this paper is organized as follows. In Section 2, we explain previously proposed multichannel MAC protocols and their problems. Section 3 describes our proposed method of multichannel MAC protocol with receiver-prioritized next transmission. We evaluate our proposed method by network simulation and make a consideration in Section 4. The conclusion of this paper and future works are given in Section 5.

2. Multichannel MAC Protocol

Many research works of MAC protocols in wireless ad-hoc networks assume the usage of IEEE802.11 DCF with RTS/CTS basically. However, it has some problems such as interference, hidden terminal and exposed terminal among adjacent nodes which want to transmit data frames. One of the techniques to reduce the effect of the above problems is multichannel MAC protocol, in which each node transmits data frames on the different channel from the channel on which the transmission procedure of data frames between other nodes is ongoing. This technique enables for the nodes to transmit data frames simultaneously without any interference, and can increase the network performance.

Some of the traditional multichannel MAC protocols divide the available channels into one control channel and the other data channels. The control channel is used for channel usage negotiation among nodes with exchanging some control frames, and all nodes basically listen to it when they are in idle status. The data channel is used for data frame transmission after the negotiation.

Also, the traditional multichannel MAC protocols can be classified into two categories at the point of the number of network interfaces which each node is equipped with. Namely, one is that each node has only one network interface, and another is that each node has several network interfaces. For the methods only using single network interface, in the methods such as Refs. [3] and [4], the transmitter and the receiver nodes select the data channel with exchanging RTS/CTS frames before transmitting a data frame. To do this, the transmitter node selects an available or preferable data channel by checking its current channel status from (virtual) carrier sense and past transmission results, and it transmits an RTS frame including the candidate channel number. After receiving the RTS frame, the receiver node checks the availability of the data channel specified in the RTS frame, and returns a CTS frame to the transmitter node if the data channel is now available. Then, the transmitter and the receiver nodes switch from the control channel to the data channel, and they transmit/receive the data frame. After that, they return to the control channel. In CARMA-MC protocol [5], each node defines its own default channel by using its assigned unique value like network address, and the node which wants to transmit a data frame to the neighbor node switches from its own default channel to the receiver's default channel, and then transmits the data frame to the receiver node. In some multichannel protocols such as MMAC protocol [6], EFCM protocol [7] and CR-MAC protocol [8], the time axis is divided into fixed time slots, and each time slot is divided into a channel negotiation period and a data frame transmission period. At first each node which wants to transmit a data frame reserves a data channel by negotiating with the receiver node, then they switch to the data channel and transmit/receive the data frame.
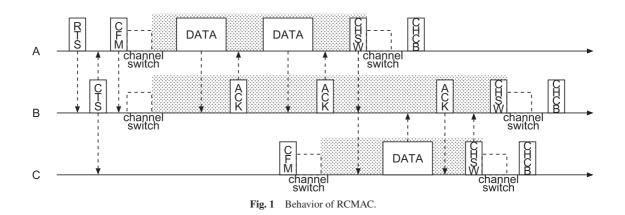
For the methods using multiple network interfaces, in DCA protocol [9], it assumes that each node is equipped with two network interfaces, and one is set to the control channel for exchanging control frames among nodes, and another is set to one of data channels for transmitting and receiving data frames. By keeping listening to the control channel during data frame transmission on the data channel, every node can have more opportunity to receive broadcast frames and control frames from the neighbor nodes. In DSP protocol [10], each node has two network interfaces with fast channel hopping and slow channel hopping, and the transmitter node transmits data frames from the interface with fast channel hopping to the receiver's interface with slow channel hopping. In MMAC-HR protocol [11], each node is equipped with the network interface with slow channel hopping as well as DSP protocol, but another one is set to the dedicated control channel. In xRDT [12] and CRCS [13], each node has another network interface for busy tone, and a busy-tone channel is prepared to each data channel. When a node uses one data channel to transmit or receive a data frame, it also broadcast busy-tone signal to its neighbor nodes. By checking busy-tone signals, each node can recognize which data channels are idle. However, these approaches takes more cost for equipping each node with multiple network interfaces than the single network interface approach. In this paper, therefore, we consider only the single network interface approach, not the multiple network interfaces approach.

Moreover, there are several approaches to combine other concepts with multichannel MAC protocols. For example, in M-VRMA protocol [14] and DMAC protocol [15], each node has a network interface with transmission power control to avoid the hidden/exposed terminal problems by the difference of communication capability among terminals. In CMDMAC [16] protocol and MMAC-DA [17], to enhance spacial reuse for multichannel MAC protocol, each node is equipped with a directional antenna and transmits signals to a specific direction, not omnidirectional.

As above mentioned, many multichannel MAC protocols have been proposed to enhance the network performance in wireless communication. Here, these methods need frequent channel switching for the transmitter and receiver nodes to transmit and receive data frames. However, this behavior needs to take some time period to switch from one channel to another channel. It may be less than 100 microseconds, or more than several milliseconds at some devices shown in the papers [2], [10]. Therefore, it is easily understandable that this switching delay affects the network performance.

One of the simple ways to reduce the effect of channel switching delay in a multichannel MAC protocol is to decrease the number of channel switching in the transmission procedure of data frames. To achieve this, the RCMAC [2] method introduces the concept of "receiver-centric" which means that the transmitter adapts its channel setting according to the receiver's current channel setting status. In **Fig. 1**, for example, node *A* has a data frame to forward to node *B*, then they switch to the same data channel by exchanging RTS/CTS/CFM frames, and node *A* transmits the data frame to node *B*. Here, each gray area in Fig. 1 means that the node is on the data channel. After that, if node *A* has another

Fig. 1   Behavior of RCMAC.

data frame to forward to node *B*, then it can continuously transmit the data frame on the same data channel. If node *A* has no data frame to node *B*, then it broadcasts a CHSW frame to notify that it leaves the data channel. After switching back to the control channel, node *A* broadcasts a CHCB frame to notify that it has returned to the control channel. In contrast, node *B* as the receiver stays on the data channel for some period. In this period, if the other node like node *C* has a data frame to forward to node *B* and it knows node *B* is now on the data channel, then it switches to the same data channel and can transmit to the data channel to node *B*. The channel information where a node resides can be retrieved from RTS/CTS/CFM frames or the neighbor nodes by NCTS frame. By this behavior, the receiver node doesn't have to switch back to the control channel when it needs to receive more data frames from its neighbor nodes, and can also decrease the number of exchanging RTS/CTS frames for data frame transmission.

As above mentioned, the RCMAC protocol has a good concept and may be able to enhance the network performance. However, it has some problems to employ for wireless ad hoc networks. In the RCMAC protocol, the time period on the data channel is not specific, because the number of neighbor nodes which want to transmit to the node on the data channel is unknown. This may cause unnecessary wait or unreachable control frame transmissions to its neighbor nodes. The RCMAC protocol has the way to avoid this problem by broadcasting notification frames about leaving from the data channel and returning to the control channel. However, broadcast frames have no guarantee to be received by all neighbor nodes. Therefore, the node may not be able to recognize which channel its neighbor node is using now.

3. RPNT-MMAC: Receiver-prioritized Next Transmission in Multi-channel MAC Protocol

To reduce the adverse effect of channel switching delay in a multichannel MAC protocol, we propose a new multichannel MAC protocol called RPNT-MMAC (Receiver-Prioritized Next Transmission in Multichannel MAC) protocol. In this paper, we assume that each node has only one network interface. Also, we assume that several orthogonal channels are available for wireless communication and divided into one common control channel and the other data channels. Every node can use only one of these channels at a time.

As mentioned in Section 2, one of the simple ways to reduce the adverse effect of channel switching delay is to decrease the number of channel switching as the RCMAC protocol has introduced, and our proposed method also employs the same concept as well. Contrary to the RCMAC protocol, in the RPNT-MMAC protocol, the node which receives a data frame from its neighbor node on a data channel can acquire the right of next transmission of a data frame on the same data channel. This means that after receiving a data frame on a data channel, if the receiver node has a data frame to be forwarded to its neighbor node, then it can transmit a data frame on the same data channel subsequently. This behavior can decrease the number of channel switching, because the receiver node of a data frame doesn't need to switch back to the control channel for the next transmission of a data frame by the node. Also, contrary to the RCMAC protocol, in our method the receiver node is permitted to transmit only one data frame to its neighbor node after receiving a data frame. This means that the maximum time period for which each node is on the data channel is at most the time of two data frame transmissions. It is easier for each node to predict whether its neighbor node is currently on the control channel or not, than in the case of the RCMAC protocol. Moreover, our proposed method can also enhance the fairness among data flows in the network, because our proposed method can decrease the difference between the number of receiving and transmitting frames for each node, and avoid the packet losses by buffer overflow of the bottleneck node which is on the several paths of data flows. This is substantially different from the fairness among adjacent nodes which the IEEE802.11 DCF MAC protocol achieves.

To realize the above behavior, we need to add and modify control frames defined in the IEEE802.11 DCF MAC protocol with RTS/CTS. In the following subsections, at first we will explain control frames of our proposed method, and then describe the transmission procedure of data frames in detail.

As for the data channel selection for data frame transmission, we don't consider any more in this paper. Of course, this issue is one of the most important, and we need to consider it eventually.

3.1 Control Frames

In IEEE802.11 DCF MAC protocol with RTS/CTS, three control frames of RTS, CTS and ACK are used for unicast transmission of data frames. In our proposed method, these frames are used in the same roles, namely RTS and CTS frames are used for
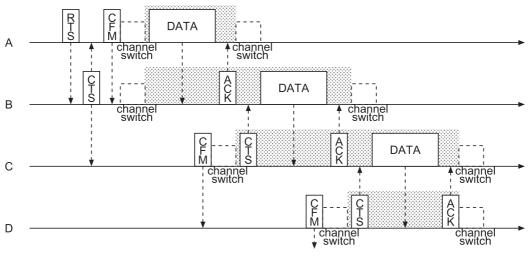
Fig. 3 Example of transmission sequence.

notification of current transmission to the neighbor nodes on the control channel, and ACK frame from the receiver node is used for acknowledgment to the transmitter node on the data channel. Moreover, RTS and CTS frames are used for negotiation of data channel selection between the transmitter and the receiver nodes. Therefore, RTS and CTS frames are modified to add a new field to set the channel number for negotiation between the transmitter and the receiver nodes and notification to the neighbor nodes which data channel is used for the current data frame transmission. In this paper, the size of this channel field of RTS and CTS frames is defined as one octet. However, we don't take care of the channel selection method and employ one of the methods in the traditional multichannel MAC protocols. In some selection methods, the transmitter node transmits the RTS frame with the currently available channel list for it, so the size of the channel field of RTS can be changed according to the channel selection method.

Moreover, for CTS frame, we add two more fields, the transmitter address field and the receiver address of the next transmission field. The former one is included in the default RTS frame, but not included in the CTS frame for the IEEE802.11 DCF MAC protocol. In our method, however, the CTS frame also plays a role of the RTS frame for the next transmission, therefore the CTS frame needs this field to notify the transmitter of the CTS frame to the next receiver node. The latter is also necessary for the next transmission to notify which node is the receiver of the next transmission. The size of these fields is six octets.

Also, we add a control frame called as CFM (ConFirMation) frame which is used in the RCMAC protocol. As well as the RCMAC protocol, the CFM frame is transmitted by the transmitter node of a data frame after receiving the CTS frame, to announce switching to the data channel to its neighbor nodes. In our proposed method, moreover, the CFM frame is transmitted by the receiver of the next transmission before switching to the data channel, and this CFM frame plays the same role of the CTS frame which is used for the second receiver node to notify the third data frame transmission to the third receiver node. Therefore, the frame format of the CFM frame is the same as the CTS frame format. The frame formats of RTS, CTS and CFM are
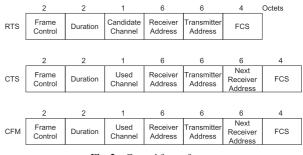

Fig. 2 Control frame format.

shown in **Fig. 2**.

3.2 Transmission Procedure

In our proposed method, the transmission procedure is similar to the traditional IEEE802.11 MAC protocol with RTS/CTS, namely at first the transmitter and receiver nodes exchange RTS and CTS frames on the control channel, and the data frame and ACK frame are transmitted after that. Also, as well as traditional multichannel MAC protocols, the data channel is selected while exchanging RTS/CTS frames, and channel switching is executed after the RTS/CTS exchange. In our proposed method, the NAV (Network Allocation Vector) timer is set to each channel, and can be used for extracting available data channels.

Here, we will explain the proposed procedure using an example shown in **Fig. 3**. Each gray area in Fig. 3 means that the node is on the data channel. In this example, we assume that four nodes A, B, C and D exist and node A has a data frame to node B, and node B also has a data frame to node C. Here, suppose that node A first starts to transmit the data frame. At first, node A transmits an RTS frame to node B as well as the traditional IEEE802.11 MAC protocol with RTS/CTS. After receiving the RTS frame, the other nodes except for node B set the NAV timer of the control channel, according to the duration until the end of the CTS frame reception. When node B receives the RTS frame, it checks the NAV timer of the designated data channel in the RTS frame. If the NAV timer is expired, then node B prepares to transmit a CTS frame to node A. Here, node B has a data frame to be forwarded to node C, and node B sets the address of node C into

the next receiver address field. Then, node *B* transmits the CTS frame to node *A*. As well as the RTS frame, the other nodes except for node *A* and *C* which receive the CTS frame set the NAV timer of the designated data channel included in the CTS frame. When node *A* receives the CTS frame, it transmits a CFM frame and switches from the control channel to the selected data channel. When node *C* receives the CTS frame, it recognizes that it is the receiver node of the next data frame transmission, and set the NAV timer of control channel to the end of the frame transmission between node *A* and *B*. After receiving the CFM frame, node *B* switches to the selected data channel, and node *A* transmits the data frame to node *B*, and node *B* receives it and returns an ACK frame to node *A*. After receiving the ACK frame, node *A* switches back to the control channel.

After transmitting the ACK frame, node *B* stays on the data channel for the next data frame transmission. Node *C* transmits a CFM frame to the neighbor nodes at the end of the first data frame transmission and switches to the same data channel, and it transmits a CTS frame to node *B* to tell that it is on the same data channel. After receiving the CTS frame, node *B* transmits the data frame to node *C*, and then it receives an ACK frame from node *C* if node *C* could receive the correct data frame. After that, node *B* and *C* switch back to the control channel.

In this example, if node *C* has a data frame to node *D*, then node *C* notifies that node *D* is the receiver node of the next transmission by using the CFM frame, as well as node *B* did to node *C* by using the CTS frame. By doing this procedure, each receiver node can acquire the right to the next transmission of a data frame.

Here, we suppose that node *C* is just node *A*. In this case, node *B* sends a data frame to node *A* on the same data channel after node *A* sent a data frame to node *B*. However, node *A* is already on the same data channel, so the transmission of a CFM frame on the control channel that node *C* executes in Fig. 3 is omitted. Therefore, the transmission from node *A* to node *B* completes on the data channel, node *A* and node *B* stay on the same data channel and node *A* transmits a CTS frame to *B*. After receiving the CTS frame, node *B* transmits a data frame to node *A*.

Also, we suppose that node *C* has a data frame to node *B*, not node *D*. In this case, node *C* can't transmit it to node *B* in this channel switching, though they can be on the same data channel. The reason is that node *B* can't receive the CFM frame from node *C* because node *B* has already switched to the data channel. In this paper, we designed the proposed procedure for each node to keep the duration time of residing a data channel which is notified to the neighbor nodes on the control channel. To do so, the CTS frame transmitted on the data channel doesn't include the receiver address of the next transmission. Therefore, both node *B* and *C* switch to the control channel after node *B*'s data frame transmission. After returning to the control channel, node *C* tries to transmit an RTS frame to node *B* to forward the data frame.

In Fig. 3, when node *C* can't receive the CTS frame from node *B*, node *C* never switches to the data channel. In this case, node *B* waits for the period of CTS frame transmission on the data channel, and then switches back to the control channel. This wait period will cause the packet transmission delay. The case that

node *D* can't receive the CFM frame from node *C* causes the same result. Therefore, in the situation that such CTS/CFM reception errors frequently happens, the proposed method may lose the advantage.

A similar method using the CTS frame in the role of the RTS frame to the next receiver has been employed in the MARCH protocol [18]. Contrary to our proposed method, in MARCH, the consecutive transmission procedure is for the same data frame, therefore each node needs to manage the path information of data flows. Also, the MARCH protocol is one of single channel MAC protocols.

4. Performance Evaluation

To evaluate our proposed method, we made a network simulation based on the network simulator ns-2.35 [19]. In this simulation, we assume that each mobile node moves with a maximum 15 m/s velocity in a 1,500 m × 1,500 m square area. The source and the destination nodes of each data flow are randomly located in the area, and we used the AODV method as routing protocol in ad-hoc networks. A MAC-level retransmission mechanism is the same as in IEEE802.11. Simulation parameters are shown as **Table 1**. The simulation results are the averages of the values for 100 mobility patterns of mobile nodes. We compared our proposed method (RPNT-MMAC) with IEEE802.11 DCF MAC with RTS/CTS, the traditional multichannel MAC protocol like Ref. [3] (Here, we called SMMAC), and RCMAC protocol.

4.1 The Case with Shorter Switching Delay

At first, we show the simulation results in the case that the effect of switching delay isn't so large, and we used 0.1 msec as the switching delay.

Figures 4 and **5** show the graphs of the average packet arrival rate and the end-to-end packet delay using IEEE802.11, SMMAC, RCMAC and RPNT-MMAC. The horizontal axis means the number of data flows. From these graphs, our proposed method (PRNT-MMAC) had better performance than the other methods. The main reason of these results seems that our proposed method has a better spatial usability by using several channels to transmit data frames and a better temporal usability by decreasing the number of channel switching and transmitting control frames.

As the number of data flows increases, the network perfor-

Table 1　Simulation parameters.

Area size	1,500 m × 1,500 m
Number of Nodes	100
Velocity of Nodes	0–15 m/s
Mobility Pattern	Random Way Point
Transmission range	250 m
MAC Protocols	based on IEEE802.11b 11 Mbps
Number of Channels	5
Switching Delay	0.1 ms, 5 ms
Propagation model	TwoRayGround
Routing Protocol	AODV
Transport Protocol	UDP
Application Protocol	CBR
Packet size	1,000 bytes
Flow Rate	50 kbps
Number of Data Flows	5–30
Simulation time	300 sec

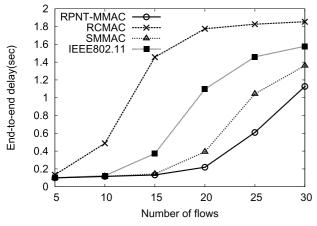**Fig. 4** Comparison of average packet arrival rate (0.1 msec).

Fig. 6 Comparison of fairness among data flows (0.1 msec).

$$F = \frac{(\sum_{i=1}^{n} x_i)^2}{n \sum_{i=1}^{n} x_i^2},$$

where n and x_i represent the number of data flows and the arrival rate of each data flow, respectively. **Figure 6** shows the graphs of average fairness among data flows using IEEE802.11, SMMAC, RCMAC and RPNT-MMAC. We can easily understand that our proposed method (RPNT-MMAC) had better performance than the other methods. The reason is that in the traditional methods, the fairness is based on nodes, not data flows, and the node which becomes the relay node of some data flows has the unfairness between receiving and transmitting frames, and tends to be the bottleneck in the path of data flow. In contrast, our proposed method (RPNT-MMAC) can make the fairness between receiving and transmitting frames by using receiver-prioritized next transmission procedure. Therefore, our proposed method can improve the fairness among data flows.

Fig. 5 Comparison of average end-to-end packet delay (0.1 msec).

mance of RPNT-MMAC becomes close to one of SMMAC. The reason seems as follows. As the number of data flows increases, many nodes tend to communicate with their neighbor nodes. In such a case, the intended receiver can't receive CTS or CFM frame with its own address as the receiver of the next transmission from the neighbor node, if it is in communication with the other node. This causes the similar behavior of SMMAC such that only one data frame is transmitted during one channel switching. Also, if a node notified to the receiver of the next transmission by CTS or CFM frames, it needs to stay on the same data channel at least for the period of CTS frame transmission from the intended receiver. Therefore, it causes more delay in data transmission.

The result of RCMAC was the worst among the methods. The reason seems that the RCMAC protocol uses broadcast transmission to notify the neighbor nodes to leave and come back to the channel, which plays an important role of the procedure. This protocol may have a good performance in the simple network topology. However, especially in a random network topology with many data flows, the broadcast without retransmission is unreliable to deliver the frame to the neighbor nodes by frame collisions.

Moreover, we checked the side-effect of our proposed method, namely the fairness among data flows. In this paper, we used The Jain's fairness index [20] as the fairness index F calculated as the following equation:
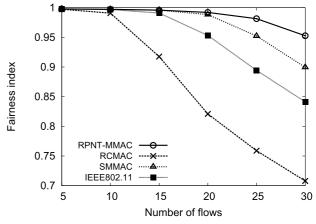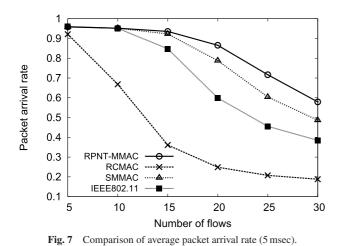
4.2 The Case with Longer Switching Delay

Next, we show the simulation results in the case that the effect of switching delay is larger than the above case, and we used 5 msec as the switching delay.

Figures 7 and **8** show the graphs of the average packet arrival rate and the end-to-end packet delay using IEEE802.11, SMMAC, RCMAC and RPNT-MMAC. For the result of the average packet arrival rate, as well as the case using a 0.1 msec switching delay, we can see that our proposed method (RPNT-MMAC) had better performance than the other methods. However, this result shows that the longer channel switching delay deteriorates the network performance in multichannel MAC protocols, as we mentioned in Section 2. Especially, as shown in Fig. 8, the longer channel switching delay causes an adverse effect to the end-to-end packet delay, and the result of multichannel MAC protocols is worse than a single channel MAC protocol, in some cases. From these results, we should carefully choose which MAC protocol is better, a single channel MAC protocol or a multichannel MAC protocol in the specific situation.

We also checked the fairness among data flows in the case with a longer switching delay. **Figure 9** shows the graphs of average fairness among data flows using normal MAC, SMMAC, RCMAC and our proposed method (RPNT-MMAC). From these graphs, as well as the results in the case with a small switching
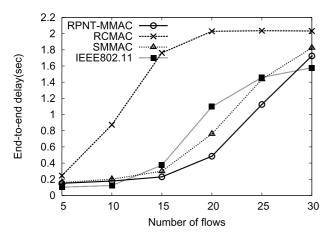
Fig. 7 Comparison of average packet arrival rate (5 msec).

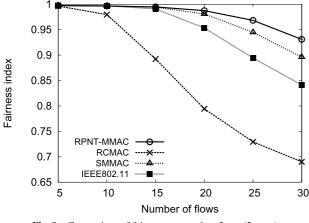**Fig. 8** Comparison of average end-to-end packet delay (5 msec).

Fig. 9 Comparison of fairness among data flows (5 msec).

delay, our proposed method (RPNT-MMAC) had the best performance among the methods.

5. Conclusion

In this paper, we proposed a new multichannel MAC protocol called RPNT-MMAC (Receiver-Prioritized Next Transmission in Multichannel MAC) protocol, in which the receiver node of a data frame at a data channel can acquire the right to transmit the next data frame on the same data channel. Our proposed method can improve the temporal usability by reducing the number of channel switching and the fairness among data flows. The simulation results showed better performance of our proposed method than

the traditional methods.

We have some future works. In the current proposed method in this paper, we don't take care of the channel selection method, and need to consider it to enhance the performance. Also, as we mentioned in Section 4, we should carefully choose the MAC protocol if the channel switching delay is long. Therefore, the switching method between a single channel MAC protocol and a multichannel MAC protocol according to the situation should be investigated.

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