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LETTER

Retransmission Decision Method for Wireless Multicast in Ad-Hoc Networks

Byung-Seo KIM[†] ***and*** **Sung Won KIM**[††a)], ***Members***

SUMMARY In order to improve multicast performance in wireless networks, we propose two methods for reducing the number of retransmissions and decreasing the backoff duration. Reducing the number of retransmissions is achieved by introducing a target packet delivery ratio. Acknowledgement from a member node initializes the backoff window, which decreases the backoff duration.
key words: *wireless multicast, protocol, ARQ, OFDM*

1. Introduction

Multicasting over wired and wireless mediums involves transmitting data to a group of nodes identified by a single destination address. Thus, multicast is a potential bandwidth-efficient technique for group communication. However, in contrast to multicast over wired mediums, the reliability of wireless multicast is restricted by the fact that member stations (STAs) do not return acknowledgements. When there are acknowledgements from all multicast members, it causes high overheads that increase as a function of the number of members. Even though the provision of multicast reliability at the MAC layer has received increasing attention in [1]–[5], none of these studies solved the problems of the hidden node and overheads in wireless multicast over ad-hoc networks. On the other hand, the OFDMA-based ACK (OMACK) in [6] achieves a remarkable reduction in the overhead by utilizing OFDMA characteristics in the acknowledgement (ACK) frame format. Automatic RepeatreQuest (ARQ) over wireless multicast is implemented using OMACK. However, the retransmission methods used in the wireless multicast proposed in [1]–[6] have two remaining issues requiring resolution. The first issue is that the proposed methods require perfect reliability, which means retransmission is repeated until all member nodes have received each of the multicast data packets. However, some packet losses of streaming video or audio are tolerated for members depending on the traffic Quality of Service (QoS) such as priority, delay constraints, etc. This is achieved by modern coding technologies [7]. Therefore, retransmission satisfying the conditions of perfect reliability wastes limited network resources. The second issue is the increase of the contention window for retransmission. Unlike unicast, multicast retransmits a packet if any member does not acknowledge, even if one member does so. Since multicast retransmission follows a unicast rule, the contention window increases for every retransmission up to the maximum contention window size. As a consequence, retransmission of wireless multicast suffers from the large backoff time. However, in a one-hop communication environment, if any member acknowledges a multicast packet, the packet loss for members is most likely due to channel error instead of collision. Therefore, increasing the contention window at every retransmission is inefficient. In this paper, an efficient retransmission method for wireless multicast is proposed to solve the aforementioned two issues.

2. Preliminary Study

The OMACK packet, which is proposed in one of our previous works [6], is a simple packet consisting of a preamble and an OFDM symbol with a cyclic prefix. Each member STA has a pre-assigned unique sub-carrier allocation for each group ID. When a member STA receives a multicast packet from the sender, it allocates one of two BPSK symbols (1 or -1) on the pre-assigned sub-carrier as an acknowledgement for the packet. A successful and failed reception of the multicast packet on the sub-carrier is indicated by 1 and -1, respectively. Even though all member STAs simultaneously send their OMACKs after an SIFS idle period, the OMACKs are simultaneously received at the sender without collision due to the orthogonality of sub-carriers. So no additional overhead is created compared to unicast. The time offset problem due to imperfect time synchronization and different propagation delays from member STAs is solved by using the longer cyclic prefix shown in [8], which is longer than the delay spread profiles.

3. Proposed Protocol

In this section, an efficient retransmission strategy is proposed and illustrated in the OMACK system. However, the proposed method can also be used in other ACK-based multicast systems [2], [3]. The proposed strategy is composed of two parts: contention window adjustment and making a decision on retransmission. As mentioned above, all members acknowledge their reception status using their pre-

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[†]The author is with the Department of Computer and Information Communication Engineering, HongIk University, Chungcheongnamdo, 339-701, Korea.
[††]The author is with the Department of Information and Communication Engineering, Yeungnam University, Gyeongsang-bukdo, 712-749, Korea.
a) E-mail: swon@yu.ac.kr
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assigned subcarriers in an OMACK packet. In addition, the network topology is one-hop communication. Thus, it is assumed that all nodes are able to hear each other's transmissions if there is no channel error. Initially, the contention window for retransmission increases only when no member acknowledges the most recently transmitted multicast data packet. When any member acknowledges, even if other members do not, the contention window size is reset to the initial value. The contention window is designed to resolve collisions due to simultaneous transmissions by multiple nodes. However, if at least one member acknowledges the sender, it means there might be no collision in one-hop communication. The reason for non-acknowledgment is channel error instead of collision. Initializing the backoff window size for any success prevents any unnecessary increase of the contention window, thus it reduces the time wasted during the backoff period. Second, retransmission is decided based on how many multicast data packets have successfully been delivered for each member. We define the Packet Delivery Ratio (*PDR*) as the percentage of successfully delivered packets out of the transmitted packets for each member. The *PDR* for member i is defined as follows:

$$PDR_i = \frac{m_i}{M}, \quad i \in \{0, 1, \cdots, N\}, \tag{1}$$

where M is the total number of multicast packets transmitted so far, m_i is the number of multicast packets acknowledged from member i, and N is the number of multicast group members. Before a new multicast packet transmission, M is updated to $M + 1$. After the first transmission or retransmissions of the multicast packet, PDR_i is updated based on the OMACK packet from members as follows;

$$PDR_i = \frac{m_i + \alpha}{M}, \tag{2}$$
$$\alpha = \begin{cases} 1, & \text{if OMACK from member } i \text{ is received} \\ 0, & \text{otherwise.} \end{cases}$$

Updating for a member's *PDR* stops once the member acknowledges the multicast packet. The *Target* PDR_i is the required *PDR* for member i and is a predefined value from 0 to 1 depending on the reliability level of the multicast traffic. Moreover, the *Target PDR* for each member can be set depending on the priority or required reliability level of the member. If a multicast traffic needs perfect reliability for all members, the *Target PDR*s for all members are set to 1. If the *PDR* of a member is higher than its *Target PDR*, the member is virtually considered to return an OMACK at each transmission, even if it does not do so. In other words, the member does not affect the retransmission policy, because it has already achieved the *Target PDR*. The process of retransmitting a multicast packet is as follows.

Step 1. A sender transmits a multicast packet to all members, which are required to acknowledge the sender using OMACK packets. For the retransmission of the multicast packet, although a member has successfully received the multicast packet in the previous transmission, it needs to acknowledge the retransmitted packet.

Step 2. When an OMACK packet is received, the sender checks whether the members sent their ACKs using their subcarriers in the OMACK packet. Then, the sender updates the *PDR*s of the multicast group members using (2).

Step 3. Each member's *PDR* is compared with its *Target PDR*. If any member's *PDR* is less than its *Target PDR* and the member does not return an OMACK packet, the current multicast packet is retransmitted. On the contrary, if all members meet at least one of two requirements (an OMACK is returned or the *PDR* is higher than its *Target PDR*), then the retransmission of the multicast packet is stopped and a new packet is transmitted.

Step 4. The sender adjusts the contention window size for the retransmission as follows. If any member returns an OMACK packet, the contention window size (CW) for the retransmission is set to the minimum value, and the backoff time is chosen from the new CW. If no member sends an OMACK packet, then the CW is increased in accordance with the IEEE 802.11 standard.

4. Performance Evaluation

The performances of the retransmission methods are evaluated. We consider an OFDM-based physical (PHY) layer as in IEEE 802.11a [9] operating in the 5 GHz frequency band. The wireless channel characteristics are modeled as three components: path loss, shadowing and multipath fading. The path loss is modeled with a path loss exponent of 2.56. To represent fading, we consider the "*ETSI indoor channel A*" delay profile in [10]. The power delay profile has an RMS delay spread of 50 ns and a maximum delay spread of 390 ns. This delay profile results in frequency selective fading in the IEEE 802.11a 20 MHz band. Simulation results in this paper have been generated by the event-driven simulator used in [6]. The system under consideration is an IEEE 802.11a-based Basic Service Set (BSS) in which a group of multicast members are communicating. The communication channel of one communication pair experiences a particular fading realization different from that of another communicating pair, even in the same BSS. All nodes are randomly distributed in a 100 m × 100 m square area and move randomly at a speed of 0.1 m/sec. The transmission queue of the source node is assumed to be always nonempty. The packets' life time is 20 msec, and the PHY data rate is 6 Mbps with a packet size of 2000 bytes.

Figure 1 shows the throughput and delay performances of four retransmission methods: the OMACK method, the proposed CW method, the proposed PDR method, and the proposed CW & PDR method. The *PDR* threshold is set to 0.99. The OMACK method retransmits until all members acknowledge an OMACK packet and CW increases at every retransmission. The proposed CW method uses the proposed CW adjustment method for retransmissions. That is, it resets CW when any member acknowledges, but retransmits until all members acknowledge in one OMACK packet. In the proposed PDR method, the retransmission is stopped when an OMACK packet is returned or the *PDR* is higher

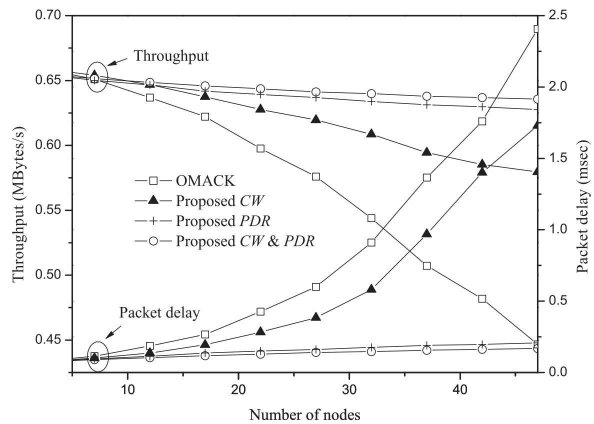

Fig. 1 Throughput and packet delay according to the number of nodes.

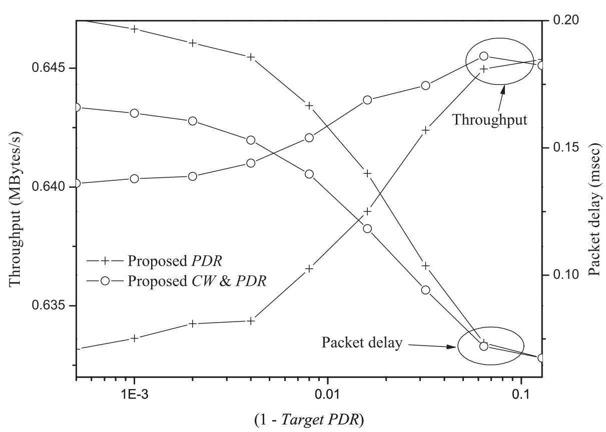

Fig. 2 Throughput and packet delay according to the *Target PDR*.

than its *Target PDR*. The proposed CW & PDR method is fully implemented with two proposed methods: CW adjustment and PDR. The throughput of the proposed CW & PDR method increases up to 40% and 20% of the OMACK and the proposed CW method, respectively. The proposed CW & PDR method significantly reduces the transmission delay up to 90% and 85% of the OMACK and the proposed CW method, respectively. These improvements are due to the reduced number of retransmissions and decreased backoff duration. It is also found that reducing the number of retransmissions (the proposed PDR method) has a greater effect than decreasing the backoff duration (the proposed CW method).

The effect of the *Target PDR* on the performance is shown in Fig. 2, where 1 — *Target PDR* is used to achieve clarity of scale. The number of nodes is set to 25. The results of the OMACK and the proposed *CW* methods are not shown in the figure because their performances do not depend on the *Target PDR*. As the value of the *Target PDR* increases (i.e., 1 — *Target PDR* decreases), the performance difference between the proposed *PDR* method and the proposed *CW* & *PDR* method increases. This is because ignoring non-acknowledgments has less effect as the value of the *Target PDR* increases. In this case, the decreased backoff duration plays a dominant role in the proposed *CW* & *PDR* method.

5. Conclusions

In this paper, an efficient retransmission method for wireless multicast over contention-based wireless networks is proposed. It not only provides a means to adjust the contention window size for retransmission, but also a means to make a decision on retransmission using PDR. As a result, the proposed method increases the network performances by reducing unnecessary processing time.

Acknowledgments

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