Reliable data delivery scheme for real-spatial information based group communication

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Abstract: Herein, we propose a novel scheme that combines information exchange and user activities in real-time so that those users can integrate their communications seamlessly with their daily lives. Called the Real-Spatial Information-Based Group Communication (r-Space) system, this scheme creates r-Space groups by considering personal and location information and enables users to share information within those groups. In a conventional message sharing scheme, when a user sends a data to other group members, multicast is normally used for the data delivery. However, because multicast does not have a mechanism to ensure the delivery of lost packets, the message may not be able to reach all of its intended recipients. With that point in mind, this paper proposes a reliable data delivery scheme that can improve packet delivery ratios and reduce transmission delays for r-Space communication. Later, we will evaluate this scheme via simulation.

Keywords: reliable data delivery, group communication, FEC

Classification: Network

References


1 Introduction

Wide spread of smartphones and social network services (SNSs) such as Facebook and Twitter allows us to exchange various items of information, anywhere and at any time, with someone else who has the same news interests or shares the same hobbies. However, it is still difficult to find neighbors in real space within a short time for the purpose of sharing information that would only be of immediate interest with those neighbors. To realize this, we have proposed the Real-Spatial Information based Group Communication (r-Space) system [1, 2] which provides group communication infrastructure among persons related to each other in consideration of real-space information.

As shown in Fig. 1(a), the r-Space system consists of the r-Space Control Server (SCS) and user devices (UD) such as smartphones with two types of interfaces that band-limited wide-area wireless networks (WAWN) and wireless local area networks (WLANs) for multi-hop wireless networks (MWNs). The SCS periodically collects information from UDs. It also picks up appropriate UDs to be grouped by request from a UD and sends group creation requests to UDs which should join it. The UDs deliver messages via SCS to all UDs in the group. This paper focuses on the message delivery procedure from SCS to UDs and proposes a reliable data delivery scheme for the r-Space system.

2 Related works of reliable data delivery for group communication

In this system, all UDs exchange data among group members. While UDs in WAWN directly receive data via SCS, UDs in MWN receives data through other UD in WAWN by using IP multicast along a multicast tree generated by the SCS prior to data delivery. For the latter WMN case, the performance of data delivery is
highly affected by the number of neighboring nodes. We focus on performance improvement in reliability of data delivery by using IP multicast in MWNs.

Many related works are classified three types generally: forward error collection (FEC), Automatic Repeat Request (ARQ), and Hybrid type [3]. The methods of FEC can improve data delivery rate by using a redundant packet [4, 5]. However, excessive packets may transmit at a node that is less degree. On the other hand, methods using ARQ can improve the performance by an acknowledgment. Also, the methods to reduce rebroadcast redundancy of multicast communication about these methods are proposed [6, 7]. However, these methods increase end-to-end delay because a node with a high degree must wait for ACK packets from all neighboring nodes. A hybrid type can improve the performance by balancing between FEC and ARQ [8]. Because these methods do not consider the node degree, unnecessary delays and packets may occur. Furthermore, the transparent unicast translation that an intermediate node translates multicast communication to unicast one per each node for a multicast group [9]. Although this scheme can improve a delivery rate for multicast packets, a delay for delivery increases due to transmitting by transmitting with unicast to each user.

3 Proposed scheme

We propose a reliable data delivery scheme for the r-Space system. Consider the case that a node in MWNs using WLANs forwards data sent by its representative node as a sender to group members. We assume that all nodes preliminarily have knowledge of network paths in the process of periodical r-Space information
collection via the representative node to the SCS. Such knowledge includes the number of neighboring nodes and the MAC addresses. This assumption provides two types of assist scheme. One is IP multicast with MAC layer unicast for easy feasibility. The other is IP multicast with adaptive redundancy by FEC. A node switches these two types depending on the number of its downstream neighboring nodes. Thus, we employ IP multicast with these supports on MAC layer to improve the performance of multicast in MWN, not by end-to-end but by hop-by-hop approach.

3.1 Transmission switching: IP multicast with MAC unicast

An r-Space system node forwards data from a sender via multicast. In multicast frame transmission, MAC layer has no retransmission method for lost packets. Therefore, packet loss could cause severe reliability degradation.

We propose the transmission switching scheme and Fig. 1(b) shows its procedure on the MWN’s topology with 4-hop. In this scheme, a forwarding node in multicast tree modifies the destination MAC address of outgoing MAC frame to a unicast MAC address in case of the number of neighboring nodes is one, and to the multicast address otherwise. This operation is performed by hop-by-hop. MAC layer unicast transmission expectedly ensures reachability by conventional retransmission process of the MAC layer. This destination switching manner improves reachability and reduces packet transmission delays.

3.2 Improvement of a delivery ratio for multicast using FEC

For the case of multiple downstream neighboring nodes, we also propose to adopt FEC technology to improve reachability in packet transmission via multicast. A node creates a redundant packet using the exclusive OR (XOR) from multiple packets when forwarding a packet by using multicast. Redundancy \( r \) for packets is calculated based on the performance of links between neighboring nodes as follows:

\[
((1 - E_M)^r)^{N} + (1 - E_M)^r \times E_M \times r^{N-1} \geq p
\]

where \( p \) is the desired value for packet delivery ratio, \( N \) is the number of neighboring nodes, and \( E_M \) indicates the maximum frame error rate (FER) from each neighboring node. We assume that the FER can be calculated by using the received signal strength indicator (RSSI) of the node device. The left member shows the probability that a node can transmit a packet successfully with a redundant packet based on \( r \) to \( N \) nodes when the maximum FER is \( E_M \). Basically, the node calculates a redundancy \( r \) that can satisfy the desired value \( p \). The calculated \( r \) shows a coefficient for the redundant packet. Nodes create one redundant packet per \( r \) data packets using XOR. A small \( r \) indicates high redundancy. For example, in the case that \( p \) is 0.98, \( N \) is 4, \( E_M \) is 0.005, \( r \) is able to satisfy \( p \) when \( r \) is less than 3.

4 Performance evaluation by a simulation

This section evaluates our proposed scheme using a simulation to compare the delivery ratios and delay of conventional methods. This paper does not focus on
characteristics of throughput because the r-Space system does not suppose to send consecutive data and a significant amount of data. In this simulation, the conventional methods send data to group users via both multicast and unicast.

4.1 Packet delivery ratio for redundancy \( r \)
First, we will evaluate an impact of a packet delivery ratio for \( r \). Table I shows the simulation specifications. A sender transmits a data packet to three neighboring nodes directly via multicast. We set the FER of the links based on the distance between nodes, and the FER between a sender and each neighboring node is set at 3\%. The nodes have no mobility, and we evaluate packet delivery ratios when \( r \) varies between 1 and 5.

From simulation result shown in Fig. 2(a), our proposed scheme achieves a higher delivery ratio when \( r \) is lower (higher redundancy). The delivery ratios of \( r \) between 5 and 1 are especially notable at 96.3\% and 98.2\%, respectively. As a result, based on the high redundancy levels achieved via multicast with FEC in our proposed scheme, we can predict high delivery ratios.

4.2 Performance for FER of links
In this scenario, we set to the network topology as Fig. 2(b) to evaluate an impact of combining the transmission switching scheme and our FEC mechanism. The simulation result specifications used were the same as described in section 4.1. The FER of each link between intermediate node and group members was set at 1\% to 5\%, and the desired probability \( p \) of our proposed scheme is set at 0.95 and 0.98.

Figs. 2(c) and 2(d) show the results of delivery ratio and delay, respectively. From Fig. 2(c), two proposed schemes have improved delivery ratios compared to the conventional multicast, especially our proposed scheme with \( p = 0.98 \), which can obtain an approximately 95\% delivery ratio. Next, we focus on the delivery delay of Fig. 2(d). From Fig. 2(d), redundancy of our proposed schemes is higher due to the FER increases (\( r \) is reduced). Therefore, the delivery delay of our proposed scheme is increased with the increase of the FER because the number of redundant packets has increased. However, our proposed schemes were still able to reduce the delivery delay below that the conventional unicast method.

From these results, it can be seen that our proposed scheme is capable of both improving delivery ratios and reducing delivery delays.

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<thead>
<tr>
<th>Table I. Simulation specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network Simulator</td>
</tr>
<tr>
<td>I/F of Wireless LANs</td>
</tr>
<tr>
<td>Transmission Rate</td>
</tr>
<tr>
<td>Transport Protocol</td>
</tr>
<tr>
<td>Packet Size</td>
</tr>
<tr>
<td>The number of transmitting packets</td>
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<tr>
<td>The number of trials</td>
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</tbody>
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5 Conclusion

In this paper, we focused on the data delivery system and proposed a data delivery scheme for the r-Space system. Our proposed scheme switches transmission methods between unicast and multicast based on the number of neighboring nodes, and introduces FEC to facilitate multicast transmission when necessary. Finally, we show the efficiency of our proposed scheme by simulation.

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