A new Method for Scalable and Reliable Multicast System for Mobile Networks

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Abstract. This paper proposes a new method aiming at realizing a scalable and reliable multicast system focused on mobile network. For reliability, retransmission scheme was adopted. The main idea of the proposed method is that network node does take care of error recovery by retransmission instead of a sender or receivers by which conventional methods have been done. Consequently terminal mobility can be dealt with more simple. This paper shows that the proposed method has much better performance compared with existing methods through simulation.

1 Introduction

Recent rapid advance of mobile communications technology allows users in mobile environment to enjoy not only voice service but also the Internet. And especially the enlarging capacity of wireless link makes it possible to accept the communication with large amount of data (file, picture and video, etc.) [1].

In these days, one of the main services is sure to be delivery-type service of, for example, music, game software and so on, to many mobile terminals (MT) utilizing the Internet. The purpose of our study is to develop a new method suitable for this kind of service over mobile network.

To realize delivery service, network must support some characteristics. First is an efficient data routing. Multicasting, which provides a very efficient routing way of one-to-multipoint communication, is suited to delivery service very well. Many kinds of multicasting protocols have been developed [2][3]. Data generated by the sender runs over the multicast tree that was organized in advance by the existing multicasting protocol to group members. The second is reliability that is to guarantee error-free in the sending data at all receivers. There are two classified techniques for reliability. One is feedback-less scheme, which adds to the multicast data, some redundant information so that receivers could correct the erroneous data using the redundant information. The other is feedback (reception state report) scheme; retransmission which sends again the same data to the erroneous receivers. Our concern is on feedback approach for complete (high) reliability. The third is high scalability, which is to be able to deal with extremely many mobile receivers with connection to networks, is essential to the service. The last is terminal mobility that is to guarantee the continuation of service session for moving receivers.

There are already several scalable and reliable multicast protocols with retransmission for reliability. They address the scheme to avoid implosion problem, which is caused by swamping on a sender with feedback messages from all receivers, in order to obtain scalability. SRM (Scalable Reliable Multicast) [4] proposes the random delay feedback scheme with multicast to reduce the implosion on the sender. A receiver suppresses its feedback after its random time passed if another receiver responds the same feedback. A successful receiver retransmits the data for erroneous MTs. PGM (Pretty Good Multicast) [5], LGMP (Local Group Multicast Protocol) [6], RMTP (Reliable Multicast Transport Protocol) [7] [8] and MESH protocol [9] employ local group (LG) concept to avoid the implosion and aim at shorter delay on recovery. In these methods a multicast group is divided into several LGs for local recovery. The main difference exists on the way to define LG and determine local controller (LC) of the group for the recovery. In PGM, error-free receiver volunteers to become LC. Hence LCs dynamically changes. On the other hand, LGMP, RMTP and MESH adopt fixed LC scheme. That is, LC is pre-defined depending on the multicast service type and network topology. MESH protocol [9] is targeted on the specific application of time-constrained data streams. Therefore, high reliability could not be gained since it protects delay-sensitive stream against errors.

As shown so far, the conventional methods can provide scalable and reliable multicast system. However, no consideration for mobile environment in these existing methods causes following the problems. For example, the low capacity of the wireless link between network and LC does not always lead to efficient recovery. The movement of LC could make local recovery complex. Consequently, these conventional methods do not have aspect to meet the described requirements.

This paper provides a new method of scalable and reliable multicast system not only for fixed networks, but also for mobile networks. Rest of the paper is organized as follows. Section II shows the conventional approach and discusses its characteristics. Section III presents the new method in detail. In the Section IV, the evaluation of the new method is shown through comparing to conventional methods by computer simulation. Finally, Section V describes the concluding remarks.

2 Conventional Approach and New Approach

Regarding the existing method, we categorized existing methods into two types of approach with respect to who does take care of recovery.

2.1 Conventional approach

(1) Sender-Based approach (SB)
A sender performs retransmission with Nack (error report) or/and Ack (error-free report) feedback scheme. In SB approach, the sender repeats retransmission in multicast until all members get multicasting data correctly. This approach includes typical point-to-point reliable protocols (TCP, HDLC etc.) and early multicasting protocol. This approach causes implosion problem with the number of member increased. And the bandwidth for feedback is required over the whole network, i.e., resource consuming problem issues.
(2) Receiver-Based Approach (RB)
This approach employs local group concept. In this approach, recovery is carried out by a receiver which represents its LG instead of sender. LC (Local Controller) is predefined. It can avoid implosion problem thanks to local management of feedback and recovery. Recent most efforts, SRM, PGM, LGMP, RMTP and MESH that I cited in section1, belong to this approach.

As already explained, the problem for mobile network is that the low capacity and instable quality of the wireless link and the low performance of LC make local recovery inefficient. Other is that the movement of LC could cause terminal mobility difficult.

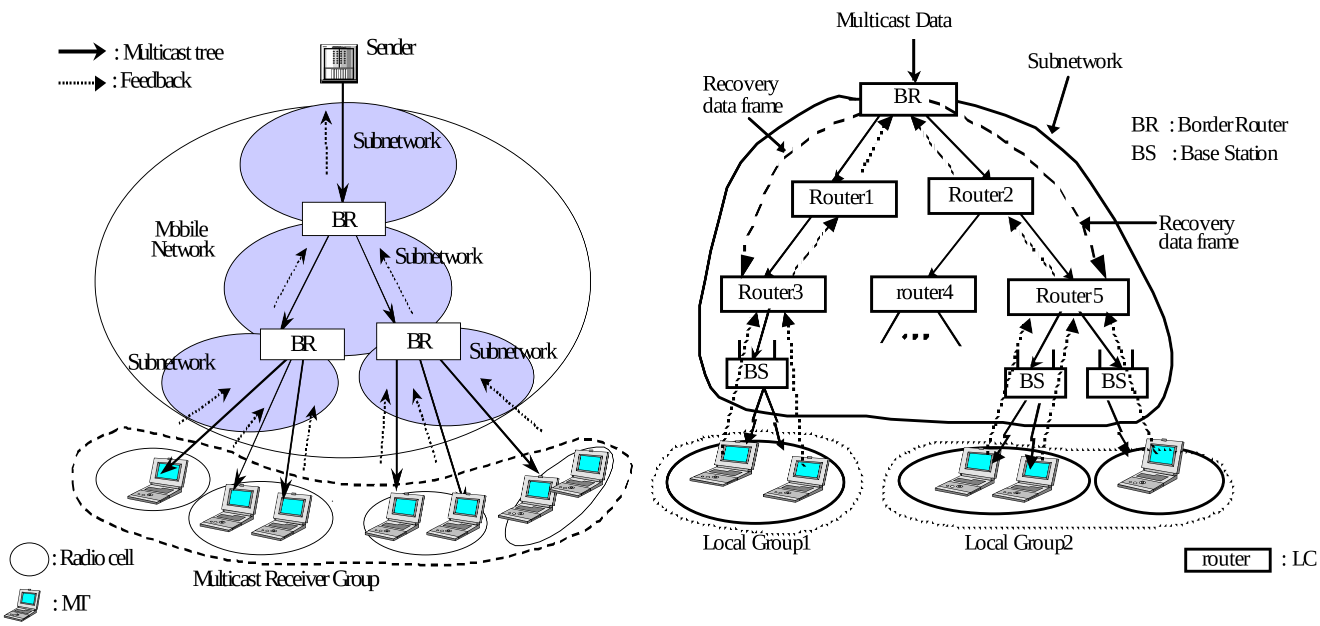
2.2 New approach

(3) Network-Based Approach (NB)
The new approach also adopts local group concept. In this approach, it is a network node that takes care of recovery instead of a sender or receivers. The node forms LG dynamically to execute local recovery. Therefore, it is not difficult for the network to track the movement of MT with usage of terminal mobility function of mobile network. As a result, it is expected to solve the problems that conventional approach issues as explained previously, and to satisfy the four requirements that described in section1. The next section explains the new method including how to decide the network node as LC in the next section.

3 New Method

3.1 Network architecture

We assume mobile network with IP-based which is constructed by router as network node. The network consists of several subnetworks in Figure1(a). Each subnetwork is connected by Border Router (BR) which keeps temporarily relaying data frames for recovery, or manages local group address and so on for management of subnetwork. Figure1(b) illustrates an example of subnetwork near MT. In this Figure, router3 and router5, which are LCs for local group1 and local group2, respectively, request and download recovery data from BR for its own group.



(a) System structure (b) Subnetwork

Fig.1. System architecture

3.2 Algorithm for decision of LC (Local Controller)

The policy of the algorithm is that it could reduce traffic generated in recovery and save the network resource as much as possible. Using Figure2, the algorithm is demonstrated as follows. After a given data frame is multicast to all MTs of a multicast group, feedbacks from MTs come up to routers. The router that has received the feedbacks makes judgement if there is a coincidence with feedback for error from plural lower routers (Figure3). If not, the router orders the lower router with negative feedback to become a LC. If any, it sends negative feedback up to the higher router. In figure2, at router1, for instance, there is a coincidence with feedbacks with error from router3 and router4, and the router1 reports the coincidence to the higher router0. At the router0, the coincidence with the feedbacks breaks, and the router0 indicates the router1to become LC. Accordingly router1 as LC organizes its LG (Local Group) to carry out recovery in multicast; the router1 gets the recovery data and local multicast address from BR and defines the LG by a set of erroneous MTs under the routers of which the highest is router1, and then executes retransmission.

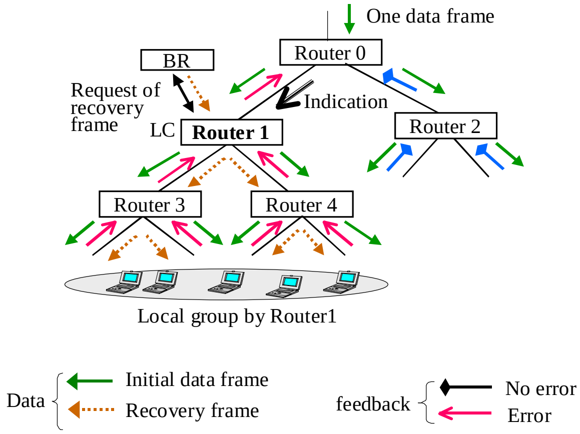


Fig.2. DSD algorithm

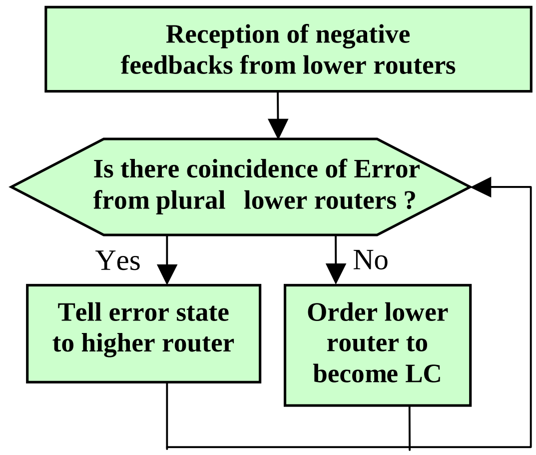


Fig.3. DSD **:** LC selection

Thus, LC router is selected considering the geographical distribution of erroneous MT (we named the algorithm "DSD; Dynamic Selection based on the Distribution") and dynamically forms LG for recovery. In this way, we can obtain the characteristics that the more densely error happens, the higher router would become LC for covering erroneous MTs properly. As a result, efficient recovery and usage of resource can be expected.

3.3 Terminal Mobility

The new method, NB, could make realization of the mobility much easier. The process of mobility is able to make use of the existing mobile IP function of network because it is the network node that takes care of recovery in NB.

Here we just outline only the point of study for mobility since the objective of this paper is to prove that NB-DSD algorithm is effective for mobile networks.

The action sequence of mobility was considered on the timing of MT movement to the algorithm execution. In case of the movement of MT before NB-DSD algorithm execution, LC router in the destination of MT recovers it, while in the reverse case, the original LC router continues to recover it.

4 Evaluation

In this section, the evaluation of the new approach with NB-DSD method is described through comparison with conventional approaches (SB and RB).

4.1 Outline of evaluation

The evaluation consists in verification of scalability, efficiency of reliability and effectiveness of dynamism of the new method. The mean transmission time per one data frame and the mean number of retransmissions were observed in the simulation. It is enough that the evaluation is done only on subnetwork with connection to MT in Figure1 since the highest LC router is BR.

Table1. Notation

Nm	The number of MT
Pr	Data frame error probability at wireless link
Cn	Capacity of the link inside network
Cr	Capacity of the receiver–network wireless link
Cs	Capacity of the sender–network link

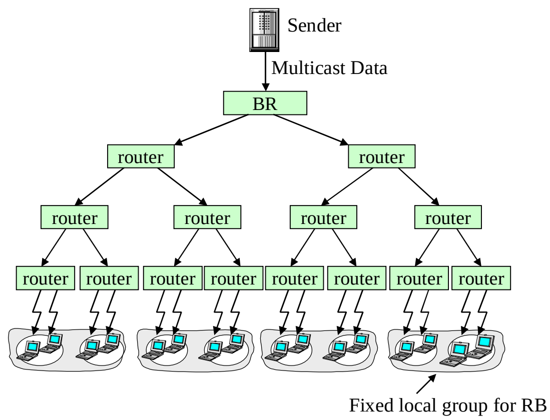


Fig.4. Simulation model
(for the case of MTs =16)

4.2 Simulation Model and Assumptions

Figure4 is an example of simulation model for a subnetwork which consists of one sender, sixteen MTs and fifteen routers. There are some assumptions;

- Each router has two interfaces to lower router and one interface to upper router and the lowest router accommodates two MTs.
- Regarding the method RB, one local group is defined by every four MTs including LC for recovery.
- Error with data arises only on wireless link in accordance with probability of uniform random distribution.
- Multicast transmission is simulated for total file = 500[kB], data frame length = 2000[bit]. Table1 shows the parameter notation.

4.3 Results

(1) Scalability

For evaluation of scalability, the increase ratio of the mean transmission time per one frame was measured with a variation of the number of MTs that represents network scale as appeared in Figure5. The increase ratio was calculated using the standard case of the transmission time for Nm = 4. In this Figure, only SB has much higher ratio with the number of MTs. It is because, in SB, the sender has to take care of retransmission for all of increased erroneous members, while, in RB and NB-DSD, each LC does it only for local erroneous members.

In Figure6 shows the number of retransmissions for the same conditions as that of Figure5. From this result, only on SB, the more the number of MTs increases, the more the sender repeats retransmission over the whole subnetwork, that causes wasting of network resource.

These results indicate that the local group scheme has much better scalability.

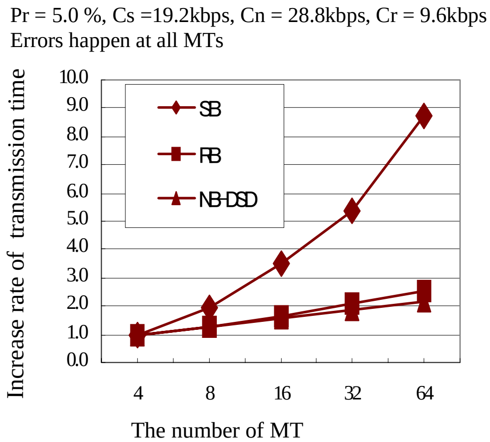


Fig.5. Increase ratio vs. Network scale

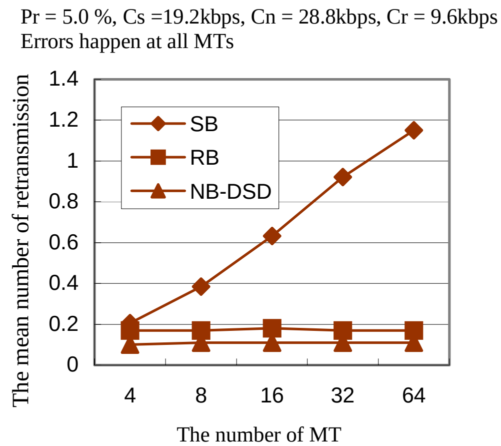


Fig.6. The number of retransmission vs. Network scale

<u>(2) Efficiency of reliability</u>

Figure7 illustrates the increase ratio of the mean transmission time with a variation of frame error probability of wireless link. This result also shows that SB has much worse performance in recovery than the local schemes. The fact suggests that SB cannot deal with recovery in efficient manner for deteriorated wireless link quality. And the result shows that NB-DSD has considerably (about by a half) lower ratio than SB.

Compared with RB and NB-DSD using the result of the number of retransmissions in Figure8 for the same conditions as that of Figure7, in which NB-DSD is lower than RB by about a half, we see that the quality of wireless uplink (MT → mobile network) impacts directly on recovery efficiency considering that the main difference between RB and NB-DSD is whether the wireless uplink is used for retransmission.

Moreover the uplink capacity also influences the efficiency in negative on RB as appears in Figure9. The influence is bigger particularly for the condition of low capacity of wireless uplink. Therefore, the conditions of wireless link exert worse influence on recovery efficiency of RB than that of NB-DSD.

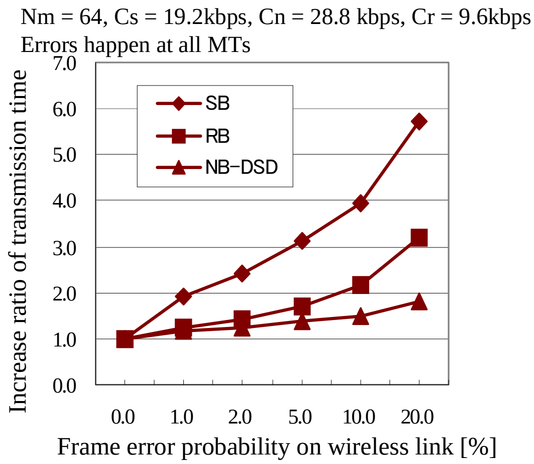


Fig.7. Increase ratio vs. Wireless link quality

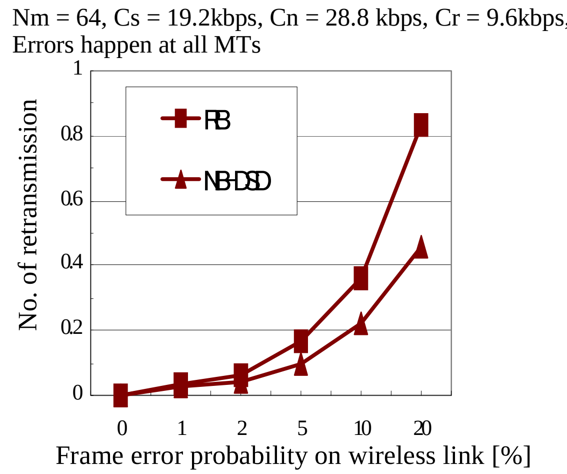


Fig.8. The number of Retransmission vs. Wireless link quality

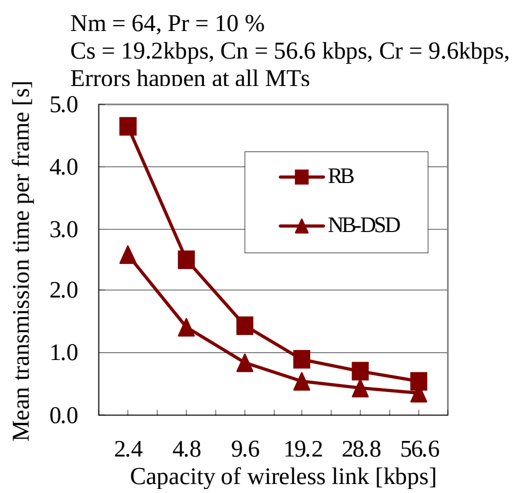


Fig.9. Mean time vs. Capacity of wireless link

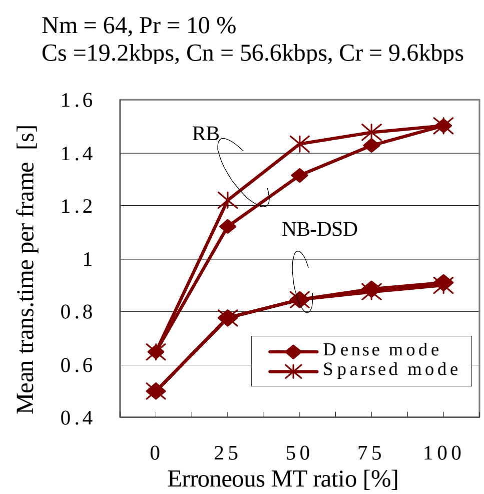


Fig.10. Mean transmission time vs. Distribution of erroneous MTs

<u>(3) Dynamism of NB-DSD algorithm</u>

The effectiveness of the dynamism on NB-DSD is made clear through comparison with RB as fixed strategy. Figure10 shows the mean transmission time per one data frame with a variation of ratio of erroneous MT. The two kinds of the geographical distribution of erroneous MT were selected as parameter, i.e., sparse mode and dense mode. Sparse mode is the state that erroneous MTs lie scattered uniformly over the network. On the other hand, dense mode is that erroneous MTs lie together. In this result, it is evident that the transmission time is different depending on the distribution for RB method, while it is almost the same for NB-DSD method. The fact implies the new algorithm can dynamically choose LC routers considering the state of erroneous MT distribution for covering erroneous MTs properly (i.e. the more densely error happens, the higher router would become LC for this area) so as to form several proper groups for local recovery towards the reduction of recovery traffic and network resource consumption.

5 Conclusion and Future work

In this paper, we examined the problems of existing protocols for reliable multicast when applying them to mobile network, and proposed the new method. The new method (NB-DSD) was compared with two conventional generic approaches (SB and RB) with regard to scalability and efficiency of reliability and dynamism. Concerning terminal mobility, we can expect that the new method reduces greatly the difficulty of its realization.

Our conclusion by the evaluation is the following;

(1) The new method (NB-DSD) which employs dynamic local group concept is the most suitable for mobile network with regard to large scalability and efficiency for reliability and can be expected to realize a very large scale and high reliable multicast system.

(2) The dynamism of new method (NB-DSD) enables to absorb the volatile geographical distribution to reduce traffic generated in recovery and economize the network resource.

In the future, we will take additional metrics (e.g. link congestion etc.) into account for the decision LC algorithm in order to obtain more fitting algorithm for real network.

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