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Dynamic Hybrid Active Multicast Services for Wireless Networks

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ABSTRACT: One of the important problems in multicast communication is decreasing generated redundant NAKs to avoid NAK implosion. A number of NAK suppression mechanisms which try to resolve this technical problem have been proposed so far. In a mobile environment, as a mobile node moves from one point of attachment to another during an ongoing session it is subjected to packet loss due to network and link layer transition. Such packet loss affects the quality of the ongoing communication session. This means handover will introduce long shutdown of connection, because not only handover process in layer 2 but also multicast join and multicast tree construction is necessary. This causes loss of large amount of packets and finally causes NAK implosion. In this paper, we claim our protocol DHARM which is originally developed for wired networks can be applied to wireless multicast communications and resolve this NAK implosion problem caused by handover. Our simulation results show that our approach significantly improves scalability of reliable wireless multicast networks.

KEYWORDS: Wireless networks; Reliable multicast;NAK suppression ; handover; packet forwarding; DHARM; sub casting**.**

I. INTRODUCTION

Multicast communication can support dissemination of the same data to potentially large number of receivers. In IP multicast, a source sends a single data packet whose destination IP address is the address of the corresponding multicast group. The data packet is replicated at an adequate router and forwarded to an interface below which there are receivers. IP multicast uses UDP in the transport layer, so originally it does not support any reliability. A large number of reliable multicast protocols have been developed for ensuring reliability at the transport Layer. Most of them fall into one of the following classes: sender-initiated, receiver-initiated and receiver-initiated with local recovery. In sender-initiated protocols, the sender is responsible for both the loss detection and the recovery as in XTP [1]. These protocols usually do not scale well to a large number of receivers due to the ACK implosion problem. Receiver-initiated protocols move the loss detection responsibility to the receivers. They use NAKs instead of ACKs. However they still suffer from the NAK implosion problem when a large number of receivers have subscribed to the multicast session. In receiver-initiated protocols with local recovery, the retransmission of a lost packet can be performed by some other nodes in the multicast tree. Local recoveries can decrease the recovery latency. There are basically many ways for ensuring local recoveries. For example, the replier could be any receiver in the neighborhood as in SRM [2], a designated receiver as in RMTP [6] or a logging server as in LBRM [3]. These protocols work with out any router support. On the other hand, protocol such as PGM [8] requires the assistance of the routers to achieve local recovery.

In active networks approach [7] routers perform customized computations on the messages flowing through them. This approach uses the active routers close to the losses as the agent for local recovery. Protocols such as ARM [4] and DyRAM [5] come under this category. However, all these protocols are based on receiver- initiated approach, where the receiver takes the responsibility of loss detection regardless of the links where the losses occur. In [9] we proposed a new approach in which the responsibility of loss detection is distributed between the source and the receivers considering the links where the losses occur. Our approach provides solutions to the scalability problems at the routers by enabling local recovery from the receivers thus reducing caching at the routers. In [10] we presented a detailed analysis of the throughput achieved by our approach.

In mobile environment, it is expected that a mobile host (MH) may experience a period of no network connectivity during its movement from one network to another due to layer 2 and layer 3 re-association. Therefore, packets in transit

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destined for the MH will be lost during the handoff period. The handoff period is exacerbated by the fact that the traffic path of packets for MH still goes through the previous network until such time as the MH has notified the proper entity of its new location. In such cases, packet loss is incurred from the moment the MH leaves the previous network up to the time the appropriate entity learns of the MH's new location and forwards the packets appropriately. This amount of delay and packet loss severely hinders the quality of interactive and streaming applications that are intolerant of delay and packet loss beyond certain threshold. This paper introduces a solution to this problem by providing a per-mobile packet buffer at an active router (Buffering Node) near the edge of the network where the mobile is moving away from or moving towards. Packets that are in transit during the handoff period get buffered in the Buffering Node (BN). When handoff completes, the buffered packets are flushed and forwarded to the MH in its new location. This approach provides zero packet loss for all packets destined for the MH that have reached the BN.

The rest of the paper is organized as follows. Section 2 gives the description of DHARM protocol. Section 3 presents the background of wireless reliable multicast. Section 4 presents our algorithm for wireless reliable multicast. Section 5 presents the simulation model. Section 6 presents the results and discussion. Finally, Section 7 concludes the paper.

II. DHARM : PROTOCOL DESCRIPTION

Goals of DHARM

DHARM[9] is a reliable multicast protocol with a recovery strategy based on a tree structure constructed on a per packet basis with the assistance of routers. This protocol uses a hybrid approach in implementing the local recovery. In our approach the source handles the losses occurring on the links that connects the source to the active routers and the receiver handles the losses occurring on the links that connect the active router to the receivers of the multicast routing tree. Our protocol provides the following reliability services.

A. Reducing the feedback implosion problem

1) ACK Suppression by active routers and the receivers

When an active router receives the first ACK for any data packet it first creates AS structure and dispatches the ACK on all the downstream links and then forwards to upstream link in the multicast tree. This allows the receivers having received the data packets correctly to suppress their corresponding ACKs. If the active router receives ACK for the same data packet again, it does not send it to the upstream.

2) NAK Suppression by the active router

When a router receives a NAK packet, it looks for a corresponding NS structure. If such a structure exists, it concludes that at least one similar NAK has already been processed otherwise a new NS structure will be created for this NAK.

B. Distributing the burden of loss recovery between the sender and receivers

Our protocol ensures a better distribution of loss recovery burden between the source and the receivers, by combining sender-initiated and receiver-initiated classes with the contribution of the active routers as follows

- the detection of a loss at the source is made when a timer associated with the transmitted data packet expires, which means that the loss has occurred on the source link and no receiver has received it.
- the detection of a loss at the receivers is made when a receiver receives an ACK for a data packet which has not been received.
- the contribution of the active router in loss recovery is by sending the data packet if it is available in its cache, otherwise the request will be forwarded to the replier (the first receiver having sent an ACK).

C. Limiting the retransmission scoping

To save the bandwidth, the repair packet is not sent using multicast. The active router registers in the NS list structure the address of each receiver announcing the loss of data packet. After a waiting period, the time to know the receivers having lost the data packet, the active router subcasts the data packet to the receivers having requested it thus sends the repair data only in the required links. Thus our protocol always saves the network bandwidth and reduces unnecessary burden on the network elements such as routers.

D. Optimal use of router's cache

Most of router's caching means are limited and the routers must support many sessions in parallel. In our protocol the burden on the router is reduced by electing replier for local recovery dynamically on per packet basis. After the replier is elected, the router can remove that data from its cache. And also the use of positive acknowledgements allows a better management of the active router's memory by removing the acknowledged data packet from the cache.

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III. BACKGROUND OF WIRELESS RELIABLE MULTICAST

Due to advancements in the wireless technology, a multicast member can have access to the Internet via not only wired access but also wireless access[11,12] . In mobile network, users can move from one access point to another easily. We call this kind of host as a mobile host (MH). As shown in fig.1, as the MH moves, continuous service is achieved by supporting handoff (or handover) from one cell to another. Handoff is the process of changing the channel (frequency, time slot, spreading code, or combination of them) associated with the current connection while a call is in progress. It is often initiated either by crossing a cell boundary or by deterioration in quality of the signal in the current channel. The undesirable effects of user movement include packet losses, disruptions in connectivity and increased latencies.

Each Base Station (BS) periodically broadcasts a beacon message to all the MHs in range of it [11]. Each MH keeps track of all the recent beacons it has received to approximate its current location and motion. The MH uses statistics such as the received signal strength of the beacons and communication quality to identify which BSs are nearby. The MH also determines which wireless network cell it should join as well as which cells it is likely to handoff to in the near future. Based on this determination, the MH configures the routing between the Home Agent (HA) and the various BSs.
Handoffs are mobile-initiated and occur when the mobile host discovers a base station with a stronger signal than the current one. The sequence of events typical of a handoff are shown in Fig.2. The figure shows what happens when a mobile host moves from BS1's cell to BS2's cell. The handoff begins when the MH receives a new beacon measurement. Based on its beacon measurements and some

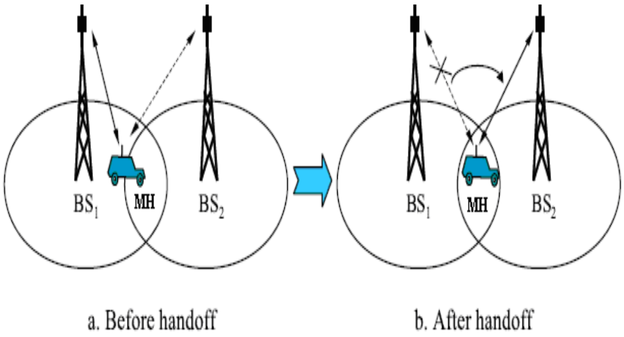

Figure 1. Handoff in wirless network

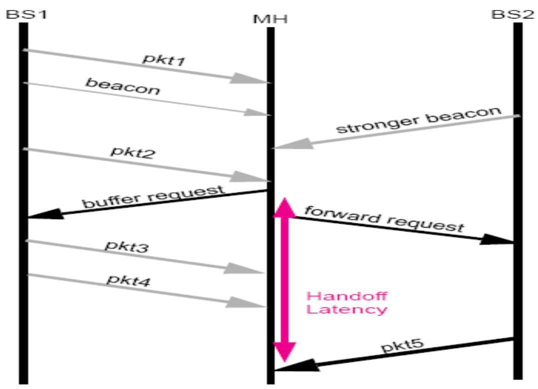

Figure 2. Handoff Signaling

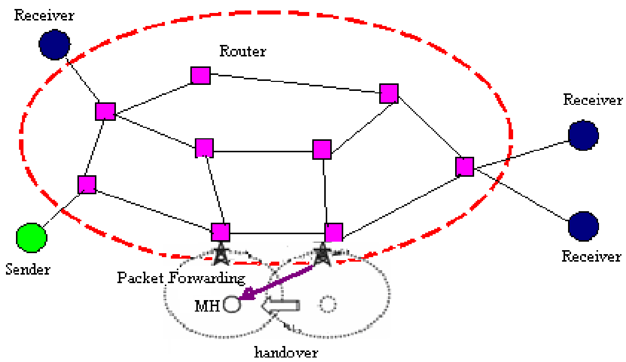

Figure 3. Packet Forwarding services with DHARM

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Figure 4.

hysteresis, the MH computes that BS1 should be buffering (rather than forwarding) packets and that BS2 should be forwarding packets as explained in fig.3. Using hysteresis ensures that very frequent and unnecessary handoffs don't occur. After comparing the desired state for each of the BSs in the area with their current state, the MH transmits a set of control messages to the various BSs. These control messages request each BS to either begin or end forwarding and buffering of packets.

When a MH moves from home network to foreign network, care-of-address(CoA) is assigned temporally to this MH. The network portion of CoA matches that of the foreign network, which means by CoA a datagram can be forwarded to a foreign network by ordinary IP routing. A MH also has its IP address in its permanent home network, home address. A CoA of MH is registered at the agent located at the home network, which is called home agent. When a correspondent node would like to communicate with a MH, it can forward a datagram to its home address. When this datagram reaches a home network, a home agent can identify the CoA of MH and forwards this datagram to a foreign network by encapsulation technique.

IV. DHARM FOR WIRELESS RELIABLE MULTICAST

As an effective way to resolve handover loss discussed in the previous section, we claim that our proposed protocol DHARM can be extended for wireless networks. In our protocol an active router performs many active services and achieves scalability. In DHARM protocol various nodes behave as follows.

Algorighm

1) Source

- the source multicasts data packets to the multicast address subscribed to by all the receivers and starts a timer. If the timer expires without receiving ACK, then there is a loss in the source link. So it retransmits the data packet to the group.

2) Active Router

- upon reception of a data packet, an active router stores the packet in its cache and forward it downstream in the multicast tree.
- upon reception of ACK , if it is from the downstream link, adds the replier address and forwards the ACK in all downstream links excepting on the ACK incoming link to enable the receivers to suppress their ACKs. If ACK is from upstream link for a packet that is not yet received, it sends NAK upstream.
- upon reception of a NAK from downstream, if it has data packet it forwards to the requesting receiver, otherwise records the receiver address for subcasting in NS structure and sends NAK upstream.
- upon reception of repair packet, subcasts the data packets only to the requested receivers.
- upon detection of a packet loss, active router send a NAK packet to the source (early loss detection service).

3) Receiver

- upon detection of a packet loss, a receiver sends a NAK packet to the upstream link.
- upon receiving a data packet sends starts a timer, if receives ACK before the timer expires suppresses the ACK, otherwise sends the ACK to the upstream link.
- upon receiving ACK, if the data packet is not received , sends NAK to the upstream link, otherwise suppresses the ACK.
- upon receiving NAK, sends the data packet to the receiver.

V. SIMULATION MODEL

We consider the network model similar to the one proposed in [13] as shown in Fig.4. For LAN, we assume two kinds of networks, one is wired and the other is wireless and 50% of LANs in the generated topology are assumed to be wireless. Wireless LANs are located randomly in the network. Multicast hosts are connected to MAN router with

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probability of 0.2 and LAN with probability of with 0.8. We assume one static host as the source of data transmission.

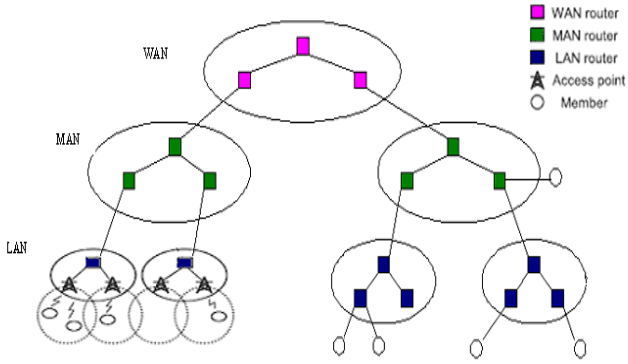

Figure 5. Network Topology for Simulation

Parameter	Value
Arrival Rate of Data Packet	0.1
Packet Loss Probability at WAN router	0.2%
Packet Loss Probability at WAN ↔MAN	0.1%
Packet Loss Probability at MAN router	2%
Packet Loss Probability at MAN ↔ LAN	1%
Packet Loss Probability at LAN router	0%
Average Processing Delay of Data packet	0.5msec
Average Processing Delay of ACK,NAK packet	0.1msec
Mobility Speed	10 - 30 m/s

TABLE I. SIMULATION PARAMETERS

Loss probabilities and other simulation parameters are shown in Table1. Packet loss probability is assigned to each Tier from the measured results reported in [14]. During handover, a handover delay of 1 sec is assumed for the case that another multicast member does not exist in the new network, and for cases where another member already exists in the new network , the handover delay is assumed to be 0.

VI. SIMULATION RESULTS

Fig.5 shows the total number of hops for data packets, repair packets, ACKs and NAKs. The total number of hops can be used as a performance metric for efficient usage of network resources. As shown in this figure DHARM which implements active services with Packet Forwarding mechanism in the routers decreases the total number of hops than the normal NAK suppression protocols without active services.

Fig.6 shows the average delay characteristics of DHARM and NAK suppression protocol without packet forwarding mechanism. As shown in the figure, normalized delay is improved in DHARM. This is because in DHARM, active routers buffer the lost packets and deliver them to the mobile host as soon as the hand off process is over. Thus DHARM provides quick recovery from hand over losses than the protocols with out local recovery.

Fig.7 and fig.8 show similar characteristics of fig.5 and fig.6, but they show characteristics for only lost packets during handover period. As shown in these figures, DHARM provides significant performance improvement to handover packet loss from the viewpoint of both delay performance and network resource usage.

In our performance evaluation so far, we use homogeneous model for wireless networks, i.e. packet loss in wireless network occurs similarly in every network. In fig.9, we evaluate delay characteristics of DHARM and normal NAK suppression protocol for heterogeneous networks. From the figure it is clear that DHARM provides better performance for both homogenous and heterogeneous networks than the protocol without the active services.

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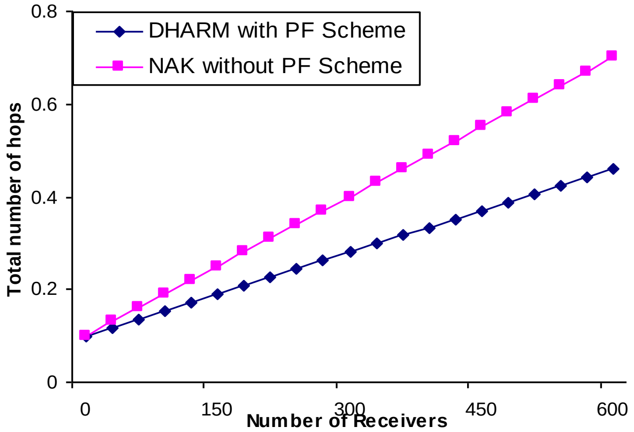

Figure 6. Total Number of Hops for Data, Repair, NAK, ACK packets (excluding lost packet)

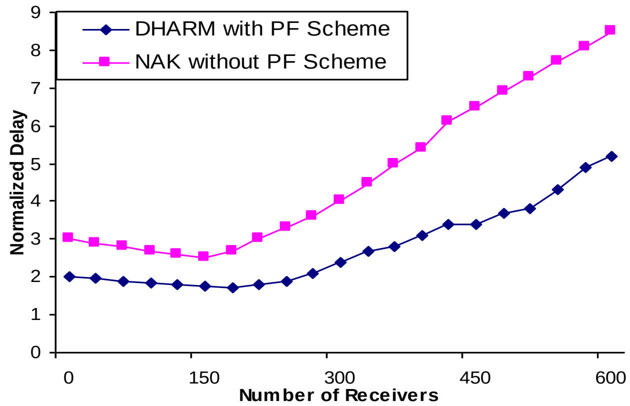

Figure 7. Normalized Delay Characteristics

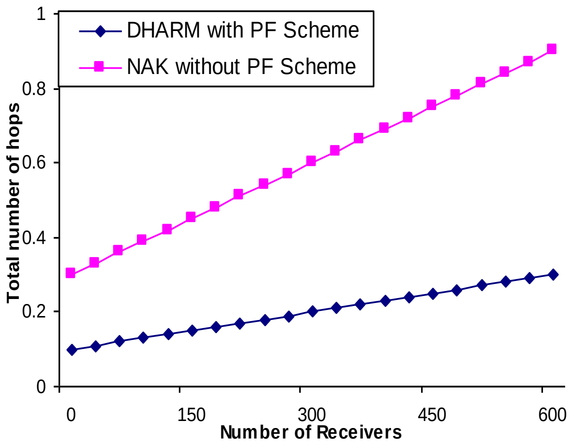

Figure 8. Total Number of Hops for Data, Repair, NAK, ACK packets (only for lost packets)

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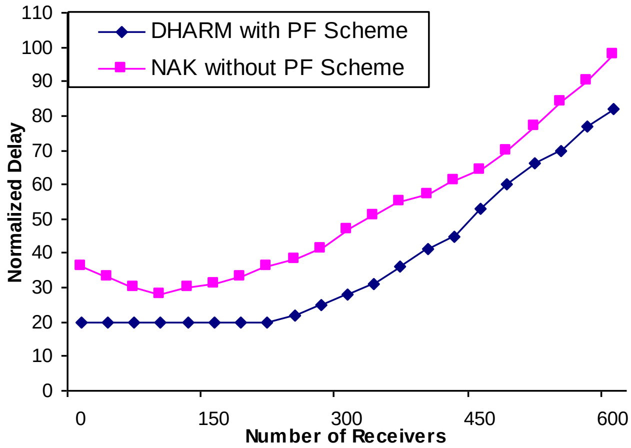

Figure 9. Normalized Delay Characteristics (only for lost packets)

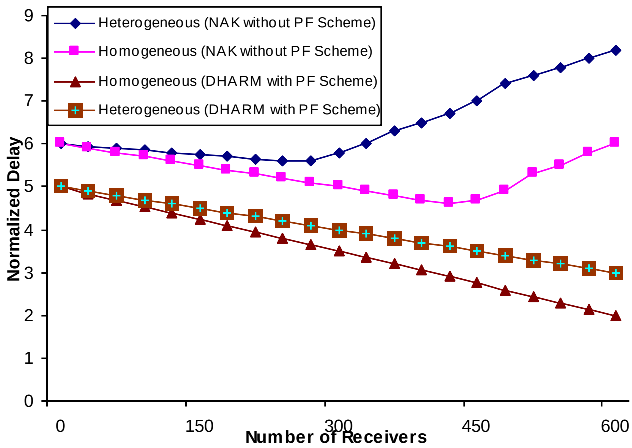

Figure 10. Normalized Delay Characteristics for Homogenous & Heterogenous Environment

VII. CONCLUSION

In this paper, we discuss how the handover of the mobile node creates packet loss in wireless reliable multicasting. We claim that our protocol DHARM which implements packet forwarding recovers packet loss caused by handover by forwarding cached packets from the old access point to the mobile multicast host will bring significant performance improvement. This is because in our protocol we use local repair error recovery mechanism for packet forwarding. Simulation results show that Packet Forwarding mechanisms with DHARM brings significant performance improvement from the viewpoint of scalability and efficient network resource usage.

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