Improving QoS Under Lossy Channels Through Adaptive Redundancy

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Abstract

Quality of Service (QoS) of a network-wide broadcast (NWB) protocol is one of the most important performance metrics, especially in mobile ad hoc networks, where channel conditions and network topology change frequently. We propose a mesh networking inspired approach to overcome the performance degradation caused by lossy channels. We show that our adaptive approach, whereby the amount of redundancy is adjusted to the current link conditions, can achieve good performance while simultaneously reducing unnecessary energy dissipation.

1 Adaptive Redundancy

Our primary goal is to overcome the performance loss in a network-wide broadcasting protocol called NB-TRACE (Network-wide broadcasting through Time Reservation using Adaptive Control for Energy efficiency) [1] by utilizing a wireless mesh topology, which promises greater stability in the face of changing conditions or failure at single nodes [2, 3]. However, redundancy has a cost associated with it, both in terms of energy as well as bandwidth due to the forwarding of a greater number of packets. Moreover, when link breakages are low, even protocols that do not provide redundancy have excellent packet delivery ratios [1]. In such conditions the additional cost incurred by redundant mesh based protocols is unnecessary and often wasteful. We aim to locally vary the number of upstream nodes according to the data packet reception history. In order to do this, each node monitors data packet receptions and the corresponding upstream nodes to make sure that data packets are arriving regularly from the same upstream node. If there is a disruption of data packet flow, our mechanism will increase the number of upstream nodes until a maximum number of allowed upstream nodes is reached.

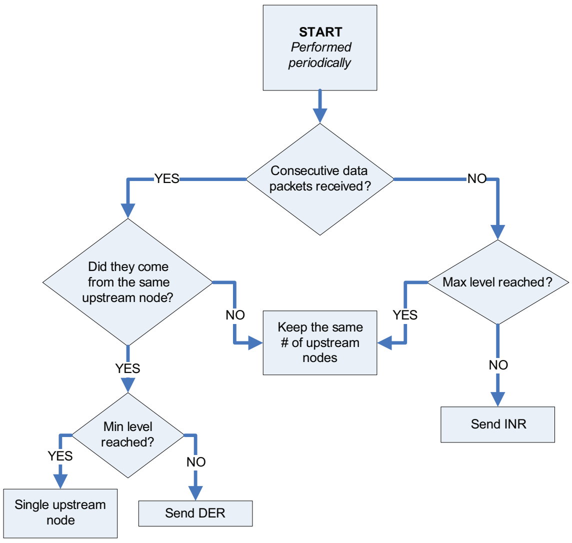

Figure 1. Simple flow chart of the adaptive redundancy algorithm.

Under perfect channel conditions and in the presence of a well maintained broadcast tree, node A periodically receives data packets broadcasted by the source node through the branch formed between itself and the source node. However, when an expected (note that nodes have periodic channel access) data packet is not received (*i.e.,* dropped or never routed to node A), node A starts the process that will increase its number of upstream nodes. Node A sends out an *INcrease Redundancy* (INR) packet. Nodes hearing the INR packet start to rebroadcast data, and node A chooses one of these nodes as its second upstream node and sends ACKs to keep the new upstream node rebroadcasting. Upon receiving the first sequential set of data packets from the same upstream node, node A will reduce the number of its upstream nodes by sending out a *DEcrease Redundancy* (DER) packet. Therefore, the data packet reception history plays the main role in determining the level of redundancy in the network.

Figure 1 shows a simple flow chart for our adaptive redundancy mechanism. In NB-TRACE, channel access is

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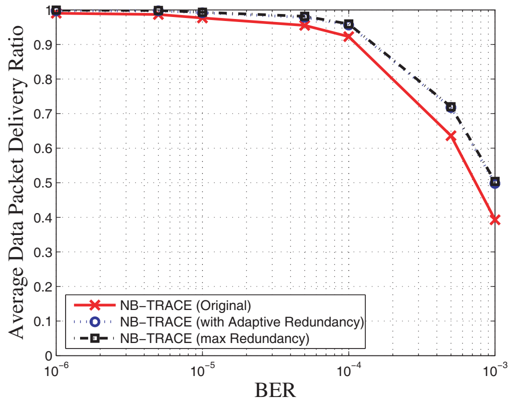
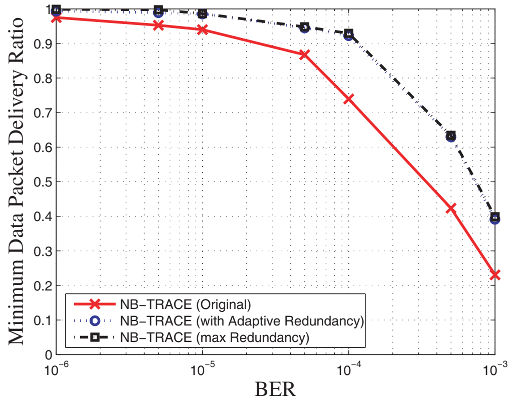


(a) Average packet delivery ratio versus bit error rate (BER).



(b) Minimum packet delivery ratio versus bit error rate (BER).

Figure 2. Average and minimum PDRs versus BER.

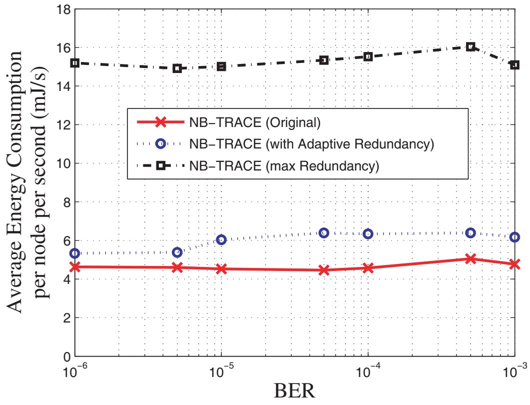


Figure 3. Average energy consumption per node per second versus BER.

periodic, using cyclical superframes. After each superframe nodes check whether or not consecutive data packets have been received from the same upstream node. The level of redundancy is updated periodically after each superframe according to two conditions; (i) a node must receive two packets in a row from the same upstream node to be able to send a DER packet, and (ii) failure to receive any consecutive data packets is enough to increase the level of redundancy.

2 Simulations

We performed simulations with the modified (adaptive) version of NB-TRACE and compared it to the original version. We implemented the adaptive redundancy approach into the source code of NB-TRACE without modifying the frame structure and initial branch formation mechanisms. Our patch activates itself when a packet drop happens and none of the NB-TRACE repair mechanisms takes action.

Figure 2 shows the average and minimum PDR values obtained with the original NB-TRACE, NB-TRACE with adaptive redundancy, and NB-TRACE with maximum redundancy. The adaptive redundancy enables more packets to be delivered in a more consistent manner to all nodes in the network. This results in an $\sim 1-27\%$ increase in average PDR for NB-TRACE. In particular, improvement becomes more visible at higher bit error rates. High minimum PDR values are vital to any protocol that aims to offer QoS. NB-TRACE with adaptive redundancy performs $\sim 2-70\%$ better than the original NB-TRACE protocol in terms of minimum PDR achieved at any node in the network.

Figure 3 shows that we achieve $\sim 60-65\%$ reduction in energy consumption when compared with the maximum redundancy approach. We would like to point out that the increased energy consumption with adaptive redundancy can be seen as a trade-off between PDR and energy consumption.

As our future work, we plan to implement the adaptive redundancy approach in a multicasting scenario where a smaller, more focused, and potentially more vulnerable multicast tree is formed between the source and multicast member nodes.

References

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