Harnessing the Parity of Multiple Errors in End-to-End MAC Schemes

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Abstract— **We present the results of simulation experiments that compare end-to-end error management (used in controlled access MAC protocols) against hop-by-hop error management (used in random access MAC protocols). Our experiments are novel in that we restrict both MAC schemes to identical power budgets and power distribution strategies. By making such a normalized comparison, we observe that end-to-end schemes are more effective than hop-by-hop schemes at reducing connection BER. We are also able to quantify the sensitivity of this relative advantage to various environmental parameters, including power budget size, geographic distance, the number of hops, and power distribution scheme.**

Index Terms— **wireless ad-hoc networks, MAC protocols, multi-hop path, lower bit error rate, Power budget, end-to-end error, hop-by-hop error.**

I. INTRODUCTION

Wireless communication networks are being deployed at a tremendous rate, reshaping the way we live. For example, wireless ad-hoc networks combined with satellite data networks [6], [1], [16] are now able to provide global information services to users in remote locations that could not be previously reached by traditional wired networks. Advances in hardware technology are enabling explosive proliferation of new wireless communication devices to an growing user population.

Maximizing the potential of such trends requires the design of effective wireless communication protocols that are both energy efficient and packet loss resilient. Packet loss in wireless networks is due to various factors including signal fading, interference, multi-path effects, data packets collisions, etc [10], [4], [18], [20], [21], [5]. There are two well-known ways to achieve end-to-end reliability on multi-hop paths.

1) *Hop-By-Hop* schemes require the data link layer to detect errors at each hop of the path, and address such errors by retransmitting lost frames or by using forward error correcting codes.
2) *End-to-End* schemes assume data link layers are unreliable and retransmissions are performed end-to-end.

It is sometimes possible to consider a mixed strategy, where link layers perform a few retransmissions if necessary, but perfect reliability is only guaranteed through end-to-end mechanisms. Link layer technologies such as the 802.11 MAC protocol [15] adopt such a mixed approach, making a bounded number of retransmission attempts for each lost or corrupted frame. Further losses are then recovered through end-to-end retransmissions.

Regardless of where a scheme lies in the spectrum between Approach 1 and Approach 2, the ultimate measure of its efficacy must be its ability to support end-to-end reliable transfer. Indeed, as long as there is some link in the multi-hop path that can not guarantee reliable packet delivery, we must rely on TCP-like transport protocols to initiate end-to-end retransmissions by the source. This is true for several reasons, including:

- Link layer technologies such as IEEE 802.11 [15] implement a limited number of retransmissions, which results in possible delivery failure over lossy links.
- There are link level technologies that do not provide hop-by-hop retransmission (e.g. TRAMA [12]).
- Given link layer reliability, packet loss may still occur at network layer due to congestion [17].
- Nodes may move, sleep, or fail. In such cases, hop-by-hop reliability cannot be assumed, since even if a sleeping node can receive packets after waking up, the transport protocol may have timed out.

There are two categories of MAC layer protocols used in mobile ad hoc networks:

1) *Random Access* protocols require nodes to compete with each other to gain access to the shared wireless medium.
2) *Controlled Access* protocols utilize a master node to determine which node gets access to the wireless medium.

Random access protocols are a natural choice for medium access control in MANETs, because of their lack of fixed infrastructure. Examples of MAC random access protocols include Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA).

Controlled access protocols are preferred in environments that require Quality of Service (QoS) guarantees since node transmissions are collision free. QoS MAC protocols are an essential component in QoS support within MANETs. All upper layer QoS components including QoS routing and QoS signaling are dependent on the services of QoS MAC protocols operating at the data link layer. Large-scale MANETs are usually organized into clusters in order to minimize QoS routing traffic overhead and increase the network throughput.

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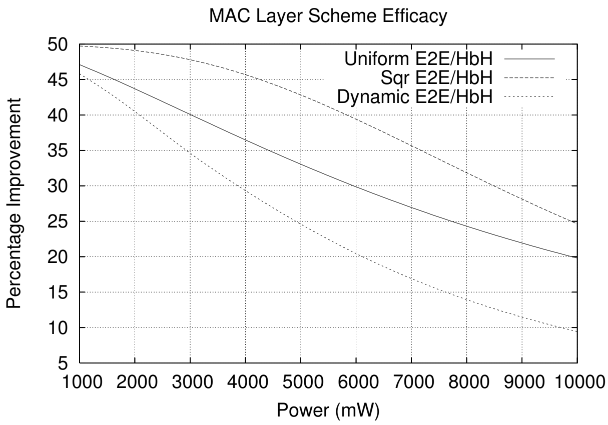

Fig. 4. Percentage improvement vs. total connection power budget

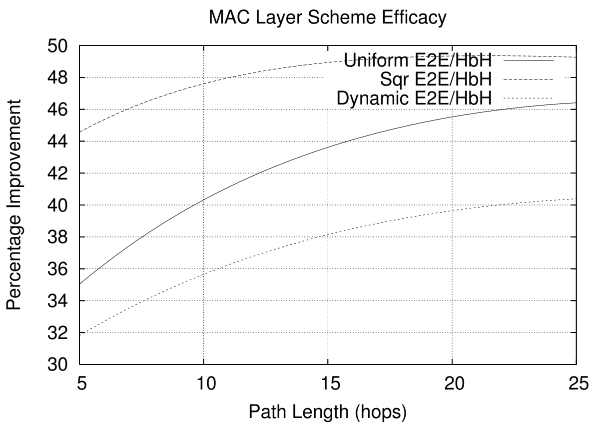

Fig. 5. Percentage improvement vs. path length

drawing upon the two experiment scenarios described earlier. Considering the *asymptotes* of these curves we conclude that the improvement of the *E2E* scheme relative to the *HbH* schemes converges to a plateau value, ranging from 41 to 50%. The *Sqr* scheme derives the greatest benefit from the *E2E* MAC, while the *Dynamic* scheme derives the least benefit. The *Uniform* scheme consistently derives intermediate benefit from the choice of MAC error management strategy.

VI. Conclusion

The results of our simulation experiments validate the theoretical ideas derived from our initial, somewhat paradoxic observation, the *parity of multiple errors* can be used to reduce the effective connection BER Rate. Our comparison of end-to-end error management (used in controlled access MAC protocols) against hop-by-hop error management (used in random access MAC protocols) were conducted in a setting in which both schemes were subject to identical power budgets and power distribution strategies. In all scenarios, end-to-end schemes attained lower BER than hop-by-hop schemes. In making such a normalized comparison, we were able to quantify the sensitivity of this relative advantage to various environmental parameters. We found that the advantage of end-to-end schemes is maximized in settings where the power budget is small, the endpoint separation is high, or the number of intermediate hops is high. The *Sqr* power distribution scheme consistently derives the greatest benefit from *E2E* MAC, while the *Dynamic* scheme derives the least benefit.

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