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POSTER

Towards a life without link estimation

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Poster Abstract: Towards a Life without Link Estimation

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1 Introduction

Link estimation provides a long-term estimate of the quality of a link based on its past history. However, this need for a history of past packets is also its main drawback: First, most link estimators only adapt slowly to changing link conditions, being mainly designed to identify long-term stable links. As a result they leave out bursty, potentially long ranging links [2, 4]. Second, in low traffic environments, as seen in many of today's typically heavily duty-cycled application-slink estimates are potentially outdated as they are based on old packets. Finally, it requires to store estimates, i.e., state information, for its neighbors, and (4) relies on beacons to probe links.

In this paper we show how routing protocols can be designed without relying on link estimation. Our design is based on the following observation: duty-cycled MAC layers such as RI-MAC [8] or X-MAC [3] operate on asynchronous sleep cycles. To initiate communication, a node sends one or more probe packets to ensure that the destination is awake before actual data packets are sent. We use these probe packets as an instant link availability indicator and design a routing protocol for it. This design provides the following characteristics: (1) It is a highly agile link availability test that does not rely on long-term estimates. Using the probe packets of estimating duty cycled MAC layers it does not (2) require own probing packets nor (3) nor does it store link state information.

2 Design

In this section we discuss the design in detail and introduce a routing protocol operating on top of it.

2.1 MAC Probes for Link Assessment

In a receiver initiated MAC (also called low power probing, LPP), such as RI-MAC, potential receivers wake according to their duty cycle and send a small probe packet to signal that they are awake. Nodes with data to send listen to the medium until they receive such a probe from their intended receiver and then transmit their data. In contrast, in low power listening MACs (LPL), such as X-MAC, the sender transmits a number of strobes before transmitting the data itself. Upon receiving such a strobe, the receiver stays awake until it receives the data packet itself.

We use these probe packets as link assessment: For example, in RI-MAC, when a node receives a ping, we do not only conclude that the receiver is awake. We also conclude that currently the medium at the receiver side should be free and that the link between sender and receiver is good. Hence, a packet sent now should have a good chance of a successful transmission. Overall, the availability of a link to a neighbor is determined instantly from the probe packets. The strobe packets of LPL MACs such as X-MAC can be used similarly. As X-MAC even sends multiple strobes, it will provide us with a more accurate link assessment. We rely on contention avoidance mechanisms of the MAC layer, such as channel sensing, random backoffs, and link layer retransmissions, to handle collisions and interference.

2.2 Routing on Dynamic Links

In a typical routing protocol such as CTP a forwarding node checks its routing table, e.g., it uses link estimates and ETX, to determine the node to forward a packet to. In contrast, our scheme cannot determine the next hop directly, as it does not employ link estimation and neighbor tables. To enable routing we introduce a novel routing scheme operating on top of the link availability assessment discussed in the previous section. We extend the probes of the duty cycled MAC by a single protocol field: The ETX that the probing node has to the root (assuming a tree based routing). The forwarding node receives these probes and can select a good candidate to route to.

More specifically it works as follows: Based on past experience, the routing node defines an expected routing progress towards the destination that the packet should make when being forwarded. The packet is then transmitted immediately to the first node which ETX to the destination indicates that it can provide this routing progress (see Fig. 1(a)). If during the duration of one duty cycle no such neighbor is found, the routing threshold is recomputed based on the routing progress offered by the neighbors during this past duty cycle. The result of this design is a highly agile, low-delay routing scheme that flexibly adapts to node and link failures. Furthermore, probe packets provide the forwarding nodes with up-to-date information about the receiver and can be extended to other routing metrics such as remaining energy, bandwidth, or queue length.

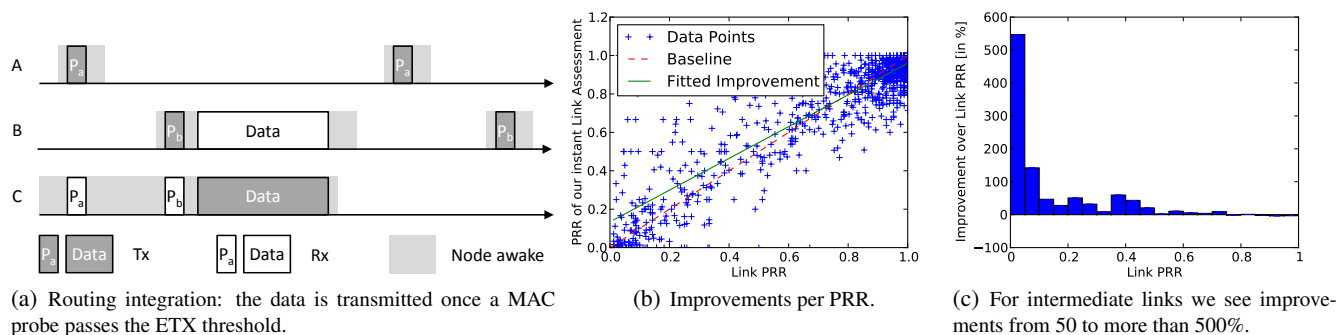


Figure 1. Improvements of our instant link availability test over the link PRR and integration of a routing protocol.

3 Preliminary Evaluation

In our first prototype implementation we focus on intermediate links as these typically provide the best routing progress [2]. We analyze if the successful transmission of a single probe sent by a potential receiver is sufficient to quantify the link as good enough to send a data packet.

Figure 1 shows that transmitting data packets after a successful probe packet improves transmission success by 50 to 500% for our main target group, the intermediate links. For good links we only see a small degradation of less than 1% (see Fig. 1(b) and 1(c)). Based on our previous work [2] we expect that sending the data not after one but after multiple probe packets will increase the receive ratio of data packets even further. However, it also increases the energy of probing. Hence, one key goal of our ongoing work is to minimize the overall energy cost of probing and data (re)transmissions.

4 Related Work

The identification of good links has been an ongoing research topic [5,9]. In the recent years, the dynamics of intermediate links [2,7] received new attention as they often offer good routing process.

Motivated by these observations, new routing protocols, try to utilize link dynamics for routing [1] or build routing metrics [6] that can adapt dynamically to changing network conditions. These approaches rely on overhearing data packets to flexibly adapt their routing tables. For example, BRE [1] identifies when an intermediate link is available for transmission when overhearing three data packets, or BCP [6] uses the current routing queue length to determine the next hop. Overall, they show the feasibility of adaptive routing and its benefits. However, their need for overhearing makes it inefficient to deploy these schemes, as the energy cost of overhearing nullifies their advantages such as less transmissions to the root and higher throughput. Similarly, opportunistic routing strongly relies on overhearing and hence has similar disadvantages.

5 Future Directions and Conclusions

In this paper we discuss our ongoing work on removing the need for long-term link estimation: First, we introduced how probe packets of today's duty cycled WSN MACs can be employed for instant link availability testing and, second, we showed the design of an adaptive routing scheme operating on top of this agile link assessment. Based on the design

and the initial evaluation discussed in this paper, our current work focuses on the following: (1) Full featured implementation of the routing scheme, and (2) integration of LPL MACs in addition to the LPP MAC.

Overall, we believe that instant link availability testing and our corresponding routing protocol provide key features that promise efficient routing at low overhead: Using the probe packets of duty cycled MAC layers it does not require own probing packets or overhearing nor does it need to store link state information. Additionally, it is highly agile as it does not rely on long-term estimates. Hence, it can flexibly handle changes in link quality or even node failures.

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