Poster: Single Packet Link Estimation

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Abstract

The state-of-the-art routing protocols for Wireless Sensor Networks (WSNs) require statistical information about the wireless links to the neighbors in order to estimate their quality and select the best route to convey the data. This information is obtained through probing the neighborhood with beacons and/or the application traffic, thus becoming overhead expensive in terms of energy and bandwidth or dependent on the presence of application traffic (in the case of low power Medium Access Control - MAC layers).

This work proposes the idea of obtaining the link quality information from a resource commonly present in WSNs but so far unexplored: the packet repetitions used for transmission (TX) in sender initiated preamble sampling MAC protocols. It explains an approach for modifying ContikiMAC (the default MAC protocol in Contiki's Rime stack) to extract useful link quality information from a single packet. The study performs an estimation of the cost of the proposal in terms of energy and reliability. The results support the claim that the method can yield an overall reduction in energy and bandwidth if the routing layer uses the provided link quality information.

Categories and Subject Descriptors

C.2.1 [**Computer-Communication Networks**]: Network Architecture and Design - *Wireless communication*

General Terms

Reliability, Performance

Keywords

WSN, Medium access control, routing, Contiki, link estimation

1 Introduction

State-of-the-art collection protocols for WSNs, such as Collection Tree Protocol (CTP) [4] and its similar Contiki-Collect [2], incur in an energy and bandwidth overhead to estimate the quality of the links, cannot separate the quality of a link in each TX direction and use samples taken with a period of ~seconds, thus hiding the link dynamics that occur within a smaller time-scale. The previous features can be improved if the link quality information is provided by the MAC layer by analysing the packet repetitions used for signalling a transmission (TX) in preamble sampling MAC protocols, such as WiseMAC [3] or ContikiMAC [1].

This work details a novel approach for extracting useful statistics for link estimation (LE), such as the Packet Success Ratio (PSR) and the average Received Signal Strength Indication (RSSI), from a single packet in preamble sampling MAC protocols. It presents an estimation of its cost in terms of energy and reliability.

2 Design

The MAC repetitions from both unicast and broadcast packets can be used for LE. ContikiMAC-Repetitions (ContikiMAC-R) uses only the broadcast ones. It is based on ContikiMAC modified as follows: i) upon reception (RX) of a broadcast repetition, the radio keeps listening during a time window W_m so that it listens to m repetitions (assuming they have a constant length and no TX failures) and ii) the TX of broadcasts must also be extended by W_m to ensure that a receiver will always listen for m repetitions from each broadcast. The following events illustrate its operation (Figure 1):

(A) Node N1 broadcasts a beacon by sending repetitions of the packet to fill a sampling period.

(B) Then N1 extends the broadcast time by W_{10}.

(C) N2 wakes up and receives one of the repetitions from N1. Since it is a broadcast, it extends its listening interval by W_{10}. During the window it receives 10/10 repetitions (PSR=100% for this link).

(D) N3 receives 7/10 repetitions (PSR=70%).

(E) N3 wakes up and receives a repetition from the packet already used in (D) for LE. This signals that there might be less than 10 repetitions left for RX and the result of a new LE could be erroneous. Therefore, N3 does not extend the listening interval.

In contrast to the state-of-the-art, ContikiMAC-R uses a single network layer broadcast packet to estimate the link quality. It isolates the quality of a single link direction and performs a fine granularity LE by using samples taken with a ~ms period.

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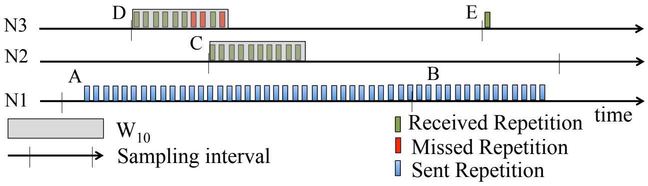

Figure 1. LE from the MAC repetitions.

Table 1. Cooja Simulation Settings

Parameter	Value
OS	Contiki v3, no collect announc.
Simulator	Cooja [5], 16 repetitions per point
Channel Model	Unit Disk Graph - Distance Loss
Application traffic	50 packets, period 90s, max. 32 reTX
Topology	grid, 30m separation, sink in corner
Radio Ranges	TX = 200m, interference = 250m

3 Results and Discussion

An experiment was performed to measure the cost in terms of energy and reliability of the link quality information extracted by ContikiMAC-R. It consisted of simulating the network using ContikiMAC (W_0) and ContikiMAC-R with m=5 (W_5) and m=10 (W_{10}), while using the same routing layer (Contiki-Collect). Therefore, the nodes expend the energy to extract the link quality information with ContikiMAC-R in W_5 and W_{10}, but they do not use it in the routing layer.

It can be expected that any negative effects due to the extension of TX and RX times become more evident when the channel is highly occupied. This motivated the use of a challenging scenario where: i) all the nodes are within TX range and ii) the PSR of the links decreases logarithmically with the distance so that it is 1% at the border of the TX range.

The results show that ContikiMAC-R does not have a statistically significant impact on the TX energy and the PSR (>99% until 40 nodes). For a 50 nodes topology the PSR of W_0 is ~60%, showing that the experiment is close to the congestion limit. Figure 2 shows that the RX energy increases with the size of W and follows the same non-linear growth trend of ContikiMAC. Figure 3 shows that the overhead RX energy stabilizes at ~10% for W_5 and ~20% for W_{10}.

The results show that ContikiMAC-R can perform a LE with no cost in terms of reliability. Moreover, the cost in TX energy is negligible and the RX energy does not increase with the density of the network. This suggests that ContikiMAC-R can achieve an overall energy and bandwidth reduction if the routing layer uses the extracted link quality information for reducing the number of TX beacons. Moreover, the information of each sense of the link and the fine granularity of the LE could be exploited to further increase the reliability of the network by improving the accuracy of the LE. This method for LE could also be applied for routing in mobile networks. These claims will be further investigated.

4 Conclusions and Next Steps

This study proposes a novel method for extracting statistical information about the link quality, such as the PSR and mean RSSI, by increasing the listening time during a broadcast. The state-of-the-art routing protocols use multiple packets to obtain the link quality that this method can provide with a single packet, with fine granularity accuracy and decoupled on each transmission direction.

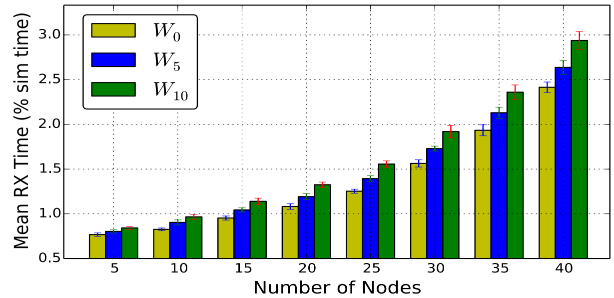

Figure 2. Average percentage of the simulation time that the nodes spend with the radio in RX state.

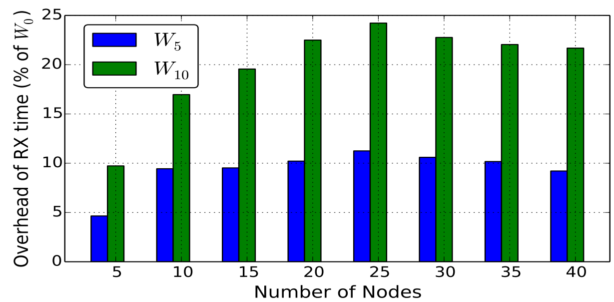

Figure 3. Overhead RX time as a percentage of W_0.

The results suggest that even in challenging conditions of high network density and channel occupation, the energy overhead of ContikiMAC-R can be compensated with the energy savings of the routing protocol due to the reduction of beacon TX. This method could also reduce the channel occupation and yield a better accuracy of the LE and an increase in reliability. The next step is to enable Contiki-Collect to take advantage of ContikiMAC-R.

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