# Dependable Interference-Aware Time-Slotted Channel Hopping for Wireless Sensor Networks

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## Introduction

Time-Slotted Channel Hopping (TSCH)'s main goal is to ameliorate communication reliability in Wireless Sensor Networks (WSNs). This is accomplished by reducing the medium access contention (MAC) impact. Elements that comprise the MAC impact include blocking of wireless links and multi-path fading. TSCH performs better than single-channel communications. For instance, in-vehicle networks include interference which is dynamic and leads to non-guaranteed reliability throughout time. This poster depicts an Enhanced version of the TSCH protocol together with a Distributed Channel Sensing technique (ETSCH+DCS) which aims to detects good quality channels to be utilized for communication. The channel quality is extracted using a distributed channel-quality estimation technique. The central technique uses a Non-Intrusive Channel-quality Estimation (NICE) technique that detects energy interference in each timeslot's idle parts at the network coordinator location.

## Results

Figure 4 shows the distribution of average PRR of all links in the network over a window of 500 transmissions for the different mechanisms and scenarios. The results show that using an (Enhanced Beacon Slotted List) EBSL generally leads to a lower standard deviation in the PRR results. This guarantees a higher reliability level for the links of the network. Figure 7(a) shows that for the scenario with no controlled noise generator, the standard deviation of ETSCH–EBSL results is higher than for TSCH. This is because TSCH always uses the same HSL for hopping, while ETSCH–EBSL may use different sets of channels as the HSL due to detecting low noise on some channels.

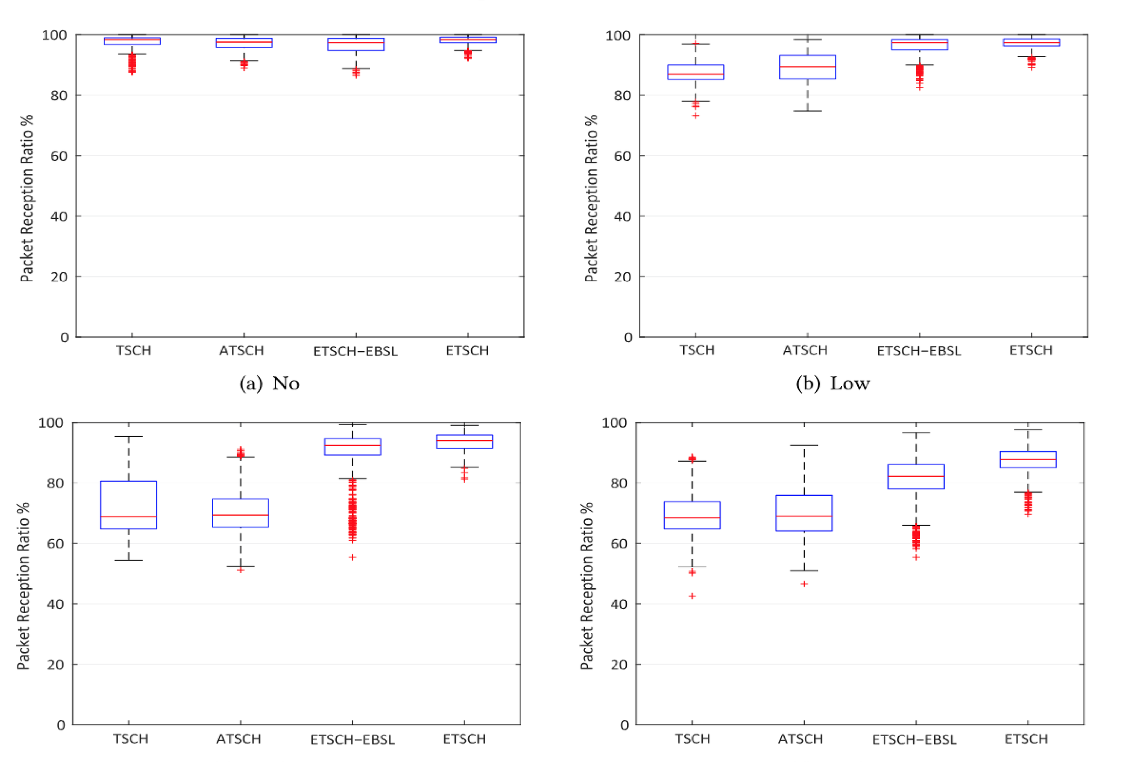


Figure 4: PRR distribution of all network links, over a window of 500 transmissions

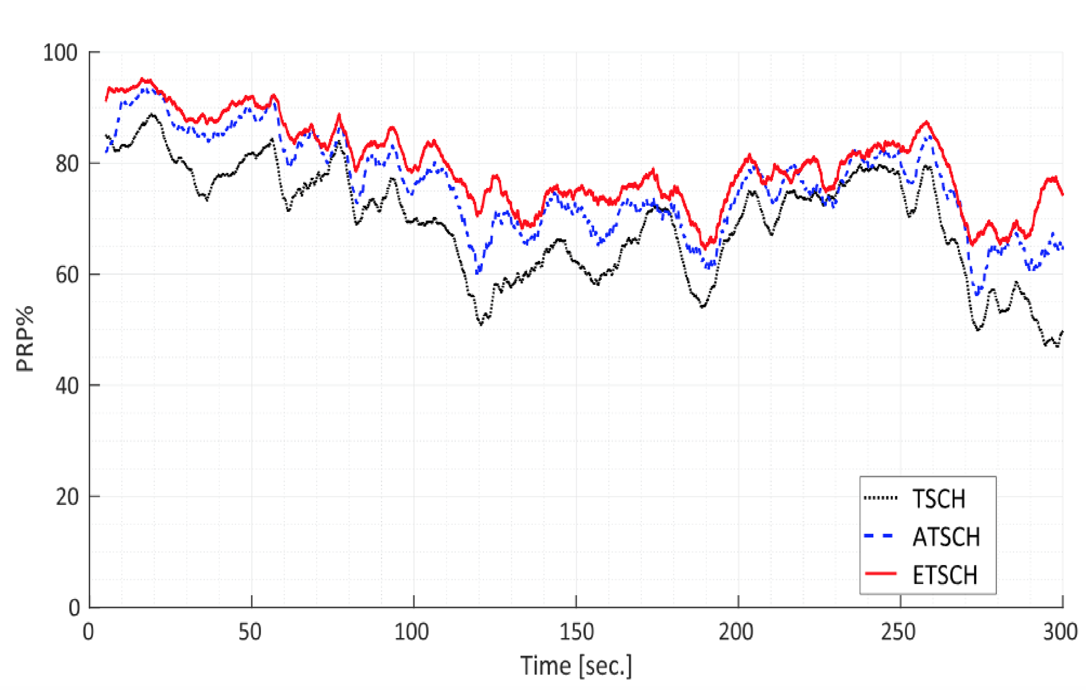


Figure 5: Effect of the Mixed lifelike interference

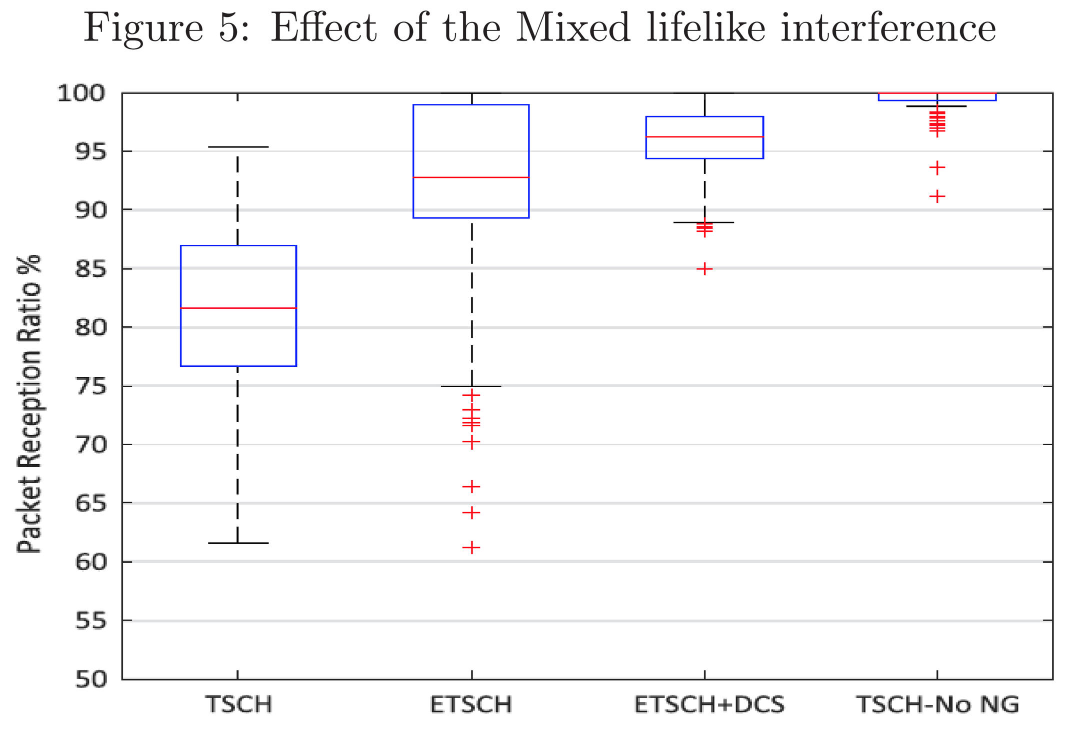


Figure 6: PRR distribution (of all links in the network).

Figure 5 shows the Packet Reception Probability (PRP) changing over a timeslot of 300s. As shown, ETSCH detects noisy channels at the beginning of the simulation very fast (about 1 to 2s), while it takes about 10s for ATSCH to detect the noisy channels and follow interference. Figure 6 depicts that on average, ETSCH provides better PRR in comparison with TSCH.

## Background

The basic idea of ETSCH is to adaptively select a subset of low-noise channels called the whitelist and use it as an input for the channel hopping algorithm. Centralized whitelisting performs well for networks in which all the nodes are in the communication range of the coordinator. Data links can be established between any couple of nodes following a mesh topology using the whitelisted channels. ETSCH adds three components to the basic TSCH protocol at the coordinator node. Figure 1 shows the placement of these techniques together with DCS technique within the protocol stack at the coordinator node, while Figure 2 shows their occurrence within the TSCH slotframe and timeslot structure.

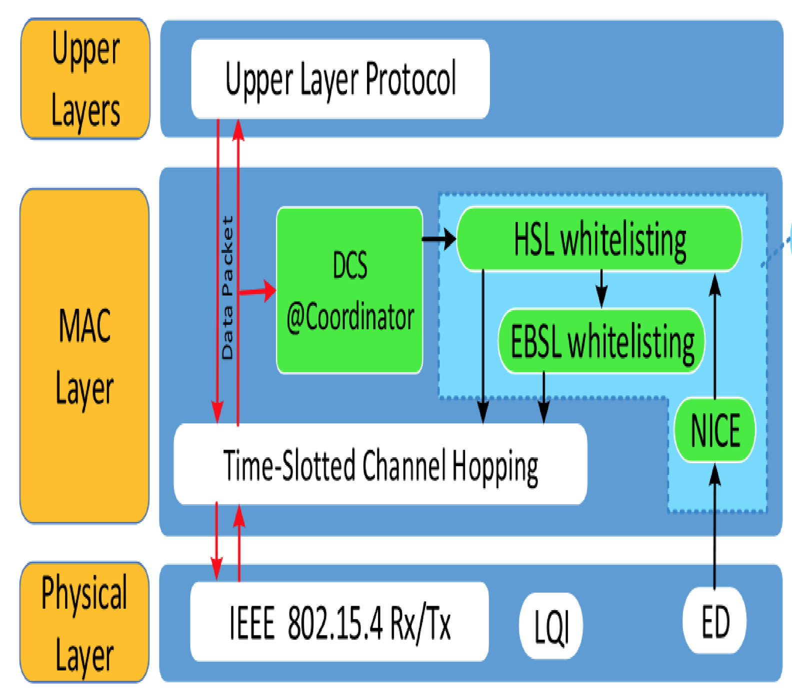


Figure 1: ETSCH+DCS components in the coordinator node.

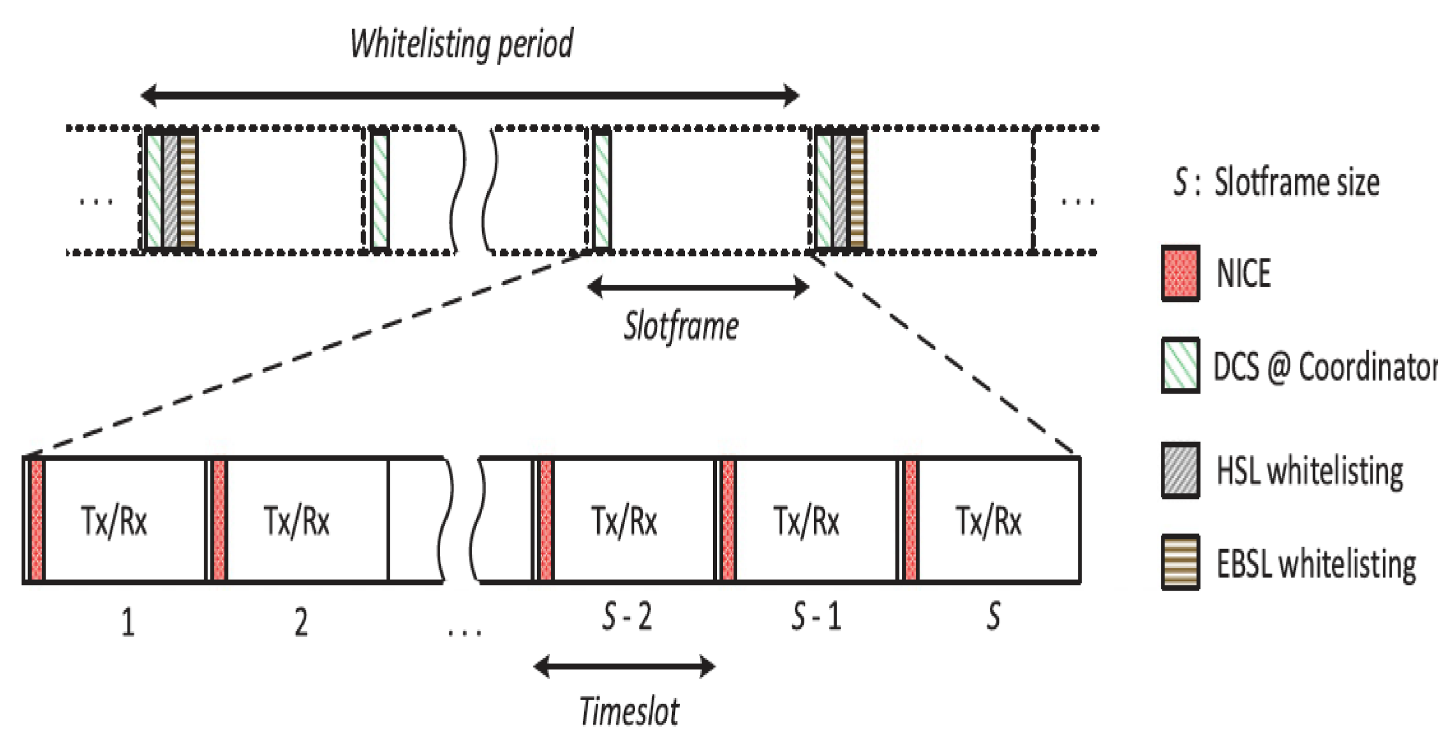


Figure 2: ETSCH components within TSCH

As Figure 1 shows, NICE runs in parallel with TSCH on the MAC layer of the coordinator to extract the quality of all available channels. NICE uses the Energy Detections (EDs) introduced in the protocol to measure the quality of each frequency channel. An ED is an estimate of the received signal power within the bandwidth of a channel and takes eight symbol periods.

## Experiment

Packet Reception Ratio (PRR) is the number of packets that are successfully received at the receiver node over the total number of packets transmitted by the sender node, extracted from the experiments. This metric reflects the quality of the links. The length of burst packet losses is the number of consecutive packets losses over a link and shows the time duration of link level disconnections. This metric is important for many applications to avoid long disconnections, as they required continuity of correct service over time. Figure 3 shows the average of achieved PRR of all links in the network for different mechanisms and interference scenarios. Both versions of ETSCH provide better PRR on average in comparison to TSCH and ATSCH when the network experiences dynamic interference. This shows the effect of highly adaptive channel quality estimation that is realized by NICE, which selects the best quality channels for hopping. Table 1 considers four interference scenarios in our experiments as follows: high, medium, low, and no interference and observes the behavior of Noise Generators (NGs) at each level of interference. In the no interference scenario, we run the experiments without any controlled noise generator to see how the cost of periodic Hopping Sequence List (HSL) changes.

Table 1: Interference Scenarios and Behavior

| Interference Scenarios | |
|---|---|
| *Scenario* | *Behavior of NG(s)* |
| No interference | no controlled NG |
| Low interference | noise on 2 channels (1 NG), hop every 20s to new channels |
| Medium interference | noise on 6 channels (3 NGs), hop every 20s to new channels |
| High interference | noise on 6 channels (3 NGs), hop every 5s to new channels |

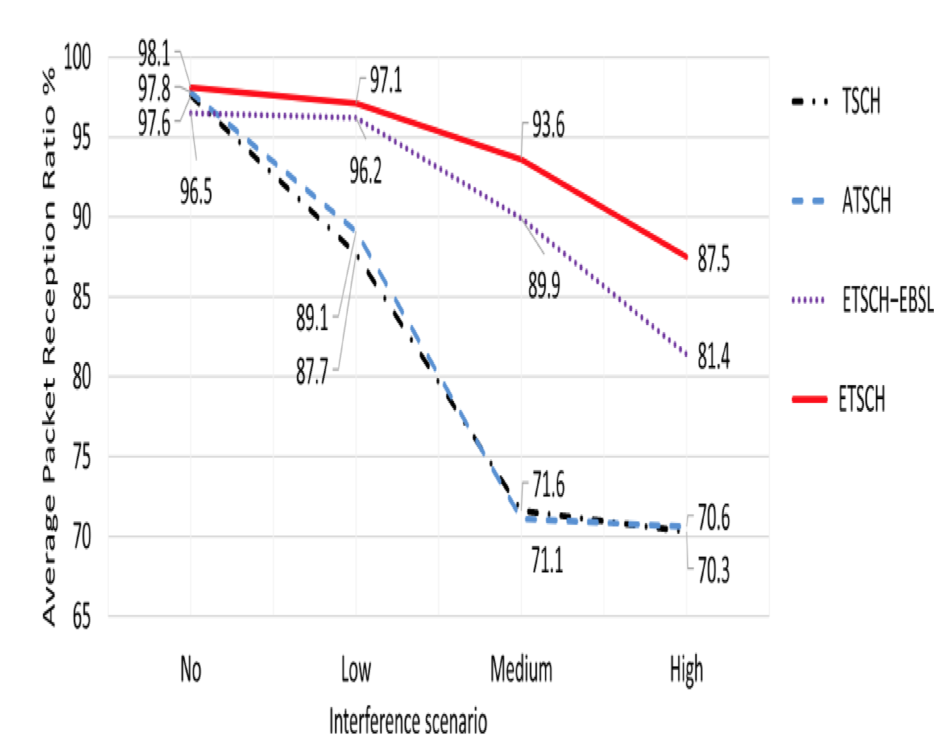


Figure 3: Avg. PRR of different interference scenarios.

As depicted in Figure 3, ATSCH performs almost the same as basic TSCH. There are two reasons for these results: (1) The rate of channel samplings by ATSCH is much lower than for ETSCH. Therefore, it can only deal with very low dynamic interference, and it cannot detect and follow the highly dynamic interference (that exists in in-vehicle networks). This leads to increasing packet losses when noisy channels are also selected to be used in the HSL. (2) ATSCH does all the samplings in one timeslot every slotframe. Our NICE technique spreads channel samplings over a slotframe, and therefore it can detect noisy channels better. Figure 3 also shows that using an EBSL to disseminate EBs improves the PRR of ETSCH compared to ETSCH–EBSL in all the interference scenarios. This is because it reduces the possibility of EB losses and accordingly, HSL mismatches between the coordinator and nodes.

## Conclusion

The results of the centralized and distributed channel quality estimation techniques are used to assign a quality factor to each channel. Using these qualities, channels with better qualities are periodically selected as the hopping sequence list of TSCH. ETSCH+DCS also uses a small secondary hopping sequence list (EBSL), that consists of the best quality channels, to disseminate periodic EBs. These EBs contain control information of the network such as the HSL. Only one field of the EBSL is updated per period, and thus the rate of EB losses in the network is reduced compared to using the regular HSL for broadcasting EBs. Experimental and simulation results show that ETSCH with NICE and EBSL provides higher packet reception ratios and lower length of burst packet losses compared to the plain TSCH protocol and another related work called ATSCH. Experiments also show that the DCS technique can detect existing interference in parts of the network that is not detectable by the centralized NICE technique, and thus it increases the PRR in those scenarios.

## References

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