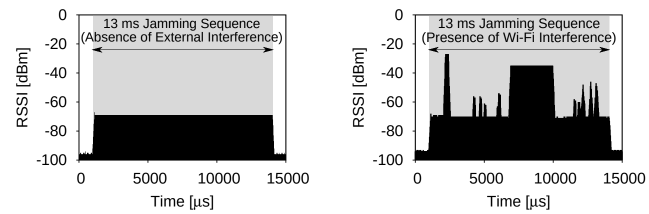
Poster Abstract: Agreement for Wireless Sensor Networks under External Interference

Carlo Alberto Boano and Kay Römer
University of Lübeck, Germany

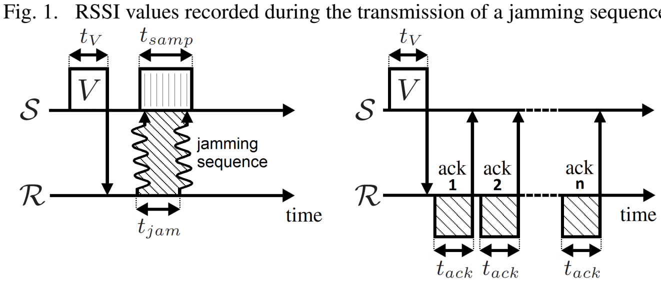
Thiemo Voigt
SICS, Sweden

Marco Antonio Zúñiga
University of Duisburg-Essen, Germany



(a) Absence of Interference (b) Presence of Interference

Fig. 1. RSSI values recorded during the transmission of a jamming sequence.



(a) *Jam-2* (b) *Ack-2*

Fig. 2. Illustration of two-way handshake agreement protocols.

***Abstract*—Wireless sensor nodes often need to agree on fundamental pieces of information: at the MAC layer, sensor nodes may need to agree on a new time slot or frequency channel; at the application layer they may need to agree on handing over a leader role from one node to another. With the increasing congestion of the unregulated ISM frequencies, the quality of communications deteriorates, leading to packet loss and higher latencies that may break agreement in two different ways: none of the nodes agree on the new information (time slot, frequency channel) and stick with the previous state, or – even worse – some nodes agree on the new information and some do not. In this work, we propose a protocol that exploits jamming instead of message transmissions to confirm the reception of a packet. We show that, in the presence of common interference patterns, this approach outperforms packet-based handshake protocols in terms of both agreement probability and energy consumption.**

I. Introduction and Motivation

In distributed systems, no delivery guarantee can be given on the messages that are sent [1], therefore traditional agreement protocols make use of several messages to agree on a piece of information among 2 nodes. A well-known agreement protocol is the *n-way handshake*, in which the first message conveys the descriptive information (e.g., "switch to channel x"), and the following $n \geq 1$ messages are sent in an alternated manner to acknowledge the reception of the previous packet(s). For example, TCP employs a 3-way handshake to establish connections over a network, and an agreement is reached only if all packets have been correctly received by both nodes.

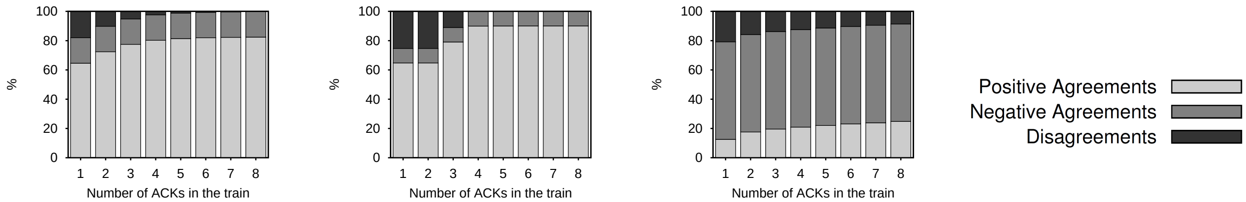
This approach is however not optimal for wireless sensor networks challenged by external interference for two main reasons. Firstly, the probability of receiving successfully a long sequence of packets is very low. Secondly, the overhead introduced by the packet header and footer is much larger than the information carried by an acknowledgment message itself, making it unnecessarily more vulnerable to interference.

In unregulated ISM bands such as the 2.4 GHz frequencies, wireless sensor nodes coexist with higher-power transmitters such as WLAN and Bluetooth. As a result, low-power transmissions may result in corrupted and undecodable packets [2]. In IEEE 802.15.4 devices, a packet is composed of a synchronization, physical and MAC header in addition to the payload carrying the actual data. Even when the information enclosed into the packet is minimal (such as in the case of an ACK), the probability of having a corrupted packet is given by its complete size, inclusive of headers and footers.

The main idea of our work is to use jamming as the binary signal to acknowledge the packet reception, in order to remove the overhead introduced by the packet headers and footers: after the transmission of the data packet(s), the subsequent acknowledgments can be sent in the form of jamming signals. The key insight behind this approach is that jamming can often be detected even under external interference, while ACK packets would instead be lost. We design *Jam-2*, a two-way handshake protocol in which the message receipt is sent in the form of a continuous jamming signal, and show its performance improvements under interference with respect to the traditional packet-based two-way handshake protocol.

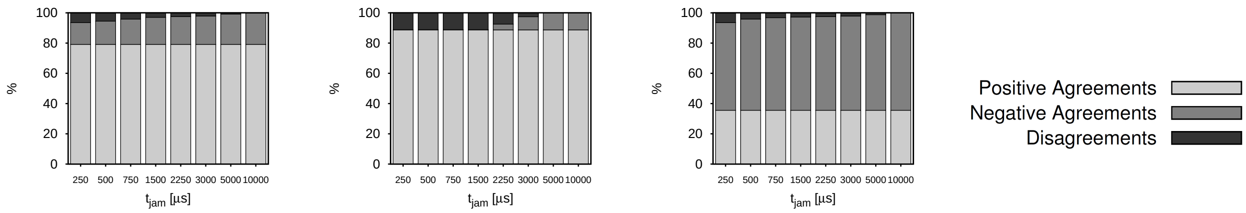
II. Contribution

Fig. 1(a) shows a jamming sequence lasting for a time window t_{jam} as perceived by a receiving node employing the CC2420 radio transceiver: in absence of interference, the RSSI values are stable and clearly above the sensitivity threshold of the radio. In the presence of external interference (Fig. 1(b)), the RSSI register will return the maximum interfering signal observed among the jamming signal (flat baseline) and the external source (bursty spikes) due to the co-channel rejection properties of the radio [3]. Typical interference sources – in contrast to a jamming signal – do not produce continuous interference for long periods of time, rather they alternate between idle and busy periods. That is, if t_{jam} lasts longer than the longest busy period of the interfering signal, we can detect if a jamming sequence was sent or not by checking if



(a) Bluetooth (b) Microwave oven (c) Heavy Wi-Fi

Fig. 3. Performance of the packet-based two-way handshake *Ack-2* when using $n \geq 1$ acknowledgment packets.



(a) Bluetooth (b) Microwave oven (c) Heavy Wi-Fi

Fig. 4. Performance of *Jam-2*: compared to *Ack-2* (Fig. 3), *Jam-2* maximizes the amount of positive agreements and minimizes the amount of disagreements.

any of the RSSI samples equals the radio sensitivity threshold. We use this observation to design *Jam-2*. Our implementation on Maxfor MTM-CM5000MSP motes uses Contiki and two main building blocks: (i) the generation of a jamming sequence and (ii) the high-frequency RSSI sampling that detects the presence of a jamming sequence. We implement the former using the CC2420 test modes as in [4] and the latter following the approach in [3] to obtain an RSSI sample every 20μs.

Fig. 2(a) shows a sketch of the protocol: given two nodes $\mathcal{S}$ and $\mathcal{R}$, where $\mathcal{S}$ initiates the exchange and sends the information V towards $\mathcal{R}$, we call *Jam-2* the two-way handshake in which $\mathcal{R}$ accepts V and sends the acknowledgment to $\mathcal{S}$ in the form of a jamming sequence of duration t_{jam}. While $\mathcal{R}$ transmits a jamming signal, $\mathcal{S}$ carries out a high-frequency RSSI sampling for a period $t_{samp} \leq t_{jam}$. Denoting r_{noise} as the maximum RSSI value measured in the absence of interference, and $\{x_1, \ldots, x_n\}$ as the sequence of RSSI values sampled during t_{samp}, we define the binary sequence $\{X_1, \ldots, X_n\}$ as follows: if $x_i \leq r_{noise}$, then $X_i = 1$, else $X_i = 0$. If $\sum_{i=1}^{n} X_i = 0$, $\mathcal{S}$ assumes that a jamming sequence was transmitted by $\mathcal{R}$ and deems the exchange as successful.

We compare the performance of *Jam-2* with the performance of *Ack-2*: a 2-way handshake protocol employing ACK packets to confirm the reception of the information (Fig. 2(b)). In order to increase the performance of *Ack-2*, we consider packet redundancy, that is, $\mathcal{R}$ sends a sequence of $n \geq 1$ ACK messages to confirm the reception of V, and $\mathcal{S}$ deems the exchange successful if it receives at least one ACK packet.

The exchange between $\mathcal{S}$ and $\mathcal{R}$ can have three possible outcomes. If both nodes deem the exchange as successful and accept V we have a *positive agreement*. If both nodes deem the exchange as unsuccessful and discard V we have a *negative agreement*. We have *disagreement* when one of the nodes deems the exchange as successful, while the second node deems the exchange as unsuccessful. While a disagreement is a potentially pernicious outcome, a negative agreement is often less severe. For example, if the shared value contains the next wireless channel to be used for communication, two nodes are better staying in the same lossy wireless channel, rather than having only one of them move to a different channel.

We compare the performance of the 2 protocols under realistic interference patterns generated using JamLab (Bluetooth/Wi-Fi file transfer, active microwave oven) [3]. Fig. 3 and 4 show the results: the probability of disagreements with *Jam-2* is much lower than that of *Ack-2* even for short t_{jam}. Furthermore, due to the reliable detection of a jamming signal, in *Jam-2* the amount of positive agreements remains constant and reaches the maximum already with short t_{jam}.

We have verified experimentally that a 1-byte payload ACK message has a transmission delay of 782 μs. This implies that under a fair comparison (t_{jam} = 750 μs for *Jam-2* and one ACK packet for *Ack-2*), *Jam-2* significantly outperforms *Ack-2* (more positive agreements and less disagreements). In practice, the difference would be even more favorable to *Jam-2*, because the processing and sending time of 1-byte ACK takes 2083 μs.

III. Outlook

We have proposed a jamming-based agreement protocol for wireless sensor networks challenged by external interference that overcomes the fundamental limitations of regular ACK packets being corrupted under interference. This approach can be used to build robust agreement protocols for wireless sensor networks. We are currently implementing a broadcast agreement protocol with encouraging preliminary results.

Acknowledgments

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