Competition: BigBangBus

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Abstract

A wireless bus based on flooding and the capture effect is proposed to achieve highly reliable broadcast communication in a Wireless Sensor Network (WSN) working in harsh environments in a multi-source-to-multi-sink topology where multiple hops are required (Fig. 1). Different sources access the medium without colliding using network-wide predefined time slots and frequency channels. Frequency-, spatial- and time-diversity is exploited using redundant retransmissions.

1 Introduction

Constructive Interference (CI) is only achieved if the senders synchronize their packet transmissions with sub-microsecond accuracy (0.5 μs with an IEEE 802.15.4 radio working at 2.4 GHz REF [1]). The exploitation of CI in wireless sensor networks (WSNs) has already been demonstrated, for instance in Glossy [1], Splash [2], Sparkle [3] and Disco [4].

In RedFixHop [5][6][7][8], the required synchronization precision is achieved using hardware-triggered retransmissions (automatic ACKs). However, commercial transceivers limit the efficacy of this mechanism, restricting the payload and structure of the packets [7].

As a trade-off, BigBangBus, a wireless bus using software-triggered retransmissions exploiting the capture effect, which requires less demanding synchronization accuracy [9], is proposed.

2 BigBangBus

BigBangBus is based on scheduled flooding bursts (Fig. 2), each initiated by a predefined source. How the network-wide consensus to assign the slots to the different sources is achieved is not in the scope of the protocol.

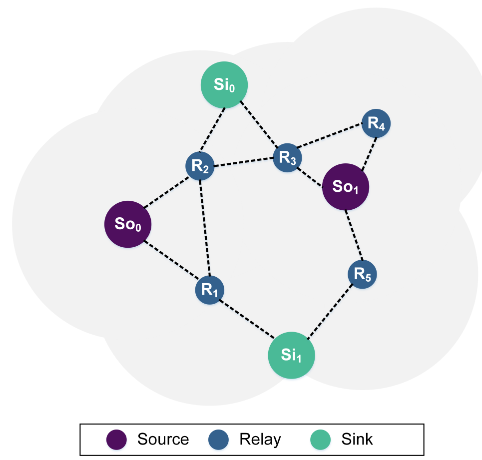

Figure 1. Multi-source-to-multi-sink topology

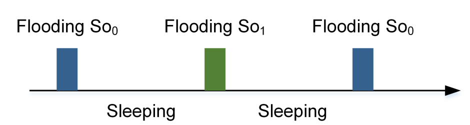

Figure 2. Periodic flooding periods

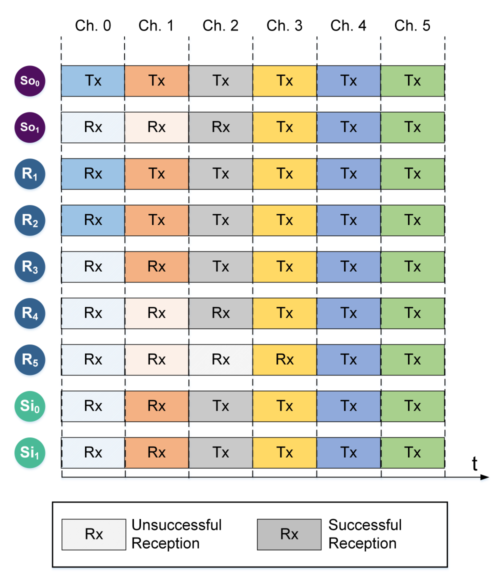

Figure 3. Flooding period of So_0

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BigBangBus works as follows (Fig. 3):

1. Every node is synchronized to turn its radio on at the beginning of the flooding period.
2. The source assigned to this period sends the packet, with several repetitions, in a predefined channel sequence.
3. All the relays receiving the packet transmit it immediately, following the same channel sequence, potentially exploiting the capture effect.
4. When the flooding period has finished, the radios switch off until the beginning of the next flooding cycle.

3 Low-Level Optimization

BigBangBus is based on extensive low-level optimization. No operating system, like Contiki, is used. Microcontroller and radio registers are directly accessed and fine-tuned to achieve optimal performance. Assembly language is needed in critical parts, like synchronization timers. BigBangBus's distinctive features are:

– *Sub-microsecond high-resolution timers*. Since software-triggered retransmissions are employed, high-resolution timers are needed in the microcontroller to reliably exploit the capture effect. Timers are calibrated with an algorithm that combines the fast, inaccurate, RC-type oscillator with the slow, accurate, 32 kHz crystal oscillator, the latter used as reference. With the MSP430 used in the competition, featuring an internal DCO of approximately 5 MHz (with strong variability between different nodes), sub-microsecond accuracy is achieved. Recalibration is periodically performed during run-time, since DCO operating frequency strongly depends on variable factors like temperature and operating voltage.

– *Optimal SFD and preamble lengths*. Success of CI and the capture effect is dramatically affected by the low-level behavior of the demodulator. DSSS used in 2.4 GHz IEEE 802.15.4 is a key factor [10], but also the synchronization mechanism, with longer preamble and SFD fields generally leading to increased chances of triggering the capture effect and reducing the number of collisions and false frames detected due to noise.

– *Optimal packet structure with extensive CRC coverage*. In the competition, an extremely high level of interference is expected. In this unusual and particularly harsh scenario, reliable error detection is a challenging task. BigBangBus uses CRC techniques with polynomial sizes similar to the size of the payload, leading to extremely low chances of undetected errors in the packet. Optimal lossless payload compression techniques are also exploited.

– *Transmission power randomization and pseudo-random channel-hopping sequence*. Wireless channel is expected to change quickly, with jammers randomly hopping between different channels. Using pseudo-random sequences, a higher level of diversity is introduced, since channels are used in a different order in every repetition of the flooding sequence. In addition, introducing some degree of randomization in the transmission power of the nodes, decreases collisions due to a high number of concurrent transmitters, improving scalability.

– *High-priority flows and smart slot skipping*. Different priorities are assigned to the sources, with those of higher priority (e.g. those relevant to multiple sinks) being scheduled more often in the flooding burst, achieving lower latencies. Furthermore, to save energy, relays can decide whether to send in every slot of the sequence or to sleep in some of them, based on measured parameters, such as RSSI, LQI and number of unsuccessful receptions.

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