Demo: RedFixHop - Reliable Real-time Network Flooding

Antonio Escobar[1,2,5], Fernando Moreno[1,5], Antonio J. Cabrera[1,5], Javier Garcia-Jimenez, Francisco J. Cruz[3], Angel Corona[3], Jirka Klaue[4], Divya Tati[4], Diego P. Morales[5]

[1]Infineon Technologies AG, [2]RWTH Aachen University, [3]eesy-innovation GmbH, [4]Airbus Group Innovations, [5]University of Granada

antonio.escobar@infineon.com, jirka.klaue@airbus.com

Abstract

We demonstrate the performance of RedFixHop in ultra-low-latency multi-hop applications. A source node is connected to a sensing device. The sensed value is sent to a sink node through a flexible topology of relays. The sink node is connected to a display, where metrics of the sensor network (latency, reliability) are shown in real-time. The main goal is demonstrating the simplicity and seamless adaptation of RedFixHop to fast-changing scenarios, without introducing overhead or increasing the latency.

1 Introduction

RedFixHop [1][2][3][4] is a scalable and latency-optimal protocol for Wireless Sensor Networks (WSNs) based on constructive interference (CI) and the capture effect.

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 [5]). The exploitation of CI in wireless sensor networks (WSNs) has already been demonstrated, for instance in Glossy [5], Splash [6], Sparkle [7] and Disco [8].

In these protocols, the synchronization is achieved by finely tuning the retransmissions, adjusting the software running in the main microcontroller at the instruction level. RedFixHop's novelty is that the required synchronization precision is achieved using hardware-triggered retransmissions, without requiring the involvement of the main microcontroller, achieving better synchronization, which means greater scalability, and easier application programming.

Hardware-triggered retransmissions are packet transmissions triggered autonomously by the radio transceiver. To achieve this behavior with commercial components, transceivers with automatic ACK feature are used. Automatic ACKs allow the quick and accurate dissemination of the packet, since they are normally generated after a deterministic short delay, following the reception of the last symbol of the previous packet. This delay is generated using the radio transceiver crystal, which is normally more accurate than the crystal of the main microcontroller, and it is not affected by the application running on it. ACKs include a reference (normally a short address) that points to the received packet. This reference is used here as payload, being this short payload the greatest limitation of the protocol [3].

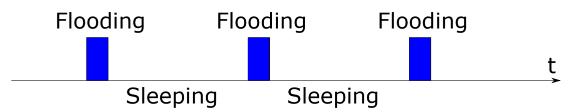

Figure 1. Periodic flooding periods

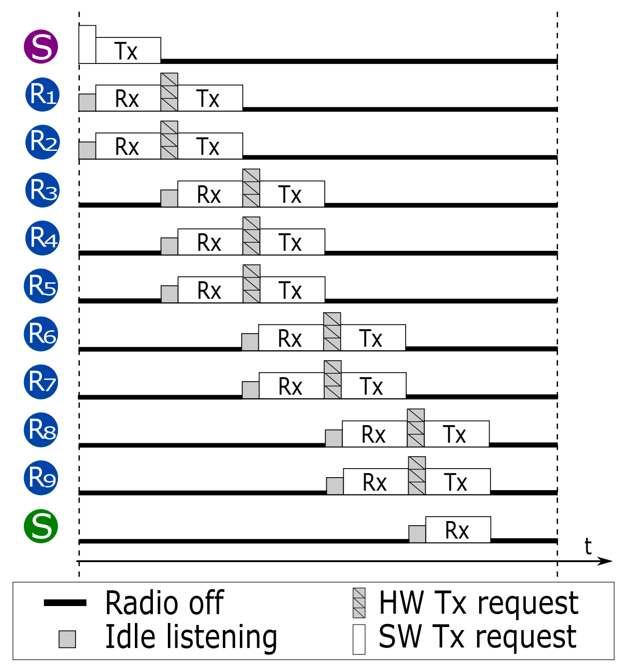

Figure 2. RedFixHop protocol

Furthermore, to achieve energy-efficient operation, the flooding mechanism uses synchronous radio duty-cycling based on periodic active bursts (Fig. 1 and Fig. 2).

International Conference on Embedded Wireless Systems and Networks (EWSN) 2018
14–16 February, Madrid, Spain

ISBN: 978-0-9949886-2-1

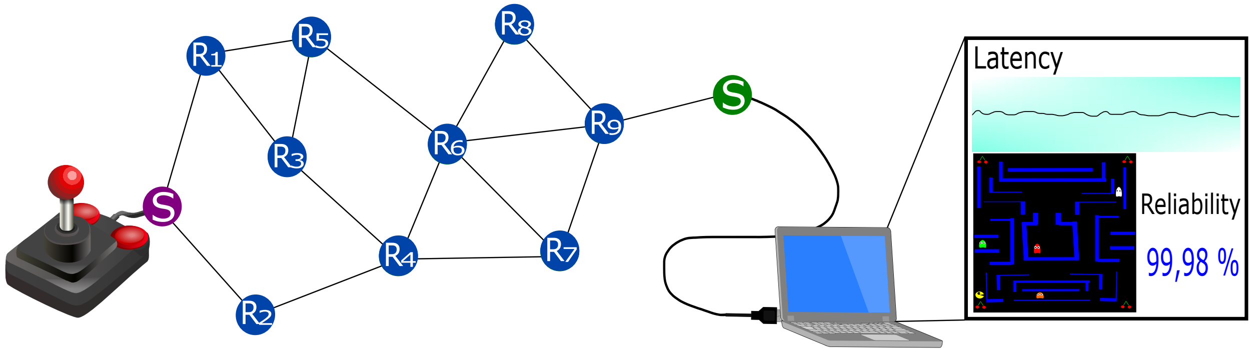

Figure 3. Demo topology

2 Demonstration

The demo is built using TelosB motes, IEEE 802.15.4 compliant nodes composed of the MSP430 microcontroller and the CC2420 radio chip. The CC2420, by default, does not allow successive rounds of hardware-triggered retransmissions, since the Ack.Req bit is automatically cleared, forcing us to alternate between software- and hardware- triggered retransmissions [3]. To overcome this, the SACK command strobe is sent while receiving a packet, hacking the radio behavior, and forcing the unconventional hardware acknowledgment of packets with the Ack.Req bit cleared [9], as successfully used in the EWSN 2017 Dependability Competition [4].

The source node is connected to a sensing device. The sensed value is sent to the sink node through a flexible network of relays that can be freely moved or switched on and off. The sink node is connected to a display, where metrics of the sensor network (latency, reliability) are shown in real-time (Fig. 3). The sensing device is a controller that provides remote input to a video game connected to the sink node in order to play in real-time, as an engaging experience to visualize the impact of latency and error rate in the multi-hop wireless link.

3 Conclusions

With no routing overhead, RedFixHop achieves optimal latency and reliability, even during dynamic conditions, with relays appearing and disappearing or moving closer and farther from the source.

In RedFixHop, unconventional use of commodity IEEE 802.15.4 hardware is shown to obtain hardware-triggered CI flooding, hacking the ACK behavior. This misuse of the ACKs creates an important drawback by limiting the maximum payload of the transmitted packets to 1 byte [3]. In the future, specialized radio hardware may overcome this limitation, while also include native channel hopping and security features.

To summarize, we demonstrate that flooding protocols based on CI are a promising, reliable and simple solution for dynamic multi-hop networks working in harsh environments, particularly for modulations with CI-suitable channel coding, like the direct-sequence spread spectrum (DSSS) used in IEEE 802.15.4 [10].

4 References

[1] J. Klaue, A. Corona, M. Kubisch, J. Garcia-Jimenez, and A. Escobar, "Competition: Redfixhop," in *Proceedings of the 2016 International Conference on Embedded Wireless Systems and Networks*, EWSN '16, (USA), pp. 289–290, Junction Publishing, 2016.

[2] A. Escobar, C. Gonzalez, F. J. Cruz, J. Garcia-Jimenez, J. Klaue, and A. Corona, "Redfixhop: Efficient ultra-low-latency network flooding," in *2016 13th Annual IEEE International Conference on Sensing, Communication, and Networking (SECON)*, pp. 1–2, June 2016.

[3] A. Escobar, F. J. Cruz, J. Garcia-Jimenez, J. Klaue, and A. Corona, "Redfixhop with channel hopping: Reliable ultra-low-latency network flooding," in *2016 Conference on Design of Circuits and Integrated Systems (DCIS)*, pp. 1–4, Nov 2016.

[4] A. Escobar, J. Garcia-Jimenez, F. J. Cruz, J. Klaue, A. Corona, and D. Tati, "Competition: Redfixhop with channel hopping," in *Proceedings of the 2017 International Conference on Embedded Wireless Systems and Networks*, EWSN '17, pp. 264–265, Junction Publishing, 2017.

[5] F. Ferrari, M. Zimmerling, L. Thiele, and O. Saukh, "Efficient network flooding and time synchronization with glossy," in *Proceedings of the 10th ACM/IEEE International Conference on Information Processing in Sensor Networks*, pp. 73–84, April 2011.

[6] M. Doddavenkatappa, M. C. Chan, and B. Leong, "Splash: Fast data dissemination with constructive interference in wireless sensor networks," in *Presented as part of the 10th USENIX Symposium on Networked Systems Design and Implementation (NSDI 13)*, (Lombard, IL), pp. 269–282, USENIX, 2013.

[7] D. Yuan, M. Riecker, and M. Hollick, *Making 'Glossy' Networks Sparkle: Exploiting Concurrent Transmissions for Energy Efficient, Reliable, Ultra-Low Latency Communication in Wireless Control Networks*, pp. 133–149. Cham: Springer International Publishing, 2014.

[8] Y. Wang, Y. Liu, Y. He, X. Y. Li, and D. Cheng, "Disco: Improving packet delivery via deliberate synchronized constructive interference," *IEEE Transactions on Parallel and Distributed Systems*, vol. 26, pp. 713–723, March 2015.

[9] CC2420-Datasheet, "2.4 ghz ieee 802.15.4/zigbee-ready rf transceiver datasheet (rev.c)," *Chipcon Products from Texas Instruments*, 2013.

[10] M. Wilhelm, V. Lenders, and J. B. Schmitt, "On the reception of concurrent transmissions in wireless sensor networks," *IEEE Transactions on Wireless Communications*, vol. 13, no. 12, pp. 6756–6767, 2014.