DEMONSTRATION ABSTRACT: DECENTRALIZED TIME-SYNCHRONIZED CHANNEL SWAPPING

George Smart
Electronic and Electrical
Engineering Department
University College London
London, WC1E 7JE, UK
george.smart@ucl.ac.uk

Nikos Deligiannis
Vrije Universiteit Brussel -
iMinds
University College London
ndeligia@etro.vub.ac.be

João F. C. Mota
Electronic and Electrical
Engineering Department
University College London
London, WC1E 7JE, UK
j.mota@ucl.ac.uk

Yiannis Andreopoulos
Electronic and Electrical
Engineering Department
University College London
London, WC1E 7JE, UK
i.andreopoulos@ucl.ac.uk

ABSTRACT

We are working on a new concept for decentralized medium access control (MAC), termed *decentralized time-synchronized channel swapping* (DT-SCS). Under the proposed DT-SCS and its associated MAC-layer protocol, wireless nodes converge to synchronous beacon packet transmissions across all IEEE802.15.4 channels, with balanced numbers of nodes in each channel. This is achieved by reactive listening mechanisms, based on pulse coupled oscillator techniques. Once convergence to the multichannel time-synchronized state is achieved, peer-to-peer channel swapping can then take place via swap requests and acknowledgments made by concurrent transmitters in neighboring channels. Our implementation of DT-SCS reveals that our proposal comprises an excellent candidate for completely decentralized MAC-layer coordination in WSNs by providing for quick convergence to steady state, high bandwidth utilization, high connectivity and robustness to interference and hidden nodes. The demo will showcase the properties of DT-SCS and will also present its behaviour under various scenarios for hidden nodes and interference, both experimentally and with the help of visualization of simulation results.

1. INTRODUCTION

This demo comprises the experimental deployment of our theoretical framework for decentralized multichannel medium access control (MAC) [2]. Our deployment is based on 16–64 low-power TelosB motes running the Contiki OS and the Contiki network simulator, Cooja.

The concept of channel hopping has gained acceptance as a good solution according to high-bandwidth, energy-efficient, wireless sensor networks (WSNs), with time synchronized channel hopping (TSCH) [4] now being part of the IEEE802.15.4e-2012 standard. With TSCH, each node reserves timeslots within a repeating slotframe, within the 16 channels of IEEE802.15.4. Nodes transmit and listen in different channels, thus avoiding concentrated interference. However, the TSCH slotframe has a rigid (pre-defined) structure, and filling up available slots follows a rather complex advertising request and acknowledgment (RQ/ACK) process on a coordination channel, which is prone to interference and occasional self-inflicted collisions when nodes advertise slots aggressively. Conversely, if advertising is not aggressive, slots abandoned by sleeping or departed nodes may remain unoccupied for long periods until another advertisement RQ/ACK process reassigns them to other nodes. This limits the bandwidth usage per channel. Our work addresses these issues based on the concept of pulse coupled oscillators (PCOs) [1, 3].

In our work [2], we analyzed the theoretical foundations of our novel decentralized time-synchronized channel swapping (DT-SCS) framework, where nodes randomly join a channel and achieve PCO-based coordination via the periodic transmission of beacon packets at the MAC layer. For channels with equal number of nodes, DT-SCS converges to synchronized beacon packet transmission at the MAC in a completely uncoordinated manner. Furthermore, it allows for arbitrary pairwise swaps between nodes in neighboring channels with limited effort and without disrupting the WSN operation. Finally, due to the inherent adaptation of PCO mechanisms to the effects of nodes joining and leaving the process, our protocol is robust to interference as well as node churn during WSN reconfiguration [2].

2. EXPERIMENTS WITH TELOSB MOTES

Towards a practical evaluation testbed, we implemented the proposed DT-SCS as an application in the Contiki 2.7 operating system running on TelosB motes. By utilizing the NullMAC and NullRDC network stack options in Contiki, we control all node interactions at the MAC layer via our

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Figure 1: Example of our experimental setup. The 4 nodes located right-most in the image are used for monitoring purposes, with the RF signal generator used to generate interference shown in the background.

application code.

For demonstration purposes, we consider a WSN deployment with $W = 16$ nodes in $C = 4$ channels, which leads to $W_c = 4$ nodes per channel in the steady state. The 16 nodes can be distributed in one area or a long flat surface, as depicted in Fig. 1. Four extra nodes can be configured to listen in the four channels for monitoring purposes and for collecting experimental results.

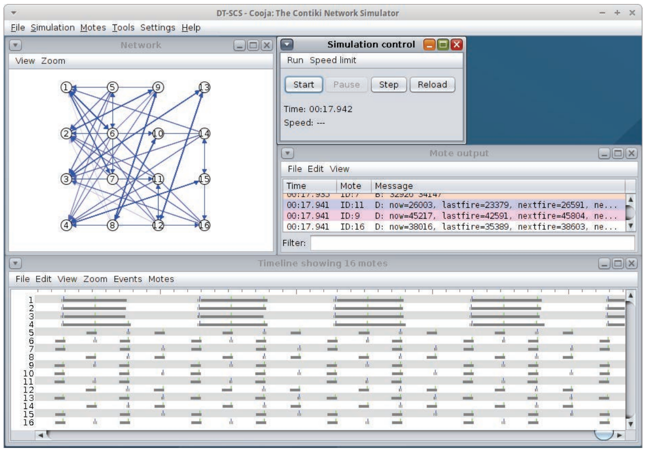
3. SIMULATIONS WITH COOJA

To aid with visualising the behaviour of the network, a DT-SCS node can be simulated from within the Contiki network simulator, Cooja. The simulator uses the same binary program as is flashed into the TelosB motes and provides an accurate simulation of node, as well as entire network behaviour.

Using the Cooja simulator it is possible to create intricate hidden terminal scenarios and cases of jamming in certain channels of the unlicensed IEEE802.15.4 spectrum, and observe how the protocol adapts to such interference. Nodes can easily be added and removed from the network to simulate node churn, and the effects are easily observable. For the node configuration outlined in Section 2 and Fig. 1, a snapshot of the corresponding Cooja simulation is shown in in Fig. 2. The upper left of the figure shows the physical arrangement of the nodes, with the arrows corresponding to beacon packet reception. The bottom of the figure shows the timeline of beacon packet transmissions in all four channels, as well as additional information concerning the transceiver status. Finally, detailed debugging information is available in the mote output and the simulation can be executed in a step-by-step manner to examine the microscale behaviour of DT-SCS convergence and steady-state operation.

4. USER EXPERIENCE FROM THE DEMO

Researchers interested in our work will be able to see the detailed operation of the distributed synchronization and desynchronization of DT-SCS with examples in the Cooja simulator, which are also deployed in the real testbed. In addition, possibilities for high-volume data transfer from many-to-many sensors will be showcased, both in the demo deployment and in the simulation. Artificial interference generation will be demonstrated by having some additional nodes transmit jamming packets in the network, and the impact of hidden nodes on the distributed protocol convergence and stability will be demonstrated in the simulation and in the real hardware deployment.



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00:17.941  ID:11  D: now=26003, lastfire=23379, nextfire=26591, ne...
00:17.941  ID:9   D: now=45217, lastfire=42591, nextfire=45804, ne...
00:17.941  ID:16  D: now=38016, lastfire=35389, nextfire=38603, ne...
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Figure 2: Simulation of nodes comprising our experimental setup.

5. ACKNOWLEDGMENTS

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