

Report on PhD Thesis: “Optimized TDMA Scheduling Algorithms for Cluster-Tree WSNs”

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Content and contribution of the thesis

The submitted PhD thesis focuses on design, implementation and evaluation of algorithms to scheduling of transmissions in cluster-tree WSNs. The work is motivated here by systems consisting of a large number of communicating components that may need to self-organize at runtime – such as Internet of Things and Industry 4.0.

In this context, the thesis focuses on short range low-power networks based on IEEE 802.15.4/ZigBee, in particular in the Cluster-Tree topology. This topology poses many challenges, when it comes to scheduling that considers collision avoidance, energy-efficiency and real-time requirements. This becomes especially complex when large networks are considered, where multiple collision domains emerge.

The thesis addresses the problem of real-time scheduling in three parts, which form the main contribution of the thesis.

The first part (presented in Chapter 3) focuses on collision-free TDMA scheduling in a single-collision domain cluster-tree topology. The main contribution in this chapter lies in simplifying the collision-free TDMA cluster scheduling problem by expressing precise end-to-end deadlines into maximum number of crossed periods. This allows polynomial-time solution (instead of traditional NP-hard complexity). The thesis further proposes an optimal polynomial TDMA algorithm (TDMA^{scd}), which allows solving large size instances of the problem in relatively short time. The evaluation of the algorithm is achieved through simulation scenarios in Opnet Modeler to demonstrate the impact of the number of re-transmissions on the network reliability and timeliness of the data flows. The evaluation also focuses on energy consumption.

The second part (presented in Chapter 4) focuses on TDMA scheduling in multiple-collision domains cluster-tree topology. In this respect, the thesis contributes a realistic model that expresses end-to-end deadlines by the maximum number of crossed periods and proposes an optimal and exact scheduling algorithm (E_TDMA^{mcd}) that is based on integer linear programming. Due to its complexity, the algorithm is suitable only for small-size instances. To cope with larger instances of the problem, the thesis further proposes a heuristic scheduling algorithm (H_TDMA^{mcd}). The evaluation with respect to various QoS properties is again performed using the Opnet Modeler. The evaluation also discusses comparison between the two proposed algorithms and the TDCS algorithm (by the same research group).

The third part of the contribution (presented in Chapter 5) focuses on on-the-fly deployment and reconfiguration. In this respect, the thesis proposes an exact algorithm for distributed time division multiple access scheduling for single-collision domain (DTDMA^{scd}) and a heuristic distributed algorithm for multiple-collision domains (DTDMA^{mcd}). The chapter provides an

evaluation by comparing the proposed algorithms with existing works to show the overhead of the algorithms and QoS properties.

In addition to these main chapters, the thesis also provides a nice quick overview of IEEE802.15.4 and ZigBee, which simplifies orientation in the thesis' contributions.

Presentation and writing style

The thesis is well written and structured. The structure essentially follows the three main contributions and each chapter nicely builds on the previous ones. The flow of information is appropriate and their presentation too. There are a few typos in the text, which however do not hinder understanding.

Questions for the defense

The topic of the thesis is interesting and relevant. I especially find the aims of Chapter 5 very relevant. The text in Chapter 5 seems to assume that the on-the-fly deployment and reconfiguration is a one-time job. The next-generation IoT and Industry 4.0 systems are however more likely to be in the state of constant evolution and reconfiguration (due to mobility of components or just the fact that new components gradually appear in the system and others disappear). In this context, I would like to know how the algorithms presented in the thesis (in particular Chapter 5) can cope with such scenarios. For instance, can the algorithms take advantage of the current state and work for example incrementally?

Judgment

The candidate has without doubts proved that he is able to work creatively and come with innovative solutions to research problems. The thesis deals with relevant goals and succeeds in fulfilling them. The method of achieving the goals is also sound and the solution has been experimentally evaluated. Thus, the thesis represents a significant and novel contribution to current state-of-the-art in the area of distributed real-time systems. The work presented in the thesis has been also already published in a top-tier journal and another journal publication is on its way. There are also a few conference/workshop publications.

Overall, I have no objections against the thesis. I deem its contribution very solid and I recommend the thesis for a defense and judge the candidate worthy of a PhD degree.



Tomáš Bureš

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