Doctoral Thesis Review

Doctoral Graduate: Ing. Jiří Trdlička
Supervisor: Doc. Dr. Ing. Zdeněk Hanzálek
Reviewer: Ing. Jan Beran, Ph.D.

The doctoral thesis under review focuses on the topic of distributed and real-time routing in sensor networks. The work is divided into three comprehensive parts. The first part is dedicated to centralized routing algorithms, the second part is dedicated to distributed routing algorithms, and the third part is dedicated to distributed routing algorithms considering real-time communication.

The chosen topic is utmost actual both from the theoretical viewpoint and the viewpoint of industrial applications. The aspects of real-time behaviour and optimisation with respect to energy consumption belong to the most acute problems requiring immediate solutions. These aspects are pertinent especially in products with mission-critical systems, custom control task in industrial setups, and home automation.

The author introduces the following objectives of his doctoral thesis:

1. Develop a centralized algorithm for real-time routing in multi-hop sensor networks.
2. Derive in-network distributed routing algorithm for data flow in multi-hop sensor networks.
3. Derive in-network distributed routing algorithm for real-time data flow in multi-hop sensor networks.
4. Evaluate behaviour of all derived algorithms on benchmarks for energy optimal routing in multi-hop sensor networks.

Based both on the content of the doctoral thesis and on the reviewer's judgement, the reviewer can state that the aforementioned objectives have been fulfilled.

The content and composition of the thesis is of very high quality. The author progressively introduces different models of data flows and explains them in a straightforward manner on a specific repeating example. This approach not only allows for rapid orientation in the problems but also increases the chances for practical application of the introduced algorithms. Proofs of convergence are provided for iterative algorithms. The author provides abundance of simulation cases in which he concentrates on identification of dependencies between single parameters of the simulated network, such as number of nodes, number of communication demands, latency, etc. Both linguistic quality and the level of mathematical formalism is abnormal.

The major contribution of the doctoral thesis consists especially in allowing solution of several optimisation problems in the area of data flow routing in wireless networks using ILP solvers with very good results. Seeing the fact that ILP solvers are suitable for many families of optimisation problems, I consider leveraging of ILP solvers for the routing problems very adequate.

Practical use of the achieved results can be expected especially in the area of centralized routing algorithms, constituting the first part of the doctoral thesis. The approach to optimisation is

comprehensible and thus easier to prove correct. Distributed algorithms would probably have to be exposed to further analysis and benchmarking to gain confidence in reliable operation under different unexpected circumstances. Moreover, computation performance could be an issue.

The reviewer suggests the following questions and recommendations:

- The notion *integral flow* can be misleading and in the available resources not easily traceable. Provided the nature of this type of flow, it could be more intuitive to use the notion *fragmented flow* or *packet-oriented* flow.
- Surprisingly fast is convergence of the ILP solver in case of the fragmented flow. This fact can be caused by some implicit conditions pertinent in this type of network which can significantly reduce the problem complexity. Is it possible to provide some hypothesis?
- What is the major advantage of the possibility to solve the optimisation problem using dual decomposition of the NUM linear optimisation function?
- In case of distributed routing algorithms, it makes sense to consider the computation power of the routing nodes. Has any consideration been made in terms of run-time performance on typical wireless node? Similarly, has any consideration been made in terms of payoff between the power consumed to find the energy-optimal path and the power representing penalty for choosing a non-optimal communication path?

The reviewer herewith states that the doctoral thesis of the graduate ing. Jiří Trdlička satisfies the conditions of scientific research and contains original results published by the author in transactions and several international conferences.

For the aforementioned facts, the reviewer recommends the doctoral thesis to be defended and upon successful defence to be granted the doctoral degree.

(Práci ing. Jiřího Trdličky doporučuji k obhajobě.)

Brno

Ing. Jan Beran, Ph.D.