THESIS INFORMATION

Title: **Towards a formal dynamic modeling for congestion detection on Wireless Sensor Networks.**

Major:	Computer Science
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1. ABSTRACT

Congestion detection is one of the most popular research fields in Wireless Sensor Networks (WSNs for short). Congestion needs to be detected soon to reduce packet loss and prolong system lifetime since the sensors can save their energy consumption. There are many ways to detect congestion in WSN including two popular streams simulation-based and model-based.

Following the model-based orientation, formal modeling techniques are used for analyzing the congestion property of WSNs. Place Transition Nets and Coloured Petri Net are chosen for modeling the models in this thesis. Both of such languages are Petri Nets modeling language, a powerful language that used in many research. The proposed models describe parameters and behaviors of all elements in a WSN (i.e. sensors and channels). Then the congestion detection problem is verified on the state space of the model.

However, the famous "the state space explosion" problem is occurred and leads to decrease the speed of congestion detection. In order to overcome such problem, two algorithms including congestion-based clustering and heuristic search are proposed. On the one hand, clusters of congested potential sensors are grouped and verify firstly. On the other hand, one guidance heuristic search shows the fastest way to reach the congestion node on the state space. Thanks to both algorithms, congestion can be detected earlier.

Moreover, congestion probability is also added in the model to eliminate the false congested alarm.

2. MAIN CONTRIBUTIONS

- **Propose WSN-PN model**, a WSN model that has two main elements including sensors and channels by using Place Transition Nets.

This thesis proposes a formal modeling method for modeling WSN by using Place Transition Nets (P/T Nets for short), a low-level Petri Net Modeling language. The mathematic structure of P/T Nets is quite simple and suitable to define a WSN topology. Once WSN is modeled, congestion detection is also represented to formal property and is verified by Model Checking technique.

- **Propose *WSN-CPN* model**, a WSN model by using Coloured Petri Net.

Coloured Petri Net is one of the high-level Petri Net Modeling languages. All variables which use to represent a WSN can be shown explicitly on model definitions, not under the code. Hence, the modeler can easily monitor and modify when the model is executing.

- **Propose two fast congestion detection algorithms**

  Using Model Checking to verify a property is not a complicated idea but easy leading to state space explosion. As the number of state variables in the system increases, the size of the system state space grows exponentially. This is called "state space explosion". The state space of the system can be very large, or even infinite. Thus, it is impossible to explore the entire state space with limited resources of time and memory and the system cannot know whether congestion occurs on WSN certainly.

  To deal with such a problem, this thesis proposes two indirect reducing state space explosion methods by increasing the speed of find congestion. Once the congestion is detected soon, the system can save more resources to maintain its normal working.

  - **Fast congestion detection on WSN based on clustering technique**

    WSNs are clustered based on the congestion-oriented measurement first. Then, the verification process is performed on each individual cluster. Congestion is detected earlier if it exists within a cluster. Otherwise, the verification process is repeated on a new abstracted network obtained from abstracted clusters and abandoned sensors in case clusters are confirmed congestion-free in the previous step. Experiments show that in most cases, congestion is detected on clusters, which significantly decreases the verification time.

- **Fast congestion detection on WSN based on heuristic search**
  The combination of model checking and heuristic search approach can potentially reduce the resource consumed as well as the verification time on a WSN system. Searching on state space is guided by a heuristic function to ensure reaching the target (congested node) faster.

- **Propose dynamic WSN model**

  The dynamic model allows the parameters of WSN components, like sensors or channels, can be re-configured to be added or removed without remodeling the network topology. In this thesis, we realize this idea by a formal modeling mechanism, where WSN sensors and channels are parameterized by a set of characteristic functions, each of which represents a certain characteristic of sensor/channel as a mathematical expression. Those characteristic function sets can be dynamically modified to support verifying the networks on various aspects of WSN without re-modeling. In addition, this model also supports inferring congestion probability based on the domain knowledge conveyed by the characteristic functions.

3. QUESTION ISSUED TO CONTINUE THE RESEARCH

Formal modeling for congestion detection on WSNs in this thesis can be continued including

- Using real-time parameters in the model. Time was also considered in WSN-CPN model as events only.
- Expanding the number of parameters that are affected to the congestion probability such as the noise of the environment.
- Improving the detection time, congestion cannot detect after a few seconds.

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