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Poster Abstract: Numerical Analysis of WSN Protocol Using Probabilistic Timed Automata

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Poster Abstract: Numerical Analysis of WSN Protocol Using Probabilistic Timed Automata

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I. Introduction

In order to run Cyber-Physical Systems (CPS) correctly and efficiently, the communication processes, especially the underlying wireless sensor network (WSN) protocols, must be robust and reliable. Timing-sync Protocol for Sensor Networks (TPSN) is a widely used time synchronization protocol which provides synchronization in the whole sensor network. As CPS systems could work in all kinds of open environments, it is critical to ensure the correctness of TPSN and to evaluate the performance of TPSN under different harsh environments. Clearly, if we can build an accurate model of the protocol then verify it, the correctness of the protocol can be proved.

For modeling, we build timed automata model to describe the behavior of TPSN. Furthermore, in order to model the uncertainties in the realistic world such as message loss, node failures, probabilistic transitions are extended. For verification, besides classical model checking of functional properties like verification of deadlock, we also use Statistical Model Checking technique(SMC) to analyze the probabilistic model to evaluate the performance of the protocol under different environments and help with the parameter configuration.

II. Modeling of TPSN

The workflow of TPSN basically consists of a *level discovery phase* to assign each node a level, then the *synchronization phase* to synchronize the clock of all the nodes and several *special provisions* caused by node dynamics. As TPSN is high time-related, we model the workflow of it with timed automata.

In real environments, message loss and node dynamics are common. We use probabilistic transitions to describe these phenomenons. Take the sending of message *level_discovery[id]* for example, the probabilities of sending it are marked as *SUC* and *FAIL* respectively, and message is only sent after the *SUC* branch as shown in Fig.1. Similar method is used to model node dynamics. The final probabilistic timed automaton is shown in Fig.2. Due to space limitation, the complete models are available from http://seg.nju.edu.cn/people/~bl/exp/TPSN.rar.

III. Verification of TPSN

We conduct a series of verification, including functional correctness and numerical analysis, on the probabilistic model built for TPSN. Due to space limitation, we only introduce the numerical analysis done by SMC technique in this abstract.

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Parameter Configuration: Resynchronization Interval (*RESYNC*) is the period a synchronization phase lasts. There is a tradeoff of configuring the value of it. If it is too small, synchronization will be difficult to finish in one cycle. If it is too large, the clock drift will be large also. To decide the proper value of this parameter, we analyze the probabilities of a series of systems, 3-6 nodes, to synchronize in a cycle with different values of *RESYNC*. We can see the relation between *RESYNC* and the synchronization probability very clearly from Fig.3, which can help us to configure this parameter easily.

Performance Evaluation: To analyze the efficiency of TPSN, like how fast the nodes can be synchronized. We have checked the probabilities of a system consisting of 3 nodes to synchronize successfully in M cycles with *FAIL* is set to 0, 0.1, 0.2, and 0.3 respectively. The results are plotted in Fig.4. From this graph we can see that TPSN is very sensitive to disturbations, like message loss and node dynamics. Thus, it could not be very suitable to choose this protocol while the CPS system is supposed to work in harsh environments.

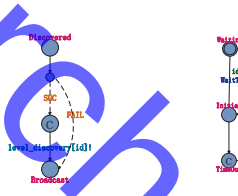

Fig. 1. Probabilistic Extension

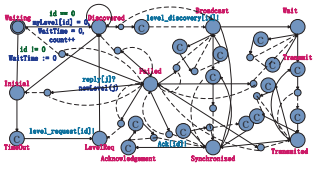

Fig. 2. Timed Automaton of TPSN

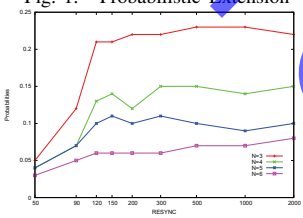

Fig. 3. Sync. Probability VS *RESYNC*

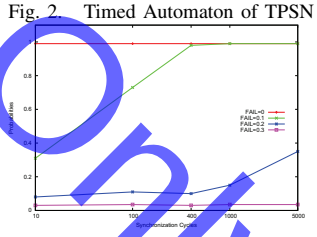

Fig. 4. Sync. Probability VS *FAIL*

IV. Conclusion

Our works show that probabilistic timed automata can be used to model the WSN protocols more realistically. Furthermore, besides classical model checking, statistical model checking can be used in the designing and evaluation of WSN protocols. They can verify the functional correctness of the protocol, and also analyze the performance of the protocol in different configurations, to tell whether the current parameter configuration is reasonable and whether the protocol is a suitable choice for different objectives.

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