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Availability evaluation of controller area networks under the influence of intermittent connection faults

Key words: Controller area network; Intermittent connection fault; Arrival rate; Deterministic and stochastic Petri net; Availability evaluation

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Motivation

- Controller area networks, as one of the widely used fieldbuses in the industry, have been extended to the automation field with strict standards for safety and reliability.
- In practice, factors such as fatigue and insulation wear of the cables can cause intermittent connection faults to occur frequently in the controller area network, which will affect the dynamic behavior and safety of the system.
- Hence, quantitatively evaluating the performance of the controller area network under the influence of intermittent connection faults is crucial to real-time health monitoring of the system.

Main idea

- An approach for real-time estimation of the intermittent connection fault arrival rate based on the error information in the data link layer is developed.
- A novel deterministic and stochastic Petri net (DSPN) model for the communication states of the controller area network under intermittent connection faults is constructed.
- An online availability evaluation methodology for the controller area network is developed based on the probability distribution and physical meaning of markings in the DSPN model.

Framework

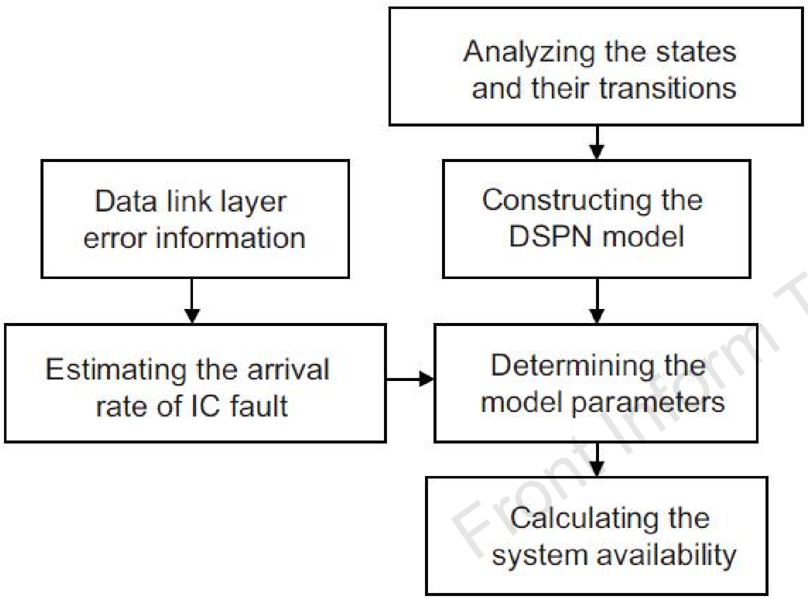

Fig. 1 Framework of the evaluation procedure

First, the relationship between the error frame and intermittent connection (IC) fault is established, and the IC fault arrival rate is estimated based on the error information collected from the data link layer. Second, the network states and their transition relationship when synthesizing bus messages and IC faults are defined. Then, the DSPN model is constructed to describe the state transition relationship, and the model parameters are determined based on the IC fault arrival rate. Finally, the system availability is calculated based on the probability distribution of the markings in the DSPN model.

Method

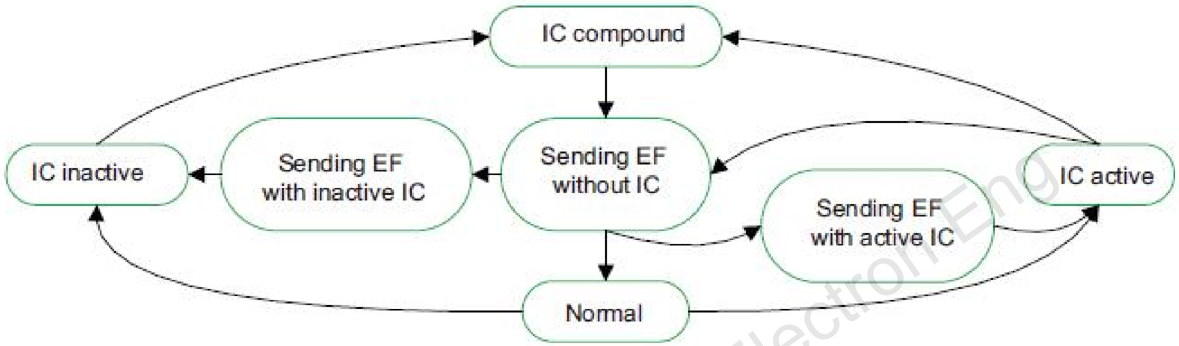

Fig. 3 Transition relationship among the controller area network states (EF: error frame; IC: intermittent connection)

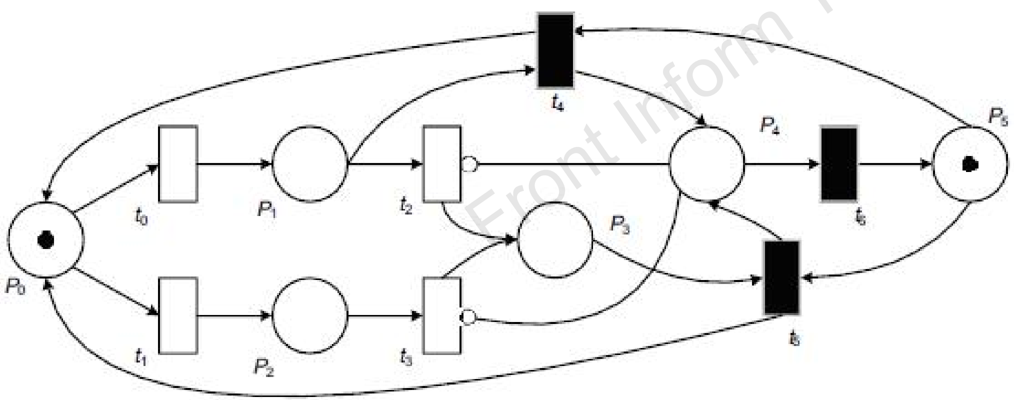

Fig. 4 DSPN model of the CAN bus when considering IC faults

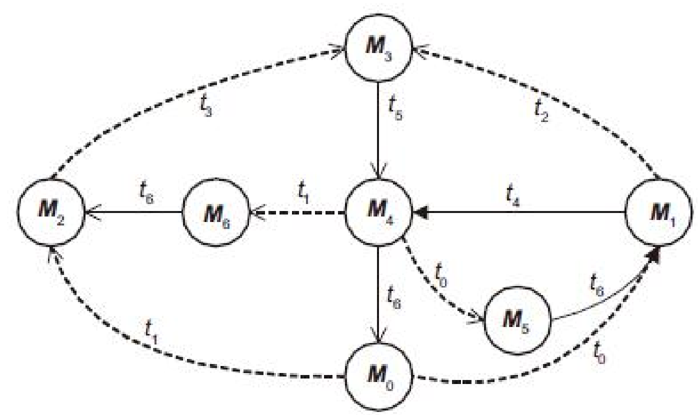

Fig. 5 Reachability graph of the DSPN model

The dashed arcs represent the firing of exponential transitions, and the solid arcs represent the firing of deterministic transitions

Conclusions

In this paper, we propose a DSPN model-based method to estimate the availability of CAN under IC faults using the estimated IC fault arrival rate. The fault arrival rate is estimated based on the counting model of error frames. The transition relationship among the network states when considering IC faults is described by a DSPN model. The model parameters are calculated based on the fault arrival rate. The probability distribution of network states is obtained by solving a Markov regenerative process, based on which the network availability is calculated. The experiment results show that the availabilities calculated by the proposed method match the actual values within a 0.5% error.

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