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Real-time based Superframe for ISA100.11a in Wireless Industrial Network

Oka Danil Saputra[1] and Soo Young Shin[2]

1. Department of IT Convergence, School of Electronic Engineering, Kumoh National Institute of Technology, Gumi-South Korea

2. Wireless Emerging Networking System Lab, Kumoh National Institute of Technology, 730-701, South-Korea

Abstract: In real-time WIN (wireless industrial network), the deadline is one of the main parameter should considered. Due to miss deadline, ultimately network performance decreases even in the worst case can lead to system failure. In this paper, we propose the real-time model of ISA100.11a superframe to enhance the performance of the network. Deadline Monotonic Scheduling is proposed to check the schedulability of superframe and OPNET model is used to evaluate the network performance. The main advantage of getting knowledge about scheduling of the superframe, we can guarantee data transmission and instead decreased the data to missing the deadline. The result show, our propose scheme is completed to pass the scheduling test and network performance increase likewise.

Key words: Real-time, deadline monotonic, superframe, ISA100.11a.

1. Introduction

Nowadays, wireless technology has grown rapidly that offers low cost, flexibility, reliability and ease of installation. An increasing number of wireless technologies force industries to develop a standard for wireless industrial networks. Currently, there are two kind of protocols are developed for an industry where both standards are namely Wireless HART and ISA100.11a. Furthermore, in term of the technical aspect, both standard relative similar while the physical layer is adopted based on IEEE 802.15.4 with 2 MHz bandwidth by using 2.4 GHz frequency band. The maximum data rate is supported up to 250 kb/s while direct-sequence spread spectrum (DSSS) is used for modulation scheme [1]. However, in Ref. [2] the author is verified that ISA100.11a has an advantage more interoperability with other protocol compared to Wireless HART. In next section, the detail discussion about related work is presented.

Corresponding author: Soo Young Shin, Professor, research fields: wireless LAN, WPAN, WBAN, wireless mesh network, coexistence among wireless networks, industrial network. E-mail: wdragon@kumoh.ac.kr.

2. Related Works

The ISA100.11a standard is developed to meet challenges for the industry to deploy wireless sensor network in their environments. The application is designed to follow [3]:

- Highly reliable data communication;
- Safe and secure networks;
- Robust against interference.

In case of reliable data communication, CSMA/CA (carrier sense multiple acces with collision avoidance) and TDMA (time division multiple access) are applied to to provide robust data exchange in networks. To specify the function of both algorithms, CSMA/CA is assigned to transmit non periodic data while the periodic data is delivered by using TDMA scheme. In Ref. [4], the author proposed a scheme to configure packet priority under different configuration parameters of CSMA/CA. For example, data of alarm or event get the higher probability to access the channel. Their result shows that, the transmission and queuing delay are reduced. However, scheduling effect in the network is disregarded by the authors. Meanwhile, in the term to provide secure and safe network, 2-step verification method is used in ISA100.11a network. ISA100.11a natively supports to upgrades the security policy. In order to optimize the security protocol, other article proposed scheme known as optimizing time schedule [5]. Their main target was to reduce the barrier number of data verification while in a network device try to join particular session communication for data communication.

As ISA100.11a operates in 2.4 GHz unlicensed band, a well-known as ISM (industrial scientific and medical) spectrum, the impact of coexistence protocol must be calculated. Due to this reason, the performance analysis of ISA100.11a under the IEEE 802.11a network is investigated in Ref. [6]. The author simulated scenario while the ISA100.11a node operate alongside with IEEE 802.11b device. According to their result, the minimum distance should be considered to operate both protocols in the same area. The interoperability of ISA100.11a with CAN protocol is investigated in Ref. [7]. The author proposed a gateway to gather data between ISA100.11a nodes and CAN nodes. Their results show that, ISA100.11a side is the main bottleneck and generate high end to end delay as compared with CAN edge. To observe the reason parameter why the ISA100.11a produced more delay, the evaluation of ISA100.11a network was proposed in Ref. [8]. The article clarifies that maximum back-off, time slot duration, and superframe period are the parameter effect on the network performance. However, about periodically data communication and scheduling test of superframe in the network has never been examined in previous work. In this work, we proposed the scheduling test of ISA100.11a superframe while deadline monotonic scheduling is used to check the test the superframe scheduling [9].

The rest of this paper is organized as follows. Section 3 shows system model while simulation result is presented in Section 4. Finally, the conclusion and future work is drawn in Section 5.

3. System Model

The model is developed close to the real-time ISA100.11a wireless industrial network by using OPNET Modeler Software [10]. The default wireless models of OPNET library is used in physical layer. Furthermore, there are fixed node N with denote the maximum number of the node located randomly in the network. The configuration of the system model is depicted in Fig. 1. The system is assumed operating as a monitoring system. The traffic scenario starts from the gateway as coordinator sent beacon periodically to N node in the network. We assume all message are periodic. In our model, three layers are assumed to represent the ISA100.11a gateway and node model as shown in Fig. 2. The battery module is used to produce the power supply for node but in our case this module is switched off mode. The packet are generated by traffic source and GTS (guaranteed time slot) in the application layer. The traffic sink is used to receive the data from MAC (media access control) layer. MAC layer itself consist wpan_mac and synchro. The CSMA/CA and GTS process model are determined to construct the MAC. The main function of synchro is produced the beacon and transmitted to the network. Furthermore, beacon and all the message determined the superframe pattern. The configuration of the superframe is constructed by two parameters, the superframe period and beacon interval as shown in Eq. (1).

$$S = B + \sum_{N=1}^{N=\eta} M_N \tag{1}$$

where, S, B and η are the superframe, beacon, and maximum number of nodes in the network. In our scheme, we added 25 time slot which is the maximum number of superframe slot allow by standard [11]. Also we used that deadline monotonic scheduling technique, the detail about scheduling analysis and message parameter is presented in Ref. [12].

4. Simulation Result

In order to evaluate the performance of proposed

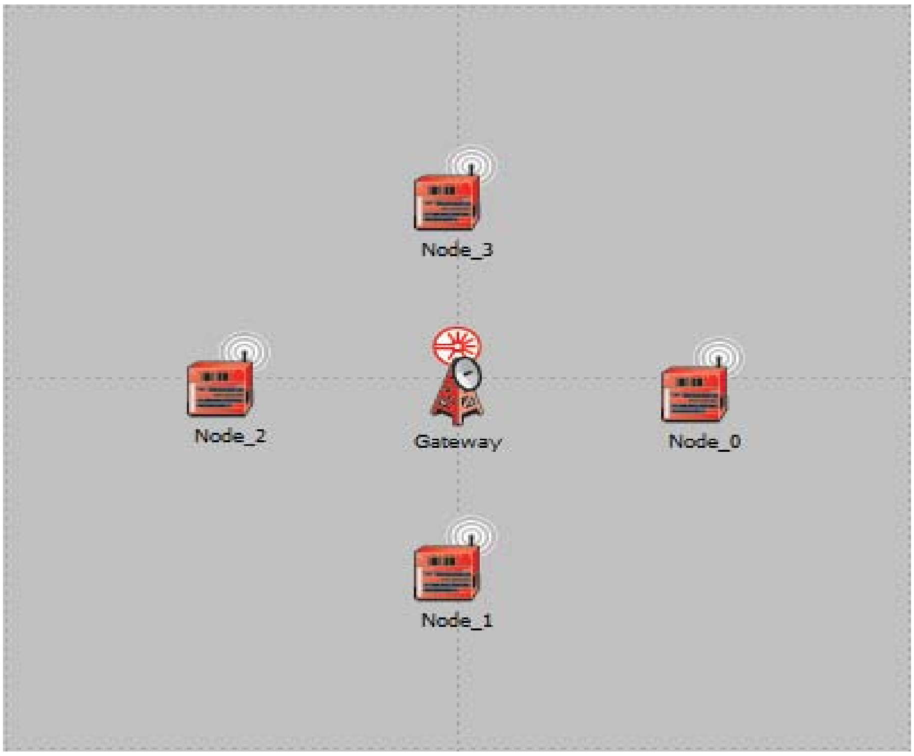

Fig. 1 System model of ISA100.11a networks.

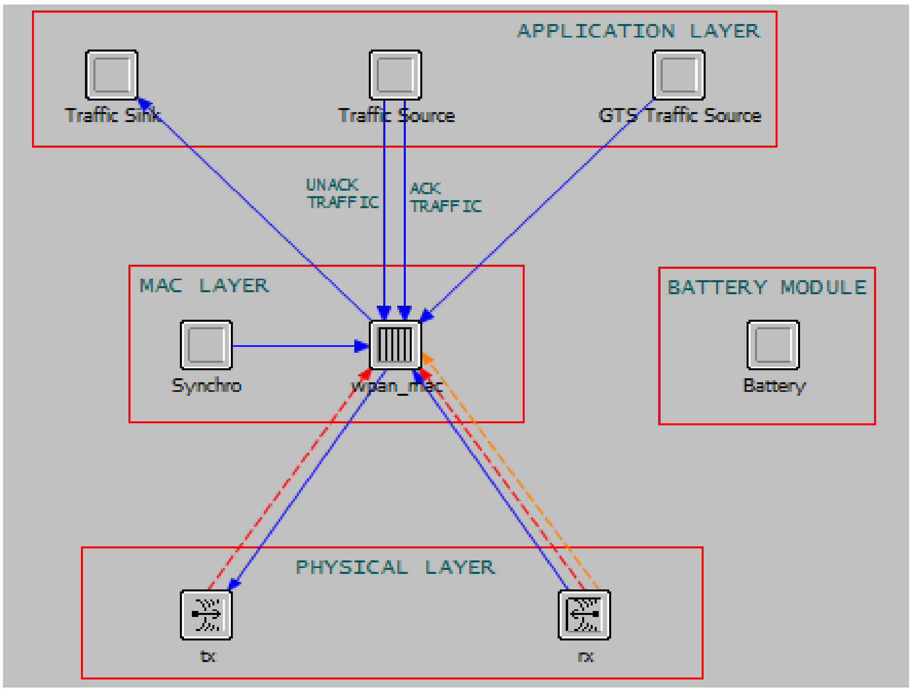

Fig. 2 System model of ISA100.11a gateway and end node.

scheme in ISA100.11a networks and MATLAB program is developed [11]. The objective of investigation is to test the schedulability of superframe ISA100.11a network. Table 1 shown the parameter of message uses in the simulation. In this scheme, deadline monotonic scheduling, a message with the lowest deadline had priority to occupy the superframe and transmit data first as compared the other lower deadline. For example, in case of node 4 (layer 1) and node 2 (layer 3), the data communication of node 4 is assigned first and in next superframe time slot followed by data from node 2. We can figure out that all messages satisfy to complete computation time before the deadline as presented in Fig. 3.

Table 1 Simulation parameter in deadline monotonic scheduling test.

	Release (ms)	Period (ms)	Deadline (ms)	Computation (ms)
Beacon	0	250	10	10
Node 1	10	150	20	20
Node 2	20	80	80	20
Node 3	30	100	100	30
Node 4	40	50	50	10

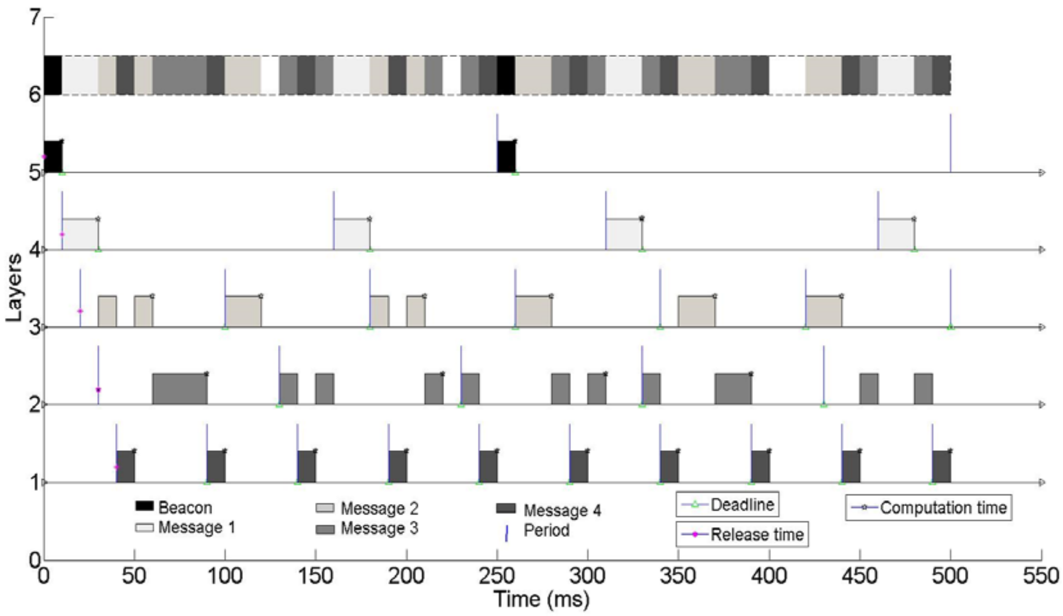

Fig. 3 Scheduling test is applied in ISA100.11a superframe.

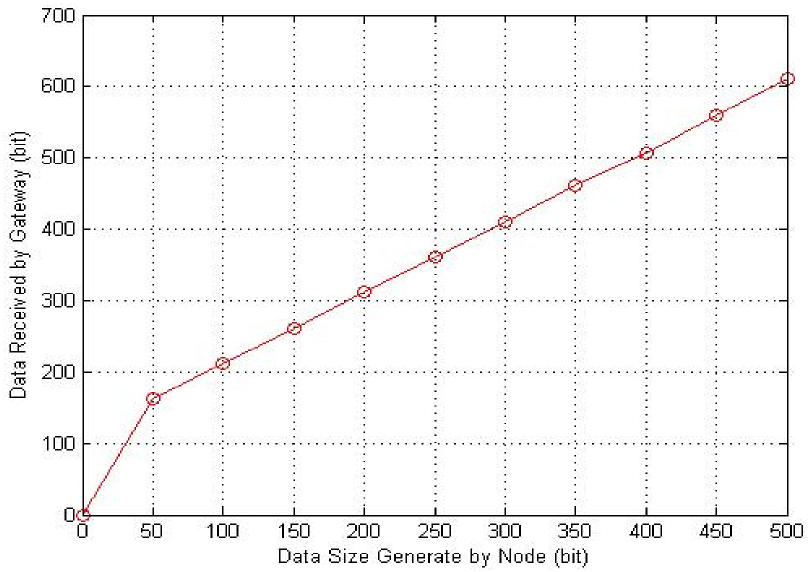

Fig. 4 Data is received by the gateway in traffic sink.

The result of data is received by the gateway in traffic sink shown in Fig. 4. In our case, we set 4 number of fixed node while one Gateway is located in the center of the network. The poisson distributed mean is assigned as the packet size with vary value 50 bit. The packet interval time is followed based on table 1. As the expected, the result presents the graph which is data receive by gateway proportional with increased number of packet generates by node.

5. Conclusion

In this paper, an application of deadline monotonic scheduling is proposed to check and test superframe scheduling. We also demonstrated the schedulability test by using the deadline monotonic scheduling. The OPNET model is developed to evaluate the network performance. Hence, the proposed method could assign more data to be sent in the network. For future work, we will examine multi-tree and multi-channel by apply Nash equilibrium approach from game theory.

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