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Feasibility analysis of hybrid control networks based on common industrial protocol

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ABSTRACT

This paper reports a feasibility analysis of the use of a hybrid control network based on the Common Industrial Protocol (CIP). For this feasibility analysis, the message service time between DeviceNet and the wireless devices is investigated. The feasibility of hybrid control networks is analyzed using a mathematical analysis and experimental tests. The experimental results show the feasibility of the hybrid control networks in terms of the polling/COS service time and the average end-to-end delays.

1. Introduction

Hybrid control networks have been used as solutions for industrial networks. At the field-level of FA (factory automation), a wired/wireless control network can be a useful tool. However, a hybrid control network has several problems in relation to real-time communication, reliability, and compatibility with an existing Fieldbus network.

A hybrid control network has stringent requirements for control applications. However, the specific properties of the wireless channel make it difficult to meet the real-time communication, reliability, and compatibility requirements in industrial environments [1,2].

Several studies have been performed on hybrid control networks. In [2], the extension of Fieldbus to wireless nodes was presented. This hybrid control network was based on PROFIBUS-DP, with wireless networks for FA.

In [3], two models were presented that used IEEE 802.11 and Bluetooth for wireless networks at a low level of factory automation. This study gave the mean update time and the alarm latency versus packet error rate for IEEE 802.11 and Bluetooth. In [4], a wireless transmission technology based on IEEE 802.11 with PROFIBUS was proposed. However, it showed that IEEE 802.11 was not a suitable protocol for PROFIBUS. In [5,6], the implementation of a hybrid control network that used PROFIBUS-DP with Bluetooth was presented. A theoretical framework was discussed that enables the evaluation of two performance metrics: the cycle time and alarm latency.

To the best knowledge of the authors, a feasibility analysis of a hybrid control network based on the CIP has never been reported in the technical literature. This paper describes a mathematical framework for analyzing a hybrid control network based on the CIP. The feasibility analysis is presented on the basis of the results of experiments. A Bluetooth gateway [7] and Elpro's wireless gateway [8] on DeviceNet are used for the experimental tests.

This paper is organized as follows. The following section presents a problem analysis of the hybrid control network. Section 3 presents a mathematical analysis for the feasibility analysis of the time delay for each system. In Section 4, the feasibility analysis of the hybrid control network is analyzed using the experimental results. Finally, the conclusions are given in Section 5.

2. Problem analysis of the hybrid control network

Protocol selection is essential in the design of a hybrid control network with specific requirements. The solution lies in the use of the available wireless technologies, provided that these wireless technologies are able to cope with the field-level communication requirements at the data link layer. The reuse of the protocols defined for the Fieldbus is desirable at the application layer because these protocols have demonstrated their effectiveness in wired applications [5].

2.1. Common Industrial Protocol (CIP) and DeviceNet

DeviceNet uses the CIP as an upper layer. The CIP is object-oriented, and each object has attributes (data), services (commands), and behavior (reaction to events). Since CIP-based networks are based on a common application layer, the application data remain the same regardless of which network hosts the device.

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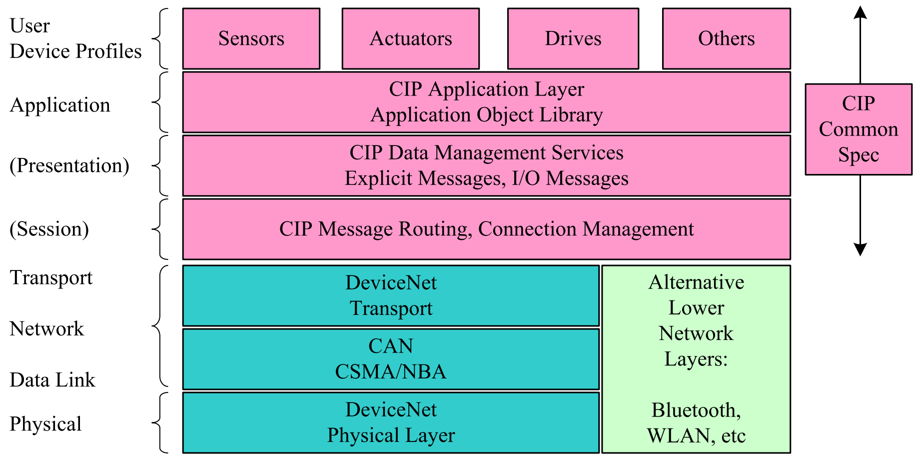

Fig. 1. CIP object model.

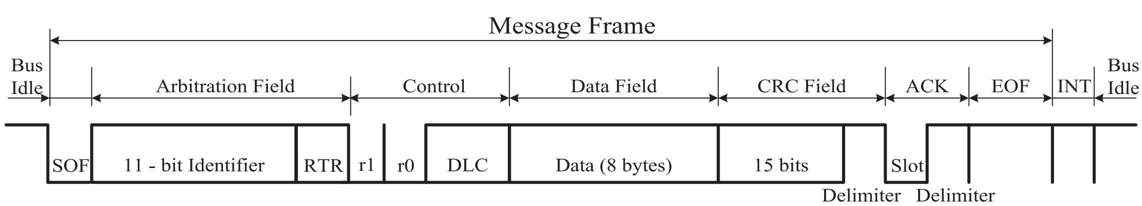

Fig. 2. Frame format of DeviceNet.

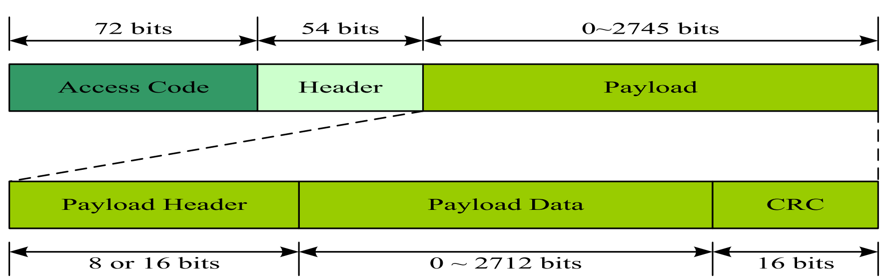

Fig. 3. Frame format of Bluetooth.

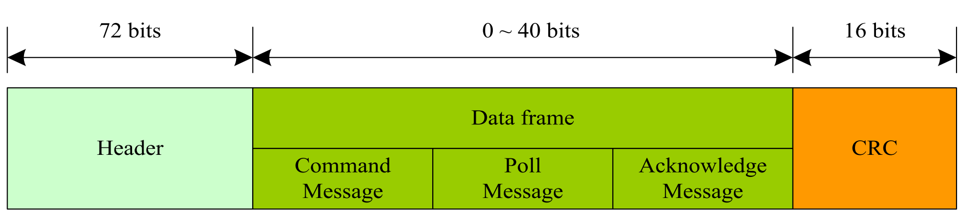

Fig. 4. Frame format of wireless protocol.

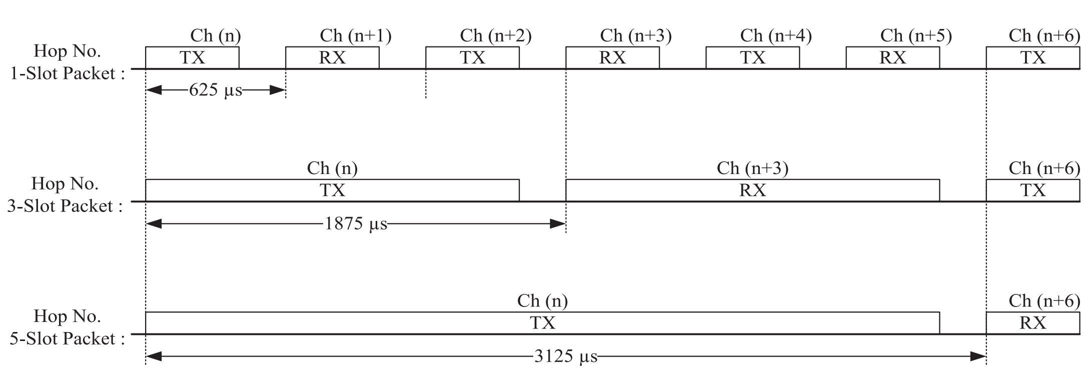

Fig. 5. Slot timing for multi-slot packets on Bluetooth.