Bluetooth and Wireless Multihop Networks in Industrial Communication Systems

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Abstract

The objective of this thesis is to investigate the use of short-range wireless communication technology in industrial communication systems where there is a need for guaranteed timely delivery of correct information. Methods for achieving such capability are developed in the context of the physical layer, the data link layer and the application layer. Based on the insight that it is impossible to achieve strict determinism in a wireless communication system, a probabilistic definition of hard real-time systems is suggested, and thus a guarantee is given in the form of the probability of fulfilling a certain goal. Since a wireless channel is time variant, it is also necessary to continuously keep track of available resources. Allocation and link management methods for wireless communication systems therefore need to be dynamic and of an online character. An exhaustive resource allocation method with redundancy is first proposed for single message delivery and then extended for the operation of a single Bluetooth piconet. However, many devices in an industrial automation system have limited computational resources, especially if wireless sensors/actuators powered by battery or wireless power are considered. This implies that methods used for resource allocation must be of low computational complexity. The complexity issue becomes evident when large systems are implemented, even if each individual sensor generates small amounts of data. The upstream and downstream flows of data grow rapidly in a hierarchical system with many sub-systems, sensors and actuators. It is empirically shown that the aggregated data flow in a monitoring system requires powerful communication nodes already at low levels in the industrial communication hierarchy. A predictable system requires that representative entities for the available resources are defined. In a communication system with a single broadcast domain, such as a single Bluetooth piconet, the resource space is often limited to the time domain. When a multihop wireless network with multiple broadcast domains is considered, the spatial domain is added as an available resource and, if a multi-channel radio transceiver is used, the frequency is also added as an available resource domain. These three domains represent the physical resource space that is available for a wireless multihop network. These are subject to trade-off in all of the three lowest protocol layers, and one of the most challenging problems in the design of a wireless multihop network is how to achieve efficient sharing of these resources. This problem is addressed by proposing a clustered architecture based on a dual-radio node that enables dynamic use of these resource domains.

Keywords: Bluetooth, industrial communication systems, short range devices, wireless multihop networks, wireless sensor networks, real-time communication, resource allocation