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Relaying for Timely and Reliable Message Dissemination in Wireless Distributed Control Systems

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Abstract

Distributed control applications enabled by wireless networks are becoming more and more frequent. The advantages of wireless access are many, as control systems become mobile, autonomous and connected. Examples include platooning and automated factories. However, distributed control systems have stringent requirement on both reliability and timeliness, the latter in terms of deadlines. If the deadline is missed, the packet is considered useless, similarly to a lost or erroneous packet in a system without deadlines. In addition, wireless channels are, by nature, more exposed to noise and interference than their wired counterparts. Consequently, it implies a considerable challenge to fulfill the deadline requirements with sufficient reliability for proper functionality of distributed control applications. However, by taking advantage of cooperative communications, increased reliability can be achieved with little or no additional delay.

Reducing the delay until a message is successfully received is a two-fold problem: providing channel access with a predictable maximum delay and maximizing the reliability of each transmission, once granted by the medium access method. To this end, this thesis proposes a framework that provides a bounded channel access delay and handles the co-existence of both time-triggered and event-driven messages encountered in distributed control applications. In addition, the thesis proposes and evaluates an efficient message dissemination technique based on relaying that maximizes the reliability given a certain deadline, or alternatively determines the delay required to achieve a certain reliability threshold for both unicast and broadcast scenarios. Numerical results, which are verified by Monte-Carlo simulations, show significant improvements with the proposed relaying scheme as compared to a conventional scheme without cooperation, providing more reliable message delivery given a fixed number of available time-slots. It also becomes clear in which situations relaying is preferable and in which situations pure retransmissions are preferable, as the relay selection algorithm will always pick the best option. The relay selection algorithm has a reasonable complexity and can be used by both routing algorithms and relaying scenarios in any time-critical application as long as it is used together with a framework that enables predictable channel access. In addition, it can be implemented on top of commercially available transceivers.