Abstract

Recently, the IEEE 802.15.6 Task Group introduced a new set of physical layer and medium access control sublayer protocols for wireless communication involving wireless body area networks (WBANs). The IEEE 802.15.6 standard is designed specifically to support short-range (within 10 m), ultra-low power wireless communications with very high data rate (up to 10 Mbps) within or in the vicinity of human body. The fundamental changes proposed through the standard are introduction of eight user priorities (UPs) based on the traffic designation, and the corresponding sets of minimum and maximum values for the contention window. However, one of the most important changes introduced through the standard is the work-flow of the IEEE 802.15.6 CSMA/CA MAC protocol, where a transmitting node may lock its backoff counter under certain conditions and unlock the same upon the resumption of favorable conditions, which is unlike any previously known CSMA/CA protocol. This backoff counter locking mechanism ensures higher reliability in data transmission for nodes operating in higher user priority (UP), and prevents the nodes from transmitting data frames without checking the channel conditions and superframe status, which in turn, significantly decreases the probability of frame collision. However, on the other hand, in the process of ensuring higher reliability in data transmission, a node may suffer from starvation, i.e., it may have to wait for a prolonged duration of time, while the other nodes in the network might be transmitting. This leads to undesirable delay in data transmission, and under saturated traffic conditions, may even lead to transmission of old data packets or packet loss in the process of prolonged starvation. Specifically, for nodes attempting to transmit frames of lower UP, a higher value of backoff counter is chosen with higher probability, which leads to locking of the backoff counter of a longer period, thereby incurring additional delay during the process.

The thesis investigates the impact of the backoff counter locking mechanism on the transmission latency in the IEEE 802.15.6 CSMA/CA protocol and proposes a solution to the problem. As a first step towards this contribution, a discrete-time Markov chain (DTMC) is designed, which models the different states of a node operating in the standard. Based on the DTMC constructed, the delay introduced during frame transmission is probabilistically quantified in the following step, and UP-wise analysis of the effects of the different factors is presented. Upon analysis, the thesis proposes the Fair and Latency-aware backOff cOunter Decrement (FLOOD) algorithm, which optimizes the delay incurred during frame transmission. Results confirm that the proposed modified CSMA/CA algorithm substantially improves the mean frame transmission latency under saturated traffic conditions compared to that for the original IEEE 802.15.6 CSMA/CA regime.

The thesis also aims at proposing a context-aware frame transmission algorithm, which ensures prioritized transmission of data frames, based on certain crucial properties of the transmitting WBAN and the criticality of the data being transmitted. The proposed Priority-based Allocation of Time-Slots (PATS) algorithm runs as an application routine and is executed on top of the FLOOD algorithm, which operates in the underlining MAC sublayer. The PATS algorithm is based on the constant model hawk-dove game, which is a variant of evolutionary game. Together, these two routines — FLOOD and PATS — lead to transmission of data frames with minimum delay incurred while ensuring prioritized transmission for critical WBANs.

Keywords: Wireless body area networks (WBANs), IEEE 802.15.6, discrete-time Markov modeling, delay optimization.