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Study and Analysis of IEEE 802.15.4 Media Access Control (MAC)

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Abstract

The Low rate wireless Personal Area Networks (LR-WPAN) allows the optional use of a superframe structure. The superframe is bounded by network beacons and is divided into 16 equally sized slots. The superframe can have an active and an inactive portion. During the inactive portion, the coordinator shall not interact with its PAN and may enter a low-power mode. The format of the superframe is defined by the coordinator. The active portion consists of Contention Access Period (CAP) and contention free period (CFP)

Keywords: MAC, CSMA, Contention Access Period.

Introduction

Detection of the human face is an essential step in IEEE 802.15.4 standard represented a significant break from the "bigger and faster" standards that the IEEE 802 organization continues to develop: instead of higher data rates and more functionality, this standard was to address the simple, low-data volume universe of control and sensor networks, which existed without global standardization through a miasma of proprietary methods and protocols [1]. The lack of a standard approach and protocol was seen that would serve to drive down the cost per node of these networks.

This standard defines the protocol and interconnection of devices via radio communication in a personal area network (PAN). The standard uses **C**arrier **S**ense **M**ultiple **A**ccess with collision avoidance (CSMA-CA) medium access mechanism and supports star as well as peer-to-peer topologies [2]. The media access is contention based; however, using the optional superframe structure, time slots can be allocated by the PAN coordinator to devices with time critical data. Connectivity to higher performance networks is provided through a PAN coordinator.

The MAC sublayer provides two services: the MAC data service and the MAC management service interfacing to the MAC sublayer management entity (MLME) service access point (SAP) (known as MLME-SAP). The MAC data service enables the transmission and reception of MAC protocol data units (MPDUs) across the PHY data service.

802.15.4 : MAC

The MAC sub layer provides an interface between the service-specific convergence sub layer (SSCS) and the PHY. The MAC sub layer conceptually includes a management entity called the MLME. This entity provides the service interfaces through which layer management functions may be invoked. The MLME is also responsible for maintaining a database of managed objects pertaining to the MAC sub layer. This database is referred to as the MAC sub layer PIB. The MAC sub layer provides two services:

The MAC data service and The MAC management service interfacing to the MAC sub layer management entity (MLME) service access point (SAP) (MLMESAP). The MAC data service enables the transmission and reception of MAC protocol data units (MPDU) across the PHY data service. The features of MAC sub layer are beacon management, channel access, GTS management, frame validation, acknowledged frame delivery, association and disassociation[2].

Superframe Structure

The superframe structure is an optional part of a WPAN. It is the time duration between two consecutive beacons. The structure of the superframe is determined by the coordinator.

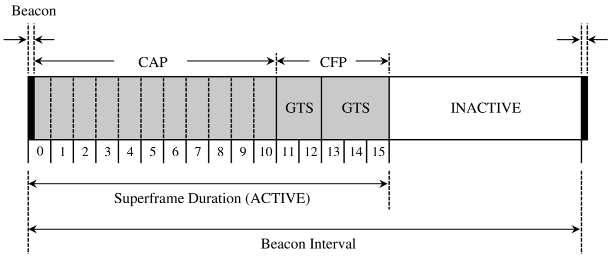

Fig.1:Superframe Duration Structure

The coordinator can also switch off the use of a superframe by not transmitting the beacons. The superframe duration is divided into 16 concurrent slots. The beacon is transmitted in the first slot. The remaining part of the superframe duration can, shown in fig.1, be described by the terms, Contention Access Part (CAP), Contention Free Period (CFP) and Inactive.

The superframe can have an active and an inactive portion. During the inactive portion, the coordinator shall not interact with its PAN and may enter a low-power mode. The active portion consists of contention access period (CAP) and contention free period (CFP). Any device wishing to communicate during the CAP shall compete with other devices using a slotted CSMACA mechanism. On the other hand, the CFP contains guaranteed time slots (GTSs). The GTSs always appear at the end of the active super frame starting at a slot boundary immediately following the CAP. The PAN coordinator may allocate up to seven of these GTSs and a GTS can occupy more than one slot period. The superframe is used to provide vital statistics like synchronization, identifying the PAN and the superframe structure, to the devices connected in a Wireless PAN. This information is critical for the operation of the PAN in a Beacon enabled network[2].

CSMA-CA Algorithm

When more than one station attempts to transmit a frame at the same time, a collision occurs, and subsequently all frames get corrupted. The standard mechanism for contention resolution in computer networks is called carrier-sense multiple access (CSMA).

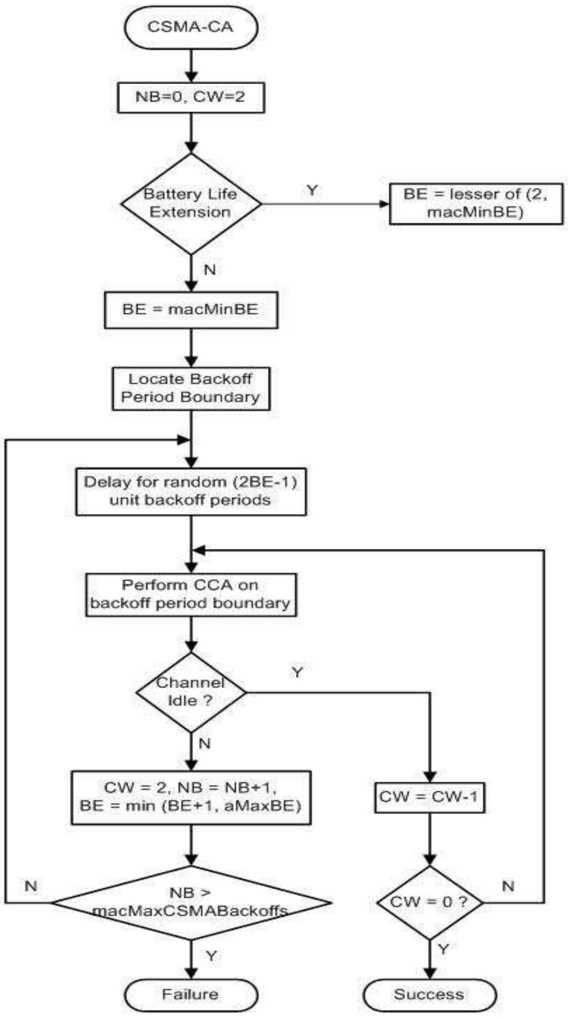

Fig.2 Flowchart showing CSMA-CA Algorithm

As shown in Fig.2, the flowchart CSMA algorithms attempt to break symmetries of failing transmissions being restarted at almost the same time by using randomized binary exponential back off procedures. While wired devices can listen during their own transmissions and employ CSMA with collision detection (CSMA/CD), stations in wireless networks usually cannot listen to their own transmissions, and consequently colliding transmissions can only be detected after they have been completed. Thus wireless devices use CSMA with collision avoidance (CSMA/CA or CSMA-CA). If superframe structure is used in the PAN, then slotted CSMA-CA shall be used. If beacons are not being used in the PAN or a beacon cannot be located in a beacon-enabled network, un-slotted CSMA-CA algorithm is used. In both cases, the algorithm is implemented using units of time called ***Backoff Periods***, which is equal to a Unit Backoff Period symbols. In slotted CSMA-CA channel access mechanism, the

Backoff period boundaries of every device in the PAN are aligned with the superframe slot boundaries of the PAN coordinator. In slotted CSMA-CA, each time a device wishes to transmit data frames during the CAP, it shall locate the boundary of the next backoff period. In unslotted CSMA-CA, the Backoff periods of one device do not need to be synchronized to the Backoff periods of another device [x].

Analysis of Contention Access Period in MAC

In this article, the performance analysis of the CAP of the IEEE 802.15.4 superframe has been done by modelling it as non-persistent CSMA with Backoff. Markov models are developed separately for the channel and node states, to determine the fractions of time that a node spends in different states, which are then used to determine the throughput and energy consumption characteristics [3]. We then analyse the standard that could potentially improve the throughput and energy consumption in general.

A node is in an IDLE state when it does not have a packet to transmit. When it receive a packet to transmit in backoff slot (with probability p), it transition to the random backoff stage, BO_1, corresponding to the first backoff attempt. The backoff exponent BE=3 for the first backoff BO_1, the number of backoff slots that the node spend in BO_1 is random variable drawn uniformly between 0 and 2^{BE} -1=7. Now replace this uniform random variable with a geometric random variable with parameter $P^n{}_{1}$. After leaving the BO1, the node moves to CS11 state, which corresponds to the first of the two backoff slots a node confirm that the channel is idle or not. If the channel is found to be idle in the first backoff slot, with probability P_i^c , the node moves to the next state i.e. CS12 at the next backoff slot3. The notation CS12 denotes the second backoff slot corresponding to the first stage backoff stage, BO1. In general, CSij 1≤i≤5, 1≤j≤2, to denote the jth carrier sensing backoff slot after ith random backoff stag, BOi. If the node again finds the channel to be idle, it enters transmits (TX) state and starts transmitting the packet. The probability of the finding the channel idle in the second backoff slot does not equal P_i^c since the channel state is not independent between backoff. We characterize the probability that the second backoff slot in idle by the conditional probability $P^c{}_{i|i}$, which is the probability that the channel is the idle in the second backoff slot given that it is idle in the first backoff slot. When the node is in the TX state, it spend N backoff slots in that state(since length of a packet, in terms of number of backoff slots, is equal to N) and then transitions to the IDLE state with probability 1.

If the channel busy when the node state in CS11 or CS12 states, with probabilities $(1-P^c{}_i)$ and $(1-P^c{}_{i|i})$ respectively, the node transition to the second backoff stage BO2. The number of backoff slots X2 that the node spends in BO2 is geometrically distributed with parameter given as- $P^n{}_2 = 1/8.5$, since BE=4 for BO2:

The main emphasis is on the evaluation of the performance of IEEE802.15.4 standard MAC layer and our interest is in the analysis of the performance of the contention access part (CAP) of IEEE 802.15.4 MAC. We also will evaluate channel throughput and average power consumption per node during contention access period (CAP).

Conclusion

In this paper we provided an overview of IEEE 802.15.4 and MAC layer. Next, we analyzed CSMA-CA algorithm, and its standards, and medium access strategies. Thus, we can analyse the impact of various modelling decisions on model checking performance and accuracy of results. Also, we can consider different parameters for operation mode viz. unslotted and slotted, modelling of the data frame length (fixed or nondeterministic), and granularity of the timescale abstraction, in terms of its throughput and energy.

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