Poster

An Efficient approach to Multisuperframe tuning for DSME networks

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Abstract

Deterministic Synchronous Multichannel Extension (DSME) is a prominent MAC behavior first introduced in IEEE 802.15.4e that supports deterministic guarantees using its multisuperframe structure. DSME also facilitates techniques like multi-channel and CAP reduction that help to increase the number of available guaranteed timeslots in a network. However, no tuning of these functionalities in dynamic scenarios is supported in the standard. In this paper, we present an effective multisuperframe tuning technique that also helps to utilize CAP reduction in an effective manner improving flexibility and scalability, while guaranteeing bounded delay.

Poster Abstract: An Efficient approach to Multisuperframe tuning for DSME networks

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ABSTRACT

Deterministic Synchronous Multichannel Extension (DSME) is a prominent MAC behavior first introduced in IEEE 802.15.4e that supports deterministic guarantees using its multisuperframe structure. DSME also facilitates techniques like multi-channel and CAP reduction that help to increase the number of available guaranteed timeslots in a network. However, no tuning of these functionalities in dynamic scenarios is supported in the standard. In this paper, we present an effective multisuperframe tuning technique that also helps to utilize CAP reduction in an effective manner improving flexibility and scalability, while guaranteeing bounded delay.

KEYWORDS

IEEE 802.15.4e, DSME, Multisuperframe tuning

1 INTRODUCTION

IEEE 802.15.4 [2] was one of the legacy protocols that supported low-rate communication with Guaranteed Time Slot (GTS) allocation mechanism that provides guaranteed bandwidth for time-critical data. However, it was not able to provide more scalability as the number of GTS provided was restricted to 7. The enhancement of this protocol, the IEEE 802.15.4e [1], rectifies this problem by the provision of multichannel and CAP reduction. DSME is supported by a multisuperframe structure (Fig. 1) which is a stack of several superframes containing Contention Access Period (CAP) and Contention Free Period (CFP) for communication. DSME introduces a new technique called CAP reduction with which the number of GTS resources to accommodate transmissions can be further increased by removing the CAP in the multisuperframe except for the first.

In our previous research [4], we observed the network throughput of normal DSME networks with CAP reduction and found it to be 7% better. Works such as [3], [6] have used algorithms to adjust Superframe Order (SO) at the coordinator by considering parameters of end devices such as queue size, queuing delay, energy consumption per bit and data rate. This helped in improving the overall network life time. Dynamic tuning of the multisuperframe has a possibility to yield better network performance, hence we investigated several scenarios of a DSME and proposed a dynamically tunable multisuperframe scheme that yields better performance. In what follows, we present the system model in which we provide a brief introduction to DSME networks and the CAP reduction technique. Then we present some of our models and preliminary results on delay analysis.

2 SYSTEM MODEL

The DSME network provides deterministic communication using its beacon enabled mode in which the entire time frame is separated into multisuperframes accommodating several superframes as shown in Figure 1. The superframe is defined by *BO*, the *MAC Beacon Order* which is the transmission interval of a beacon in a superframe. *MO* is the *MAC Multi superframe Order* and it represents the beacon interval of a multi-superframe. The number of superframes in a multisuperframe can be given by $2^{(MO-SO)}$ and the number of superframes that a multisuperframe should accommodate is set by the PAN coordinator and is conveyed to the nodes via an Enhanced Beacon (EB) at the beginning of each Multisuperframe. As an example, in (T1-T2) of Figure 1, two superframes with MO=3 and SO=2 are combined to a Multisuperframe.

Under CAP reduction, all the superframes in a multisuperframe can be converted into complete CFPs except for the first (T2-T3) of Figure 1. In accordance to the standard, both CAP reduction and MO are determined statically at the start of a multisuperframe by the PAN-C. The network statically defined at the beginning will have limited capabilities to cope with constantly evolving network with joining and leaving of the nodes. Some of the adverse results can be *an improper bandwidth allocation either due to not enough GTS slots or to wasted bandwidth increasing the contribution to the delay.*

Having a routing layer such as RPL over DSME is fundamental mechanism to solve this problem. In our approach, RPL provides at everybeacon interval, an updated routing tree of the varying network topology to the PAN-C via its RPL backbone. As the number of nodes changes (via association/disaocciation), RPL updates this information and the PAN-C generates a schedule spread into the available GTSs resources. In our contribution, we designed an algorithm that is able to set the most adequate value of MO and toggle CAP reduction based on the needed resources. This information will be sent in the beacon payload of an EB at the beginning of every multisuperframe. A detailed report on implementing RPL over DSME can be found in [5].

3 DELAY ANALYSIS

For our delay analysis, we consider a time-critical DSME mesh network with S nodes under the network coverage of the PAN Coordinator. The schedule of the topology will be sent for every multisuperframe duration and every device is allocated with one

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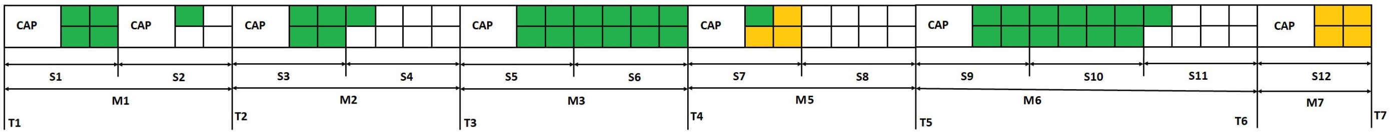

Figure 1: multisuperframes in DSME network

or more GTS based on the topology issued by RPL. We assume that the maximum number of GTSs available in a multisuperframe is δ_{SN}, where N is the number of CFPs encompassed in the specific multisuperframe. Every CFP will have δ_S GTSs. Let T_{CAP} and T_{MS} be the duration of the CAP and multisuperframe slot respectively. T_{MD} be the total number of symbols forming the multisuperframe, T_{MD_i} be the total number of symbols forming the multisuperframe since the value of $SO = 0$,

$$T_{MS} = \frac{T_{MD}}{CAP + \delta_S} = T_{MD_i} \times 2^{MO-4} \quad (1)$$

A single GTS can span across several superframe slots, we should provide a constraint on it. GTS must be greater than the total forward delay $\vartheta_N D_{max}$. Let us consider θ_{min} to be the minimum number of superframe slots a single GTS can extend over.

$$\theta_{min} = \left\lceil \frac{\vartheta_N D_{max}}{T_{MS}} \right\rceil \quad (2)$$

Under CAP reduction the absolute number of GTSs is not certain as it varies on MO, however it can be expressed as $m \times T_s$ where m is the number of channels and T_s is the number of timeslots in CFP. From these, the maximum number of GTSs that can be allocated to devices can be given by:

$$\delta_{SN} = min\left(\left\lceil \frac{(CAP + \delta_S)(1 - \frac{T_{CAP}}{T_{MS}})}{\theta_{min}} \right\rceil, m \times T_s\right) \quad (3)$$

For the need of simplicity, we consider a CFP with just 2 timeslots and 2 channels (4 available GTSs resources), this can be generalized for a larger number of channels. We consider a multihop scenario with different number of transmissions for our experiment.

Based on our equations we performed a delay analysis for three cases shown over the timeline of Figure 1. *Case i:* a normal DSME network with no CAP reduction (T1-T2), *Case ii:* DSME network with CAP reduction but with a fixed MO - (T4-T5) excess resources and exhausted resources (T3-T5), *case iii:* DSME network with a dynamic MO that changes with the addition of nodes in the network - exhausted resources increasing MO (T5-T6), excess resources (T6-T7) - decreasing MO and deploying CAP reduction. We calculated the delay for the network for all the use cases as mentioned above. For fixed CAP reduction scenarios we take the value of MO to be 3 and SO as 2. From Figure 2, it can be noticed that with Dynamic change in MO with respect to needed resources, we can reduce the delay by 5-30 %

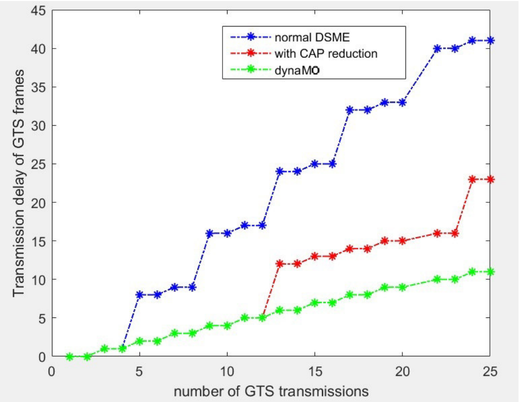

Figure 2: Comparison in terms of delay

4 FUTURE WORK

In this paper we showcased an efficient multisuperframe tuning technique and usage of CAP reduction to reduce delay by 5-30%. As a future scope of this research work, we intend to implement our model in a network simulator to check the performance of the algorithm for different network topologies.

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