Proceeding Paper

Temporary Resource Allocation for Event-driven Traffic in IEEE 802.15.4 DSME

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Abstract: This paper proposes a temporary resource allocation (TRA) scheme for IEEE 802.15.4 DSME networks to improve resource utilization under event-driven traffic. Unlike the static resource allocation in legacy DSME, TRA dynamically distinguishes periodic and event-driven traffic using a flag and assigns temporary SAB sub-blocks accordingly. Temporary resources are automatically released in the next multi-superframe to enhance adaptability. Simulation results show that TRA outperforms legacy DSME in resource utilization and overall network performance under varying traffic conditions, demonstrating its effectiveness in managing dynamic traffic patterns.

Keywords: DSME, event-driven traffic, IEEE 802.15.4, temporary resource allocation

1. Introduction

The deterministic and synchronous multichannel extension (DSME), standardized in IEEE 802.15.4-2015 [1], provides a medium access control (MAC) protocol optimized for reliable communication in low-power, bandwidth-constrained Internet of Things (IoT) environments. By enabling concurrent transmissions across multiple channels, DSME reduces the probability of collisions and enhances channel utilization. Nodes operate based on a multi-superframe structure and employ a time division multiple access (TDMA) mechanism to allocate resources known as guaranteed time slots (GTSs), thereby ensuring deterministic communication latency [2]. Figure 1 illustrates an example of the multi-superframe structure.

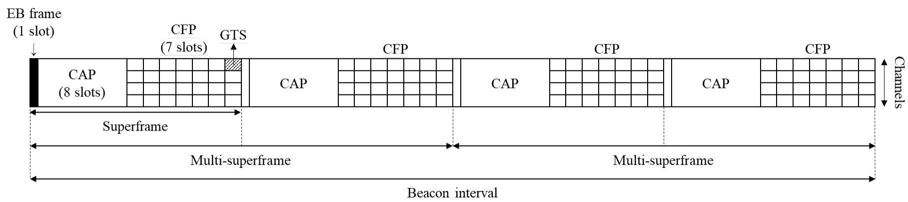

Figure 1. DSME multi-superframe structure.

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A multi-superframe consists of a repeating cycle of superframes, each divided into 16 slots categorized into the Enhanced Beacon (EB) frame, the contention access period (CAP), and the contention-free period (CFP). The first slot is dedicated to the EB frame, during which the coordinator transmits the EB. The subsequent 8 slots, immediately following the EB period, constitute the CAP, where nodes exchange control commands using carrier sense multiple access with collision avoidance (CSMA/CA). The remaining slots are allocated for the CFP, with each slot corresponding to a GTS, facilitating communication based on these slots.

To manage DSME GTS allocations within a DSME network, each node maintains two essential data attributes: the slot allocation bitmap (SAB) and the allocation counter table (ACT). The SAB is a bitmap that records the status of GTSs allocated within a multi-superframe for the node and its one-hop neighboring nodes. Each bit in the SAB indicates whether a CFP slot is being utilized as a GTS (1 for used, 0 for available). The ACT is a data table that contains the information necessary for managing the allocated GTS.

Meanwhile, DSME maintains fixed GTS allocations across superframes. However, deallocation occurs only when a slot remains unused for more than 7 consecutive multi-superframes. This expiration-based mechanism can result in inefficient resource utilization under dynamically varying traffic conditions.

To address this issue, we propose a temporary resource allocation (TRA) scheme specifically designed for event-driven traffic in DSME networks. TRA enables flexible and responsive slot allocation without the need for complex superframe reconfiguration or frequent control signaling.

2. Temporary resource allocation

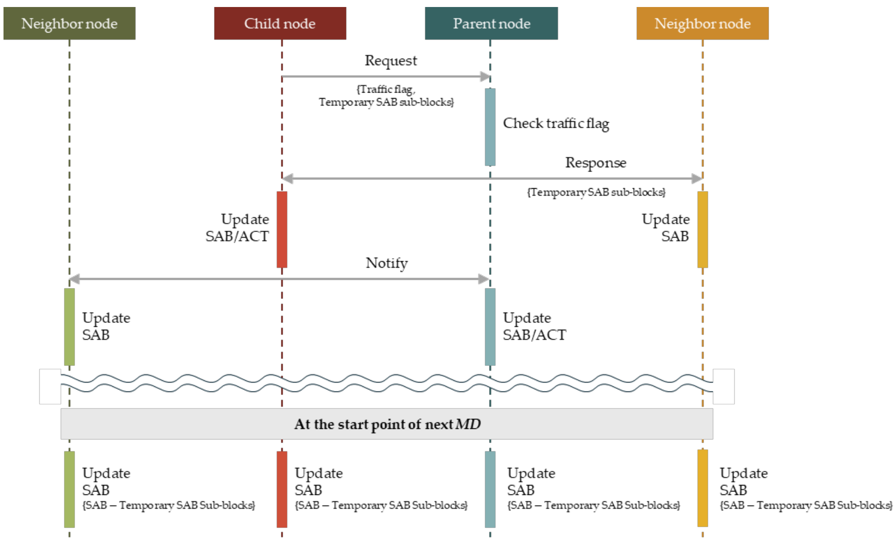


Figure 2. Overall operation of TRA.

TRA scheme enhances the DSME protocol by introducing the concept of ephemeral resource allocation for event-driven traffic. To achieve this, TRA maintains two key elements: a traffic flag and a temporary SAB sub-block for each node. The SAB sub-block is a component of the bitmap that indicates whether a resource is allocated in each superframe. When allocating resources, a node sends a request message including the flag value to its parent node so that the parent node can identify the traffic type generated by its child node. If the traffic is event-driven, the index of resource to be allocated to the child node is specified in the temporary SAB sub-block. This sub-block is propagated to all neighboring nodes according to the resource allocation procedure defined in the IEEE

802.15.4 standard. During resource deallocation, all nodes remove all information corresponding to temporary SAB sub-blocks from the SAB, thereby omitting the control packet exchange process required for the deallocation process. When a node detects event-driven traffic, it initiates a temporary resource allocation request using a specially marked traffic flag. The parent node processes this request by comparing the child node's proposed SAB sub-block with its own and, if feasible, allocates the necessary slots on a temporary basis.

Temporary resources are managed using additional SAB sub-blocks, which are propagated to neighboring nodes via standard control messages. Crucially, these temporary sub-blocks are automatically removed at the beginning of the next multi-superframe, eliminating the need for explicit deallocation messages and ensuring that resources are quickly made available to other nodes.

This lightweight and dynamic allocation mechanism enables rapid adaptation to fluctuating network conditions while minimizing control overhead and ensuring fair access to limited resources.

3. Performance evaluation

3.1. Simulation settings and configuration

In the simulation, a network comprising one Personal Area Network (PAN) coordinator and varying numbers of transmitting and receiving nodes—specifically 10, 20, 30, 40, 50, 60, 70, and 80—was analyzed. Each transmitting node generates one data packet per multi-superframe and transmits it to its corresponding receiving node. Additionally, each node is equipped with a queue capable of holding up to 10 data packets. When the queue reaches its capacity and a new packet is generated, the oldest packet in the queue is discarded.

All nodes maintain a consistent DSME multi-superframe configuration. The structure of the multi-superframe utilized in the simulation is illustrated in Figure 3.

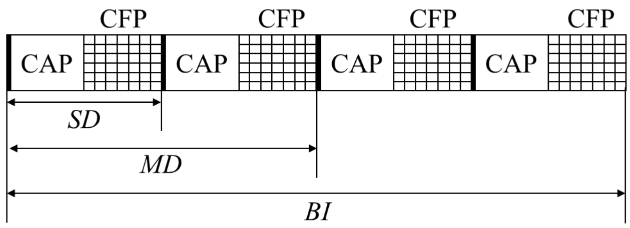


Figure 3. Multi-superframe structure in simulation.

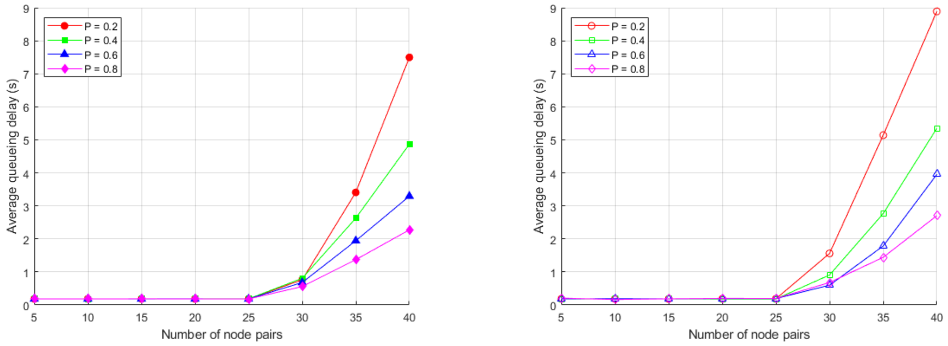
Each transmitting node generates a data packet at the beginning of every multi-superframe. Among all transmitting nodes, 60% generate packets periodically, while the remaining 40% generate packets aperiodically based on a predefined probability. The probabilities for event-driven packet generation are set at 20%, 40%, 60%, and 80%.

The performance of the proposed TRA scheme was evaluated using the following metrics: average queueing delay. Each simulation scenario was executed for 1,000 iterations, and the detailed simulation parameters are summarized in Table 1.

Table 1. Simulation parameters.

Parameters	Values
Payload size	127 bytes
Superframe duration (*SD*)	245.76 ms
Multi-superframe duration (*MD*)	491.52 ms
Beacon interval (*BI*)	983.04 ms

3.2. Simulation results



(a) (b)

Figure 4. Average queueing delay: (a) TRA, (b) Legacy DSME.

Figures 4(a) and (b) show the average queueing delay according to the number of node pairs. Average queueing delay refers to the average amount of time each packet waits in the queue before transmission. In both figures, the average queueing delay begins to increase when the number of node pairs exceeds 30. This is due to the insufficient number of available resources, causing some nodes to fail in obtaining resource allocations, which results in longer queueing times. The performance of average queueing delay also varies depending on the packet generation probability P. Higher values of P result in shorter average queueing delays, whereas lower values of P lead to longer delays. This is because higher values of P cause packets to be generated more frequently, and queues are consistently filled with new packets. If the allocated resources are not available, packets are quickly discarded, reducing overall queueing time. Overall, TRA exhibits shorter average queueing delays than legacy DSME. This is because TRA provides more frequent opportunities for resource allocation, particularly for nodes that generate packets intermittently, which helps reduce queueing time. On the other hand, in legacy DSME, the longer deallocation interval leads to fewer opportunities for reallocation, thereby increasing queueing time. Quantitatively, TRA achieved an average of 14.52% shorter queueing delay compared to legacy DSME.

4. Conclusion

This paper presented a temporary resource allocation (TRA) scheme for IEEE 802.15.4 DSME networks, aimed at improving responsiveness and slot efficiency in the presence of event-driven traffic. By integrating a traffic classification mechanism and temporary SAB sub-blocks, the proposed method enables rapid allocation and automatic deallocation of time slots without additional signaling burden. Simulation results validate the effectiveness of TRA in enhancing key network performance metrics and demonstrate its superiority over conventional DSME in dynamic and mixed traffic scenarios. The TRA approach thus represents a practical and scalable enhancement to existing DSME-based IoT infrastructures. Quantitatively, compared to the legacy DSME, TRA reduced the average queuing delay by 14.52%.

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S.-B.L., J.-H.K., and E.-J.K.; writing—review and editing, I.K., S.-B.L., J.-H.K., and E.-J.K.; visualization, I.K.; supervision, E.-J.K.; project administration, E.-J.K.; funding acquisition, E.-J.K. All authors have read and agreed to the published version of the manuscript.

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Abbreviations

The following abbreviations are used in this manuscript:

ACT	Allocation counter table
CAP	Contention access period
CFP	Contention free period
CSMA/CA	Carrier sense multiple access with collision avoidance
DSME	Deterministic and synchronous multichannel extension
EB	Enhanced beacon
GTS	Guaranteed time slot
IoT	Internet of Things
MAC	Medium access control
PAN	Personal area network
SAB	Slot allocation bitmap
TDMA	Time division multiple access
TRA	Temporary resource allocation

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