

A GTS Allocation Scheme for Emergency Data Transmission in Cluster-Tree WSNs

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Abstract— The WSNs (Wireless Sensor Networks) is a network technique for the implementation of Ubiquitous computing environment. The GTS (Guaranteed Time Slot) of the IEEE 802.15.4 standard, which is the contention free access mechanism, is used for low latency applications or applications requiring specific data bandwidth. The current standard GTS allocation scheme uses FIFS (First In First Service) scheduling. So it reduces the emergency data transmission reliability and has problems. In this paper, we design a GTS allocation scheme for emergency data transmission in cluster-tree WSNs. The proposal scheme using the EDG (Emergency Data Slot) decreases the transmission delay and increases the packet throughput, so the emergency data transmission is more efficient than the current standard.

Keywords— Wireless Sensor Networks, GTS allocation, Priority, Superframe, IEEE 802.15.4 MAC protocol

I. INTRODUCTION

The WSNs is a network technique for the implementation of Ubiquitous computing environment. It is the wireless network environment that consists of the many sensors of the lightweight and the low power. It is researching and developing at the various standards and the research organizations such as IEEE, IETF and etc. As a result, various fields such as the logistics, the environmental control and the home network applied to the sensor networks.

The GTS (Guaranteed Time Slot) of the IEEE 802.15.4 standard, which is the contention free access mechanism, is used for low latency applications or applications requiring specific data bandwidth. However it has some problems such as transmission delay and low packet throughput due to FIFS (First In First Service) scheduling in cluster-tree WSNs.

In this paper, we propose a GTS allocation scheme for emergency data transmission in cluster-tree WSNs. The proposal scheme using the *EDG* (Emergency Data GTS) improves the transmission delay and packet throughput for emergency data transmission, so it is more efficient than the current standard.

The structure of the paper is organized as follows: Section 2 describes the superframe and the GTS management; Section 3 describes the proposal GTS allocation scheme; Section 4 presents the transmission delay and packet throughput for emergency data transmission; and Section 5 concludes this paper.

II. IEEE 802.15.4 MAC

A. Superframe

The IEEE 802.15.4 [1][2] standard allows the optional use of a superframe structure. The format of the superframe is defined by the coordinator. The superframe is bounded by network beacons sent by the coordinator and is divided into 16 equally sized slots. Optionally, the superframe can have an active and an inactive portion. During the inactive portion, the coordinator may enter a low-power mode. The beacon frame is transmitted in the first slot of each superframe. If a coordinator does not wish to use a superframe structure, it will turn off the beacon transmissions. The beacons are used to synchronize the attached devices. Figure 1 shows that an example of the superframe structure.

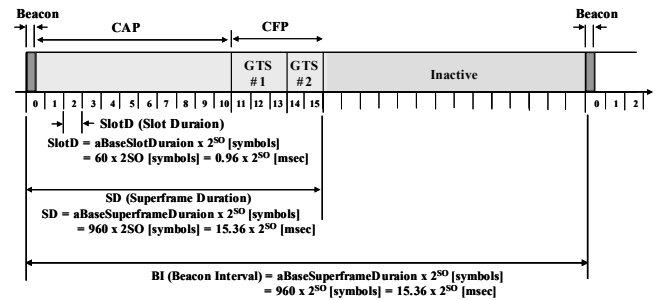


Figure 1. An example of the superframe structure

The superframe [1][3] can have an active and an inactive portion. The active portion consists of CAP (Contention Access Period) and CFP (Contention Free Period). Any device wishing to communicate during the CAP shall compete with other devices using a slotted CSMA/CA mechanism. On the other hand, the CFP contains GTS (guaranteed time slots).

The length of the superframe calculates that using the *BO* (Beacon Order) and the *SO* (Superframe Order) in the PIB (PAN Information Base).

The length of the superframe is following:

$$\begin{aligned} SD &= aBaseSuperframeDuration \times 2^{BO} \\ BI &= aBaseSuperframeDuration \times 2^{SO} \\ (0 \leq SO \leq BO \leq 14) \end{aligned} \quad (1)$$

B. GTS management

A GTS allows a device to operate on the channel within a portion of the superframe that is dedicated (on the PAN) exclusively to that device. A GTS shall be allocated only by the PAN coordinator, and it shall be used only for communications between the PAN coordinator and a device associated with the PAN through the PAN coordinator. A single GTS may extend over one or more superframe slots. The PAN coordinator may allocate up to seven GTSs at the same time, provided there is sufficient capacity in the superframe.

A GTS shall be allocated before use, with the PAN coordinator deciding whether to allocate a GTS based on the requirements of the GTS request and the current available capacity in the superframe. GTSs shall be allocated on a first-come-first-served basis, and all GTSs shall be placed contiguously at the end of the superframe and after the CAP. Each GTS shall be deallocated when the GTS is no longer required, and a GTS can be deallocated at any time at the discretion of the PAN coordinator or by the device that originally requested the GTS. A device that has been allocated a GTS may also operate in the CAP.

A data frame transmitted in an allocated GTS shall use only short addressing.

The management of GTSs shall be undertaken by the PAN coordinator only. To facilitate GTS management, the PAN coordinator shall be able to store all the information necessary to manage seven GTSs. For each GTS, the PAN coordinator shall be able to store its starting slot, length, direction, and associated device address.

The GTS direction, which is relative to the data flow from the device that owns the GTS, is specified as either transmit or receive. The device address and direction shall, therefore, uniquely identify each GTS. Each device may request one transmit GTS and/or one receive GTS. For each allocated GTS, the device shall be able to store its starting slot, length, and direction. If a device has been allocated a receive GTS, it shall enable its receiver for the entirety of the GTS. In the same way, the PAN coordinator shall enable its receiver for the entirety of the GTS if a device has been allocated a transmit GTS. If a data frame is received during a receive GTS and an acknowledgment is requested, the device shall transmit the acknowledgment frame as usual. Similarly, a device shall be able to receive an acknowledgment frame during a transmit GTS.

A device shall attempt to allocate and use a GTS only if it is currently tracking the beacons. The MLME is instructed to track beacons by issuing the MLME-SYNC.request primitive with the TrackBeacon parameter set to TRUE. If a device loses synchronization with the PAN coordinator, all its GTS allocations shall be lost.

III. PROPOSAL GTS ALLOCATION SCHEME

In this paper, we propose a GTS allocation scheme for emergency data transmission in cluster-tree WSNs. The proposal scheme improves the transmission delay and packet throughput of emergency data using the *EDG*. The *EDG* is

dedicated GTS slot for the emergency data transmission. If nodes send emergency data to the PAN coordinator, the emergency type in the GTS request frame set to 1.

A. GTS request frame format

The nodes that request GTS send GTS request frame to the PAN coordinator. The GTS request frame consists of the MHR (MAC header), the Command Frame Identifier and the GTS Characteristics. For proposal scheme, we add GTS Characteristics in GTS request frame to the new fields (Emergency Type). Figure 2 shows that GTS request frame for .proposal scheme.

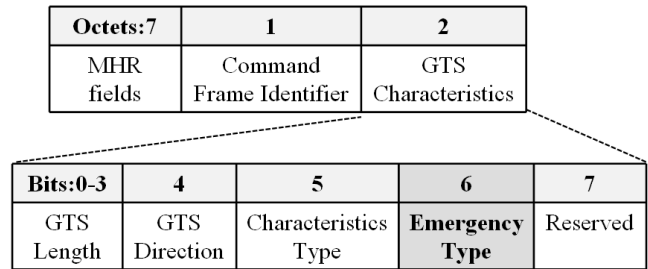


Figure 2. A GTS request frame for proposal scheme

The proposal GTS request frame is following:

- The GTS Length shall contain the number of superframe slots being requested for the GTS.
- The GTS Direction shall be set to one if the GTS is to be a receive-only GTS.
- The Characteristics Type shall be set to one if the characteristics refer to a GTS allocation or zero if the characteristics refers to a GTS deallocation.
- The Emergency Type shall be set to one if the emergency data transmission occurs or zero if the data general transmission occurs

B. Emergency Data GTS

The *EDG* is dedicated GTS slot for the emergency data transmission. Figure 3 shows that the structure of *EDG*.

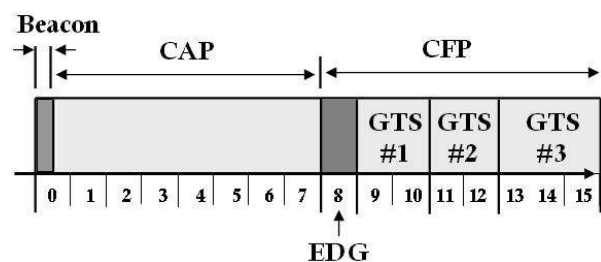


Figure 3. The structure of *EDG*

If all of the nodes for cluster-tree WSNs send emergency data to the PAN coordinator, nodes uses *EDG*, so it is more efficient than the current standard. Figure 4 shows that the data transmission using *EDG*.

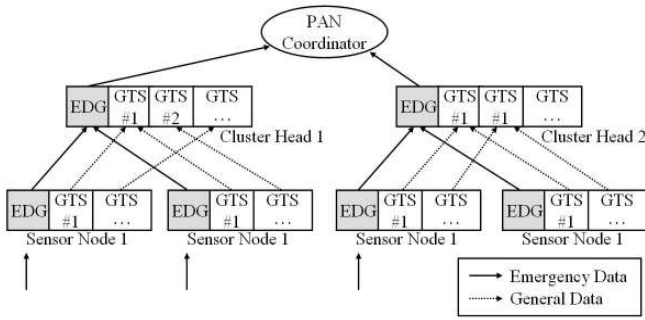


Figure 4. The data transmission using EDG

If the Sensor Node 1 occurs the emergency situations, Sensor Node 1 sends to Cluster Head 1 using *EDG*.

GTS allocation flow is following:

- (1) A Sensor Node 1 is sends Cluster Head 1 using *EDG*.
- (2) Cluster Head 1 checks an emergency type of GTS request frame format.
- (3) If value of emergency type is 1, Cluster Head 1 set 1 to the value of emergency type and allocates my GTS.
- (4) Cluster Head 1 is sends PAN coordinator using *EDG*.

IV. PERFORMANCE ANALYSIS

A. Simulation model

For performance analysis of the proposal scheme, we use OPNET simulator [5]. Figure 5 shows that the simulation model for performance analysis.

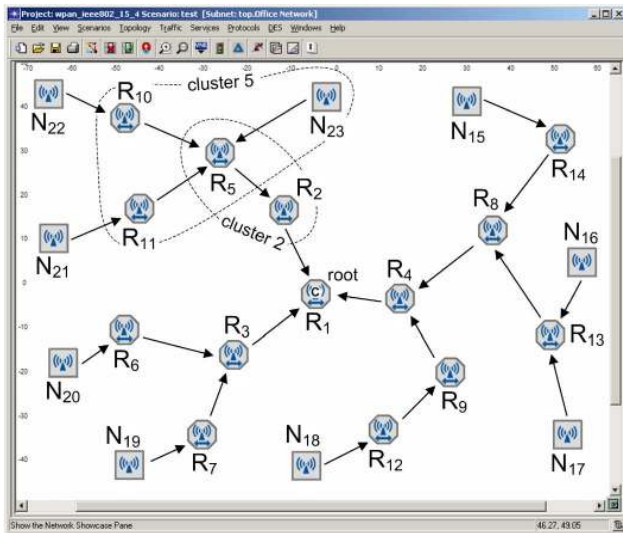


Figure 5. The simulation model for performance analysis

We consider a typical wireless sensor network in a surface of (100 m x 100 m) with one PAN coordinator and 30 identical nodes generating the poisson distributed arrivals, with the same mean arrival rate. Table 1 shows that the system parameter for performance analysis about the proposal algorithm.

TABLE 1. THE SYSTEM PARAMETER FOR PERFORMANCE ANALYSIS

Cluster	BO	SO	Node	GTS length	GTS direction
Cluster 1	6	2	R ₂	1	transmit
			R ₃	1	transmit
			R ₄	2	transmit
			R ₂	2	receive
			R ₃	1	receive
Cluster 2	1	1	R ₅	2	transmit
			R ₅	3	receive
Cluster 3	0	0	R ₆	2	transmit
			R ₇	2	transmit
			R ₆	4	receive

B. Transmission delay

In this subsection, we prove that the proposal scheme (*P.S*) is more effective than the current standard (*STD*) through the transmission delay. Figure 6 and Table 2 show that average of transmission delay by the hop count.

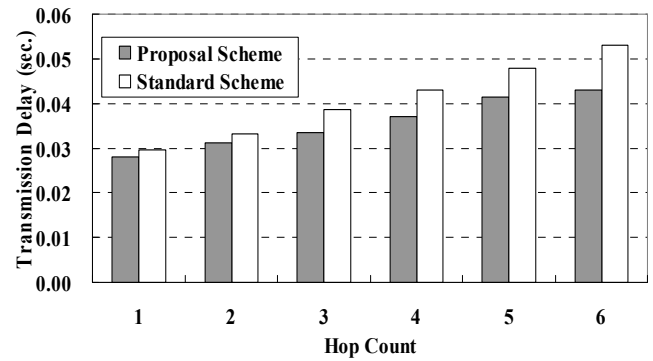


Figure 6. Average of transmission delay by the hop count

TABLE 2. AVERAGE OF TRANSMISSION DELAY BY THE HOP COUNT

Hop Count	1	2	3	4	5	6	tot
<i>P.S</i>	0.0281	0.0311	0.0335	0.0371	0.0415	0.0431	0.2145
<i>STD</i>	0.0296	0.0332	0.0387	0.0431	0.0480	0.0531	0.2457

In the result, the hop count is more increases, the transmission delay is more increases because of the standard scheme not applied the emergency data transmission. The total of *P.S*, the average of transmission delay, is 0.2145. The total of *STD*, the average of transmission delay, is 0.2457. The transmission delay of *P.S* reduces the about 13% than the *STD*. Therefore, the transmission delay of the *P.S* is efficient than the *STD*.

C. Packet throughput

In this subsection, we prove that the proposal scheme (*P.S*) is more effective than the current standard (*STD*) through the

transmission delay. Figure 6 and Table 2 show that average of transmission delay by the hop count.

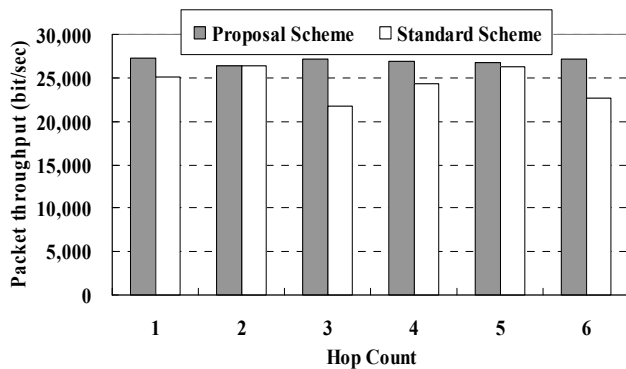


Figure 7. Average of Packet throughput by the network hop count

TABLE 3. AVERAGE OF TRANSMISSION DELAY BY THE HOP COUNT

Hop Count	1	2	3	4	5	6	tot
<i>P.S</i>	27,335	26,445	27,113	26,883	26,742	27,224	161,739
<i>STD</i>	25,134	26,421	21,744	24,335	26,224	22,712	146,570

In the result, P.S is similar to each hop count of the packet throughput. But *STD* is not similar to each hop count of the packet throughput. The total of P.S, the average of packet throughput, is 161,739. The total of *STD*, the average of packet throughput, is 146,570. The packet throughput of P.S increases the about 9% than the *STD*. Therefore, the packet throughput of the P.S is efficient than the *STD*.

V. CONCLUSIONS

The GTS of the IEEE 802.15.4 standard, which is the contention free access mechanism, is used for low latency applications or applications requiring specific data bandwidth. However it has some problems such as transmission delay and low packet throughput due to FIFO scheduling in cluster-tree WSNs.

In this paper, we propose a GTS allocation scheme for emergency data transmission in cluster-tree WSNs. The proposal scheme uses the *EDG*. The *EDG* is dedicated GTS slot for the emergency data transmission.

In order to evaluating the performance of proposed scheme, the proposed scheme is more effective than the standard on the transmission delay, the packet throughput.

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