Issues in Designing 6TiSCH Wireless Networks

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***Abstract*—Industrial Internet of Things (IoT) communication systems are becoming critical for the efficient operation of industrial wireless sensor networks. The IPv6 over IEEE 802.15.4e Time Slotted Channel Hopping (TSCH) (6TiSCH) group enables system to fill in the blank between IP-enabled protocol stack and IEEE 802.15.4e link layer. In this paper, we identify and investigate three issues related to 6TiSCH networks and suggest potential solutions.**

Keywords-Industrial IoT; Wireless sensor networks; 6TiSCH.

I. INTRODUCTION

Sustainable operation is critical for Wireless Sensor Networks (WSNs), such as the recently developed industrial IoT. Particularly, to offer the desired level of service, wireless computer networks, characterized by Information Technology (IT) and Operational Technology (OT), are expected to operate over long duration. IT deals only with data and OT deals only with the physical world; therefore, the convergence of IT and OT is necessary. Nowadays, a lot of studies have been reported related to the convergence of IT and OT [1][2].

Of these Industry 4.0 related research areas, the IoT is expected to play the main role of data acquisition system, which is fundamentally important for Industry 4.0. The IoT stack consists of the IEEE 802.15.4 simple physical layer, IEEE 802.15.4e (TSCH) MAC layer, Internet Engineering Task Force (IETF) 6TiSCH, IETF IPv6 over Low-power Wireless Personal Area Networks (6LoWPAN), the User Datagram Protocol (UDP), and the Constrained Application Protocol (CoAP) [3]. Especially, IETF 6TiSCH is related to the scheduling of the resources and is thus important for efficient resource allocation and traffic management.

To implement efficient resource allocation of the IoT, many scheduling approaches have appeared in the literature. Scheduling in wireless networks can be divided into two groups: centralized scheduling methods and decentralized (distributed) scheduling methods. The centralized scheduling strategy for 6TiSCH wireless networks is introduced in [4]. This strategy deals with a Traffic Aware Scheduling Algorithm (TASA), which allocates cells and resources to all the nodes deployed in the service area. On the other hand, the Decentralized Traffic Aware Scheduling (DeTAS) algorithm was investigated to solve four critical problems, which can be enumerated as small end-to-end latency, small queue but still capable of traffic, collision-free networking, and distributed scheduling [5].

In this paper, we address three issues in industrial IoT and suggest potential solutions for each. The first issue is the problem of multiple sensor nodes running out of power or malfunctioning. The second issue is data processing of information sensed by two or more sensors. Out of these multiple sensor nodes, selection of a sensor node in charge of data transmission to the root (sink) node depends on various criteria. The third issue is to detect malfunctioning sensor nodes. To this end, choosing the right sensing results, obtained from two or more sensor nodes, should be implemented.

Compared to the other works presented above, our contributions are to manage the network balance efficiently so that end-to-end delay can be dramatically reduced, and to bring up practical issues that have not been raised in the literature up to now, thus improving our knowledge of the 6TiSCH network.

The rest of this paper is organized as follows. In Section II, the 6TiSCH IoT network is presented. Section III deals with three issues of network operation; Section IV concludes this paper.

II. SYSTEM MODEL

The baseline 6TiSCH configuration is presented in Table 1.

TABLE I. 6TISCH CONFIGURATION [7]

Property	Value
Number of timeslots per Slotframe	Variable (default 11)
Number of available frequencies	16
Number of scheduled cells (active)	1
Number of unscheduled cells (off)	The remainder of the slotframe
Number of MAC retransmissions (max)	3 (4 transmission attempts)
Default timeslot timing	10ms
Enhanced Beacon Default Period	10s
Default Channel Hopping sequence for the 2.4GHz OQPSK PHY	[5, 6, 12, 7, 15, 4, 14, 11, 8, 0, 1, 2, 13, 3, 9, 10]

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We adopt the topology of wireless sensor networks described in [6]. The balanced binary tree from [6] enables us to characterize the network width. Also, this topology is suitable for adopting nearly realistic dense networks. The Destination-Oriented Directed Acyclic Graph (DODAG) root has rank 1, which is denoted as 0 in Figure 1. This root can be represented as: $S_{1,1}$, $S_{a,b}$ where a and b represent the rank and the ID of the node numbered from the leftmost one in the rank. For instance, the node with ID=1 in the 2nd rank is represented as $S_{2,1}$ and the node with ID=2 in the 2nd rank is labeled as $S_{2,2}$.

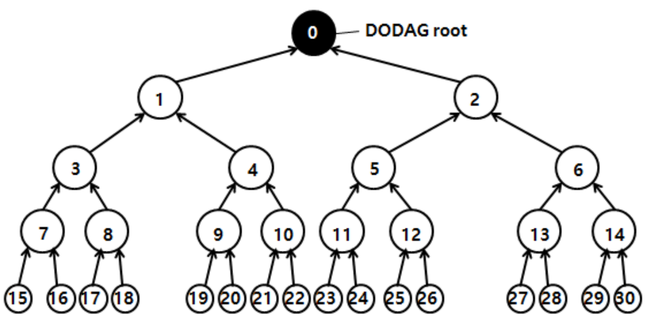


Figure 1. Topology of balanced binary tree.

This wireless sensor network is assumed to be randomly distributed in the service area. The density of the sensor nodes can be visualized according to the corresponding population in the binary tree topology. In Figure 1, circles with numbers represent sensor nodes, which are individual entities of nodes in the wireless sensor network. Arrows represent the directions of data flow.

III. Issues in Network Operation

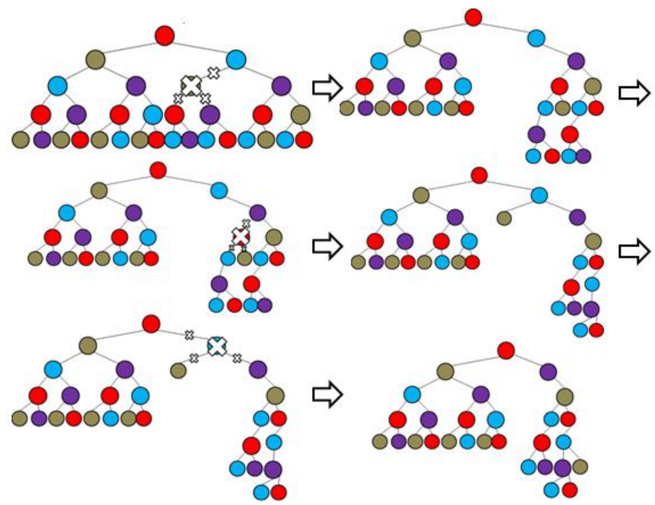
A. Solution to eliminate the problem of sensor nodes running out of energy and/or malfunctioning

Time Slots

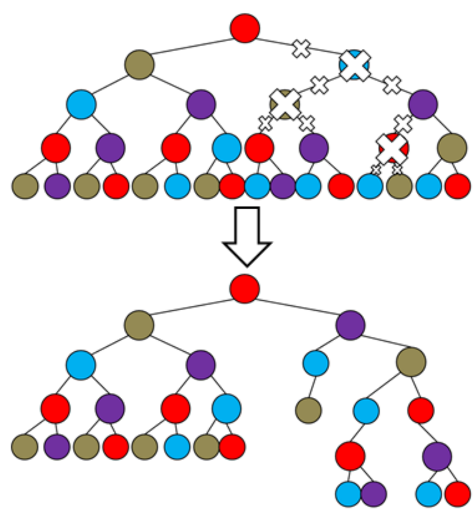
Frequency Offsets						
0						…
1						…
2						…
3						…
4	18	19	25	24	18	…
5	0	1	2	4	0	…
6	7	5	3	6	7	…
7	11	15	20	12	11	…
8	30				30	…
9						…
10						…
11	26	28	29		26	…
12	9	14	10	8	9	…
13						…
14	22	21	27		22	…
15	13	17	23	16	13	…

Figure 2. 6TiSCH cell coloring mechanism.

In Figure 2, we propose a coloring method that is characterized by 'two-hop skipping'. This method enables nodes of the same color to use the resources as efficiently as possible, while avoiding collision. The process of 'two-hop skipping' is carried out by placing nodes of the same color in the two hops higher position. These nodes of the same color are activated after a certain timeslot period; in this case, after four time slots, as shown in Figure 2.



(a)



(b)

Figure 3. Scenarios for dropping sensor nodes out of wireless sensor network squentially and simultaneously: (a) sequential drop out, (b) simultaneous drop out.

Figure 3 shows network topology changes after introduction of least amount of degradation by the 'two-hop skipping' method.

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B. Solution for the problem of choosing a sensor node to send information to DODAGroot when two or more sensor nodes simultaneously sense the object

For example, when sensor nodes $S_{5,15}$ and $S_{5,16}$ detect the same object, sending all the sensed information is not a good idea from the point of view of network sustainability, because using more sensor nodes in communications will incur more energy consumption. Therefore, we have to set a criterion to ameliorate this issue. Suppose that node $S_{5,15}$ has only 100mJ of energy, while node $S_{5,16}$ has 500mJ of energy. Then, node $S_{5,16}$ sends the information to the DODAGroot.

C. Solution for the problem of choosing sense results obtained from two or more sensor nodes that demonstrate dissimilarity

When sensor nodes $S_{5,15}$ and $S_{5,16}$ detect the same object, but with different sensed information, it is likely that one or both of them are providing erroneously sensed information. Therefore, for the sustainability of the 6TiSCH network, erroneously working sensor nodes must be removed. This issue can be solved by comparing the Signal to Noise Ratio (SNR) of the sensed signals of the sensor node to the other. For example, when node $S_{5,15}$ sensed a signal with an SNR value ten times larger than that of sensor node $S_{5,16}$, the sensed results of $S_{5,15}$ can be selected.

IV. Conclusion and Future Work

Sustainable operation of 6TiSCH networks is a critical issue in the realization of industrial IoT. To attain such sustainability, we have to deal with practical issues in 6TiSCH networks. This paper has identified three issues that can occur in 6TiSCH networks. Each issue has been addressed with practical solutions. For future work, by considering various network performance metrics, solutions to these issues will be derived.

References

[1] M. R. Palattella, P. Thubert, X. Vilajosana, T. Watteyne, Q. Wang, and T. Engel, "6tisch wireless industrial networks: Determinism meets ipv6," In *Internet of Things,* Springer International Publishing, pp. 111-141, 2014.

[2] M. Domingo-Prieto, T. Chang, X. Vilajosana, and T. Watteyne, "Distributed pid-based scheduling for 6tisch networks," *IEEE Communications Letters*, vol. *20*, no.5, pp. 1006-1009, 2016.

[3] B. Martinez et al., "I3Mote: An Open Development Platform for the Intelligent Industrial Internet," *Sensors*, vol. *17*, 2017.

[4] M. R. Palattella, N. Accettura, M. Dohler, L. A. Grieco, and G. Boggia, "Traffic Aware Scheduling Algorithm for reliable low-power multi-hop IEEE 802.15. 4e networks," In *Personal Indoor and Mobile Radio Communications (PIMRC), 2012 IEEE 23rd International Symposium on*, pp. 327-332, September 2012.

[5] N. Accettura, M. R. Palattella, G. Boggia, L. A. Grieco, and M. Dohler, "Decentralized traffic aware scheduling for multi-hop low power lossy networks in the internet of things," In *World of Wireless, Mobile and Multimedia Networks (WoWMoM), 2013 IEEE 14th International Symposium and Workshops on a*, pp. 1-6, June 2013.

[6] N. Accettura et. al., "Decentralized traffic aware scheduling in 6TiSCH networks: Design and experimental evaluation," *IEEE Internet of Things Journal*, vol. *2*, pp. 455-470, 2015.

[7] X. Vilajosana, and K. Pister. Minimal 6TiSCH Configuration. [Online]. Retrieved: August, 2017. Available from: https://tools.ietf.org/html/draft-ietf-6tisch-minimal-16

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