The Korean Institute of Communications and Information Sciences
Available online at www.sciencedirect.com
ScienceDirect
ICT Express 2 (2016) 100–102
www.elsevier.com/locate/icte

A comparison of 802.11ah and 802.15.4 for IoT[☆]

N. Ahmed, H. Rahman, Md.I. Hussain[*]

Department of Information Technology, North-Eastern Hill University, Shillong, India

Received 1 May 2016; received in revised form 26 July 2016; accepted 27 July 2016
Available online 6 August 2016

Abstract

The emerging IEEE 802.11ah is a promising communication standard that supports a massive number of heterogeneous devices in the Internet of Things (IoT). It provides attractive features like improved scalability, low energy consumption, and coverage of large area. In this paper, we analyze the performance of IEEE 802.11ah, and compare it with a prominent alternative, the IEEE 802.15.4. The simulation results show that the new 802.11ah standard performs better than the 802.15.4 in terms of association time, throughput, delay, and coverage range.

Keywords: Internet of Things; IEEE 802.11ah; Smart city; IEEE 802.15.4

1. Introduction

In the vision of a smart world, the deployment of Internet of Things (IoT) is progressing very fast. "Things" include not only computers, people, and mobile phones but also sensors, actuators, refrigerators, vehicles, clothes, food, medicines, etc. [1]. According to the Cisco Internet Business Solutions Group (IBSG), the number of devices in the Internet will reach 50 billion by 2020 [2]. Wireless network technologies seem to be the best option to connect such a huge number of devices [3].

The communication technology for IoT operates in both sensor and backhaul network scenarios. The sensor network standards (such as ZigBee, RFID, or Bluetooth) work over relatively short distances (i.e., tens of meters), with low data rates and low energy consumptions. On the other hand, standards like GPRS, LTE, WiMAX, etc., work over long distances and provide high throughput; however, they consume more energy, and demand an expensive and fixed infrastructure of base stations with proper line of sights [4]. Owing to its low power consumption, the IEEE 802.15.4 is a suitable standard for many IoT applications. However, it is not suited for facilitating communication among a large number of IoT devices or for covering large areas.

The latest IEEE 802.11ah standard fills this gap to a certain extent by combining the advantages of Wi-Fi and low-power sensor network communication technologies. To achieve communication over longer distances among a large number of low-power devices, several innovative concepts such as hierarchical Association IDentification (AID), Restricted Access Window (RAW), Traffic Indication Map (TIM) and segmentation, Target Wake Time (TWT), and shorter header formats have been introduced in the PHYsical (PHY) and Medium Access Control (MAC) layers of 802.11ah ([5] and [6]). In this paper, the relevance of IEEE 802.11ah and 802.15.4 in the context of IoT is examined, considering their various key aspects. Performances of both technologies are evaluated and compared, assuming realistic scenarios with a significantly large number of devices.

The rest of this paper is organized into three sections. Section 2 discusses the important IoT features provided by 802.11ah and 802.15.4. Comparison of the evaluated results is presented in Section 3. Finally, Section 4 concludes the paper.

2. Features of 802.11ah and 802.15.4

This section presents a comparison of the different features provided by the 802.11ah and 802.15.4 standards.

2.1. Network structure

The 802.11ah standard enables single-hop communication over distances up to 1000 m. Relay Access Points are used to

* Corresponding author. Fax: +91 3642723606.
E-mail addresses: nurzaman713@gmail.com (N. Ahmed), hafizjec@gmail.com (H. Rahman), ihussain@nehu.ac.in (M.I. Hussain).

Peer review under responsibility of The Korean Institute of Communications Information Sciences.

☆ This paper is part of a special issue entitled ICT Convergence in the Internet of Things (IoT) guest edited by Yacine Ghamri-Doudane, Yeong Min Jang, Daeyoung Kim, Hossam Hassanein and JaeSeung Song.

http://dx.doi.org/10.1016/j.icte.2016.07.003

Table 1
802.11ah vs. 802.15.4.

Features	802.11ah	802.15.4
Suitable applications	Smart city, Smart home	Smart agriculture, Environment monitoring
Network support	Sensor, Backhaul	Sensor
Frequency	Sub-1 GHz	2.4 GHz, Sub-1 GHz
Channel access	RAW	CSMA/CA
Data rate (maximum)	78 Mbps (16 MHz in Sub-1 GHz)	250 Kbps (2 MHz in 2.4 GHz)
Range (maximum)	1000 m (without repeaters)	100 m (without repeaters)
Power saving	TIM, DTIM, TWT	Sleep–wake strategy
Relay feature	Relay AP	Full Function Device (FFD)

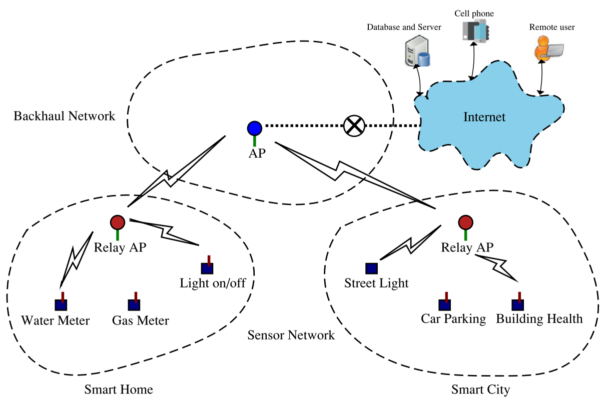


Fig. 1. IEEE 802.11ah-based network structure for an IoT spreading over a large coverage range.

extend the connectivity to Access Points (APs) that are two-hops away. Fig. 1 shows a typical network architecture of IoT where two smart IoT networks (smart home and smart city) are connected to the Internet. With its smaller coverage range (maximum 100 m), the 802.15.4 alone cannot provide a communication framework combining the sensor and backhaul networks for a larger coverage range.

2.2. Channelization

The legacy 802.15.4 standard usually operates in the unlicensed 2.4 GHz band using Direct Sequence Spread Spectrum (DSSS), which can accommodate data rates up to 250 Kbps. On the other hand, the 802.11ah utilizes the sub-1 GHz license-exempt bands to provide an extended range to Wi-Fi networks. In US, up to 26 MHz of spectrum is available in the 902–928 MHz band. Modulation and Coding Schemes (MCSs) are proposed based on the available channel bands (i.e., 1, 2, 4, 8, and 16 MHz) in order to provide different data rates. For example, MCS0 with a 2 MHz channel band provides data rates from 650 Kbps to 7.8 Mbps.

2.3. Large number of stations

The 802.11ah proposes a hierarchical network organization with a large number of associated stations (STAs), to improve simplicity and scalability. Every node in such a network is assigned an Association IDentification (AID), which is a four-level structure having pages, blocks, sub-blocks, and STAs as fields. The STAs are grouped based on their similarities in the values of pages, blocks, and sub-blocks. Further, a fast association mechanism proposed in 802.11ah reduces collisions to improve scalability [5]. Although the 802.15.4 is capable of associating with 65 000 devices, the *sink* node becomes overburdened.

2.4. Channel access

The Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)-based MAC of 802.15.4 fails to handle collisions, especially when thousands of STAs simultaneously contend for a channel. To address this issue, the 802.11ah introduces a RAW-based mechanism that improves the network performance significantly. This mechanism splits the STAs into groups and allows the STAs belonging to a certain group to access the medium at any particular time frame. The RAW Parameter Set (RPS) information containing one or more RAW intervals is carried forward through the beacons transmitted by the APs.

2.5. Power saving

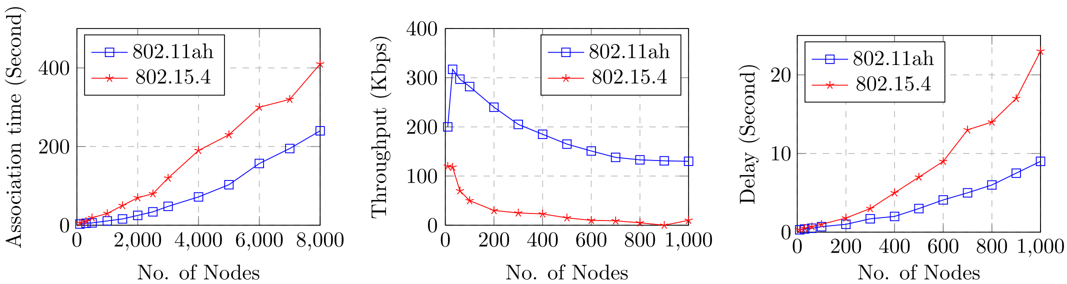
The 802.11ah defines two data structures, the Traffic Indication Map (TIM) and the Delivery TIM (DTIM) for the APs to communicate the group information and for the STAs, which are expected to communicate next. The STAs belonging to the given TIM segments are required to wake up and listen to their corresponding beacons. The 802.15.4 uses a sleep–wake control mechanism in a super frame structure for improving energy efficiency. The STAs may sleep for longer periods over multiple beacons.

2.6. Relay node

Relay APs in the 802.11ah relay packets for the STAs, allow the use of different MCSs, and provide connectivity for the STAs located outside the coverage ranges of the APs. In the 802.15.4, devices are associated with a Full Function Device (FFD) forming a cluster, which in turn communicates with the *sink*. Table 1 gives a point-wise comparison of both the standards.

3. Performance evaluation

The simulation parameters considered while evaluating the performances of 802.11ah and 802.15.4 standards are given in Table 2.



(a) Association time. (b) Throughput achieved. (c) End-to-end delay.

Fig. 2. Performance of 802.11ah and 802.15.4 with different network sizes.

Table 2
Default simulation parameters.

Parameter	802.11ah	802.15.4
Bandwidth	2 MHz (MCS0)	2 MHz
Data rate	650 Kbps	250 Kbps
Payload size	256 Bytes	256 Bytes
Slot time	52 µs	–
SIFS	160 µs	–
DIFS	264 µs	–
RAW size	10	–
Backoff	–	320 µs
CCA	–	128 µs
Traffic	UDP	UDP
Area	400 m × 400 m	400 m × 400 m

Table 3
Coverage range and power consumption.

	802.11ah	802.15.4
Coverage range	870 m (outdoor), 543 m (indoor)	37 m
Power consumptions	63 mJ/Packet (100 nodes)	17 mJ/Packet (100 nodes)

3.1. Association time

The fast authentication mechanism of 802.11ah allows a large number of devices to associate with the APs in a shorter duration, than the schemes available in 802.15.4. This is apparent from Fig. 2(a).

3.2. Network capacity

The throughput performance is measured under saturated traffic conditions. Performance of 802.11ah is observed to be consistently better than that of 802.15.4 (Fig. 2(b)). The reason is that, the MAC layer of 802.11ah can quickly and efficiently adapt to a higher number of nodes than that of 802.15.4. The RAW mechanism employed reduces the possibility of collisions in such situation to a great extent.

3.3. End-to-end delay

As shown in Fig. 2(c), the 802.11ah significantly improves the delay performance over 802.15.4. Restricting the contention window of STAs through the use of dedicated RAW reduces the access delay.

3.4. Network coverage and energy efficiency

The use of the sub-1 GHz band, macro propagation model [7], and MCS techniques of 802.11ah help in increasing the network coverage area. Table 3 shows the maximum distance covered by the two propagation models proposed for 802.11ah and 802.15.4. It can be observed that the 802.15.4 is more energy efficient than 802.11ah under saturated traffic conditions.

4. Conclusion

Simulation studies clearly indicate the improvement of 802.11ah over 802.15.4 in terms of association time, throughput and delay performance, and network coverage range in the context of IoT. However, 802.15.4 demonstrates higher energy efficiency than 802.11ah. Performance comparisons of 802.11ah with other relevant low power network technologies proposed for IoT are kept as future works.

Acknowledgment

This work was supported by the project titled “QoS Provisioning in Internet of Things (IoT)” (Grant No. 13 (7) /2015-CC&BT dated: 28/09/2015) funded by DeitY (CC & BT), Govt. of India.

References

[1] G.M. Lee, J. Park, N. Kong, N. Crespi, The Internet of Things: Concept and problem statement: 01, Internet Engineering Task Force, Institut TELECOM (2011).

[2] D. Evans, The Internet of Things, How the Next Evolution of the Internet is Changing Everything, White paper, Cisco Internet Business Solutions Group (IBSG) (2011).

[3] R. Want, B.N. Schilit, S. Jenson, Enabling the internet of things, Computer (1) (2015) 28–35.

[4] I.-G. Lee, M. Kim, Interference-aware self-optimizing Wi-Fi for high efficiency internet of things in dense networks, Comput. Commun. (2016).

[5] E. Khorov, A. Lyakhov, A. Krotov, A. Guschin, A survey on IEEE 802.11ah: An enabling networking technology for smart cities, Comput. Commun. 58 (2015) 53–69.

[6] IEEE Draft Standard for Information Technology-Telecommunications and Information Exchange Between Systems-Local and Metropolitan Area Networks-Specific Requirements-Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Amendment 2: Sub 1 GHz License Exempt Operation, IEEE P802.11ah/D6.0, (Amendment to IEEE Std 802.11REVmc/D5.0) (2016) 1–645.

[7] A. Hazmi, J. Rinne, M. Valkama, Feasibility study of IEEE 802.11 ah radio technology for IoT and M2M use cases, in: Globecom Workshops, IEEE, 2012, pp. 1687–1692.