ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645
Indian Journal of Science and Technology, *Vol 8(S8), 112–117, April 2015*
DOI: 10.17485/ijst/2015/v8iS8/64233

An Efficient Data Forwarding Scheme for Internet of Things in Wi-Fi Networks

Won-Shik Na[1] and Seok-Hoon Kim[2*]

[1]Department of Computer Science, Namseoul University, Cheonan, 331-707, South Korea
[2]Department of Mobile Communications Engineering, Changshin University, Changwon, 630-764, South Korea; shkim@cs.ac.kr

Abstract

Recent IT technology trends are confronted with a new technological phenomenon. It is the intersection of technology and liberal arts. That is, IT convergence. Although the convergence trends will keep going in the future, there is the Internet of Things which are a new priming to accelerate these trends. A multitude of IoT devices will transmit various information through Internet, and the main channel of information flows will be a Wi-Fi networks. However, current Wi-Fi technology isn't prepared to accommodate these data yet. Therefore, we propose the Efficient Data Forwarding Scheme (EDFS) to solve these problems. The proposed EDFS assigns a proper transmission opportunity (TXOP) to the IoT devices for supporting efficient data transmission. In the EDFA, Wi-Fi AP (Access Point) gives a calculated or pre-defined TXOP, which is suitable for the data transmission attributes of IoT device. Due to the fact that the data transmission feature of IoT devices isn't the real-time traffic in the most cases. Based on the EDFA, a Wi-Fi AP can not only assign an efficient TXOP to a device, but also support various IoT device requirements within the Wi-Fi hotspot. We compared it with legacy Wi-Fi transmission scheme to prove the outperforming results by using the OPNet simulator.

Keywords: Data Forwarding, Internet of Things, TXOP, Wi-Fi

1. Introduction

Nowadays, IT infrastructure environments have been dramatically changed and this trend will be accelerated. It has been mainly caused by various types of multimedia data, deepened fluctuation of daily traffic, rapid deployment of cloud computing, huge size data center, spreading IT-based business and so on. These changes does not only required a simple and flexible infrastructure scheme, but also needed super high speed and bandwidth networks as a necessity. Therefore, the telecommunication service providers are competitively adopted to gigabit technologies such as gigabit Ethernet, IEEE 802.11ac, etc. from all over the world. In addition, Internet of Things (IoT) will be an inevitable and essential technology in the middle of this trend. Actually, the IoT technology isn't dropped it from skies. It has been constantly evolving from RFID (Radio Frequency IDentification) technology in the past few years. It just had gotten into a limelight as a next generation business in recent days. However, the IoT is a most important and influential technology in the IT industry and business, because it can be easily adapted to other industries and businesses. That is, the IoT has been the eye of a typhoon in the nowadays converged trends.

Although it seems to be evolving with the trends respectively, these trends are tightly coupled to each other. Due to the fact that the present ICT infrastructures, which are used to IoT, Wi-Fi, and etc., will pursue to be changed from hardware based technology to the efficient and flexible software based technology. That

*Author for correspondence

is, the programmability of topology and behavior, IaaS (Infrastructure as a Service), virtual infrastructure, integrated smart infrastructure, interworking to other network techniques, and so on, will be the main functionalities in the near future[1,2].

Actually, the Wi-Fi technology could have died out the technology in the past few years ago, if there was no various hand-held devices and the smart phone. However, it has been continuously spotlighted technology, since the tremendously increasing wireless data are needed in the smart phone and hand-held device. These tendencies can't be out-of-hand thing by only mobile networks such as LTE (Long Term Evolution), Mobile WiMAX (Worldwide Interoperability for Microwave Access), and etc. This is why the current limelight of Wi-Fi technology is still continuing. In addition, there is one other important reason. It is the IoT technology because it is not only causing the explosive effects in the data usages, but also using the Wi-Fi technology as a fundamental transmission scheme[3,4].

In spite of this technical background, the existing Wi-Fi standards and technologies didn't consider the data transmission of IoT devices yet. That is, the IoT devices are handled a normal station within the Wi-Fi hotspot. It can be one of the reasons which causes the inefficient Wi-Fi network throughput, because most of the IoT devices' traffic attribute aren't a real-time feature. To solve this problem, we propose an efficient data forwarding scheme, which is very appropriate to the traffic attribute of IoT devices. The proposed EDFS can assign the proper TXOP, which dose not only consider a traffic attribute of IoT device, but also calculated or pre-defined with time interval, to the IoT devices within the Wi-Fi hotspot.

The rest of this paper is organized as follows. Section 2 describes the related works such as Wi-Fi network technologies and IoT technologies. Section 3 discusses the proposed scheme and the performance evaluations. Finally, we offer concluding remarks in Section 4.

2. Related Works

2.1 Wi-Fi Technology

Recently, there are many Wi-Fi technologies such as Gigabit Wi-Fi, Super Wi-Fi, Wi-Fi Direct, and so on. Although there are many Wi-Fi standards, technologies, and applications, the current Wi-Fi evolutions are focused on the bandwidth expansion, as shown as Table 1.

The evolution of Wi-Fi technology has mainly led by some PHY techniques. It means that MAC techniques didn't almost change up to now than PHY techniques relatively. However, there are introducing various MAC techniques in recent years. Especially, these MAC techniques, which are related to reduce the control frame overhead and to adjust the back-off time, are focused on the improving Wi-Fi network efficiency and the providing user QoS/QoE.

Legacy IEEE 802.11 Distributed Coordinating Function (DCF) has some lacks in these functionalities. These limitations are as followings in detail. First, All stations (STAs)' services have equal priority when they access the media. Second, the media access control of each STA is impossible. Third, an Access Point (AP) and STA have same priority so that it makes a beacon frame transmission delay. In the IEEE 802.11e standard, the enhanced Distributed Channel Access (EDCA) uses 4 access categories (ACs) to solve the above problems as shown in Figure 1. In addition, the OFDMA (Orthogonal Frequency Division Multiple Access) based techniques, which are currently being discussed in the IEEE 802 TG (Technical Group), are as shown in Figure 2[5–9].

2.2 IoT Technology

Generally, wireless sensor network technology is a kind of surveillance/control/communications technology, which can support self-networking configuration & organization, and to collect information from some sensor nodes. Nowadays, the ultimate goal of wireless sensor network technology is evolving to Internet of Things (IoT) and M2M (Machine to Machine). To achieve this goal, there are some important elemental technologies, which are a sensing, information processing and exchanging, intellectual network configuration, wireless sensor routing technology and so on.

On the one hand, wireless sensor networks are based on the non-IP communications, the common devices, whereas, are based on the IP communications, which are connected to the Internet. In the non-IP communications, the devices can use various technologies for their communications, such as Bluetooth, ZigBee, RFID, Z-Wave and etc. These typical non-IP base sensor nodes can exchange the information to connect Internet through a sink node. Due to the fact that the sensor nodes should adopt some technologies to establish an Internet connection. For example, the sensor nodes can be applied

Table 1. Wi-Fi technology

Name	Features
IEEE 802.11ac	• Enhanced technology from IEEE 802.11n • Bandwidth: 20MHz ~ 160MHz • Maximum Throughput: 6.9Gbps (Theoretically) • Using 8 spatial stream • 256 QAM • Multi-user MIMO • Beamforming • Etc.
IEEE 802.11ad	• IEEE 802.11ad is a discrete technology • Throughput: 6.8Gbps (Single Antenna, 64QAM without channel bonding) • Maximum Throughput: 30Gbps (Theoretically) • Frequency Band: 60GHz • LOS (Line-Of-Sight) indispensability • Etc.
IEEE 802.11af	• IEEE 802.11af is a Wi-Fi technology which is used in TV white space band • Extended Hot Spot (broad service coverage) • There are many applicable services • It is one of the next generation Wi-Fi technology • Etc.
IEEE 802.11p	• Established standard in 2010 for supporting the next generation ITS • Bandwidth: 10MHz • Throughput: 6 ~ 27Mbps • Frequency Band: 5.850 ~ 5.925GHz • Etc.

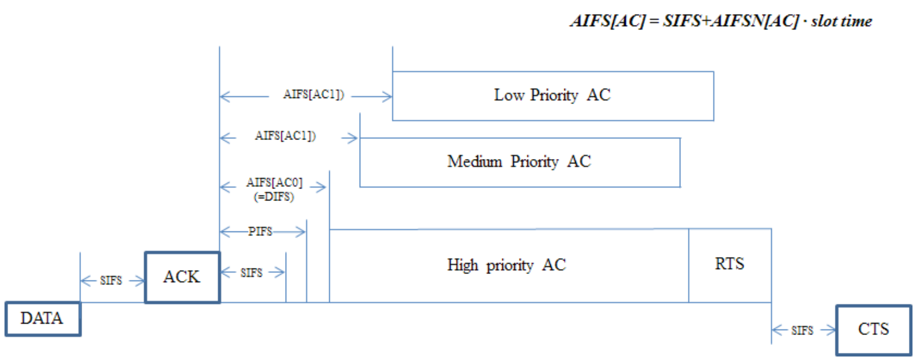

Figure 1. Priority based backoff algorithm in IEEE 802.11e.

6LoWPAN (IPv6 over Low power WPAN) technology, as shown as Table 2, which is based on the IEEE 802.15.4 PHY/MAC[10].

3. Efficient Data Forwarding Scheme

Basically, IoT devices have same priority with other STA when they should access the medium. Although the IoT devices or sink node of the IoT devices have few transmission data, and they don't need high bandwidth, the devices should contend for gaining a TXOP in the current Wi-Fi networks. It is very inefficient situation in the Wi-Fi networks because most of the IoT devices have to save their battery, and they usually need to make a periodic connection. Nonetheless, the current Wi-Fi standards haven't any considerations about that[11–13].

To solve these problems, we propose an efficient data forwarding scheme for IoT devices. Basically, the proposed scheme assign the differentiated access privilege to

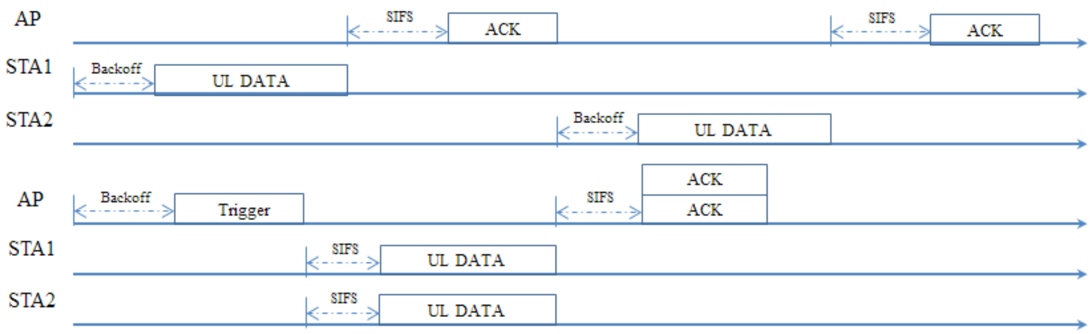

Figure 2. UL Transmission scheme and OFDMA based UL transmission scheme.

Table 2. Non-IP communication technology

Name	Features
ZigBee	•Wireless network technology for low transmission speed and short distance communication • Low power consumption and low cost • Various and broad applicable scopes for intelligent home network, factory automation, distribution, HCI, telematics, environment monitoring, etc. • Consist of physical layer, MAC layer, network layer, and application layer • IEEE 802.15.4 standard • Supporting the routing and addressing scheme for tree topology and mesh topology • Profile: ZigBee Home Automation Public Profile, ZigBee Smart Energy Profile • RF4CE: Enhanced ZigBee specification (including remote control solution and network stack) • Supporting AES-128 in RF4CE
Z-Wave	• Home automation wireless transmission technology, which is established by Z-Wave Alliance • Supporting the reliable communication between one or more nodes and control units • Consist of physical layer, MAC layer, transport layer, routing layer and application layer • Frequency Band: 869MHz/908MHz(Europe/America) and 2.4GHz • Maximum Throughput: 9.6kbps, 40kbps, 200kbps (Theoretically) • There are 2 types (Controller and Slave) • Supporting the source routing base routing in the routing layer
6Lo WPAN	• It is a technology to connect to the legacy IP networks with IPv6 in low power WPAN • Based on IEEE 802.15.4 PHY/MAC • It is possible to connect to a IP base network without gateway or intermediate device

guarantee a TXOP of IoT device. It can be a kind of application of IEEE 802.11e standard.

The back-off process is determined by various parameters such as CW_{min} (minimum congestion window), CW_{max} (maximum congestion window), *AIFS* (arbitration inter-frame space), and $TXOP_{limit}$, as shown as Figure 1. The CW_{min} is most important factor to affect all of the stations in the Wi-Fi networks because Wi-Fi network, which is based on the IEEE 802.11 standards, frequently encounter congestions, which are caused by contention. However, if the IoT device has same parameter value with other normal station (N-STA), the IoT device can't achieve their efficient data forwarding. That is, the device can't save their battery life time, because the device has to keep the status as a wake when it has to transmit their data. Therefore, the proposed EDFS assign the parameters of IoT device (i-DEV) and N-STA including Access Point (AP) to avoid the situations as follows:

$$i = DEV\{(CW_{\downarrow}\min^{\uparrow}(i-\mathrm{DEV}) = CW_{\downarrow}\min^{\uparrow}\ default\ RP2\ (w_{\downarrow}\max/w_{\downarrow}(i-DEV))@CW_{\downarrow}\max^{\uparrow}(i-DEV = CW_{\downarrow}\max^{\uparrow}\ default\ RP2(w_{\downarrow}\max/w_{\downarrow}(i-DEV)),\text{and}\ @\ \mathrm{AIFS}_{\downarrow}(i-DEV) \tag{1}$$

$$N-STA\{(CW_{\downarrow}\min^{\uparrow}(N-STA) = CW_{\downarrow}\min^{\uparrow}\ default\ 2^{\uparrow}i@CW_{\downarrow}\max^{\uparrow}(N-STA) = \mathrm{CW}_{\downarrow}\max^{\uparrow}\ default\ 2^{\uparrow}i, and\ @\ AIFS_{\downarrow}(N-STA) = DIFS)-1 \tag{2}$$

$$RP2(k)\begin{cases} 2[\log_2(k)] & k-_2[\log_2(k)\leq_2[\log_2(k)]-k \\ _2[\log_2(k), \text{otherwise} \end{cases} \tag{3}$$

where w_{max} represents the highest weight in the Wi-Fi network, $w_{\text{i-DEV}}$ is a weight for the i-DEV and AP, and *RP2(k)* is the integer power of 2 closest to *k*.

The proposed EDFS assign higher weight tothe *i-DEV* than the *N-STA*, as shown in equations (1), (2), and (3). Based on these equations, *AP* and *i-DEV* can be acquired high priority than *N-STA*. It means that the *i-DEV* has a shorter back-off time, and then the device can keep high medium access privileges than *N-STA* based on the short back-off time. Therefore, the *i-DEV* can retain much more TXOP than *N-STA* based on the scheme in the proposed EDFS, because the *i-DEV* has more media access privileges with short back-off times. However, it isn't enough to save the battery and to guarantee the IoT devices' data transmissions, because the IoT device doesn't need high bandwidth than N-STA. Although the EDFS assign the high priority to an IoT device when the device wants to transmit their data, it doesn't need to keep the status all the time because the IoT data transmission will be periodically occurred. So, we adjust admission control functions to solve this problem in the EDFS. The admission control part in the EDFS handles the admission of i-DEV and N-STA to improve the entire Wi-Fi network throughput and the efficient data transmission of IoT devices. The admission control part of EDFS manages admission processes by using each stations local variables, which are *admitted_time* and *used_time*. It is almost similar to the IEEE 802.11 EDCA contention-based admission control usages. However, the IoT devices will send a specific traffic specification (TSPEC) to AP, when they have to send the TSPEC. Basically, all stations send a QoS request frame to AP, when they negotiate the traffic stream (TS). In the QoS request frame, there are many values such as the TSPEC of mean data rate, delay bound, minimum PHY rate and so on. On the other hand, it is added the periodic value of IoT device in the EDFS. Based on the periodic value, the EDFS control the admission processes of IoT device. As a result, the EDFS can keep the high weight status for a while.

Since the AP receives the QoS request frame of IoT device, it distinguishes the QoS request frame is the corresponding TS of IoT device or not. And then, the AP determines that the request will be accepted or not. The AP calculates a medium_time if it is accepted. The calculated medium_time is as follows, and then the value will send to the each station,

$$medium_{time}\begin{cases} medium_{time\,i-DEV} = medium_{time\,i}\times w_{i-DEV} \\ medium_{time\,N-STA} = medium_{time_i} \end{cases} \tag{4}$$

where, $w_{\text{i-DEV}}$ means the weight of the IoT device, and the $medium\_time_{\text{i-DEV}}$ value is 0 < $medium\_time_{\text{i-DEV}}$ > requested time of the IoT device. The later process is same as the IEEE 802.11 EDCA admission control part.

We have implemented a network topology by using the NS-2 to verify the EDFS performance. There are 4 stations, one is a sink node of IoT devices, the other are normal stations in the simulation networks. The normal stations are configured to generate streaming traffic for 1 hour, the sink node of IoT devices is configured to generate the data transmission periodically in every 5 minutes. On the one hand, we set the weight ($w_{\text{i-DEV}}$) of sink node data transmission to 5.

Figure 3 shows delay comparison results of the *i-DEV* and *N-STAs*. The average delay of *i-DEV* is 241.38ms, and the *N-STAs*' average delay are 496ms, 501ms, and 492ms, respectively. Based on these results, we are proven that the proposed EDFS can provide acceptable delay to the IoT devices. The bandwidth of IoT device isn't an important matter, because the IoT device doesn't need high bandwidth. Therefore, the proposed EDFS could be improved the overall Wi-Fi network throughput, including the IoT devices and sink nodes.

4. Conclusion

The proposed EDFS can be a kind of QoS scheme, because it could assign various weight or priority to each station in the Wi-Fi networks. In addition, the EDFS has a consideration of IoT device and sink node. However, normal stations and IoT devices have a different traffic attribute

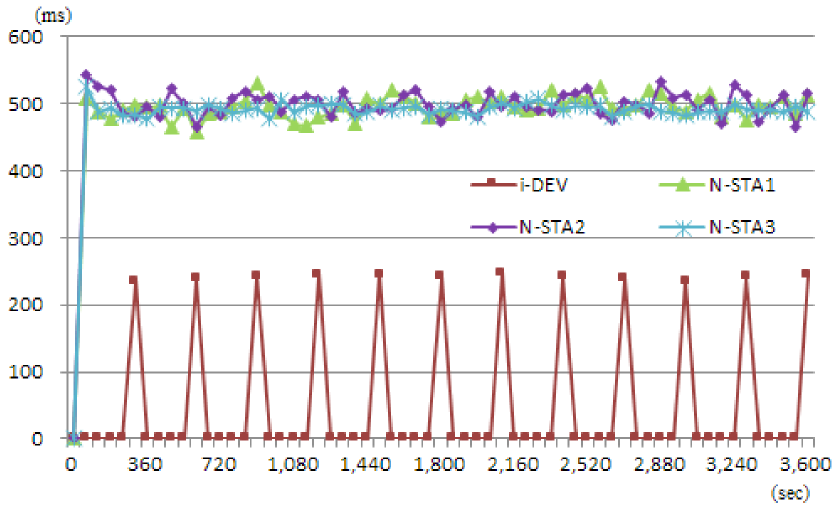

Figure 3. Delay comparison of i-DEV and N-STAs.

such as bandwidth, delay, jitter and so on. Due to the fact that the legacy Wi-Fi networks can't support an efficient data transmission of the IoT devices until now. So, we propose the EDFS to solve these problems. The EDFS assign the various weight to the IoT device so that the traffic attributes of devices are applied to the transmissions when they need to transmit their data. Nevertheless, the EDFS can't assign dynamic weights to each station yet. It can be a very important thing, because the IoT technology and device will be certainly deployed in the near future, and there are various types of the devices. So, it will be one of our future researches.

5. Acknowledgement

Funding for this paper was provided by Namseoul University.

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