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Research Article

Data Transmission in Backscatter IoT Networks for Smart City Applications

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Backscatter communication is a battery-less data transmission method for massive IoT devices. These backscatter devices receive an incident signal from an RF-source gateway to harvest energy. These devices can be operated to transmit data after harvesting energy. This technology is widely applied to smart city applications. In general, IoT devices in the smart city applications have insufficient resources. They use narrowband communication to transmit small sizes of data. Thus, a simple channel access approach should be considered for data transmission. In addition, network scalability is also important in the backscatter network for smart city applications. According to energy harvesting and data generation, devices participating in data transmission can change frequently. Providing the network scalability by the changing devices can improve the transmission efficiency in the backscatter network. Therefore, we propose a novel media access scheme for the backscatter network in the smart city applications. The proposed scheme is designed by the contention-based approach to support the network scalability. It controls backscattering signal for energy harvesting and distributes contention in multiple access. It allows additional data transmission in backscattering period for harvesting energy to provide fairness of devices. For performance evaluation, extensive computer simulations are carried out and the proposed method is compared to TDMA that is a typical media access scheme in the backscatter network.

1. Introduction

Recently, the Internet of Things (IoT) has become common in the computing paradigm and is being used in many places. Many smart applications, such as smart cities and smart factories, are based on IoT. IoT provides various intelligent services using information collected by tiny computing devices. The use of tiny IoT devices is growing rapidly for various services [1–6]. These kinds of IoT devices are usually battery powered. To expand intelligent services to various domains of smart city applications, it is necessary to collect a lot of information through IoT devices. However, battery-driven IoT devices may pose limitations for device use. In smart city applications, there are a lot of spots in hard-to-reach. If IoT devices are deployed in hard-to-reach areas, it is very difficult to replace their batteries [7]. Therefore, it is necessary to apply backscatter communication to the applications in order to implement stable service. By configuring a backscatter network based on backscatter communication, it is possible to expand IoT data collection for smart city applications and provide flexible smart services with energy constrained devices.

Backscatter communication is a communication methodology in devices without batteries or power sources. Data transmission in this communication takes place in two steps: energy harvesting and transmission. In the energy-harvesting step, a device receives an RF signal from a power source and harvests energy for transmission. In the transmission step, a device attempts to transmit data.

In the backscatter communication devices, data cannot be transmitted without energy harvesting. Thus, a backscatter network consists of an RF source and backscatter devices (i.e., senders and receivers) [8–10]. The RF source generates an incident RF signal. The backscatter devices employ the signal for the energy harvesting. A backscatter sender is usually an IoT device, but a backscatter receiver can be various devices. A backscatter device or a handheld device can receive data from a backscatter sender. A gateway or an RF source can also receive data from a backscatter sender. Backscatter systems are divided into two types depending on what the backscatter receiver is. When data is transmitted from the backscatter sender to the RF source that generated the incident signal, it becomes a monostatic backscatter system. When a backscatter sender transmits data to a device other than the RF source, it becomes a bistatic backscatter system. Both network architectures can be used flexibly for IoT service expansion [11–14]. Figure 1 shows the backscatter network system architecture.

In the backscatter network, multiple devices can participate in data transmission as in general wireless transmission. To achieve successful data transmission for multiple devices, media access control should be provided. The media access control schemes for wireless communication are classified into guaranteed media access control and contention-based media access control. The guaranteed media access control performs stable data transmission by transmitting data during a given time slot. In the guaranteed manner, there is an overhead of managing the time slots to be allocated to the devices and a master node is required to handle them. On the other hand, the contention-based media access control acquires the opportunity to use the media for data transmission through competition among devices. Even though a device transmits data with a media access opportunity, transmission failure may occur due to transmission collisions.

The backscatter network for smart city services can be composed of tiny backscatter devices with insufficient resources. A large number of devices attempt to transmit data via the network. According to an event generation, the number of devices that attempt to transmit data is frequently changed. In addition, a backscatter device should consider energy harvesting. Therefore, in the backscatter network, devices adopt a simple algorithm for media access and the algorithm should reflect the energy-harvesting period. In addition, it also provides scalability to the number of devices participating in data transmission. However, in general, a media access approach in the backscatter network deals with the guaranteed media access control. Thus, the proposed approach attempts media access control that can provide scalability that is not supported by the conventional method. It can provide flexibility for smart city services through the scalability support for transmitting participating devices.

The rest of this paper is organized as follows. In Section 2, related work for data transmission in the backscatter network is described. In Section 3, the proposed media access approach is explained. Section 4 presents performance evaluation for the proposed media access approach. Computer simulations are used for the performance evaluation. In Section 5, the paper is concluded.

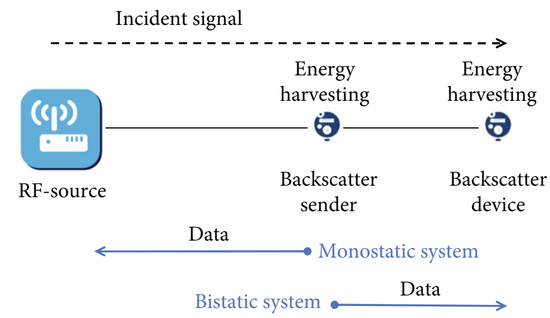


FIGURE 1: Backscatter network system architecture.

2. Related Work

Backscatter communication is an effective data transmission method for energy constrained IoT devices. Using the energy harvesting, it allows a battery-less IoT device to transmit data. Backscattering devices can only transmit data after energy harvesting. For the backscattering IoT devices, a following transmission power model can be provided [15].

$$P_{\mathrm{Tx}} = \gamma + \mathrm{PL}(d) + P_n, \quad (1)$$

where γ is the received signal-to-noise ratio (SNR), $\mathrm{PL}(d)$ is the path loss at the given distance d, and P_n is the noise power. From equation (1), γ can be given as

$$\gamma = P_{\mathrm{Tx}} - \mathrm{PL}(d) - P_n. \quad (2)$$

Through the bit error rate (e) model (In IEEE Std. 802.15.4, the bit error model is provided as follows [15].) using γ, e can be calculated. Then we can obtain the packet reception rate (PRR) as

$$\mathrm{PRR} = (1 - e)^l, \quad (3)$$

where l is the frame size. In wireless channel for IoT devices, the PRR can be easily used.

In general backscatter communication, wireless data transfer is used for multiple IoT devices. For the wireless data transfer, various multiple access schemes for media access control can be applied. However, several multiple access schemes such as space division multiple access (SDMA), frequency division multiple access (FDMA), and code division multiple access (CDMA) do not account for the backscatter communication because they have high system complexity [8]. In general, IoT backscatter devices have insufficient computing resources. For system operations with limited resources, system complexity should be low given that high system complexity is not adequate. Therefore, simple multiple access schemes such as time division multiple access (TDMA) or carrier sense multiple access (CSMA) can be used. Several approaches deal with a TDMA-based scheme as the most practical data transmission in the backscatter communication [8, 9]. TDMA-based scheme has a simple structure and can easily apply the energy harvesting. In addition, it guarantees stable data transmission in a given time slot.

Lyu et al. [11] provided a practical data transmission scheme based on TDMA for a backscatter network. They construct several time slots, and each time slot is divided into two modes: the harvest-then-transmit (HTT) mode and the backscatter mode. In the HTT mode, a device harvests energy from an RF source and then transmits data. In the backscatter mode, a device attempts to transmit data using instantaneous excitation energy from multiple ambient signals. Thus, data transmissions in the backscatter devices occur by obtaining operating energy from the RF sources or ambient sources. Figure 2 represents the TDMA frame structure of Lyu et al. Other TDMA-based transmission schemes are designed in a similar manner and there is a difference in the configuration method of the time slots in TDMA.

Fang et al. [16] dealt with three multiple access methods in the backscatter network with an RF source: TDMA, FDMA, and nonorthogonal multiple access (NOMA). In particular, NOMA uses successive interference cancellation (SIC) at a base station to avoid collision during data transmission. That is, the base station controls transmission power of each device for SIC. It is hard to control each device's transmission power considering the interference and noise level of the device in real systems. Thus, in the backscatter system, TDMA, which can be easily controlled, is widely used. Ye et al. proposed a resource allocation scheme for task offloading considering energy consumption in a backscatter network [17], a resource allocation scheme to ensure throughput fairness in a backscatter network [18], and a resource allocation scheme to improve data rate in an ambient backscatter network [19]. Ye et al. adopted TDMA as a multiple access for data transmission. The algorithms divided a TDMA frame to several phases and allocated TDMA slots. Devices transmitted data according to the scheduled TDMA slots.

The TDMA-based data transmission is a simple and powerful scheme, but it has weakness in scalability. A gateway schedules time slots for devices and broadcasts the transmission schedule to assign time slots to devices. If a device does not have a time slot, the device waits for the next schedule to transmit data [20]. In general, a number of devices are deployed in a service domain for IoT services. The IoT devices have different activation cycles according to their type: they either transmit data periodically or when a specific event occurs. These characteristics are also the same in backscatter-based IoT networks. A number of activated devices can be frequently changed. In the case of the TDMA-based scheme, a fixed number of time slots is used from data transmission. If the number of activated devices is changed, the data frame structure assigned to a device should be changed. This causes decreased transmission efficiency.

Therefore, the proposed approach considers contention-based data transmission. The contention-based data transmission provides salability even when the number of activated devices changes. In the contention-based scheme, a device attempts to transmit data when a medium is ideal. If a medium is busy, a device waits until the medium is ideal. That is, the device that loses the competition should acquire

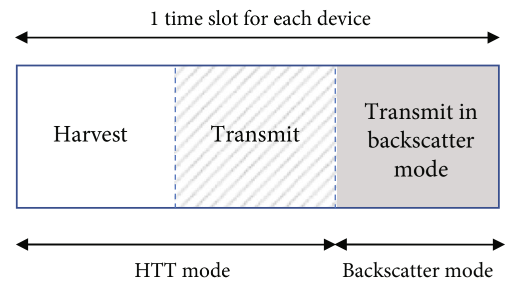


Figure 2: TDMA-based data transmission in Lyu et al. [11].

the next transmission opportunity for data transmission. If several devices attempt to transmit data at the same time, collision occurs. In a collision, a random backoff occurs on the devices, and the media access time of the devices is changed to avoid the collision [20–23]. In addition, the contention-based approach can cause an aging condition in which a device cannot transmit data because it does not continuously obtain the transmission opportunities. To prevent the condition, increasing the priority of the device that loses the competition is needed. The proposed approach is designed by considering these points in the backscatter IoT networks. The contributions in the proposed scheme are as follows: (1) the proposed method provides the contention-based multiple access to support network scalability. (2) To support data transmission of a device that has not participated in data transmission in the HTT period, a data transmission scheme is provided in the BP period.

3. Proposed Data Transmission Approach

In a backscatter IoT network, various IoT communication technologies are used such as NB-IoT, LTE-M, LoRa, 5G MTC, and WiFi. As mentioned earlier, the number of data transmission devices in the network is frequently changed. A device can transmit data after harvesting its operating energy. Thus, data transmission in the backscatter network has more restrictions than conventional IoT networks. For efficient data transmission in the backscatter IoT network, the characteristics of the backscatter network should be considered.

3.1. Media Access Control Using a Superframe Structure. Data transmission in the proposed approach is based on a superframe structure. Backscatter devices attempt to transmit data by contention-based manner in a superframe. The superframe consists of a beacon period, HTT period, and backscatter period. In the beacon period, the time schedule for the HTT and backscatter periods is delivered from a gateway (i.e., RF source). The HTT period is divided by energy-harvesting and transmission blocks such as that of Lin et al. In the energy-harvesting block, devices receive an RF signal to acquire operating energy. However, in the transmission block, a transmission slot is not allocated to a device, and devices acquire a transmission opportunity by contention. In the backscatter period, a device can attempt to transmit data after harvesting energy from multiple ambient signals. In addition, devices that do not participate in transmission in the HTT period may attempt data transmission. Figure 3 shows the superframe of the proposed approach.

A gateway broadcasts a beacon periodically. Through the beacon, the superframe structure is shared to devices. As mentioned earlier, the gateway is the RF source and it issues the RF signal for the energy harvesting in backscatter devices. The transmission power of an RF signal is controlled by the gateway according to the given steps. By adjusting the transmission power for the RF signal in this way, the number of devices participating in transmission can be reduced. In the proposed approach, devices have transmission levels assigned by the RF signal. According to this transmission level, a competition group for data transmission is determined. Figure 4 and Pseudocode 1 represent assigned transmission levels to devices.

3.2. Media Access Control for Backscatter Devices. In the proposed approach, the RF-signal power is adjusted in steps: the RF signal repeats the increasing of the signal range sequentially from the transmission level 1 (Tx level 1) region. According to the RF-signal range, backscatter devices participate in data transmission. Pseudocode 2 represents the media access control in the proposed approach. As mentioned earlier, a device uses the HTT period and the backscatter period in the superframe for data transmission as shown in Figure 3.

cls determines a group for media channel access. Depending on the cls, the range of the media access time is given differently. A device periodically receives a beacon frame through an RF signal. This beacon describes the HTT and backscatter periods in the superframe. A device can attempt to transmit data using those periods. Of course, in a backscatter IoT network, the device has to attempt transmission after harvesting energy from an RF signal (lines 1–3). As mentioned earlier, a gateway periodically adjusts the RF-signal range. When a device is deployed, a transmission level (i.e., txlv) is assigned through the received RF signal. The beacon frame periodically issued by the gateway contains the transmission level (i.e., beacon.lv) for the devices to participate in the data transmission. When the device receives the beacon frame, it compares its transmission level to the beacon frame. If the transmission level of the beacon is greater than the assigned transmission level, the device increments the cls value by 1 (lines 4–6). When the transmission level of a device has reached a threshold value (i.e., beacon.thrd; a beacon frame contains the threshold value), the cls value is initialized (lines 7–9). Then, a media channel access time (acc) is randomly chosen, and a device attempts to transmit data according to the access time (lines 10–11). As shown in Figure 4, when beacon frames with different transmission levels are periodically issued, devices closer to the gateway have higher cls values. A high cls value means low priority to access media. This priority is reflected to media access time. Because the device participates in the data transmission with different media access time according to the transmission level, the collision probability can be decreased. If a collision occurs, the device performs binary exponential backoff and then attempts to retransmit data.

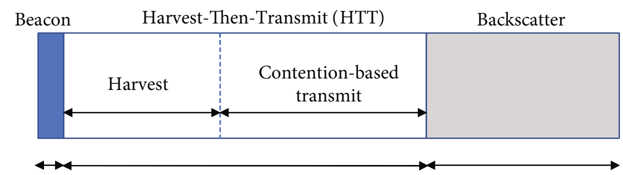


Figure 3: The superframe structure of the proposed approach.

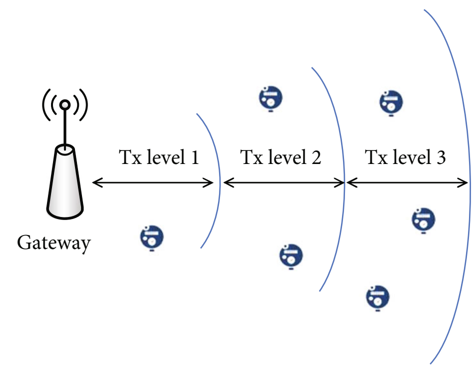


Figure 4: Transmission-level assignment of devices.

The backscatter period can be used in various ways. As mentioned earlier, devices in this period can harvest energy from multiple ambient signals to participate in data transmission. In addition, a device that has not obtained a transmission opportunity in the HTT period may attempt transmission in this period. To transmit data, a device determines media access time as shown in Pseudocode 3. b_cls means a group of the range of the media access time in the backscatter period. If a transmission level of a device is less than the beacon frame's level issued by a gateway (beacon.lv), b_cls is determined by the difference between the beacon level and the transmission level of the device (lines 1–3). If the transmission level of a device is the same as the beacon frame, the beacon level is assigned to b_cls (lines 4–6). As in the HTT period, after the transmission priority range (i.e., b_cls) is determined, the media access time (acc) is determined through random selection. The device accesses the channel at a given time and transmits data. In the backscatter period, the transmission priority is given to devices that have long lost the opportunity to transmit.

4. Performance Evaluation

4.1. Transmission Environment. The backscatter IoT applications usually use narrowband communication because they collect data from devices with insufficient resources. The data transmission model should be designed and evaluated in a low-rate communication environment. Therefore, in this paper, the proposed transmission method and comparison method (i.e., TDMA-based backscattering) are simulated in a low-rate communication environment (250 Kbps). For data transmission, backscatter devices should harvest energy from other RF signals. In the simulation, it is assumed that the backscatter IoT devices in a network have the same energy-harvesting period. The data transmission period is evaluated

< Tx-level assignment >
Initialize: $txlv_i \longleftarrow$ NIL
1: receive an *RF-signal*
2: if $txlv_i$ = NIL:
3: $txlv_i \longleftarrow RF - signal.lv$
4: end if

PSEUDOCODE 1: Pseudocode for the transmission level assignment of a device *i*.

< Media access control in HTT period>
Initialize: $cls_i \longleftarrow 1\ (init.value)$
1: receive an RF-signal
2: receive a beacon frame
3: perform energy- harvesting
4: *if* $txlv_i < beacon.lv$:
5: $cls_i \longleftarrow cls + 1$
6: end if
7: *if* $txlv_i = beacon.thrd$:
8: $cls_i \longleftarrow 1\ (init.value)$
9: end if
10: $acc \longleftarrow random(0, group(cls_i))$
11: Transmit(acc)

PSEUDOCODE 2: Pseudocode for the media access control of a device *i* in the HTT period.

< Media access control in Backscatter period>
1: $b\_cls_i \longleftarrow cls_i$
2: if $txlv_i < beacon.lv$:
3: $b\_cls_i \longleftarrow beacon.lv - cls_i$
4: else if $txlv_i = beacon.lv$:
5: $b\_cls_i \longleftarrow beacon.lv$
6: end if
7: $acc \longleftarrow random(0, group(b\_cls_i))$
8: *Transmit(acc)*

PSEUDOCODE 3: Pseudocode for the media access control of a device *i* in the backscatter period.

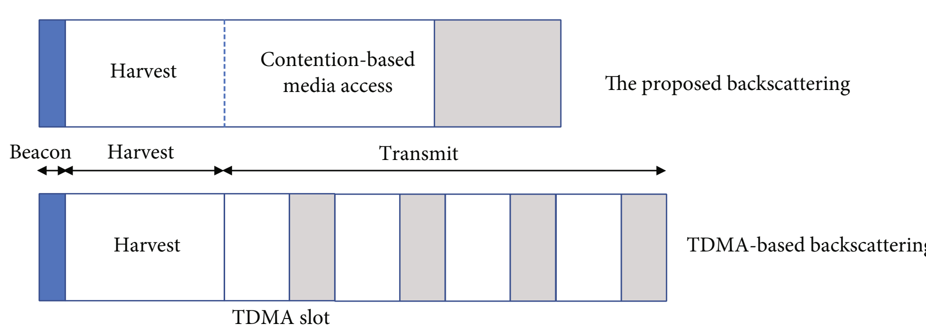


FIGURE 5: The data transmission model for the simulation.

by dividing the proposed method and the comparison method as shown in Figure 5.

In the proposed method, the superframe for data transmission consists of beacon, energy harvesting, contention-based transmission, and backscatter periods. In the beacon period, information on the frame configuration is included. Thus, the backscatter IoT device that receives the beacon can transmit data according to the beacon information. The beacon period is set to 20 ms. The energy-harvesting period and the transmission period for HTT are set to 30 ms and 40 ms, respectively. In addition, the backscatter period is set to 30 ms. Thus, the superframe has a size of

120 ms and is sent by the gateway every time. As shown in Pseudocodes 2 and 3, the proposed contention-based approach uses a group time for media access. In the simulation, three groups are used (i.e., access-group1, access-group2, and access-group3). Each group randomly selects a media access time from 0 to 2 ms, 1 to 3 ms, and 2 to 4 ms, respectively. If a collision occurs in the media, a binary exponential random backoff is performed based on 2 ms. Retransmission is allowed up to 2 times. In addition, a packet size used in this backscatter IoT network is set to 125 Bytes. In the comparison method, the data frame consists of beacon, energy harvesting, and TDMA-based transmission periods. The number of TDMA slots is determined by the number of activated backscatter devices, and information on TDMA slots is shared with the backscatter devices through the beacon. The sizes of the beacon and energy-harvesting periods are set to 20 ms and 30 ms, respectively, as in the proposed method. The TDMA slot is set to 5 ms, and if energy-harvesting is not completed, the device is set to use in backscatter mode within a given slot. Table 1 represents the simulation parameters for data transmission.

4.2. Performance Analysis. As mentioned earlier, scalability is important in the backscatter IoT networks. In data transmission that does not consider scalability, delay time may increase. Thus, the average transmission delay is analyzed for network multiple access with high practicality. The proposed approach uses contention-based method. The contention probability of wireless networks can be obtained by ref. [24]. The contention probability (p_c) is

$$p_c = 1 - \left(1 - \left(\frac{p_a}{N+1}\right)\right)^N, \tag{4}$$

where p_a means active probability of devices and N is the number of devices in the network. In the proposed method, active devices have different media access time according to groups. Thus, p_c can be represented as

$$p_c = 1 - \left(1 - \frac{1}{G}\left(\frac{p_a}{N+1}\right)\right)^N, \tag{5}$$

where G is the number of groups. When two retries in transmission failure are considered, the mean delay ($E[D]$) is

$$E[D] = (1-p_c)T_s + (p_c T_B + p_c(1-p_c)T_s) + \left(p_c^2 T_B + p_c^2(1-p_c)T_s\right) \tag{6}$$

If the number of devices is 30 and p_a is 30%, p_c is 0.907. Assuming that the slot time (T_s) and the backoff time (T_B) are 4 ms and 10 ms, respectively, $E[D]$ can be 5.01 ms.

In TDMA and FDMA, p_a is also 30% in the network and unscheduled devices are assumed to be 10% of active devices. Then, the scheduled active node (N_s) is 9 and unscheduled node (N_u) is 1. In TDMA and FDMA, when a device is scheduled for data transmission, it can transmit data in its transmission slot. However, unscheduled devices should wait until they are scheduled. Thus, $E[D]$ in TDMA is

Table 1: Transmission parameters.

Parameters	Values
Superframe size	120 ms
Beacon period	20 ms
Energy-harvesting period	30 ms
Contention-based transmission for HTT	40 ms
Number of retransmissions	2
Backscatter mode period	30 ms
Access-group1	Random (0, 2 ms)
Access-group2	Random (1, 3 ms)
Access-group3	Random (2, 4 ms)
Packet size	125 Bytes
Data rate	250 Kbps
TDMA slot size	5 ms

$$E[D] = \frac{T_s N_s + \left(T_f + T_s\right)}{N_s + N_u}, \tag{7}$$

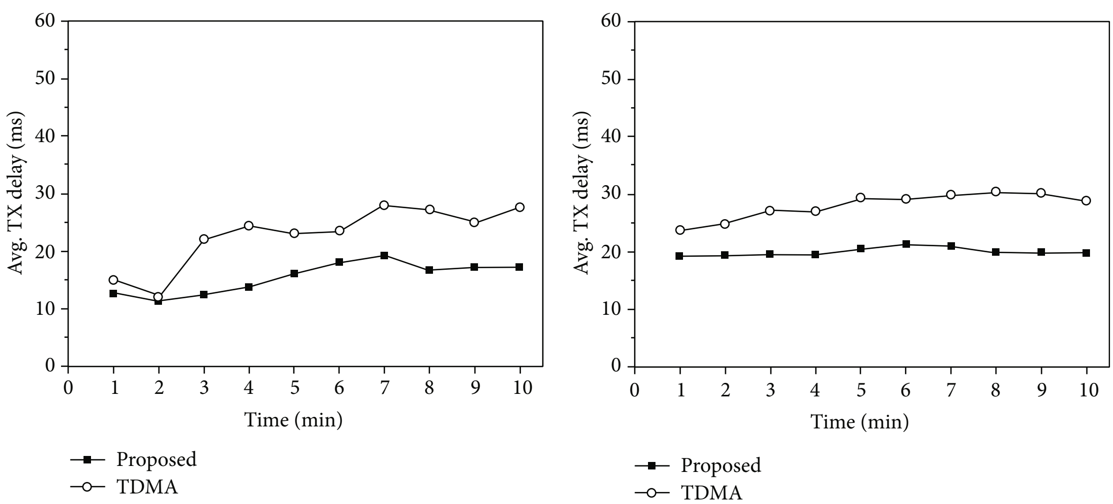
where T_f is the size of the TDMA frame. Then, $E[D]$ is 16 ms. FDMA employs several subchannels by dividing the bandwidth. To transmit data, it uses long transmission slots to compensate the reduced bandwidth of the subchannel. Unscheduled devices (i.e., not allocated subchannel) should also wait such as TDMA. Thus, FDMA has the longer $E[D]$ under the same condition as TDMA. Analysis of the mean delay also means average throughput. Considering the scalability of devices in the network, the proposed method is analyzed to be effective.

4.3. Simulation Environment. For performance evaluation, the simulator was implemented with the event-driven library, SMPL [25]. It is based on C-language. The simulation is performed for 10 min using the transmission environment described in the previous subsection. The simulation is repeated 10 times, and the results are represented as an average. The average delay of packet transmission, which is a performance metric, is recorded as a log every minute. The number of deployed backscatter devices is 30 and they have different distances from their respective gateways. Data traffic is generated using uniform distribution [26, 27] in the given time. The traffic range is set to 10 and 30 sec. When the traffic is generated, a proportion of devices participating in data transmission is randomly determined between 0.4 and 0.8. Each device has a randomly determined energy-harvesting time within 10.5 sec. In addition, for the backscattering of the proposed method, the RF signal of the gateway is adjusted in 5 steps and radiated. A beacon message is broadcasted using this RF signal from the gateway. It is assumed that the RF that received the power of a device in the network always satisfies the received sensitivity. Table 2 shows the parameters for the simulation environments.

4.4. Simulation Results. As mentioned earlier, the simulation measures the average transmission delays and compares the

Table 2: Simulation parameters.

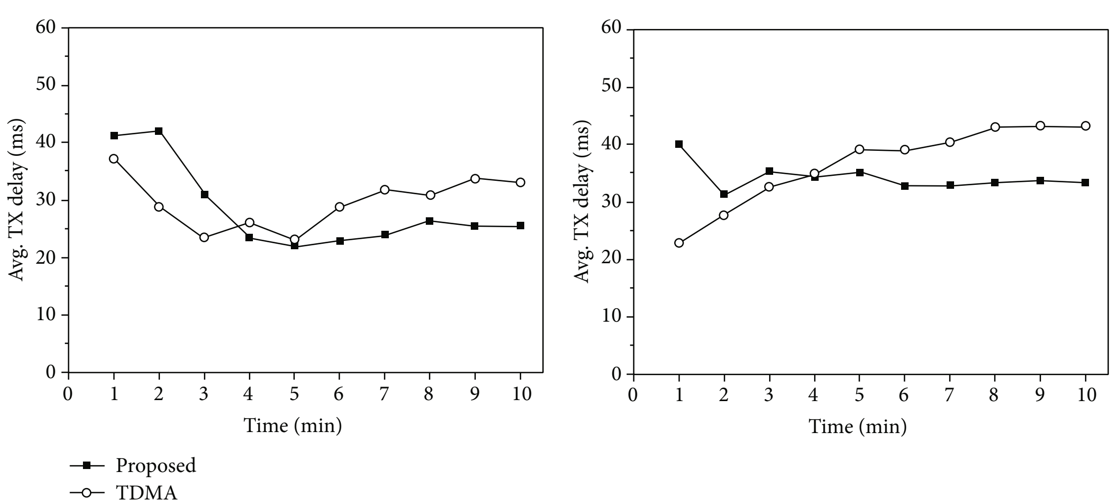
Parameters	Values
Simulation time	10 min.
Performance report	Every 1 min.
Number of deployed devices	30
Traffic generation	Uniform (10) and Uniform (30)
Device ratio participating in transmission	Random (0.4, 0.8)
Energy-harvesting time	Random (10.5)
RF-signal strength levels	5
Data transmission	Proposed and TDMA-based
Tx power	0 dBm



(a) Traffic generation: uniform (30 sec)

(b) Traffic generation: uniform (10 sec)

Figure 6: Average transmission delays: # of devices is 20.



(a) Traffic generation: uniform (30 sec)

(b) Traffic generation: uniform (10 sec)

Figure 7: Average transmission delays: # of devices is 30.

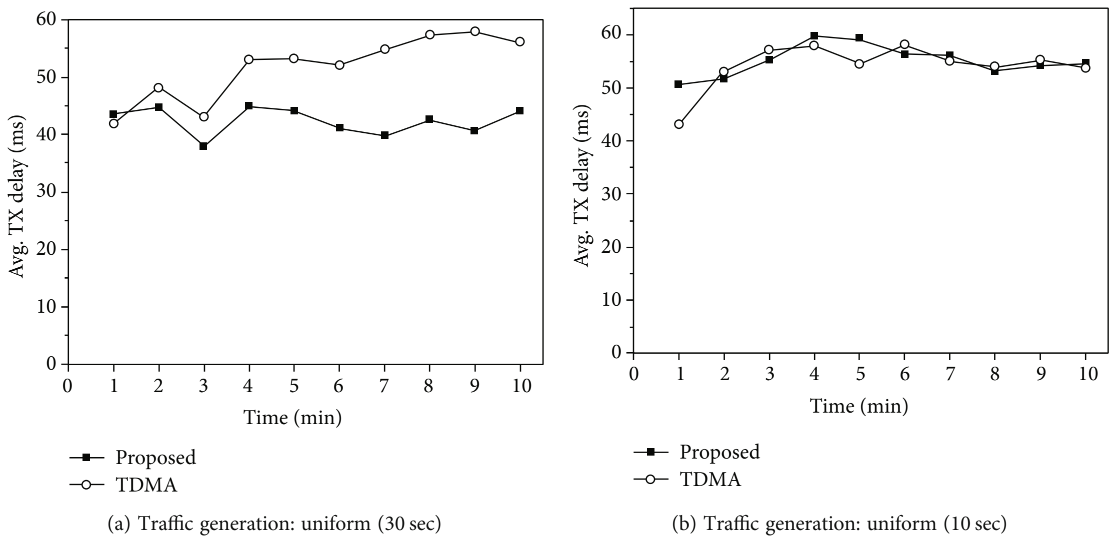


Figure 8: Average transmission delays: # of devices is 40.

proposed method with the TDMA-based method in a backscatter IoT network. Even if a device is activated, it cannot participate in data transmission if it does not complete energy harvesting. In the proposed method, contention-based transmission is used. Collision can occur and retransmission is supported for collision. In the TDMA-based method, transmission slots are generated according to the number of activated devices. Increasing or decreasing the number of transmission slots is reflected in the next data frame. Figures 6–8 show the average transmission delays in a backscatter IoT network when the number of devices is 20, 30, and 40. In the given environments, the average transmission delay of the proposed method is generally lower than that of the TDMA-based method. When the number of devices participating in data transmission is variable, it can be seen that the proposed method provides scalability. The device can attempt to transmit data flexibly through the contention-based method. In addition, the proposed method supports a device that does not have a transmission opportunity in the HTT period to participate in data transmission through contention in the backscatter period. In the TDMA-based method, when the number of activated devices varies, a device newly participating in data transmission has to wait until the next frame to have a transmission opportunity.

In the backscatter IoT network, the number of data transmission devices changes frequently. With a rigid data transmission, it is difficult to support an efficient service that considers this characteristic of the backscatter IoT network. The TDMA-based method has a rigid data transmission, but its implementation is very simple. However, although the proposed method has overhead of transmission delay due to retransmission, it provides flexibility for changing the number of activated devices. In Figures 6(a) and 6(b), the difference in transmission delay is 10 ms and 9 ms, respectively. In Figures 7(a) and 7(b), the difference in transmission delay is 7.5 ms and 9.8 ms, respectively. In Figure 8, when the data generation interval is short, there is almost no difference in transmission delay between the proposed method and the TDMA-based method. The reason may be that the difference between the delay caused by creating new transmission slots in the TDMA-based method and the delay caused by retransmissions in the proposed method is similar.

5. Conclusion

Devices in a backscatter IoT network harvest energy from other RF signals. After the energy harvesting is completed, they can participate in data transmission. Thus, the number of devices participating in data transmission changes frequently. This is a crucial characteristic in the backscatter communication. In general, a backscatter network employs TDMA-based transmission, which is easy to implement and can ensure data transfer. However, it is a rigid data transmission method, and thus it has difficulty in providing scalability considering the characteristic of the backscatter IoT network. To solve this problem, the proposed method uses a contention-based system. As a result of the performance evaluation, the proposed method showed advantages over the existing method in terms of the average transmission delay. Through the proposed method, various backscatter IoT network services can be efficiently supported.

Data Availability

Data is available on request from the corresponding author.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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