

# CSMA/CA-RBT: A Novel Media Access and Power-Saving Mechanism for M2M Communications

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**Abstract**—Although Machine-to-Machine (M2M) communication has advantages of high flexibility and the ability of network communication, once the number of devices increases, collision occurrence rises, and thus causes efficiency degradation of the Media Access Control (MAC) layer and consumes more power for data transmission. To resolve the problems M2M devices confront in a WiFi wireless network, this paper modified the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) mechanism of IEEE 802.11 to propose a media access mechanism called CSMA/CA-RBT. CSMA/CA-RBT is an improved media access control mechanism that is compatible with the traditional CSMA/CA mechanism. Using CSMA/CA-RBT, the occurrence of collision can thus be reduced. In addition, to improve the performance of CSMA/CA, CSMA/CA-RBT can also add the power-saving improvement mechanism to tackle the power-saving issue. The performance analysis results showed that, when the number of mobile nodes increases, the transmission performance and the energy efficiency can be greatly improved using the proposed CSMA/CA-RBT scheme.

**Keywords**-M2M; Power saving; CSMA/CA; IEEE 802.11.

## I. INTRODUCTION

Machine-to-Machine (M2M) communication is a machine-independent communication approach without needing human intervention during the communication. It is integrated with sensors, micro and low-priced processing units, and equipped with wireless communication capability. Thus, some machines can form Internet of Things (IoT) [1] using independent communication mechanisms over the Internet. Through the connection of Wireless Sensor Networks (WSNs), M2Ms can collect data using the sensors on the devices and respond to the collected data accordingly to monitor objects or circumstances [2]. Typical M2M applications include interconnected devices and backbone network transmitting two-way data between devices and applications [3].

Although M2M communication has advantages of high flexibility and the ability of network communication, once the number of devices increases, the increased data would have considerable impact on the network. On the other hand, the 802.11 random backoff procedure that is used during the transmission would further cause a delay in data

transmission. Once nodes have a frequent occurrence of collisions and repeatedly conduct the random backoff procedure, the increased delay causes efficiency degradation in the MAC layer. Thus, a new access method that can reduce the occurrence of the possibility of collision and increases the performance is urgently required.

To reduce the occurrence of collision and avoid energy waste, this paper devises a modified media access control mechanism of IEEE 802.11 protocol to improve the transmission efficiency. In our proposed method, each mobile node randomly selects the next time slot  $t$ , which is called Registered Backoff Time (RBT), that it wants to transmit its next packet and indicates RBT  $t$  in the currently transmitted data packet  $P_t$ . When an Access Point (AP) receives data packet  $P_t$ , AP extracts and stores RBT  $t$  and the corresponding mobile node's identification (ID) in its record. AP checks its RBT record and indicates the next time slot  $t$  and the corresponding mobile node's ID  $M_t$ , which denotes when the channel can be used and which mobile node can transmit its data packet in the nearest future, in the acknowledgement (ACK) packet  $P_A$  for acknowledging data packet  $P_t$ .

Since the ACK packet  $P_A$  is transmitted in a broadcast way, all mobile nodes in AP's signal coverage can receive it. After receiving the ACK packet  $P_A$ , the mobile node  $M_t$  can understand that it can transmit its next data packet  $t$  time slots later and the other mobile nodes can know the channel will be busy and which mobile node gets the next channel access privilege. At the same time, those mobile nodes whose selected time slots for transmitting their data packets are also  $t$  time slots later but are not scheduled as the one that can have the channel access right, would randomly select the other time slots for their next data packet's transmission. Using the piggyback concept, the collision's situation can be improved. Additionally, since all mobile nodes can know the next time slot, e.g.,  $t$  time slots later in the aforementioned example, all mobile nodes can switch to the sleep mode from the current time until  $t$  time slots later. It can thus reach the goal of saving power.

The remaining part of the paper is organized as follows. Section II introduces the related work. Section III presents the analysis of power consumption. Section IV

describes the proposed CSMA/CA-RBT scheme in detail. Section V explains the power saving mechanism in CSMA/CA-RBT. Section VI contains the performance analysis. Finally, the conclusion remarks of this paper are given in Section VII.

## II. RELATED WORK

In past years, the research on power-saving was mainly based on improving the power-saving mode (PSM) [4]. The common approaches are adding a scheduling mechanism to PSM, which allows AP to schedule the data to be transmitted and adjust power-saving states of mobile nodes (MNs) according to the scheduling. The authors in [5] proposed an implementation allowing station (STA) to dynamically adjust active time in which AP would be able to predict the next optimal beacon time for STA, enabling STA to be active and conducting transmission after the beacon time.

IEEE 802.11 Distributed Coordination Function (DCF) utilize the CSMA/CA mechanism to conduct media access control, which makes mobile nodes except the sender-receiver pair consume a lot of energy to receive unnecessary packets and thus causes energy waste. The authors in [6] therefore proposed a Bi-Directional Sleep DCF (BDSL-DCF) to (1) improve the energy efficiency of DCF, (2) prolong the lifetime of the mobile node in wireless network, (3) utilize bi-directional communications to enhance throughput and (4) prolong transmission time.

Similarly, for resource competition, the authors in [7] proposed to improve the selection process of contention window (CW) using a method named New Binary Exponential Backoff (N-BEB), which can achieve fairness and efficiency and reduce the packet lost rate. To adjust CW, the work in [8] proposed an algorithm that enables every mobile node to dynamically adjust the CW size according to channel congestion and thus can reduce the occurrence of collision and obtain better performance accordingly.

## III. ANALYSIS OF POWER CONSUMPTION

During the operation of a mobile node, whether it is at transmission, reception, idle mode or sleep mode, it consumes power. Beside, when a collision occurs, it would cause the network system an additional burden. Hence, to understand the influence of collision on the overall network operation, we use the CSMA/CA access to explain how the design of the MAC protocol influences power consumption.

Referring to Fig. 1, it is assumed that MN1 and MN2 have 2 and 3 packets to be transmitted, respectively, and the initialized binary exponential backoff (BEB) time are 8 and 12 slots respectively. Since the BEB time of MN1 is shorter, after waiting for 8 slots, MN1 would acquire the right for channel access MN would reselect a random time slot from the contention window after receiving the ACK packet. Thus, the example depicted in Fig. 1 follows the sequence of MN2→MN2→MN1→MN2 thereafter to obtain the right for channel access. In Fig. 1(b), collision occurs when MN1

is transmitting the 2<sup>nd</sup> data packet and MN2 is transmitting the 3<sup>rd</sup> data packet, which leads to the execution of the random backoff procedure and thus the transmission time is re-selected.

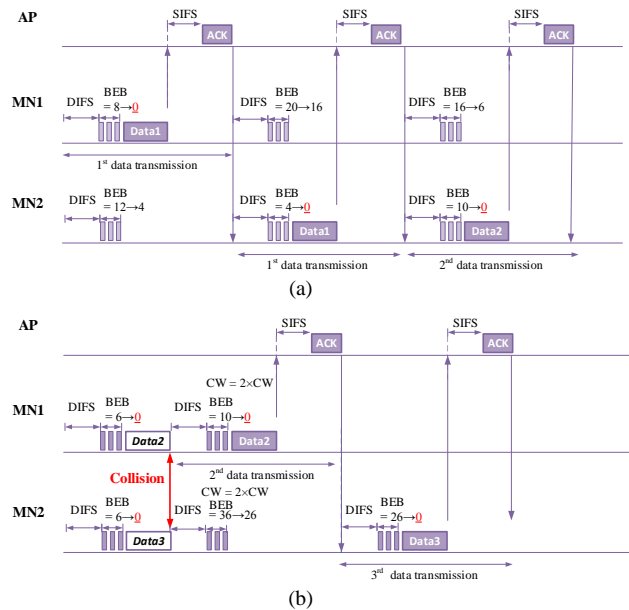


Figure 1. An example of executing CSMA/CA.

Assuming the packet size is 512 bytes, bit rate is 150 Mbps and slot time is 9 μsec., Table I shows the involved related parameters [9] during the transmission. The power consumption  $E$  of the transmission process in Fig. 1 can be calculated as follows:

$$E = M_{\text{transmission time}} \times P_{\text{transmission}} + M_{\text{reception time}} \times P_{\text{reception}} + M_{\text{idle time}} \times P_{\text{idle}} \quad (1)$$

TABLE I. SYSTEM PARAMETERS

Parameter	Value
Transmitting power	550 mW
Receiving power	250 mW
Idle listening power	200 mW
Sleeping power	40 mW
SIFS	16 μsec
DIFS	34 μsec
Slot time	9 μsec
Physical preamble	20 μsec
Bit rate	150 Mbps
Packet size	512 bytes
CW <sub>min</sub>	32
CW <sub>max</sub>	1024
CW <sub>minOriginal</sub>	32

MN1 conducted transmission (including resending data 2) three times, idle time for 38 slots, and receiving the ACK packets, thus the power consumption  $E_{m1}$  of MN1 is as follows:

$$\begin{aligned}
 E_{m1} &= MN1_{transmission\ time} \times P_{transmission} + MN1_{reception\ time} \times P_{reception} + MN1_{idle\ time} \times P_{idle} \\
 &= 3 \times \frac{512bytes}{150Mbps} \times 0.55W + 5 \times \frac{14bytes}{150Mbps} \times 0.25W + (8 + 20 + 10) \times 9\mu sec \times 0.2W \\
 &= 7.41 \times 10^{-5} J
 \end{aligned} \tag{2}$$

MN2 conducted transmission (including resending data 3) four times, idle time for 64 slots, and receiving the ACK packets, thus the power consumption  $E_{m2}$  of MN2 is as follows:

$$\begin{aligned}
 E_{m2} &= MN2_{transmission\ times} \times P_{transmission} + MN2_{reception\ time} \times P_{reception} + MN2_{idle\ time} \times P_{idle} \\
 &= 4 \times \frac{512bytes}{150Mbps} \times 0.55W + 5 \times \frac{14bytes}{150Mbps} \times 0.25W + (12 + 10 + 6 + 36) \times 9\mu sec \times 0.2W \\
 &= 1.23 \times 10^{-4} J
 \end{aligned} \tag{3}$$

Power consumption of these 2 MNs for transmitting a data each time is  $E_{data}$ :

$$\begin{aligned}
 E_{data} &= \frac{512bytes}{150Mbps} \times 0.55W \\
 &= 1.88 \times 10^{-6} J
 \end{aligned} \tag{4}$$

The rate of wasted energy in collision (including wasted energy  $E_{idle}$  at the idle mode) over the total power consumption can be calculated as follows:

$$\begin{aligned}
 \text{Energy was te rate} &= \frac{\text{packet collision power consumption}}{\text{total power consumption}} \\
 &= \frac{E_{data} + E_{idle}}{E_{m1} + E_{m2}} \\
 &= \frac{2 \times 1.88 \times 10^{-6} J + (20 + 6) \times 9\mu sec \times 0.2W}{7.41 \times 10^{-5} J + 1.23 \times 10^{-4} J} \\
 &\approx 25.66\%
 \end{aligned} \tag{5}$$

From the above examples, according to the calculation results depicted in (2) and (3), it is known that the consumed power of MN1 transmitting two packets is  $7.41 \times 10^{-5} J$ , consumed power of MN2 transmitting three packets is  $1.23 \times 10^{-4} J$ . Since there is one collision, (1) both MN1 and MN2 waste the transmitting power ( $1.88 \times 10^{-6} J$ ) of transmitting a packet, (2) MN1 wastes 20 idle time slots before its 1<sup>st</sup> transmitting its 2<sup>nd</sup> data, and (3) MN2 wastes 6 idle timeslots before its 1<sup>st</sup> transmitting its 3<sup>rd</sup> data, which occupies 25.66% power consumption of the overall network. Therefore, if the collision can be predicted and avoided in advance, the power consumption is expected to be reduced and the system performance can be enhanced.

#### IV. THE PROPOSED CSMA/CA-RBT SCHEME

In the proposed CSMA/CA-RBT method, the mobile node would attach a random number in the packet when the mobile node transmits data to AP. This random number is called Registered Backoff Time (RBT). When an AP receives the data packet, it would add the RBT to AP side's RBT list, which is called Registered-Time-Slot-List (RTSL), to conduct the scheduling. When replying the ACK packet, it would add prescheduling information, e.g., MAC address of the next transmitter's node and the estimated transmission slot time of the follow-up time period, in the

ACK packet. Since the ACK packet is transmitted using broadcast, all of the mobile nodes that are in the signal coverage of the AP can receive the ACK packet transmitted by the AP. This way, all of the covered mobile nodes can get the prescheduling information for the follow-up time period of the network channel and thus can adjust their backoff timers to reduce the occurrence of collision.

In the proposed scheme, when the backoff timer counts down to 0, the mobile node would select one random number to be the RBT for its next data transmission and put the RBT to the data packet. The ACK packet sent from AP has a similar effect as the CTS packet. Mobile nodes can obtain information related to RBT from the ACK packet and acknowledge which mobile node, including AP, would conduct the transmission after some slot times. Let  $x$  be the slot time after the current time when a mobile node conducts the next transmission. At this moment, all mobile nodes can temporarily switch from the idle mode to the sleep mode during the  $x$  slot times.

In contrast, when an AP receives the data packet, it would take out the RBT  $i$  of the mobile node and match it with the record in RTSL to determine whether the slot denoted by RBT  $i$  is occupied or not. If  $RTSL[i] = 0$ , it represents that slot  $i$  is not reserved before and AP can add RBT  $i$  to RTSL by means of setting  $RTSL[RBT] = 1$ . After updating RTSL, AP can understand which slot time is registered by which mobile node according to the scheduling record in RTSL. AP sends the ACK packet which contains the information of the following transmission about registered time slot and node ID to the mobile node. On the contrary, if  $RTSL[i] = 1$ , it represents that slot  $i$  has been registered. RTSL remains unchanged, and thus AP sends ACK packet according to RTSL directly.

The proposed scheme allows AP to coordinate using RBT messages and thus some collisions can be avoided. As mentioned in Section III, MN1 and MN2 have two and three packets to be transmitted, respectively. Fig. 1 depicts the execution flow using CSMA/CA. Fig. 2 depicts the execution flow using the proposed CSMA/CA-RBT scheme. In this example, we highlighted the improvement of the collision's situation of the proposed CSMA/CA-RBT only. However, the power saving mechanism in CSMA/CA-RBT would be discussed in detail in Section V.

Referring to Fig. 2, the backoff time in the beginning is 8 and 12 slots for MN1 and MN2, respectively. Since the backoff time of MN1 is shorter, MN1 would select a random number as RBT after waiting for 8 slots and then send the data packet with the selected RBT, which is 20 in Fig. 2(a). After MN1 has successfully completed packet transmission (DATA+RBT) and passes 4 slot times, MN2 would send its first data packet with the selected RBT, which is 10 in Fig. 2(a). Then, according to the schedule, MN2 would transmit its data packet after waiting for 10 time slots. MN2 selects RBT=6 when it transmits its 2<sup>nd</sup> data packet. After receiving MN2's 2<sup>nd</sup> packet, which indicates its RBT is 6 time slots, AP knows that both MN1 and MN2

plan to transmit packets after 6 time slots. In the proposed CSMA/CA-RBT Scheme, AP adopts the first-come-first-served principle and thus selects MN1 as the mobile node to have the next channel access right.

As illustrated in Fig. 2(a), after MN2 has transmitted its 2<sup>nd</sup> data packet, AP sends ACK to notify MN1 to transmit its packet after 6 slot times. Since the ACK is transmitted in a broadcast way, MN2 can also receive the ACK and thus can find that it would collide with MN1's data transmission. Therefore, MN2 would modify its backoff time to avoid collision after receiving the ACK. In the example depicted in Fig. 2(a), MN2 modified its RBT to 36. Fig. 2(b) depicts the execution flow after MN2's RBT modification.

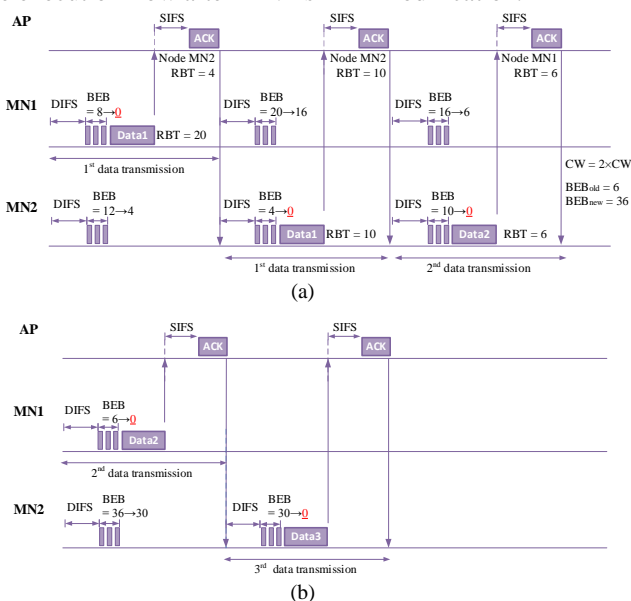


Figure 2. An illustrated execution flow of the proposed CSMA/CA-RBT Scheme.

Based on the execution flow depicted in Fig. 2, the corresponding power consumption is calculated as follows. MN1 has transmitted two data packets. The generated idle time during backoff is 8+20 time slots, and receiving the ACK packets, thus the power consumption  $E_{m1}$  for the data transmission is as follows:

$$\begin{aligned}
 E_{m1} &= MN1_{transmission\ time} \times P_{transmission} + MN1_{reception\ time} \times P_{reception} + MN1_{idle\ time} \times P_{idle} \\
 &= 2 \times \frac{512\text{bytes}}{150\text{Mbps}} \times 0.55\text{W} + 5 \times \frac{14\text{bytes}}{150\text{Mbps}} \times 0.25\text{W} + (8 + 20) \times 9\mu\text{sec} \times 0.2\text{W} \\
 &= 5.43 \times 10^{-5}\text{J}
 \end{aligned} \tag{6}$$

MN2 has transmitted three data packets. The generated idle time during backoff is 12+10+36 time slots, and receiving the ACK packets, thus the power consumption  $E_{m2}$  for the data transmission is as follows:

$$\begin{aligned}
 E_{m2} &= MN2_{transmission\ on\ time} \times P_{transmission} + MN2_{reception\ time} \times P_{reception} + MN2_{idle\ time} \times P_{idle} \\
 &= 3 \times \frac{512\text{bytes}}{150\text{Mbps}} \times 0.55\text{W} + 5 \times \frac{14\text{bytes}}{150\text{Mbps}} \times 0.25\text{W} + (12 + 10 + 36) \times 9\mu\text{sec} \times 0.2\text{W} \\
 &= 1.1 \times 10^{-4}\text{J}
 \end{aligned} \tag{7}$$

Comparing CSMA/CA-RBT with CSMA/CA, the saved power of MN1 and MN2 can be calculated as follows:

$$\begin{aligned}
 \text{MN1 Saved Power Rate} &= 1 - \left( \frac{\text{Power Consumption of CSMA/CA - RBT}}{\text{Power Consumption of CSMA/CA}} \right) \\
 &= 1 - \left( \frac{5.43 \times 10^{-5}\text{J}}{7.41 \times 10^{-5}\text{J}} \right) \\
 &\approx 26.72\%
 \end{aligned} \tag{8}$$

$$\begin{aligned}
 \text{MN2 Saved Power Rate} &= 1 - \left( \frac{\text{Power Consumption of CSMA/CA - RBT}}{\text{Power Consumption of CSMA/CA}} \right) \\
 &= 1 - \left( \frac{1.1 \times 10^{-4}\text{J}}{1.23 \times 10^{-4}\text{J}} \right) \\
 &\approx 10.57\%
 \end{aligned} \tag{9}$$

According to the results of (8) and (9), MN1 and MN2 can save 26.72% and 10.57% power, respectively. From the aforementioned analysis results, we can understand that the proposed CSMA/CA-RBT has better execution performance and better power-saving efficiency than the original standard CSMA/CA.

## V. THE POWER SAVING MECHANISM IN CSMA/CA-RBT

Owing to the AP has notified the next transmission time slot, the mobile node can enter into sleep mode to save power consumption before this registered time slot is due. To increase power-saving in mobile nodes, the proposed CSMA/CA-RBT scheme enables a power-saving mechanism which lets all mobile nodes sleep before the estimated transmission time. This can assure that there is a complete sleep time period for mobile node.

The example depicted in Fig. 3, in which mobile nodes A, B, C and D have requested for prescheduling toward AP in advance (mobile nodes send RBT to AP), and in between, A sends data to B. Owing to the infrastructure network between A and B, A sending data to B is internal data exchanging, packets are sent to AP (slot 2) from A and then forwarded to B (un-scheduled) from AP. For mobile nodes, except for a few registered slots, most slots belong to idle slots.

Referring to Fig. 4(a), after passing 2 slots, A acquires the right for channel access and sends its RBT to AP. To assure the completion of communication between A and AP and the mobile node has sufficient time to update RBT information, AP would arrange to transmit A's data transmitted to B based on the next known prescheduled slot, i.e., the next slot after the slot reserved by mobile node C, which is the 13th slot in Fig. 4(b). From Fig. 4(b), we can observe that there are 12 idle slots between slot 0 and slot 13. Thus, mobile nodes can switch to the sleep mode during this period to save power. On the other hand, owing to switching between the idle mode and the sleep mode takes the time of 1 idle slot, although there is 1 idle slot between slot 1 and slot 3 in Fig. 4(c), mobile nodes would not switch to the sleep mode in time slot 2 of Fig. 4(c). There are more than

one idle slot between slot 3 and slot 7 in Fig. 4(c), mobile nodes can switch into the sleep mode between slot 3 and slot 7, depending on the implementation's convenience to save energy.

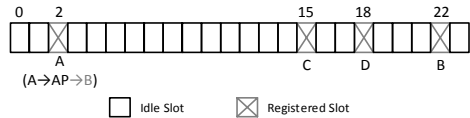


Figure 3. The distribution of idle slots and registered slots in RTSL.

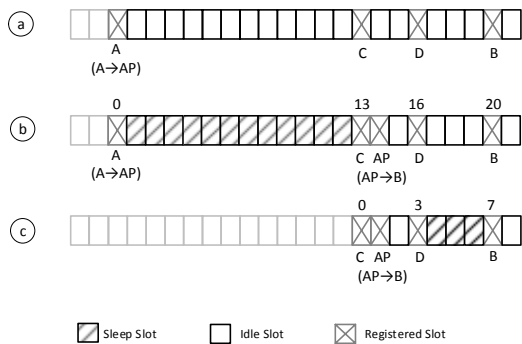


Figure 4. The distribution of idle slots, sleep slots and registered slots after mobile node A transmitting its data packet.

Compared to the idle mode, a mobile node consumes relatively little power in the sleep mode. Theoretically, if we can let the mobile node immediately enter into sleep mode once it is idle, it can be very helpful to save power. Taking Fig. 4 as an example, when mobile nodes are idle and wait for transmitting/receiving packets, they can automatically enter into sleep mode. The power consumption can be calculated as follows:

$$\begin{aligned}
 \text{Power Saving Rate} &= 1 - \left( \frac{P_{\text{sleep}}}{P_{\text{idle}}} \right) \\
 &= 1 - \left( \frac{0.04W}{0.2W} \right) \\
 &\approx 80.00\%
 \end{aligned}
 \tag{10}$$

According to the calculation result of (10), comparing with the original power-saving mechanism, the proposed CSMA/CA-RBT scheme can further reduce the power consumption as follows:

$$\begin{aligned}
 E_{\text{idle}} &= 4 \times 15 \times 9 \mu\text{sec} \times 0.2W \\
 &= 1.08 \times 10^{-4} \text{ J}
 \end{aligned}
 \tag{11}$$

$$\begin{aligned}
 E_{\text{sleep}} &= 4 \times 15 \times 9 \mu\text{sec} \times 0.04W \\
 &= 2.16 \times 10^{-5} \text{ J}
 \end{aligned}
 \tag{12}$$

Equations (11) and (12) show the total power consumption of a mobile node in the idle and sleep modes, respectively. Although the power consumption in the idle mode is not much, however, 80% energy can be saved when a mobile

node is switched from idle mode to sleep mode based on (10). Referring to the example depicted in Fig. 4, mobile nodes A, B, C and D can save considerable power when there are 15 time slots that allow them to switch from idle mode to sleep mode.

## VI. PERFORMANCE ANALYSIS

The performance of the proposed CSMA/CA-RBT scheme was evaluated by performing a series of simulations on the WiFi simulator using the IEEE 802.11 infrastructure-based network model, for which Table I summarizes parameter values used in the simulations.

Fig. 5 depicts the variations of the average network throughput vs. the number of mobile nodes. Referring to Fig. 5, it is observed that when there are not many nodes within the network, e.g., there are only 5 to 10 mobile nodes, owing to CSMA/CA-RBT can reduce the occurrence of collision and mobile node can complete the data transmission earlier, CSMA/CA-RBT has higher throughput comparing with the traditional CSMA/CA. In contrast, when there are a lot of mobile nodes, e.g., 50 mobile nodes, CSMA/CA-RBT can enhance  $1 - (0.0698/1.0570) = 33.96\%$  of the throughput comparing with the traditional CSMA/CA. In view of this, it is known that CSMA/CA-RBT is beneficial to enhance network performance in terms of throughput.

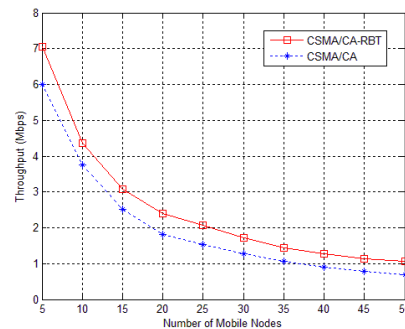


Figure 5. The throughput vs. the number of mobile nodes.

Fig. 6 shows the delay time for transmitting a fixed amount of packets vs. the number of mobile nodes. Referring to Fig. 6, when compared to CSMA/CA, CSMA/CA-RBT has less delay time than that of the traditional CSMA/CA because CSMA/CA-RBT can reduce the occurrence of collisions and avoiding using larger contention window when there is random backoff, which is especially true when the number of mobile nodes is increased. When there are 50 mobile nodes, CSMA/CA-RBT can reduce  $1 - (0.0199/0.0268) = 25.75\%$  of the delay time. The simulation results depicted in Fig. 6 show that CSMA/CA-RBT always has better performance in terms of delay time when the number of mobile nodes is increased.

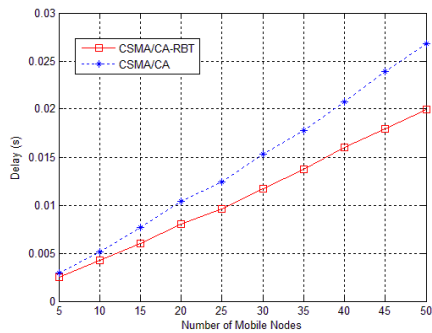


Figure 6. The delay time vs. the number of mobile nodes.

Fig. 7 depicts the power consumption of CSMA/CA-RBT and CSMA/CA vs. the number of mobile nodes. To analyze the result clearly, we classify the CSMA/CA-RBT into two types: the one that lets mobile nodes switch from idle mode into sleep mode is called CSMA/CA-RBT (PSM); the other one that does not let mobile nodes switch from idle mode into sleep mode, e.g., the example depicted in Fig. 2, is called CSMA/CA-RBT (idle).

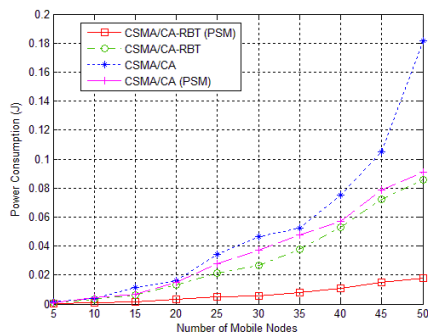


Figure 7. The power consumption vs. the number of mobile nodes.

The simulation results depicted in Fig. 7 show that, with the increased number of mobile nodes, the transmission efficiency degrades because the competition for the right of channel access gets worse, which also causes the power consumption to increase. The power consumption of using CSMA/CA (PSM) is lower than that of CSMA/CA. Since (1) both of the CSMA/CA-RBT types can reduce the power consumption of retransmission from the collision and (2) CSMA/CA-RBT (PSM) allows mobile nodes to switch the operation mode from idle mode to sleep mode, CSMA/CA-RBT (PSM) can more effectively reduce power consumption than CSMA/CA-RBT (idle).

It can be seen from the simulation results that CSMA/CA-RBT can effectively reduce the occurrence of collisions and thus can enhance throughput, alleviate the delay, and avoid unnecessary power consumption. The results also show that the more mobile the nodes are, the better performance CSMA/CA-RBT can achieve.

## VII. CONCLUSION

The proposed CSMA/CA-RBT simply requires to modify the media access mechanism of the MAC layer, and meanwhile is compatible with the downward legacy IEEE 802.11 protocols. In comparison to the original IEEE 802.11 MAC mechanism, the proposed CSMA/CA-RBT scheme can reduce collision and delay, enhancing the performance of M2M communication over wireless network. The simulation results showed that when the number of mobile nodes increases, the proposed CSMA/CA-RBT scheme can not only significantly improve the system performance, but also save considerable power for the overall network.

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## REFERENCES

- [1] P. C. Jain, "M2M Wireless Communication", Annual Seminar on C-DAC Noida Technologies, pp.51-59, 2012.
- [2] M. Chen, J. Wan, and F. Li, "Machine-to-Machine Communications Architectures Standards and Application", *KSII Transactions on Internet and Information Systems*, VOL. 6, NO. 2, pp.480-497, February 2012.
- [3] D. Walczak, M. Wrzos, A. Radziuk, B. Lewandowski, and C. Mazurek, "Machine-to-Machine Communication and Data Processing Approach in Future Internet Applications", *Proceedings of the 8th International Symposium on Communication Systems, Networks & Digital Signal Processing (CSNDSP)*, pp. 1-5, 2012.
- [4] IEEE, Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, IEEE 802.11 Std., 2012.
- [5] H. Tabrizi, G. Farhadi, and J. Cioffi, "An Intelligent Power Save Mode Mechanism for IEEE 802.11 WLAN", *Proceedings of 2012 IEEE Global Communications Conference (GLOBECOM)*, pp. 3460 – 3464, 2012.
- [6] R. Palacios, F. Granelli, D. Kliazovich, L. Alonso, and J. Alonso-Zarate, "An Energy Efficient Distributed Coordination Function Using Bidirectional Transmissions and Sleep Periods for IEEE 802.11 WLANs", *Proceedings of 2013 IEEE Global Communications Conference (GLOBECOM)*, pp. 1619 – 1625, 2013.
- [7] M. Shurman, B. Al-Shua'b, M. Alsaadeen, M. F. Al-Mistarihi, and K. A. Darabkh, "N-BEB: New Backoff Algorithm for IEEE 802.11 MAC Protocol", *Proceedings of the 37th International Conference on Information and Communication Technology, Electronics and Microelectronics (MIPRO)*, pp. 540 - 544, 2014.
- [8] K. Hong, S. Lee, K. Kim, and Y. Kim, "Channel Condition Based Contention Window Adaptation in IEEE 802.11 WLANs", *IEEE Transactions on Communications*, VOL. 60,

- NO. 2, pp. 469 - 478, 2012.
- [9] H. H. Lin, H. Y. Wei, and R. Vannithamby, "DeepSleep: IEEE 802.11 Enhancement for Energy-Harvesting Machine-to-Machine Communications", Proceedings of 2012 IEEE Global Communications Conference (GLOBECOM), pp. 5231 – 5236, 2012.