2009 International Conference on Communications and Mobile Computing

A Reader Anti-collision MAC Protocol for Dense Reader RFID System

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Abstract

In dense reader RFID system, a number of readers in the same interrogation area want to access the channel at the same time suffer from reader collision problem. In this paper, we propose a distributed reader anti-collision MAC protocol (RAMP) for dense reader environment. We extended the pulse protocol by adding multiple data channels and the channel hopping algorithm. The channel hopping algorithm helps to decide whether to hop for new channel or wait in the same channel. Also, channel utilization probability based random backoff mitigates the collision possibility in the control channel. Simulation result shows that our protocol mitigates reader's collision, hence decreases waiting time significantly than the existing RFID MAC protocol.

1. Introduction

Readers in the RFID system are becoming mobile and the stationary readers are becoming more functional in the same work place. Readers in such work place will try to access the same tag at the same time. The situation when multiple readers are in the interference region of one another will lead to the reader collision problem and will dither the communication with the tag. Passive tags are cheaper and are widely used, but they lack frequency selectivity. In such an environment, the problem of reader to reader and reader to tag collision occur, which leads to the reduction of the efficiency and reliability of the RFID system, resulting in the mis-reading, crash reading and an increase in the tag interrogation time.

The reader collision problem models the task of assigning radio frequency spectrum over time to a set of RFID readers. There are two types of interference in the reader side. (i) Two or more readers communicating on the same frequency at the same time called frequency interference. In Fig. 1, T1 lies in interference region of reader R2. The reflected signals reaching reader R1 from tag T1 can be easily distorted by signals from reader R2. This kind of interference is possible even when the read range of the two readers do not overlap. This situation occurs in the RFID system when there is unwanted transmission from a nearby reader interfere with a tag's ability to decode a desire signal. (ii) Two or more readers attempting to communicate with a particular RFID tag at the same time called tag interference. In Fig.2, the two readers R1, R2 are in the same work place. When both readers R1 and R2 try to read a tag T1 at the same time, neither of them can read the tag T1.

In RFID system, the passive tags lack the frequency tuning circuitry. Therefore in denser reader environment, collision problem is highly prevalent causing serious degradation in the performance of RFID system.

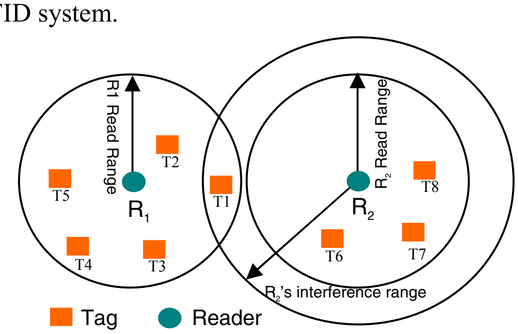

Fig. 1. Reader-to-reader collision.

Due to emergence of new technologies various MAC layer protocols have been proposed that perform limitedly and cannot satisfy the performance requirements fully, thus leaving some room for improvement. Thus, in this paper, we proposed a distributed MAC protocol in order to mitigate the reader collision problem and solve the hidden and exposed node problem. The remainder of this paper is

978-0-7695-3501-2/09 $25.00 © 2009 IEEE
DOI 10.1109/CMC.2009.283

organized as follows. In section 2, we describe related works. In section 3, we illustrate our novel protocol. In section 4, we describe about the simulation results and finally, section 5 is the conclusion.

2. Related Works

Many multiple access schemes such as the Time Division Multiple Access (TDMA), Frequency Division Multiple Access (FDMA), Code Division Multiple Access CDMA, and Carrier Sense Multiple Access (CSMA) are proposed to solve the problem of collision.

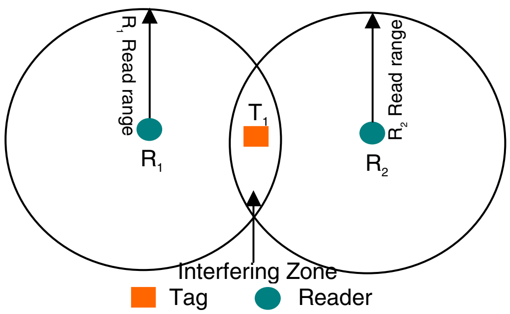

Fig. 2. Reader-to -Tag Collision

Listen-Before-Talk (LBT) is multiple access schemes that work on the principle of CSMA scheme. This is standardized as ETSI EN 302 208 [1] and is developed for the RFID. In this standard it requires that all the reader must listen to the ongoing transmission in the channel before accessing it. If the channel is idle it starts reading tags, otherwise it waits for certain time. However, only by carrier sensing, reader collision problem cannot be solved. Further, the carrier sensing mechanism is ineffective in solving collision problem.

Colorwave Reader anti-collision algorithm [2] is a distributed TDMA based algorithm. Each slot is allocated with a different color. The readers in the network will randomly choose color ranges from [0, Maxcolors]. The reader with a queued request for transmission can transmit data in its color timeslot. Colorwave enables the RFID system to easily adapt to local disturbances, based on local information, such as the instillation of the new readers or the presences of the mobile readers. However, the colorwave requires the firm time synchronization between the readers. In the wireless mobile reader environment, the overhead of time-slot reselection continuously increases that wastes resources.

Pulse [3] is a CSMA based notification protocol that attempts to solve the reader collision problem using two separate channels for the data and control packets in the RFID system. This protocol mitigates the reader collision problem by continuously transmitting the beacon through the control channel while the communicating with the tag through the data channel. In this protocol beacon can collide with another beacon form another reader. The hidden terminal and exposed terminal problem are not solved.

DiCa (Distributed Tag Access with Collision Avoidance) [4] is a distributed and energy efficient collision avoidance algorithm. Similar to the pulse protocol, it also has data channel and control channel. Each reader contends through control channel and the contention winner reads tags through data channel and other wait until channel is idle. DiCa requires sufficient time to exchange the contention message. It tries to prevent the collision after it takes place rather than acting actively at the first sight. So, it does not reduce the collision problem efficiently.

3. A Reader Anti-collision Algorithm

We extended the pulse protocol by adding multiple data channels and the channel hopping algorithm. The channel hopping algorithm helps to decide whether to hop for new channel or wait in the same channel. Also, random backoff based on channel utilization probability mitigates the collision possibility in the control channel.

We assume that there are n number of data channels and a control channel. Data channels are for the readers to tag communication and control channel is for the reader to reader communication. Reader can transmit control signal through the control channel while it is communicating with tags through the data channel. We only consider the reader side because tags do not contribute any role in reader collision problem.

As in LBT, in RAMP each reader listens before talk. At first, reader enters into the Listening Stage (LS) for T-listen time targeting to win contention in a particular data channel. In the LS, if the reader receives any control message (in a control channel) from any of neighboring readers, it determines that the data channel is not idle. Now the reader has two options: (i) wait in the same channel for a certain period of time (random backoff) or (ii) search for an idle channel. We discuss these both of two options in later section.

On contrary, if reader in LS does not receive any control message within T-listen time, it enters in the Waiting Stage (WS) and waits for T-waiting time. T-waiting time is similar to the DIFS in 802.11. In the WS, if reader receives beacon message, it goes back to the LS again. If not receive, then the reader broadcasts the beacon message to the neighbors in the control channel and occupies the data channel. After broadcasting beacon message, reader waits for T-waiting time and starts communication with tags in the data channel. Fig. 3 shows the control packet frame structure. Type field in beacon packet indicates the packet is beacon and sequence number is the number of beacon transmitted.

Type	Seq. No.	Reader's ID	Channel Selected	Checksum

Fig. 3. Beacon packet structure.

3.1. Random Backoff Time (for Beacon message)

Random backoff mechanism is necessary to avoid the possible collisions due to accessing the control channel by multiple readers at the same time. This mechanism transmits data after waiting the random amount of slot within backoff windows slot. The reader that selects the lowest slot size can occupy the channel. The backoff windows slot can be calculated as follows:

$$B_t(i) = \frac{pkt\_size}{Tx} \times \frac{1}{U_t(i)} + B_{\min} \qquad (1)$$

Where, B_{min} is a minimum backoff time, Tx is packet transmission rate and U_t denotes the channel utilization. RAMP uses the linear historical prediction model to update the utilization of channel i for the next time slot t.

$$U_t = (1-\alpha)\ U_{t-1}(i) + \alpha\ U' \qquad (2)$$

Where, U_{t-1} is the channel utilization of last time slot t-1 by channel i. U' is the average experienced utilization of the past.

3.2. Channel hopping algorithm

It is obvious that if a number of readers in the same interrogation area want to access the channel at the same time collision occurs. The probability to win the channel access depends on the density of the readers in the reader's interrogation area. If there are many numbers of readers than the channels available, the probability to gain access in the channel is less. In this case waiting in the current channel is not efficient. If the number of channels are more than the number of readers at any time it may not be efficient to wait in the same channel. In [5] hopping is performed in random fashion, which is not efficient way to search idle channel because reader might perform continuous channel hopping for a long time in order to find idle channel when channel utilization is high. To make a decision on the basis of density of the readers is an estimable way to decide either to hop for new channel or just wait in the same channel. We calculate reader density as follows:

$$d = \frac{|N|}{I} \qquad (3)$$

Where, |N| is number of readers residing in the same interrogation area, which can communicate with each other. I is the number of data channels available. If d < 1, hopping is better than waiting in the same channel. If d > 1, the probability of getting ideal channel with hopping is relatively low. Thus, waiting in the same channel is better than hopping for new channel. However, only d cannot give the perfect decision for channel hopping. For example, there are N reader readers and I number of channels, where N=I (i.e. d=1). Two new readers, r_1 and r_2 are trying to get access into the channel i_1, at this time if they decide to wait into the same channel by considering only density; one of them has to wait for the long time get access into it. Sometimes, even if d is very high (i.e. d>1), it is wise decision to hop channel, particularly when the channel utilization of some other channels are lower than the currently reader trying to access channel. To solve inefficiency we make a cost function that decides considering both density and channel utilization of the particular channel.

$$C_i = (d_t)^{\beta} + U_t \qquad (4)$$

Where, C_i is the cost of the channel i, d_t is the density of the readers in a particular time t and β is a positive weighting factor.

4. Performance evaluation and simulation results

In this section we evaluate RAMP and compare with CSMA in a dense reader environment. In our simulation module readers are distributed by poison distribution. The T-listen time is 15ms for both RAMP and CSMA (similar to ETSI EN 302 208 [1]), channel switching time is 0.1ms. and T-waiting time for RAMP is 0.5ms. There are 4 channels and readers are chosen randomly. All the readers are homogeneous having radio range of 30 meters.

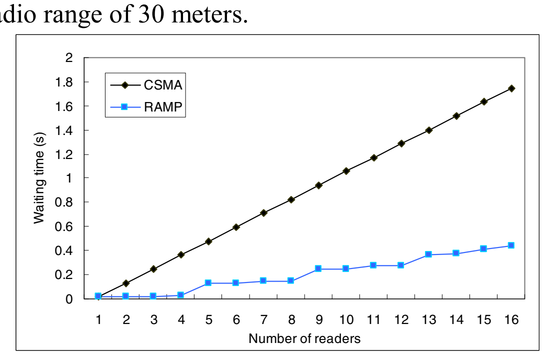

Fig. 4. Waiting time of reader vs. number of readers.

Fig. 4 shows the waiting time of the readers. When there is a single reader, it gets channel without switching. Once the number of readers increases waiting time increases in both protocols but waiting time difference is very high in between CSMA and RAMP.

In Fig. 5, we compare collision between CSMA and RAMP. When number of readers increase, collision occurs more frequently in both of protocol but in CSMA frequency is very high comparing to RAMP due to the hidden terminal problem in the case of CSMA. This problem is reduced in the RAMP as we use the notification mechanism.

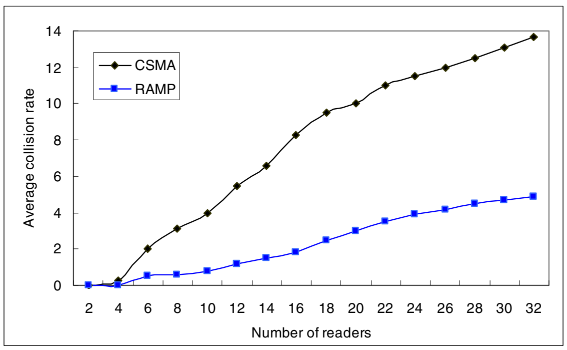

Fig. 5. Number of readers vs. average collision rate.

4. Conclusions

We presented a distributed MAC layer protocol for the dense RFID system. Its probability based channel hopping algorithm facilitates readers to utilize channels efficiently. This protocol not only mitigates the reader collision problem but also gives solution to the hidden terminal problem. Simulation result shows, this protocol is more efficient than CSMA, hence is suitable for the wireless mobile RFID system.

6. References

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