M-027

Developing of Dynamic Collision Avoidance Algorithm for Indoor Active RFID Tracking System

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1． Introduction

As the need for asset and human resource management in specific fields such as institutes, schools or harbors increases, many indoor tracking systems have been introduced. Systems based on active RFID are especially becoming more pervasive because of RFID's effectiveness. Under this circumstance, the collision problem, as in other communications systems, is a critical issue with regard to throughput and power consumption. Although there are already plenty of algorithms which effectively work in communications systems, or in passive type RFID, there is no specific algorithm for this specific indoor tracking system.

All algorithms for passive type RFID are basically deterministic methods. A power-free reader interrogates to all tags by giving the logic to respond, and the tags are completely controlled by the given logic. Since all tags are powered by the interrogation, the interrogation count does not affect system performance. Therefore, the deterministic methods are achieved by suppressing or activating the ID bits with some logic until the whole tags are responded.[1] However, this method is not effective for the active tags which can’t keep up listening for the interrogation as they are activated by limited battery power.

Meanwhile, the active RFID systems have many aspects in common with wireless communications systems. For example, they care about the power consumption and uses some beacon based synchronized techniques. The most typical method for avoiding the collision is a technique called CSMA. With CSMA, each station ready to transmit first assess the media to see if the channel is available which is called as Clear Channel Assessment (CCA). This method also possibly can be adapted to an active RFID system. However, the RFID system is not a communication, but rather a process of identification. Only a tag to reader transmission is the target of collision avoidance control. In addition, the packet length is all same and even very short. CCA, however, is required to assess the channel for certain frame length to be effectively working, which might be longer than a normal packet length for a RFID system. The performance deterioration has actually been observed under most likely situation by my previous simulation, which is not published yet.

For this reason, a dedicated collision avoidance method for the active RFID system under a certain indoor environment is devised and introduced in this paper.

2. Proposed Method

2.1 Basic Configuration of the Method

Once an active RFID system is designed for a site, an average identification period for each tag would be given. We call this a ‘Round’. Within a round, two separated sections are defined. One is called as Scheduled Tag Access Period(STAP) and the other is called as Random Tag Access Period(RTAP). Each section would contain multiple slots to synchronize the tag transmissions. There would be only one STAP at the very first of a round, while RTPAs would be multiple. However, the number of slot in each RTAP would be same within a round. Fig.1 depicts the configuration of a round.

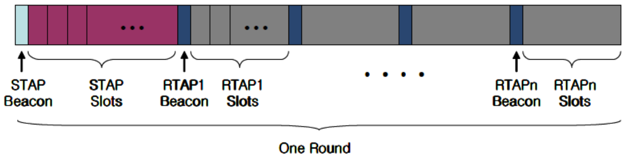

Figure 1: A round consists of single STAP and multiple RTAPs

STAP is placed at the beginning of the round followed by multiple RTAPs composing the rest of the round. At the beginning of every STAP and RTAP, there is a beacon which enables the tags to be synchronized to the slots. A tag has an internal flag specifying whether it's in a Random Mode or in a Scheduled Mode. Firstly, a tag starts from the random mode. It wakes up periodically and listens to the channel for some amount of time. Every RTAP beacon signal would include the ID of the base station as well as the number of slots in that RTAP. Once a tag finds the RTAP beacon, it transmits its ID at a randomly chosen slot during the RTAP. If there is only one tag transmitted at a specific slot, then it would succeed and be replied with an ACK from the reader. This ACK would contain some information to turn the tag into the scheduled mode. For example, it would contain the slot index that the tag should transmit at from the next STAP, estimated time to the next STAP beacon so that the tag can fall into a sleep mode to save power. On the other hand, if more than two tags transmit at a same slot causing a collision, the reader would detect and skips the ACK transmission for that slot. Then the tags those transmitted would fail to receive the ACK, thus causing them to wait until the next RTAP beacon. From the second try, the effort to find a RTAP beacon can be omitted since the previous RTAP beacon may contain the time to the next RTAP beacon or the RTAP interval is fixed in the system wide.

2.2 STAP and RTAP management

A tag scheduled at a STAP by successfully transmitting during a RTAP would never fail to transmit, thus guaranteeing the maximum identification period as one round. This is because that a scheduled tag occupies its own slot in the STAP exclusively.

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And other tags including any unscheduled one would never try at that slot. It also implies that the number of STAP slots should be same as or more than the number of currently scheduled tags. For this reason, the slot count of a STAP should dynamically vary. At the very first time, the slot count would be zero. But soon as a tag succeeds the transmission in a RTAP, the STAP slot count would increase to afford the tag. And eventually the slot count of the STAP would reach to the number of the available tags leaving no unscheduled tags.

Now the problem is how to determine one RTAP length. For this, two key items should be considered-Throughout and Power Consumption.

First of all, as easily be inferred, the throughput is directly affected by the slot count. If the number of slot increases, the probability of collision in a slot is reduced. But it does not mean an improvement of the throughput. As the number of slots increases, the length of a RTAP is also increased causing a tag to take longer time for one random transmission. Although the probability of a successful transmission in a RTAP is increased, the penalty that a failed tag has to wait is increased, too. Taking this into consideration, an optimal slot count regarding the throughput should be obtained. A former study has proved that an optimal slot count for slotted aloha system is same as the ready-to-transmit stations.[2] Therefore, in our case, the optimal slot count for a RTAP can be determined as the number of tags ready-to-transmit. The left problem is how to find the number of ready-to-transmit tags.

For this, a successful transmission rate P_{empty} can be obtained as follow.

$$P_{empty} = L \times \left(1 - \frac{1}{L}\right)^{n} \qquad (1)$$

where L is the current slot count in a RTAP and n is the ready-to-transmit tag count.

Since we can measure the empty slot count from the previous RTAP result, the only unknown value in (1) is n. From this, the tag count n can be obtained as,

$$n = \frac{log\left(\frac{P_{empty}}{L}\right)}{log\left(1-\frac{1}{L}\right)} \qquad (2)$$

If a RTAP slot count is not fixed, hence is able to be adjusted, the slot count for the next RTAP can be determined based on (2) as a result of previous RTAP. But as a second key item to be considered, there is the power consumption problem. If we adjust the slot count of a RTAP only by a measured tag count, it can be long enough to occupy the entire round or even exceed the round. Even in case that it could be less than a round, it still can become too long causing an unscheduled tag to take more effort to find a RTAP beacon. Since a big portion of the power consumption happens during the listening, this RTAP period should not be determined only by an optimal throughput.

For this reason, small and fixed slot count of the RTAP is preferred. Instead, we make the RTAP beacon include a probability parameter to transmit, P_{trans}. This is a probability at which a tag decide the transmission during the RTAP. For example, assume that the slot count of a RTAP is fixed to 50, and the previous result of estimated tag count is 100. For an optimal throughput, the slot count should be same as the number of ready-to-transmit tags. But, since we fixed the slot count , we rather adjust the ready-to-transmit tag count by giving them the probability of transmission as 0.5. As a result, only half of the 100 tags would transmit, and the 50 of the slot count would be the optimal count. If a tag fails to transmit by either of collision or choosing not to transmit, it would simply turn into a sleep mode until next RTAP beacon, then try again. This might seem to result in an accumulation of tags as the RTAP is repeated. However, the tags that have successfully transmitted would be scheduled to the STAP quitting from the ready-to-transmit tags group. Therefore, in calculating the P_{trans}, the number of successfully transmitted tags should be eliminated.

Let N_{succ} and N_{est} be the number of successfully transmitted tags and estimated ready-to-transmit tags respectively. Then N_{est} is

$$N_{est} = \frac{log\left(\frac{P_{empty}}{L}\right)}{log\left(1-\frac{1}{L}\right)P_{trans\ \_previous}} - N_{succ} \qquad (3)$$

where $P_{trans\ \_previous}$ is the probability of transmission specified in the previous RTAP beacon.

Based on (3), the probability of transmission for the next RTAP can be determined as

$$P_{trans\ \_new} = \frac{L}{N_{est}} \qquad (4)$$

where L is the fixed slot count for a RTAP.

3. Conclusion

In this paper, a dedicated collision avoidance method considering the system characteristic was proposed. Moreover, some analysis on the slot count of RTAP was performed. As the future works, simulation and an implementation of the actual prototype will be conducted.

REFERENCES

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