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An Introduction of main RFID Anti-Collision Protocols

I. Introduction

Radio frequency identification (RFID) systems play an important role in the internet of things (IoT) technology which has received extensive attention. There are 2 main reasons. On the one hand, RFID systems has a great capacity of identifying, locating, tracking and monitoring things. On the other hand, the cost of commercial RFID tags is negligible compared to the value of the products to which they are attached.

In one RFID system, generally, the collision problems can be divided into 2 situations. Firstly, reader collisions occur when more than one reader wants to communicate with the same tag which is in the scopes of multiple readers. The second one is tag collision when multiple tags in the scope of one reader send data at the same time. Then the reader will receive mixture tags' signals but cannot understand it [1].

In order to avoid reader collision, there are 2 different RFID reader anti-collision protocols. The coverage-based algorithm can change the transmit power of the reader to adjust readers' communication ranges and thus reduce collision. Besides, the scheduling-based algorithm can prevent readers from sending signals to the tag at the same time.

In order to avoid tag collision, for decades, scholars have proposed four types of RFID tag anti-collision protocols. Firstly, space division multiple access (SDMA) divides the total channel capacity into separate areas. Secondly, frequency division multiple access (FDMA) divides the total channel into different frequency channels requiring a complex receiver at the reader. Then, Code Division Multiple Access (CDMA) can multiply the tag's ID by a pseudo-random sequence (PN) before transmission [2]. The final method is Time Division Multiple Access (TDMA). Because of its least cost, TDMA becomes the most widely used RFID tag anti-collision protocol. After a lot of practice, scholars invented two kinds of TDMA protocols. The Aloha-based protocol which divides time into frames and the tags respond one slot per frame randomly. Tree-based protocol splits tags into subsets, then continue splitting the subsets until all tags responding successfully are in an interrogation zone. In the recent decade, one hybrid protocol combining the advantages of both Aloha-based and tree-based protocols has a great performance [3].

The various algorithms mentioned above have their own advantages and disadvantages. There are thousands of research paper for each algorithm in IEEE journals. However, due to time and space limitations, this article will mainly compare RFID TDMA tag anti-collision protocols which have the largest range in daily life.

II. Related works

II.I Aloha-based protocols

Above all, we can divide Aloha-based protocol into 4 different branches [4]. The Pure Aloha (PA) protocol which is the oldest protocol can only handle some really simple problem. Both complete collision that messages start transmitting at the same time and incomplete collision which one message start before another message end can occur in PA. No matter what kind of collision occurs, the message from tag should be repeated [2].

Another Aloha protocol which can avoid incomplete collision is Slotted Aloha (SA). In this protocol, every tag can only transmit data in a random slot. Because the communications between tags and reader are synchronous, SA can handle the more complicated problem than PA. When collisions occur, the tag will repeate its message.

The third Aloha protocol is Framed Slotted Aloha (FSA) which divide the total time into different frames and divide every frame into many slots. When a tag transmits a message, the tag should compress the message into one fixed length frame. In every frame, the reader will only respond to one slot. Therefore, the probability of collision is small enough. If a collision occurs, the tag only needs to transmit a message in the slot of next frame. However, if the number of tags is significantly smaller than the frame, channel utilisation will be really low [2].

How could we deal the above problem? If the frame length is not fixed, the FSA could have a higher utilisation rate. Therefore, Dynamic Fram Slotted Aloha (DFSA) which can change the frame length by analysing the number of tags was created. In this protocol, the reader can decide the number of a slot by analysing the tags in the last frame. When the number of tags are large, the frame will be larger. However, because the size of the frame is changing, when the number of tags is variable, the cost of analysing will be unacceptable.

II.II Tree-based protocols

Plus, other main methods are tree-based protocols. When a reader requires a tag to give a response, the tag's ID will be used to match the query which contains the tags that is available. If the ID is not matched, the command will be rejected. All tree-based protocols can be divided into 2 groups. The differences between 2 groups are whether using Manchester coding in searching [5].

The Query Tree Protocol (QT) and Smart Trend Traversal Protocol (STT) are in the first group. The QT is most memoryless since the tag response only depends on the current query. When a collision occurs that more than one tag responds to the reader query, the reader will append the current query [2]. If only one tag responds, we can identify the tag. However, in this protocol, the happening of collision is random.

In order to reduce the collision in QT, the STT has the ability to dynamically issue queries. The reader will keep track of tag to decide the number of slots. Therefore, there are less empty slots in low load and less collision in high load. When the protocol discovers the potential collision, it will move to the bottom level of the query tree to avoid it [2].

In the second group, the Manchester coding is helpful to locate bits that have collided. The way to trace the collision using the Manchester coding is called bit-tracking. Based on Manchester coding, there are 2 main methods named Binary Search Protocol (BS) and Collision Tree Protocol (CT). For BS, the reader will transmit a serial number to all tags, and only the tag ID equal or lower than serial number will get a response. CT is similar to QT, which when the reader uses Manchester coding to check the responses bit to search. The tag will be divided into the collided subset when a collision occurs.

II.III Hybrid protocols

The algorithms mentioned above have more or less their own advantages and disadvantages. A protocol that combines Aloha-based and tree-based protocols were created, which is hybrid protocols. This kind of protocols using the tree-based procedure and tag estimation procedure to predict the number of tags. Therefore, for some complicated problem, the hybrid protocols have good performance, but for sample systems, the hybrid protocols requiring high complexity and hardware demands will be unexpected. There are two main hybrid protocols named Tree Slotted Aloha (TSA) and Binary Tree Slotted Aloha (BTSA) [6]. The TSA is an improved version of the FSA protocol designed to reduce the number of collisions. The efficiency of the TSA is between 37% and 41% [2]. Using a dynamic frame length adjustment, every tag will choose a slot randomly and transmit its ID. In this protocol, it will use binary tree splitting to resolve collision.

In recent years, with the development of the IoT technology, some papers improving the above algorithms have been published. In traditional anti-collision protocols, there is no tag coming or leaving the system during tags identification. But in our daily life, mobile phones or laptops are widely used tags. Therefore, a mobile RFID system protocol is required that allows the reader or tags moving continuously. One protocol using Manchester code to teach the position of collided can using in variable tags system is created by Xiaolin JIA named Dynamic Collision Tree Protocol (DCT) [3]. In a DCT system, the reader scans the dynamic collision tree from root to leaf and left to right repeatedly. Once a leaf node is searched, the tag at the leaf node is identified. When a new tag enter, we only need to add 2 nodes to the tree. One is a leaf node (tag node), and another is an internal node.

According to the tree slotted Aloha, one new method using Chaos Optimisation Algorithm was created by Elham Siri [7]. This method which examined in a logistic chaotic map has a great improvement than traditional protocol named Assigned Tree Slotted Aloha (ATSA). This protocol key idea is applying the prefix matching to the DFSA. Besides Hassan Sharabaty created a protocol especially for student attendance system, and Qinshu Liu made an improvement based on ACT [8].

Many scholars have improved the method. These methods work well in some cases. But these methods are not bound to the original method. I think that they are only improving rather than creating. So they can't be listed as a new class.

III. Comparison

A great amount of research in this area shows a fact that the two main types of anti-collision protocol are probabilistic and deterministic.

The Aloha-based protocols are probabilistic. All tags transmit its ID and select slot randomly. Because there are random events, we can only add rules to reduce the possibility of collisions and increase channel utilisation. However, when we add rules, the complexity of protocol is increasing. We need better hardware and more complicated problems to achieve the new protocol. As a result, comparing Aloha-based protocols, the PA may have complete collisions and incomplete collisions. But it is easier and more useful when the number of tags is small. If there are lots of data to transmit, the SA only need to handle complete collision. The possibility of collision is less than PA. After dividing the time into different frames (FSA), the possibility becomes smaller because the respond time of every tags are limited to 1 in a frame. However, when the frames' size is not reasonable, the utilisation becomes lower. When we change it into DFSA, the protocol is much complicated but has good performances in most systems.

On the other hand, the tree-based protocols are deterministic. The ideal design is to identify the complete set of tags in the query area. Comparing tree-based protocols, QT is most memoryless, but when collisions occur, this method needs more time to find out collision tags. STT needing more memory can reduce the number of collisions and identification time. BS and CT using Manchester coding have a great convenient in tracking. But they have a bad performance in low load systems.

Final, the key idea of all the hybrid protocols is finding a balance between probabilistic and deterministic. According to the performance, the successful hybrid protocols are better than not only Aloha-based protocols but also tree-based protocols. But they still are the combination of high complexity and hardware demands. They are expensive in most systems comparing with basic protocols.

IV. Conclusion

For a system with a small amount of data transmission and relatively simple composition, the basic RFID protocols are sufficient for normal communication needs. But for some special areas, designing the right hybrid protocols is the best option when the budget is sufficient.

In the future, if these technologies are to be truly implemented and used, how to achieve anti-counterfeiting and security control is a problem that has to be considered. As hardware advances, complex protocols will guarantee a reduction in collisions. But the more complex the protocol, the higher the risk of stealing information, the longer the processing time. Finally, the support for mobile devices will drop, but wearable devices, which are absolutely moveable, will be the biggest market.

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