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Simulation and Analyses of Anti-Collision Algorithms for Active RFID System Based on MiXiM Simulation Module

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Abstract: Anti-collision algorithms of active RFID system are studied and simulated by the OMNeT++ software. The active RFID system based on ZigBee RF module is analyzed firstly, which uses the anti-collision mechanism involving the CSMA/CA algorithm of IEEE 802.15.4 protocol. Given the IEEE 802.15.4 simulation framework and configurations on the OMNeT++ simulation platform, simulations and analyses about anti-collision performance for the proposed active RFID system is carried out. For two customer anti-collision algorithms, the simulation results show that CSMA/CA algorithm presents excellent performance than ALOHA algorithm and its performance can meet the actual needs. *Copyright © 2013 IFSA.*

Keywords: Active RFID, OMNeT++, MiXiM module, Anti-collision, ZigBee.

1. Introduction

RFID technology (Radio Frequency Identification) [1] and ZigBee wireless sensor network are two key technologies to build the Internet of things (IOT). RFID is a non-contact automatic identification technology, which can identify the target objects through RF signal and get the relevant data. It has the advantages of small volume, large capacity, long life and reusable, etc, so that it has been used more and more widely, especially suitable for low power wireless tracking. As the basic IOT technology, RFID works in the sensor layer of the Internet of things to collect data.

According to the label energy access, RFID system can be divided into two categories, passive and active. Active RFID tags inside the system are provided by the battery energy, which has large quantities of transmitted data, long reading and writing distance, good compatibility and reliability. But the traditional active RFID also has some disadvantages: read/write devices installation needs to be fixed position, to read and write tags in the direction of the position and direction of antenna has certain requirements, the flexibility of the system is restricted. What's more, in terms of communication distance, use flexibility and function, it cannot be compared with the micro power transceiver. So some new type of active RFID system has been studied in [2-4]. ZigBee technology is a kind of low cost, low power consumption and low rate of two-way wireless communication technology, which can coordinate with each other between the thousands of tiny sensor, using very little energy in the form of relay to realize wireless communication. ZigBee technology and traditional RFID advantage are complementary [3], so the design and implementation of active RFID system in combination with ZigBee RF modules has certain practical significance.

Anti collision algorithm becomes one of the key technologies [4], under the circumstances of the label number identified by the active system is more. Because the read/write devices need to be able to successfully complete electronic label identification within the scope and realize the data reading and writing operations. Currently collision algorithm of RFID system mainly includes ALOHA and binary tree search method, and ALOHA algorithm is one of the most simple and basic collision algorithms, which belongs to the TDMA mode. ALOHA algorithm is simple, and large randomness, but has the disadvantage of high collision rate, low system utilization, and error decision problems. And binary tree algorithm is long delay, information disclosure, poor security [5-7]. So it is necessary to analyze and simulate the performance of new collision algorithm of RFID system, in order to guide the practical application. This paper will show the analyses and simulation for anti collision algorithm of the active RFID system. First, we analyze the active RFID system based on ZigBee rf module; then we use the simulation module of MiXiM [8] to systematically simulate and analyze the anti collision algorithm based on the IEEE 802.15.4 protocol.

2. Active RFID System Based on ZigBee RF module

Active RFID system based on ZigBee consists of a ZigBee gateway, several ZigBee card readers and ZigBee tags. ZigBee device includes three types: coordinator, routers and end devices. Card reader can be either a ZigBee coordinator or a ZigBee router. When the network is on a smaller scale, the card reader only need to be set as ZigBee coordinator, network don't need the router. When the tag number is more and widely distributed, card reader will be set as ZigBee router, at this time network also need to have a ZigBee coordinator name to be the ZigBee gateway. The system structure is shown in Fig. 1.

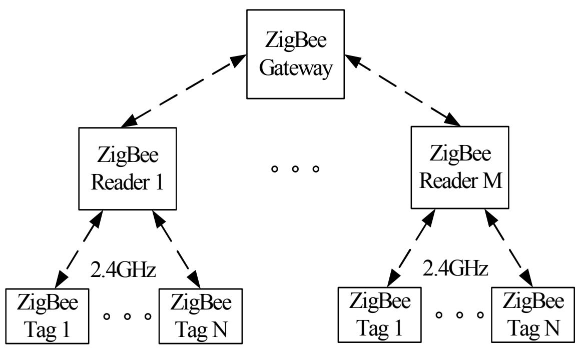

Fig. 1. The active RFID system based on ZigBee.

In Fig. 1, the ZigBee pooled gateway is responsible for setting up the RFID network, distribution address labels, allowing tags to join the network, updating device data, maintaining the associative device table and automatically updating task according to the state of network, etc. It is the core of the whole RFID system, undertakes the task of the control center, and is responsible for all the label sensor data gathering, processing, and network communication with the outside world. The basic working process is as follows: the reader starts the RFID network after powered firstly; then processing functions in the application layer start to test the ZigBee signal of the environment. When there is a label added to the network, reader is responsible for assigning network addresses to labels, after the success, reader began to receive and preserve the data from tags.

ZigBee tags begin to apply to join the RFID network after powered, waiting for the response of the reader and the distribution of network address. ZigBee pooled node and reader have the functions of allowing devices to join the network. After the tags joined the network, they will enter a state, and every once in a while send a data to the reader or the gathering node, back into the sleep state after the success of the sending. If sending is failed, it needs to be resent. Messages sending aren’t terminated until up to the maximum retransmission times.

ZigBee protocol channel access method use CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) mechanism [9-10]. All tags that want to communicate must be through the CSMA/CA mechanism to compete the transmission media. All equipments ready to transmit data, will monitor the current wireless transmission media. If the channel is free, the device will produce a backward delay time, to stagger the time of devices sending data. If the current wireless transmission media is in the busy, these devices will and compete for CSMA/CA after monitoring the media for free.

3. Collision Performance Simulation Based on MiXiM Module

OMNeT++ is a component-based, modular network simulation software, which is mainly used in wired and wireless communication network simulation, the design and validation of communication protocol and the performance of and the communication network architecture design. MiXiM module is a new type of OMNeT++ software module. MiXiM module combines with and expands the some existing OMNeT++ based simulation framework for the development of wireless mobile network simulation. It provides the wireless channel model in detail, such as wireless, mobile module, barrier model and many communication protocols, especially the protocol in the media access control layer of MiXiM can support the network simulation up to 1000 nodes, with the graphical configuration interface to help users select the correct module, according to the layer combination, and conveniently set the parameter values.

There are three important parameters in the IEEE 802.15.4 CSMA/CA algorithm need to be maintained by the devices: Nb, CW and BE. Nb (back number): the initial value is 0, when the device has data to send, after a backward time and CCA detection, if channel is busy, it will create back time, the Nb value will add 1 again. In IEE802.15.4, Nb is defined as the maximum value for 4, when the channel still busy after four times of backward delay, it will give up the sending, in order to avoid too much overhead. The CW (collision window length): is the back length of the delay time, the unit is the Backoff, regressive cycle defined by the parameter in the MAC PIB a UnitBackofPeriod given, for 20 symbol. The initial value of the CW is 2, and the maximum 31. BE (back exponent) the value range is 0~5, default value recommended by 15.4 is 3, the maximum is 5. When BE is set as 0, then only a collision detection. In IEEE 802.15.4, the number of failure (the retransmission) is up to 3 times.

As shown in Fig. 2, MiXiM node is composed of modules, including mobility module, phy module, utility module, app module and nic module. Nic module consists of the MAC and phy module.

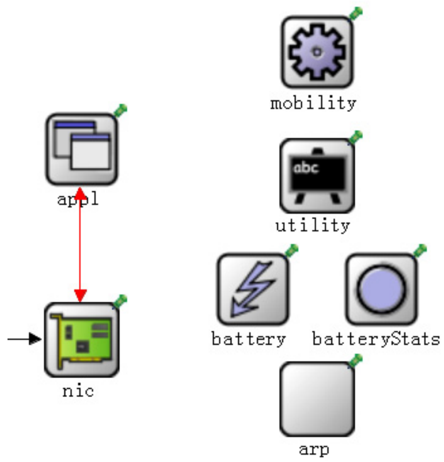

Fig. 2. Composition of PhyMacHost of MiXiM node.

A) MAC module

MAC module used in the simulation parameter configuration uses CSMA/CA algorithm. According to the rules of CSMA/CA algorithm, parameters are defined as follows:

```
simple CSMA802154 extends csma
{ parameters:
  @class(CSMA802154);
  sifs @unit(s) = 0.000192 s;
  headerLength @unit(bit) = 72 bit;
  queueLength = default(100);
  bitrate @unit(bps) = 250000 bps;
  ackLength @unit(bit) = 40 bit;
  macMaxCSMABackoffs = default(4);
  macMaxFrameRetries = default(3);
  acAckWaitDuration@unit(s)=0.00056s;
  ccaDetectionTime @unit(s)=0.000128s;
  aTurnaroundTime @unit(s)=0.000192s;
  useMACAcks=default(true);
  backoffMethod="exponential";
  UnitBackoffPeriod@unit(s)=0.00032s;
  macMaxBE = default(5);
  macMinBE = default(3);
}
```

B) PHY Module

Each received packet of receiving node, need to be determined whether as the packet or as noise by the physical layer according to the strength of the received signal. The module of Ned description file is used PhyLayerBattery, the inheritance in BasePhyLayer module, module defines the channel delay, the noise of the basic level, information transmit power and sensitivity, as well as the connection definition parameters, such as door. Ned description of the module is as follows:

```
package org.mixim.base.phyLayer;
simple BasePhyLayer
{ parameters:
    ……
    bool usePropagationDelay;
    xml analogueModels;
double sensitivity @unit(dBm);
double maxTXPower @unit(mW);
intinitialRadioChannel=default(0);
bool useThermalNoise;
    ……
}
```

The phy layer parameters are set in the “omnetpp.ini”. The receiving sensitivity is set –100 dBm, maximum transmitted power is set 100 mw. The specific configurations are as follows:

```
*.phy.usePropagationDelay = false
*.phy.analogueModels=
xmldoc("config.xml")
*.nic.phy.sensitivity = -100dBm
*.nic.phy.maxTXPower = 110mW
*.nic.phy.initialRadioState = 0
*.nic.phy.useThermalNoise = true
```

C) Mobility module

This module provides the location of the host and is responsible for mobility handling. It completes the dynamic connection management together with the channel control module. Channel control module controls all of the connections among them.

ConnectionManager is used during the simulation module to achieve this function. The parameters are also defined in the Ned file, and the parameters configurations are in “omnetpp.ini” file. Its configuration parameter values are consistent with the PHY layer parameters, transmission power is

110 mw, sensitivity is -100 dBm, and the transmitting frequency is 2.4 GHz. The specific configuration code is as follows:

```
*.connectionManager.sendDirect = false
*.connectionManager.pMax = 110 mW
*.connectionManager.sat = -100 dBm
*.connectionManager.alpha = 2.5
*.connectionManager.carrierFrequency=2.4E+9 Hz
```

D) App Module

Application layer module can be used for traffic source node and sink node. It adopts flexible parameter structure based on XML, and supports the simulation of dynamic change transfer mode.

We use NetworkStackTrafficGen to define it in the simulation. The Ned description is as follows:

```
simple NetworkStackTrafficGen
{ parameters:
  double packetTime @unit(s);
  double packetsPerPacketTime;
  int burstSize = default(1);
  int packetLength @unit("bit");
 int destination = default(-1);
  ……
}
```

The arameters configurations are also set in “omnetpp.ini” file. The length of the packet is set 24880 bit.The specific parameters are as follows:

```
**.appl.packetLength = 24880 bit
**.appl.packetTime = 0.1 s
**.appl.packetsPerPacketTime = 0.15
```

In the process of the establishment of simulation model and configuration, modules are established in the NED description file, and then modules are connected by the gates, thus it makes a complete network. Finally we create ‘omnetpp.ini’ files in which the parameters of each module are configured, and you can name different parameter settings in a file on the same network by using [config name] command.

4. Simulations and Discussions

After completing omnetpp.ini configuration, we can get the simulation log file (Eventlog), then through using the Filter options to analyze the data and making use of the Dataset tool drawing we can get the statistical analysis results. In order to facilitate comparison, some OMNET++ data is saved to regenerate the simulation curve.

1) The relationship between channel utilization and tag number.

Fig. 3 shows the relationship between channel utilization and tag number. Configuring two algorithms in the simulation, the tag number from 2 to 2 step length in turn increased to 50. Known from the figure, using CSMA/CA algorithm, with the increase of the tag number, channel utilization efficiency increased, when the number of tags to 26, the channel utilization rate significantly increased with the increase of the tag number, no longer changes remain at around 80 %. ALOHA algorithm on the tag number is small, with labels on the rise, the channel utilization rate on the rise, as more than 10, conflict between tags, channel utilization is lower. Obviously, the collision performance of CSMA/CA algorithm is better than pure ALOHA algorithm.

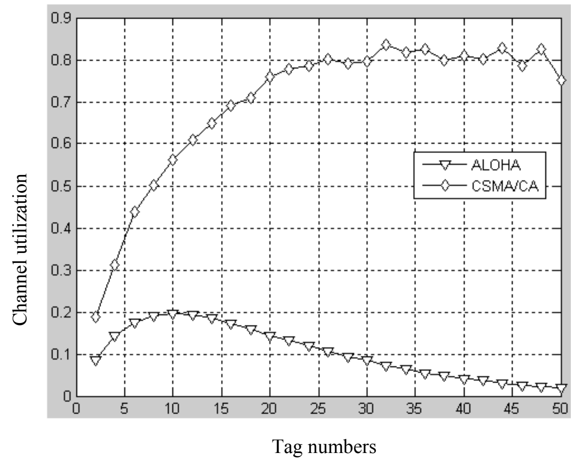

Fig. 3. The relationship between channel utilization and tag numbers.

2) the relationship between channel utilization rate and packet interval curve.

Fig. 4 shows the relationship between channel utilization rate and packet interval curve. The tag number is set to 10; packet interval is increased from 0.02 s to 0.4 s. In comparison with CSMA/CA algorithm, the channel utilization rate of ALOHA algorithm is lower and the collision probability is far greater than CSMA/CA.

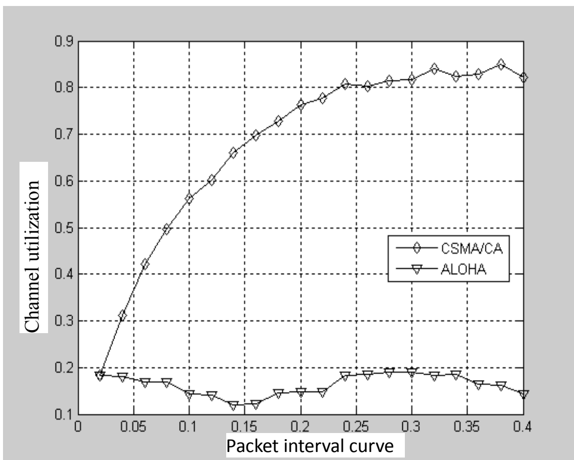

Fig. 4. The relationship between channel utilization rate and packet interval curve.

3) The relationship between the retreat number and node number.

Fig. 5 shows the change curve of retreating time and retreat number that each node needs when the number of node is increased in exponent in the CSMA/CA algorithm. The number of nodes in the simulation increase according to the index law of 2. We can see from the figure, along with the index growth of node number, the retreat time of each node also increases in index law and retreat number is increasing linearly.

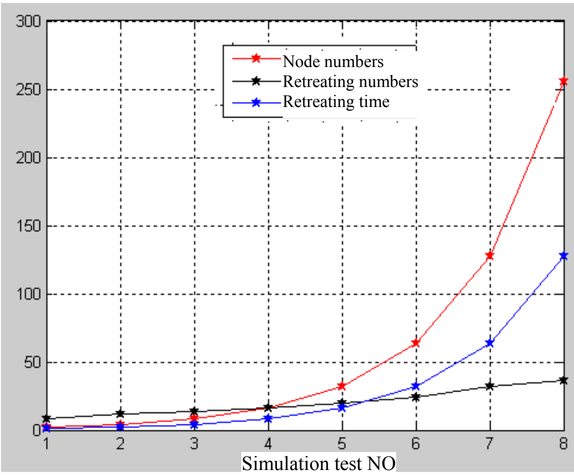

Fig. 5. The relationship between the retreat number and node number.

4) The relationship between the channel utilization and the distance of nodes.

Two aspects are contained: one study the impact of MAC-ACK frame on communication, MAC-ACK frame is used in Test-A instead of Test-B. The data is sent from one node to another node in two tests, receiving node is fixed. The distance between the fixed node and mobile node changes from 40 meters to 300 meters. Test-C has carried on the simulation of hidden nodes (hidden node is the node within the coverage scope of the receiving node but outside the coverage scope of the sending node). It may also make collision in receiving node because the hidden node sends data to same receiving node due to not hearing another sending. There are two nodes sending data to the center node in this test and one of the sending nodes is mobile.

Configuration is as follows: of the fixed receiving node is {350,250}, the coordinate of the moving sending node is {350-${dist40, 45... Step 5}, 250}, and the coordinate of another sending node is {480,250}. The simulation results are shown in Fig. 6.

As is shown in Fig. 6, when there is only one node sending, comparison Test-A and Test-B shows: in a certain distance, confirm frame has no difference in channel utilization, so in the practical application network can be configured to no using confirm frame in order to remove the frame overhead. But with the increase of distance, the channel utilization drops down later when using the MAC-ACK frame; beyond a certain range, no matter use or not use the MAC-ACK frame, the channel utilization will decline sharply. IEEE802.15.4 protocol only constitute a small network, the distance between the nodes has certain restrictions.

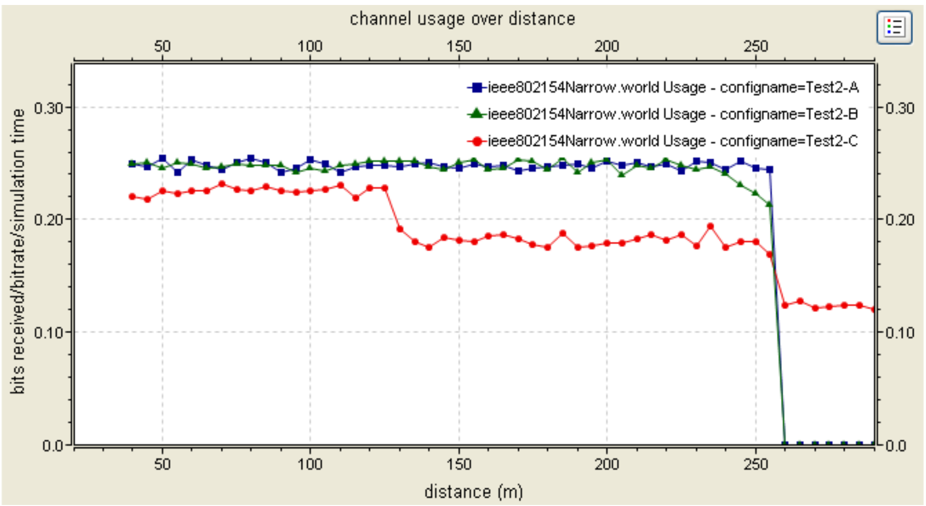

Fig. 6. The relationship between the channel utilization and the distance of nodes.

The results Test-C show that the channel utilization is decrease obviously if the distance between the fixed receiving node and the mobile node exceeds 125 m when the two nodes send information to a same node at the same time. In this case, the mobile node and the fixed sending node are hidden nodes. So when using the IEEE802.15.4 protocol of network, we must pay attention to the problem of the distance between the nodes in order to avoid the problem of hidden nodes causing unnecessary conflict.

6. Conclusions

Collision algorithm based on the ZigBee module is one of the key technologies to research the active RFID system. The system adopts the CSMA/CA algorithm from IEEE 802.15.4 protocol as collision mechanism, etc. Simulation and analyses based on MiXiM module for the collision performance of active RFID system is carried out in the paper, which can provide necessary reference for the practical application.

Acknowledgements

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