A MAC Protocol Optimization Algorithm in Wireless Sensor Network Based on Real Platform

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***Abstract*—For multi-hop wireless sensor networks traffic aggregation mode transmission characteristics, proposed optimization algorithm based on CSMA protocol. Adjust the channel access strategy based on the location of of the nodes in the network, The optimization algorithm improves the equalization channel access strategy in CSMA to fit the transmission feature of WSNs,improve the efficiency of network transmission.**

Keywords-throughput; WSN; CSMA; Channel access distribution

I. INTRODUCTION

Wireless sensor network (WSN) is one of the supporting technologies of Internet of Things, and has broad application prospects, and much characteristics different from traditional wireless networks[1]. WSN come in a wide variety of forms, covering different geographical areas, A large number of sensor nodes are randomly deployed in the monitoring area inside or near, the monitoring data along with other sensor nodes through multi-hop transmission to the sink node. This is one of the main transmission mode in the WSN.As the cost and energy limitations of sensor nodes, each node will take on different specific functions generally, and its function in their life cycle are hardly change. In the data transfer process, closer to the sink node more traffic. The network load accumulated near the sink node, with the traffic flow and increasing the transmission delay, packet collisions because severe congestion, loss of satisfied even congestion collapse. As traffic flow and the transmission delay increasing, packet collisions cause severe congestion, packet loss, network congestion or even collapse. The result is due to the characteristics based on the MAC layer protocol and topology in WSN no match. In the entire network topology, the nodes at different levels need to be transmitted is different, It is not necessary to have equal opportunity access the channel at different level because nodes at different levels of the transmission data traffic is different.

Aiming at these problems, proposed an improved MAC protocol based on competitive category optimization algorithms and non-equalization channel distribution solutions depending on the application of wireless sensor network transmission structure. The remainder of the paper is structured as follows. In Section II gives the status of research in related fields, and the contribution of this paper describes the characteristics of work. Section III describes the network model used in this paper and related definitions. In Section IV describes our experimental setup. We discuss the observations from our measurement-based study on the hardware platform and an in-depth analysis of our findings, and finally the conclusion

II. BACKGROUND AND RELATED STUDIES

Nodes transfer the data through wireless channel in WSN, Wireless channel, as a medium of communication, has limited spectrum. Because of the radio characteristics of wireless channel, when several sensor nodes access the channel at the same time, it can cause conflicts within the data, and it is difficult for the receiver to confirm whether the data is send to it or not, therefore, resulting in the waste of spectrum resources and the decline of network throughput. However, MAC protocol will efficiently coordinate the access of multiple sensor notes to shared channel, enabling the data sent by different nodes to avoid conflicts. In addition, the limited bandwidth resource can be used fairly and efficiently.

MAC protocols play a very important role in energy efficiency, especially in the energy efficiency of WSN, which applying the low duty cycle factor channel. According to the working principle of MAC protocol, MAC protocols of WSN are divided into three types: competition, distribution, hybrid combinations (mixing the type of distribution and competition). The main characteristic of competitive MAC protocol, represented by CSMA is that it can be better to adapt to changes in the dynamic network topology and that it has good extensibility. The main characteristic of MAC protocol based on the scheduling, represented by TDMA is that it requires strict time synchronization between nodes; more additional control of the information produce more energy consumption; it also has bad scalability and adaptability to network changes. Due to the shortcomings such as complexity of terminal design, high requirement of synchronization accuracy, scheduling MAC protocols is rarely used in WSN[2]. The characteristics of hybrid MAC protocol is that it can effectively combine the advantages of competitive MAC protocol and scheduling MAC protocol according to the characteristics of the wireless sensor network (WSN), and some specific application requirements. But the protocol is more complex[3]. The competitive MAC protocol is simple, flexible and strong; it does not need too much infrastructure support; it doesn't need clock synchronization and entire network topology information; it is able to deal with the dynamic login and logout of the notes moderately without additional costs; it can reduce collision in adjacent area substantially. So the CSMA protocol is a more suitable MAC protocol when used in wireless sensor network. Asides those advantages listed before, it has strong scalability, so a variety of competitive MAC protocol has been designed for the applications of wireless sensor network, such as S-MAC[4], B-MAC[5] and X-MAC[6].

Currently used in wireless sensor networks CSMA protocol is based on IEEE802.11 Distributed Coordination, standard MAC protocols developed for duty-cycled WSN can be roughly categorized into synchronized and asynchronous approaches, along with hybrid combinations. These approaches are motivated by the desire to reduce idle listening, which is the time that the node is awake listening to the medium even though no packets are being transmitted to that node. Synchronized protocols, such as S-MAC [4] ,S-MAC protocol is suitable for wireless sensor network MAC protocol proposed earlier, it is based on the IEEE 802.11 protocol standards, the introduction of periodic listening and sleep, the message conflicts with over-hear avoidance, long message confirmation mechanism, the disadvantage is the larger message delay. Asynchronous protocols such as B-MAC [5], rely on low power listening (LPL), also called preamble sampling, to link together a sender with data to a receiver who is duty cycling. Idle listening is reduced in asynchronous protocols by shifting the burden of synchronization to the sender. When a sender has data, the sender transmits a preamble that is at least as long as the sleep period of the receiver. The receiver will wake up, detect the preamble, and stay awake to receive the data. X-MAC[6] protocol is an improvement over B-MAC protocol based on mainly a longer preamble sampling to replace many short preamble sampling, adding the destination node address, the defect cannot be adjusted duty-cycled adaptively according to the network Performance. BoX-MAC protocol is cross-layer design; BoX-MAC protocols provide a comprehensive set of low-power link-layer primitives for a wide range of network workloads. The advantages of these cross-layer MAC designs over single-layer approaches provide in-sight on requirements for future radio chip and platform designs. The disadvantage is can't automatic switching between BoX-1and BoX-2 according to the state of the network and protocols is more complexity. These protocols are aiming at sleep mechanisms, low power listen; does not provide an effective and reliable solution for channel match.

Wireless sensor network show a unique funneling effect [7] where events generated in the sensor area travel hop-by-hop in a many-to-one traffic pattern toward one or more sink points. The combination of hop-by-hop communications and centralized data collection at a sink creates a choke point on the free flow of events out of the sensor network. Which typically carry considerably more traffic than nodes further away from the sink node. The traffic pattern leads to significant packet collision, congestion, packet loss and delay as events move closer toward the sink. Traffic pattern is incremental in wireless sensor network, through non-equalization channel to increase channel utilization, ease congestion and collisions caused by incremental traffic.

Based on the competition class MAC protocol is discussed in the article. Data transmission process in WSN, Away from and near the sink node that traffic events are different sizes; different positions of the nodes propagation delay are not the same, so the probability of each node to channel competition should also be different. Improved algorithm proposed in this paper is considered in a few jumps near the sink node, small number of nodes and large data, should allocate more opportunities for channel access; away from the sink node, Large number of nodes and for each node itself has small data flow, should be allocated fewer opportunities for channel access to avoid simultaneously send data cause collisions. Can improve throughput and reduce packet transmission delay to a certain extent.

III. Non-equalization Channel Performance Analysis

Efficient packet transmission is a very important research topic in WSN. Existing contention based MAC protocol, when a node has data to send, the sending node will do a random initialization back to avoid sending data with other nodes simultaneously causing a collision. All nodes use the same pseudo-random number generation method to generate a pseudo-random number as the sensor node initialization back window. Generally use linear congruential method (LCG) to generate pseudo-random numbers, such as formula (1):

$$X = Radom.rand16()\bmod(T_0) + T_1 \qquad (1)$$

T0 is a constant, T1 is the minimum back -off window, Radom.rand16 () is a function that the size is 16 binary random number, the node ID number as a random number seed, X is initialized randomly generated back-off window. According to the formula (1) to calculate the back-off window to avoid sending nodes simultaneously transmit data and collisions. To make the different sensor nodes have different initialization back window, nodes use different parameters to generate a pseudo-random seed number. Because of different nodes have different ID numbers, so that the nodes generate different pseudo-random number sequence as back-off window.

Node during initialization back-off will detect whether the channel is idle or not, if the channel is idle put the packet sent done; otherwise, according to the channel

Conflict back-off occurs, conflict back window as shown in equation (2). While continuing to detect whether the channel is idle or not, when the idle channel is detected, the packet is sent.

$$X_1(n) = Radom.rand16() \bmod (T_0 \times n) \qquad (2)$$

Where n represents the number of the nodes compete for the channel to send a packet time, T_0 is a fixed value determined back-off window size, T_0 is a fixed value that determines the size of the window back.

In the packet transmission process, the parent node support traffic more than the sum of traffic by the child nodes. When the channel continue to busy for a period, due to the parent and child nodes only with the same probability to compete the channel, packets accumulate in the parent node, the information easily be dropped due to buffer overflow. Child nodes compete successfully channel, information is sent to the parent node will further increase the burden on the parent node and packet loss rate, Meanwhile, the child node sends invalid also waste of energy resources and channel. Thus, the equalization channel preemption mechanism is not fully applicable to the network model described in the article. The parent should be given channel contention opportunity more than the child node and non-equalization process channel. Treat the contention window that from source node to sink node which hops is maximum as reference value of the minimum contention window. Other various levels minimum contention window value calculated as formula (3) shown based on the minimum contention window upper node values and upper average number of child node.

$$X' = Radom.rand16() \bmod (T_0) + \alpha \times T_1 \qquad (3)$$

Introducing a new parameter a, using different a values at different levels in the topology dynamically adjust node initialization back window to accommodate changes in the location of the network. While the corresponding back-channel conflict, in order to guarantee that node waits for a long time have more opportunity to compete for the channel, avoid small data rate node information was flooded by large data rate nodes, making small data rate nodes can not convey information, adding fairness control, the formula (2) be amended to:

$$X_1'(n) = Radom.rand16() \bmod (T_0 \times n) + (1 - 0.1 \times \alpha) \times X_2'(n-1) \qquad (4)$$

The traffic are very large near the sink node generally, stored in the cache of each node will have a significant amount of data, which means that the channel is obtained at the node when the competition, while there will be a large amount of data to be received. If there are multiple nodes want to transmit data to the node, the amount of data to be transmitted for each node are large, so the conflict phenomenon packets can be severe. The use of hierarchical way non-equalization channel competition between parent and child node to different probability of competing channels, largely reducing the data packet collisions.

IV. TESTBED DESCRIPTION

We using sensor network node hardware platform is produced by ATMEL microcontroller chip Atmega128A as well as TI's CC1100 RF production. TinyOS[8] operating system design and implementation of the system based on the above combination node transplantation to drive different source rates. Using the TinyOS CSMA-based B-MAC[6] protocol, Modulation is GFSK, Manchester coding is enabled, and the source node data transfer rate is 100kpbs, the sink node serial port baudrate 57.6kpbs. We use TinyOS packet size frame format shown in table 1.Node spacing and transmission power of the sensors are set such that one-hop neighbors achieve > 80% delivery, while two-hop neighbors achieve < 20% delivery. In this way, a fairly strict and dense multi-hop radio environment is constructed for experimentation.

V. PERFORMANCE ANALYSIS

Designed in accordance with the precise interval timing of the test environment for data transmission experiment on real platform, validate MAC optimize the efficiency of the proposed method in data packet delivery ratio and throughput, and so on. The network topology is shown in figure 1. Assuming that only one sink node in the network and all sensor nodes are isomorphic which has the same distance wireless communication. Each node has at most only two-hop neighbor nodes within communication range, namely routing parent and child nodes, thus forming a linear network routing. In this topology, because the adjacent nodes are in the domain of each other conflict range, such as node1 and node3 are in the collision range of node2, when three nodes have packet to be transmitted at the same time, it may lead to confliction, and this topology is relatively common in practice, so it is deserved to be research, have high practical value.

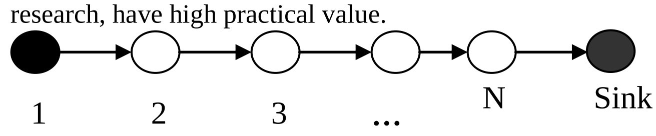

Figure 1. Network Topology

Table 1 Packet format

Frame delimiter	AM type	Destination address	Source address	Payload length	Node ID	Frame ID	Payload	CRC
1Byte	1Byte	2Byte	2Byte	1Bytes	2Byte	2Byte	20Byte	2Byte

A. Packet Delivery Ratio

Source node is used to set the saturation data stream, the data source node i.e. the maximum PPS (packet per second) can be transmitted. In the experiment, under conditions of saturation channel, adjusting the initialization back window size of source node, setting the saturation channel data stream. Figure 2 show the results of this experiment about packet delivery ratio. Both algorithms have high packet delivery ratio in two hops. However, with the increase of the number of hops, the probability of packet collisions occurred is increased, packet delivery ratio of two kinds algorithm have declined, but the delivery ratio of equalization channel fell faster, the variation is very intuitive in fact. When only two nodes in the network communication, there is no competition with other nodes, the packet delivery ratio is maximization. When a two-hop communication network has three nodes, the nodes in the sensor network is a half duplex mode of operation, Node1 and Node2 compete for the channel, so the packet delivery ratio has decreased; the use of Non-equalization channel algorithm decreases the probability of channel competition to improve the channel utilization, that's why the data packet delivery ratio is relatively high. With the number of network nodes increasing, the communication of the network reaches more than 4-hop, the node added to the previous node influence smaller. Therefore, the network packet delivery ratio eventually converges to a stable value.

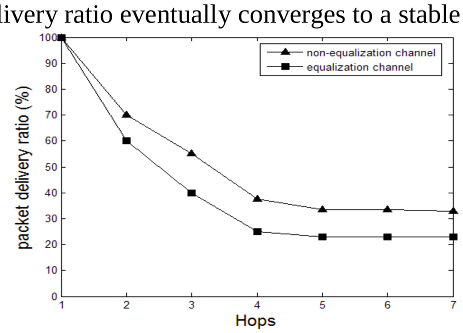

Figure 2. packet delivery ratio over varying hops from the sink for equalization and non-equalization channel

B. Throughput

It is shows that if the hops communication is more than 4 in wireless sensor networks, packet delivery ratio converges to a stable value by Figure 2. Accordingly to that, 5 hops network communication model with multiple source nodes to transmitted packet is chosen in the experiment. Research the relationship between PPS and the throughput with two algorithms. Through the experiments it can be found that when there is little data traffic in the channel, the throughput of the two algorithms essentially flat, and the channel is free relativity; and when the channel flow is saturated or oversaturated, the non-equalization channel allocation scheme have certain improvement compared to baseline scenario, which is shown in Figure 3.

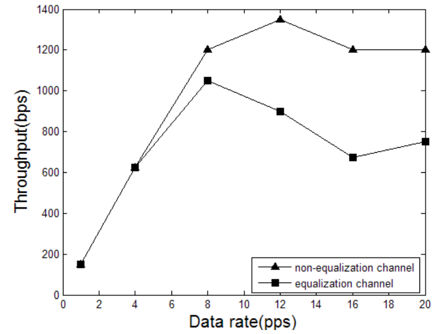

Figure 3. Throughput with equalization and non-equalization channel

VI. CONCLUSION

According to the characteristics of the transmission disequilibrium for wireless sensor networks, CSMA protocol family and wireless sensor network topology mismatch, An optimization algorithm is proposed based on CSMA protocol suite. According to the number of nodes in the hierarchy and the sub-node topology adjustment channel access probability, give the level of the minimum contention window calculation model. Finally, experimental method based on TinyOS system hardware platforms; proven algorithms in terms of packet delivery ratio and throughput are improved. We believe that our studies can aid researchers and practitioners in future work, and so may have broader applicability in wireless sensor network.

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