Multi-channel distribution mechanism based on BP neural network

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Abstract. In order to make better use of wireless channel resources and improve the reliability and throughput of network and reduce network latency, multi-channel MAC protocol is becoming a hot topic to solve the problem. But the existing multi-channel MAC protocols for wireless network have their own restrictions. Due to the characteristics of the WSNs we propose a channel allocation algorithm based on BP neural network. And we compared with the MMAC protocol and the SMAC protocol on NS2. The MAC protocol we proposed in this paper performed better in terms of network throughput and network delay.

Introduction and Research Status

WSNs mainly use single-channel MAC protocol in practice. Using a single channel for communication simplifies the implementation of the protocol. However, when the amount of data is very large, it may cause severe communication competition. Multi-channel protocol allows many nodes of a wireless sensor network to communicate in parallel, thus it can improve the utilization of network bandwidth resources and improve the throughput of the network communications. When one channel is disturbed, the node can use other channels to communicate, so that it can improve the anti-interference ability of WSN [1].

To improve the QOS of WSN, utilizing multi-channel mechanism has become a hot topic [2,3]. Literature [4] proposed a multi-channel protocol VLMAC based on virtual link, it performed well to avoid channel interference, but there is no good solution to the problem of time synchronization. Literature [5] proposed an interference-aware busy tone based MAC protocol (IABTM). This protocol used a busy tone channel to transfer control information, so it can solve the problem of hidden terminal and exposed terminal in the period of channel allocation. But in this MAC protocol all nodes will listen to the same channel before each data transmission. Since this agreement only reserved one control channel to transmit control information, so it may cause serious conflicts.

Agreement and Algorithm

In the process of channel estimation, this paper applied BP neural network to predict which channel is reliable. The model of channel reliability prediction mechanism is shown in Figure1:
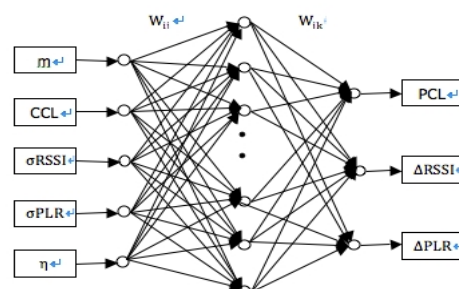

Fig.1 the model of channel reliability prediction mechanism based on BP neural network

Take the ideality factor m, the current channel list (CCL), and the standard deviation of RSSI as input. And take the PCL, the received signal strength instruction degradation and the packet loss degradation as output. According to the research of the neural network system, it found that if we take enough quantity of hidden layer nodes take, single hidden layer neural network can satisfy the accuracy requirements of nonlinear [6], so we take only one hidden layer.

BP neural network completes self-learning function through adjusting connection weights. BP neural network self-learning process mainly includes forward delivery process of signals and error feedback process; forward delivery process of signals is shown in Eq. 1:

$$\begin{cases} net_j = \sum_{i=1}^{M} x_i W_{ij}, net_k = \sum_{j=1}^{N} O_j W_{jk} \\ O_j = f(net_j), y_k = f(net_k) \end{cases} \quad (1)$$

The net_j and net_k in the equation denote the net input of hidden layer and output layer nodes respectively in this model. The x_i and y_k denote input and output of the model respectively. M and N represent the number of input and hidden nodes in this model, W_{ij} and W_{jk} represent the connection weights between the input layer, hidden layer and output layer. O_j denotes the output of the hidden layer node. f indicates a connection function, in this article we used *sigmoid* function:

$$f(x) = \frac{1}{1 + e^{-(x-q)}} \quad (2)$$

In Eq.2, it shows the threshold of the node.
Network error function can be expressed by the formula (3):

$$E = \frac{\sum_{k=1}^{L} (d_k - y_k)^2}{2} \quad (3)$$

In Eq.3, L denotes the number of nodes in the output layer. d_k indicates the output expected.

In this paper, we correct the weight through making the direction of the error gradient dropping, so as to achieve the purpose of error feedback. The error feedback weights of input layer and hidden layer set as follows:

$$\begin{cases} \Delta W_{ij} = -h \dfrac{\partial E}{\partial W_{ij}} \\ \Delta W_{jk} = -h \dfrac{\partial E}{\partial W_{jk}} \end{cases} \quad (4)$$

h represents the learning rate, $0 < h < 1$, ΔW represents the correction weights.
The error feedback weight of output layer and hidden layer set as follows:

$$\begin{cases} \Delta W_{ij} = h x_i O_j (1 - O_j) \sum_{k=1}^{L} d_k W_{jk} \\ \Delta W_{jk} = h y_k O_j (d_k - y_k)(1 - y_k) \end{cases} \quad (5)$$

Correction of the threshold value set as follows:

$$\begin{cases} \Delta q_j = hO_j\left(1-O_j\right)\sum_{k=1}^{L}d_kW_{jk} \\ \Delta q_k = hy_k\left(d_k-y_k\right)\left(1-y_k\right) \end{cases} \tag{6}$$

When the algorithm is in the process of initialization, we set the threshold values and weights in advance. Then we adjust the thresholds and the weights according to the degradation of the received signal strength indication $\Delta RSSI$ and the degradation of the packet loss ΔPLR.

The Experiment and Simulation Analysis

We test and analysis the efficiency of the MDMAC, SMAC and MMAC on the NS2 simulation platform in certain aspects of overall throughput, average latency and other aspects.

As shown in figure 3, the throughput of MDMAC, MMAC and SMAC is approaching when the packet arrival rate at a low level. Because, when the network load is very small, even single-channel protocol can meet the transport requirements of the network. However, when the packet arrival rate is above a certain threshold value, the throughput of MDMAC is significantly higher than the SMAC and MMAC protocol, and with the increasing rate of packet arrival, MDMAC agreement performed obviously better than the other two protocols in terms of network throughput. The reason is that the MDMAC we designed in this paper applied channel prediction mechanism based on BP neural network to reduce the interference between adjacent channels and alternate channels.
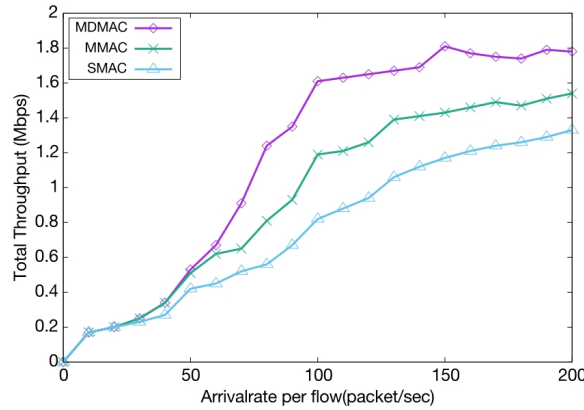

Fig.2 Relationship between throughput and packet arrival rate in static network

We compared MDMAC with SMAC and MMAC in aspect of the average latency with the changes of packet arrival rate in figure 4. According to the figure, the average latency of MDMAC and MMAC protocol is higher than the SMAC, because when the network load is low, single-channel SMAC protocol can meet the needs of network transmission, and the transmission process does not exist the latency of channel negotiation and handover. While the packet arrival rate exceeds a certain value, the network average latency of all of the three kinds of MAC protocol increase in a certain degree. However, the growth rate of the MDMAC is significantly smaller than the other two. The reason is that the SMAC and MMAC protocol both adopt back off mechanisms. The back off time of the conflict nodes increases significantly when the network load is high enough. The MDMAC protocol can dynamically switch the channels according to the QOS, and it can predict the channel quality by utilizing the BP neural network algorithm. Meanwhile, MMAC agreement may lead to multiple nodes continuously compete to use the same channel until a failure

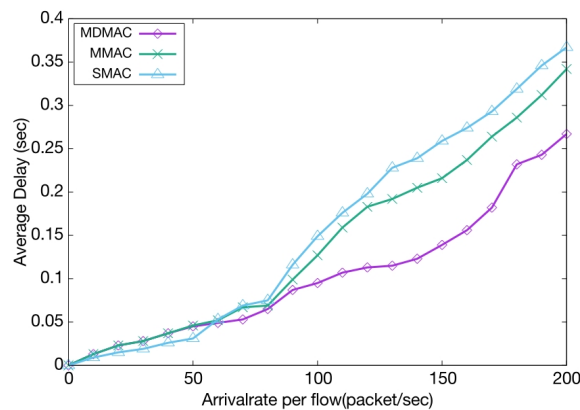competition, which will result in a great increase of the average latency.

Fig.3 Relationship between average latency and packet arrival rate in static network

Summary

According to the data features and the structure characteristic of the WSNs. A new channel allocation strategy based on BP neural network was proposed. The network uses channel assessment mechanism based on BP neural network to assess which channel sequences may not exist interference in the next stage. The simulation result shows that the MDMAC we designed can effectively increase the throughput of the network and reduce average latency.

In practical applications, network environment may be complex and changeable. Network topology, interference between channels and external interference such as WiFi signals may always be changing. The above-mentioned problems were not in-depth discussion and analysis in this paper. Therefore, in order to make the MDMAC agreement still having high reliability under the complex external environment and rapidly changing network topology, there are many factors that need to be studied and analyzed.

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