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Multi-Channel Three-Dimensional Probability CSMA Protocol of Analysis with Monitoring Function for WSN

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1. INTRODUCTION

Wireless Sensor Network (WSN) concerns the current international multidisciplinary and highly cross-frontier researches in the emerging hot areas [1].It has a very broad application prospects in many areas, such as: military defense, biomedical, environmental monitoring, having important scientific and practical value.

Sensor network implements three functions: data collection, processing and transmission. It and communication technology and computer technology together constitute the three pillars of information technology [2]. Wireless sensor networks is a wireless network by a large number of stationary or mobile sensors to self-organization and multi-hop constituted to collaboration and awareness, acquisition, processing and transmission network within the geographic area covered by the perceived object information, and finally sends the information to the owner of the network [3]. And the WSN typical structure is showed in Figure 1.

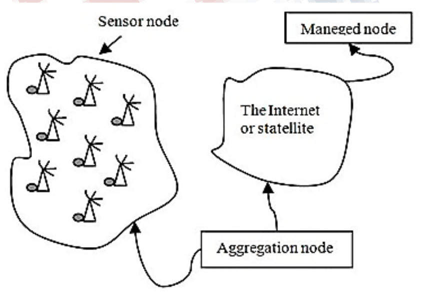


Figure 1. The WSN typical structure

In wireless sensor networks, sensor nodes are usually battery-powered, and therefore energy resources is very limited; the survival time of the network, namely the life cycle, it requires several months or even years, which we need to use as little as possible energy to transmit as much information [4]. On the other hand, due to the characteristics and advantages of the case, the energy is generally difficult to replace. Therefore, energy efficiency as a wireless sensor network is the most important performance indicators, which usually defined as the transmission of information data and the energy consumption ratio.

Since slotted ALOHA (S-ALOHA) and carrier sense multiple access (CSMA) protocols have been proposed, S-ALOHA protocol has been mostly used in cellular networks or satellite networks, where users request uplink resource in the course of signaling, or transmit small-sized data packets sporadically generated [5]. On the other hand, CSMA protocols have been deployed in IEEE 802.11 wireless local area networks (WLAN) and IEEE 802.15 wireless personal area networks (WPAN), in which carrier sensing is effective in small geographical areas with a longer packet transmission time relative to the propagation delay [6-8]. Under this circumstance, users may want to know the performance of the system.

In the monitoring mechanism, if the recipient successfully receives the data, it will return an ACK. ACK signals usually have their own fixed format, the length of size, to reply to the sender by the recipient [9]. The format depends on which kind of the network protocol is taken. When the sender receives the ACK signal, it can send the next data [10]. If the sender does not receive a signal, then the sender may retransmit the current data package, data transfer may stop. The process is depending on the network protocol used [11-13]
When we introduce the multichannel mechanism, the system has N channels to transmit packets, the nodes occupied of channel resources randomly according to their different business requirements [14]. Each priority has no limit on the number of users, the order of priority

from high to low be priority N, priority N-1... priority 1. Priority i of business occupied the channel 1 to channel i , as shown in Figure 2. The arrival Information packets on the channel i obey Poisson distribution with arriving rate is Gi , the arrival process of priority r on the channel i obedience the process with arrival rate λi = Gi / (N − i +1) [15]. Such system is a load balancing system, the same arrival rates for each channel isGi = G (i = 1, 2,..., N) . Different quality of service according to different requirements, the multi-channel CSMA protocol realized different services of different QoS prioritization requirements by prioritizing [16]. The structure of multi-channel mechanism is showed in Figure 2.

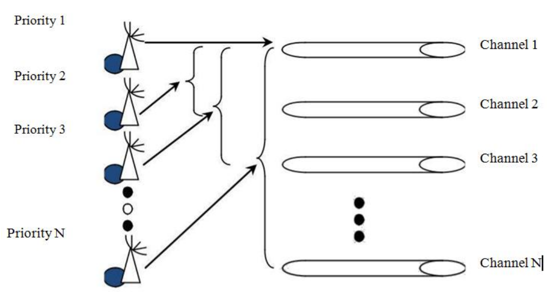


Figure 2. The structure of multichannel mechanism

To sum up, the multi-channel three-dimensional probability CSMA wireless with monitoring function the paper presented can improve channel utilization, communication security and total system controllability.

The organization of the lecture is as follows. After the analysis of the proposed in section II, we get the exact expression of relevant indicators. The results of simulation and analysis have been showed in section III. The lecture has been concluded in section IV.

II. ANALYSIS OF MATP-CSMA PROTOCOL

a. The model of protocol

The model of three-dimensional probability CSMA protocol with monitoring function is shown in Figure 3.

When analyzing the above model, the average cycle analysis method proposed by Professor Zhao Dongfeng is used [17].

Under the control of the protocol, there are three random events in the channel: the successful event U , collision event C (the successful event U and the collision event C are forced into the combined event CU) and idle event I [18]. And these three events can also be divided into two events I and B . These two events appear alternately on the channel axis. The time that information packet transmitted, the transmission time of monitoring signal A , round-trip propagation delay 2a , and the average retransmission delayδ [19].

A cycle period isT_n . The three events above continuously staggering circulate on the time axis and the cycle is variable T_n [20]. TP is the transmission period [21]. Use three-dimensional probability: $P1$, $P2$, $P3$ to control the period of I events, CUI events and CU events separately.

b. Analysis of system throughput

Before analyze the system performance, first do the following assumptions:

1)The channel is ideal with no noise and interference;

2)The basic unit of the system control clock is a , the information packets arrived at time a will transmit at the starting time of the next slot;

3)The channel propagation delay is a ,the packet length is unit length and is an integral multiple of a [22];

4)The access method of number i (i = 1, 2,..., N) channel is timeslot three-dimensional

probability CSMA protocol, and the arrival process of number i channel satisfy the Poisson process whose independent parameter is Gi [23], each arrival process on the channel is independent of each other;

5)The channel using three-dimensional probability CSMA protocol with multichannel mechanism, the information packets need to be sent at the first slot in the transmission period can always detecting the state of the channel at last moment;

6)During the transmission of information packets, the phenomenon of packet collisions occur inevitably, and continues to be sent after a random time delay, it sends will not produce any adverse effects on the arrival process channel [24-26].

The arrival process of channel satisfies the Poisson process:

$$P(n) = \frac{(aG)^n e^{-aG}}{n!} \qquad (1)$$

In I events, at idle time slot a , if there is no information packets to be sent in channel i , its possibility is:

$$q_1^0 = e^{-ap_1 G_i} \qquad (2)$$

In I events, at idle time slot a , if there is only one information packet to be sent in channel i , its possibility is:

$$q_1^1 = ap_1 G_i e^{-ap_1 G_i} \qquad (3)$$

At the transmission period, if there is no information packets to be sent in channel i , its possibility is:

$$q_2^0 = e^{-(3ap_3 + p_2)G_i} \qquad (4)$$

In the transmission period (1 + 3a) , if there is only one information packet to be sent in channel i , its possibility is:

$$q_2^1 = (3ap_3 + p_2)G_i e^{-(3ap_3 + p_2)G_i}$$

In a cycle, the possibility of continuous r I events and j B events in channel i is:

$$\cdot (1-e^{-(3ap_3+p_2)G_i})^{j-1} e^{-(3ap_3+p_2)G_i} \qquad (5)$$

The possibility of E (NI) , the average number of r continuous I events in channel i in a cycle is:

$$E(N_I) = \sum_{r=1}^{\infty}\sum_{j=1}^{\infty} rP(N_I = r, N_B = j) \qquad (6)$$

$$= \sum_{r=1}^{\infty}\sum_{j=1}^{\infty} r(e^{-ap_1G_i})^{r-1}(1-e^{-ap_1G_i}) \cdot (1-e^{-(3ap_3+p_2)G_i})^{j-1} e^{-(3ap_3+p_2)G_i} = \frac{1}{1-e^{-ap_1G_i}}$$

The possibility of E (NB) , the average number of j continuous B events in channel i in a cycle is:

$$E(N_B) = \sum_{r=1}^{\infty}\sum_{j=1}^{\infty} jP(N_I = r, N_B = j)$$
$$= \sum_{r=1}^{\infty}\sum_{j=1}^{\infty} j(e^{-ap_1G_i})^{r-1}(1-e^{-ap_1G_i}) \cdot (1-e^{-(3ap_3+p_2)G_i})^{j-1} e^{-(3ap_3+p_2)G_i} = \frac{1}{1-e^{-(3ap_3+p_2)G_i}} \qquad (7)$$

The number of information packet transmitted successfully in channel i in I events is:

$$E(N_{U1}) = ap_1 G_i e^{-ap_1 G_i} \qquad (8)$$

The average length of information packet transmitted successfully in channel i in I events is:

$$E(U_1) = E(N_{U1}) \times 1 = ap_1 G_i e^{-ap_1 G_i} \qquad (9)$$

In a cycle, the average length of continuous K U events in the TP time in channel i is:

$$E(U_2) = \sum_{r=1}^{\infty}\sum_{j=1}^{\infty}\sum_{K=0}^{r-1} KP(N_I = r, N_B = j)$$
$$= \sum_{r=1}^{\infty}\sum_{j=1}^{\infty}\sum_{K=0}^{r-1} K(e^{-apG_i})^{r-1}(1-e^{-apG_i})$$
$$\cdot(1-e^{-(3ap_3+p_2)G_i})^{j-1}e^{-(3ap_3+p_2)G_i}$$
$$= (3ap_3 + p_2)G_i \qquad (10)$$

In a cycle, the average length of time slot that information packet has been successfully sent in channel i in a cycle is:

$$E(U_i) = E(U_1) + E(U_2) = \frac{apG_ie^{-apG_i}}{1-e^{-apG_i}} + (3ap_3 + p_2)G_i \qquad (11)$$

The average length of B event in channel i is:

$$E(B_i) = E(N_B)\times(1+3a) = \frac{1+3a}{1-e^{-(3ap_3+p_2)G_i}} \qquad (12)$$

The average length of I event in channel i is:

$$E(I_i) = E(N_I)\times a = \frac{a}{1-e^{-apG_i}} \qquad (13)$$

The throughput of the MATP-CSMA protocol in channel i is:

$$S_i = \frac{E(U_i)}{E(B_i)+E(I_i)} = \frac{apG_ie^{-apG_i} + (3ap_3+p_2)G_i}{\frac{1+a}{1-e^{-(3ap_3+p_2)G_i}} + \frac{a}{1-e^{-apG_i}}} \qquad (14)$$

In the N channels of wireless communication system, because this channel model is a load equilibrium model [27], so the arrival probabilities of each channel are the same, that is to say:

$$G_1 = G_2 = G_3 = \cdots = G_i = \cdots = G_N = G \qquad (15)$$

The systemic throughput of the protocol is:

$$S = NS_i' \qquad (16)$$

Then multichannel protocol with the priorityl :

$$_{pl} \sum_{i=1}^{l}\left(\frac{1}{N-i+1}\right)S_i' \qquad (17)$$

c. Analysis of system delay

First do the following assumptions before analyze the system delay: the monitoring signal can always being transmitted correctly; the time generating monitoring signal can be ignored; *R* is the average delay of a packet to be transmitted twice, then *R* is formed by four parts: the time that information packet transmitted 1, the transmission time of monitoring signal τ_A, round-trip propagation delay 2*a* , and the average retransmission delay δ . *R* is the average delay of a packet to be transmitted twice, then $R = 1 + 2a + \tau_A + \delta$ [28].

$(\frac{G}{S} - 1)$ is the average number of information packets be retransmitted [29].

$$D = \left[\frac{\frac{(1+a)G}{1-e^{-(3ap_3+p_2)G_i}} + \frac{aG}{1-e^{-apG_i}}}{apG_ie^{-apG_i} + (3ap_3+p_2)G_i} - 1\right]R + 1 + \tau_A \qquad (18)$$

d. Analysis of system energy efficiency

This paper uses the model literature proposed to analyze the life cycle of the nodes.

1. Energy consumption analysis

1)Sending consumption: during the busy time, the average number of the information packets which arrived within a transmission period $(1 + \tau_A)$ [30], to be sent at the starting

time of next transmission period in the idle state is $G(P2 + \tau_A P3)$. There are $(E(B) - 1)$ transmission periods in a channel period [31].

1+ 2a +τ A

The sending consumption in the transmission period is:

$$W_t = P_{Tx} G[2aP_3 + P_2 + t_A P_3]\left(\frac{E(BU)}{1+2a+t_A} - 1\right) + P_{Tx1} GPa \quad (19)$$

2) Receiving consumption: the receiving consumption in the next transmission period is:

$$W_{rec} = E(U)P_{Rx}. \quad (20)$$

3) Sensing consumption is:

$$t_d(B) = \frac{E(B)}{}[2Ga^2 + (P_2 + t_A P_3)(2a + 0.5 + 0.5t_A)G] \quad (21)$$

The detecting duration of all service nodes in the idle time is:

$$t_d(I) = \frac{a^2}{2} GE(I)\frac{a}{1-e^{-GPa_1}} \quad (22)$$

Then the sensing consumption in the next Ti is:

$$W_d = (t_d(B) + t_d(I)) P_{lsm} \quad (23)$$

The average operating power of channel i is:

$$P_i = \frac{W_t + W_{rec} + W_d}{E(B_i) + E(I_i)} \quad (24)$$

Then the average operating power of all system is:

$$P(S) = \sum_{i=1}^{N} P(i) = NP(i) \quad (25)$$

2. The life cycle of node

For the terminal nodes, assuming it sleeps 1 at a time, then it sleeps a within time a, the average power of the node which priority is l in the N nodes is:

$$P_d = \frac{\frac{2l}{(W_t + W_d)(1+N)N}}{E(B) + E(I) + [q_2^0 + q_A^0 t_A + 2aq_1^0]\frac{E(B)}{1+2a+t_A}} \quad (26)$$

Equation (22), $q_{\tau A}^0$ is the definition of the probability that there is no packet to be sent within time τ_A in a transmission period, $q_{\tau A}^0 = e^{-GP_3\tau A}$ [32].

For the aggregation nodes, the average power is:

$$P_s = \frac{W + P_{\min}\frac{E(I) + E(B)}{T_s}a}{2E(B) + E(I) + \frac{E(I)}{a}} \quad (27)$$

Since the energy consumption is constant in the transmission process, the lifecycle T_d is:

$$T_d = \frac{E}{24 \times 365 \times P_d + 0.1E} \quad (28)$$

For the aggregation node, the lifecycle T_s is

$$T_s = \frac{E}{24 \times 365 \times P_s + 0.1E} \quad (29)$$

III. COMPUTER SIMULATION

Based on the above theoretical analysis, this part will simulate the protocol using MATLAB R2010a.

During the simulation, assume that:

a)The channel is ideal with no noise and interference;

b)The basic unit of the system control clock is a , the information packets arrived at time a will transmit at the starting time of the next slot;

c)The channel propagation delay is a , the packet length is unit length and is an integral multiple of a ;

probability CSMA protocol, and thearrival process of number channel satisfy the Poisson process whose independent parameter is Gi , each arrival process on the channel is independent of each other;

e) The packet length is 1.

f) a = 0.01.

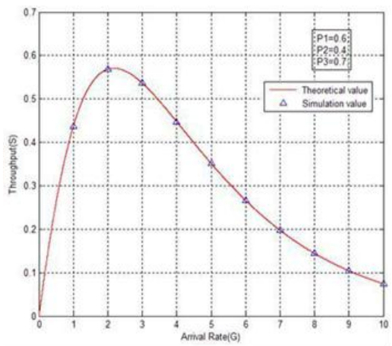


Figure 4. The throughput of the protocol for channel

In the Figure 4, at the beginning, when the arrival rate increases, the system throughput also increased; then throughput reaches its maximum under the condition. Finally, with the increasing amount of the arrival rate, the system throughput decreases. The simulation values of system throughput under the protocol are consistent with the theoretical ones.

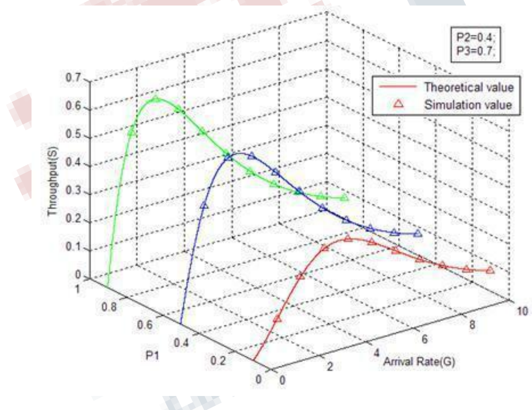


Figure 5. The throughput of the protocol with variable parameter P1

Can be seen from the Figure 5, with the P1increases, the system throughput is increases too. This is laying that when the arrival rate is small, if the probability of arrival information sent is too small at the I events, the channel resource is not fully utilized. Thus, if we increase the probability of the arrival information transmitted, we can improve the efficiency of channel resources and increase the value of the system throughput.

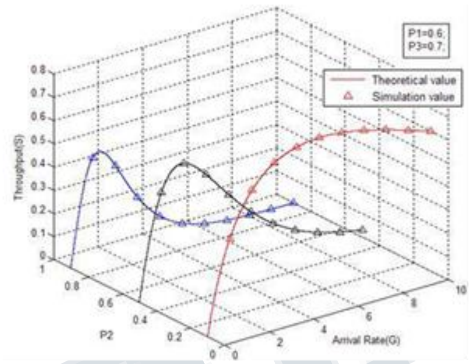


Figure 6. The throughput of the protocol with variable parameter P2

In the Figure 6, when P2 becoming bigger, the throughput will decrease; because when the channel is busy sending the packet, the more new arrival information packets to send at the CU events the more collisions will be.

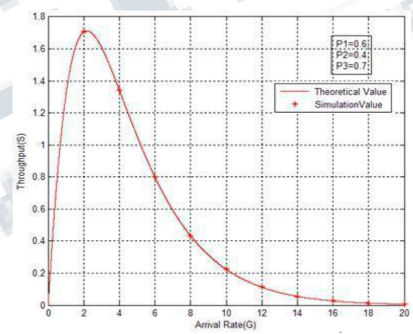
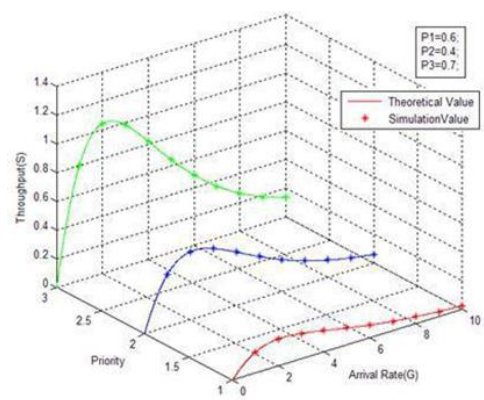


Figure 7. The throughput of the new protocol with 3 channels



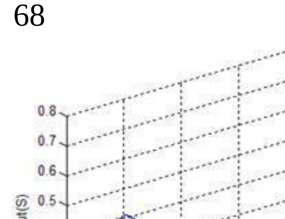


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Figure 8. The comparison of 3 channels with different priorities

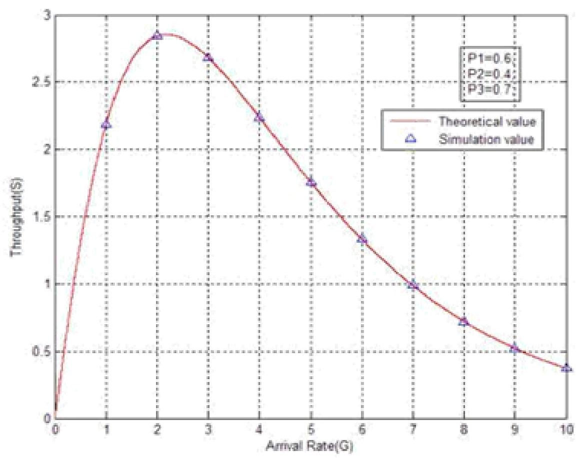

Figure 9. The throughput of the protocol with 5 channels

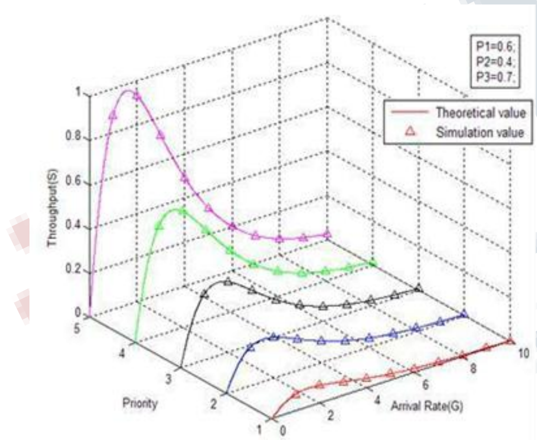

Figure 10. The comparison of 5 channels with different priorities

From Figure 7 to Figure 10, the simulation values of system throughput under the protocol are consistent with the theoretical ones. With the total number of channels increases, the value of the protocol's total system throughput will increases; the channel resources can distribute to every channel according to their priority according to their own priority separately; when the priority is higher, the corresponding single channel will get more network resources than the lower priorities; thus the value of throughput with higher priority channel is bigger than others with lower priorities. With the multi-channel mechanism, the network resources utilization has been improved significantly.

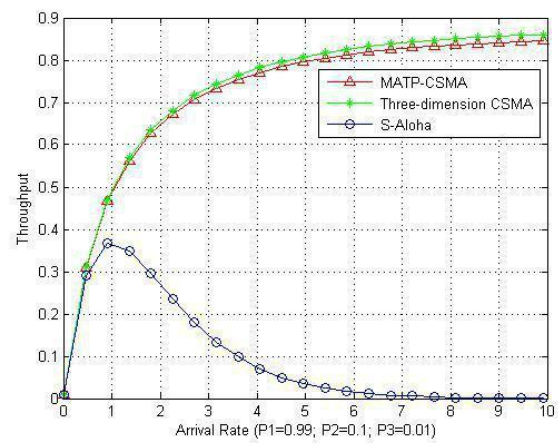

Figure 11. The comparison of system throughput under different protocols

From Figure 11, we can know the system throughput under the MATP-CSMA protocol and the three-dimension CSMA protocol is bigger than the one under S-Aloha protocol. The throughput with MATP-CSMA protocol is a little smaller than the three-dimension CSMA protocol's. Because the signal of ACK occupies some information resources during the data is transmitted, which is inevitable. But with the ACK mechanism, we can make the transmission process of data is visible and the sacrifice of degrading the throughput lightly is worthy.

REFERENCES

[1]Chandra Khatua, Ipsita Chinya, Debdulal Saha, Shyamal Das, Ranjan Sen and Anirban Dhara. Modified clad optical fibre coated with pva/tio2 nano composite for humidity sensing application [J]. International Journal on Smart Sensing and Intelligent Systems. 2015, 8(3): 1424 - 1442.

[2]Shengjie Zhou, Hongwei Ding, Yifan Zhao, Zhijun Yang and Qianlin Liu. Research on the discrete time three-dimensional probability csma protocol in ad-hoc

network [J]. International Journal of Recent Scientific Research, 2015, 6(5): 4257-4262.

[3]Yifan Zhao, Shengjie Zhou, Hongwei Ding, Qianlin Liu, Zhijun Yang, Chunfen Li. The p-persistent csma with the function of monitoring based on time division mechanism [J]. International Journal of Innovative Research in Technology & Science, 2015,3 (6): 38-42.

[4] Conti M, Giordano S. Mobile ad hoc networking: milestones, challenges, and new research directions [J]. Communications Magazine, IEEE, 2014, 52(1): 85-96.

[5] Gandhi C, Arya V. A Survey of Energy-Aware Routing Protocols and Mechanisms for Mobile Ad Hoc Networks [J]. Intelligent Computing, Networking, and Informatics. Springer India, 2014: 111-117.

[6] Payman Moallem, Mohammad Ali Abdollahi, and S. Mehdi Hashemi. Compensation of capacitive differential pressure sensor using multi layer perceptron neural network [J]. International Journal on Smart Sensing and Intelligent Systems. 2015, 8(3): 1443 - 1463.

[7] Xiaoping Wu. Research on the hidden and exposed terminal problem in the Ad Hoc network[J]. Microcomputer Information, 2006 (10X): 35-37.

[8]H.X. Tian, W.F. Wu, P. Wang and H.Z. Li. Modelling of equipment failure rate accounting for the uncertainty [J]. International Journal on Smart Sensing and Intelligent Systems. 2015, 8(3): 1484 -1504.

[9]Wang L, Wu K, Hamdi M. Attached-RTS: Eliminating an Exposed Terminal Problem in Wireless Networks [J]. IEEE Transactions on Parallel and Distributed Systems, 2013, 24(7): 1289-1299.

[10]Yifan Zhao, Shengjie Zhou, Hongwei Ding, Qianlin Liu, Zhijun Yang and Chunfen Li. Analysis of double clocks multi-channel two-dimensional probability csma based on binary tree conflict resolution mechanism [J]. International Journal of Information Research and Review, 2015, 2(11): 1419-1428.

[11] Yingying Guo, Jing Nan, Hongwei Ding, Yifan Zhao and Shengjie Zhou. Research on the multi-channel p-persistent csma protocol with monitoring function [J]. International Journal of Future Generation Communication and Networking, 2015, 8(5): 115-124.

[12] Cheng B, Ci L, Tian C, et al. A Multi-channel MAC Protocol with High Throughput for Wireless Sensor Networks [J]. Advanced Technologies in Ad Hoc and Sensor Networks. Springer Berlin Heidelberg, 2014: 145-154.

[13] Jia He. Research on the access protocol of Ad Hoc network based on the multi-channel [J]. Modern Computer: half Edition, 2008 (10): 113-115.

[14] Hongwei Ding, Yingying Guo, Qianlin Liu and Shengjie Zhou. The multichannel pd-csma with 3-way handshake based on conflict resolution algorithm in wsn [J]. International Journal of Recent Scientific Research, 2015, 6(4): 3714-3718.

[15] S.J. Zhou, H.W. Ding, Y.F. Zhao, P. Li. The discrete time non-persistent csma protocol with functions of monitoring and multichannel mechanism based on binary tree conflict resolution in wsn [C]. International Conference on Computer Information Systems and Industrial Applications, 2015: 118-121.

[16] Hongwei Ding, Yingying Guo, Yifan Zhao, Shengjie Zhou, and Qianlin Liu. Research on the Multi-channel Probability Detection CSMA Protocol with Monitoring Function [J]. Sensor Lett, 2015, 13: 143-146.

[17] Chunfen Li, Shengjie Zhou, Hongwei Ding, Qianlin Liu, Zhijun Yang and Yifan Zhao. Study on double clocks two-dimensional probability csma with the functions of monitoring [J]. International Journal of Current Advanced Research, 2015, 4(11):488-490.

[18] Chunfen Li, Shengjie Zhou, Hongwei Ding, Zhijun Yang, Qianlin Liu. The double clocks two-dimensional probability csma with three-way handshake mechanism [J]. International Journal of Recent Scientific Research, 2015, 6(11): 7464-7468.

[19] Ha, J.Y.; Kim, T.H.; Park, H.S.; Choi, S.; Kwon, W.H. An enhanced CSMA-CA algorithm for IEEE 802.15.4 LR-WPANs [J]. IEEE Commun. Lett. 2007, 11, 461–463.

[20] Mahmood, D.; Khan, Z.A.; Qasim, U.; Naru, M.U.; Mukhtar, S.; Akram, M.I.; Javaid, N. Analyzing and Evaluating Contention Access Period of Slotted CSMA/CA for IEEE802.15.4 [J]. Proc. Comput. Sci. 2014, 34, 204–211.

[21] Khanafer, M.; Guennoun, M.; Mouftah, H. A Survey of Beacon-Enabled IEEE 802.15.4 MAC Protocols in Wireless Sensor Networks [J]. IEEE Commun. Surv. Tutor. 2014, 16, 856–

876.

[22] IEEE 802.15.4 Standard: Wireless Medium Access Control and Physical Layer Specifications for Low-Rate Wireless Personal Area Networks, IEEE, 2006. Available online: http://www.ieee802.org/15/pub/TG4.html (accessed on 25 March 2015).

[23] Gubbi, J.; Buyya, R.; Marusic, S.; Palaniswami, M. Internet of Things (IoT): A vision, architectural elements, and future directions [J]. Grid Comput. Escience 2013, 29, 1645–1660.

[24] Gaynor, M.; Moulton, S.L.; Welsh, M.; LaCombe, E.; Rowan, A.; Wynne, J. Integrating wireless sensor networks with the grid [J]. IEEE Internet Comput. 2004, 8, 32–39.

[25] Moritz, G.; Golatowski, F.; Lerche, C.; Timmermann, D. Beyond 6LoWPAN: Web Services in Wireless Sensor Networks [J]. IEEE Trans. Ind. Inf. 2013, 9, 1795–1805.

[26] Kyusakov, R.; Eliasson, J.; Delsing, J.; van Deventer, J.; Gustafsson, J. Integration of Wireless Sensor and Actuator Nodes with IT Infrastructure Using Service-Oriented Architecture [J]. IEEE Trans. Ind. Inf. 2013, 9, 43–51.

[27] Tong, E.D.; Niu, W.J.; Li, G.; Tang, D.; Chang, L.; Shi, Z.Z.; Ci, S. Bloom filter-based workflow management to enable QoS guarantee in wireless sensor networks [J]. Comput. Appl. 2014, 39, 38–51.

[28] Martinez, J.F.; Familiar, M.S.; Corredor, I.; Garcia, A.B.; Bravo, S.; Lopez, L. Composition and deployment of e-Health services over Wireless Sensor Networks [J]. Math. Comput. Model. 2011, 53, 485–503.

[29] Kifayat, K.; Merabti, M.; Shi, Q.; Abbas, S. Component-based security system (COMSEC) with QoS for wireless sensor networks [J]. Secur. Commun. Netw. 2013, 6, 461–472.

[30] Zhou, Y.; Zhang, Y.; Liu, H.; Xiong, N.; Vasilakos, A.V. A Bare-Metal and Asymmetric Partitioning Approach to Client Virtualization [J]. IEEE Trans. Services Comput 2014, 7, 40–53.

[31] Cheng, H.; Guo, R.; Su, Z.; Xiong, N.; Guo, W. Service-Oriented Node Scheduling Schemes with Energy Efficiency in Wireless Sensor Networks [J]. Sens. Network. 2014, 247173:1–247173:12.

[32] ZHANG Yi, YANG Xiu-xia, ZHOU Wei-wei and ZHAO He-wei. Study of three-dimensional on-line path planning for uav based on pythagorean hodograph curve [J]. International Journal on Smart Sensing and Intelligent Systems. 2015, 8(3): 1641 -1666.