行政院國家科學委員會專題研究計畫 成果報告

在移動式隨意網路中以 IEEE 802.11 為基礎之同時具有延遲保證與節省電池能量的分散式排程

研究成果報告(精簡版)

計畫類別：個別型
計畫編號：NSC 97-2221-E-343-006-
執行期間：97年08月01日至98年07月31日
執行單位：南華大學資訊工程學系

計畫主持人：吳建民

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報告附件：出席國際會議研究心得報告及發表論文

處理方式：本計畫可公開查詢

中華民國 98年10月27日

■成果報告

行政院國家科學委員會補助專題研究計畫

□期中進度報告

在移動式隨意網路中以IEEE 802.11為基礎之同時具有延遲保證與節省電池能量的分散式排程

計畫編號：NSC 97-2221-E-343 -006 -
執行期間：97 年 8 月 1 日至 98 年 7 月 31 日

計畫主持人：吳建民
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計畫參與人員：王士彥、莊東霖、蔡志汶、李欣鴻、李宏緯、范雅絜、簡岳生、黃百昆、林明鋒、陳清益、吳松展

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執行單位：南華大學

中 華 民 國 98 年 10 月 23 日

中文摘要

在本計畫中，將提出一種以IEEE 802.11 DCF為基礎，同時具有延遲保證與節省電池能量的分散式優先排程方法，把一條單一流量的封包傳送比率當作優先權指標考慮因素，把成功跳躍比率(Hop put ratio)與節點的電池能量當作後退時間考慮因素。成功跳躍比率愈高的節點其後退時間會愈長。具備較低電池能量的節點，為了減少競爭次數，因此其後退時間會較短。因此本計畫將重新定義封包傳送比率、封包的優先權指標、倒退時間機制與系統效能的判斷因子，並且將本研究方法與IEEE 802.11 DCF及先前的分散式方法比較，證明本計畫所提出來的方法，確實比先前的方法更能提升系統效能。

關鍵詞：IEEE 802.11 DCF，跳躍式無線特殊網路

Abstract

The performance of backoff scheme plays an important role in designing efficient Medium Access Protocols for ad hoc networks. In this paper, we propose an energy aware backoff scheme and evaluate the performance of the proposed scheme for ad hoc networks. The backoff mechanism devised by us grants a node access to the channel based on its battery power in comparison to those of nodes in the two-hop contention area. We have studied the performance of our energy aware backoff mechanism in multihop ad hoc network through simulation experiments, and the simulation results show that our protocol exhibits a significant improvement in power saving, end-to-end goodput, and hop put, compared to the existing IEEE 802.11 DCF.

Keywords: IEEE 802.11 DCF, Ad Hoc Networks.

1. Introduction

There has been a growing interest in mobile multihop wireless networks in recent years. Such networks are formed by mobile hosts (or nodes, users) that do not have direct links to all other hosts. They can be rapidly deployed without any established infrastructure or centralized administration. In this situation, they are called ad hoc networks [1]. Because of the greater affordability of commercial radios, ad hoc networks are likely to play an important role in computer communications. The applications of ad hoc network are in a building, campus, battlefield or a rescue environment.

Unlike wired networks, problems such as, mobility of nodes, shared broadcast channel, hidden and exposed terminal problem, and constraints on resources such as, bandwidth and battery power, limit the applications of ad hoc networks. Due to the above factors, providing energy aware, packet delivery ratio, and end-to-end goodput guarantees in ad hoc networks are some tough propositions.

Packet scheduling in Medium Access Control (MAC) layer is to choose the next packet to transmit, such that a real attempt is made to satisfy the end-to-end delay and packet delivery ratio guarantees.

Wireless scheduling algorithms significantly differ from their wired network correspondences. In a multihop wired network, when a node has data packets for transmission, it cares only for the packets in its own transmission queue. But in ad hoc networks, the channel is broadcast, multiple nodes may contend for the channel simultaneously, resulting in collisions. To avoid the collision problem, a node must be aware of traffics at nodes in its two-hop contention area [2]. Therefor, an efficient backoff algorithm is an important issue for packet scheduling in ad hoc networks.

Recently, the renewed interests in multihop ad hoc networks have been centered around using the IEEE 802.11 MAC mechanism. In [3], the authors raised the question: Can the IEEE 802.11 work well in multihop wireless ad hoc networks? They concluded that the protocol was not designed for multihop networks. Although IEEE 802.11 MAC can support some ad hoc network architecture, it is not intended to support the wireless multihop mobile ad hoc networks, in which multihop connectivity is one of the most prominent features.

The performance of IEEE 802.11 MAC mechanism is determined by backoff scheme, RTS/CTS mechanism, and transmission range, etc. In addition, whether the IEEE 802.11 MAC protocol is efficient or not will affect the performance of ad hoc networks. The metrics for the performance of multihop 802.11 ad hoc networks may have throughput, delay, jitter and energy aware, etc.

A simulation analysis of the backoff mechanism in the IEEE 802.11 standard has been presented in [4]. The backoff and contention window are closely related, so the selection of contention window will affect the network throughput. The authors in [4] shown the effective throughput and the mean packet delay versus offered load for different values of the contention window parameter and the number of contending stations.

The throughput and the mean frame delay as functions of offered load for different RTS threshold values and numbers of stations transmitting frames of random sizes are presented in [5].

When the number of stations increase, then the RTS threshold should be decreased. While transmitting frames of random sizes, it is recommended to set the RTS/CTS mechanism always on independently of the number of contending stations. The absence of RTS/CTS mechanism brings considerable network performance degradation, especially for large values of offered load and numbers of contending stations.

A new backoff algorithm is proposed in [6] and the authors model it with a discrete-time Markov chain; measuring its saturation throughput under several conditions and several sets of parameters which are to be adjusted according to the network condition, with the aim of approaching maximum throughput when stations are saturated.

In this paper, we present the results of a simulation study that characterize the energy aware, packet delivery ratio, end-to-end delay, and throughput of multihop ad hoc networks. In particular, we use the CBR connection numbers as the main varying parameters for the above performance metrics. If the backoff scheme donot consider the battery power of a node, this may cause some nodes premature death than other nodes. And this situation will affect the establishment of a route and degrade the performance of the entire network. In order to save the power, if a node has lower battery power, the node should have lower backoff time and higher priority to transmit its packets. On the other hand, if a node has higher battery power, the node should have higher backoff time and lower priority. Therefore, we redefine the backoff mechanism in IEEE 802.11 DCF as an energy aware backoff scheme.

2. IEEE 802.11 Medium Access Schemes

IEEE 802.11 is a standard for wireless ad hoc networks and infrastructure LANs [7] and is widely used in many testbeds and simulations in wireless ad hoc networks researches. IEEE 802.11 MAC layer has two medium access control methods: the distributed coordination function (DCF) for asynchronous contention-based access, and the point coordination function (PCF) for centralized contention-free access. In this paper, we consider the IEEE 802.11 DCF MAC protocol as the medium access control protocol in wireless multihop ad hoc networks.

The DCF access scheme is based on a carrier sense multiple access with collision avoidance (CSMA/CA) protocol [8]. Before initiating a transmission, a station senses the channel to determine whether another station is transmitting. If the medium is found to be idle for an interval that exceeds the distributed inter-frame space (DIFS), the station starts its transmission. Otherwise, if the medium is busy, the station continues monitoring the channel until it is found idle for a DIFS. A random backoff interval is then selected and used to initialize the backoff timer. This timer is decreased as long as the channel is sensed idle, stopped when a transmission is detected and reactivated when the channel is idle again for more than a DIFS. When a receiver receives a successful data frame then it sends an acknowledgement frame (ACK) after a time interval called a short inter-frame space (SIFS) to the sender.

The integer number of backoff time slots is uniformly drawn in an defined interval called contention window. The algorithm used by 802.11 to make this contention window evolving is called Binary Exponential Backoff (BEB). After each successful transmission, the contention window is set to [*0, CWmin-1*] (its initial value). When node successive collisions occur, the contention window is set to [*0, min(1024, 2^i*CWmin-1)*]. *i* is the number of retransmission. If *i* > 7, the contention window is set to its initial value. It is the retry limit of the BEB algorithm[9].

Following equation is the backoff mechanism for IEEE 802.11.

Backoff=INT(CW*Random())*SlotTime

Where

CW = an integer between CWmin and CWmax,

Random = real number between 0 and 1,

SlotTime = transmitter turn-on delay +

medium propagation delay +

medium busy detect response time.

3. Energy aware IEEE 802.11(E802.11)

3.1 Energy aware back off mechanism

The objective of the energy aware backoff procedure is to save the power for a node with respect to those nodes in two-hop contention area of the node. Let ***Power*** be the remaining power of a node, *i* denote the number of retransmission attempts made for a packet, and ***i_max*** represent the maximum number of retransmission attempts permitted.

Our proposed energy aware backoff mechanism is defined as follows.

Backoff=RPP*CWmin+Uniform[0,(2^{i}*CWmin)-1)]

Where

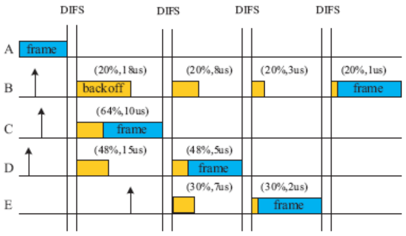
RPP indicates the remaining percentage of the ***power***=(the remaining energy of the node/the initial energy of the node) *100%,

Uniform[*] is the random number generation function with uniform distribution.

If a node has the lowest energy in its two-hop contention region, then it has the lowest backoff period according to our energy aware backoff mechanism. Otherwise, it will have higher backoff period.

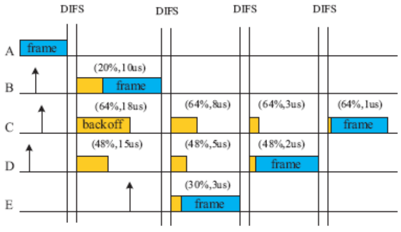
3.2 Examples for data transmission using 802.11 and E802.11

In Fig. 1, nodes A, B, C, D and E are neighbors in two-hop contention area. In the beginning, node A has the right to access the medium, and nodes B, C and D want to access the medium during the transmission period of node A. When the transmission period of node A finished, nodes B, C and D wait for a DIFS time and create their backoff time using IEEE 802.11 backoff mechanism. Let the backoff time for B,C and D be 18, 10, 15 $m\mu\sec$, respectively. Among nodes B, C, and D, the backoff time of node C is the shortest one. In such a case, node C has the right to access the medium and transmit its frame. When the transmission period of node C is ended, nodes B and D must decrease their backoff time by the backoff time of node C. If node E wants to transmit data during the transmission period of node C. Node E should create its backoff time after waiting for a period of DIFS. Let the backoff time of node E be 7 $m\mu\sec$. Then, the transmission sequence of nodes B, D and E changes to D, E and B according to their updated backoff time. The backoff scheme of IEEE 802.11 for this case is thus completed.



(48%,15us)=(the remaining percentage of the power for a node, backoff time)
The initial energy for each node is all the same.

Fig. 1. An example for 802.11



(48%,15us)=(the remaining percentage of the power for a node, backoff time)
The initial energy for each node is all the same.

Fig. 2. An example for E802.11

In Fig. 2, nodes A, B, C, D and E are neighbors in two-hop contention area. In E802.11, it takes the remaining energy of a node into consideration at the backoff mechanism. Therefore, the transmitting sequence due to varied backoff time will be different from 802.11. Firstly, node A is accessing to the medium, and nodes B, C and D want to access the medium during the transmission period of node A. At the end of node A's transmission, nodes B, C and D wait for a DIFS time and create their backoff time using the energy aware backoff mechanism. Let the backoff time for nodes B, C and D be 10, 18 and 15 $m\mu$sec, respectively. Here, node B has the shortest backoff time. Therefore, node B has the right to access the medium and transmit its frame. When the transmission of node B has finished, node E also wants to access the medium. Then, nodes C and D decrease their backoff time and node E creates its backoff time after waiting for a period of DIFS. If the backoff time of node E is 3 $m\mu$sec. Then the transmission sequence of nodes C, D and E is E, D and C. The backoff scheme of E802.11 for this case is thus completed.

4. Simulation Environment

We use simulations to study the performance of the multihop ad hoc network using the IEEE 802.11 DCF MAC. Results reported in this paper are performed under *ns2* network simulator [10]. The radio model has similar characteristics to a commercial radio interface, Lucent's WaveLAN [11]. WaveLAN is a shared-media radio with a nominal bit-rate of 2 Mb/sec and a nominal radius of 250 meters. The link layer models the complete distributed coordination function (DCF) MAC protocol of the IEEE 802.11 wireless LAN standard [7].

We place much effort on studying the impact for the remaining power of a node on the network performance. The remaining power of a node ia added to the energy aware backoff mechanism in E802.11. In most simulation runs, we considered 100 nodes randomly distributed over a square area of 670x670 m^2, and simulated 150 seconds of real time. To focus on the power aware study, we did not consider mobility in this paper and all nodes were assumed stationary to eliminate packet loss due to broken routes caused by mobility.

Communications between nodes are modeled using a uniform node-to-node communication pattern with constant bit rate (CBR) UDP traffic sources sending data in 512-byte packets at a rate of 20 packets/sec [12]. Each CBR source corresponds to 94,720 bps bandwidth requirement for data frames (including the 8-byte UDP header, 20-byte IP header, 24-byte MAC header and 28-byte physical layer header) at the radio channel and 81,920 bps useful data throughput. A total of 5, 10, 15, 20, 25, 30 CBR connections were generated to represent different levels of loading, with a node being the source of only one connection. All CBR connections were started at times uniformly distributed during the first one second of simulation and then remained active throughout the entire simulation run.

Each of our simulation result is the average from 5 randomly generated network topologies. Furthermore, in order to generate a more uniform topology so that the network will not becomes disconnected when N (the average number of neighbors) is small, we divide the topology into 25 regions and 4 nodes are randomly placed in each region. The distances between the source node and the destination node are also made uniformly distributed. That is, we make sure that there are roughly equal numbers of short, medium, and long connections.

In multihop networks, a routing mechanism is needed for communication between two hosts that are not within wireless transmission range of each other. We chose DSR (Dynamic Source Routing), a commonly used source routing protocol in the wireless multihop ad hoc networks [13], as the routing protocol in our simulations.

In order to better understand the characteristics of E802.11 multihop networks in scenarios considered for this paper, we evaluated the performance of E802.11 in ad hoc networks based on the following metrics:

Fruitful hop-put: the numbers of radio transmission (or hops) for data packets that successfully arrive at their final destinations.

Wasted hop-put: the numbers of radio transmission (or hops) for data packets that cannot successfully arrive at their final destinations.

End-to-end goodput: the actual bandwidth that is obtained by CBR connections.

End-to-end delay per packet: the total delay experienced by a packet that successfully reached the destination node.

End-to-end delay per hop: the average delay per hop that experienced by a packet that successfully reached the destination node.

Energy dissipation per packet: the average energy dissipation experienced by a packet that successfully reached the destination node.

Energy dissipation per hop: the average energy dissipation per hop that experienced by a packet that successfully reached the destination node.

Received packet per energy dissipation: the number of received packets per energy dissipation.

5. Performance Evaluations

In this section, we evaluate the impact of the residue power for a node on the performance of the wireless multihop ad hoc networks.

5.1 Hop-put

In Fig. 3, we plot hop-puts (number of radio transmissions) vs. connections. Both the fruitful hop-put and the wasted hop-put are shown. We can see that 802.11 has bigger differences in the fruitful hop-put and the wasted hop-put than E802.11. In other words, more successful radio transmissions are spent on packets that do not reach their final destinations. The reason that some packets cannot reach their destinations is due to the increased traffic loading at the MAC layer. In addition, E802.11 takes the remaining energy as the metric of backoff scheme and this will decrease the congested nodes. When the energy is included in backoff scheme (near a distributed network), more successful radio transmissions create more successful CBR packet delivery. The network waste less network resource and this will improve the network performance. This shows that E802.11 achieves better network performance than 802.11.

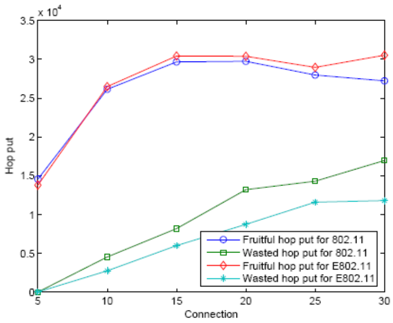


Fig. 3. Fruitful hop put and wasted hop put vs. the number of connections.

5.2 End-to-end goodput

Fig. 4 shows the end-to-end goodput versus the connections for 802.11 and E802.11. And we know that the end-to-end goodput for E802.11 is much higher than that for 802.11. In Fig. 4, as the number of CBR connections increases, the end-to-end goodput increases. When the number of connections is large, the end-to-end goodput suffers from the traffic increase due to the increased connections. Nonetheless, given a particular CBR connection number, the goodput for E802.11 is still higher than 802.11.

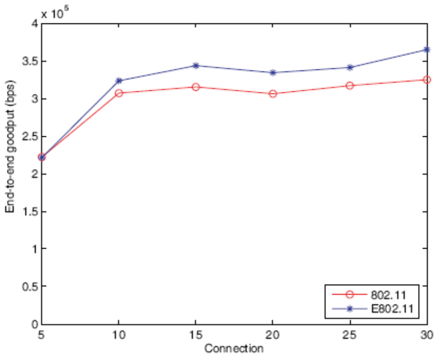


Fig. 4. End-to-end goodput vs. connections.

5.3 End-to-end delay

From Tables I and II, we see that E802.11 there is slightly larger than 802.11 for end-to-end delay per packet or per hop. In order to save energy, E802.11 takes the energy into consideration at backoff mechanism. In E802.11, the increase in the power saving is achieved by using the energy aware backoff mechanism, but adding certain quantity of delay.

5.4 Energy dissipation

Fig. 5 shows the energy dissipation per packet versus the connections for 802.11 and E802.11. And we know that the energy dissipation per packet for E802.11 is much lower than that for 802.11.

TABLE I
END-TO-END DELAY PER PACKET (SEC) VS. THE NUMBER OF CONNECTIONS

Conn.	5	10	15	20	25	30
802.11	0.01	1.17	2.28	3.55	3.95	4.29
E802.11	0.02	1.11	2.16	3.20	3.90	4.37

TABLE II
END-TO-END DELAY PER HOP (SEC) VS. THE NUMBER OF CONNECTIONS

Conn.	5	10	15	20	25	30
802.11	0.01	0.40	0.79	1.16	1.44	1.63
E802.11	0.01	0.39	0.78	1.13	1.48	1.72

Fig. 6 shows the energy dissipation per hop versus the connections for 802.11 and E802.11. We see that the energy dissipation per hop for E802.11 is much lower than that for 802.11.

In Fig. 5 and 6, as the number of CBR connections increases, the energy dissipation increases. When the number of connections is large, the energy dissipation increases. Nonetheless, given a particular CBR connection number, the energy dissipation per packet or per hop for E802.11 is still lower than 802.11.

From Table 3, we see that E802.11 is higher than 802.11 for received packets that has same energy dissipated.

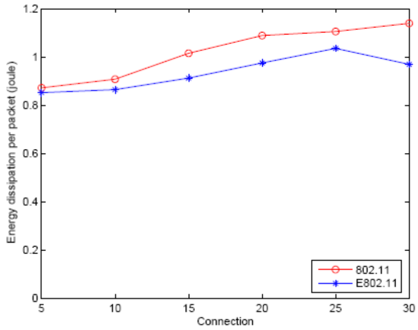


Fig. 5. Energy dissipation per packet vs. connections.

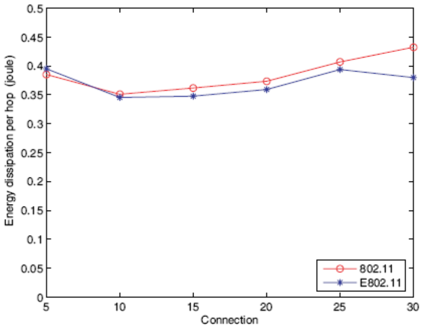


Fig. 6. Energy dissipation per hop vs. connections.

TABLE III
RECEIVED PACKET PER ENERGY DISSIPATION VS. CONNECTIONS

Conn.	5	10	15	20	25	30
802.11	1.15	1.10	0.99	0.92	0.91	0.88
E802.11	1.17	1.16	1.10	1.03	0.97	1.03

6. Conclusions

We have studied the performance of a wireless multihop ad hoc networks which uses the 802.11 and E802.11 as its MAC mechanism. We found that E802.11 is higher than 802.11 in end-to-end goodput of the multihop network. In E802.11, the increase in the power saving is achieved by taking the energy aware into consideration at backoff mechanism, thereby saving some powers and adding certain quantity of delay. We see that E802.11 is slightly larger than 802.11 for end-to-end delay per packet or per hop. Nonetheless, given a particular CBR connection number, the energy dissipation per packet or per hop for E802.11 is still lower than 802.11. We also show that E802.11 can receive more packets than 802.11 at same energy dissipated. There are many other factors (e.g., routing, mobility) that affect the performance of a multihop ad hoc network and they are topics for future research.

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出席國際學術會議心得報告

計畫編號	NSC 97-2221-E-343 -006 -
計畫名稱	在移動式隨意網路中以 IEEE 802.11 為基礎之同時具有延遲保證與節省電池能量的分散式排程
出國人員姓名 服務機關及職稱	吳建民 南華大學資訊工程系 助理教授
會議時間地點	2009/3/26 ~ 2009/3/29 日本/崗山
會議名稱	IEEE ICNSC 2009
發表論文題目	Adaptive TDMA slot Assignment in Mesh Wireless Networks

一、參加會議經過

3/26 邀請一些有關無線光纖通訊與網路的專家學者與會進行專題演講
3/27~3/29 進行各個主題所接受論文的研討會

二、與會心得

由於 IEEE ICNSC 2009 是屬於 EI 的研討會, 對於個人論文能被接受, 表示自己的研究受到高度肯定, 內心深感欣慰, 與會過程當中, 也認識了一些國內外在無線光纖通訊與網路的專家學者, 經過交換心得, 更加增強個人的研究實力, 對於將來的研究方向有莫大的助益, 因此能參於這次研討會, 深覺獲益良多。