Efficient Power Management Scheme Considering Inter-user QoS in Wireless LAN

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***Abstract*— In wireless LAN, power saving is the essential issue to the node since the node has the limited battery. Hence, the nodes can use the Power Saving (PS) mode unless transmitting or receiving packet exists for the certain period. For the PS node to receive the buffered packet in Access Point (AP), the PS nodes periodically check the Traffic Indication Map (TIM) field in the beacon frame that contains the information about buffered packet. If the buffered packet exists, they must transmit the PS_ POLL to the AP. The AP transmits the buffered packet to the node that succeeds to transmit the PS_POLL. However, when the node transmits the PS_POLL, the transmission order is determined without any priority. Therefore, we propose the efficient power management scheme to support inter-user QoS and reduce the power consumption in wireless LAN. In the proposed scheme, the node with high priority transmits PS_ POLL earlier than that with low priority, so the node with high priority receives the buffered packet faster than that with low priority, and reduces the power consumption by converting the mode from Active Mode (AM) to Power Saving (PS) for remaining beacon interval (BI). Through the analysis and simulation, we show that the proposed scheme reduces power consumption and guarantees inter-user QoS compared to conventional scheme.**

I. INTRODUCTION

FOr the advent of IEEE 802.11b WLAN standard, we have been experienced many wireless devices which have the feature of mobility. Owing to the characteristic of mobility, the device operates without any line such as power cable, that means the device operates depending on the limited battery. Therefore, the power saving is the important factor in wireless LAN [1]. To diminish the power consumption of node, many researches have been carried in WLAN. Ning Li *et al.* proposed the scheme which the nodes allow their Network Interface Card(NIC) to sleep mode if the data packet length included in the RTS or CTS is larger than certain threshold length [2]. In [3], the mobile nodes can implement their own independent and dynamic power management algorithm and obtain an optimum balance between packet delay and battery consumption. In [4], they proposed a scheme that adjusts the ATIM window size to optimize the power saving scheme.

In IEEE 802.11b wireless LAN [5], in order to reduce the power consumption, the nodes can change from Active mode (AM) to the Power Saving (PS) mode by setting the power management (PM) bit to 1 in the MAC header if they don't have any packet to transmit or receive for a certain period. Then, the PS nodes wake periodically to check the TIM field in the beacon frame since the TIM field contains existing information about receiving packet that is buffered by AP. If the TIM field is set in beacon frame, they must transmit PS_POLL to the AP for receiving the buffered packet. When the node transmits the PS_POLL to the AP, the node sends the PS_POLL to AP after a random delay so that they should avert the collision from other nodes which transmit the PS_POLL. If the collision will happen, the node must do backoff procedure again. On the contrary, if the any node succeeds in transmitting the PS_POLL to the AP, the AP will transmit the buffered packet to the node which transmitted the PS_POLL. After finishing packet reception, the node can save the power consumption by changing mode from AM to PS during remaining Beacon Interval (BI). If a certain PS node is receiving the buffered packet now, any other PS nodes which can't transmit PS_POLL must wait until the node that transmits the PS_POLL early finishes receiving the buffered packet. On the other hand, if the TIM field is not set, the nodes change the mode from AM to PS and keep PS mode until another beacon frame is received.

However, when the PS nodes transmit the PS_POLL, any transmission order doesn't exist. In other word, without any decided sequence, all PS nodes try to transmit the PS_POLL competitively since all the nodes share the radio resource, and there is not any policy that supports the Quality of Service (QoS) in IEEE 802.11b WLAN. For this reason, when any one tries to transmit the PS_POLL, the node must perform a random-backoff procedure to avoid the collision among other nodes.

Therefore, we propose a new power management scheme to support inter-user QoS and reduce the power consumption in current 802.11b WLAN. Here, inter-user QoS means that users' service policy is prioritized in accordance to the initial service contract level [7]. When the nodes register on the network, AP retrieves user profile information from AAA (Authentication, Authorization and Accounting) server and decides the suitable priority such as Gold, Silver, and Bronze. Then, in the proposed scheme, we classify the chance of packet reception by using the user priority. The nodes with high priority (Gold) have the chance to receive the buffered packet faster than those of low priority (Bronze). Namely, the nodes with high priority (Gold) transmit PS_ POLL earlier than those with low priority (Bronze). Consequently, the node with high priority receives the buffered packet faster than that with low priority, and reduces the power consumption by converting the

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mode from AM to PS for remaining beacon interval (BI). In other word, by separating PS_POLL transmission according to node's priority, we can support inter-user QoS in WLAN. Owing to the user priority, the proposed scheme also can be applied to PS mode of 802.11e MAC [6].

The rest of the paper is composed as follows. Section 2 explains the proposed scheme in detail, and we analyze numerically about the conventional and proposed scheme in section 3. In section 4, we evaluate the conventional scheme and proposed scheme through the simulation. Finally, we conclude the paper in section 5.

II. Proposed Scheme

As we mentioned above, it is desirable that when the PS node receives the buffered packet, the node should avoid the contention to send the PS_POLL if possible. Moreover, it is the effective plan that the node receives the buffered packet faster than other nodes. The reason is that if the packet is received earlier than other nodes, the node can keep the PS mode for long remaining beacon interval (BI). Therefore, we propose a new power management scheme that can reduce the power consumption and support inter-user QoS in wireless LAN.

A. Protocol Assumption

To begin with, we make the two assumption to explain the proposed scheme.

1) All the nodes have already registered to the network, so AP knows the priority of all nodes in the network.
2) The channel is error-free channel. Therefore, the packet will be transmitted or received very well except the collision with other nodes.

B. Protocol Operation

To support the inter-user QoS of proposed scheme, we define a new PUN packet as follows:

- *PUN* : a packet that holds the number of PS nodes that have a buffered packet to receive, sorted into different fields according to their priority. (So, for example, suppose there are two priorities, A and B. There are 11 PS nodes in total that have a buffered packet to receive. Five of them have priority A, while six of them have priority B. Hence, the PUN packet has the two field with 5 in field A and 6 in field B.)

With above PUN packet, the operation of the AP and node is changed slightly. First of all, the action of AP is modified as following. As AP receives the downlink packet from the network, AP stores the packet to buffer, and classifies the node number to receive the buffered packet per each priority since AP already knows the priority of all nodes. Then, AP writes the node number to receive the buffered packet per priority in each filed of PUN packet. When AP broadcasts the beacon frame, AP transmits PUN packet along with the beacon frame.

Secondly, the act of PS node is reformed as following. When all the PS nodes receive new beacon frames, they change the mode from PS to AM, and check the TIM field in beacon frame. If TIM field is set, the nodes see PUN packet. After receiving the PUN packet, the nodes can know how many nodes whose priority is higher than its priority are among the nodes which will receive the buffered packet from AP. Then, the nodes can't transmit the PS_POLL and await in AM mode until the nodes whose priority is higher than its priority finish receiving the buffered packet. After the nodes with higher priority finish receiving the buffered packet, the nodes with low priority can try to send the PS_POLL to AP. If the node with the same priority can try to send a PS_POLL, the PS_POLL packet may collide with other PS_POLL packets. Then, if the PS_POLL transmission is collided, the nodes set the backoff-window value again, and retry to send the PS_POLL. For example, the nodes that have the first priority will try to send the PS_POLL without waiting any time since they have the highest priority. In the other hand, nodes with the second priority will try to send the PS_POLL after the nodes with the first priority finish receiving the packet. If no packet is received from AP, the nodes change the mode from AM to PS, and keep PS mode until next beacon frame reception.

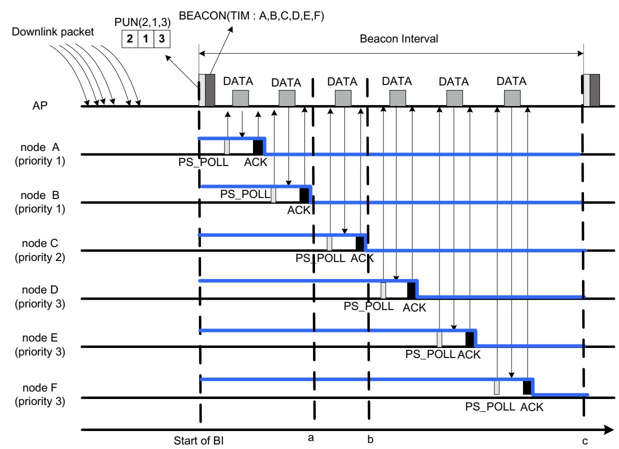

Fig. 1. Example operation of proposed scheme(Priority Group=3)

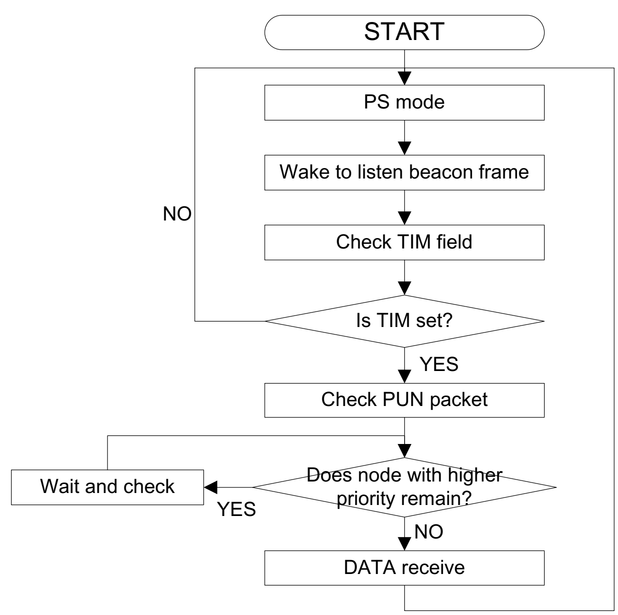

Fig. 2. Flow chart of power management scheme based on priority

The example operation for the proposed scheme is shown in Fig.1. In this figure, the priority group is classified by three group. As you can see in the figure, node *A* and *B* have the highest priority, so they try to transmit the PS_POLL without waiting any time. However, node *C* can't try to transmit the PS_POLL until time 'a' since all the nodes which whose priority is higher than its priority do not receive the buffered packet yet. After the time 'a', the node *C* can try to transmit the PS_POLL. When the node *C* receive the buffered packet, the node *D, E*, and *F* can'transmit until time 'b'. Therefore, according to node's priority, we guarantee the inter-user QoS by controlling the trial to transmit the PS_POLL. The flow chart for the operation of the proposed scheme mentioned above is shown in Fig.2.

III. Performance Analysis

We want to know the power consumed by the nodes per each priority, when they receive their buffered packet. We don't consider uplink stream since we just want to know the performance of node when the PS nodes receive the downlink stream. To simplify the analysis, we assume that RTS/CTS packet are not used. Therefore, the average time needed for receiving one buffered packet is denoted as follows :

$$T_{data}=\frac{CW_{min}}{2}+T_{PS\_POLL}+2SIFS+T_{packet}+T_{ack}+DIFS \quad (1)$$

where CW_{min} is the minimal value of the contention window, and T_{PS_POLL}, and T_{ack} are the time taken to transmit the PS_POLL, the ACK, respectively. In addition, T_{packet} is the time needed to receive the buffered packet.

Let *M* denote the total number of node in network, I_b beacon transmission interval, λ the packet arrival rate of each node which is expressed a Poisson distribution, and N_{pg} the number of priority group. Using the N_{pg}, *M* can be expressed as

$$M = \sum_{k=1}^{N_{pg}} M_k \quad (2)$$

where M_k is the number of nodes in the *k* th priority group.

Moreover, we define α_i as the number of buffered packets in the AP at the *i* th beacon interval, and β_i as the number of nodes that have a buffered packet to receive in the AP at the *i* th beacon interval. Then, α_i, and β_i can be obtained as

$$\begin{aligned} \alpha_i &= M\lambda I_b. && (3)\\ \beta_i &= MP\{N(I_b) \geq 1\} \\ &= M(1-P\{N(I_b)=0\}) = M(1-e^{-\lambda I_b}) && (4) \end{aligned}$$

Here, among the buffered packets, the number of the *k* th priority packet, and the number of the node that is to receive the *k* th priority packet are derived from (3) and (4) as follows:

$$\begin{aligned} \alpha_{k,i} &= M_k\lambda I_b. && (5)\\ \beta_{k,i} &= M_k(1-e^{-\lambda I_b}) && (6) \end{aligned}$$

Then, in *i* th beacon interval, the waiting time that the node needs to receive the buffered packet is described as follows :

$$\begin{aligned} T_{wait,i} &= T_{data}\frac{1}{\alpha_i}\sum_{j=1}^{\alpha_i-1} j = \frac{1}{2}(\alpha_i-1)T_{data} && (7)\\ T_{wait\_k,i} &= T_{data}\frac{1}{\alpha_{k,i}}\sum_{j=1}^{\alpha_{k,i}-1} j = \frac{1}{2}(\alpha_{k,i}-1)T_{data} && (8) \end{aligned}$$

where $T_{wait,i}$ is the waiting time of conventional node, and $T_{wait\_k,i}$ is the waiting time of node with *k* th priority in the proposed scheme.

In *i* th beacon interval, the idle time that the node needs to receive the buffered packet is composed from from (7) and (8) as follows :

$$\begin{aligned} T_{conv\_idle,i} &= T_{wait,i} && (9)\\ T_{prop\_idle\_k,i} &= T_{wait\_k,i} \qquad , \ k=1 && (10)\\ &= T_{data}\sum_{j=1}^{k-1}\alpha_{j,i} + T_{wait\_k,i} \ , \ k \neq 1 && (11) \end{aligned}$$

In (11), the first part is the sum of times taken by the nodes whose priority is higher than that of a node with a particular priority to receive their buffered packets.

Then, during the *i*th beacon interval, the total power consumption that the conventional node and *k* priority node uses to receive the buffered packet can be formulated from (1) to (11) as

$$\begin{aligned} E_{conv\_i} =& T_{conv\_idle,i}\cdot E_{idle} + \frac{\alpha_i}{\beta_i}T_{data}\cdot E_{active} \\ &+ (I_b - T_{conv\_idle,i} - \frac{\alpha_i}{\beta_i}T_{data})\cdot E_{sleep} && (12) \end{aligned}$$

$$\begin{aligned} E_{prop\_i,k} =& T_{prop\_idle\_k,i}\cdot E_{idle} + \frac{\alpha_{k,i}}{\beta_{k,i}}T_{data}\cdot E_{active} \\ &+ (I_b - T_{prop\_idle\_k,i} - \frac{\alpha_{k,i}}{\beta_{k,i}}T_{data})\cdot E_{sleep} && (13) \end{aligned}$$

where $E_{idle},\ E_{active},\ and\ E_{sleep}$ is each power consumption per second by the IEEE 802.11 WLAN network interface in idle, active, and sleep mode, respectively [8].

IV. Numerical and Simulation Results

We analyzed and simulated to evaluate the performances of the conventional scheme and the proposed scheme using C++ programming.

A. Simulation model

For simplicity, we assume that the uplink data is not generated. We used 60 terminal nodes for simulation. To evaluate the performance of proposed scheme, we set the number of priority group to 3 and 6. We execute the simulation with varying traffic density from 0.6 to 1.0, which is defined as

$$traffic\,density = \frac{(number\ of\ node)\times(packet\ length)\times(traffic\ rate)}{transmission\ rate}$$

The other parameter related with IEEE 802.11b WLAN is shown in Table I.

TABLE I

SIMULATION PARAMETER

Parameter	Value	Parameter	Value
Simulation runs	1000runs	ACK transmission time	60 μs
Packet length	1000bytes	SIFS transmission time	10 μs
Transmission rate	2M bit/sec	DIFS transmission time	50 μs
Beacon Interval	50msec	E_{idle}	1.5mW
PS_POLL size	24bytes	E_{active}	1.15mW
CW size	32	E_{sleep}	0.045mW

B. Simulation metrics

We used two metrics to evaluate the performances of conventional scheme and proposed scheme.

1) Power consumption
   The Power consumption is defined as the average of the power used to receive the buffered packet at each priority node during one Beacon Interval.
2) Delay
   The delay is defined as the average of waiting time that the node needs to receive the packet.

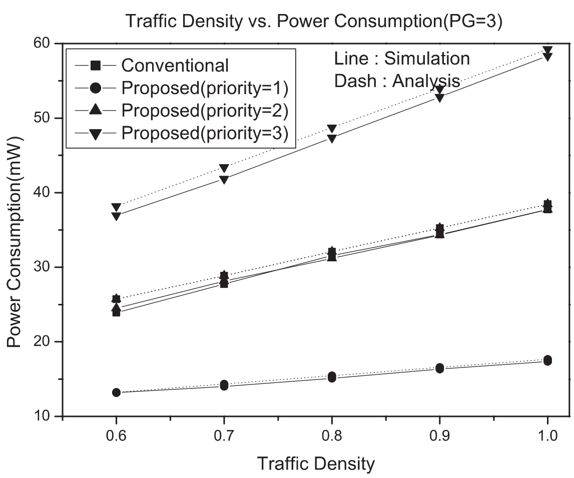

Fig. 3. Traffic density vs. power consumption(PG=3)

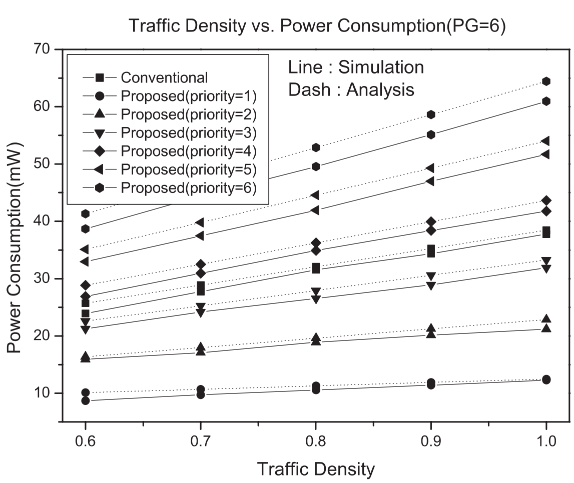

Fig. 4. Traffic density vs. power consumption(PG=6)

C. Simulation results

Fig. 3 shows the simulation and analysis result of the the average power consumption versus traffic density for conventional scheme and the proposed scheme, respectively. In this figure, the number of user priority in proposed scheme is 3. When the traffic density increases, we can know that the power consumption of node in both schemes is larger. Moreover, we can also identify that the power consumption is different according to user priority in the proposed scheme. Namely, the higher user priority is, the less power consumption is. When the proposed scheme is applied, the power consumption of node with '1' priority is less than the power consumption of node with conventional scheme since average waiting time that nodes with '1' priority required for transmitting the PS_POLL is less than that of conventional node. Therefore, the node with '1' priority has much time to save the power than conventional node. However, the node with priority '3' uses much power compared to conventional scheme, and the power consumption of the node with priority '2' is similar to that of conventional node.

Fig. 4 shows the power consumption for the conventional and proposed scheme in case that the number of priority

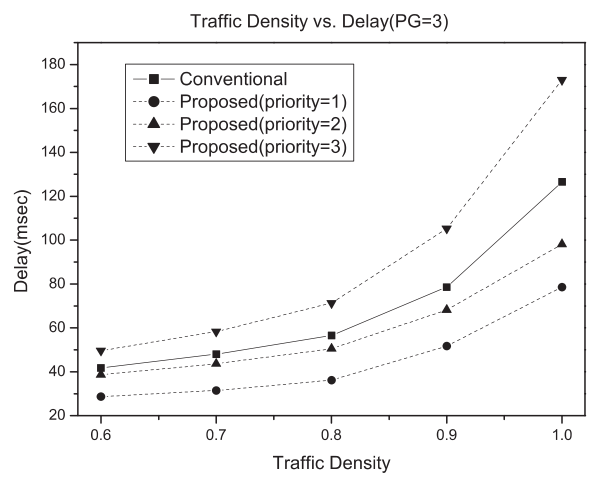

Fig. 5. Traffic density vs. delay(PG=3)

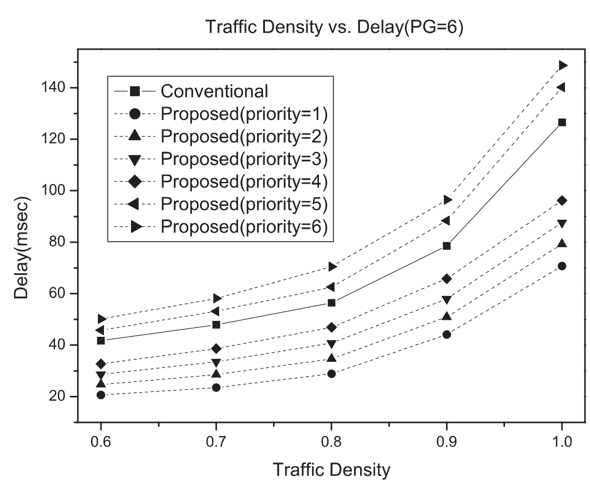

Fig. 6. Traffic density vs. delay(PG=6)

is 6. Similar to Fig. 3, the power consumption is classified according to user priority. The node that has ‘1’, ‘2’, and ‘3’ priority uses less power compared with conventional scheme, but on the other side, the node that has ‘4’, ‘5’, and ‘6’ priority uses much power compared with conventional scheme.

Fig. 5 shows the simulation result of the delay versus the traffic density in case that the number of priority is 3. We can see that as the traffic density is larger, the delay is also larger. Moreover, we can know delay differentiation according to each priority. Like power consumption, the delay of node with high priority is smaller than that of node with low priority.

Therefore, the proposed scheme can support the inter-user QoS. The delay of node that has ‘1’ and ‘2’priority is generally smaller than that of conventional scheme, but the delay of node that has ‘3’ is larger than that of conventional scheme.

Fig. 6 shows the delay for the conventional and proposed scheme in case that user priority is 6. Similar to Fig. 5, the delay is differentiated by user priority.

V. Conclusions

In this paper, we propose power management scheme using priority for supporting inter-suer QoS and power saving in IEEE 802.11b WLAN. Little modification is required for the proposed scheme to be applied to the present IEEE 802.11b WLAN. In the proposed scheme, by adjusting the packet reception according to user priority, we can support the inter-user Qos in IEEE 802.11b WLAN. Furthermore, the nodes save the power consumption by changing the mode from AM to PS after receiving the buffered packet. Therefore, through analysis and simulation result, we can conclude that the proposed scheme gives the inter-user QoS and power conservation to current WLAN system.

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