Dynamically controlled transmission standby in WLAN systems

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Abstract: With the spread of the WLAN, WLAN devices densely exist, and radio interferences between devices which degrade performance of WLAN systems have been increasing. In this study, we propose the WLAN system which has the transmission standby in which devices with poor channel condition wait for transmissions, and other devices can transmit frames without radio interferences from the devices which are waiting for transmissions. Simulations to evaluate transmission performance of WLAN systems show the transmission standby technique reduces radio interferences and effectively utilizes radio resources.

Keywords: wireless LAN, transmission standby

Classification: Wireless communication technologies

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1 Introduction

With the spread of the WLAN (Wireless Local Area Network), WLAN devices densely exist, and radio wave interferences between devices [1] which degrade performance of WLAN systems have been increasing. The SINR (Signal to Interference plus Noise power Ratio) which indicates the condition of a received signal is expressed as

$$\gamma_{\text{SINR}} = \frac{S}{\sum_n I_n + N},$$

where $S$ represents the received signal power, $I_n$ represents the interference power from the device with number $n$, and $N$ represents the noise power. As the sum of interference power increases, SINR decreases.

In a WLAN system, one AP (Access Point) and STAs (Stations) belonging to BSS (Basic Service Set) deployed by the AP perform frame transmissions and receptions. Channel assignment schemes [2] reduces interferences by setting the channel of each BSS to a different channel from channels used by BSSs which cause strong interferences to the BSS. In this study, we propose the transmission standby technique to reduce interferences. The WLAN system which has the transmission standby in which devices whose SINRs are lower than the threshold wait for transmissions, and other devices can transmit frames without radio interferences from the devices which are waiting for transmissions. Because the transmission standby technique decreases the number of devices which compete with one another to obtain access opportunity, interferences from adjacent devices are less, and devices with better channel condition can transmit frames with less transmission failure and higher transmission rate.

2 Related works

The conventional WLAN system based on DCF (Distributed Coordination Function) which is a specific CSMA/CA (Carrier Sense Multiple Access/Collision Avoidance) mechanism defined in IEEE 802.11 standard [3] provides an equal access opportunity to WLAN devices, and Tuning the Carrier Sensing Range [4] can reduce harm of interferences by optimization of carrier sensing range.

A WLAN system with Opportunistic CSMA/CA [5] provides efficient use of radio resources by giving transmission opportunity to WLAN devices with better channel condition. A WLAN system with RATOP (Resource Allocation based on the area Throughput Optimization Policy) [6] effectively utilizes radio resources by setting the bandwidth and the channel of each AP based on channel state information which is collected from APs in an area.
3 Proposed method

We propose the transmission standby technique to use radio resources more efficiently by reducing interferences. A WLAN system with the transmission standby technique has two parameters TSR (Transmission Standby Rate) and TSL (Transmission Standby Length) which decide the rule to wait for transmissions. In the proposed WLAN system, at first, the AP measures the distribution of the SINR for $i$-th STA $\gamma_{\text{SINR}_i}$ and determines the threshold for $i$-th STA $v_{\text{thi}}$ to satisfy following equation.

$$\int_{\gamma_{\text{SINR}_i}}^{v_{\text{thi}}} p(\gamma_{\text{SINR}_i}) d\gamma_{\text{SINR}_i} = \text{TSR}. \quad (2)$$

In the above equation, $\gamma_{\text{SINR}_{\text{low}}}$ is the lowest SINR to receive a frame with no bit error, $p(\gamma_{\text{SINR}_i})$ is the probability density function (pdf) of $\gamma_{\text{SINR}_i}$, and TSR ($0 \leq \text{TSR} < 1$) is the parameter to control the rate of the transmission standby possibility for $i$-th STA. The AP collects data of $\gamma_{\text{SINR}_i}$ only when $\gamma_{\text{SINR}_i}$ is higher than $\gamma_{\text{SINR}_{\text{low}}}$, in other words, when frames are received with no bit error. If the set of samples of $\gamma_{\text{SINR}_i}$ which are collected by the AP is $\{X_1, X_2, ..., X_m, ..., X_M\}$ in ascending order, $v_{\text{thi}}$ will be $X_m$ when TSR is $\frac{m}{M}$. TSL determines the duration to wait for transmissions. If TSR and TSL are too large, since all devices in the proposed WLAN system will concurrently wait for transmissions and not able to utilize radio resource efficiently, TSR and TSL need to be optimized.

In the proposed WLAN system, by using TSR, the fairness in transmission opportunity will be kept as the conventional DCF-based WLAN system since devices which have higher average of SINR are set the threshold to higher value and devices which have lower average of SINR are set the threshold to lower value. The proposed WLAN system has the advantage to improve the received SINR and efficiently utilize the radio resource because the devices with lower SINR which can not utilize the radio resource efficiently wait to transmit frames and devices with better channel condition can transmit frames with less interferences.
The uplink transmission sequence of the proposed WLAN system which has the transmission standby is shown in Fig. 1. The proposed WLAN system is based on the DCF protocol with the medium reservation scheme using an RTS/CTS(Request to Send/Clear to Send) frame. In proposed WLAN system, the AP assesses SINR of the STA by the received RTS frame from the STA, and devices perform two types of transmission as shown in Fig. 1.

1. SINR of the STA ≥ the threshold
   In case 1), devices transmit frames same as the conventional WLAN system. The STA transmits an RTS frame to the AP, the AP transmits a CTS frame to the STA, the STA transmits a data frame to the AP, and the AP transmits an ACK (ACKnowledge) frame to the STA.

2. SINR of the STA < the threshold
   In case 2), a TSC (Transmission Standby Command) frame is transmitted to the STA by the AP instead of a CTS frame. If the STA receives a TSC frame, the STA suspends the transmission of data frame and sets the waiting time of which length is TSL.

Since channel condition changes with time, and a BSS can move around with a mobile AP, the mechanism for dynamic control of TSR and TSL in the transmission standby technique is necessary to obtain maximum benefit of waiting for transmissions. We propose the dynamic control mechanism for the transmission standby technique in which a controller for optimization of TSR and TSL collects throughput data in each BSS from APs in an area via the network, and sets TSR and TSL by using collected data. In the proposed WLAN system, the mechanism for setting parameters TSR and TSL has only two patterns of process which are a process to increase a parameter and a process to decrease a parameter. Since the optimum values of TSR and TSL change with situation of transmissions which changes with time, TSR and TSL are not fixed to a specific value in the dynamic control mechanism.

The mechanism for setting TSR in the proposed WLAN system will simply perform the same process as the previous process when the total throughput is improved by performing the previous process, and the mechanism will simply perform the opposite process to the previous process when the total throughput is reduced by performing the previous process. The mechanism for setting TSL is similar to the mechanism for setting TSR.

Since the proposed WLAN system has a mechanism to keep equal access opportunity to devices, the proposed WLAN system considers only the total throughput to set parameters. When devices in the proposed WLAN system share a same band with other wireless devices, equal access opportunity between devices in the proposed WLAN system and other devices will not be kept. However, at least, devices in the proposed WLAN system do not give harm to other devices because devices in the proposed WLAN system only wait to transmit frames according to TSR and TSL.
Table I. Simulation conditions.

| Maximum transmission opportunity length | 4 ms |
|-----------------------------------------|------|
| MCS (Modulation and Coding Scheme) of data frame ($r$ is a coding rate) | 256QAM ($r=5/6$), 256QAM ($r=3/4$) 64QAM ($r=5/6$), 64QAM ($r=3/4$) 64QAM ($r=2/3$), 16QAM ($r=3/4$) 16QAM ($r=1/2$), QPSK ($r=3/4$) QPSK ($r=1/2$), BPSK ($r=1/2$) |
| Channel frequency | 2.4 GHz |
| Path loss model | $30 \times \log_{10}x$ (dB) ($x$ (m) is the distance between transmitter and receiver.) |
| Traffic model | Full buffer |
| Fading model | Flat Rayleigh fading |
| Number of STAs in each BSS | 2 |
| Distance between the AP and a STAs in each BSS | 5 m |

4 Performance evaluation

We carried out two computer simulations to examine the performance of the proposed WLAN system, which are a simulation performed by two BSSs and a simulation performed by three BSSs. Table I shows the simulation conditions. In the simulations, if there are premises that there are no radio interferences and $\gamma_{\text{SINR}}$ continues to increase, it is assumed that the transition from the minimum value to the maximum value of $\gamma_{\text{SINR}}$ takes 0.1 s on an average. In the proposed WLAN system with the mechanism of dynamically setting parameters, as the time for collecting throughput data sufficiently to set TSR and TSL, the periods for setting TSR and TSL are set to 1 s and 5 s respectively in the simulations. In the proposed WLAN system with fixed parameters, TSR and TSL is set to the best value in each arrangement of devices to obtain maximum benefit of waiting for transmissions.

Fig. 2 (a) shows relationship between total throughput of each WLAN system and distance between APs of each BSSs, and transmissions are performed by two BSSs for 4,000 s at each distance between APs in this simulation. Throughput in the WLAN system with the proposed technique of which TSR and TSL are set dynamically is close to the throughput in the WLAN system with the proposed technique of which TSR and TSL are fixed to the best values. At the distances between APs which are around 100 m, effect of interferences becomes higher, and throughput in WLAN systems with the proposed technique do not become as low as throughput in the conventional DCF-based WLAN system. This is because effect of interferences is reduced by waiting for transmissions in WLAN systems with the proposed technique.

In the simulation to output numerical data shown in Fig. 2 (b), transmissions are performed for 6,000 s at each distance by three BSSs which are set on an equilateral triangle. The more BSSs are, the higher effect of interferences is. Fig. 2 (b) shows that, effect to improve the throughput by the proposed technique will become higher when effect of interferences is higher.
Fig. 2. Relationships between throughput and distance between APs, simulations were performed by (a) two BSSs, and (b) three BSSs.

From these results, we can conclude that, the proposed WLAN system reduces radio interferences and effectively utilizes radio resources.

5 Conclusion
In densely deployed WLAN systems, the interference from adjacent WLAN device is one of the major causes of performance degradation of WLAN system. In this study, we proposed the transmission standby technique to improve the performance of WLAN systems by reducing interferences from other WLAN devices in any environments where are radio interferences from adjacent WLAN devices. In a WLAN system with the transmission standby technique, since WLAN devices with poor channel condition wait for transmissions, other WLAN devices can transmit and receive frames with higher SINR. From the numerical results, we confirmed that, the proposed WLAN system works better in environments where are higher effect of interferences.