A Common Control Channel Transmission Based on Contention and Reservation for Signaling and Data in W-CDMA System

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Abstract—In this paper, we propose new channel access mechanism for effective transmission of signal and data in IMT-2000 W-CDMA system proposed by NTT DoCoMo. In proposed mechanism, base station broadcasts channel status information to prevent mobile station from unnecessary transmission collision. That is, proposed mechanism uses competition mechanism for the transmission of first radio frame and utilizes reservation mechanism for the transmission of other following continuous radio frame. According to performance analysis, proposed mechanism has better performance than slotted-ALOHA because of using contention and reservation in the case that signal and data messages are transmitted.

I. INTRODUCTION

IMT-2000 system, called mobile communication system for next generation, could interwork with various wire/wireless networks, and could support wireless access to reliable connection. At RTT of IMT-2000 system, a channel access mechanism is very important techniques to improve system performance\cite{1,2,3,4}.

In this paper, we propose a MAC protocol to improve transmission performance of signals and data through common control channels in W-CDMA system proposed by NTT DoCoMo. Dedicated signaling channels are allocated to terminals by requesting channel allocation through common control channels, and signaling messages are transmitted through dedicated signaling channel. Also, packet data transmission is performed through common control channels when user packet channel is not available. In this case, packet transmission through common control channels is performed by using contention method, and performance decreases because of collision. In order to solve these problems, base stations broadcast channel status information, and terminals perform transmission based on channel status information.

In section II following this introduction, problem of common control transmission in W-CDMA system are described, in section III, the new channel access mechanism are described to solve the problems of W-CDMA system. Also, in section IV, performance analysis of the proposed mechanism is done by simulation and conclusions are made in section V.

II. THE PERFORMANCE OF COMMON CONTROL CHANNEL TRANSMISSION IN W-CDMA SYSTEM

1. Channel Access Mechanism

A channel access mechanism for allocation of signal channel in wideband CDMA system is shown in Fig. 1.

Mobile stations keep synchronization with system time through BCCH, and transmit channel allocation demand to RACH based on offset timing after random delay. When signals and data are transmitted by RACH, signal and data are transmitted in the 10ms radio frame unit. Base stations check CRC value after decoding channel coding information, and determine that frame error occurs or not. When there are no errors, base stations respond by transmitting PID of the access terminals based on ACK mode frame of the FACH-S. When multiple terminals achieve access, base stations can perform simultaneous response by transmitting PID up to maximum 7 mobile stations. When the random access attempts are greater than 7, base station transmits response form the oldest random access attempt to new random access attempt. If $T_{wK}$, which is waiting time for random access expires, then the responses are not transmitted.

When transmitting multiple radio frame data, mobile station transmits the next frame only after receiving ACK responses to the previous frames. If mobile station has not received an ACK response during $T_s$, msec after transmitting signal data through RACH, mobile stations decide that a collision occurs during transmission. In this case, the mobile station performs retransmission after random delay time, and the maximum retransmission number is described as $N_{sS}$.

The values of parameters such as $T_{wK}$, $T_s$, and $N_{sS}$, which are used in channel access mechanism, could be different according to channel environments.

2. Channel access problems in wideband CDMA system

Signaling channel in wideband CDMA system is allocated by channel allocation request through random access channels and response to the demand is transmitted through forward access channels. Mobile stations try signals and data transmission according to access offset based on radio frame.
of physical layers, while maintaining synchronization with base stations. One radio frame has 4 offsets, and a collision occurs when two or more terminals access the same offset of the same code. These transmissions based on offset time have the advantage of decreasing unnecessary delay time.

When having signal messages or data to transmit toward base stations, mobile stations try data transmission referring to the access code and offset information needed to perform random access. One radio frame includes U/C field identifying control information and user data, TN field indicating message termination, W field indicating continued message transmission, S field detecting redundant receive caused by one layer retransmission, and PID field, an indicator of mobile stations or call of transmission terminals. When an upper-layer message is too big to be included in one radio frame, mobile stations split this upper-layer message into a frame length and set W bit to 1. When radio frames are completed, mobile stations transmit signal or data messages to base stations through the determined channel at the offset point, and wait to receive the response. On receiving data from mobile stations, base stations check CRC to detect errors, and respond in FACH ACK mode using PID of mobile stations if there is no error. Also, when they find out that there are more messages to receive by checking W bit, base stations wait additional message until message construction is completed. When message construction is completed, base stations transfer this data to the upper-layer. On receiving ACK response from base stations, mobile stations perform transmission of additional data or new data after random delay time. If mobile station does not receive the response for specific time, mobile stations perform retransmission.

In general, slotted-ALOHA mechanisms provide better transmission performance than ALOHA mechanisms. However, when the length of signal messages is longer than that of a radio frame, mobile stations transmit sequentially after splitting these messages into the size of a frame, and receivers complete the messages by constructing these splitted messages. That is, in the case of continuous data transmission, when senders receive ACK response for previous radio frame, they transmit the next data frame after random delay time. In this case, continuous frame and new data frame compete equally, and the transmission performance of continuous signal and data frame is not guaranteed. Especially, when user packet channels are unavailable, packet data service is provided through common signal channels. Thus, packet transmission delay owing to channel access causes serious problems.

III. NEW COMMON CONTROL CHANNEL TRANSMISSION BASED ON CONTENTION AND RESERVATION METHOD

1. Channel and Frame Structure

The proposed channel access mechanism can be supported in wideband CDMA system just by changing logical field of MAC frame without changing physical channel structure. Signal messages being able to consist of a single radio frame are transmitted based on slotted-ALOHA in wideband CDMA system. However, in order to transmit signal and data messages composed of multiple radio frames, channel access mechanism needs reservation mechanism. Thus, the frame structure of BCCH and FACH is partially changed to apply reservation mechanism to slotted-ALOHA mechanism. Base stations transmit reservation related information of channels to mobile stations through BCCH frames, and reserved location and terminals through FACH frames.

BCCH frame structure for transmission of status information related with reservation and contention of random access channels is shown in Fig. 2.

![Fig. 2. BCCH frame structure](image)

As shown in Fig. 2, newly added NR field in BCCH channel frame indicates the number of reserved slots for RACH slots in the next BCCH transmission duration. Base stations allocate slots sequentially from the beginning of the transmission duration. Then, NR value shows the location where contention slot starts.

FACH frame structure showing reserved channel location and terminal information in response to random access of mobile stations is shown in Fig. 3.

![Fig. 3 FACH-S(ACK mode) frame structure](image)

In FACH-S(ACK mode), NR field and SI field are newly added. NR field indicates the number of the ACK including
reservation information among response messages in existing ACK mode. SI field shows the location information of reservation slots which terminals having relevant PID are going to use.

2. Random Access Procedure

To transmit data, mobile stations acquire information on the location of random access slots from BCCH. Access slots are determined based on random access codes and offset values. In this case, access is determined by calculating access probability of each terminal using the number of reserved slots out of whole slots. Random access probability is as follows

\[
P_a = 1.0 - \frac{\text{the number of reserved slots}}{\text{the number of whole slots}}
\]

When access probability is 0 or access is not permitted, access is retried after random back off delay.

Base stations perform the transmission of ACK responses after determining random access data errors. Also, base stations maintain reservation related information and inform mobile stations of this information. On receiving data, base stations detect errors and check W bit when there is no errors. If W bit shows continuous frames, base stations reserve slots using resource table information. Otherwise, only PID is kept. At the point when response messages are transmitted through FACH, base stations generate and transmit ACK response. At the point of BCCH frame transmission, they transmit the number of reserved slots and update resource tables. This operating procedure of base stations is shown in Fig. 4.

Base stations inform the number of mobile station on reserved-slots in response to random access during the next transmission duration through BCCH. Also, in response mode of FACH, they inform mobile stations of the location of allocated slots in response to the demand received through contention slots of RACH. Therefore, only when each mobile station transmits the first data, transmission in contention mode is performed using one of random access slots of RACH. On the other hand, the transmission for the rest continuous data is performed in reservation mode.

IV. SIMULATION RESULTS AND DISCUSSION

1. System Model for Simulation

System queuing model for performance analysis of channel access mechanism is shown in Fig. 6.

Arrival interval of signal and data messages at each mobile station follows exponential distribution. Each mobile station generates MAC frames depending on the length of messages and transmits them through random access channels after random delay. Random delay for random access is assumed to be exponential distribution with average 20ms. Signal channels for random access are composed of 4 channels with 16ksps, and terminals try transmission based on designated offset after choosing one out of four channels. Base stations
perform CRC check for received frames and respond by transmitting relevant PID through forward access channels when there are no errors. In this case, the procedure including CRC check, generation of response frame, access channel reservation, and organization of FACH and BCCH process frame is assumed to be completed within 2.5ms. On receiving ACK response information and reservation information, mobile stations perform continuous transmission to base stations through designated channels. When mobile stations do not receive channel reservation information, they perform the next transmission through contention slots after random delay, and perform access procedure again after random delay in the case of not receiving response message within 40ms. Mobile stations determine the locations of random access channels using channel information of BCCH, and mobile terminals determine actual access by calculating allowable probability of channel access. When access is not permitted, mobile stations receive channel information again in the next BCCH transmission duration, and try access again after determining the access channel location.

2. Result and Discussion

We analyze the signal or data transmission performance of proposed mechanism and compared the performance of proposed scheme with that of slotted-ALOHA mechanism used in the W-CDMA system.

The proposed mechanism improves performance by applying reservation mode in the case that the length of signal messages is longer than that of a radio frame. This mechanism has the advantage of improving transmission performance without changing physical channels of W-CDMA system. We analyze the signal or data transmission performance of proposed mechanism and compared the performance of proposed scheme with that of slotted-ALOHA mechanism used in the W-CDMA system.

Average transmission delay occurring in the case that one data or signal message is transmitted through one radio frame is shown in Fig. 7.

As shown Fig. 8 and Fig. 9, the more traffic load increases, the better performance the proposed mechanism shows in view of delay and throughput than existing mechanisms. In the case of existing slotted-ALOHA, twice channel contentions occur to transmit two radio frames. On the other hand, in the proposed mechanism, the completion of a channel contention for first frame guarantees channel reservation for the rest continuous transmission, and transmission is performed without extra channel contention. Increased collision probability for access channel caused by reduce available contention channels owing to channel reservation is controlled by adapting the channel access admission probability of mobile station. Compared with existing mechanisms, this proposed mechanism has the 20% performance gain when traffic load is above 0.5.

The throughput vs. message length of the proposed mechanism and the existing mechanism is shown in Fig. 10.
In this figure, the number in parentheses shows the number of radio frame which is needed to transmit signal or data messages. In slotted-ALOHA mechanism, the longer the length of messages is, the worse the performance is. However, in the proposed mechanism, base stations inform mobile station of reservation channels and available channels for random access, and give access probability to each mobile station to reduce collision probability. Then, contention mechanism causing collision is applied only to the first radio frame. In this case, the longer the length of message is, the less the effects of collision are.

V. CONCLUSIONS

In this paper, an effective signal or data message transmission method through common signal channels in W-CDMA system for IMT-2000 service is studied. W-CDMA system requires the allocation of SDCCH to transmit signal messages. These SDCCH request messages are transmitted through RACH based on slotted-ALOHA mechanism. These SDCCH request messages can be included in one radio frame. For additional signaling which requires more than one radio frame, continuous frame indicating field is included in radio frames to accommodate these signal messages. Also, when user packet channel is unavailable, the transmission of user packet data is performed through common signal channels.

When each terminal performs transmission of signals or data through common signal channels, each radio frame needs to compete. Then, message transmission delay gets longer and throughput gets lower because of collision and retransmission to recover this collision. Therefore, in order to improve transmission performance, the method to reduce the frequencies of channel contention is required. In this paper, a new mechanism to employ contention mechanism only for the first radio frame transmission and use reservation mechanism for the transmission of the rest radio frames is proposed. The proposed mechanism can be easily supported by changing several fields of BCCH and FACH without changing physical channels. Also, channel access allowance probability is given to each terminal to decrease random access channel collision owing to channel reservation.

The proposed mechanism shows the same performance as existing mechanisms when a signal or data message is composed of one radio frame. However, this mechanism guarantees better performance than existing mechanisms in case of transmitting more than one signal or data frames. In addition, while the existing mechanisms show decreased process rate in the case that signal message is getting longer, the proposed mechanism shows performance improvement by relatively decreasing collision frequency. Therefore, the proposed mechanism is very useful in the case of transmitting signal and data frame through common signal channels.

REFERENCES