THE DESIGN AND PERFORMANCE EVALUATION OF HIGH-SPEED PACKET DATA MAC PROTOCOL FOR CDMA BASED IMT2000

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( Abstract )

In this paper, we propose and evaluate the performance of CDMA (Code Division Multiple Access) based high-speed packet data service MAC (Medium Access Control) protocol for IMT2000 system. This proposed MAC supports smooth evolution from conventional IS-95 based system to IMT2000. Also, proposed MAC supports connection-less packet transmission over wireless channels. Channel utilization is maximized by using dis-continuous transmission mode technology and efficient channel re-use property. Most of all, 5ms-size message structure based control mechanism provides fast MAC management scheme. Then Sleep-mode based physical channel control function is provided to support power save effect and fast channel activation method. Also, channel related information is minimized by using state transition characteristics of propose MAC. Especially, proposed MAC is admitted by TR45.5 as a part of cdmaOne standard, and proposed to ITU-R as a CDMA based IMT2000 radio transmission technology candidate.

Then, we evaluate the performance of proposed MAC by using computer simulation. Especially, proposed MAC characteristics are approved by cdmaOne, and currently submitted to ITU-R as an IMT2000 RTT based on CDMA technology.

Following introduction, third generation CDMA MAC is proposed for IMT2000 system in section II. Also, major characteristics of proposed functionality are described and explained. Then, performance evaluation environments of proposed MAC are explained, and performances are evaluated and results are analyzed in section III. Finally, we conclude this paper at section IV.

II. Proposed Third Generation CDMA MAC Protocol

In this section, we consider major characteristics of cdmaOne's third generation CDMA MAC protocol. Basically, new third generation CDMA MAC is designed based on conventional IS95 system [4].

1. Channel Structure

According to channel structure of 3G (Third Generation) CDMA MAC, logical channels and physical channels are considered. Physical channels are defined as orthogonal CDMA codes, and logical channels are defined as conceptual channels for MAC layer protocol. Logical channels are mapped to physical channels according to conceptual MAC state.

1.1 Logical channel configuration

Logical channels of 3G CDMA MAC are defined as follows.

dsch (Dedicated Signaling Channel) is allocated at Active/Control-Hold state to exchange dedicated signaling information. dsch transmits L3/Call-Control messages, and message structure uses by 5 and 20 ms fixed size message format. dmch (Dedicated MAC Channel) is allocated at Active/Control-Hold state to exchange dedicated MAC control messages. dmch transmits MAC control messages, and uses 5ms-size message structure. cmch (Common MAC Channel) is allocated at
Suspended/Dormant state, and commonly used by multiple mobile stations to carry MAC control messages. cmch (dedicated Traffic Channel) is based on 20ms-size message structure. dtx (Dedicated Traffic Channel) is allocated at Active state and used as a dedicated traffic transmission link. ctc (Common Traffic Channel) is allocated at Dormant state, and commonly used by multiple mobile stations to transmit packet traffic.

According to the direction of logical channels, prefix ‘r’ means reverse channel, and ‘f’ means forward channel. Prefixes could be used for each logical channel to define direction of channel.

1.2 Physical channel configuration

Physical channels of 3G CDMA MAC are defined as follows.

DCCH (Dedicated Control Channel) is the dedicatedly allocated control channel for each mobile station. DTX mode is used in DCCH, and DTX mode uses wireless resource only if traffic should be exchanged. Also, multiple mobile stations could share one DCCH without contention by using orthogonal long code for each dsch/dmch. CCH (Common Control Channel) is commonly used by multiple mobile stations, and shared by using time - multiplexed scheme. Also, CCH is mapped to cmch. FCH (Fundamental Channel) is inherited from Fundamental Channel of conventional IS 95 system. Thus, backward compatibility with IS 95 is provided, and advanced high-speed service could be supported. Both traffic and signaling information could be exchanged by using FCH like IS 95. SCH (Supplemental Channel) is inherited from Supplemental Channel of IS 95. Mainly, packet traffic is carried via SCH. Then, SCH is dynamically allocated and released by using dmch control scheme, and variable rate property is provided.

2. State Transition of cdmaOne's 3G CDMA MAC

State transition and channel allocation scheme of cdmaOne's 3G CDMA MAC are described in Fig 1. As depicted in Fig 1, MAC has many states. Then, timer operations or protocol primitives trigger state transition. Also, proposed MAC protocol could support interactive packet data services such as world wide web, and delay bounded services such as packet voice service. Thus, state transition parameters should be customized according to service requirements.

Before MAC establishes call connection, MAC is in Null state. In Null state, no connection and no MAC related information are maintained. As packet service is requested and call negotiation starts, MAC enters into Initialization state. Common channels carry call negotiation information. After call negotiation and establishment procedures are done, MAC enters into Control-Hold state. In this case, dsch and dmch is dedicatedly allocated to mobile station. If mobile station or base station has packet traffic to transmit, dtx is allocated by using dmch. Then, MAC enters into Active state. Thus, packet traffic could be exchanged. When packet traffic is not exchanged for more than T_active timer duration, MAC enters into Suspended state and releases dedicated control channels such as dsch and dmch. In Suspended state, control information and traffic are exchanged via common channels like cmch and ctc. If there is no traffic exchange more than T_suspend timer duration, MAC enters into Dormant state and releases call related information at 1 and 2 layer protocol. In this case, only PPP (Point to Point Protocol) related information is maintained by IWF (Inter-Working Function) at network level as a management plane information. When packet traffic arises at Dormant state, MAC enters into Reconnect state. In this case, most procedures are the same as call establishment phase except PPP negotiation is not required.

<Fig 1> State Transition of cdmaOne's 3G CDMA MAC

3. Sleep-mode Operation

Sleep-mode provides power save effect for mobile station and base station. Also, fast control mechanism could be supported for real-time multimedia services and high-speed packet data service. Sleep-mode is only used when a MAC is in Control-Hold state. When Sleep-mode is used, based on request of either base station or mobile station, reverse pilot channel comes to ‘off’. If reverse pilot channel is ‘off’, power control bit of forward link becomes ‘off’, and all reverse physical channels are released. In this case, only logical link information is maintained. Especially, when a MAC triggers Sleep-mode, forward physical control channel remains as ‘on’ state to detect control message from base station at the mobile station.
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If mobile station has data to send, it powers on reverse pilot channel. When a base station detects power on of reverse pilot channel, it transmits acknowledgement message to mobile station and activates forward physical channels according to power control information from mobile station. Merit of Sleep-mode is that fast service control and MAC control mechanism could be supported. These functions are due to the fact that mobile station keeps dedicated control channel during Sleep-mode. Thus, additional delay for allocation procedure as in Suspended and Dormant state is not required. Also, power save effect is provided [4].

III. Simulation Results and Discussion

In this section, system modeling of proposed 3G CDMA MAC, traffic modeling and MAC parameter configuration are considered.

1. System Modeling

To evaluate the performance of 3G CDMA MAC protocol, some assumptions are used. CRC and Tail-bits are considered as physical channel overhead in wireless link. Also, FIFO (First In First Out) based packet transmission scheduler is considered in base station, and forward link performance is only considered. If we consider reverse channel performance, the same results could be obtained due to similar channel request and allocation mechanism for both reverse and forward link. Different configuration could be supported in real world. According to wireless channel of cdma2000, one 307.2 Kbps channel is considered. Packet Traffic Channel carries fixed 20ms size message, and out-band signaling mechanism is considered. Thus, signaling information is transmitted via physically different dedicated signaling channel. 1% FER (Frame Error Ratio) is assumed for both traffic and signaling link. RLP is considered and selective retransmission mechanism of RLP is used. According to FER, error detection and immediate retransmission is considered. Also, processing and transmission delay is considered for error recover procedure. Error detection time at transmitter for transmitted packet traffic is assumed to be 400ms. Then, when packet traffic arrives and a destination mobile station receives traffic from base station via dedicated traffic channel at that time, arrived traffic could be transmitted via currently allocated channel without additional traffic channel request and allocation procedures.

According to performance evaluation measures, throughput is defined as the ratio of serviced packets over requested packets. Mean packet delay is defined as the mean delay from the arrival of packet to the end of successful transmission. Packet blocking ratio is defined as the ratio of dropped packets over requested packets. Signaling information ratio is defined as the ratio of signaling information over total signaling channel capacity. Scheduler is designed based on FIFO algorithm, and exists in base station. Especially, scheduler allocates efficiently buffer to maximize the utilization of wireless resource and minimize the packet transmission delay. Corrupted frame is moved to the end of transmission buffer for fairness. We ignore scheduling processing time in performance evaluation.

2. WWW Service Modeling

As an input traffic model, empirical WWW (World Wide Web) traffic model is used. Thus, input traffic is generated by using CDF of empirical model. According to [6], 90% of WWW page is 1 Kbyte~10 Kbyte size.

3. MAC Parameters Configuration

Number of users is assumed to be 30, and packet blocking boundary is assumed to be 30 sec. Also, T_active is 6 sec, T_hold is 4 sec, T_sleep and T_hold is confInt as 4 sec, and T_suspend is 60 sec. As a required time for state transition, 40ms is considered as the transition time from Suspended state to Control-Hold state. Also, 120ms is considered as the transition time from Dormant state to Control-Hold state. State transition time is calculated based on required message number, message size and message processing time. Moreover, 10ms is considered for transition from Sleep-mode to Normal-mode.

4. Performance Evaluation and Results Analysis

Performance is evaluated by using computer simulation. Then, performance is evaluated for Sleep-mode based environments and non Sleep-mode based environments.

Throughput characteristics are depicted in Fig 2. If 307.2 Kbps is assumed as a wireless channel bandwidth, throughput meets 0.8 at 1.0 traffic density. Performance degradation of 0.2 is due to the internal fragmentation of fixed size message and overhead fields. Thus, when cdma2000 be comes to be realized in real world, intelligent scheduler is required to calculate the efficient channel speed for arrived packet traffic to minimize the internal fragment and overhead. On the other hand, two results for sleep mode and non-sleep mode show the same throughput. This shows that Sleep-mode does not degrade to throughput result.

Delay performance is depicted in Fig 3. Similar to throughput result, delay abruptly increases as traffic density increases. This is due to the fact that internal fragment and overhead degrades the performance at high traffic density environments. Especially, if Sleep-mode is
used, delay is smaller than non-Sleep-mode mechanism. The reason is that Sleep-mode keeps dedicated control channel, and dedicated traffic channel could be allocated in short time. In non-sleep mode operation, when traffic density is low, inter-arrival time between traffic is large and state transition to suspended state and dormant state is frequent than high traffic density status. Thus, more large state transition delay is required for low traffic density environments for non-sleep mode operation. However, non Sleep-mode requires state transition from Control-Hold state to Suspended State and requires more time to acquire dedicated control channel and dedicated traffic.

Blocking performance result is depicted in Fig 4. Similar to throughput result, blocking ratio abruptly increases at high traffic density, and proposed MAC shows very little blocking ratio at low traffic density.

![Fig 4] Blocking Performance Result

![Fig 5] Signaling Information Ratio VS. traffic density

Signaling information ratio over DCCH during unit time is depicted in Fig 5. If Sleep-mode is not used, state transition from Control-Hold state to Suspended state, as well as state transition from Suspended state to Dormant state is more frequently required. Thus, more control messages are exchanged for transition to Active state. Also, in this case, 20ms-size messages are used for Suspended state and Dormant state. Thus, non sleep mode based operation carries more signaling information than Sleep-mode based operation.

If we consider the signaling information ratio to circuit-mode mechanism, required signaling information ratio of proposed MAC is about 1% degree. Thus, signaling overhead of proposed MAC is not so large, and does not degrade the channel utilization.
IV. Conclusions

In this paper, we proposed new 3G CDMA MAC for CDMA based IMT2000. Then, proposed MAC could support high-speed packet data service and provide backward compatibility to conventional IS95 system. Also, we evaluated the performance of proposed MAC and analyzed the results.

Proposed 3G CDMA MAC could be used in both conventional IS95 system configuration environments and future IMT2000 system environments. Moreover, proposed MAC could provide smooth evolution phase based on low cost and short time from conventional second-generation system to IMT2000. Especially, DTX mode of proposed MAC does not degrade the wireless channel utilization, and dedicated control mechanism could support fast control mechanism. Also, dedicated control mechanism could provide efficient channel allocation and release method. Thus, wireless channel utilization is maximized. Also, 5ms-size message structure enables fast MAC control and fast signaling information exchange. For these reasons, proposed MAC could support efficiently the multimedia services with QoS constraints. Moreover, Sleep-mode could reduce the transition delay as well as the power consumption.

According to simulation results, proposed MAC requires very little signaling information for MAC control compared with circuit mode service architecture. Also, performance for high-speed packet data service such as WWW is efficient at high density.

Currently, proposed MAC is partially approved by cdmaOne, and submitted to ITU-R as an IMT2000 RTT Candidate. In near future, packetized multimedia services will be studied based on 3G CDMA MAC protocol[10].

References


