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The Forwarding Channel of a BTS in IS-95 CDMA Cellular Network

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Abstract : The design of LAI(Local Area Identifier), the first paging area for searching the mobile terminal has a close relation with the performance of paging channel in CDMA cellular network. This paper discusses the performance of the forward channel of IS-95 CDMA standard, known as the paging through the related messages such as call control message, channel assignment message. Modeling and simulation work were conducted to quantify the performance of paging channel in terms of traffic handling capacity and blocking levels. This result serves as illustrative guidelines for the proper engineering of common control channel, which has a major impact on the overall performance of cellular network.

I. Introduction

The forward and reverse control channels have an important role of system performance in a mobile communication network. Base station periodically sends the information including itself and is in charge of call control functions such as the set-up of terminating call, the access of originating call and location registration through paging channel[1][2]. Continuing technical development have led to the diverse emergence of a whole new set of communications service such as short message service, over the air functions(OTAF), voice message indication, access authentication, etc. Despite of these functional expansion, an important concept in designing mobile communication is to improve utilization of common control channel while keeping the existing service quality.

The first paging area to seek mobile according to terminating call is called LAI(Local Area Indicator). Therefore, LAI means a community consisting of one or several base stations. In operating the mobile communication service, formation of LAI greatly affects the load of whole system. If unit LAI consists of a base station, paging failure can occur frequently and the effect of location registration can decrease although paging channel has low load. If LAI includes all base stations in a MSC(Mobile Switching Center), the success rate of first paging is high but the processing load can be serious. Therefore, the service quality of paging channel can be dependent upon the structure of LAI and service types using paging channel. It is very meaningful to diagnose the capacity of current control channel under IS-95 CDMA cellular network to analyze new service and factors of traffic fluctuations. As the number of CDMA subscribers currently increases, the study on this field has been actively advanced through simulation and theoretical analysis[3][4][6].

This paper provides standard for the engineering capacity of LAI to meet call quality in one MSC by analyzing paging channel so that it would be reference for cell planning according to base station disposition. The constitution of this paper is as follows. Chapter 2 describes the structure and operating principle of paging channel and introduces the related messages, based on IS-95 CDMA network. Chapter 3 introduces protocols relate to paging channel and Chapter 4 leads modeling procedure for capacity analysis and produces channel capacity using parameter based on statistics of field operation, and chapter 5 draws conclusion.

2. The constitution and functions of Paging Channel on IS-95

Base station have from minimum 1 to maximum 7 paging channels per cell(FA/Sector). When turning on mobile or moving into the contiguous cell with non-traffic mode, the mobile in slotted mode receives the information of base station over overhead information message through paging channel. Then, CDMA Channel, paging channel and paging slot is determined by using MIN (Mobile Identification Number) and hash function, the mobile receives messages from paging channel. Until the mobile in slotted mode decides a paging slot , the mobile receives messages from all slots. With a paging slot decided, mobile checks paging channel in only the allocated slot and examines whether it is itself or not.

As indicated in Figure 1, paging channel consists of 80 ms slots and has maximum 2048 slots. 80 ms slot consists of 20 ms Paging Channel Frames and each Paging Channel Frame consists of 10ms Paging Channel Half Frames. The first bit of each Half Frame is Synchronized Capsule Indicator (SCI). Paging Channel Message Capsule consists of message and padding, and a message consists of length(8bits), message body and CRC(30bits) [1]. If Half Frame has less than 8 bits at the completion of the transmission of message, transmitting of new message at next Half Frame is started with 0 filled and SCI set to 1.

2.1 Overhead Information Message

Base station needs to broadcast the information including itself through Overhead Message per 1.28 second which is required by mobile. Overhead Message types and its contents for transmitting are as indicated in table 1. The size of message include 8bit field and CRC(30bits) field and hypothesis to have reference size is required because it supports variable size.

Each Overhead Message is distributed all over whole slots and all message should be sent through paging channel more than 1 time for 1.28 sec. Mobile moving into new base station searches all paging slots and receives Overhead Message for 1.28 sec and obtains new base station information in order to

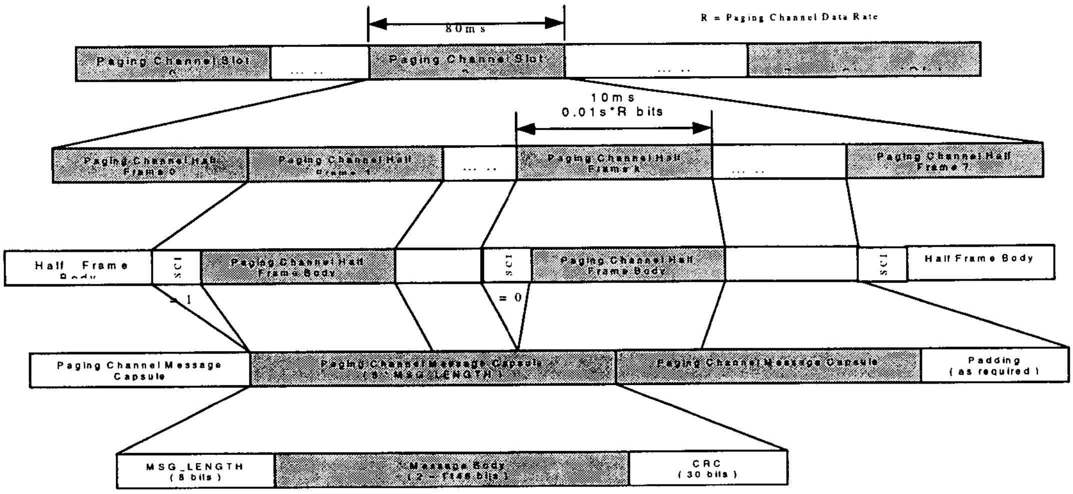

Fig. 1. The structure of paging channel in IS-95

be ready for communication with new base station

Table 1. Overhead Messages for Paging Channel

Message Type	Length	Assumption
System Parameters Message	260	
Access Parameters Message	152	No Authentication
CDMA Channel List Message	310	20 Neighbors
Neighbor List Message	110	4 CDMA channel
Extended System Parameter Message	104	Reserved length=1

2.2 Mobile Station Directed Message

Base station sends a message over any paging slot when mobile is non-slotted mode. Given Slot Cycle Index under Slotted Mode, it transmit message through the specified Paging Channel Slot[1]. The length of message includes 8bits field and CRC field(30bits),and is like table 2 according to hypothesis for variable length. By hypothesis, message of which the quantity of traffic is little enough to be ignored and non-functional message are excluded on analysis.

Table 2. Mobile Station Directed Message from Paging Channel

Message Types	Length	Assumption
Slotted Page Message	181	
Page Message		Ignored
Order Message	104	
Channel Assignment Message	119	
Data Burst Message	432	
Authentication Challenge		Ignored
SSD Update Message		Ignored
Feature Notification Message		Ignored
Null Message		Ignored

3. Call processing message flow

In the state that traffic channel between mobile and base station is not set up, they communicate on Access Channel and Paging Channel. In Figure 2, base station sends Slotted Page Message

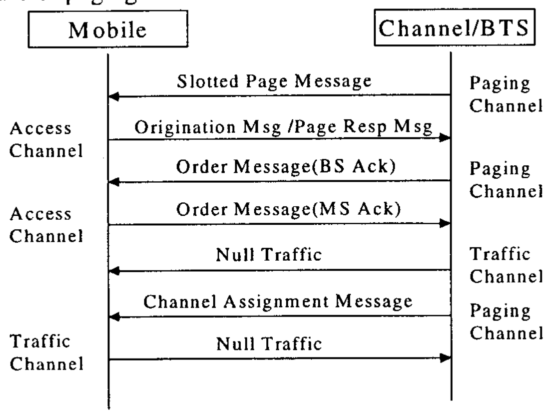

Fig. 2. Call flow for the paging channel of terminating call and the originating call

to mobile through paging channel to set up connection in case of the terminating call. if the MIN in Slotted Page Message received from base station is the same as the MIN of mobile, the mobile responds Page Response Message on access channel. In case of originating call, mobile requests call set-up to base station by sending Origination Message through access channel. Mobile which is going to send Page Response Message or Origination Message, is changed into non-slotted mode until a traffic channel is opened.

Base station which receives a response of paging or request of call set-up from mobile, notifies the correspondent mobile message acceptance by sending Order Message through paging channel. Just after receiving Order Message, the mobile stops sending request of call set-up and page response, and responds to the base station by sending Order Message. Base station send page message all over the sectors but Order Message on only the specific sector because the mobile was known to be located. Base station transmits Channel Assignment Message through paging channel to notify information of the allocated channel, after following transmission of Null Traffic on the allocated traffic channel. When mobile receives information on the allocated traffic channel ,it communicates with base station by sending Null Traffic on the traffic channel. Control messages after setting up traffic channel are transmitted over the traffic channel.

Mobile request location registration through access channel and checks paging channel in non-slotted Mode in Figure 3. Base

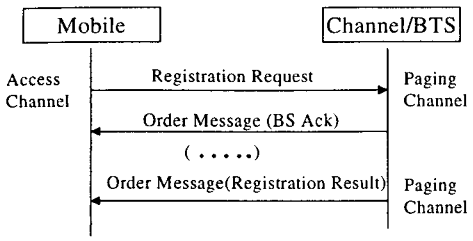

Fig. 3. Call flow for location registration

station notifies the mobile that it received a message of location registration by sending Order Message through paging channel and sends the message of location registration to VLR/HLR at the same time. The mobile which receives Order Message is changed into Slotted Mode and checks paging channel to receive message. The notification of location registration to VLR/HLR is completed by sending Order Message through the specific slot of paging channel which is decided by MIN of mobile.

4. Modeling and analysis of capacity

4.1 Traffic of paging message in LAI

Let LAI(Local Area Identifier) be indicator of the first paging area and derive the capacity of a LAI by using the call processing capacity of paging channel. A MSC can cover many calls which are generated in some LAIs. It is assumed that second paging includes the area covered by a MSC and paging is successfully processed.

Now, define BHCA which occurs in MSC, LAI i and the base station which belong s to LAI i, R, λ_i and λ_{ij} respectively. Let N and N_i be the number of LAIs and the number of base stations which belong to LAI i. Then, the following relation is given by,

$$R = \sum_{i=1}^{N} \lambda_i = \sum_{i=1}^{N} \sum_{j=1}^{N_i} \lambda_{ij} \tag{1}$$

Suppose that the portion of terminating call in LAI i is p_i^t and the first paging successfully ends with the probability p_i^1. Let F_{ij} be the number of FA(Frequency Assignment) of base station j in a LAI i. Then the number of paging messages Λ_{ij}^p which occurs in a paging channel can be derived as

$$\Lambda_{ij}^p = (\lambda_i p_i^t + \sum_{k=1}^{N} \lambda_k p_k^t (1 - p_k^1)) \frac{1}{F_{ij}} \tag{2}$$

As mentioned above, Order Message is used for location registration and originating/terminating call and is sent to the specific mobile over the specific FA and the sector. Let l and r be the number of order messages of location registration and the accessed call, respectively. Suppose that the number of location registration per the accessed call is c and the number of sectors of base station j in LAI i is S_{ij}. Then , the number of order messages Λ_{ij}^o which occurs in paging channel of base station j in LAI i is as follows,

$$\Lambda_{ij}^o = \frac{\lambda_{ij}}{F_{ij} S_{ij}} (r + lc) \tag{3}$$

As likely, suppose that the number of channel assignment messages is given by m. Then the number of messages in paging channel of base station j in a LAI i, Λ_{ij}^c is as follows,

$$\Lambda_{ij}^c = \frac{\lambda_{ij}}{F_{ij} S_{ij}} m \tag{4}$$

It is assumed that Data Burst Message used in SMS(Short Message Service) is the same processed as paging message and its first paging includes the area which a MSC covers. Suppose that the portion of SMS message per terminating call is a, the portion of the terminating calls out of the total call in an MSC is p^t and the portion of the first successful paging is p^1. Then the number of messages including SMS and Data Burst messages in an paging channel with the base station j in an LAI i can be given by

$$\Lambda_{ij}^d = R p^t a (2 - p^1) \frac{1}{F_{ij}} \tag{5}$$

When supposing that an occurring frequency of other messages mentioned before is low and can be ignored because of the related functions not being implemented, the number of whole messages an hour which occur in an paging channel of base station j based on LAI i, Λ_{ij} is derived as follows.

$$\Lambda_{ij} = \Lambda_{ij}^p + \Lambda_{ij}^o + \Lambda_{ij}^c + \Lambda_{ij}^d \tag{6}$$

4.2 Queuing Modeling

As all slots of paging channel are operated under the same environment, let us analyze the processing capacity with transmission capacity and buffer size in an arbitrary slot. If paging channel can be modeling into queuing system, one server by slot_cycle_index exists and each slot has buffer. Although server stays for 80 ms at each slot and sends messages according to the order of priority, FIFO(First In First Out) is supposed for service discipline. Now say that message arrives to the paging channel according to a Poisson process with the rate $\lambda = \Lambda_{ij}$ regardless of the specific base station and LAI. Let l_{ref} be the length of reference message that is necessary to get the average time of message processing. Given that length of Page Message, Order Message, Channel Assignment Message and Data Burst Message is l_p, l_o, l_c and l_p and the weight of each message is given into w_p, w_o, w_c and w_p, respectively, the length of reference message l_{ref} can be given by

$$l_{ref} = \frac{l_p w_p + l_o w_o + l_c w_c + l_d w_d}{w_p + w_o + w_c + w_d} \tag{7}$$

It can be inferred that $w_p = p^t(2 - p^1)$, $w_o = r + lc$, $w_c = m$ and $w_d = ap^t$ because the weight value for each message is proportional to the number of frequency of call occurrence. Observing one arbitrary slot, the transmission speed of server is inversely proportional to the number of slots, N_{slot}. The processing time of overhead message should be deducted for effective transmission speed. It is sent in period of maximum 1.28 sec so that it has 16 periods slots of 80 ms. It is assumed that Overhead Message is uniformly distributed and more than 2 Overhead Messages are not transmitted in one slot. Consider that the number of Overhead Message is N_{ov} and the length of Overhead Message i is l_i^{ov}. Let C_p be the transmission speed except SCI. Then the transmission speed of message except SCI and Overhead Messages, C_m is as follows.

$$C_m = C_p - \sum_i^{N_{ov}} \frac{l_i^{ov}}{1.28} \quad (8)$$

We get overhead message distributed uniformly because otherwise the call success rate of the mobile station via the specific slot can be low. Therefore, it can be supposed that the service time of server has exponential distribution with the service rate $\mu = {l_{ref} N_{slot}}/{C_m}$. If buffer size of each slot is N, the structure of paging channel can be modeled into $M/M/1/N$ queuing system as depicted in Figure 4,

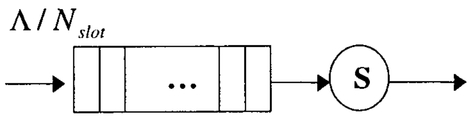

Fig 4. Queuing Model of Paging Channel

4.3 Numerical Analysis

For the effective analysis, system parameters in Table 3 are assumed based on the field data of site survey unless otherwise specified.

Table 3. Traffic environment for call generation

System Parameter	Value
Terminating call	$p^t = p_i^t$ =0.46
First Paging	$p^1 = p_i^1$ =0.85
SMS Rate	A=0.01/Ter. call
Local Registration	c =2/call
Channel Assignment	m =1.03/call
Order Message	l =2/LR, r =1/call
Fas/sector	F_{ij} =1, S_{ij} =1
Call Holding Time	60 sec.
Traffic Channels	20/sector
Channel QoS	P_{bl} =0.01
MSC Capacity	R =500,000 BHCA

Figure 5 shows the relation between pagings in an hour and BHCA of LAI as response rates of the first paging varies with 0.8, 0.85 and 0.9. the frequency of paging increase in case that response rate of the first paging decreases. Based on Table 3, the rate of arriving message can be derived as in Table 4 according to the traffic density of LAI by using the equations (1)-(8). Let's l_{ref} be equal to the length of Data Burst Message so that the service time of message might be uniform. Then, the result in Table 4 can be calculated by using table 3 and the equation (8). And, parameters of paging slot are assumed, transmission capacity 9600 bps, C_p =9500 bps, N_{buff} =10, N_{ov} =6 and N_{slot} =32. Then, figure 6 shows blocking probability of paging channel according to the call attempts. This figure means it processes LAI of up to 350,000 BHCA and Engineered Capacity of paging channel is about 300,000 BHCA under blocking Probability 0.01,. A paging message can normally carry information on several call attempts at one time and BHCA processed by paging message can more increase. For paging channel of 9600 bps, There is no need for limiting maximum capacity of LAI. For reference, figure 7 shows an incensement of number of paging messages and a change of Blocking Probability under supposition that one paging message transmits information of 4 call attempts. When the load of traffic is heavy, a reasonable capacity is to process 300,000 paging messages with slight difference, which is based on 1% blocking Probability. Thus, when the capacity of base station by table 3 is standard, maximum 130 base stations could be tied in one LAI. But if it is consisted by BSC which has 100,000 BHCA, the base stations belonging to maximum 3 BSC's are constructed in one LAI, which is better solution.

5. Conclusion

Call processing capacity of paging channel is largely affected by the size of LAI which means the area of first paging. The success rate of paging increase in spite of deterioration of processing load of paging as LAI becomes to be large. The CDMA network can be designed so that processing capacity of LAI can accommodate that of from a base station to MSC. We analyzed call blocking probability of paging channel as given the capacity of the accessed call in an LAI by using some messages processed in paging channel based on CDMA IS-95A. In case of one call-to one paging message, we can recommend the proper capacity of LAI 300,000 BHCA which can be handled by paging channel. It can be inferred that more than one call per paging message exceed too much the maximum capacity of MSC, 500,000 BHCA.

LAI structure through the quantity of paging message occurrence has a set of base stations, which is based on the capacity of base station supposed above. As paging message is distributed on each FA, the base station with smaller FAs should process more paging messages in case that the number of FAs of base station is not uniform in an LAI. Therefore, the number of FA of base station can be considered in a more detail in deciding the capacity of LAI.

Table 4. The number of messages per sector/FA in paging channel

λ_i	50000	100000	15000	200000	250000	300000	350000	400000
Slotted Page	57500	80500	103500	126500	149500	172500	195500	218500
Order Message	3600	3600	3600	3600	3600	3600	3600	3600
Channel Assig. Message	742	742	742	742	742	742	742	742
Data Burst Message	2645	2645	2645	2645	2645	2645	2645	2645
λ_{ij}	64487	87487	110487	133487	156487	179487	202487	225487
λ (/sec/slot)	0.56	0.76	0.96	1.16	1.36	1.56	1.76	1.96

[Reference]

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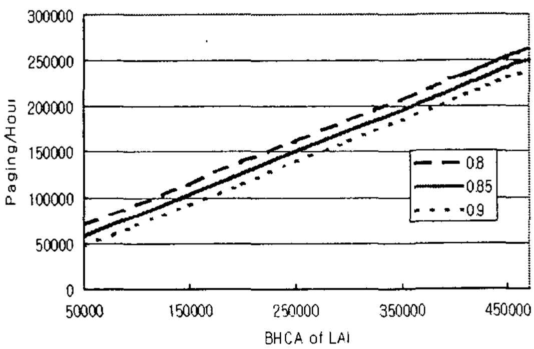

Fig. 5. The number of pagings with the 1st response rate

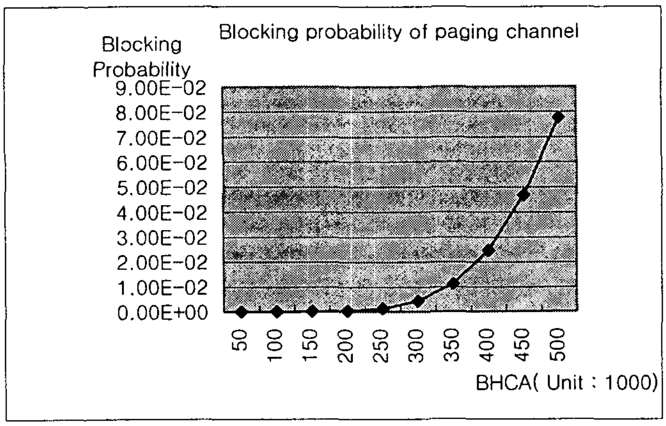

Fig 6. Blocking probability of paging channel

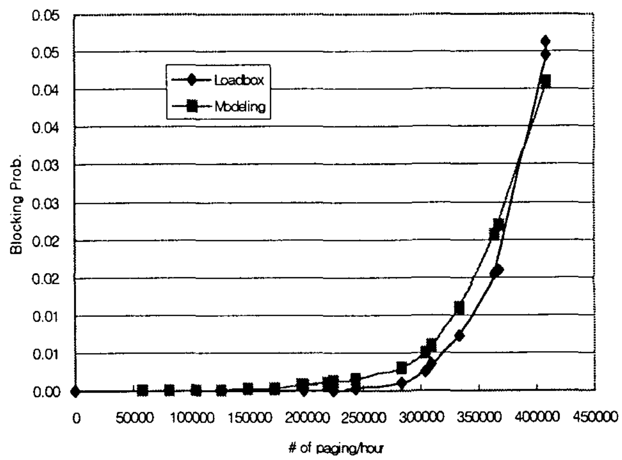

Fig. 7. Blocking Probability in the paging message processing