Performance Analysis of FCL(Frequently Called List) Table Sizes in a Circuit-Switched Network including Wireless Subscribers

ABSTRACT

In this paper, we study optimal FCL(Frequently Called List) table sizes in a grid topology circuit-switched network including wireless subscribers. The FCL table gives the position information of a destination subscriber for a call. When the call is generated in a node, this call is routed by the referenced position information of the destination subscriber in the FCL table. We propose an efficient routing algorithm, mixed FSR(Flood Search Routing) and DAR(Dynamic Adaptive Routing), considering moving wireless subscribers. Also we simulate hit ratio and incorrect ratio as performance parameters, consequently propose an objective function composed of table search time, hit ratio, incorrect ratio, FSR time, and DAR time, and derive the optimal FCL table size by using it.

I. Introduction

In this paper, we analyze optimal FCL(Frequently Called List) table sizes in a grid topology circuit-switched network including wireless subscribers. In these days, advances in wireless communication technologies lead cable networks to evolve into future networks including wireless subscribers, such as PCN's(Personal Communication Networks)[1],[2]. As a number of wireless subscribers is increased, it is more difficult to identify positions of mobile subscribers. Therefore, it is obvious that existing routing algorithms are no longer economically justified to effectively deal with uncertain positions of wireless subscribers. So we propose a new routing algorithm using FCL table, FSR(Flood Search Routing) and DAR(Dynamic Adaptive Routing) methods [3-5], and analyze optimal FCL table sizes in the grid topology circuit-switched network model. In case of this new routing algorithm, the FSR is used to search

the position of mobile subscribers, but redundant packets in FSR cause to increase network traffic. Using the FCL table is to complement these kinds of defects. The DAR algorithm used to determine a route for frequent calls.

We consider the grid topology circuit-switched network model, which uses common channel signaling for control signaling method. we assume that this network consists of 35 nodes and each node includes 200 subscribers. In case of this model, we evaluate hit ratio and incorrect ratio as network performance factor for various FCL table sizes, the number of mobile subscriber and moving rate for mobile subscribers. And then, we propose an objective function composed of table lookup time, hit ratio, incorrect ratio, FSR time and DAR time, and analyze optimal FCL table sizes with it.

In Section Ⅱ, we describe network model in detail, and performance parameters for this network in Section Ⅲ. We analyze optimal FCL table sizes in Section Ⅳ, and conclude in Section Ⅴ.

II. Network Model

1. Grid Topology Circuit-Switched Network Model

The grid topology circuit-switched network has high reliability and efficiency, so it is one of the network models which are widely used in telecommunication systems, such as Manhattan Street Network, and military networks. In a topology comparison view, the grid topology circuit-switched network can achieve high throughput and reliability because of increased connectivity. This network is easy to add and delete nodes. Therefore this network will be able to adapted to future communication networks where need high reliability. The grid topology circuit-switched network considered in this paper is shown in Fig. 1

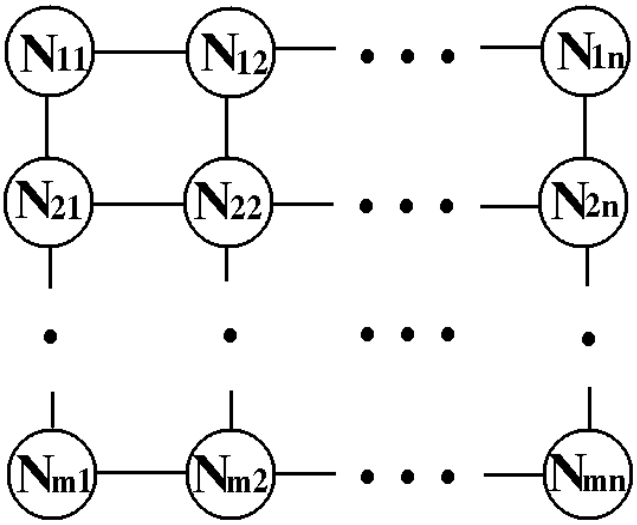


Fig. 1 m × n Network configuration

We assume that this network model use CCITT recommendation Q.700 Signaling System No. 7 (SS7), which is used in ISDN system, as control signaling method. SS7 protocol is optimized for using in digital telecommunication networks, designed to meet present and future information transfer requirements for call control, remote control, management, and maintenance. It provides a reliable means for the transfer of information in the correct sequence without loss or duplication [6-8].

2. Routing Algorithm

The routing algorithm, selecting an outgoing link, is required to determine a best available path from source node to destination one during the operation of network. The routing is a principal function of network layer in the reference model of OSI(Open System Interconnection) and it must provide correctness, optimality, reliability, simplicity, and fairness [9]. There are a number of ways to classify routing algorithms. One way is to divide them into non-adaptive routing algorithms and adaptive ones. In case of non-adaptive routing algorithm, the paths are pre-determined and fixed regardless of traffic or network conditions. It is recommended for either very simple networks or for networks where efficiency is not essential. While in the adaptive routing algorithm, the

paths can change occasionally in response to network topology and traffic loads.

The FSR(Flood Search Routing) algorithm is one of the non-adaptive protocols, and it retransmits the incoming call to the neighbors except the one which has transmitted the call. One of the paths in the FSR must be a shortest path, since all parallel paths are used. It has an minimum delay in low traffic and find a path at least, if an available path exists. In the contrast of these advantages, it produces redundant calls by retransmitting the incoming call to the all adjacent nodes. During operation of a network, it often changes network topology, status of nodes or links, and traffic loads. The DAR(Dynamic Adaptive Routing) algorithm, one of the adaptive protocol, guarantees minimum delay by changing paths in response to the states of networks. The DAR is adaptive to the change of traffic, the operation status of node or links and topology, and it is an efficient algorithm in a sense that routing is flexible to times or network states.

We propose new routing algorithm, which is basically a hybrid of FSR and DAR scheme. In the other research for FSR and DAR scheme, the FSR shows better delay characteristics than the DAR at low traffic, while the DAR shows better performance than the FSR as increasing traffic load [10]. We use the DAR scheme for routing the call and use the FSR scheme for searching the position of mobile subscribers. If only the FSR scheme is used in the grid topology circuit-switched network, link capacity must be increased because a call setup time is increased by redundant packets under high traffic conditions. In the other hands, if only the DAR scheme is used in this networks, it is necessary to have other algorithm for searching the position of the mobile subscriber. Therefore, we use the merit of two schemes in considering the traffic load and wireless subscribers. Even if this new algorithm is somewhat complex, this new scheme distributes traffic in whole network, and provides service for wireless subscribers. The call setup process in proposed routing algorithm is as follow. At first, each node looks up position information of a destination subscriber in its FCL table, when the call is generated in the node. If position information of the destination subscriber is recorded in the FCL table, this call

is routed to the destination node by the DAR algorithm. Otherwise this call is routed by the FSR algorithm. If position information for destination subscriber is found by FSR, this new information is inserted in the FCL table for the next retrieval. Since the number of wireless subscriber will be increased in the future networks, position information of these subscribers is updated frequently. When the wireless subscriber moves to another coverage area, new position information of this subscriber can be searched by the FSR algorithm, and incorrect position information of the FCL table should be updated with it. So FSR algorithm is necessary to the future networks. Fig. 2 shows the flowchart of proposed new routing algorithm.

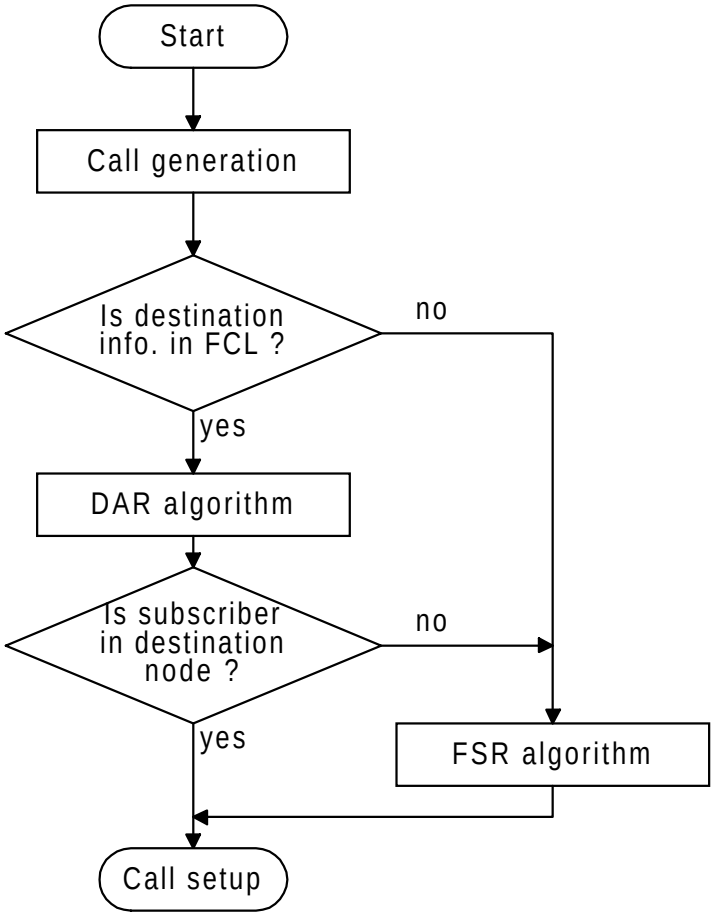


Fig. 2 Flowchart of the proposed routing algorithm

III. FCL Table and Performance Parameters

1. FCL Table

The FCL tables have position information of the destination node which includes the destination subscriber. The routing paths are determined by the DAR scheme referencing information in the FCL table, if same source-destination pair call is generated. The FCL table is composed of source node address, destination node address, subscriber ID, and call generation time. Fig. 3 shows entities of the FCL table.

SA	DA	Sub_ID	CGT

- SA : Source Node Address
- DA : Destination Node Address
- Sub_ID : Subscriber Identification
- CGT : Call Generation Time

Fig. 3 FCL table format

We assume that the FCL table size is fixed at 100, 200, 300, 400, or 500 and, is manipulated by FIFO(First In First Out). Information of the oldest call is updated by new position information of the call, because the FCL table size is fixed at constant length.

2. Hit ratio and Incorrect ratio

Hit ratio and incorrect ratio are important factors which determine the FCL table size. In order to evaluate optimal FCL table sizes, we simulate the future network model from two parameter points of view, such as hit ratio and incorrect ratio. Hit ratio means the ratio of finding calls in the FCL table to all referencing calls. Incorrectness means that a destination subscriber is absent in a destination node, when a call is routed by position information in the FCL table. i.e., incorrectness is occurred since the wireless subscriber has moved to

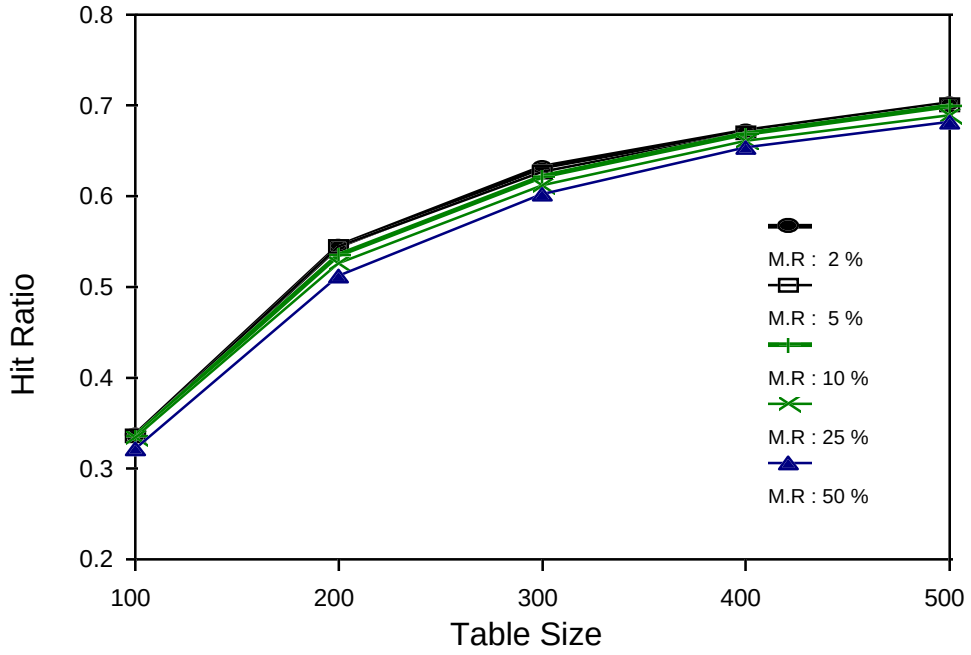
another coverage area. Incorrect ratio is the ratio of incorrect information to all recorded calls in the FCL table. We evaluate hit ratio and incorrect ratio, when the number of wireless subscribers, moving ratios, and FCL table sizes are varied. Moving ratio is the probability that wireless subscriber moves to another coverage area and time between each movement for a wireless subscriber is exponentially distributed.

We consider that a network configuration is a 5×7 grid topology circuit-switched network and each node is composed of 200 subscribers. We assume that wireless subscribers are included in 200 subscribers from 12.5 % to 75 % and moving ratio of wireless subscribers is ranged from 2 % to 50 %. In order to obtain the practical results, we use a predictive traffic load in 1995, referencing the voice traffic data of KT(Korea Telecommunication Inc.). We estimate call arrival rate based on the automatic telephone calls in 1992, using by Kalman-filtering method [11]. We assume that a call is generated with 0.6329 calls/hour in a subscriber and with 126.5896 calls/hour (0.6329 calls/hour $\times$ 200) in a node. Calls are generated by Poisson process and the call is force to have same destination node in the rate of 80 % to whole generated calls, because practical call generation is followed by this fashion. The node includes wireless subscribers and these subscriber can move to the other node in a random fashion.

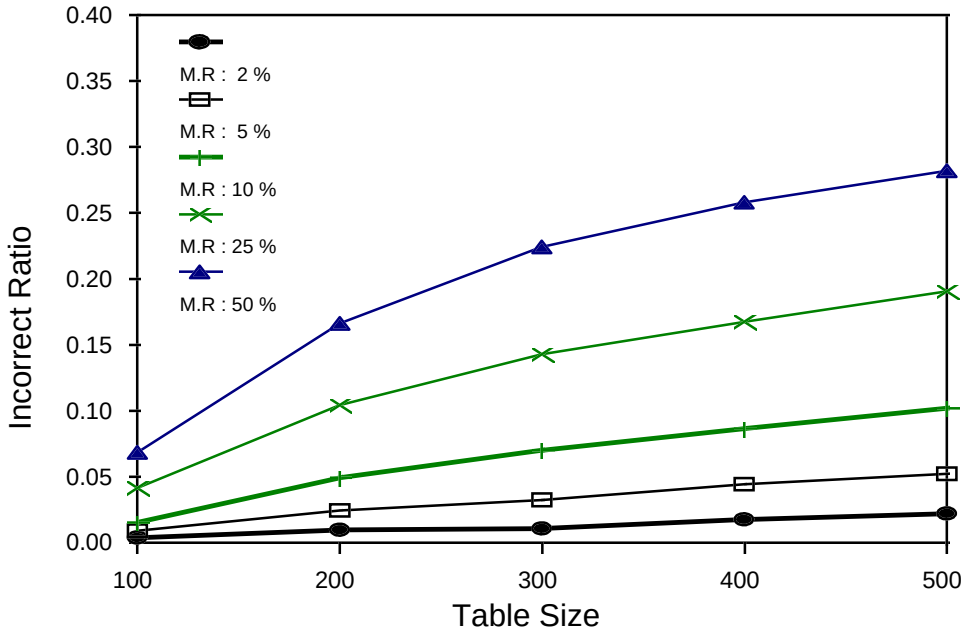
As results of simulation, hit ratio and incorrect ratio are increased according to the FCL table sizes in the range from 100 to 500. Hit ratio is not so much varied while incorrect ratio is increased, as the number of wireless subscribers or moving rate are increased. If the destination subscriber is absent in the destination node, when the call is routed by the position information in the FCL table, this call is return back to the source node and then searched by the FSR algorithm. The call setup time is maximized with FSR time + ($2\times$ DAR time), when a call is routed by incorrect position information

Hit ratio and incorrect ratio are shown in Fig. 4 when the node includes 50 % wireless subscribers(100 subscribers) of whole 200 subscribers. Note that MR is moving rate for wireless subscribers. Hit ratio curves in the FCL table are

very similar to each others. As expected, hit ratio is increased when the FCL table size is increased. In the case of incorrect ratio, as the FCL table sizes and moving rate are increased, incorrect ratio is increased. We can see incorrect ratio is affected seriously by moving rate of wireless subscribers. In Fig. 5, FCL table size is kept constant at 300 and number of wireless subscribers(W.User) and moving rate of wireless subscribers are allowed to vary. Hit ratio curves are asymtotically converged to constant value under varying moving rate conditions and are not affected by the number of wireless customers, while incorrect ratio is increased as the number of wireless subscribers and moving rates are increased. As shown in two graph, hit ratio and incorrect ratio are important factor to determine the FCL table size.

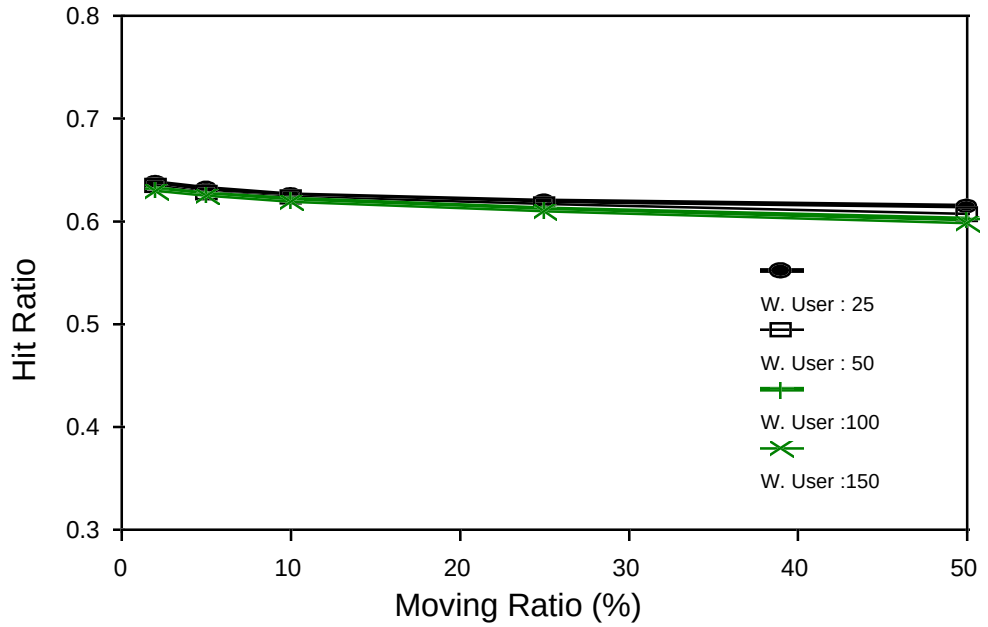


1) Hit Ratio

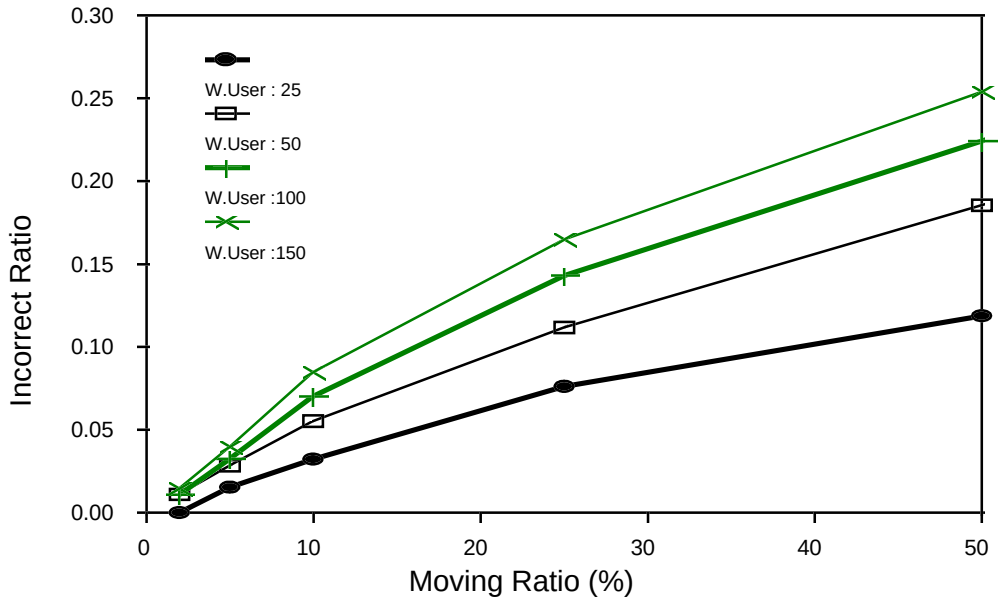


2) Incorrect Ratio

Fig. 4 Simulation results when the number of wireless user is fixed at 100



1) Hit Ratio



2) Incorrect ratio

Fig. 5 Simulation results when the table size is fixed at 300

IV. Optimal FCL Size Analysis

In the point of intuitive view, the call setup time may decrease as the FCL table size is increased. When the FCL table size is increased aboeve specific value, the call setup time is increased because table lookup time and incorrect ratio are also increased. This FCL table size determination problem must be considered with many complex factors, such as hit ratio, incorrect ratio, table lookup time, average FSR call setup time, and average DAR call setup time. In this paper, we derive the objective function to optimize FCL table size by considering above factors. The objective function $f(t)$ is shown in (1). Note that $f(t)$ means average call setup time.

$$\begin{aligned} f(t) &= (1 - P_{Incorr}) \times P_{Hit} \times (T_{look-up} + T_{DAR}) \\ &\quad + (1 - P_{Hit}) \times (T_{look-up} + T_{FSR}) \\ &\quad + P_{Incorr} \times P_{Hit} \times (T_{look-up} + 2 \cdot T_{DAR} + T_{FSR}) \end{aligned} \tag{1}$$

- P_{Hit} : Hit ratio
- T_{FSR} : Average FSR call setup time
- T_{DAR} : Average DAR call setup time
- P_{Incorr} : Incorrect ratio
- T_{lookup} : FCL table lookup time

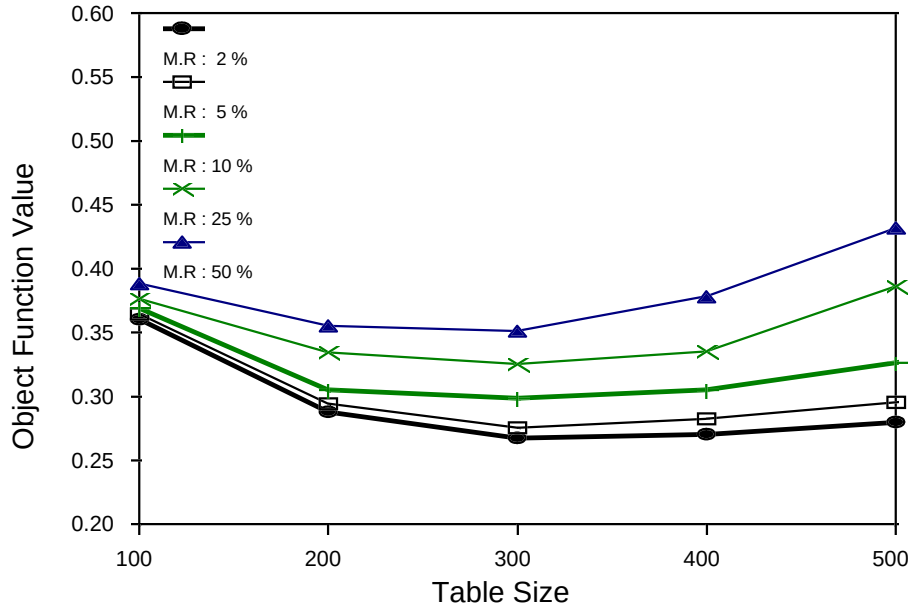
In (1), the first term { $(1 - P_{Incorr}) \times P_{Hit} \times (T_{lookup} + T_{DAR})$ } means the call setup time when the call is routed by the DAR scheme using position information in the FCL table, and then it find the destination subscriber. The second term { $(1 - P_{Hit}) \times (T_{lookup} + T_{FSR})$ } means that position information is not in the FCL table and the call is routed by the FSR scheme, and third term { $P_{Incorr} \times P_{Hit} \times (T_{lookup} + 2T_{DAR} + T_{FSR})$ } mean that the call is routed by the DAR scheme using position information in the FCL table, but destination subscriber is absent in the destination node, so this call is returned back to the source node and routed by FSR scheme again. Since these three cases are occurred independently, the call setup time is the sum of three terms. The table lookup time is assumed as Table 1 referencing a practical switching system. The average FSR time is assumed to 0.5 sec, and average DAR time is assumed to 0.3 sec due to results of previous paper[12], .

Table 1. FCL table loop-up time

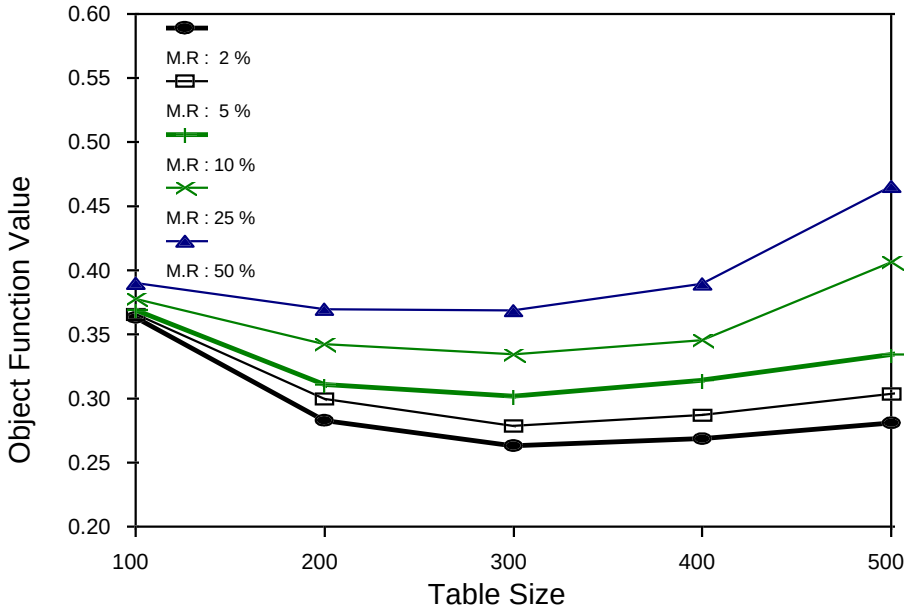
FCL Table Size	Table Look-up Time
100	3 msec
200	5 msec
300	7 msec
400	9 msec
500	11 msec

We analyze the optimal FCL table size by the objective function $f(t)$. Numerical results are shown in Fig.6 and Fig.7

In Fig. 6, the number of wireless subscribers is kept constant at 50 or 100 and moving rate of wireless subscribers varies from 2% to 50%. The objective function value is increased as the increase of moving rate of wireless subscribers. We remark that objective function values are not decreased when the table size is larger than 300. The call setup time is minimized when the FCL table sized is fixed at 300 in the 7×5 grid topology network, because incorrect ratio and table lookup time is increased as the increase of FCL table size. The objective function value is presented in Fig. 7, when moving rate of wireless subscriber is fixed at 5% or 10% and the number of wireless subscriber varies from 25 to 100. As expected, the objective function value is increased as the number of wireless subscriber is increased and shows the optimal point when FCL table size is fixed at 300. As result of analysis, We remark that the optimality of call setup times in the grid topology circuit- switched network is not always guaranteed though the FCL table size is increased.

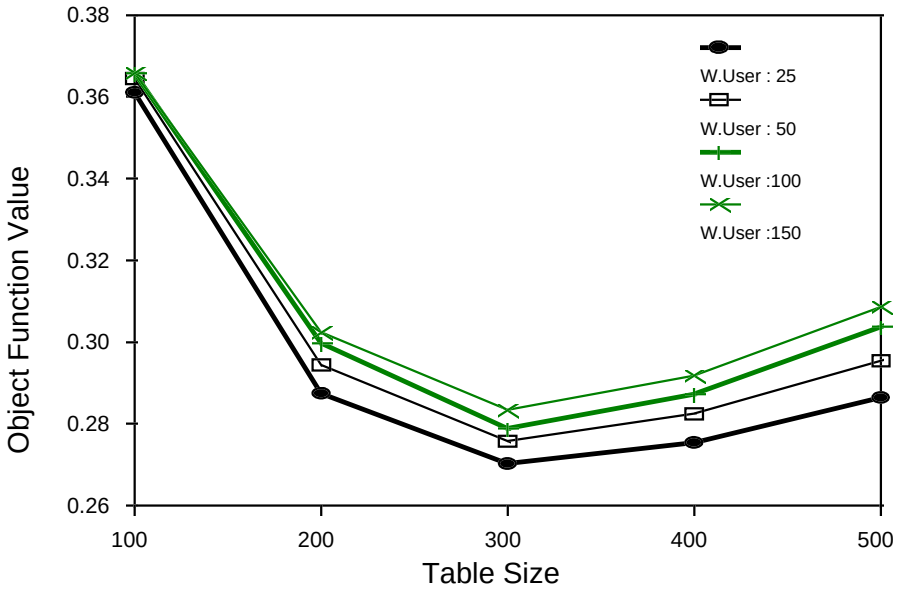


1) The number of wireless user is fixed at 50

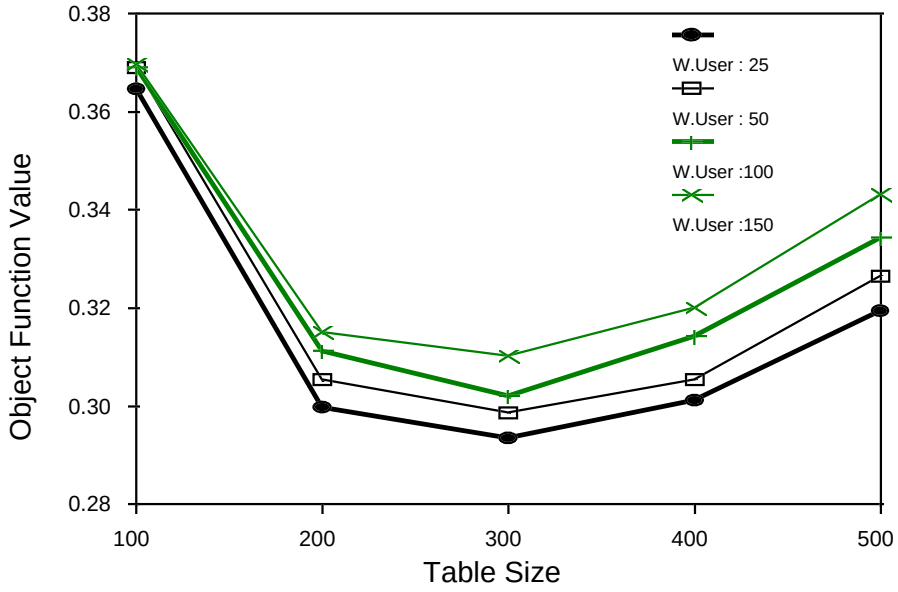


2) The number of wireless user is fixed at 100

Fig. 6 Objective function values when the number of wireless users is fixed at constant value



1) Moving ratio of wireless users is fixed at 5%



2) Moving ratio of wireless users is fixed at 10%

Fig. 7 Objective function values when the moving rate of wireless users is fixed at constant value

V. Conclusions

We analyze optimal FCL(Frequently Called List) table sizes in the grid topology circuit-switched network including wireless subscribers. We use the grid topology circuit switched network using common channel signaling as network model. We propose the new routing algorithm using FCL table, FSR(Flood Search Routing) and DAR(Dynamic Adaptive Routing) scheme. In case of this new routing algorithm, the FSR scheme is used for searching a wireless subscribers and DAR scheme is used for routing of the call which is previously serviced call. We evaluate hit ratio and incorrect ratio as performance parameters in the 5×7 grid topology network using computer simulation. As results, the hit ratio is not so much varied while incorrect ratio is increased, as the number of wireless subscribers or moving rate are increased. The call setup time is delayed as incorrect ratio is increased. So hit ratio and incorrect ratio are important factor to determine the optimal FCL table size. Then we derive the objective function to analyze the optimal FCL table size. This function is composed of hit ratio, incorrect ratio, table lookup time, average FSR time and average DAR time. We compute objective function values from above some parameters and simulation results, when the number of wireless subscribers and moving rate are varied. The graph of objective function shows the optimal point under above conditions, when the FCL table size is fixed at 300. When the FCL table size is increased above 300, call setup times are delayed, since the FCL table lookup times and incorrect ratio are increased. Also the call setup times are delayed as the number of wireless subscribers and moving rate are increased. We remark that the optimality of call setup times in the grid topology circuit-switched network is not always guaranteed, though the FCL table size is increased. After all, we conclude that the optimal FCL table size should be carefully considered, when the grid topology circuit-switched network includes wireless subscribers. Finally, results of this paper will be expected to be very helpful to design and evaluate future networks including wireless subscribers such as PCN's.

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