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A Dynamic Channel Allocation Algorithm Based on Time Constraints in Cellular Mobile Networks

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Abstract

The new realtime applications like multimedia and realtime services in a wireless network will be dramatically increased. However, many realtime services of mobile hosts in a cell cannot be continued because of insufficiency of useful channels. Conventional channel assignment approaches didn't properly consider the problem to serve realtime applications in a cell. This paper proposes a new realtime channel assignment algorithm based on time constraint analysis of channel requests. The proposed algorithm dynamically borrows available channels from neighboring cells. It also supports a smooth handoff which continuously serves realtime applications of the mobile hosts.

Key words : channel assignment algorithm, neighboring cell, mobile host

1. Introduction

The new mobile applications like multimedia and realtime services in a wireless network will be dramatically increased in the future. So the frequencies called channels should be provided for many mobile hosts. However, wireless channels are scarce resources in current mobile services. Therefore the frequency reuse is the main issue to increase system capacity of a wireless telephone system. The area in a wireless network to be served is divided into several regions, called cell. Each cell has a Base Station (BS), and the base station maintains a wireless link with mobile users.

The classical method for reusing a limited set of channels is Fixed Channel Allocation (FCA) algorithm[1, 2, 3]. In this scheme, each BS is allocated a fixed set of channels to use, and the allocation is done in a manner that the distance between cells using the same channels is large enough to avoid interference between users in different cells using the same channels[4]. This scheme works reasonably with the uniformed distribution of users, but fails to adjust for the variation in the number of users in different cells. The conventional propagation models, on which the FCA related algorithms are based on pre-assignment of channels, appear to be totally invalid for the small size cells[5]. And the FCA methods are inappropriate to the hot cell problem which dynamically happens the overloaded channel requests onto the specific cell at any time[6]. To accommodate this situation, a variety of Dynamic Channel Allocation (DCA) algorithms have been proposed based on different methods[7, 8, 9]. Graph theoretic scheme was employed in[7], probabilistic model in[8], and heuristic methods in [9].

However these papers are not appropriate to perform a realtime channel borrowing strategy because the real calls in each cell were not considered for time constraint to the deadline. Unlike other traditional works, our algorithm employs a new Realtime Dynamic Channel Allocation (RDCA) method for realtime traffic services and shows more efficiency in the dynamic use of available channels at any time. We propose a new scheme which identifies and maintains the call patterns for every σ unit times through the time constraint analysis of call requests in cells. The call requests of mobile hosts in every cell are collected every period (σ unit times) and maintained into the list of call requests called CListi, which indicates the summation of call requests of ith period in a cellular system. And channel borrowers borrow channels and lenders lend channels using information of time to deadline of call requests in the call list CListi. The channel borrowing process also supports smooth-handoff scheme. If a mobile host can continue using the same channel in the new cell, it does not have to retune to a new channel after handoff. Our algorithm keeps the current allocated channels of handoff hosts as continuously as possible when a mobile host crosses over from one cell to another.

2. Channel Borrowing Strategy based on Time Constraints

A realtime service must be arrived at the destination within its deadline, but a server fails to deliver a realtime service if the service arrives after its deadline. If a realtime service reaches at the goal before its deadline, the server needs to get the proper size of buffer to accept its calls. This paper assumes that the buffer size is infinite. The goal of this paper is to minimize the expected number of failed services over an infinite horizon. The presented algorithm logically organizes wireless environments and assumes several fundamental models as following subsections.

2.1 System model

The used models in our cellular architecture are as follows. A geographical area consists of a number of hexagonal cells, each cell served by a BS. A group of cells are again served by a Mobile Switching Center (MSC). The MSCs are connected through a wired networks, and each MSC also acts as a gateway and channel server for the wireless networks to the BSs. Each cell previously has a fixed set of Nc channels according to the compact pattern based on the fixed assignment scheme[1]. The value of Nc assigned in each cell is seven. A compact pattern with shift parameters of i=3 and j=2 is used in this paper. The number of cells, N in a compact pattern is given by following equation, which means the number of different channel sets[10].

$$N = i^2 + i \times j + j^2 \quad (1)$$

Figure 1 shows a cellular system based on compact patterns which is applied to our algorithm.

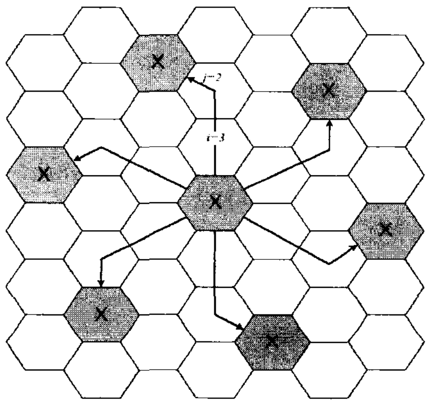

Figure 1 Cellular System based on Compact pattern

A centralized channel server dynamically services call requests in every cells. The channel server maintains a channel pool which is a set of channels in its cellular system. When calls require channels for server, the calls inserted into call entry $CList_i$ and periodically rearranged by the order of the nearest to the deadline within such a list. If there are two or more calls with both the same time constraint and the different call types in $CList_i$, those calls are rearranged according to call types of following sequences: handoff call, new call, and termination(or close) call. At initial state, the server uniformly assigns the same number of channels to each cell.

A cell can be evaluated according to the value(δ_h) of its degree of hotness defined by Equation(2). If δ_h of a cell is greater than that of others, it means that the cells with the higher value have more calls. δ_h has the range of $0 \leq \delta_h \leq 1$.

$$\delta_h = \frac{\text{vmbers of allocated channels}}{N_c} \quad (2)$$

The mobile users in wireless networks can be classified into six categories: staying user with channel requests (new call), incoming handoff user with channel requests (open handoff call), departing handoff user with returning channels (close handoff call), ending user with returning channels (close call), staying user with using channels (old call) and the user walking about cells without using channels (roaming call). The proposed algorithm only performs channel services, which allocate channels to new call and open handoff call, and recollect close call and close handoff call.

This model assumes that each call requires a unit frequency for a channel server and has time constraint information about the remaining time to the deadline. Also, the following assumptions are made: calls at any cell arrive according to Poisson process, λ; channel service time is exponentially distributed with mean length $1/\mu$; the time constraint of calls as realtime parameter has the random value within the range from the current accepted time of the call to the blocked/dropped time (or during the call duration). In our system model, the handoff users which across from a cell to the other arrive as Poisson process.

2.2 Realtime Dynamic Channel Allocation

A realtime channel borrowing algorithm can be defined by the relationship between borrower and lender. When a BS with calls requiring for channel, it becomes a borrower B. When a BS with lending channels, it becomes a lender L. The algorithm borrows channels dynamically using following parameters in each cell.

- *hotness* : The ratio of the number of allocated channels in a cell L to the total number of channels allocated determines the degree of hotness, δ_h(L), of that cell with a minimal allocated channel.
- *deadline nearness* : The temporal distances $D_{t}(B)$ by unit %time until calls of the lender L with available channels is arrived %into service deadline within its time information to deadline of %$CList_{i}$.
- *spatial nearness* : It represents the spatial cell-distance $D_s(B, L)$ between the borrower B and lender L in a compact pattern.
- available condition: The number of available channels of non-co-channel cells of the lender cells L which are also non-co-channel cells of the borrower cell B in a compact pattern, is denoted by $A_c(B, L)$. Since our cellular architecture has a compact pattern with nineteen cells as Equation(1) and each cell with seven channels, the number of channels in non-co-channel cells of the lender cell L satisfies the condition of $0 \leq A_c(B, L) \leq 133$.

To allocate channels effectively, the channel borrowing strategy selects the cell whose the value of cost function $C_f(B, L)$ is maximum among cells as lender

$$C_f(B, L) = \frac{A_c(B, L)}{\frac{D_s(B, L)}{R_{cp}} \cdot \delta_h(L)} \quad (3)$$

where R_{cp} denotes the radius of the compact pattern in terms of cell distance which implies $1 \leq D_s(B, L) \leq R_{cp}$. The proposed channel allocation scheme for cellular mobile environment is centralized in nature because it is applied to a few cells. This implies that the load on the central server would not be too high.

The proposed channel allocation algorithm including processes above is shown such as following step by step. The channel allocation steps in the algorithm employ $CList_i$, the type of call (new, handoff or close call) and cost function.

Call Arrival : When a call arrives, the algorithm evaluates the cost function $C_f(B, L)$ for each cell with free channels and assigns the channel that leads to the cost function with the largest estimated value. If no free channel is currently available, the call must be blocked.

Call Handoff : When a mobile user across from a cell to others, the call is handoff call to the cell of entry; that is, if there is the same free channel used by the handoff call, the same channel is provided to the call at the new cell. Otherwise, a new free channel is provided to it. If no such channel is available, the call must be dropped from the system.

Call Termination : When a call terminates, one by one each ongoing call in that cell is considered for reassignment to the just freed channel; the results of cost function $C_f(B, L)$ are evaluated and compared to the value of not doing any reassignment at all. The action that leads to the highest value of is then executed.

The Phase I of our algorithm can be initiated periodically by BS and *Phase II* periodically by BS whenever a borrower cell requests channels to MSC as channel server. Every BS is responsible for updating the parameters of server such as the current degree of hotness δ_h of the corresponding cells.

[Phase I] Operations at Cells :

- *Step 1* : Each BS updates its hotness δ_h on server a period.
- *Step 2* : When a MH begins its handoff service, starts or terminates its service, its BS sends the identifier, time constraint and other information of the MH and the identifiers of channels occupied by the MH to MSC.

[Phase II] Operations at Channel Server :

- *Step 1* : MSC periodically manages CListi including all calls from BSs. Firstly, all calls are arranged in the order of the earliest deadline parameter. Secondly, in the case of the same deadline values, in the order of the call types as handoff, new and termination call. Following steps focus on channel allocation for the handoff and new calls.

- *Step 2* : MSC extracts a call from CListi. Firstly, if the call is a handoff call, it collects the used channel from departing cell and allocates the same channel of incoming cell to MH for smooth-handoff if possible. Secondly, If the call is a new call, MSC gives a available channel of the corresponding cell. Finally, If the call is close call, MSC withdraws the used channel from the corresponding cell. If the call didn't have available channels yet, its BS as a borrower sends a borrowing message.
- *Step 3* : MSC receives a channel borrowing message from BS, it selects lender which maximizes the value of Equation(3) and transmits a borrowing message to the selected lender.
- *Step 4* : If the lender has a set of available channels, it locks lending channels and returns a acknowledgement message including lending channels to MSC. Otherwise, it returns a null message to MSC.
- *Step 5* : If MSC receives a set of available channels from lender, it sends a lending message to borrower. Otherwise, MSC blocks the call and goes on to Step 7.
- *Step 6* : The borrower receives a lending message from MSC. The borrowing channel is allocated to the call requiring channel.
- *Step 7* : Repeat each step after step 2 until all channel requests are satisfied or MSC has no cold cells with a set of available channels.

3. Simulation and Results

We simulated the proposed algorithm and some previous algorithms in environments with Intel Pentium-133 CPU and 32MB main memory. All programs were written using Java language. Our simulation results represent more efficient uses of available channels and more successful services of realtime channel requests over realtime applications in cellular networks. This method using the realtime channel request consideration minimizes the number of service blocking as compared to other papers. Figure 2 and Figure 3 show service failure rates in the cases of 150calls/hr and 200calls/hr. The cellular system consists of forty-nine cells, and each cell has seven channels as initial assignment.

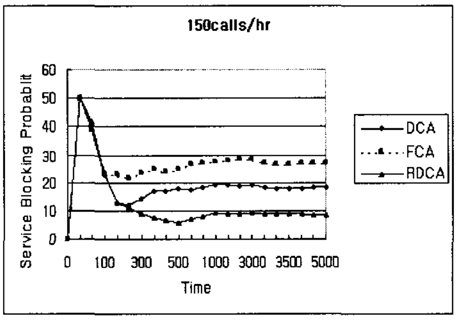

Figure 2 Results with 150calls/hr

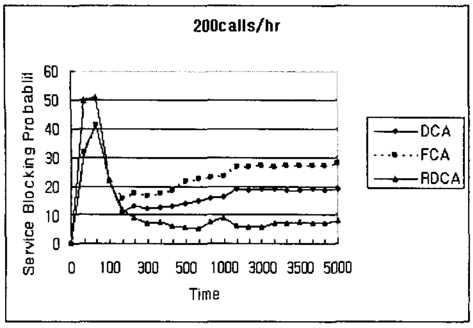

Figure 3 Results with 200calls/hr

In these figures, the curves of our RDCA method are totally low relative to those of FCA and DCA of traditional methods since RDCA reorders channel requests in its call entry $CList_i$ in the order of the earliest deadline. All simulations start with no ongoing calls and therefore the blocking probabilities are high and low in the early minutes of the performance curves. If we give more channels to our all simulations, service blocking probabilities of all algorithms will be less than current results.

The simulation results of the proposed algorithm don't show the results of call blocking ratios because of the limited space. But they also display call blocking curves similar to service blocking probabilities in Figure 2 and Figure 3 if they know transfer speed and packet size of transfer data.

4. Conclusion and Further Works

The proposed RDCA algorithm shows good experimental results since it firstly services the call with the earliest deadline and gives a new issue about wireless realtime and multimedia applications. The algorithm maintains the ordered call list with channel requests through realtime analysis in each cell. It gives new realtime channel allocation because it provides a realtime traffic service by time to deadline stored in system. This channel service minimizes the number of channel a service blocking ratio distinguishably since it firstly provide a free channel for the call request of the earliest deadline.

Future works will provide more advanced realtime allocation algorithms which efficiently execute channel services using the fixed or limited buffer size and consider admission control. We will explore the effort of decentralized approach in future work.

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