A Fault-Tolerant Capacity Enhancement Strategy for the Speed-Sensitive Allocation in Hierarchical Wireless Networks

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Abstract: Hierarchical cellular networks that employ microcells with overlaying macrocells have been proposed to increase the traffic-carrying capacity and circuit quality. A major drawback is that a large number of handoff procedures usually take place when the calls cross the cell boundary. Accordingly, the type of speed-sensitive (SS) allocation that can decrease the handoff probability was applied. However, some system problems such as the imbalance of the traffic loads with the occupied bandwidth, base stations (BSs) failed to provide wireless communication service, or the wired link failures which will lessen the traffic-carrying capacity of the SS strategy. This study proposes a fault-tolerant capacity enhancement strategy for the SS strategy. When there are variations in traffic, our strategy can adapt the system bandwidth to the traffic loads among BSs. When a BS fails to provide wireless communication service, its occupied channels cannot be used to provide services. Our strategy can revoke the occupied channels of the failed BS and reallocate to other BSs used to provide services. The reduction of the system capacity when BSs fails to provide services will be light. Moreover, our strategy can tolerate the wired link failures to enhance the system capacity.

Key-Words: Hierarchical cellular network, speed-sensing, traffic-adaptation, fault-tolerance and handoff procedure.

1 Introduction

Hierarchical wireless networking systems have been proposed [1-2, 4, 7-8], including Worldwide Interoperability for Microwave Access (WiMax) and Wireless Fidelity (WiFi), and mobile communications, such as WideBand Code Division Multiple Access (WCDMA) and High Speed Download Packed Access/High Speed Upload Packed Access (HSDPA/HSUPA), are rapidly being developed to increase the traffic-carrying capacity and circuit quality. A major drawback is that a large number of handoff procedures usually take place when the calls cross the cell boundary. The large number of handoffs increase will increase the system overheads to do channel switch, data switch, and even network switch. Accordingly, the speed-sensitive allocation strategy, termed as the SS strategy, that can decrease the handoff probability was applied. However, some system problems such as the imbalance of the traffic loads with the occupied bandwidth, base stations (BSs) failed to provide wireless communication service, or the wired link failures which will lessen the traffic-carrying capacity of the SS strategy. Therefore, providing a traffic-adaptive and fault-tolerant management strategy for the SS strategy is vitally meaningful [3, 10].

Each cell has a set of primary channels [3, 5]. When a call arrives at an area, this call is handled by the BS a cell. If no primary channels are available in this cell to serve this call, the call will be blocked. Accordingly, the number of channels allocated to a cell will affect the communication quality in this cell and the allocations of system channels among cells will affect the traffic-carrying capacity of a cellular system. A reasonable allocation should provide more channels to each cell with heavy traffic than with light traffic. Otherwise, it will experience that the heavy traffic cells do not have sufficient channels to carry their traffic loads but the light traffic cells have many available channels. Thus, the traffic-carrying capacity of a cellular system is reduced and the call blocking probability arises. To consider real-life networks, the traffic distributions among cells should be changeable according to various conditions. In order to achieve higher channel utilization, when there are variations in traffic, the channel allocations among cells should be effectively reallocated according to current traffic profile.

Efficient bandwidth scheduling of wireless bandwidth is critical to cellular system performance. Bandwidth scheduling methods can be divided into cell-layer channel allocation and call-layer channel assignment. The former type of method is
responsible for allocating system channels to cells. Accordingly, when calls arrive at cells, the latter type of method is activated in each cell to assign channels to calls to establish communication sessions. Previous studies are focused on the latter type of method \cite{3, 6, 9, 11}. Some problems, such as traffic-load variations among BSs, BSs failed to provide wireless communication service or BSs incurred the wired link failures, are the cell-layer problems and are difficult to handle using the call-layer methods.

In light of above discussions, this study presents an adaptive cross-layer bandwidth scheduling strategy for the SS strategy. This strategy is implemented to solve the traffic-adaptation and the fault tolerance problem according to the speed-sensitive call-layer method.

\begin{figure}[h]
\centering
\includegraphics[width=0.7\textwidth]{fig1}
\caption{Hierarchical infrastructure network}
\end{figure}

2 System Model

A microcell/ macrocell cellular system is a hierarchical cellular system, where a macrocell overlays a set of microcells. Each cell has a BS in its center to handle the wireless communications of a number of MHs in its covered area. The mobility of a MH is valuated as Def. 1.

Definition 1: Given a mobile host \(mh\), the mobility of \(mh\), denoted as \(M(mh)\), is the number of microcells that \(mh\) traverse for a fixed time duration. Mobile host \(mh\) is termed as a high mobility host if \(M(mh)>s_9\), where \(s_9\) is a speed threshold.

The available system bandwidth is divided into two disjoint sub-bands: \(B_{micro}\) and \(B_{macro}\), where \(B_{micro}\) is used for the microcell system and \(B_{macro}\) is used for the macrocell system.

For a microcell (or macrocell) system, the given sub-band \(B\) is divided into a number of disjoint units \(B_{CH}\) (termed as channels). Each cell \(C\) is given a subset \(P(C)\) of \(B_{CH}\), termed as the primary channels of \(C\). When a call arrives at \(C\), channels of \(P(C)\) can be used to serve the call. Two cells cannot concurrently assign the same channel to calls if their geographical distance is less than \(D_{min}\); otherwise, their communication sessions interfere with each other. This situation is referred to channel interference \cite{5}.

Definition 2: Given a cell \(C\), the set of interfering neighbors of cell \(C\), denoted by \(IN(C)\) is: \(IN(C) = \{\text{cell } C' \mid \text{the BSs of cells } C \text{ and } C' \text{ operate at the same band and } Dist(C, C') < D_{min}\}\), where \(Dist(C, C')\) is the geographical distance between cells \(C\) and \(C'\).

According to Def. 2, a cell \(C\) with its interfering neighbors \(IN(C)\) can not contain the same channel(s) as their primary channel(s). Therefore, Def. 3 is the condition of primary channel allocations.

Definition 3: (The condition of primary channel allocation): Given two distinct cells \(C\) and \(C'\), where \(C \in IN(C)\), the condition of primary channel allocation between cells \(C\) and \(C'\) is \(P(C) \cap P(C') = \emptyset\).

For cell \(C\), \(P(C)\) is used to serve the calls arrived at \(C\). For channels \(P(C)\), a channel \(ch\) is available to \(C\) if \(ch\) currently is not been assigned to any call in \(C\). Definition 4 accordingly defines the available channels of \(C\).

Definition 4: (Available primary channel): Given a cell \(C\) with primary channels \(P(C)\), the available channels of \(C\), denoted as \(A(P(C))\), is \(A(P(C))=\{ch \mid \text{the } P(C) \text{ and } ch \text{ is available to } C\}\).

In general, each macrocell \(C_i\) overlays with \(k\) microcells, \(C_{i1}, C_{i2}, \ldots, C_{ik}\). For convenience, \("C_{ij} \in C_i"\) is used to denote that microcell \(C_{ij}\) is overlaid by macrocell \(C_i\). Moreover, \(D_{micro}\) and \(D_{macro}\) to denote the minimum reuse distances of microcells and macrocells, respectively. Fig. 1 illustrates a cell configuration. \(D_{micro}\) and \(D_{macro}\) are \(\sqrt{2}R_{micro}\) and \(\sqrt{2}R_{macro}\), where \(R_{micro}\) and \(R_{macro}\) are the radiuses of a microcell and a macrocell, respectively. The interfering neighbors \(IN(C_{ij})\) of macrocell \(C_{ij}\) include macrocells \{\(C_{i1}, C_{i2}, \ldots, C_{i8}\), \(C_{i9}, C_{i10}, C_{i11}, C_{i12}\)\}. For any location of a cellular network, there are a microcell \(C_{ij}\) and a macrocell \(C_{ij}\) which can use their primary channels \(P(C_{ij})\) and \(P(C_i)\) to handle the call arrivals. For the SS strategy, when a call requesting a number \(c\) of channels with the targeted MH \(mh\) arrives at the area of \(C_{ij}\), there are three cases that \(mh\) can acquire the sufficient channels to
establish its communication sessions. Otherwise, the call is blocked. In the first case, mh can acquire the primary channels of macrocell $C_i$ that if $mh$ is a high-mobility host, i.e., $M(mh) > s_h$, and the available channels of the macrocell $C_i$ are sufficient i.e., $|A(C_i)| > c$. The second is $mh$ can acquire the primary channels of microcell $C_{ij}$ if that $mh$ is a low-mobility host, i.e., $M(mh) < s_h$, and the available channels of the microcell $C_{ij}$ are sufficient i.e., $|A(C_{ij})| > c$. The other is that the available channels of the macrocell $C_i$ are sufficient i.e., $|A(C_i)| > c$ and $mh$ can acquire the primary channels of macrocell $C_i$.

The SS strategy prioritizes a high-mobility MH to acquire the channels $P(C_i)$ of a macrocell $C_i$ and a low-mobility MH to acquire the channels $P(C_{ij})$ of a microcell $C_{ij}$. Therefore, the allocations of $P(C_i)$ and $P(C_{ij})$ will affect the performance of the SS strategy. In this study, distinct cells can dynamically change their primary channel allocations to satisfy the different variations. Let the primary cells of a channel $ch$, denoted by $PC(ch)$, be all of the cells, which contain a primary channel $ch$ in the system. According to Def. 2, if a cell $C$ acquires a new primary channel $ch$, the original owners of $ch$ in $IN(C)$ will be forbidden to keep $ch$ as their primary channel. Definition 5 presents the interfering primary cells $IP(C, ch)$.

**Definition 5:** The interfering primary cells of channel $ch$ relative to cell $C$ are denoted by $IP(C, ch)$, where $IP(C, ch) = PC(ch) \cap IN(C)$.

For instance in Fig. 1, suppose that cells $C_3$, $C_{12}$, $C_{14}$, $C_{23}$, $C_{32}$, $C_{41}$, and $C_{40}$ have a primary channel $ch$, i.e., $PC(ch) = \{C_3, C_{12}, C_{14}, C_{23}, C_{32}, C_{41}\}$. Since $IP(C_{31}, ch) = IN(C_{31}) \cap PC(ch) = \{C_{23}, C_{32}\}$, if $C_{31}$ acquires $ch$ as its new primary channel, $C_{23}$ and $C_{32}$ can not keep $ch$ as their channel.

**3 Subject Strategy**

The proposed strategy is a cell-layer bandwidth scheduling strategy and is used by the SS assignment strategy to allocate system channels to cells. The relation of the two strategies is shown as Fig. 2. When there are variations such as traffic, link profile, or service profile among cells, our strategy will be activated, accordingly to the variations, to allocate system channels to each cell. The new allocation is submitted to the call-layer strategy. Then, the SS strategy uses the new allocation to carry the traffic.

### 3.1 Allocation Condition

The discussion of the condition that a cell can acquire a new channel is presented herein. The condition connects with the traffic of the service area. To evaluate the traffic, we divide the physical service area of a cellular system into a number of units. Each unit contains the covered area of a microcell $C_{ij}$. The SS strategy prioritizes assigning the channels of a macrocell to a high-mobility MH and the channels of a microcell to a low-mobility MH. Accordingly, the traffic loads of an area of a microcell $C_{ij}$ is divided into high-mobility traffic $\lambda_{h}(C_{ij})$ and low-mobility traffic $\lambda_{l}(C_{ij})$, where $\lambda_{h}(C_{ij})$ is handled by using the overlapped macrocell $C_i$ using $P(C_i)$ and $\lambda_{l}(C_{ij})$ is handled by using $P(C_{ij})$.

#### 3.1.1 Microcell with Low-Mobility Traffic

The evaluation of using $P(C_{ij})$ to carrying the traffic $\lambda_{l}(C_{ij})$ can be represented using Erlang B formula, as shown in (1), in which $|P(C_{ij})|$ is the number of channels in $P(C_{ij})$.

Based on (1), the valuation of cell $C_{ij}$ increasing and decreasing a channel $ch$ can be represented as (2) and (3), respectively. The $incr_{micro}(C_{ij}, ch)$ is used by $C_{ij}$ to evaluate its capacity effect if it acquires a new channel $ch$. The $decr_{micro}(C_{ij}, ch)$ compares the channel utilization with the low-mobility traffic $\lambda_{l}(C_{ij})$ before and after acquiring a channel $ch$, for cell $C_{ij}$. The $decr_{micro}(C_{ij}, ch)$ is used by the interfering neighbor $C$ of $C_{ij}$, i.e., $C \in IN(C_{ij})$, to evaluate the capacity effect if $C_{ij}$ decreases a channel $ch$. Therefore, $C$ must take the states of $C_{ij}$ into consideration. If $C_{ij}$ currently cannot provide wireless communication service (Service Failure), i.e., $C_{ij}$ cannot use any channels to carry the traffic, the capacity reduction of decreasing a channel $ch$ is 0. If $C_{ij}$ has the problem of the wired-link failure (Link Failure), $C$ cannot connect with $C_{ij}$. If $C$ takes a channel $ch$ of $C_{ij}$ as its new channels, $C$ cannot inform $C_{ij}$ to give up $ch$. Therefore, $C$ and $C_{ij}$ has the probability to assign $ch$ to different calls at the same time. Since $C_{ij}$ and $C$ are within the interfering range, the calls will interfere with each other. Therefore, for Link-failure case, $C$ cannot take the channels of $C_{ij}$ as its new channels and the capacity reduction $decr_{micro}(\cdot)$ is set a very large value ($v_\infty$). For the No-Failure case, since the current operations of $C_{ij}$ is normal (No failure), $decr(C_{ij})$ is set as to compare the channel utilization with and without having a channel $ch$. 
EB(λi(Ci), P(Ci)) = \sum_{k=0}^{n} \frac{\lambda_i(C_i)^{n+k}}{n! \cdot k!}, \text{ where } n = |P(C_i)|

\begin{equation}
\text{intr}_{\text{max}}(C_{ij}, ch) = \left( [EB(\lambda_i(C_i), P(C_i))] - [EB(\lambda_i(C_i), P(C_i) \cup \{ch\})] \right) \lambda_i(C_i)
\end{equation}

\begin{equation}
\text{decr}_{\text{max}}(C_{ij}, ch) = \left\lfloor \frac{[EB(\lambda_i(C_i), P(C_i) - \{ch\})] - [EB(\lambda_i(C_i), P(C_i))]}{\lambda_i(C_i)} \right\rfloor
\end{equation}

\begin{equation}
P(C) \leftarrow P(C) \cup \{ch\}
\end{equation}

\begin{equation}
P(C') \leftarrow P(C') - \{ch\}, \text{ where } C' \in IP(C, ch).
\end{equation}

\begin{equation}
R_{\text{max}}(C_{ij}, r) = \text{intr}_{\text{max}}(C_{ij}, ch) \cdot \lambda(C_{ij}) - \sum_{ch \in IP(C_{ij}, ch)} \text{decr}_{\text{max}}(C_{ij}, ch) \cdot \lambda(C_{ij}).
\end{equation}

\begin{equation}
\lambda_c(C) = \lambda_c(C) + \lambda_c(C), \text{ where } \lambda_c(C) \text{ is the high-traffic load in the covered area of } C_{ij}.
\end{equation}

\begin{equation}
EB(\lambda_s(C), P(C)) = \sum_{k=0}^{n} \frac{\lambda_s(C)^{n+k}}{n! \cdot k!}, \text{ where } n = |P(C)|
\end{equation}

\begin{equation}
\text{intr}_{\text{max}}(C_{ij}, ch) = \left( [EB(\lambda_s(C), P(C))] - [EB(\lambda_s(C), P(C) \cup \{ch\})] \right) \lambda_s(C)
\end{equation}

\begin{equation}
\text{decr}_{\text{max}}(C_{ij}, ch) = \left\lfloor \frac{[EB(\lambda_s(C), P(C) - \{ch\})] - [EB(\lambda_s(C), P(C))]}{\lambda_s(C)} \right\rfloor
\end{equation}

\begin{equation}
R_{\text{max}}(C_{ij}, r) = \text{intr}_{\text{max}}(C_{ij}, ch) \cdot \lambda(C_{ij}) - \sum_{ch \in IP(C_{ij}, ch)} \text{decr}_{\text{max}}(C_{ij}, ch) \cdot \lambda(C_{ij}).
\end{equation}

According to Def. 5, if C takes a channel ch as its new channel, the original owners IP(C, ch) of ch must give up ch. The channel transformation among cells can be represented as (4).

According to (2)-(4), the capacity effect of a microcell C_{ij} acquiring a new channel ch and the original owners giving up ch can be represented as (5) and the necessary condition to reallocate a channel ch to C_{ij} is R_{max}(C_{ij}, ch) > 0.

### 3.1.2 Macrocell with High-Mobility Traffic

For a macrocell C_i, its allocated channels are prioritized to handle the high-traffic loads \lambda_i(C_i) as presented as (6). The evaluation of using P(C_i) to carry the traffic \lambda_i(C_i) can be represented using Erlang B formula, as shown in (7), where IP(C_i) is the number of channels in P(C_i). Based on (7), the evaluation of cell C_i increasing and decreasing a channel ch can be represented as (8) and (9), respectively.

According to (8) and (9), the capacity effect of a macrocell C_i acquiring a new channel ch and the original owners giving up ch can be represented as 0. In order to enhance the system capacity, the necessary condition to reallocate a channel ch to C_i is R_{max}(C_i, ch) > 0.
3.2 Allocation
The strategy is performed periodically by each cell. The opportunity that a cell performs the strategy can be formally described as follows.
1. Partition the set of all cells in a system into \( G_0, G_1, \ldots \) and \( G_{s+1} \) disjoint subsets, such that any two cells in the same subset are apart by at least a distance of \( D_{\text{min}} \). Accordingly, partition the time into \( T_0, T_1, \ldots \) and \( T_{s+1} \) disjoint time periods (\( cs \) is also termed as the cluster size).
2. The cells in \( G_s \) are assigned to perform the channel allocation at time period \( T_p \).

For instance in Fig. 1 with \( D_{\text{macro}} = \sqrt{2r_{\text{macro}}} \), cells \( \{c_0, c_1, \ldots, c_{48}\} \) can be divided into \( G_0, G_1, \ldots, G_6 \), where \( G_0 = \{c_0, c_9, c_{18}, c_{27}, c_{36}, c_{47}\} \), \( G_1 = \{c_1, c_{10}, c_{19}, c_{28}, c_{37}, c_8\} \), \( G_2 = \{c_2, c_{11}, c_{20}, c_{29}, c_{38}, c_7\} \), \( G_3 = \{c_3, c_{12}, c_{13}, c_{21}, c_{39}, c_6\} \), \( G_4 = \{c_4, c_{14}, c_{22}, c_{33}, c_{40}, c_{41}\} \), \( G_5 = \{c_5, c_{15}, c_{23}, c_{34}, c_{42}, c_5\} \), and \( G_6 = \{c_6, c_{16}, c_{24}, c_{35}, c_{43}, c_{44}\} \). Cells in the same group can perform the strategy at the same time period. A cell \( C \) that performs our strategy is to evaluate the current variations such as traffic loads and the wireless communication provisions of its interfering neighboring cells \( IN(C) \). Accordingly, \( C \) reschedules the system channels for \( IN(C) \) to meet the variations.

The proposed strategy is performed by each cell \( C \), which accords to the current traffic loads and the primary channels of it itself and the each interfering neighbor \( C_{\text{in}} \) to determine the new primary channels. Therefore, the inputs of the strategy including \( B \), \( \lambda(C) \), and \( P(C) \), where if \( C \) is a microcell (or macrocell), \( B \) represents the bandwidth \( B_{\text{macro}} \) (or \( B_{\text{macro}} \)) and \( \lambda(C) \) represents the low-mobility traffic \( \lambda_{l}(C) \) (or the high-mobility traffic \( \lambda_{h}(C) \)). The output of the strategy is channel sets, including C and its interfering neighbor.

As follows, we give some examples to describe the methods to handle the variations in traffic profile, link-profile, and service-profile. Suppose, in Fig. 1, the available bandwidth of the macrocell system has 70 channels, denoted as \( B_{\text{macro}}=\{c_{10}, c_{11}, \ldots, c_{38}\} \). The original primary channel sets of \( C_{24} \) is \( P(C_{24})=\{c_{10}, c_{11}, \ldots, c_{19}\} \), of \( C_{29} \) is \( P(C_{29})=\{c_{10}, c_{11}, \ldots, c_{19}\} \), and of \( C_{18} \) is \( P(C_{18})=\{c_{18}, c_{19}, \ldots, c_{29}\} \). We continually suppose, \( C_{29} \) incurs service failure, which cannot provide wireless communications. When \( C_{24} \) performs the strategy, \( C_{24} \) sets \( S(C_{24}) \) as \( B_{\text{macro}}-P(C_{24})=\{c_{10}, c_{11}, \ldots, c_{19}\} \) and then collects the high-mobility traffic loads \( \lambda_{h}(\cdot) \) and the current channel allocations \( P(\cdot) \) of \( IN(C_{29}) = \{c_{10}-c_{12}, c_{16}-c_{19}, c_{22}-c_{23}, c_{25}-c_{26}, c_{29}-c_{32}, c_{36}-c_{38}\} \).

However, since \( C_{29} \) incurs service failure, \( C_{24} \) sets \( P(C_{29}) = \emptyset \) and sets \( \lambda_{h}(C_{29}) = 0 \). Then, \( C_{24} \) round by round, evaluates \( \lambda_{h}(C_{24}, c) \) for each \( c \) in \( S(C_{24}) \). In each round, \( C_{24} \) picks up a channel \( c_{\text{max}} \) having the largest positive value and saves \( c_{\text{max}} \) into \( P(C_{24}) \) and deletes \( c_{\text{max}} \) from each \( P(C_{ip}) \), where \( C_{ip} \) is the original owner of \( c_{\text{max}} \), i.e., \( C_{ip} \in IP(C_{24}, c_{\text{max}}) \). In each round, \( C_{24} \) also deletes \( c_{\text{max}} \) and other channels with non-positive \( \lambda_{h}(\cdot) \) values from \( S(C_{24}) \). Until \( S(C_{24}) \) is empty or any channel in \( S(C_{24}) \) has non-positive \( \lambda_{h}(\cdot) \) value, the evaluation is stopped. After the evaluation, \( P(C) \) denotes the new primary channel allocation of cell \( C \), where \( C \) belongs to \( C_{24} \) and \( IN(C_{24}) \). In the evaluation, channels \( P(C_{29})=\{c_{10}, c_{11}, \ldots, c_{19}\} \), belonging to a service-failure cell \( C_{29} \), cannot use its channels \( \{c_{10}, c_{11}, \ldots, c_{19}\} \) to carry traffic. The \( \lambda_{h}(C_{24}, c) \), for \( c \) in \( \{c_{10}, c_{11}, \ldots, c_{19}\} \) will be set as 0 (as shown in (9)), i.e., no capacity effect if \( C_{29} \) gives up the channels. For other instance in Fig. 1, suppose \( IP(C_{9}, c_{39})=\{C_9, C_{17}\} \), i.e., in the interfering area \( IN(C_{9})=C_9, C_{8} \) and \( C_{17} \) have a channel \( c_{39} \). Since \( C_8 \) has channel \( c_{39} \), no cells in \( IN(C_8) \) and \( \{C_9, C_{17}\} \) have \( c_{39} \). When a large number of MHs transfers from the neighbors of \( C_9 \), such as \( C_8 \) and \( C_{17} \) into \( C_9 \), \( C_9 \) must carry more traffic. The condition will cause the carrying traffic loads with the occupied channels among \( C_8 \) and its neighbors unbalanced. Therefore, \( C_9 \) has opportunity to acquire more channels from its neighbors. Suppose \( C_9 \) performs the strategy and find \( \lambda_{h}(C_8, c_{39})=0 \), \( C_8 \) can acquire \( c_{39} \). The original owners \( IP(C_8, c_{39}) \) will give up \( c_{39} \) and transfer to \( C_8 \) to balance the traffic transformation. Moreover, for \( C_8 \) before transferring \( c_{39} \) to \( C_9 \), \( C_8 \) is the unique cell having \( c_{39} \). After \( C_8 \) transfers \( c_{39} \) to \( C_9 \), no cells in \( IN(C_9) \) have \( c_{39} \), \( C_9 \) will acquire \( c_{39} \).

4 Simulation Results
The simulation environment, as shown in Table 1, has 49 macrocells, arranged as 7-parallelogram structure, where the radius of a microcell is 400 meters and each macrocell overlaps 4 microcells. The reuse distances of the microcell system and the macrocell system are \( \sqrt{2r_{\text{micro}}} \) and \( \sqrt{2r_{\text{macro}}} \), where \( r_{\text{micro}} \) and \( r_{\text{macro}} \) are 400m and 800m, respectively. The frequency bands for microcells and macrocells are 2.24MHz/2 and 4.48MHz/2, respectively. The average number of mobile hosts, which locate at the area of a microcell, is 100. It includes 30% high-mobility mobile hosts and 70% low-mobility mobile hosts, generated according the random process. The call arrival rate of a non-calling host is generated according to the random process from 2.20 to 4.95 calls/hour.
The mobility of a mobile host is represented as the speed and is generated according to a random process from 0 to 100 km/hour. After the speed of a MH determining, the residual time of a MH at a microcell can be acquired. The simulation contains 5 hot microcells, which are generated according to the random process. When the determined residual time of a MH is escaped, this MH needs to move to its neighboring cell. The next cell is determined as follows. If no hot cells surrounding to the current cell, the probability of moving to the neighboring cell is same. If a hot cells surrounding to the current cell, the probability to move to a neighboring hot cell is 50% and to move to the neighboring non-hot cells is 50%.

The simulation results are demonstrated as Fig. 5- Fig. 6, which include no failure, and 1% and 2% of cells failed to provide communication services or wired link failures. In which, “SS” represents the SS strategy without our strategy and “Ours” represents the SS strategy with our strategy.

The results reveal that our strategy is available for the SS strategy and can greatly improve the traffic-carrying capacity. The reason is described as follows. The original cannot handle the cell-layer variations such as the change of the traffic loads among cells or the base stations failed to provide service. Ours strategy can adaptively tune the bandwidth allocations according the variation of traffic loads among cells. Moreover, when a cell failed to provide service, the neighboring non-failed cells can acquire more primary channels released from the failed cells to light the effect to the system capacity.

5 Conclusions

Bandwidth scheduling methods can be divided into cell-layer channel allocation and call-layer channel assignment. Previous studies are focused on the latter type of method. Some problems, such as traffic-load variations among base stations (BSs) and BSs failed to provide wireless communication service, are the cell-layer problems and are difficult to handle using the call-layer methods. Therefore, this study presented an adaptive cross-layer bandwidth scheduling strategy for hierarchical cellular networks. This strategy is implemented to solve the traffic-adaptation and the fault tolerance problem according to the speed-sensitive call-layer method.

The mechanism used in the proposed strategy is from the cell-layer to schedule system bandwidth to handle the variation is system profiles. It can achieve various demands for the mobile communications area by modifying the allocation conditions with more related factors [1-2]. Ergonomic and economic factors will be considered to satisfy new trends in the telecommunication industry in the future.

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Fig. 4: Service failure
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