A handover scheme in next generation mobile networks

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Abstract: Inter-RNC(radio network controller) and inter-BSC(base station center) hard handovers involve rerouting. Thus additional delay time for the new bearer setup and reroute determination should be considered. For theses kinds of handovers we propose a new scheme and coined it as ICHP(Inter-Cluster Handover Prediction).

When a call approaches a boundary cell of a cluster, ICHP prepares for the handover by performing resource reservations and reroute computation in advance. Performance analysis shows that ICHP provides faster handover and that it lowers the blocking probability.

1. Introduction

Multi-tiered cellular systems with pico-, micro-, and macrocells seem to be used in the next generation wireless networks. Figure 1. shows the structure of a multi-tiered cellular network system. Here, a cluster denotes a group of cells which are controlled by a single RNC or BSC. When a call crosses a cluster boundary and thus inter-cluster hard handover is required, new bearer setup and rerouting should be performed. Hence inter-cluster hard handover involves more delay compared with intra-cluster handover. We propose a new handover scheme which can reduce the delay associated with the bearer setup and rerouting, and coin it ICHP (Inter-Cluster Handover Prediction).

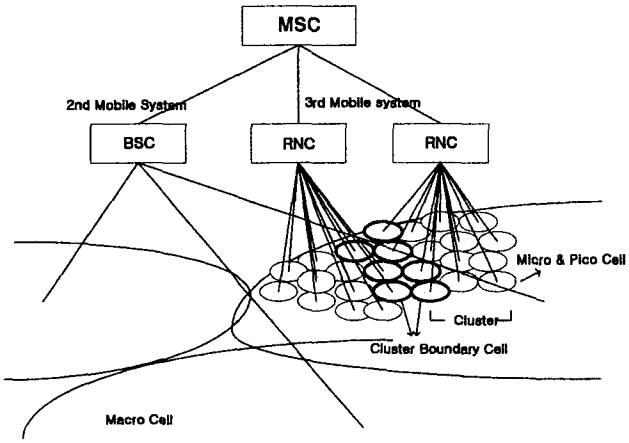


Figure 1. A multi-tiered cellular networ

When an active MT(mobile terminal) enters a cluster boundary cell, ICHP prepares for the inter-cluster hard handover by performing bearer reservation and reroute computation. That is, partial handover procedures are provided before the MT enters into handover area. But even if a MT is in a boundary cell, it doesn't always cross the cluster boundary. To reduce unnecessary signaling overhead, ICHP is applied only to the MTs with higher possibility of inter-cluster handover. The signaling procedure for the inter-cluster hard handover is shown in Figure 2.

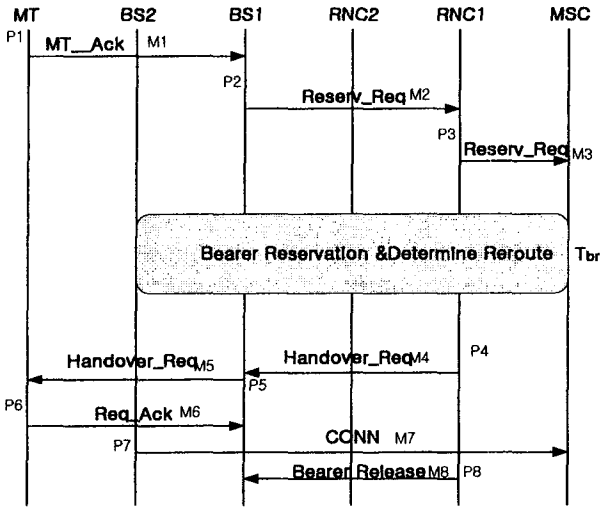


Figure 2. The hard handover procedure 1

The total processing time of the inter-cluster hard handover is T_s in (1).

$$T_s = \sum_{i=1}^{8}(M_i + P_i) + T_{br} \qquad (1)$$

,where M_i is the time to send a message, P_i is the message processing time, and T_{br} is the time spent in bearer reservation and reroute determination.

2. Analysis of ICHP

Whenever a handover call or a new call is appeared in a cluster boundary cell, its possibility of inter-cluster handover is checked. If its velocity is above the predefined threshold, it is thought to be highly probable to handover and ICHP performs bearer reservation and reroute computation in advance. Hence, when the inter-cluster hard handover is actually required, the handover delay time can be reduced.

We assume that the mobile speed V is constant in a cell and that V is a random variable uniformly distributed over [0, V_m] [1]. And we also assume circular cells with radius R. If we denote the distance from a MT to the border of the boundary cell by D, the pdf(probability density function) of D is given by

$$f_D(d)=\begin{cases}\frac{2}{\pi R^2}\sqrt{R^2-\left(\frac{d}{2}\right)^2} & for\ \ 0\le d\le 2R\\ 0 & elsewhere\end{cases} \tag{2}$$

If we denote the sojourn time of the new call in the boundary cell by T_n, the pdf of T_n is

$$\begin{aligned} f_{T_n}(t)&=\int_{-\infty}^{+\infty} v f_D(tv) f(v)dv \\ &=\int_0^{V_m}\frac{2v}{\pi R^2}v\sqrt{R^2-\left(\frac{tv}{2}\right)^2}f(v)dv \end{aligned} \tag{3}$$

,where $f(v)$ is the pdf of V.

And the mean of T_n is

$$\begin{aligned} E[T_n]&=\int_0^{+\infty} t f_{T_n}(t)dt \\ &=\int_0^{+\infty}\int_0^{V_m}\frac{2vt}{\pi R^2}\sqrt{R^2-\left(\frac{tv}{2}\right)^2}f(v)dvdt \\ &=\frac{32R}{9\pi}E[\frac{1}{V_m}] \end{aligned} \tag{4}$$

The second case of the call appearing in the boundary cell is by soft handover from the inner cell. We assume that the moving directions of MTs generating these calls are random, i.e. uniform over $[-\frac{\pi}{2},\frac{\pi}{2}]$. Then the pdf of D for the handover call is given by

$$f_D(d)=\begin{cases}\frac{1}{\pi}\frac{1}{\sqrt{R^2-\left(\frac{d}{2}\right)^2}} & for\ \ 0\le d\le 2R\\ 0 & elsewhere\end{cases} \tag{5}$$

Let us define T_h as the sojourn time of the handover call in the boundary cell. Then the pdf of T_h is

$$\begin{aligned} f_{T_h}(t)&=\int_0^{+\infty} v f_D(tv) f(v)dv \\ &=\int_0^{V_m}\frac{1}{\pi}\frac{v}{\sqrt{R^2-\left(\frac{tv}{2}\right)^2}}f(v)dv \end{aligned} \tag{6}$$

And the mean value of T_h is

$$\begin{aligned} E[T_h]&=\int_0^{+\infty} t f_{T_h}(t)dt \\ &=\int_0^{+\infty}\int_0^{V_m}\frac{1}{\pi}\frac{vt}{\sqrt{R^2-\left(\frac{tv}{2}\right)^2}}f(v)dvdt \\ &=\frac{16R}{3\pi}E[\frac{1}{V_m}] \end{aligned} \tag{7}$$

After a MT enters inter-cluster handover area, the expected mean sojourn time of the MT is as follows [2].

$$E[T_{HO}]=\frac{R}{\pi V_m}(6-\pi\sqrt{3}) \tag{8}$$

Let T be the time elapsed until a handover call is serviced after it enters target boundary cell, and T_s be the signaling time needed for the handover. We assume that T is a random variable exponentially distributed with mean $1/\mu$. Then the forced termination probability P_{pf} is

$$\begin{aligned} P_{pf}&=P\{T<T_s\} \\ &=\int_0^{T_s}\mu e^{-\mu t}dt=1-e^{-\mu T_s} \end{aligned} \tag{9}$$

Hence, for an inter-cluster hard handover scheme without prior bearer reservation and reroute computation, P_{pf} becomes

$$P_{pf}=1-\frac{1}{e^{\frac{\pi V_m}{R(6-\pi\sqrt{3})}T_s}}. \tag{10}$$

With ICHP, the forced termination probability P_{pf} of a new call becomes

$$P_{pf}=1-\frac{1}{e^{\left[\frac{1}{\frac{R(6-\pi\sqrt{3})}{\pi V_m}+\frac{32R}{9\pi}E[\frac{1}{V_m}]}\right]T_s}}. \tag{11}$$

The expected mean of T is

$$\begin{aligned} E[T]&=\int_0^{+\infty}\frac{1}{\frac{R(6-\pi\sqrt{3})}{\pi V_m}+\frac{32R}{9\pi}E[\frac{1}{V_m}]}t \\ &\quad\times e^{\frac{t}{\frac{R(6-\pi\sqrt{3})}{\pi V_m}+\frac{32R}{9\pi}E[\frac{1}{V_m}]}}dt \\ &=\frac{R(86-9\pi\sqrt{3})}{9\pi V_m}. \end{aligned} \tag{12}$$

Similarly, P_{pf} of handover call with ICHP is

$$P_{pf}=1-\frac{1}{e^{\left[\frac{1}{\frac{R(6-\pi\sqrt{3})}{\pi V_m}+\frac{16R}{3\pi}E[\frac{1}{V_m}]}\right]T_s}} \tag{13}$$

And the expected mean of T is

$$\begin{aligned} E[T]&=\int_0^{+\infty}\frac{1}{\frac{R(6-\pi\sqrt{3})}{\pi V_m}+\frac{16R}{3\pi}E[\frac{1}{V_m}]}t \\ &\quad\times e^{\frac{t}{\frac{R(6-\pi\sqrt{3})}{\pi V_m}+\frac{16R}{3\pi}E[\frac{1}{V_m}]}}dt \\ &=\frac{R(34-3\pi\sqrt{3})}{3\pi V_m} \end{aligned} \tag{14}$$

3. Numerical results

For the sake of simplicity we assume that the MT's velocity and direction are constant in the regions of our interests. Figure 3. shows the forced termination probabilities of

handover schemes with and without ICHP. Three kinds of MTs are considered – indoor, pedestrian and high mobility terminals. The characteristic parameters of each terminal group are shown in Table 1. In any case ICHP shows lower blocking probabilities.

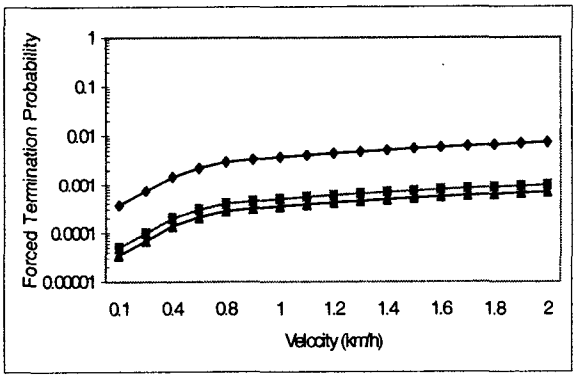
Table 1. System parameters

	Indoor	Pedestrian	High Mobility
Velocity	0~2 km/h	2~5 km/h	10~100km/h
Data Rate	2 Mbps	384 kbps	144 kbps
Radius	20~40 m	100~200 m	1~2 km
Ts	47 msec	127 msec	1027 msec

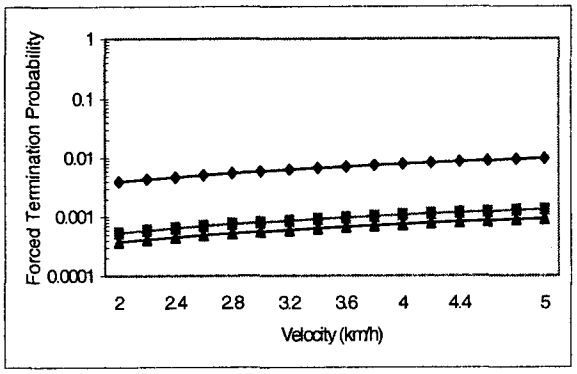
We also observed how the radii of the macro cells affect the forced termination probability. Cell radii vary between 1 and 2 km, and the velocity of the mobile terminals is assumed 100 km/h. Termination probabilities are lowered with larger cells in any case.

4. Conclusion

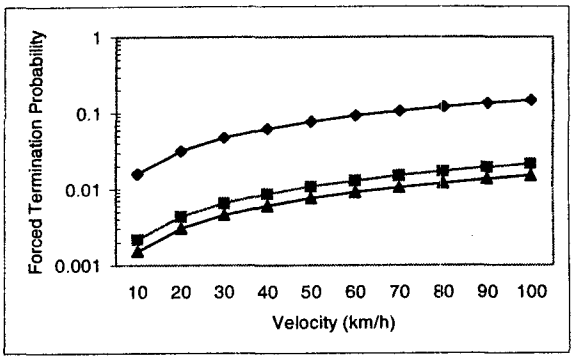
In this paper, we proposed a new hard handover scheme for the next generation wireless networks based on the multi-tired cells. When a MT call enters a cluster boundary cell, preparatory steps such as bearer reservation and reroute computation are performed for the inter-cluster handover which might occur later. The proposed scheme reduces the forced termination probability for the inter-cluster handover.



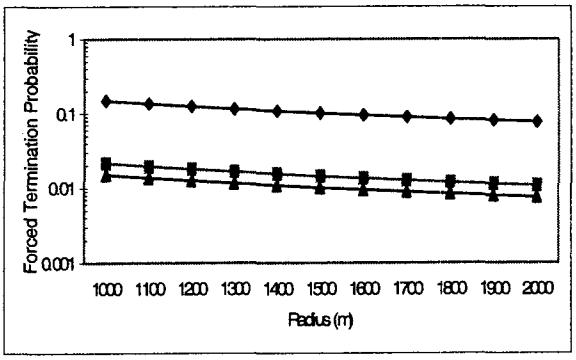
a. Indoor Systems



b. Pedestrian



c. High Mobility Systems 1



d. Macro Cell Systems 1

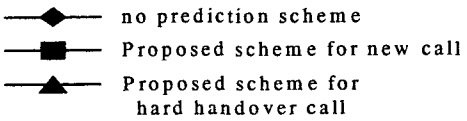


Figure 3. Forced Termination Probability 1

References

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[2] William C.Y. Lee, "Mobile Cellular Telecommunications Systems," *McGraw-Hill*, 1990