行政院國家科學委員會專題研究計畫　成果報告

超越第三代行動通訊系統效能評估

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計畫主持人：林一平

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超越第三代行動通訊系統效能評估
Performance Analysis of Beyond 3G Mobile Network

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一、中文摘要

在行動電話通訊的營運中，無線通道(radio channel)是非常珍貴的資源而需被謹慎地分配。其一方法是架設階層式蜂巢狀網路(hierarchical cellular network)。本計畫研究階層式蜂巢狀網路中的一種通道分配方法，隨需重整(repacking on demand)。隨需重整最初被應用在無線區域迴路。本計畫改良此方法以應用在行動網路並提出模擬模型(simulation model)來研究並比較隨需重整以及先前技術的系統效能。最後，此計畫定量指出，隨需重整方法較其他先前技術於未完成通話與交遞率優異。

關鍵詞: 通道分配、通道重整、階層式蜂巢狀網路、隨需重整、塞機率

Abstract

In mobile telecommunications operation, radio channels are scarce resources and should be carefully assigned. One possibility is to deploy the hierarchical cellular network (HCN). This project studies a HCN channel assignment scheme called repacking on demand (RoD). RoD was originally proposed for wireless local loop networks. We expand this work to accommodate mobile HCN. A simulation model is proposed to study the performance of HCN with RoD and some previously proposed schemes. Our study quantitatively indicates that RoD may significantly outperform the previous proposed schemes.

Key words: channel assignment, channel repacking, hierarchical cellular network, repacking on demand

二、前言

Existing second generation (2G) mobile communications systems such as *Global System for Mobile Communications* (GSM) are designed for voice services, which only have limited capabilities for offering data services. On the other hand, the third generation (3G) systems such as *Universal Mobile Telecommunications System* (UMTS) support mobile multimedia applications with high data transmission rates. The UMTS infrastructure includes the *Core Network* and the *UMTS Terrestrial Radio Access Network* (UTRAN). The core network is responsible for switching/routing calls and data connections to the external networks, while the UTRAN handles all radio-related functionalities. In this project, we consider radio channel assignment.

三、研究目的及文獻探討

One of the most important issues in cellular network operation is capacity planning. Especially when the number of cellular subscribers grows rapidly, it is required that the cellular service provider increases its network capacity effectively. One possible solution is to deploy the hierarchical cellular network (HCN) [5, 11, 13]. As shown in Figure 1, the HCN consists of two types of base stations (BSs): micro BSs and macro BSs. A micro BS with low power transceivers provides small radio coverage (referred to as microcell), and a macro BS with high power transceivers provides large radio coverage (referred to as macrocell). The microcells cover mobile subscribers (MSs) in heavy teletraffic areas. A macrocell is overlaid with several microcells to cover all MSs in these microcells.

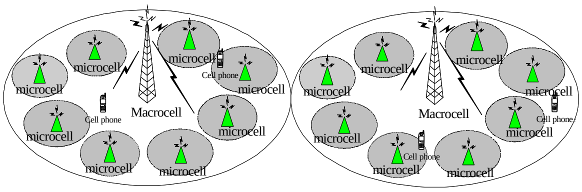

Figure 1. HCN Architecture

In a cellular network, radio channels must be carefully assigned to reduce the numbers of new call blockings as well as handoff call force-terminations. A basic scheme called no repacking (NR) was described in [16]. In this scheme, when a call attempt (either a new call or a handoff call) for an MS arrives, the HCN first tries to allocate a channel in the microcell of the MS. If no idle channel is available in this microcell, the call attempt over-flows to the corresponding macrocell. If the macrocell has no idle channel, the call attempt is rejected. Call blockings and force-terminations of NR can be reduced by repacking techniques described as follows [22]. Consider a call attempt for a microcell BS_i that has no idle channel. In NR, this call attempt is served by the corresponding macrocell. If radio channels are available in BS_i later, this call can be transferred from the macrocell to BS_i again. The process of switching a call from the macrocell to the microcell is called repacking. Repacking increases the number of idle channels in a macrocell so that more macrocell channels can be shared by the call attempts where no channels are available in the microcells. Depending on the time when repacking is exercised, several schemes have been proposed. In always repacking (AR) [1, 14, 17], the HCN always moves a call from the macrocell to the corresponding microcell as soon as a channel is released at that microcell. Some schemes [8, 20] perform repacking based on the moving speeds of MSs. In [8], the calls of slow-speed MSs are always moved from the macrocells to the corresponding microcells when these MSs move across the borders of microcells.

In [6, 20], repacking on demand (RoD) schemes were proposed. Unlike AR, RoD does not immediately perform repacking when a channel in a microcell is released. Instead, repacking is exercised only when it is necessary. Based on the speeds of MSs, the study in [20] investigated RoD for Exponential cell residence times and call holding times. The study in our previous work [6] investigated RoD for wireless local loop. This project extends the work in [6] to accommodate mobile networks. We consider general distributions for both the cell residence times and call holding times.

Our study develops a simulation model to investigate the performance (i.e., the call blocking, force-termination, and incompletion) for NR, AR, and RoD.

四、研究方法

Repacking on Demand for Hierarchical Cellular Network (HCN)

This section describes the RoD channel assignment and repacking procedures for HCN. As shown in Figure 2, when a call attempt is newly generated from or handed off to the *i*th microcell, the HCN first tries to assign a channel in the *i*th microcell to the call attempt (see Figure 2 (1) and (2)). If no idle channel is available in the *i*th microcell, the call attempt overflows to the *j*th macrocell that overlays with the *i*th microcell.

If the macrocell has idle channels, the HCN assigns one to the call attempt (Figure 2 (3) and (4)). Otherwise, RoD is exercised to identify *repacking candidates* (Figure 2 (5)). Every repacking candidate is an ongoing call that satisfies the following criteria:

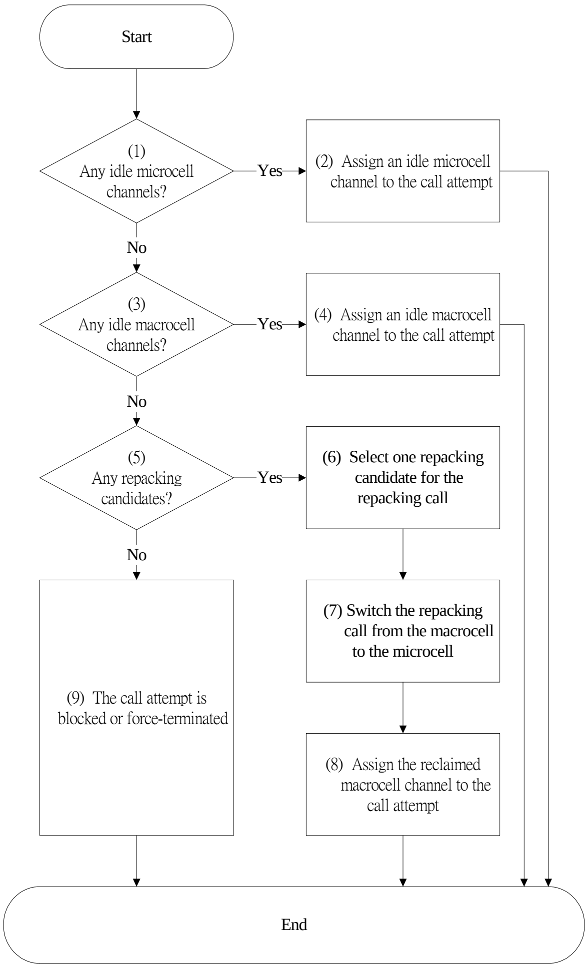

Figure 2. Channel Assignment with RoD

Criterion 1. The call occupies a channel in the *j*th macrocell.

Criterion 2. The microcell of this call (i.e., the microcell where the call party resides) has an idle channel.

RoD selects one repacking candidate to hand off from the macrocell to the microcell where the call resides (see Figure 2 (6) and (7)). Then the reclaimed macrocell channel is used to serve the call attempt (Figure 2 (8)). If RoD cannot find any repacking candidate, the call attempt is rejected; i.e., the new call is blocked or the handoff call is force-terminated (Figure 2 (9)).

We propose two policies to handle the repacking candidates in RoD at Step 6 in Figure 2. *Random RoD* (RoD-R) randomly selects a repacking candidate with the same probability. *Load Balancing RoD* (RoD-L) selects the repacking candidate whose microcell has the least traffic load. Both RoD-R and RoD-L can be adopted by an HCN that utilizes radio systems such as GSM/PCS1900 [13] or WCDMA [5], where the handoff decision is made by the network.

System Model for HCN

This section describes the input parameters and output measures for the HCN system model. Our model can accommodate any cell configurations. For the demonstration purpose, we consider a wrapped mesh cell configuration as shown in Figure 3. This configuration consists of four macrocells. Each macrocell covers 4 x 4 microcells. The wrapped topology simulates unbounded HCN so that the boundary cell effects can be ignored [12]. Without loss of generality, the MS moves to one of the four neighbor microcells with the same probability (i.e., 0.25). Three types of input parameters are considered in our model.

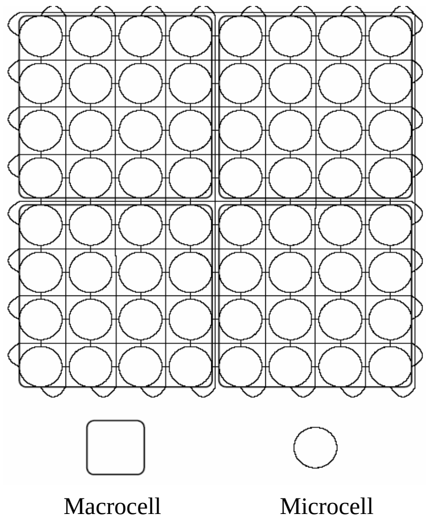

Figure 3. Hierarchical Cellular Network with Wrapped Mesh Configuration

System Parameters: Each macrocell has C radio channels, and each microcell has c

radio channels.

Traffic Parameters: The call arrivals to a microcell (for both incoming and outgoing calls) form a Poisson stream with rate λ. The expected call holding time is $1/\mu$.

Mobility Parameters: The expected microcell residence time of an MS is $1/\eta$.

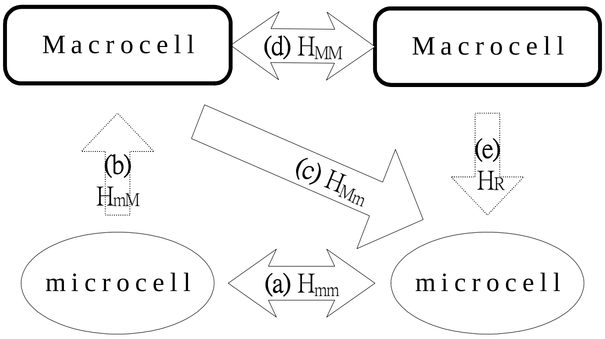

Figure 4. Handoff Types

Several output measures are defined in this study:

P_b: the blocking probability that a new call is blocked

P_f: the force-termination probability that a successfully connected call is force-terminated because of handoff failure

P_{nc}: the incomplete probability that a new call is blocked or a connected call is force-terminated

H_{mm}: the expected number of handoffs from a microcell to another microcell during a call (Figure 4 (a))

H_{mM}: the expected number of handoffs from a microcell to a macrocell during a call (Figure 4 (b))

H_{Mm}: the expected number of handoffs from a macrocell to a microcell during a call (Figure 4 (c))

H_{MM}: the expected number of handoffs from a macrocell to another macrocell during a call (Figure 4 (d))

H_R: the expected number of repackings during a call (Figure 4 (e))

From the above description, H can be expressed as

$$H=H_{mm}+H_{mM}+H_{Mm}+H_{MM}+H_R$$

五、結果與討論

This project studied repacking on Demand (RoD) for channel assignment in a hierarchical cellular network (HCN). We developed simulation models to investigate the RoD performance on the blocking probability P_b, the force-termination probability P_f, the incomplete probability P_{nc} and the expected number of handoffs H during a call. We compared RoD with other HCN channel assignment schemes including no repacking (NR) and always repacking (AR). We showed that RoD and AR have the same P_b, P_f and P_{nc} performance. Compared with NR, both RoD and AR reduce the P_b, P_f and P_{nc} performance at cost of increasing the number of handoffs. With the same P_{nc} performance, the repacking approaches can support much more call arrivals than NR does. Moreover, our study indicated that RoD results in much less handoffs than AR does.

六、成果自評

(一) 對於學術研究、國家發展及其他應用方面預期之貢獻:

1. 論文發表:本計畫之學術成果已為 *ACM MONET* 期刊接受發表。
2. 效能評估:提出 RoD 模擬模型(simulation model)來研究並比較隨需重整以及先前技術的系統效能,並定量指出隨需重整方法較其他先前技術於未完成通話與交遞率優異。

(二) 對於參與之工作人員,預期可獲之訓練。

1. 設計電腦模擬模型
2. RoD 效能分析與比較

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