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A DECISION-TREE APPROACH TO ANALYZING CHANNEL ALLOCATION ALGORITHMS FOR TWO-TIER WIRELESS LOCAL LOOPS

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ABSTRACT

A wireless local loop (WLL) uses radio signals to connect customer premise equipment (CPE) to a public switched telephone network (PSTN). It has the potential to help the telephony providers overcome the "last mile" problem in delivering telephony services. A typical WLL consists of a base station controller (BSC), a base station (BS), and subscriber terminals (STs). A WLL can be single-tier, two-tier, or three-tier, based on the configuration of the cells within it. There are numerous channel allocation algorithms for two-tier WLLs. These algorithms include no repacking, always repacking, repacking on demand—random, repacking on demand—least load, and repacking on demand—subscriber terminal. This paper provides a decision-tree approach to analyzing these channel allocation algorithms for designing two-tier WLLs. The generated decision-trees can not only help us understand these channel allocation algorithms better, but can also serve as a basis for constructing simulation models and eventually implementing simulation programs for the purpose of comparing the performance of the different network designs.

KEYWORDS

Call Overflow and Repacking, Channel Allocation Algorithm, Decision-tree, Wireless Local Loop (WLL).

INTRODUCTION

A wireless local loop (WLL) uses radio signals to connect customer premise equipment (CPE) to a public switched telephone network (PSTN) (Hung, Lin, Peng, and Tsai 2004; Xiao, Zhang, Du, and Zhang 2006). It has the potential to help telephony providers overcome the "last mile" problem in delivering telephony services (Hung et al. 2004; Xiao et al. 2006). A typical WLL consists of a base station controller (BSC), a base station (BS), and subscriber terminals (STs) (see Figure 1) (Hung et al. 2004). A BS, controlled by a BSC, can serve multiple STs that are within its radio coverage. Each CPE has a dedicated ST that is responsible for communication between the CPE and the BS (Hung et al. 2004).

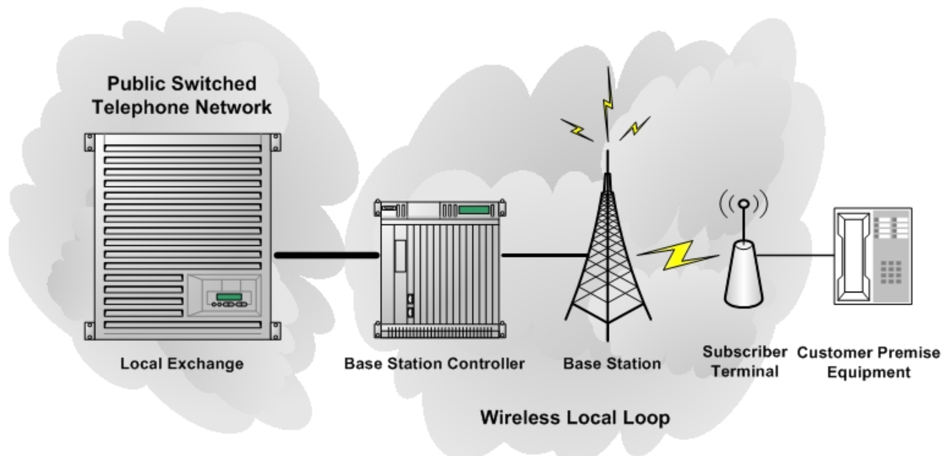

Figure 1. A Typical WLL Architecture

A WLL can be single-tier, two-tier, or three-tier, based on the configuration of the cells within it. In a single-tier WLL, no two cells fully overlap with each other; thus, each ST can be reached by only one BS. In contrast, a two-tier WLL overlays every macrocell (a cell with a higher power BS) with several microcells (cells with lower power BSs); thus, an ST in a microcell can be served either by the BS in the microcell or by the BS in the macrocell (see Figure 2) (Hung et al. 2004; Xiao et al. 2006). In this paper, we only consider two-tier WLLs.

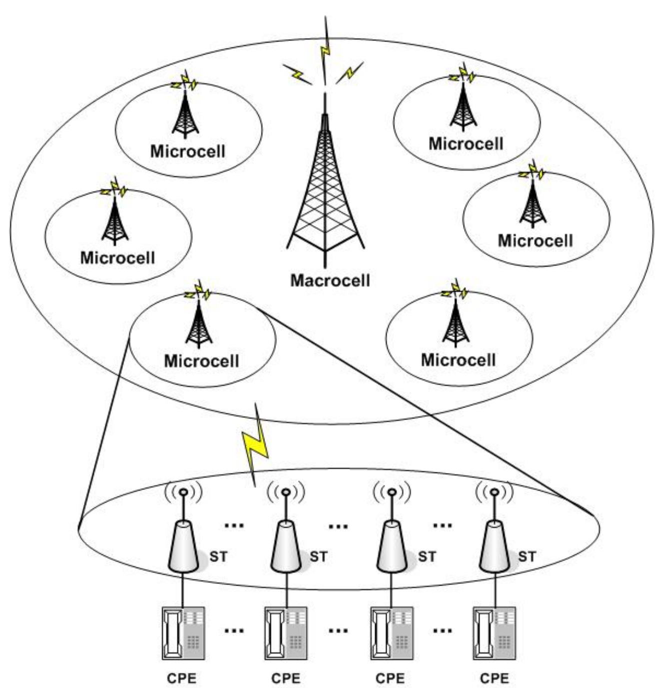

Figure 2. A Two-tier WLL Configuration

A multi-tier (i.e., two-tier and up) WLL incorporates two new operations: *overflow* and *repacking* (Hung et al. 2004; Xiao et al. 2006). Overflow is call handoff from a lower tier cell to a higher tier cell, and repacking is call handoff from a higher tier cell to a lower tier cell. In a two-tier WLL, overflow is call handoff from a microcell to the macrocell, and repacking is call handoff from the macrocell to a microcell (see Figure 3).

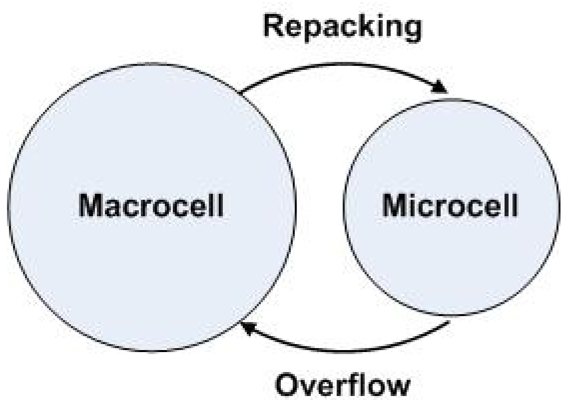

Figure 3. Overflow and Repacking in Two-tier WLLs

Note that repacking cannot be exercised if there is no repacking candidate available (Xiao et al. 2006). In a two-tier WLL, a repacking candidate is a call that: 1) occupies a macrocell channel, and 2) the corresponding microcell of which has an idle channel (Hung et al. 2004; Xiao et al. 2006).

Channel allocation algorithms for two-tier WLLs include no repacking (NR), always repacking (AR), and repacking on demand (RoD). RoD can be further categorized into repacking on demand—random (RoDR), repacking on demand—least load (RoDL), and repacking on demand—subscriber terminal (RoDST), depending on the way a WLL handles its repacking candidates in RoD (see Table 1) (Hung et al. 2004; Xiao et al. 2006).

Algorithm		Description
NR		No Repacking
AR		Always Repacking
RoD	RoDR	Repacking on Demand—Random
	RoDL	Repacking on Demand—Least Load
	RoDST	Repacking on Demand—Subscriber Terminal

Table 1. Channel Allocation Algorithms for Two-tier WLLs

All three algorithms (NR, AR, and RoD) perform overflow. However, a WLL with a NR scheme does not perform repacking (Hung et al. 2004; Rappaport and Hu 1994). A WLL with an AR scheme always performs repacking as soon as a repacking candidate becomes available (Beraldi, Marano, & Mastroianni 1996; Maheshwari & Kumar 2000; Steele, Nofal, & Eldolil 1990). In contrast, a WLL with a RoD scheme only performs repacking when it is necessary (Hung et al. 2004; Xiao et al. 2006).

Each of the three subgroups of RoD, (i.e., RoDR, RoDL, and RoDST,) handles repacking candidates differently. With RoDR, the BSC randomly selects a repacking candidate for handoff; with RoDL, the BSC selects the repacking candidate whose microcell has the least traffic load; and with RoDST, STs make decisions of selecting repacking candidates for handoff upon a repacking request from the macrocell (Hung et al. 2004; Xiao et al. 2006). Note that more than one call may be handed off from the macrocell to a microcell in RoDST. In this case, one of the released macrocell channels is chosen to serve the new call (Hung et al. 2004; Xiao et al. 2006).

In this paper, we study channel allocation algorithms for two-tier WLLs by applying a decision-tree approach. A decision-tree approach is both appropriate and useful. It is appropriate because a WLL has to make conditional decisions when performing call overflow or repacking. It is also useful because: 1) the generated decision-trees can help us understand these channel allocation algorithms better, and 2) we can use the generated decision-trees in the design and implementation of simulation models and programs to evaluate performance of different algorithms.

A DECISION-TREE APPROACH FOR TWO-TIER WLLS

No Repacking (NR)

A WLL with a NR scheme only performs overflow. When a new call *O* (either incoming or outgoing) for an ST arrives, a two-tier WLL with a NR scheme first tries to allocate an idle channel in the corresponding microcell of the ST to call *O*. If no idle channel is available in that microcell, then call *O* overflows to the macrocell. If the macrocell has any idle channels available, then one of the idle channels is allocated to serve call *O*. If the macrocell has no idle channel available either, then call *O* is blocked, as shown in Figure 4 (Hung et al. 2004; Xiao et al. 2006).

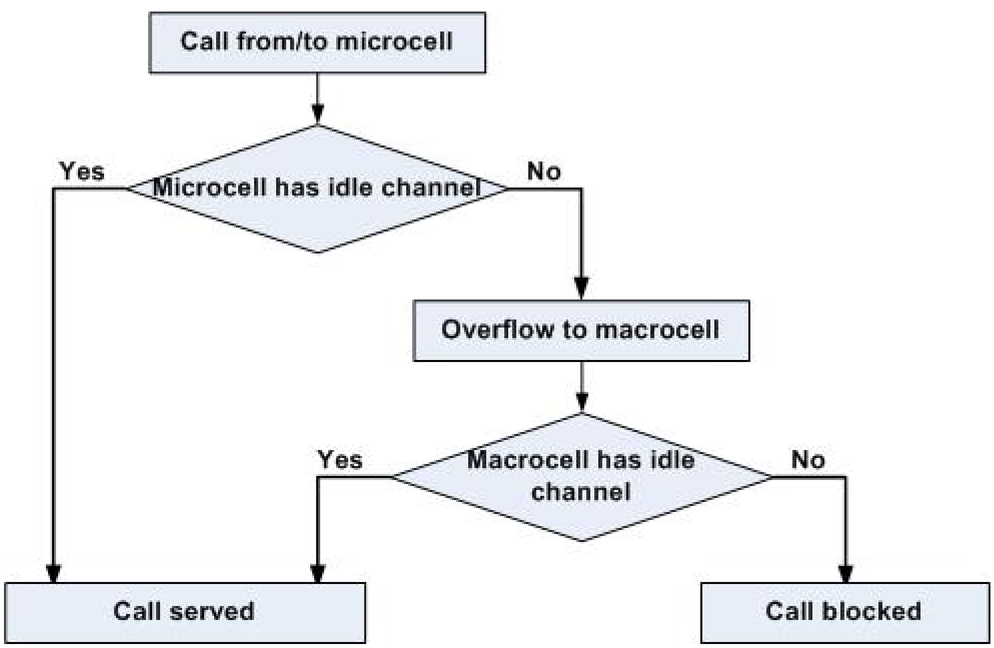

Figure 4. No-Repacking Scheme for Two-tier WLLs

Always Repacking (AR)

A WLL with an AR scheme always performs repacking as soon as a repacking candidate becomes available. In a two-tier WLL with an AR scheme, the WLL always hands off a call in the macrocell to the corresponding microcell as soon as there is an idle channel available in the corresponding microcell. In this way, AR keeps maximum number of idle channels in the macrocell at the cost of a high handoff rate (Lagrange 1997).

An interesting finding is that the decision-tree for AR scheme ends up the same "look" with that for NR scheme (Xiao et al. 2006). The reason for this is quite straightforward. When an overflowed call cannot find an idle channel at the macrocell, repacking will not succeed because if there were repacking candidates available in the macrocell at that very moment, the WLL itself should have already performed repacking. Intuitively, compared with a WLL with a NR scheme, a WLL with an AR scheme is expected to have a lower blocking rate but a higher handoff rate.

Repacking on Demand (RoD)

Unlike AR, RoD does not immediately perform repacking when repacking candidates become available. Instead, repacking is performed only when it is necessary; for instance, the new call will be blocked if repacking is not performed. Channel allocation in RoD is similar to that in NR, except that the WLL will try to perform repacking when a new call is to be blocked.

In a two-tier WLL with a RoD scheme, when a new call *O* arrives, if neither the microcell (of call *O*) nor the macrocell has any idle channel, the WLL will perform repacking by checking whether there are repacking candidates in the macrocell. If yes, the macrocell picks one of the repacking candidates, for instance, call *R*, and hands off call *R* back to its microcell. The reclaimed macrocell channel is used to serve call *O*. Otherwise, call *O* is blocked, as shown in Figure 5 (Hung et al. 2004; Xiao et al. 2006).

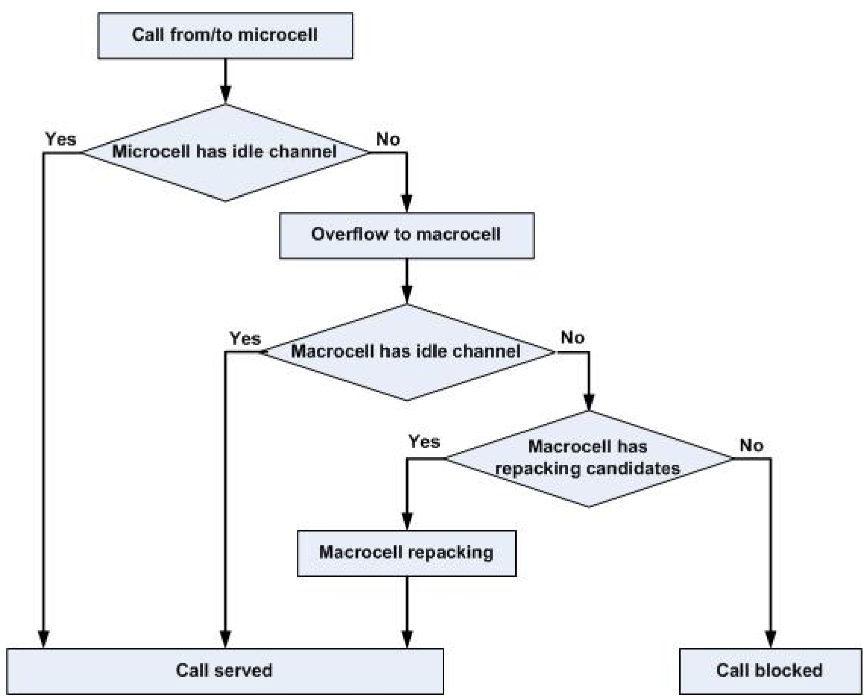

Figure 5. RoD Scheme for Two-tier WLLs

The decision-trees of RoDR, RoDL, and RoDST are identical, since the only difference among these three subgroups of RoD is the way that a WLL handles the repacking candidates, and this difference has no impact on the "look" of the decision-tree.

CONCLUSION

In this paper, we have presented and analyzed channel allocation algorithms for two-tier WLLs by applying a decision-tree approach. The decision-trees, generated from our analyses, can not only help us better understand these channel allocation algorithms, but can also serve as a basis for the design and implementation of simulation models and programs for comparing the performance of different network designs.

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