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O.R. Applications

Two new algorithms for UMTS access network topology design

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Abstract

Present work introduces two network design algorithms for planning UMTS (Universal Mobile Telecommunication System) access networks. The task is to determine the cost-optimal number and location of the *Radio Network Controller* nodes and their connections to the *Radio Base Stations* (RBS) in a tree topology according to a number of planning constraints. First, a global algorithm to this general problem is proposed, which combines a metaheuristic technique with the solution of a specific *b*-matching problem. It is shown how a relatively complex algorithm can be performed within each step of a metaheuristic method still in reasonable time. Then, another method is introduced that is able to plan single RBS-trees. It can also be applied to make improvements on each tree created by the first algorithm. This approach applies iterative local improvements using branch-and-bound with Lagrangian lower bound. Eventually, it is demonstrated through a number of test cases that these algorithms are able to reduce the total cost of UMTS access networks, also compared to previous results.

Keywords: Telecommunication; Metaheuristics; UMTS; Facilities planning and design; Lagrange-relaxation

1. Introduction

UMTS [22,25], stands for Universal Mobile Telecommunication System; it is a member of the ITU's IMT-2000 global family of *third-generation* (3G) mobile communication systems. UMTS will play a key role in creating the future mass market for high quality wireless multimedia communications, serving expectedly 2 billion users worldwide by the year 2010.

One part of the UMTS network will be built upon the transport network of today's significant 2G mobile systems [15], but to satisfy the needs of the future Information Society new network architectures are also required. Since UMTS aims to provide high bandwidth data, video or voice transfer, the radio stations communicating with

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the mobile devices of the end-users should be placed more dense to each other, corresponding to the higher frequency needed for the communication. In the traditional star topology of the radio stations, i.e. all the radio stations are directly connected to the central station, this would increase the number of expensive central stations as well. To solve this problem, UMTS allows a constrained tree topology of the base stations, permitting to connect them to each other and not only to the central station. This new architecture requires new planning methods as well.

As shown in Fig. 1 the UMTS topology can be decomposed into two main parts: the core network and the access network. The high-speed core network based on e.g. ATM technology connects the central stations of the access network. These connections are generally realized with high-capacity optical cables. In this paper the focus is on planning the access network, the design of the core network is beyond the scope. The reader is referred to e.g. [21] on this topic.

The access network consists of a set of *Radio Base Stations* (RBS nodes) and some of them are provided with *Radio Network Controllers* (RNC nodes). The RBSs communicate directly with the mobile devices of the users, like mobile phones, mobile notebooks, etc., collect the traffic of a small region and forward it to the RNC they belong to using the so-called *access links*, that are typically microwave radio links with limited length (longer length connections can be realized using repeaters, but at higher cost). In traditional GSM configuration the RBSs are connected directly to an RNC station limiting the maximum number of RBSs belonging to a certain RNC. To overcome this limitation the UMTS technology makes it possible for an RBS to connect to another RBS instead of its RNC. However RBSs have no routing capability, they simply forward all the received data toward their corresponding RNC station, therefore all traffic from an RBS goes first to the RNC controlling it. For example if a mobile phone in region A in Fig. 1 wants to communicate with a device in region B, their traffic will be sent through the RNC R. Only the RNC station is responsible for determining the correct route for that amount of traffic. It follows that the RBSs should be connected to the RNC in a tree topology. (There are research initiatives to provide some low-level routing capability for the RBSs and to allow additional links between RBSs, which may increase the reliability of the network. These developments are quite in early stage, hence we only deal with tree topology.) As a consequence, the access network can be divided into independent trees of RBSs, each rooted at an RNC. These trees are called *Radio Network Subsystems* (RNS). Further advantage of the tree topology compared to the star topology is that the links can become shorter, which on one hand reduces the cost of the links, on the other hand it may require less repeaters in the network.

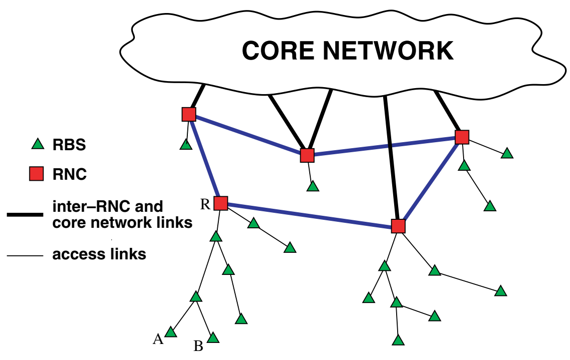

Fig. 1. UMTS topology.

Moreover, there are some additional links connecting the RNCs to each other (*inter-RNC links*) and to the core network. The planning of these links are beyond the scope of this paper.

For technical reasons the following strict topology constraints have to be taken into account:

- The limited resources of the RBS stations and the relatively low bandwidth of the access links cause considerable amount of delay in the communication. In order to reduce this kind of delay, the maximum number of the access links on a routing path is kept under a certain amount by limiting the depth of a tree to a small predefined value. This limit is denoted by l_{tree} in our model. Currently, the usual value of l_{tree} is 3.