A New Approach to Plan 3G Cellular Networks

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Abstract

In this paper, we describe a new approach to plan third generation (3G) cellular networks. Instead of partitioning the problem into three subproblems, we use a global approach in which all the subproblems (cell, access and core networks planning subproblems) are considered simultaneously. Since a global model is NP-hard, we concentrate our effort on the development of approximate solution algorithms (heuristics). The proposed approach can be used to plan a new network and to update an existing infrastructure. Two examples are presented in order to illustrate these concepts.

Sommaire

Dans cet article, nous décrivons une nouvelle approche pour planifier les réseaux mobiles de troisième génération. Au lieu de partitionner le problème en trois sous-problèmes, nous utilisons une approche globale dans laquelle les sous-problèmes (planification des cellules, du réseau d'accès et du réseau dorsal) sont considérés simultanément. Comme le modèle global est NP-difficile, nous considérons des méthodes de résolution approximatives (heuristiques). L'approche proposée peut être utilisée pour planifier un nouveau réseau et pour mettre à jour une infrastructure existante. Deux exemples sont présentés pour d'illustrer ces concepts.

1.0 Introduction

Over recent years, the third generation (3G) mobile networks, based on the universal mobile telecommunications system (UMTS) standard, are used by an increasing number of subscribers. As a result, these network operators must invest a large portion of their budget within their network infrastructure. A typical UMTS architecture is illustrated in Figure 1. As we can see, the area of coverage is divided into cells. Each cell contains a base station, called node B, which provides radio interfaces to mobile users (MUs). The wideband code-division multiple access (WCDMA) scheme is typically used in those networks. With this scheme, the capacity of each cell is based on the interference levels (for more information, see Amaldi et al. [2]). A radio network controller (RNC) connects one or more node Bs and deals with resource and mobility management. All these elements are part of the UMTS terrestrial radio access network (UTRAN). Each RNC is then linked to the core network. The latter is divided into two different parts: the circuit switched and the packet switched core network. The former is composed of mobile switching centers (MSCs) which take care of telephone call setup and routing as well as providing access to the public switched telephone network (PSTN). On the hand, the packet switched core network is composed of serving GPRS (General Packet Radio Service) support nodes (SGSN) that provide connectivity to the packet data network (PDN) and the Internet. For more details concerning UMTS networks, see Yacoub [12].

The UMTS network planning problem has been widely studied in the literature. Due to its complexity, it has been divided into three NP-hard subproblems: the cell, the access network and the core network planning subproblems:

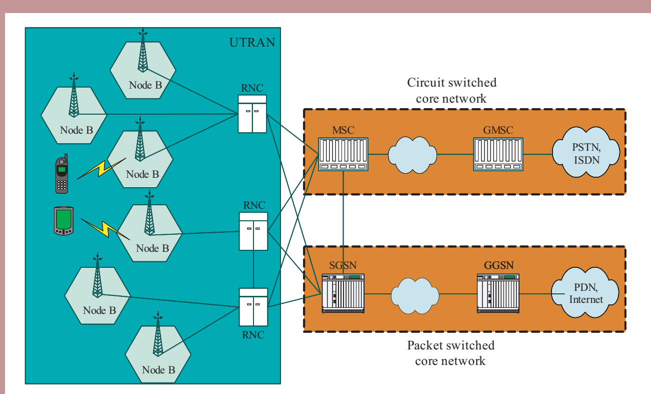

Figure 1: Typical UMTS architecture

- The cell planning subproblem consists in finding the number, the location and the type of node Bs subject to signal quality and coverage constraints. The objective is to minimize the cost of the node Bs (including the installation cost). Many different authors including Amaldi et al. [1, 2], and Thiel et al. [10] worked on this subproblem.
- The access network planning subproblem consists in determining the number, the location and the type of RNCs, the assignment of node Bs to RNC as well as the number, the location and the type of links to be used. Several authors tackled this subproblem. Here are the most interesting works: Harmatos et al. [5], Lauther et al. [8], and Wu and Pierre [11].
- The core network planning subproblem consists in determining the number, the location and the type of MSCs and SGSNs to install, the assignment of the RNCs to the MSC/SGSN and finally the number, the location and the type of links to connect the RNC to the MSC/SGSN (see Harmatos [4]).

For more details on each subproblem and for an extensive literature review, see [9].

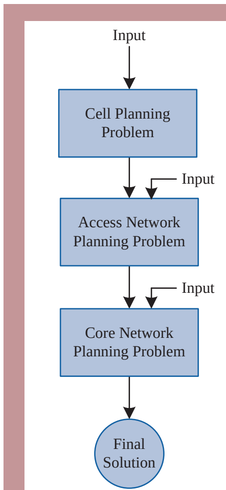

Figure 2: Sequential Planning

In order to plan a UMTS network, a sequential approach is generally used. This means that each subproblem is solved successively. As a result, we first solve the cell planning problem. Then, given the optimal number and location of the base stations, we then find the optimal number (and location) of RNCs. Finally, given all this information, we try to find the optimal solution for the core network (see Figure 2).

This methodology has the advantage of dividing the complexity of the planning problem into three different subproblems. However, the final solution obtained is usually not optimal since:

- once a decision has been made in a subproblem, it cannot be changed thereafter;
- the interactions between subproblems are not taken into consideration;
- the optimal solutions to each subproblem do not provide, in general, an optimal solution to the global problem.

Recently, St-Hilaire, Chamberland and Pierre [9] proposed an innovative global approach for planning UMTS networks. This approach considers

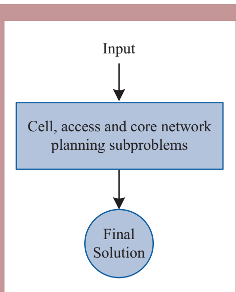

Figure 3: Global Planning

the three subproblems simultaneously (see Figure 3) and therefore, optimal solutions are always obtained. However, since this approach is NP-hard, we concentrate our efforts on the development of approximate algorithms (heuristics).

In the following section, we will provide illustrative examples of the proposed global approach. The proposed heuristic is based on the tabu search (TS) principle. The basic principle of the tabu search is to define a set of possible solutions, and starting from the current solution, to find a better one in its neighborhood. A neighborhood is a set of solutions that are found by applying an appropriate transformation of the current solution. In order for the algorithm to move away from a local minimum, the search allows moves resulting in a degradation of the objective function value, thus avoiding the trap of local optimality. To prevent the search from cycling, solutions obtained recently and moves that reverse the effect of recent moves are considered tabu. For more details about TS, see [7].

2. Illustrative Examples

In this paper, only the uplink direction (i.e., from the mobile users (MUs) to node Bs) is considered. The uplink traffic is very important when the amount of data exchanged is balanced between the uplink and the downlink directions. To simulate the traffic, we introduce the notion of test points (TPs). Each TP can be viewed as a centroid where a given amount of traffic is requested. Therefore, one TP can represent several MUs in a given area. When planning the uplink direction, the restrictions are the MU transmit power and the interference [6].

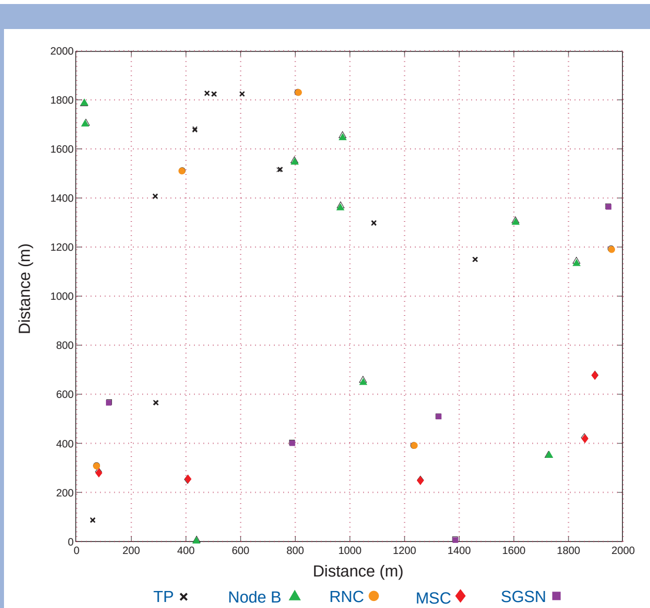

Figure 4: Region to be planned

The area to be planned is presented in Figure 4 where the geographical location of TPs and potential sites are depicted.

In order to simulate the behavior of the signal propagation, we used the extension of the Hata model proposed in [3].

To design the network, three Node B types, two RNC types, two MSC types and two SGSN types are available. Their features are respectively presented in Tables 1 to 4. Moreover, OC-3 and OC-12 links can be used to connect the node Bs to the RNCs, DS-3 links are used to connect the RNCs to the MSCs and gigabit ethernet (GE) links are used to connect the RNCs to the SGSNs (see Table 5). The costs of the interface (port) types are presented in Table 6.

Two different examples will be presented. The first one will be a planning example followed by an update example.

	Type A	Type B	Type C
Capacity (circuits)	100	200	400
Capacity (Mbps)	120	240	480
Number of interfaces	1	2	2
Sensitivity (dBm)	-90	-100	-110
Cost ($)	20,000	30,000	50,000

Table 1: Features of the node B types

	Type A	Type B
Switch fabric capacity (Mbps)	2,000	5,000
Number of nodeB interfaces	10	20
Number of MSC/SGSN interfaces	15	30
Cost ($)	50,000	90,000

Table 2: Features of the RNC types

	Type A	Type B
Switch fabric capacity (circuits)	100,000	200,000
Number of interfaces	50	100
Cost ($)	200,000	350,000

Table 3: Features of the MSC types

	Type A	Type B
Switch fabric capacity (M bps)	20,000	40,000
Number of interfaces	16	32
Cost ($)	40,000	60,000

Table 4: Features of the SGSN types

Link type	Capacity	Cost ($/km)
DS-3	2688 circuits	2,500
OC-3	155 Mbps	1,500
OC-12	622 Mbps	4,000
GE	1 Gbps	4,000

Table 5: Cost of the links

Interface type	Cost ($)
DS-3	1,500
OC-3	2,000
OC-12	4,500
GE	2,000

Table 6: Cost of the interface types

2.1 Planning Example

Starting from a green field (i.e., there is no existing infrastructure), we want to find the minimum cost network in order to cover the ten TPs as illustrated in Figure 4.

The solution obtained with the TS heuristic is presented in Figure 5. The cost of this network is $408,797. As we can see, the solution is composed of two node Bs of type C, one RNC of type A, one MSC of type A and one SGSN of type A. Note that with the sequential approach, the cost found is $422,508. This is a difference of 3.35%. Considering that the cost of UMTS network equipments is still very high, 3.35% is not negligible.

2.2 Update Example

Let's say that a network operator currently has a network infrastructure as the one presented in Figure 5. Due to its attractive plan, 35 new TPs want to subscribe to this provider. At the same time, five TPs are not satisfied and want to leave for a competitor. As a result, the operator needs to update its infrastructure at the lowest possible cost.

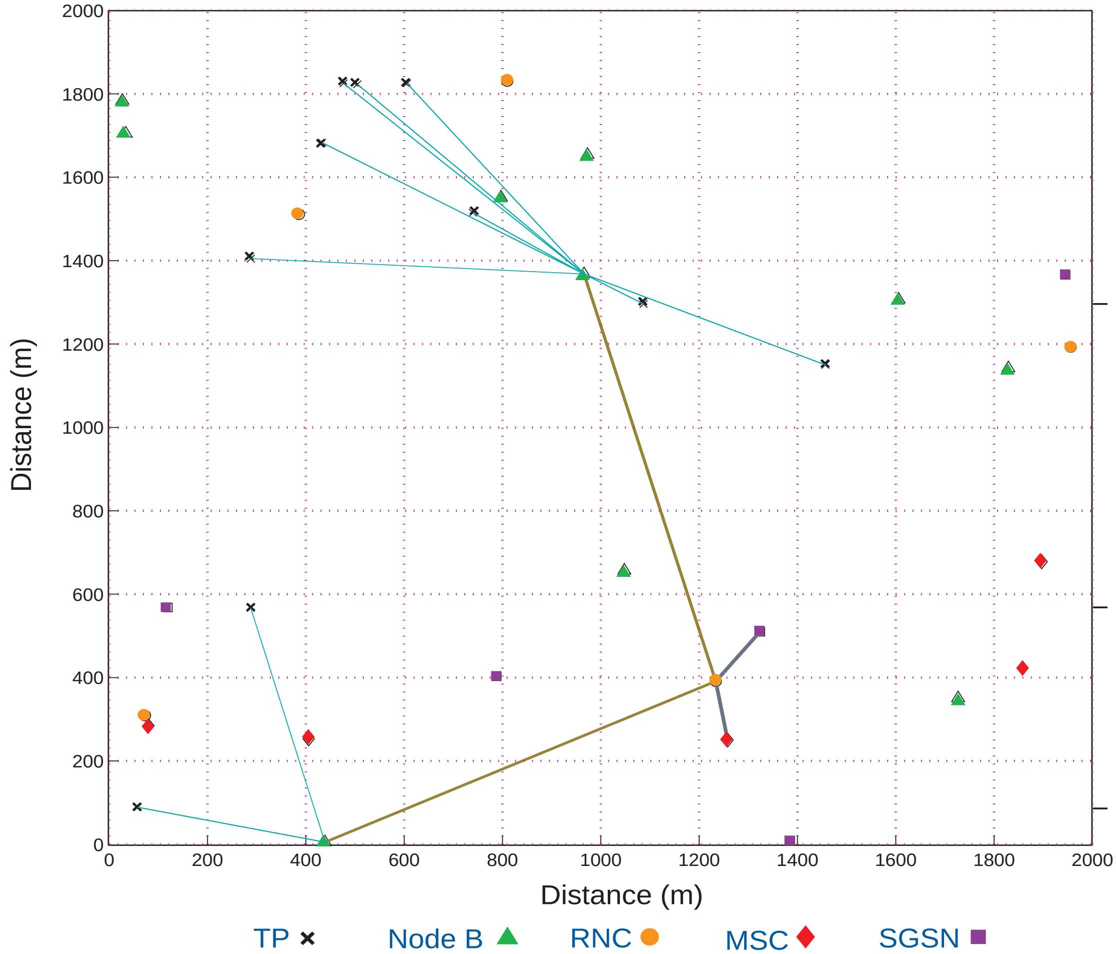

Figure 5: Solution to the planning problem

Besides the costs presented previously, additional costs are involved in an update scenario. There is a cost involved when removing (or moving) an equipment (see Table 7). There is also a cost of $100/km to remove a link between two equipments.

The solution obtained with the TS heuristic for the update problem is presented in Figure 6. The cost of this expansion amounts to $151,378. As we can see, four node Bs have been added in order to satisfy the new (and remaining) clients. The number of RNC, MSC and SGSN has not changed since they still have enough capacity to support this upgrade.

3. Conclusions

In this paper, we presented (with the help of examples) a new way to plan UMTS networks. The proposed approach can be used to plan a new network or to update an existing one. This can be very useful for service providers since the number of subscribers is continuously growing and they need tools to up-date their network in a cost effective manner.

We are currently building graphic interfaces in order to develop a software that could be used by network operators. The goal of this tool is to hide the complexity of the model and to provide an easy access to the users.

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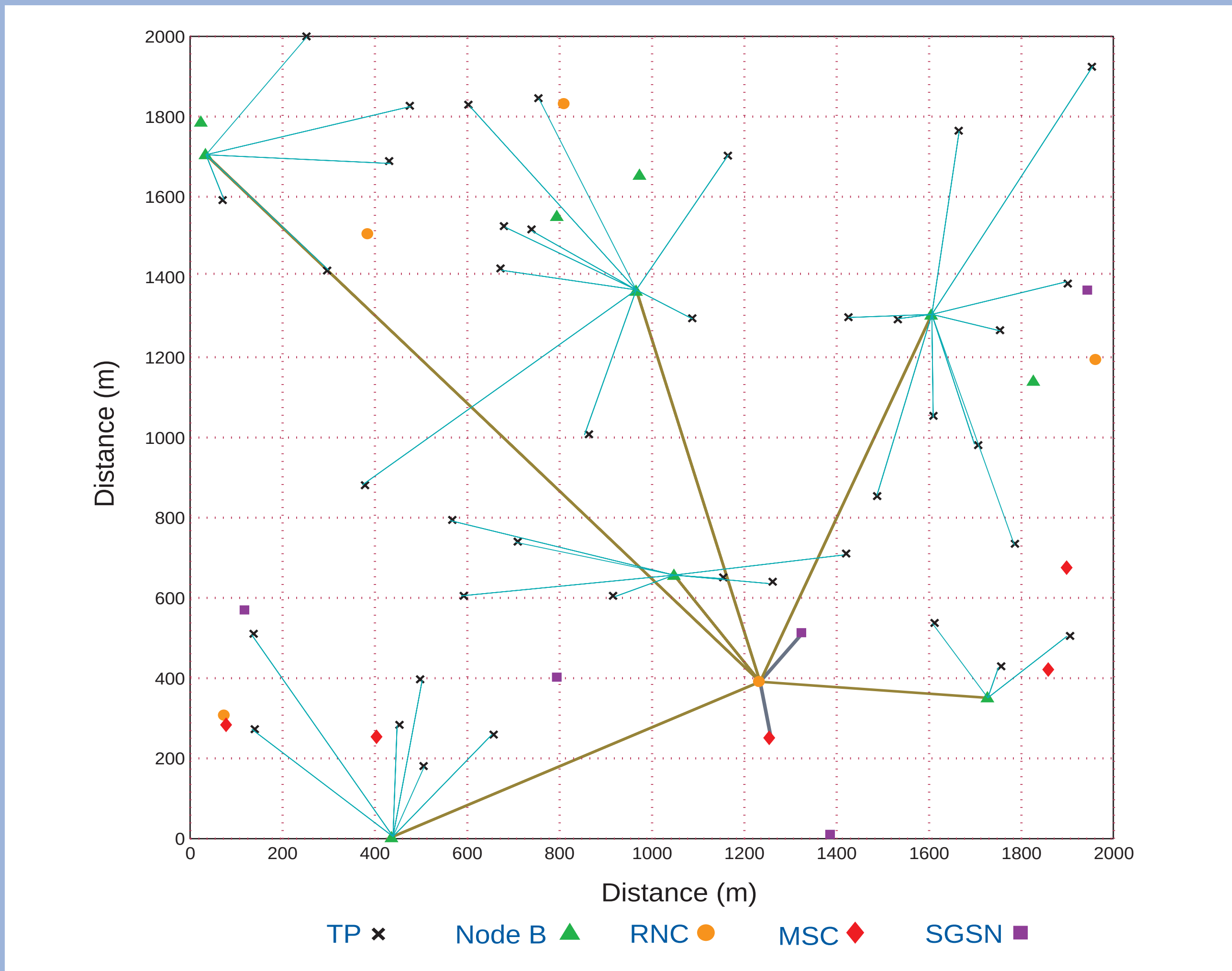

Figure 6: Solution to the update problem

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