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OPTIMIZED UTRAN TOPOLOGY PLANNING INCLUDING POINT-TO-MULTIPOINT EQUIPMENT

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Abstract
Network optimization strategies are core ingredients of radio access network planning for second and third generation mobile systems like GSM and UMTS. We present a combined approach for network topology optimization of the UMTS terrestrial radio access network (UTRAN) which considers the logical network structure as well as transport network aspects. We focus on including Point-to-Multipoint (PMP) equipment in UTRAN topology. Applications of the derived methods are illustrated with some reference examples from real-world network scenarios.

1 INTRODUCTION

With the introduction of UMTS a large variety of different mobile services became available to the cellular subscribers. In particular, different packet-oriented services extend the pure circuit-switched centered service offer available in 2G networks like GSM. The demand on date rate will also increase drastically compared for instance to GPRS networks. With this change in user behavior and increasing data demand, the importance of cost efficient network design of radio access networks is growing.

In this paper, we focus on optimizing the radio access network of UMTS networks. This includes the setup of new infrastructures as well as extending already existing networks by adding additional elements and equipment.

The choice of transmission equipment and the solution for backhauling traffic and interconnecting base stations play an important role in fixed network part of radio access networks. It determines the most cost-effective investment to be taken in order to deploy a network topology that guarantees high quality and sufficient level of network robust functionality.

In our project we extended the work of [3] and [4] in which relevant transmission aspects were already taken in account in the first steps of clustering the network. [3] and [4] focus on leased lines and point-to-point (PtP) microwave links of different bandwidth as possible solutions. Since the traffic demand is expected to grow, in particular in dense urban and suburban areas, point-to-multipoint (PMP) solutions for highly concentrating backhaul traffic becomes important in network design. It offers several benefits: high bandwidth to enable traffic concentration of many base stations and can also be easily used to groom traffic of 2G and 3G networks.

The structure of this paper is as follows. In Sec. 2, we introduce in more detail the problem of UMTS radio access network planning and the use of PMP equipment. The models and algorithms designed for automatic inclusion of PMP equipment are presented in Sec. 3. The application of the derived automatic planning methods to

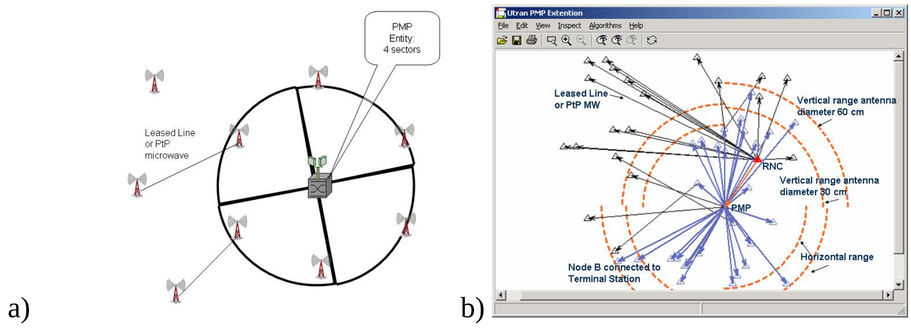


Figure 1: a) PMP entity, b) PMP entity with different ranges

some real-world network scenarios is shown in Sec. 4. Finally, in Sec. 5 we discuss benefits of using PMP in UTRAN and applying automatic planning methods as key procedure for decision support of network planners in state-of-the-art network planning tools for radio access network design.

2 UMTS RADIO ACCESS NETWORK DESIGN

The UMTS (terrestrial) radio access network (UTRAN) connects the base stations (called NodeB) to the core network. It contains the NodeB and the radio network controller (RNC) as well as the mobile switching center (MSC), carrying circuit-switched (CS) traffic, and the serving GPRS support node (SGSN), for packet-switched (PS) traffic. The NodeB are connected to one RNC via leased lines, PtP microwave links or PMP entities. A PMP entity is a collection of NodeB that are connected via PMP terminal stations (TS) to a PMP master station (MS) as depicted in Fig. 1-a). The RNC itself is connected to its respective MSC and SGSN. The logical network layout in UTRAN is described in [3, 4] in detail.

2.1 UTRAN network planning

UTRAN can be divided into the pure access part containing the fixed network infrastructure as well as the radio network part with the air interface between mobile terminals and the base stations, both parts have their own planning step in the UTRAN planning process.

The output of radio network planning is taken as input for the radio access network design. This input includes the number of base stations, their location and the traffic demand to be handled (including soft handover traffic).

In our approach, this design step decomposes into the following planning and optimization steps (see also [3, 4]): clustering of NodeB into RNC areas, placement of RNC within these clusters, inter-connecting RNC and MSC/SGSN, and network topology optimization within the RNC clusters.

2.2 PMP in UTRAN

PMP equipment plays an important role in UTRAN planning especially in high density areas. An advantage of PMP is that one PMP MS can serve a large number of NodeB which reduces link costs. Using PMP also allows simplier and more cost effective network extension for the operator - provided that he has spare capacity. All he has to do is to place an extra NodeB with its TS within the range of a PMP entity.

In this paper, we focus on including PMP optimization into the radio access network design. PMP-Optimization considers PMP equipment in addition to leased lines and PtP microwave equipment for the topology planning within the RNC clusters: placement of PMP entities, selection of NodeB to be connected to PMP MS and TS's, splitting of PMP entities into sectors, connection of PMP entities to the RNC, and connection of each so-called orphan NodeB via leased lines or PtP microwave.

Unlike PtP microwave connections, the radio transmission of PMP systems is not symmetric. Each PMP entity is divided into sectors (see Fig. 1-a)). For each sector a wide angle antenna connected to the PMP MS is used to broadcast the same signal to all TS's in the sector (downlink). On the the other side TS's use highly directional high gain antennas to direct the radio transmission to the PMP MS (uplink). For a detailed description of PtP and PMP wireless systems see [2]. For this project a sectorization of four 90 degree sectors is assumed, which is common for PMP systems (e.g. Siemens Product Skyweb [6]).

Capacity and range of PMP sectors are important inputs for PMP optimization problem, since they determine which NodeB and how much traffic can be covered by a PMP entity. The capacity of a sector depends on the configuration used: modulation of 4 QAM and 16 QAM, radio frequency channel bandwidths of 14 MHz and 28 MHz, 1 or 2 radio frequency channels (carriers).

Possible values for the SKYWEB Point to Multipoint Radio System are given in brackets. They allow maximum sector capacity of 155 Mbit/sec (with 16 QAM modulation, bandwidth 28 MHz, 2 carriers)[6].

PMP types are defined by modulation, channel bandwidth and number of carriers. The practical difference between them lies in sector capacity and costs, which depend on the above parameters. All this information can be defined in our model. Further parameters that influence the range of a sector are: frequency, climatic conditions, polarization, and antenna diameter of the TS.

The frequency range of the radio frequency bands used for PMP systems is usually global for whole area, hence this aspect does not need to be modeled. Typical frequency bands used by PMP in the UTRAN context are: 26, 28, 41 GHz ([6]). For this high frequencies the climatic impact can be described by rain zones, which can also (and often are) global for the entire project.

The use of two polarization schemes can reduce interference between PMP cells even though the same frequencies are used in each sector. However, horizontal polarization reduces the range of a sector. For our model a frequency reuse scheme 1 H/V (adjacent sectors have different polarization - see Fig. 1-b))) is assumed. It is however possible to cover applications using two vertical frequencies, namely by setting the horizontal range equal to the vertical range.

Since TS's use highly directional high gain parabolic antennas, the antenna gain is proportional to the square of antenna diameter. Depending on the frequency used, doubling the diameter of a TS antenna can increase the range by about 25%. In our model TS's may use two different types of antenna: basic and extended (see Fig. 1-b)).

The goal of optimized UMTS access networks planning apart from assisting the network planner and speeding up the planning process) is to minimize total cost of setting up and running the network. Main cost contributions considered in our approach are equipment costs and link costs [3]. For PMP equipment costs for PMP master and terminal stations, as well as costs for the links between PMP MS and

RNC have to be considered.

PMP master costs vary with PMP type - capacity depending on modulation, channel bandwidth and the number of carriers. Cost for TS's are given depending on the hardware configuration (e.g. antenna size) and the PMP type of the corresponding sector (modulation, bandwidth).

3 MODEL AND ALGORITHMS

Our optimization method consists of the following phases: **1)** reduce the number of possibilities in order to make the problem tractable during optimization; disregard all parameters that seem not crucial for solution quality; **2)** reduce the resulting optimization problem to easier combinatorial problems while retaining essential properties of the solution; **3)** use fast heuristic algorithm to solve approximately the resulting (hard) problem; **4)** fine tune the solution obtained with regarding local changes.

There are also some assumptions regarding the general approach. Since in many practical cases PMP equipment should be deployed in already functioning network, the architecture should not be redesigned from scratch. It also fits well to dynamically changing demands and growing traffic. So we make the following assumptions: **1)** PMP solutions are introduced after clustering, that is PMP connect only stations of the same cluster (see Sec. 2.1); **2)** PMP may be located only at the locations already assigned to NodeB. **3)** PMP entities are connected directly to RNC; **4)** A NodeB is connected to a TS, PMP MS, RNC or to other NodeB. The connection topology is a tree; **5)** Depending on the node type, there is a fixed number of connection lines of different type than can be supported.

In this section we describe our approach to determine localization of PMP equipment. The algorithm is executed for each cluster independently.

Phase 1 In this step each NodeB is tested for admissibility for placement of PMP MS. For each defined PMP type we test if it is possible to place PMP entity in the NodeB tested. We examine the number of NodeB for each sector and a gain for such position. The gain is the difference between the cost of a local "clique" formed by the same set of NodeB connected to an Access Concentrator and the cost of PMP equipment. For this phase PMP entity is assumed to have a circular coverage area with the radius equal to the range of the sector with horizontal polarization (which is smaller than the vertical one). If the PMP entity is profitable, then we qualify it for further phases of the algorithm. The PMP entity is also customized by choosing sector partitioning that takes into consideration the uniform capacity of sectors.

Phase 2 This phase is the key part of the algorithm. Its goal is to choose a set of PMP locations that provide highest gain. The point is that given two overlapping PMP locations, the gain for NodeB in the overlapping area is counted for both PMP locations. So in this case the total gain should be reduced respectively. On the other hand, for practical cases, the gain is not significant enough in order to remain positive in the case of any significant overlapping.

For above reasons, our approach is to solve the Weighted Independent Set Problem (WSI) for the PMP locations output from Phase 1.

In WSI problem we consider two PMP locations as dependent, if the intersection of their coverage areas contains any NodeB. The weight of a PMP location is the gain computed for this location. A solution of Weighted Independent Set Problem is a set of independent entities (non-overlapping PMP's) with the maximum total weight.

Unfortunately Weighted Independent Set Problem is NP-complete [5, 1]. Thus we have to use approximate solutions. We use two algorithms of this kind that are known for good performance. A straightforward approach for WIS Problem is the greedy algorithm described in [5].

Another natural strategy is the local search approach (see [1]): an attempt to replace small subset of candidates already included in the solution by some collection of non overlapping PMP Entities with greater total profit that does not overlap any of the remaining PMP Entities of the current solution.

Phase 3 For non-overlapping PMP Entities chosen during Phase 2 we build initial tree of links containing RNC, PMP MS's and TS's.

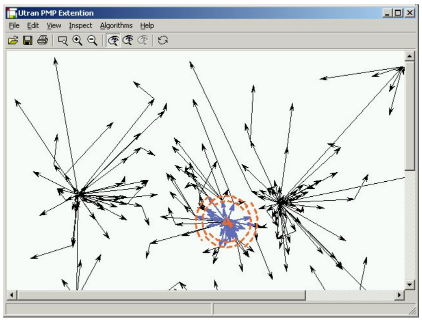
Phase 4 We add NodeB to the initial tree. We sort NodeB by their distance to the initial tree. Now we repeatedly consider NodeB with the minimal distance to the tree and add them to the tree in a cost effective way: if the NodeB is near PMP Entity but outside horizontal sector range, we consider two cases: if NodeB is inside a sector with vertical polarization – we add new TS to PMP Entity and link NodeB to this TS; second, if NodeB is inside the sector for an increased antenna diameter – we add a TS with larger antenna and link NodeB with it. Obviously, we can add these connections when there is enough sector capacity and the connectivity constraints are not violated. We now try improve the solution by detaching subtrees rooted in NodeB and trying to re-attach them while obtaining most cost effective design that conforms to the connectivity constrains.

Finally, we compare the cost of solution obtained this way with the initial solution.

4 APPLICATION

The algorithms of the previous section have been implemented in (portable) C++ and are integrated into the UTRAN optimization tool as described in [3, 4]. This tool runs under different platforms like Windows, Solaris and Linux. The PMP optimization is based on the existing UTRAN network structure either automatically generated or provided as input. Additionally, PMP specific data is used. Based on the provided RNC clusters, network solution using PMP is determined if PMP turns out to be beneficial in the scenario considered.

a)



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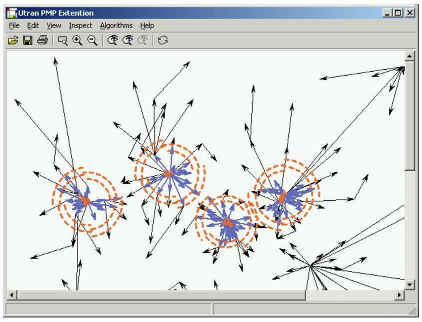

Figure 2: Cutout of PMP solutions for 359 NodeB

On the above network examples we compare PMP solution with leased lines solution using following parameters (see Sec. 2.2): leased lines of type E1 and STM-

1, PMP types with bandwidth: 14 MHz/28 MHz, modulation: 4QAM/16QAM, 1 or 2 carriers.

First we consider an area covered with 359 NodeB which has an average CS and PS traffic of 1000 kbit/sec each. This scenario is taken from a real network. The solution is generated for two different amortization periods (a) 2 and b) 4 years).

In this example placing PMP equipment already pays of for an amortization period of 2 years. In this case one PMP entity of 64 Mbit/sec capacity is placed (Fig. 2-a)).

For an amortization period of 4 years 1 PMP entity of 64 Mbit/sec capacity and 3 entities having a 16 Mbit/sec capacity are placed (Fig. 2-b)). If we compare the cost for the RNC cluster with the large PMP with pure leased lines solution we observe a profit of nearly 10%.

All computation times for the above example were less than 1 minute on a standard PC (Pentium III, 550 MHz, 256 MByte RAM).

5 CONCLUSION

In this paper an algorithmic approach for introduction of PMP positioning into automatic planning and optimization of UTRAN topology design has been presented. The algorithmic approach has been applied in a case study to different network scenarios. The examples of the case studies show that the profit of PMP solutions substantially increases with amortization period. This is due to the fact that PMP entities have high initial investment cost but low monthly cost, while in comparison - leased have high monthly costs.

PMP placement is feasible in particular for dense urban areas, however that cannot be based solely on NodeB density. Very often, the results are far away from our expectations based on viewing locations and density of NodeB's. This proves that automated planning could be of a great advantage here.

The PMP solutions generated using automatic planning approach can be used as decision support for network planners. The detailed radio conditions for proposed PMP MS and PMP TS have to be evaluated and fine tuned using radio planning tools for PMP equipment.

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