Design and Planning of Reliable Communication Networks

D. Colle , C. Develder, S. De Maesschalck, A. Groebbens, M. Pickavet, P. Demeester

Abstract **One of the research activities within the Broadband Communication Network group (part of the Department of Information Technology, INTEC) deals with network planning. The science of network planning has as aim to find the most optimal schedule for the deployment of a network. The goal of this paper is to elaborate on where network planning is situated in the daily life of a network operator and what kind of planning problems are under study in our research group.**

Keywords **telecommunication networks, operations research, network planning**

I. Introduction

In recent years, the telecommunication market has been evolving very fast, boosted by the ongoing liberalization. Because of the growing competition, it becomes very crucial and difficult for an operator to make the right decision for the deployment of its network. Network Planning tries to provide such an optimal network deployment plan for the future. Its overall goal is to optimize the profit of the network operator, by considering the expected revenues to be generated by the customers and the expected costs to implement the planned network.

II. Network Planning Process

It is clear that network planning is a continuous process and not a task that can be simply solved at a single moment in time. Since network planning dictates how the network should evolve in the future, it must rely on predictions. The longer in advance decisions are made, the harder it becomes to make an appropriate prediction. The predictions to be made are twofold:

1. **Customers**. Before a network operator is able to plan its network for the future he should be able to predict the number of customers that he will serve and their behavior (e.g., how much and how long will a typical customer occupy resources throughout the network?). Another important factor is to predict what price a customer will be willing to pay, as a network operator has to live from the revenue generated by its clients.
2. **Network deployment issues.** An operator can only plan its network, when knowing which technologies will be available at the time the network will be implemented, and what he will have to pay to buy, build or lease the necessary equipment. For example, Figure 1 shows a design problem related to the interconnection of SDH self-healing rings (see further). Traffic on the ring is always accessed with an ADM (Add Drop Multiplexer). An ADM has only two aggregate (higher bitrate signal carrying lower bitrate or tributary signals) interfaces and can only cross-connect (switch) traffic between these two interfaces or between one of these aggregates and a tributary interface. Tributary interfaces of ADMs co-located in the same building can be interconnected by manually placing a direct fiber or remotely/automatically via a central DXC (Digital Cross-Connect, having an unlimited functionality). However, the second solution may not be realistic for the targeted time, since cross-connects are harder to realize and thus become commercially available later in time than ADMs. Of course, not only technology aspects have to be predicted. For example, will the placement of an additional cable in the ground, through a particular city or street, be allowed by the government? Also the state of the real estate market comes into play, because buildings will be needed to store the equipment.

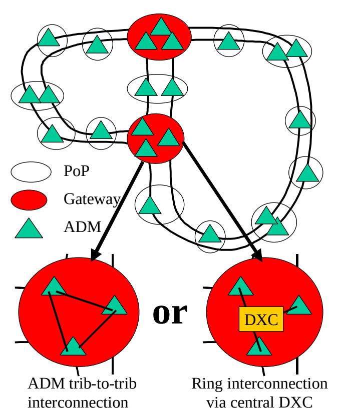

Figure 1: example of a ring-network design problem

Typically, the sub-problems to be solved within the complete network planning process are classified based on the time horizon they are targeting. **Strategic decisions** are made by **long-term planning (LTP)**: how will the network topology evolve (e.g., where to install network switches and which switches have to be interconnected via a direct line), which technologies will be deployed? More **tactical decisions** are part of the planning target on a **mid term horizon (MTP)**: for what time has the realization of the next line between two network nodes to be scheduled, which capacity has to be provided on this line, or do other lines need to be upgraded? At last the **short term planning (STP)** is dealing with **day-to-day** realization, configuration and testing of the network.

It is clear (from a theoretic viewpoint) that all these sub-problems are correlated. However, the overall network planning task is often relaxed to solving a sequence of **network design problems,** where each network design problem targets a single moment in the future instead of providing a full plan or schedule for the future.

III. Network Planning Problems

As discussed in section II, network planning is often relaxed to a sequence of network design problems targeting a different moment in the future. The goal of this section is to present the most common network design problems encountered in network planning.

D. Colle (and co-authors) are with the Department of Information Technology, Ghent University, Ghent, Belgium. Email: didier.colle@intec.rug.ac.be

A. Topology/Capacity Planning

As mentioned above, **designing a topology** corresponds to deciding where to install which network infrastructure. More precisely, one has to decide where the network nodes (in our example the PoPs, or Points-of-Presence, providing the network access to the customers and the gateways, where rings are interconnected with each other) have to be placed and how to interconnect these network nodes with each other via direct lines.

Capacity dimensioning tries to find out the required capacity for each piece of network equipment. Although capacity dimensioning is often restricted to the capacity of the network links, it is also important to dimension the capacity of a network node (e.g., processing capacity of an IP router, size of a telephone switch, or in our example the size of a DXC).

A pure topology planning problem is typically a LTP problem and pure capacity planning rather a MTP problem. However, an optimal (i.e. cheapest) network design can only be achieved by considering both problems at the same time. Let's consider the Public Switched Telephone Network (PSTN) for example. A **fully meshed topology**, where each handset is wired to each other handset, would not be very realistic because most of the connections would never be used. A **star topology**, with a single central switch, would not be meaningful either, because the central switch would simply be too large and the cost to wire each handset to this central switch would also be unrealistically high. Installing more switches closer to the handsets will increase the cost of the switches, but will decrease the cost to wire the handsets to these switches and to interconnect these switches with each other. Thus the typical **grooming problem** tries to find the optimal topology (topology planning) in order to meet the trade-off between the cost of line and node capacities (capacity planning dimensioning).

B. Network Configuration Problems

Section II situates network configuration problems in the area of STP. Examples of typical **network configuration problems** are: which timeslot on each link is assigned to which signal or which card has to be plugged in which rack? The problem, described above by Figure 1, was one of our research subjects and tried to find out whether to use a DXC or not to interconnected co-located ADMs. This choice becomes rather complex when considering the limited rack size of cheap ADMs, which may not be large enough to host all necessary tributary cards to terminate all the capacity of the ring and the fact that DXCs can cross-connect on a smaller granularity than the granularity of the ADM tributaries.

IV. Satisfying Service Requirements

As mentioned in section II an operator should not deploy a network for the sake of simply deploying a network. He should also be able to meet the end-users' requirements, in order to keep them satisfied and thus avoiding that they will go to a competitor. The requirements to be met are typically specified in a **Service Level Agreement (SLA)**. An important requirement from a network planning viewpoint is **service reliability**, discussed in section A below. Other requirements are presented in section B.

A. Design of Reliable Networks

To keep the customers satisfied, an operator should avoid that they are (frequently) confronted with the unavailability of a service. A first step in avoiding network outages is that the operator takes **preventive** actions like security rules (restricting and logging access to network infrastructure) or develops fire safety plans. However, not all network outages can be excluded that way. For example, a network operator is simply not able to prevent earthquakes, floods or other natural disasters. The most common (and of course more frequent) example of a network failure is a cable cut caused by a digging machine somewhere in the field.

Since a network operator is not able to prevent all network outages, a proper network planning process takes the network reliability into account from the very beginning (thus already in the LTP). When designing a network topology, the network planner should be careful to come up with **at least a biconnected topology** (e.g., rings are guaranteed to be biconnected making self-healing ring schemes very popular). If a network topology is not biconnected, a single failure can simply disconnect the network and any recovery mechanism would be useless. A **recovery scheme** is an automatic mechanism that **reroutes traffic along an alternative route** around the failing equipment (very similar to daily life deviations of the traffic on the road). Of course traffic can only be rerouted if there are **enough spare resources** along the alternative path. Thus a topology which is at least biconnected is not sufficient as outcome of the network planning process to guarantee network reliability, but the network planner should also choose the right recovery scheme and provide the necessary spare capacity for all **expected failures** (it is trivial that a network cannot survive any possible failure). A good design of a reliable network is typically a trade-off between the speed and intelligence of the recovery scheme, the amount of spare capacity needed and the failures that can be survived.

B. Other Service Requirements

Clearly, a customer is not only interested in service reliability but for example also in call blocking probability. A telephone user will not appreciate that his calls are frequently denied, as happens when the network is overloaded due to underdimensioning.

Of course the **Quality of a Service (QoS)** should be guaranteed. For example, the signal-to-noise ratio (SNR) or the bit error rate (BER) of a connection should be acceptable. In a packet-switched network (e.g., the Internet) packets are buffered temporarily in intermediate nodes. Therefore, one should be careful to keep the network delay and jitter (= delay variation) acceptable and avoid high packet drop probabilities due to buffer overflow.

V. Conclusions

We illustrated in this paper that network planning is a very broad research problem: it targets multiple time horizons, it takes into account all kinds of aspects, like the situation on the telecom and other markets, it covers many subproblems, etc. The main conclusion of this paper is that the outcome of this difficult network planning task has to be a network deployment schedule, which is as optimal as possible.

The content of this paper is giving a global overview of all our research topics. We have the intention to include in our poster a more detailed description of one of the sub-problems currently under study.