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A SURVEY ON NETWORK PLANNING AND TRAFFIC ENGINEERING FOR DEPLOYABLE NETWORKS

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Abstract: *This paper presents a survey of the models and software applications used in telecommunication networks that can be used to carry out network planning and traffic engineering processes in deployable networks. Deployable networks are intended to provide communication services for organizations with responsibilities for emergency response or for government structures.*

Keywords: network planning, traffic engineering, traffic models

1. Introduction

This paper presents a synthesis of models, methods and applications in the literature that can provide network planning (NP) and traffic engineering (TE) solutions for deployable communications networks (DNs). NP and TE represent debated topics in specialized papers published by both academic researchers [1-3] and communication industry specialists [4-9].
There are very few references in the literature regarding their use for DN design [10].DNs are networks designed to provide communication services for organizations with emergency response responsibilities [6,11-13] or for mobile government structures, including the military [10,14,15]. Due to the objectives of the organization, the structure of the network changes with more frequently compared to that of the classic networks (weekly or even daily). The changes are due mainly to the different locations of the communications centers (CCs) that form the backbone network (BN) and the redistribution of subscribers from the points of presence (PoP) that form the access network. CCs are fixed or mobile [6] and users can benefit from all categories of services available in a modern network. The complexity of the planning process of these networks is not due to the size (the number of CC can reach to an order of tens of units [13]) but to the fact that they have to accommodate technologies specific to both packet and circuit switching. If we also consider the need for rapid and continuous reorganization of the network structure, we create an overview of the challenges facing the network planner and the need to identify methods, models and techniques to optimize this process.
NP and TE are stages in the network design process (ND). ND is the subject of generally more extensive papers, guides, manuals or specialist books [1,6,7,13,15] in which, in addition to the planning algorithm, the authors provide detailed information about communication technologies and methods of network testing and implementation. The purpose of NP and TE is to design and optimize the

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network so that it has sufficient capacity to provide services at the parameters specified in service-level agreements (SLAs) [9].

In the literature there is no unanimous algorithm promoted by specialists for network design. The stage of the activities, more or less detailed, differs depending on the business plan and the type of network [6,7,9,16]. It is this article's purpose to present reference only for those stages of ND necessary for the development of NP and TE processes.

2. Traffic estimation

In DN, the traffic is generated in the PoPs and is transported between them through the backbone network (BN). In order to know the network-specific traffic values that the planners will design, there are two methods available: estimating the values using traffic models or measuring the traffic values at various points in the network.

2.1.Voice over circuit switching

The estimation of telephone traffic is based on the knowledge of the statistical behavior of traffic generating sources. There are many works in the literature that address this issue [1,2,13,16]. The start of research in this field was given by A.K. Erlang and led to the identification of a relationship between the value of incoming traffic in the telephone switch, the operating parameters of the switch, the value of outgoing traffic from the switch and the probability that users will not be satisfied with the requested service. Subsequently, the researchers developed a number of other models depending on the behavior of the switch and the number of traffic-generating sources. The vast majority of these models start from the presumption that, from a stochastic point of view, call duration is exponentially distributed and call arrival follows the Poisson process [1]. Syntheses of these models are presented in [1,2,13,15,16]. To estimate the traffic required to provide voice services, we have to apply the following procedure:

First, determine the required voice traffic at a switch, in Busy Hour according to equation (1):

$$y_i = \frac{a \cdot T_m}{1h} = \frac{n \cdot a_m \cdot T_m}{1h}\ [Eh] \qquad (1)$$

Where y_i is the incoming traffic in the switch, a is the total number of calls made by the network subscribers in the busy hour, T_m is the average duration of a call, n - the number of subscribers and a_m - the average number of calls made by a subscriber[13,16]. The voice traffic is calculated in Erlangs (E).

Second, the number c of circuits necessary to ensure the connection of local subscribers with subscribers from other centers is deduced by applying the stochastic model that best suits the statistical behavior of subscribers, the blocking probability (P_b) and, for some models, the maximum waiting or delay call time(W). In order to aggregate traffic values determined by the voice service, measured in Erlangs, with the traffic values required for data services, measured in bps, for each previously determined circuit a traffic value with a constant transfer rate of 64kbps will be taken into account. This value corresponds to the data flow obtained by Pulse Code Modulation (PCM) coding.

2.2 Voice over Internet Protocol (VoIP)

For VoIP, in addition to the number of calls and statistical behavior of users, the value of traffic demand depends on: type of codec used for transmission (BW_{AC}), rate of control data transfer (BW_{CD}), bandwidth required to encapsulate data in User Data Protocol (UDP) flow ($BW_{overUDP}$), bandwidth required to encapsulate data in IP datagrams (BW_{overIP}) and bandwidth required for the network protocol ($BW_{overUDP}$) [5,6,17,18]. A reserve of 25% for jitter compensation has to be added(equation 2):

$$BW_{VoIP} = 1.25(BW_{CD} + BW_{AC} + BW_{overUDP} + BW_{overIP} + BW_{overNET}) \qquad (2)$$

2.3 Packet switching

Traffic in packet switching is characterized by the following properties: *long-range* *dependence*, [2,16,19], *self-similarity* [19-21], *multifractality* [22] and *heavy distribution tail*. [2]. There are also papers that argue that at the critical time scale for achieving QoS traffic can be characterized by a Poisson distribution [23, 24]. To predict traffic values at any time scale, [25] proposes a model that captures the traffic correlation structure using a scaling coefficient and the wavelet coefficients.

Due to the segmentation of data into packets and the specificity of user applications, the cumulative transfer rate of data flows varies greatly from one moment to another and shows the tendency to group packets, generating a *bursty* traffic pattern [2,19-21].

Models used to estimate packet switching traffic can be grouped into two categories: *temporal* and *spatial* [2, 3, 16, 26].

From a ***temporal*** point of view, it was observed that data traffic manifests daily and weekly cycles depending on the type and intensity of user activities. Due to the gradual increase in the number and transfer rate of new services, this pattern also shows an increase over time, from year to year. These cycles often overlap with random fluctuations due to unpredictable events. This type of behavior can be modeled using standard time-series analysis taking into account cyclic (seasonal) components, *S(t)*, long-term evolution, *L(t)*, random fluctuations of aggregate traffic, *W(t)* and an additional random, impulsive component, *I(t)*, for extreme traffic variations such as Denial of Service attacks. The time models presented in [26] and [3], allow a consistent estimation for the variations of the aggregated traffic flows. The parameters used in the estimations are easy to determine from previous measurements or records- equation (3):

$$x(t) = L(t)S(T) + \sqrt{aL(t)S(t)}W(t) + I(t) \quad (3)$$

In situations where the traffic pattern is difficult to model, it is preferable to use *queueing models*. In order for the communications link to cope with unforeseen growth and burst grouping of packages, a capacity override factor is used in the design. In [3], this factor, called SOP (*Safe Operating Point*) is determined statistically from the data obtained from the measurement so that the load of the connections does not exceed 80% of the capacity more than 5 periods of 5 minutes per month. In [2,8,16] it is proposed to estimate this factor according to the maximum delay of end-to-end packets and the use of different value factors for flows with different QoS priorities.

Time models are used to size a link. [27] presents a synthesis of the techniques used to estimate the channel bandwidth and a taxonomy of the instruments that can be used for this purpose (Cprobe, Sprobe, Nettimer, Pathload, Cap, Treno, Pchar).

Spatial models allow the analysis of the traffic distribution at a given time on all BN connections. The spatial distribution of traffic is analyzed using the traffic matrix (TM). If traffic value data is available for the entire network, congestion that may occur on certain links can be avoided by routing flow segments to other routes. The most used models are described below.

Skewed distributions models are used for situations where most of the network traffic is made with a small number of very high value streams and the designer chooses to apply techniques based on traditional statistics (and not heavy-tailed ones). Skewed distributions follow an approximate law of traffic distribution between the elements of the matrix of 80-20 (80% of the traffic is generated by the largest 20% of the TM elements) [34].

Gravity models are inspired by Newton's law of gravity. In these models, traffic between nodes is considered to be proportional to the volumes of traffic leaving and entering them according to (4):

$$T(i,j) = \frac{T^{in}(i) \cdot T^{in}(j)}{T^{tot}} \quad (4)$$

where $T^{in}(i)$ represents the traffic entering the node *I*, $T_{out}(j)$ is the traffic matrix leaving node j, and T^{tot} is the total network traffic calculated with equation (5).

$$T^{tot} = \sum_k T^{in}(k) = \sum_k T^{out}(k) \quad (5)$$

The model is based on the condition of preserving network traffic, according to which traffic is considered neither created nor destroyed.

The *destination-based multi-commodity flow model* [28] proposes a solution for optimizing traffic in a hybrid network with circuit and packet switching. It uses the principle of optimizing the objective functions encountered in *gravity* or *min-max utility* models. The model proposes the additional realization of direct links between any two nodes of the network in order to reduce the delay due to the additional processing in the transit nodes.

Aggregation of data flows. Considering the traffic profile by application involves using different levels of prioritization through QoS policies. Given the large number of data services, application profiles can be very complex, which is why they are aggregated into categories [3,29]. In these situations, at the design stage, traffic matrices for each category will have to be deduced. Subsequently, they will be aggregated so as to obtain a single matrix. For DNs that use the two switching categories, the aggregation of service categories becomes mandatory.

3. Network simulation

The purpose of the simulation consists in obtaining predictions regarding the framing of the network parameters within the allowed limits and the determination of the capacity matrix. If one or more parameters are not met, the logical and physical structure of the network is changed and the simulation process is resumed [30]. Three categories of models are used to optimize traffic: a) models that take into account the statistical properties of traffic [31,21,22], b) models that use hybrid prediction algorithms [32] and c) models that optimize an objective function [2,20,3] by solving linear programming problems. Depending on the objectives pursued, one or more types of software applications can be used (eg. MATE, NPAT, OPNET, NNEC, Glomosim, ITS Telecom, HTZ Warfare).

4. Network optimization

Optimizing network performance is a continuous and iterative process that involves performing NE and TE actions to optimize resource utilization, maximize QoS and minimize congestion, reduce end-to-end delay, reduce lost packets, and reduce power consumption [9,33].

Traffic engineering is used to reduce congestion by balancing loads if it is found that traffic predictions are different from those estimated, [2,3,16,34]. Traffic redistribution involves modifying the traffic matrix to match the new values determined by the migration / redistribution of users between PoPs. The planning horizon is short (days). The planner can rely on data from traffic values obtained from measurements. [9] presents a summary of the practices that can be used to perform the measurements and process the data obtained. If measurements made in several stages are available, the temporal evolution of the traffic matrix can be determined. It is recommended that the temporal analysis be performed for the highest possible degree of traffic aggregation. The components *S(t)*, *L(t)*, *W(t)* and *I(t)*, in equation (3), will be deduced. If no previous measurements are available, the new traffic volume is estimated with statistical models. The volume obtained will be redistributed on each link of the matrix using the standard method presented in [3], or using the *gravity*, *tomogravity* or *Kruithof* models presented in [3,4,13,35-37]

NE involves network restructuring. If at least part of the network nodes change location, the entire network or at least part of it will be redesigned. The key difference from the original design is that traffic measurement results are now available for users who are redistributed on the network. If there is no such data for the new segments, traffic requirements will be estimated as in the initial planning situation. A very promising topic for real-time traffic optimization is SDN (Software Defined Network) technology. By decoupling the control plan from the data plan, SDN ensures the simplification of network management and control [33,38]. The fact that the market for communications devices today offers network devices with SDN support and that applications that allow traffic management (including OpenFlow) are open-source, make this technology very attractive. To this extent, literature provides works that address topics similar to classical networks such as: network protocols [33], algorithms for TE [39-41], traffic measurement and correction solutions [42] or techniques of congestion minimization [33].

5. Conclusions

Due to the fast and continuous reconfiguration of the DN structure, NP and TE become a challenging task for the network planners. In this paper we have presented the models, methods and software applications highlighted in some specialized publications that facilitate the network design process.

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