Int. J. Electron. Commun. (AEÜ) **58** (2004): 183–191
http://www.elsevier.de/aeue

International Journal AEÜ of Electronics and Communications

Aspects of Switching System Analysis a Centuries Evolution

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Dedicated to Professor Rudolf G. Schehrer on the occasion of his 65th birthday

Abstract: Traffic Theory has accompanied the evolution from early switching systems to an omnipresent communication infrastructure through the last century. Targeting at the mathematical modelling of call attempts at first the main goal was the dimensioning of telephone infrastructure. Emerging new services, mobile communication environments and the integration of packet style communication links into by then well known switched circuit equipment has put new challenges to traffic theory. Still new interpretations and facets of the basic models are found and elaborated to make traffic theory useful for modern systems as the internet.

Keywords: Traffic theory, Network analysis, Data visualisation, QoS

1. Introduction

The institute of Electronic Systems and Switching, led by Prof. Dr.-Ing. Rudolf Schehrer, has accompanied and taken part of the evolution of communication systems throughout the last 3 decades. This paper comprises notes on milestones of this work. Early issues were concentrating on the design of computer based and decentralized switching systems that would compete against classical electro mechanical designs. The scientific results led on to the ISDN era in the late 1970's, where service integration forced new strains of thought to complement the capacity oriented design of switching systems so far.

The emerging internet in the early 1990's and the simultaneous need of mobile access to communication resources added further challenges as packet stream multiplexting resulted in and contributed to ATM systems, providing a promising techology for multi service backbones. Modelling the data traffic itself instead of the utilization of trunks came into focus, while the interaction of signalling and transprort protocols for the sake of seamless mobility opened up complete new fields of research. The multitude of parameters, all showing different and partly long time correlated distributions became a severe challenge as the amount of data to be analyzed grew steadily in the recent years. Due to that, new approaches to handle the data of experiments and measurements of real traffic had to be devised.

Received February 20, 2004.

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A snapshot of the current work at the institute shall highlight these activities. Section 2 and 3 depict the application of classical traffic theory to modern mobile switching systems for the case of hierarchical networks. Section 4 gives an overview on a concept of "localisation" defined by a distance metric which is derived from a neighbourhood of information, targeting at a distribution of relevant information to a specific set of consumers.

Section 5.2 finally highlights state of the art methods to deal with the problem of getting proper information for the models devised earlier out of huge amounts of data. In addition, concepts of visualizing network traffic are introduced.

2. Aspects on calculation of hierarchical networks

During the last years the interest in mobile communication networks has tremendously grown. At the end of May 2003 there were solely about 860 Million subscribers for the leading technology GSM worldwide, not considering the growing number of mobile subscribers for other technologies. According to forecasts the number of mobile subscribers will increase further. Because of the limited frequency spectrum an efficient use of the available frequencies is an important aspect in mobile communication systems. To serve the growing number of customers the available frequencies have to be reused. For that reason the service area is split up into cells.

When a mobile host with an active call moves from one cell to another the responsibility for that mobile hosts (MH) has to be handed over to the cell, into which the mobile host is moving. This procedure called *seamless handover* can be regarded as the most important service feature to the customer. If the destination cell namely has no available channels, the call is terminated which is highly undesireable.

To minimize handover failures in mobile cellular communication networks several handover policies have been developed. One idea is based on the reservation of channels in every cell only for handover requests of neighbouring cells. As a result new call requests and a handover requests are competing for the remaining free channels of the corresponding cell. In this context it is important to know what blocking probabilities for both types of requests can be expected dependent on the number of reserved channels.

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For future communication network with additional overlaid macro cells in addition to the already existing micro cells the importance of this question will be intensified.

2.1 Reservation mechanism

Regarding channelized systems such as FDMA or TDMA, the capacity of a cell is limited by the number of frequencies or time slots. If there are a new call request and a handover request at the same instance both request are competing for the remaining free channels of the destination cell. Reservation of a portion of available ressources in the destination cell is sensible to increase the QoS of the ongoing call. However, this is synonymous with increasing the blocking probability of a new call. At best both QoS parameter, the handover blocking probability and the new call probability, fall below under an acceptable value.

Keeping in mind that handover requests shall have precedence over new call requests, the network designer can determine the expected blocking probabilities dependent on the number of reserved channels (*Guard Channels*) and the offered load. Since the offered load isn't static, the number of guard channels has to be chosen carefully not to limit the total amount of traffic being serviced. If the reserved channels are varied according to the traffic condition, this problem will be possibly avoided, assuming an opportunity to measure traffic parameters is given. But for practical reasons the number of guard channels is often held fixed [10].

On the precondition that the cellular network is homogenious a single network cell can be isolated for further examination. For this entity the blocking performance can be computed based on the following assumptions, which have to be checked in case of doubt e.g. by measurement:

- The arrival process of new calls is a Poisson process with rate λ_N
- The arrival process of handover calls is a Poisson process with rate λ_H. This rate results from the aggregation of handover requests of all neighbouring cells.
- For both type of calls the channel holding time is negative exponentially distributed with mean $1/\mu$

If there were n channels in a given cell with $(n-r)$ reserved channels for handover calls solely, the cell channel occupancy can be modeled by a continous Markov chain with $(n+1)$ states as shown in Fig. 1. Then the steady-state probabilities of the $(n+1)$ states p_i with $0 \leq i \leq n$ can easily derived by solving the recursive equations [11]. In consequence the blocking probabilities are known as well. The benefit of this calculation method in contrast to a numerical method is an analytical dependence on the input variables.

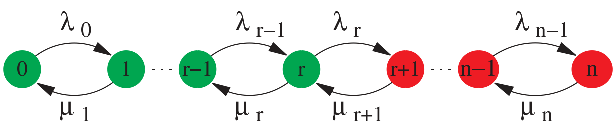

Fig. 1. State transition diagram (single cell).

2.2 Extension by overlaid cells

On the basis of the traffic density in the covered area the architecture of future communication network is extended by overlaid macro cells in addition to the already existing micro cells like shown in Fig. 2. Whereas macro cells are predestined for high mobility users (e.g. cars) and for low-density area like country, micro cells connect to low mobility users (e.g. pedestrians) and achieve high spot traffic in cities or business offices. Employing this strategy the performance of the network can be improved. In addition macro cells can also be used as overflowing channels when no free channels in the micro cells are available.

In principle the steady state probabilities can be calculated in exactly the same way like described above for the single cell. However, there are extra aspects to think about.

- In a two-tier network architecture the reservation can take place in the micro cell, in the macro cell or in both cell layers as well.
- Due to the suitability of the different layers in the network hierarchy an introduction of additional thresholds suggests itself. Assuming the velocity of the mobile hosts is obeservable, the requests can be classified in the following manner, where the r_i indicate the threshold like noted in Fig. 1:
  1. slow MH, handover, r_1
  2. slow MH, new call, r_2
  3. fast MH, handover, r_3
  4. fast MH, new call, r_4

  By exclusive reservation in the micro cell and by choosing $r_i > r_{i+1}$, it is garanteed, that fast users will be primarily served by the overlaid macro cells if in the micro cell there is no capacity available.
- The order of the difference equations is equal to the number of cells considered in calculation.

Hence the number of possibilities is increasing with the number of regarded cells. Furthermore the degree of the difference equations and the number of input parameters complicate the calculation of the probabilities.

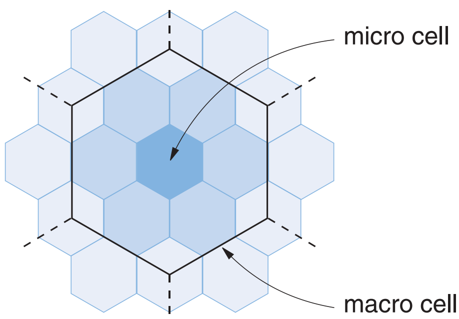

Fig. 2. Overlaid macro cell.