GENERALISED SYSTEMS APPROACH TO MODELLING ATM TELETRAFFIC

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ABSTRACT

Teletraffic phenomenon in classical and new telecommunication networks can be more systematically described and different system-type problems can be effectively solved using fundamental concepts of systems and GSPS (General Systems Problem Solver) methodology. Basic presupposition is that general systems methodology is usable as a logicomathematical methodology in formulation, derivation and explanation of relevant traffic traits of telecommunication network in structural and process dimensions. In this paper teletraffic phenomenon is defined on the object of interest (ATM teletraffic network) and relevant variables for effective network design and traffic management are discussed. Systematization of ATM teletraffic descriptors is derived from defined ATM traffic parameters.

INTRODUCTION

Traffic phenomenon in telecommunication networks were not analysed and described using general systems approach and methodology. This is a reason for difficulties in translating the existing teletraffic models developed for circuit-switched voice traffic to the networks based on packet and cell transfer modes. Expected growth in amount of teletraffic and emerging of new types of teletraffic over integrated ATM network indicate that new modelling approach is needed [1], [2].

The paper considers the generalized approach to modelling integrated teletraffic systems with packet-cells transfer modes, i.e. ATM (Asynchronous transfer modes) network. The approach is different from technical considerations of telecommunication network based on partial knowledge domene (switching and switch control, transmission technique, network protocols, etc.). We suppose that basic knowledge from technical disciplines have to be supplemented by systemic knowledge to improve understandings and overall problem solving in teletraffic systems.To keep up with the new customer-oriented telecommunications paradigm, generalised systems model has to be flexible and include humans as inherent part of telecommunication systems. According to new telecommunications paradigm the system adaptivity for different subscriber and user profiles becomes the most important requirement.

Traditional teletraffic model developed for telephony (traffic measurement in Erlang or CCS) cannot be directly used for traffic description of new ATM network. Voice, data, video and multimedia traffic have to be defined as particular traffic classes with representative space-time, bandwidth and QoS (quality of service) specifications. The proposed model estimates ATM traffic variables in relation with different class of information flows and specified performance measures. Papers based on experimental analysis confirm unexpected degree of cell loss and delays in the first ATM networks designed under traditional teletraffic assumptions [7], [8].

The flexible and efficient sharing of network resources assume traffic specifications which reflect the real traffic demand and optimise the requested resources. To generalise and simplify this basic task and problem we consider a collection of concepts related to fundamental traits of complex networked systems.

General Structure of Systems and *Architecture for Systems Problem Solving* [Klir, 1985] provide some essential concepts as background and support for systematic modelling of multiservice teletraffic network. The necessary connection and association between *object* (ATM teletraffic network) and general structure/process description require considerable efforts. We can use broad conceptual frameworks which offers two different (orthogonal) dimensions on meta-levels of description. The first dimension is structural with part-whole relationships. The second is process dimension which allows embedded patterns or structure to which we can adapt spatial and temporal description of system without falling into the trap of ultracomplexity.

RELEVANT SYSTEMS "BACKGROUND"

Proponents of systems theory consider this theory as a level of theoretical model-building which lies between the highly generalised constructions of pure mathematics and the specific knowledge of the specialised disciplines. We want to use general systems research and other supports from systems science in developing models for teletraffic ATM systems on generalized or metalevel.

GSPS (General Systems Problem Solver) is a usable conceptual and mathematical framework for dealing with large well-defined types of systems problems. The current version of the GSPS is described by Klir [5], and supported with several papers at various levels of sophistication and mathematical formalisation [6]. One of the basic role of GSPS is to assist its own user as a *road map* of problem solving. GSPS assumes combination with traditional disciplines within which the considered problem has arisen.
Respecting systemic knowledge hierarchy it is possible to identificate relevant basic stages in investigating teletraffic system (Fig. 1.).

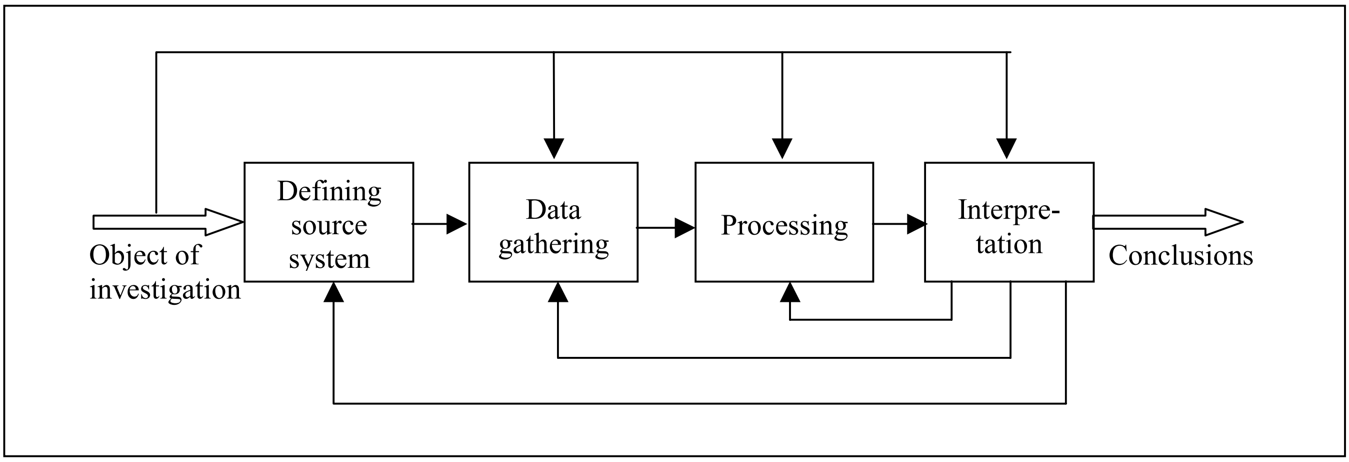

Fig. 1 *Basic stages in investigating teletraffic system according to GSPS framework* (according to source [5])

G.J. Klir describe an epistemological hierarchy of general systems which provide the framework for deal with increasingly knowledge structures [6]. Source systems are at the lowest level of hierarchy and data, generative and structure systems are defined in increasing order of knowledge content.

A *source system* is defined with consideration of relevant attributes of an object systems and backdrops (time, space, populations). In the GSPS framework a source system is at the epistemological level 0. Position includes a set of variables, a set of potential values for each variable, and some operational way of describing the manifestations of associated attributes.

For defined source system, data are gathered and organised in a suitable form. Next stage is data processing with the aim of determining support-invariant properties of the relevant variables. After data processing, proper interpretation in relation to the purpose has to be given. In several cases it will be necessary to process the data again or even redefine a source system.

At epistemological level 1, the source system is supplemented by actual states of the basic variables within the defined support set and we have *data systems*. Data from ATM teletraffic system can be obtained by measuring relevant traffic variables.

The GSPS framework recognise two forms of generative systems: behavior systems and state-transition system. The role of the behavior functional descriptions is to characterize a relationship or constraint of the variables. Examples of behavior function are selection functions, probability distribution functions, possibility distribution functions, etc.

Higher epistemological levels include knowledge of support-invariant relational characteristics of the variables through which the data can be generated. The aim of the support-invariant constraint characterisation is to describe a process by which states of the basic variables can be generated within the support set for initial and boundary condition.

At epistemological level 4 the system consists of a set of systems (defined at lower levels) and some rules or procedures by which the changes in the lower-level systems are described. Meta systems at level 5 and higher orders can be defined recursively in the similarly way.

CONCEPTS FROM TRAFFIC ENGINEERING AND QUEUEING THEORY

Basic purpose of teletraffic models is to support network design and traffic management. To be successful, modelers must quantify teletraffic generated by end-users and determine network resources needed to meet system-perfomance requirements at minimum cost. The concept of sharing telecommunications resources through switching and transmission facilities raises the engineering question how many of shared resources must be provided to ensure adequate user perfomance. Several concepts and models from queueing theory and network design can be used for teletraffic analysis and design of teletraffic networks.

Classical teletraffic models are developed for public switch telephone network with circuit-switched (voice) traffic. Traffic load is calculated simply by basic quantities:

$$A = \lambda \cdot T_S \quad \text{[erlang]}$$
$$A = \lambda \,/\, \beta \quad \text{[erlang]}$$

where:
A – offered traffic load or traffic intensity
λ – number of calls per unit time or arrival rate
T_S – means holding (or service) time
β - servicing rate ($T_S = 1 / \beta$).

The unit of traffic load in any particular network element is named erlang. One erlang of traffic is equivalent to a single call (user) who takes possession of a single resource 100% of time.

The statistical characterisations of arrivals and the holding times are essential for designing network facilities and performance evaluation. In the basic model, both quantities follow a negative exponential distribution and offered traffic load is defined for defined space-time frame (network system and relevant period of time) in stationary conditions.

The main voice traffic engineering problem was to determine the probability of blocking of a trunk system given an erlang load and the number of circuits (channels) in the system. Erlang's first formula (for smaller systems) is the mathematical formula most frequently used for determining the blocking probability and to determine capacity for the decided quality (grade) of service (for example, 1 % loss during busy hour).

In the *delay teletraffic system* relevant performance is characterised by the Erlang's second formula and associated equations for delay. The relevant descriptors of traffic and network resources are:

> message arrival rate
> average message length
> line (transmission) speed
> buffer and processor capacity.

The average message length and transmission speed in packet networks are treated separately because message length is not controllable by the system. For time-sensitive data traffic (query-and-response), which usually involve human operators, traffic description is focused on delay perfomance during busy hours.

Stochastic models of circuit-switch and packet traffic in the past were almost Markovian in nature, or more generally: short-range dependent traffic processes. Network operators used those models for calculating the expected traffic and dimensioning traffic routes and switching capacity for specialized (telephony and data) networks. These calculations supports plans and investment decisions where, when and how to increase the existing capacity.

Although the teletraffic theory for telephony and some types of data traffic is well developed, adequate models for multiservice cell-mode networks have not yet been developed. The teletraffic generated by data, video and multimedia applications have a great burstiness which can hardly be described by a static set of traffic descriptors used for voice traffic over circuit-switch networks. Using general systems approach and GSPS framework we want to consider ATM teletraffic as an object of investigation with the purpose to describe the relevant systems attributes, specific and general variables in relation with specified ATM and Broadband ISDN standards and recommendations.

SYSTEMATIZATION OF ATM TELETRAFFIC DESCRIPTORS

Starting with the fundamental purpose of ATM teletraffic system (→efficient and effectivelly service providing), we want to define system of relevant ATM traffic descriptors and associate them with service classes and categories. Effective network design and efficient traffic management are necessary to ensure that the priorities of the and-users, network operators, service providers and other stakeholders are met. Traffic contract for ATM connection specify the user requirements and transfer quality that the operator undertakes to maintain. Traffic management also includes connection admission control, traffic shaping and traffic policing [10]. The quality of network bearer service is defined as ATM network QoS (quality of service) and described in terms of network parameters.

Using existed ITU-T reccomendations and ATM-Forum specifications, we can review system of ATM teletraffic descriptors. In respect to ATM operator commitments, there are two basic QoS class of ATM services:

1) “traffic parameters specified”
2) no traffic parameters specified”.

In first QoS class there are next service categories:

> CBR (Constant Bit Rate)
> VBRrt (Variable Bit Rate, real-time)
> VBRnrt (Variable Bit Rate, non-real time)
> GFR (Guaranteed Frame Rate).

In second QoS class there are “best-effort” services for which operator makes no quality commitments. Those services are:

> UBR (Unspecified Bit Rate)
> ABR (Available Bit Rate).

UBR and ABR utilise the network capacity available after CBR and VBR service have consumed the capacity they require.

System of ATM traffic descriptor parameters is not yet been developed. Only one traffic parameter has been clearly defined (PCR-Peak Cell Rate), but there are a number of other relevant parameters for source traffic and connection traffic descriptions. Those are:

> SCR (Sustainable Cell Rate)
> MBS (Maximum Burst Size)
> MCR (Minimum Cell Rate)
> CDVT (Cell Delay Variation Tolerance).

For ATM service with Constant Bit Rate connection, only Peak Cell Rate (PCR) parameter needs to be specified in each direction. If a Variable Bit Rate connection is being requested, than PCR, SCR and MNS parameters have to be specified.

ABR teletraffic is specified by the PCR and MCR parameters. UBR teletraffic is specified by the PCR parameter and a “best effort indicator”.

The source traffic descriptors (TD_S) can be defined as a set:

$$TD_S = \{PCR , SCR , MBS , MCR\}$$

where we use intriduced acronyms.

The connection traffic descriptors can be defined as a system:

$$TD_C = (TD_S , CDTV , R_{TD})$$

where are:

TD_C – system of connection traffic descriptors
TD_S – source traffic descriptors
CDVT – cell delay variation tollerance
R_{TD} – describe interrelations between traffic descriptor parameters.

Basic (on/off or 1/0) relations between required network parameters and service categories (on ATM network connection layer) is systematically described in Table 1.

Table 1. *Required network parameters for ATM service categories*

Param. / Service Category	PCR	SCR	MCR	CDTV
CBR	1	0	0	1
VBRrt	1	1	0	1
VBRnrt	1	1	0	1
ABR	1	0	1	1
GFR	1	0	1	0
UBR	1	0	0	0

1 – required ; 0 – Not-required

It is evident that PCR have to be always specified. Network operators can reserve bandwith for CBR connections at the PCR, however, when buffering is used it is possible to reserve less than the PCR for "guaranteed traffic".

There are a wealth quantitative, fuzzy and qualitative representations which can be associated with ATM traffic descriptors. We can expect that fuzzy membership function and inferencing methods enable more accurate descriptions than binary (on/off) specifications and probabilistic functions.

CONCLUSION

Generalised system considerations can be an important background in the modelling of traffic systems on technological and beyond-technological layer. Large efforts which must be invested into understanding of generalised systems approach and methodology, have to be compared with the gains of systems models. This evaluation is important in choosing and designing models that are maximally useful for the defined purpose.

Successful network design and efficient traffic management assume adequate description of traffic phenomenon and subscriber service requirements. ATM supports almost all teleservices and therefore ATM teletraffic is very heterogeneous. One way to deal with this complexity is to define traffic classes. For each traffic class we have to:

- identify one set of traffic parameters
- define QoS per class
- use some of mathematical measures (for relevant attributes) such as probability, possibility, plausibility or creditability.

ATM traffic specifications have to reflect the real traffic demand and also dynamicaly optimise the requested network resources. Scope of possible solutions in network design and traffic management can be enchanced and more effective solutions can be derived using GSPS methodology.

Classic teletraffic models developed for telephony (circuit-switched) and data traffic (packet-switch) are appropriate for specific traffic cases and networks, but more generalised teletraffic constructs and models are required for integrated multiservices (ATM) network. Since more precise information about the relevant attributes of an teletraffic ATM system (as an object system) is accessible in terms of specific and general image system, further researches can be on that epistemological level.

ACRONYMS

ABR – Available Bit Rate
ATM – Asynchronous Transfer Mode
B-ISDN – Broadband Integrated Services Digital Network
CBR – Constant Bit Rate
CCS – Centi Call Seconds
CDVT – Cell Delay Variation Tolerance
GSPS – General Systems Problem Solver
ITU-T – International Telecommunication Union – Telecommunications Standardization Sector
MCR – Minimum Cell Rate
PCR – Peak Cell Rate
QoS – Quality of Service
SCR – Sustainable Bit Rate
TD – Traffic descriptors
UBR – Unspecified Bit Rate
VBRnrt – Variable Bit Rate, non-real time
VBRrt – Variable Bit Rate, real time.

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