OVERALL QOS REFERENCING IN TELECOMMUNICATION SYSTEMS – SOME CURRENT CONCEPTS AND OPEN ISSUES

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***Abstract**: The main current concepts in overall Quality of Service (QoS) considerations in telecommunication systems, in documents of the leading standardization organizations, are found and put together. At least fifteen Open Issues for further study are formulated. Proposed are: Work Definitions of Communication and Telecommunication; A Reference Model of a Telecommunication System; Definitions of Overall Telecommunication Network and System Performance; Two Telecommunication System States' modelling approaches are described; Parameters' Classification Based on Their Values' Establishing Method is proposed, for the needs of design models; The necessity of Causal Classification of Values in Telecommunication Systems' Models is argued; The necessity of Overall Telecommunication System's Parameters' Notation System is argued and a set of requirements is listed. An initial step of such notation system, proposed and used by authors is described.*

***Keywords:** Telecommunication Systems, Telecommunication Network, Overall Quality of Service, Multi-Conceptual Models, Models Scalability*

***ACM Classification Keywords**: C.4 Performance of Systems, H.1.2 User/Machine Systems, I.6 Simulation and Modelling, I.6.0 General, H.1.2 User/Machine Systems, K.6 Management of Computing and Information Systems, K.6.0 Genera.*

Introduction

The aims of the paper are:

- To explain the contemporary terms, building the base of the Overall Quality of Service (QoS) Concept in Telecommunication Systems in documents of the leading standardization organizations,
- To show some latest developments in concepts and conceptual modelling of Telecommunication Systems, using informational modelling approaches;
- And to list Open Issues for further study, we are facing in our work.

We use many sources, but mainly ITU-T (International Telecommunication Union – Standardization Sector) Recommendations. ITU's role as creator of the world's most universally-recognized infocommunications standards dates back as far as the organization itself. Since its inception in 1865, the Union has been brokering industry consensus on the technologies and services that form the backbone of the world's largest, most interconnected man-made system. In 2007 alone, ITU's Telecommunication Standardization Sector (ITU-T) produced over 160 new and revised standards (ITU-T Recommendations), covering everything from core network functionality and broadband to next-generation services like IPTV (Internet Protocol Television). ITU-T

Recommendations are defining elements in information and communication technologies (ICTs) infrastructure (www.itu.int/net/ITU-T/info/Default.aspx). In this paper we use only ITU-T Recommendations in force, except [ITU-T B.13, 1993], because there is not replacement of it.

This paper is not a review of ITU-T Recommendations, as the good ones: [Jensen, 2003], [Anttalainen, 2003], [Villen-Altamirano, 2002] and [Iversen, 2010].

Documents of the following organizations are studied also: ISO (International Organization for Standardization), ETSI (European Telecommunications Standards Institute), IEC (International Electrotechnical Commission) and IETF (Internet Engineering Task Force).

1. What is Telecommunication?

The following six definitions are from [ITU-T B.13 1993]. This Recommendation is withdrawn – "deleted after its content became technically out of date". Unfortunately, better definitions are not accepted. These defined terms are basic in Informatics and Cybernetics also. After the text of definitions, we'll give some comments.

Information: Intelligence or knowledge capable of being represented in forms suitable for communication, storage or processing.
Note – Information may be represented for example by signs, symbols, pictures or sounds. [ITU-T B.13, 1993], [ITU-R/ITU-T, 2010] (term 701-01-01).

Signal: A physical phenomenon one or more of whose characteristics may vary to represent information. Note – The physical phenomenon may be for instance an electromagnetic wave or acoustic wave and the characteristic may be an electric field, a voltage or a sound pressure [ITU-T B.13 1993], [ITU-R/ITU-T, 2010] (term 701-01-02).

Transmission: The transfer of information from one point to one or more other points by means of signals. Note 1 – Transmission can be effected directly, or indirectly, with or without intermediate storage. Note 2 – The use of the English word "transmission" in the sense of "emission" in radiocommunication is deprecated.

Sending, (in telecommunication): The production of a signal at an input port of a transmission line or into a transmission medium.

Communication: Information transfer according to agreed conventions.

Telecommunication: Communication by wire, radio, optical or other electromagnetic systems. Note – The following definition is given in the International Telecommunication Convention (Nairobi, 1982): Any transmission, emission or reception of signs, signals, writing, images and sounds or intelligence of any nature by wire, radio, optical or other electromagnetic systems.

Comment: The definition of telecommunication above is unacceptable from the Overall QoS (Quality of Service), point of view, in Telecommunication Systems, because it not includes humans, as main users of telecommunication services. It contradicts many UTU-T recommendations, considered human factors and overall QoS definitions. For example:

Quality of service (QoS) is: “Totality of characteristics of a telecommunications service that bear on its ability to satisfy stated and implied needs of the user of the service” [ITU-T E.800, 1994]. This is different from the “network performance”:

Network Performance: The ability of a network or network portion to provide the functions related to communications between users. NOTE 1 – Network performance applies to the network provider's planning, development, operations and maintenance and is the detailed technical part of QoSO (QoS offered/planned by service provider). NOTE 2 – Network performance parameters are meaningful to network providers and are quantifiable at the part of the network which they apply. [ITU-T E.800, 2008].

User is an entity that makes use of CE (communication entity) (e.g., initiates or answers a call, or a person or entity external to the network, which utilizes connections through the network for communication (term 2.17 in [ITU-T E.800, 2008], based on [ITU-T Q.1300, 1995]). Connection is used in the context of establishing communication between two points in a network. Note: A computer program may be a user. From the other hand, humans as telecom users determine subjective (qualitative) parameters of the QoS reflecting in the QoS experienced/perceived (QoSE) concept:

Subjective (qualitative) parameters are: “Parameters that can be expressed using human judgement and understanding may be classified as subjective or qualitative parameters. Qualitative parameters are expressed by opinion ratings.” [ITU-T E.802, 2007]

QoSE – QoS experienced/perceived by customer/user: A statement expressing the level of quality that customers/users believe they have experienced. NOTE 1 – The level of QoS experienced and/or perceived by the customer/user may be expressed by an opinion rating. NOTE 2 – QoSE has two main man components: quantitative and qualitative. The quantitative component can be influenced by the complete end-to-end system effects (network infrastructure). NOTE 3 – The qualitative component can be influenced by user expectations, ambient conditions, psychological factors, application context, etc. NOTE 4 – QoSE may also be considered as QoSD (QoS Delivered) - received and interpreted by a user with the pertinent qualitative factors influencing his/her perception of the service [ITU-T E.800, 2008].

Some authors use expression “Quality of Experience Layer” in the telecommunication system [Muntean, McManis 2004]. So “The Next Big Thing is Adaptive Web-Based Systems” [De Bra et al, 2004]. The World Wide Web Consortium (W3C) pay special attention to the development of adaptive human-computer network interface, taking into account individual human characteristics [W3C, 2003], [W3C, 2011]. Personalization of the human-computer telecommunication network interface is important research field: [Henze, Kriese, 2004], [Hewett et al, 1996], [Joffroy et al, 2007].

[ITU-T Y.2002, 2009]: The Fundamental characteristics of ubiquitous networking are: 1. IP connectivity; 2. Personalization; 2. Network Intelligence; 3. Tagging objects; 4. Smart devices. “Personalization will allow to meet the user's needs and to improve the user's service experience since delivering appropriate contents and services to the user“.

Based on these and other considerations ([Poryazov, Petkova 2004], [Dimkova, Poryazov 2009]) in this work we use other definitions of communication and telecommunication:

Definition 1: Communication is models' transfer from memory to memory. "Memory" is human or/and computer memory.

Definition 2: Telecommunication is remote communication, using electromagnetic or/and equivalent means.

Open Issue 1: These work definitions need some justifications, e.g. more formal model and memory definitions. This is issue for further study.

We make clear difference between telecommunication system and telecommunication network, see Section 2:

2. Scalable Models of Overall Telecommunication Systems

Scalability and Scalable Models

The generic non-functional recommendations for Internet traffic engineering include: usability, automation, scalability, stability, visibility, simplicity, efficiency, reliability, correctness, maintainability, extensibility, interoperability, and security [IETF RFC 3272, 2002]. In the same document scalability is described:

Scalability: Contemporary public networks are growing very fast with respect to network size and traffic volume. Therefore, a Traffic Engineering (TE) system should be scalable to remain applicable as the network evolves. In particular, a TE system should remain functional as the network expands with regard to the number of routers and links, and with respect to the traffic volume. A Traffic Engineering system should have a scalable architecture, should not adversely impair other functions and processes in a network element, and should not consume too much network resources when collecting and distributing state information or when exerting control.

Scalability: "A characteristic of a system, model or function that describes its capability to cope and perform under an increased or expanding workload. A system that scales well will be able to maintain or even increase its level of performance or efficiency when tested by larger operational demands." There is a definition from Investopedia: [Quantum Financier, 2011].

Model scalability is the ability to refactor a base model, by adding or replicating the base model elements, connections or substructures, in order to build a larger and more complex model to satisfy new design requirements. Although a number of modelling tools have been developed to create and edit models for different purposes, mechanisms to scale models have not been well-supported." [Sun at al, 2011].

The understanding of term "scalability" expressed above reflects scalability in the case of "scale up". For designing and managing telecommunication systems we need scalable models in the full meaning: "scale down: make smaller in proportion; reduce in size"; "scale up: make larger in proportion; increase in size"; "to scale: with a uniform reduction or enlargement" [COD 11].

The most close to our understanding is the following opinion: “Scalability is very important to computers and communications systems. The advantage of scalability of networks is the ease and low cost of adjusting them to the size required. This scalability has been a major factor in the success of the Internet” [LINFO, 2006].

Models scalability includes: temporal, spatial, structural, parametric, conceptual, functional and other scalabilities.

Open Issue 2: Development of General methodology of building scalable models. The most of scalabilities, mention above, are found only in several documents in Internet.

In this paper, we’ll discuss some ITU-T recommendations, existing scalable models of telecommunication systems and open issues in telecom models scalability.

Overall QoS in the telecommunication system is an aggregative result of several systems’ interaction, including network performance in every network point. Estimating and designing overall telecommunication systems, we need models on many levels, allowing parameters’ and values’ aggregation and decomposition.

Scalable reference models of Overall Telecommunication Systems

At the one extreme, the Telecommunication System is the biggest Global machine, made by humans. It comprises billions terminals all over the World, works continuously, gives about 10% of the Gross Domestic Product (GDP) of the developed countries and is the basis of the information society evolvement.

At the other extreme, each call attempt in the Telecommunication System engages concrete telecommunication equipment and may finish by many causes (see Causal Classification below). Describing network performance, we have to associate several virtual devices (“almost or nearly as described, but not completely or according to strict definition.” [COD 11]) to one real pool of recourses, reflecting causes considered. The software, realizing the intelligence in the modern telecommunication systems, is often considered as consists of virtual devices (Note: resource is “Any set of physically or conceptually identifiable entities within a telecommunications network, the use of which can be unambiguously determined.” – term 1.3 in [ITU-T E.600, 1993]). For each of the virtual devices, traffic is describing by means of incoming rate of requests and holding time. This approach is unavoidable in pool of recourses’ dimensioning. Hence, on the most detailed level, the number of performance parameters, in the Global Telecommunication System is immense.

Therefore, we need scalable reference models on many (at least 5) levels: virtual devices level; telecommunication system level; telecommunication systems’ interaction level; National telecommunications; Global Telecommunication System.

Open Issue 3: Only several scalable reference models were found, but not in telecommunications. Creation of scalable modelling methodology is an open issue.

2.1. Reference Models on the Virtual Devices Level

On the virtual devices level, there is a very usable reference model and correspondent classification of a pool of recourses with a queue – the Kendal's classification [Kendall, 1951] and its extensions, This classification considers mainly number of recourses and parameters' distributions' types. The notation of parameters and scalability are not discussed.

2.2. Reference Models on the Telecommunication System Level

On the telecommunication system level there is reference model of Ericson [Ericsson, 2001], Page 37. It contains five types of parts: Terminals; Access; Transport; Network Management; Network Intelligence.

We propose more complete reference model of a telecommunication system (Fig.1.1.), reflecting the present ITU-T terminology and making a difference between telecommunication system and telecommunication network. It contains seven types of subsystems:

- Network Environment (Nature, Technological and Socio-Economic);
- Users;
- Customers;
- Terminals;
- Telecommunication Network;
- Network's Information Servers;
- Telecommunication Administration.

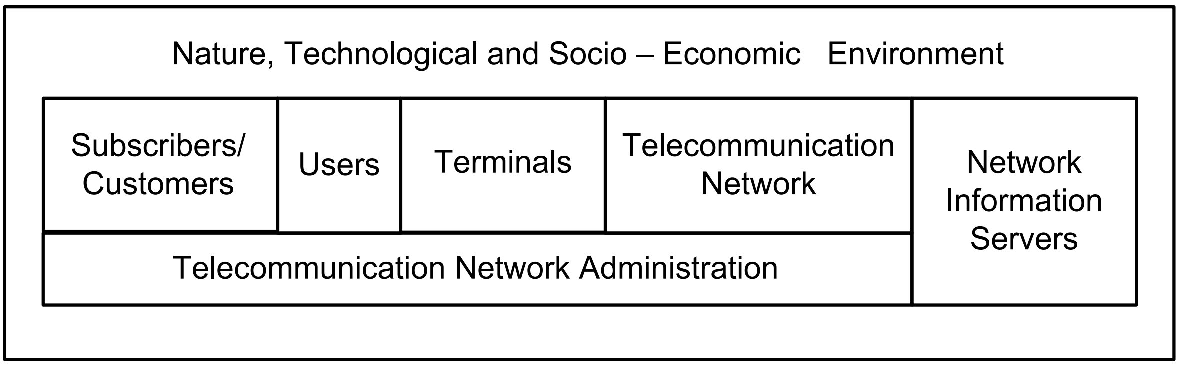

Figure 1. Overall Telecommunication System Reference Model. The subsystems are presented as rectangles. The considered possible interactions between two subsystems are presented by a common border between their presenting rectangles.

Explanations of the subsystems, and other involved terms are following:

Network Environment Subsystem (Nature, Technological and Socio-Economic) includes:

- Nature characteristics, important for cables' distribution and radio wave propagation and functioning. For example: seismic and ionosphere' geographical (position, relief, weather, flora, fauna), etc.;
- sociological (population's distribution and behaviour),
- economical (e.g. means of livelihood, GDP, competitors in the market);
- technological (availability and prices, of design, building and maintenance of the premises, hardware and software equipment) and so on.

The all parties types of telecommunications service market are: user, service provider, manufacturer, regulator [ITU-T E.800, 2008] and "academic experts who want to become inventors of new technological approaches" [Anttalainen, 2003]. In a more general view: The Information Communication Architecture (future development of information communication networks and services) accommodates the needs of different roles such as user, subscriber, network provider, service provider, network designer, service designer, developer, deployer/withdrawer, network manager, service manager, and service broker [ITU-T Y.130 2000].

The proposed general reference model, includes users, customers and Network Administration of roles described, because some quantitative models, connecting them to the existing network traffic models are known. All other players are considered as parts of the Network Environment.

Open issue 4: To develop qualitative and quantitative models allowing separating the network Environment into parts, interacting among themselves and with others subsystems of the telecommunication system.

Users' Subsystem

For users – see definitions in Section 1.

Customers' Subsystem

Customer is "a user who is responsible for payment for the services" (term 2.18 in [ITU-T E.800, 2008]). The similar term is "subscriber":

Subscriber [ITU-T M.3050.1, 2007]: The subscriber is responsible for concluding contracts for the services subscribed to and for paying for these services [ITU-T Y.1910, 2008].

Service provider A general reference to an operator that provides telecommunication services to customers and other users either on a tariff or contract basis. A service provider can optionally operate a network [ITU-T M.1400, 2006]. A service provider can optionally be a customer of another service provider. NOTE – Typically, the service provider acquires or licenses content from content providers and packages this into a service that is consumed by the end-user [ITU-T Y.1910, 2008]. Another definition is:

Service provider: An organization that provides services to users and customers [ITU-T E.800, 2008].

Content provider: The entity that owns or is licensed to sell content or content assets [ITU-T Y.1910, 2008].

“The Information Communication Architecture is aimed at both user and network operators. In this context "user" covers both "end-user" as well as "user" as a client in any client server situation. In addition, content providers and service providers may also be considered to be users” [ITU-T Y.130, 2000].

Open Issue 5: Obviously, user, end-user, customer/subscriber, content provider, network provider, service provider, network designer, service designer, developer, deployer/withdrawer, network manager, service manager, service broker etc. are not entities, there are roles. Two or more roles may belong to an entity simultaneously. The roles’ modelling of one entity is an open issue in telecommunication systems.

Terminals’ Subsystem

Terminal (terminal equipment) is a communication entity between user and communication network (see Fig. 1 in [ITU-T E.800, 2008]). Particularly, a terminal may be voice terminal, video terminal, data terminal (A device to allow a user to communicate with a computer [ITU-T Q.1300, 1995]), multimedia terminal, etc. Related term is Customer premises equipment: Telecommunications equipment located at the customer installation on the customer side of the network interface [ITU-T E.800, 2008].

Telecommunication Network Subsystem

Network is: A set of nodes and links that provide connections between two or more defined points to facilitate telecommunication between them [ITU-T Y.101 2000]. Telecommunication Network consists of Communication Entities – nodes (terminal and distribution entities) and links (lines).

Communication entity (CE) is an entity (e.g. telephone) that originates, terminates or becomes visible in a call.(term 3.1.10 in [ITU-T Q.1300, 1995]).

Telecommunication Device is abstracted as a Communication Entity (CE). Communication entities include lines and distribution entities [ITU-T Q.1300, 1995]. Distribution entities are switches and routers, for example.

Connection is "bearer path, label switched path, virtual circuit, and/or virtual path established by call routing and connection routing". ([ITU-T E.360.1, 2002] and [ITU-T E.361, 2003]). See also [ITU-T E.600, 1993]: Connection is “an association of resources providing means for communication between two or more devices in, or attached to, a telecommunication network.’

At functional view point, telecommunication network consists of “traffic network” (at “user plane” in [ITU-T Y.1711 2004]), ‘transmission network” [ITU-T E.737, 2001] (caring target users’ traffic), and “signalling network” [ITU-T Y Suppl. 11, 2010] (caring network control traffic). The both networks are strongly interconnected and often use common equipment (see ITU-T Recommendations M.760-M.799: “Common channel signalling systems)”, but in the more cases “bearer and signalling circuits” are considered separately [ITU-T E.755, 1996] and are dimensioning differently – see for example [ITU-T E.733, 1998] and [ITU-T E.734, 1996]. ”The transport plane should be separated from the control plane for efficient mobility management and scalability. Such separation of control and transport planes provides the architectural flexibility that facilitates the introduction of new technologies and services. Open interfaces between the control plane functions and the transport plane functions are necessary to implement their separation” [ITU-T Q.1706/Y.2801, 2006].

Note: The terminology here is an open issue – from one hand, “traffic network”, “transmission network”, “bearer circuits”, “transport plane”, ”Content delivery functional architecture in NGN” ([ITU-T Y.2019, 2010]) are used in similar meaning, and from the other hand: “signalling network”, “control traffic”, “control plane”, “Telecommunications Management Network” (see below). More terminology co-ordination looks necessary.

Network’s Information Servers’ Subsystem

Network’s Information Servers are intelligent network nodes [ITU-T E.415, 1991] and other network entities, providing subscribers’ identification, terminals’ location, billing and other network control and management functions. Examples are bandwidth-broker processors and other automatic/manual work centres [ITU-T E.360.7, 2002].

Note: Network’s Information Servers are part of the telecommunication network and are different from external information servers and services providers, ensuring tele-shopping or tele-medicine for example. These external service providers are users and/or customers of the telecommunication network.

Telecommunication Administration’s Subsystem

In ITU-T recommendations, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency [ITU-T G.1000, 2011].

A connected term is Network provider: An organization that owns a telecommunications network for the purpose of transporting bearers of telecommunication services [ITU-T E.800, 2008].

A function of the Telecommunication Administration is:

Customer relationship management (CRM): Identification and resolution of the issues in the contractual relationship between the service provider and the user in the provision and consumption of a service. NOTE – Examples of issues are customization of bills, tariff options, variants of service, negotiated repair arrangements, etc. [ITU-T E.800, 2008].

Other functions of the Telecommunication Administration are: network control, management, dimensioning, re-dimensioning, design, planning and interconnection:

'Interconnection' shall mean the physical and logical linking of public communications networks used by the same or a different service provider in order to allow the users of one service provider to communicate with users of another service provider, or to access services provided by another service provider [ITU-T E.800, 2008].

Open Issue 6: The Overall Telecommunication System Reference Model proposed does not explain interconnections and interactions among subsystems. There are many papers on parts of these interactions, but overall approach is missing. May be the best paper (yet !) is [ITU-CCITT, 1987], and for Bulgaria – [Todorov et al, 1981]

2.3. National Telecommunications Level Reference Models

Models on National Telecommunications Level are more complicated than reference models of a single telecommunication system, because one user may have and use several terminals and each terminal may request connections from several possible Network Providers [Andrianov et al 2009].

Open Issue 7: Complete enough Reference Telecommunication systems' models on National Level are not known.

Consideration on national (United States) level are presented in ITU-T 360.X series, e.g., a full-scale national 135-nodes network model is used, together with a multiservice traffic demand model, to study various TE scenarios and tradeoffs in [ITU-T E.360.2, 2002], but the interaction with other national networks is not considered.

2.4. Global Telecommunication System level Reference Models

On the Global Telecommunication System level we have statistical data and econometric dependencies only [ITU-D Database, 2010].

Example of end-to-end communication across different national ETS (emergency telecommunications services) is given in [ITU-T Y.2701, 2007]. This is far from a model of Global Telecommunication System level, but shows its necessity.

Open Issue 8: Creating the methodology and scalable reference models, allowing scalability in telecommunication systems' considerations, in case of global, national and local emergency situations. Such approach may help in econometric and other interactions modelling.

2.5. Inter-Conceptual Interactions and Models' Scalability

An example of Inter-Conceptual Interactions necessity is the concept of "telecommunications management network", including different, but strongly interconnected sub-concepts [ITU-T M.3050.1, 2007]:

Telecommunications Management Network (TMN): The telecommunications management network model was developed to support the management requirements of PTOs (public telecommunication operators) to plan, provision, install, maintain, operate and administer telecommunication networks and services. As the communications industry has evolved, use of TMN also evolved and it has influenced the way to think logically about how the business of a service provider is managed. The TMN layered model comprises horizontal business, service, and network management layers over network hardware and software resources, and vertical overlapping layers of fault, configuration, accounting, performance and security (FCAPS) management functional areas. The latter should not be considered as strictly divided "silos" of management functions, but interrelated areas of functionality needed to manage networks and services. Indeed, [ITU-T M.3200, 1997] and [ITU-T M.3400, 2000] define a matrix of management services and management function sets (groups of management functions), which in turn are used to define more detailed Recommendations on specific management functions

The Enhanced Telecom Operations Map (or eTOM for short) is a business process model or framework for use by service providers and their suppliers and partners within the telecommunication industry. It describes all the enterprise processes required by a service provider and analyses them to different levels of detail according to their significance and priority for the business [ITU-T M.3050.1, 2007].

Open Issue 9: In telecommunication we need scalable models with multi-conceptual interactions, by reasons explained above.

Inter-Conceptual Interactions are known in physics and engineering as “multiphysics” and is already subject of baccalaureate engineering degree programs [Eppes et al 2011].

3. The Overall Versus End-to-End Approach to Telecommunication Network Performance

The expression “overall network” is often used, but a clear definition was not fined. In an attempt to propose definitions, we’ll consider different points in telecommunication networks and their functional architecture, defined in ITU-T recommendations as follows:

Functional Architecture: A set of functional entities and the reference points between them used to describe the structure of an NGN (New Generation Networks). These functional entities are separated by reference points, and thus, they define the distribution of functions. NOTE 1 – The functional entities can be used to describe a set of reference configurations. These reference configurations identify which reference points are visible at the boundaries of equipment implementations and between administrative domains. NOTE 2 – This definition is relates to NGN. However, it is also valid for other networks, e.g., networks supporting IPTV [ITU-T Y.2012, 2010].

Functional Entity: An entity that comprises an indivisible set of specific functions. Functional entities are logical concepts, while groupings of functional entities are used to describe practical, physical implementations [ITU-T Y.2012, 2010].

Reference Point: A conceptual point at the conjunction of two non-overlapping functional entities that can be used to identify the type of information passing between these functional entities. NOTE – A reference point corresponds to one or more physical interfaces between pieces of equipment [ITU-T Y.2012, 2010].

Network head-point: A network head-point refers to a terminal at the sending user's side which is connected to the measurement system either electrically or acoustically [ITU-T P.10/G.100 Amendment 2, 2008].

Network end-point: A network end-point refers to a terminal at the receiving user's side which is connected to the measurement system either electrically or acoustically [ITU-T P.10/G.100 Amendment 2, 2008].

Network mid-point: A network mid-point refers to any point in the network that is not the head point or the end-point which is connected to the measurement system either electrically or acoustically [ITU-T P.10/G.100 Amendment 2, 2008].

3.1. End-to-end Network Approach

In the end-to-end approach, call/connections from a network head-point to a network end-point are considered usually. For example, in [ITU-T E.737, 2001]: “End-to-end call/connection blocking probability is defined here as the probability that an arriving call/connection is not successfully established due to lack of sufficient resources for the call/connection in the user-plane of the network”.

In Figure 1 in [ITU-T E.800, 2008] a “Schematic contributions to end-to-end QoS” is presented. It includes: Users, Terminal Equipment and Access networks. Users are not connected to the terminals.

In [ITU-T Y.2173, 2008] a General Reference Network Model is described: “Along the end-to-end path, there are two CPNs (Customer Premises Network), two access networks, one or multiple core networks, zero or multiple transit networks, and one or multiple service provider networks. The access networks, core networks, transit networks and service provider networks may belong to the same or different network or service providers.” In the same Recommendation, there is a more detailed “terminal equipment-to-terminal equipment” model, including Measurement points. Users are not mentioned as a part of the network in both reference models.

The understanding of end-to-end QoS definitely considers connections of one user/customer:

“End-to-End QoS consider the case when a SLA (Service Level Agreement) between an end user and a provider, for a connection passing through several SP (Service Provider) domains, is agreed. Thanks to the one stop responsibility, the end user will require the agreed QoS exclusively from the service provider with whom he agreed upon the SLA, while the latter will have to guarantee that QoS by signing, in its turn, suitable SLAs with its subproviders” [ITU-T E.860, 2002].

In accordance with this ”customizable end-to-end QoS services” are discussed in [ITU-T Y.1292, 2008] and “the fundamental challenges to achieving end-to-end QoS are present”, considering users, in [ITU-T Y.1542, 2010]. For end-to-end view of key assumptions in QoS-enabled mobile VoIP service, see [ITU-T Y.2237, 2010].

Based on these concepts, accepted in ITU-T, we propose a General reference model of contributions to end-to-end QoS (Fig. 2.). In our understanding users are indivisible part of end-to-end QoS concept (see QoSE in Section 1). NOTE – The phrase "End-to-End" has a different meaning in Recommendations concerning user QoS classes, where end-to-end means, for example, from mouth to ear in voice quality Recommendations. Within the context of this Recommendation, end-to-end is to be understood as from UNI-to-UNI (UNI = User-Network-Interface) [ITU-T Y.1541, 2006].

On Figure 2: User A is calling user. User B is called user.

Network Terminal: See Terminals' Subsystem above

Customer Premises Network: A network administered by the users [ITU-T Y – Supplement 7, 2008]; Customer premises network includes business premises network, where some kinds of information appliances such as telephone, TV and PC are interconnected via wired or wireless LAN, and residential premises network, where such information appliances are interconnected via access unit. Various kinds of network services would be provided by means of such network segments. Some other components such as video servers, head ends, and routers might be necessary for specific services [ITU-T Y.110 1998]; A Mobile Customer Premises Network (MCPN) is a subnetwork in a mobile vehicle (e.g. train, ship, car, etc.). Thus MCPNs involve radio interfaces at both the terminal and the network side ITU-T E.751 1996].

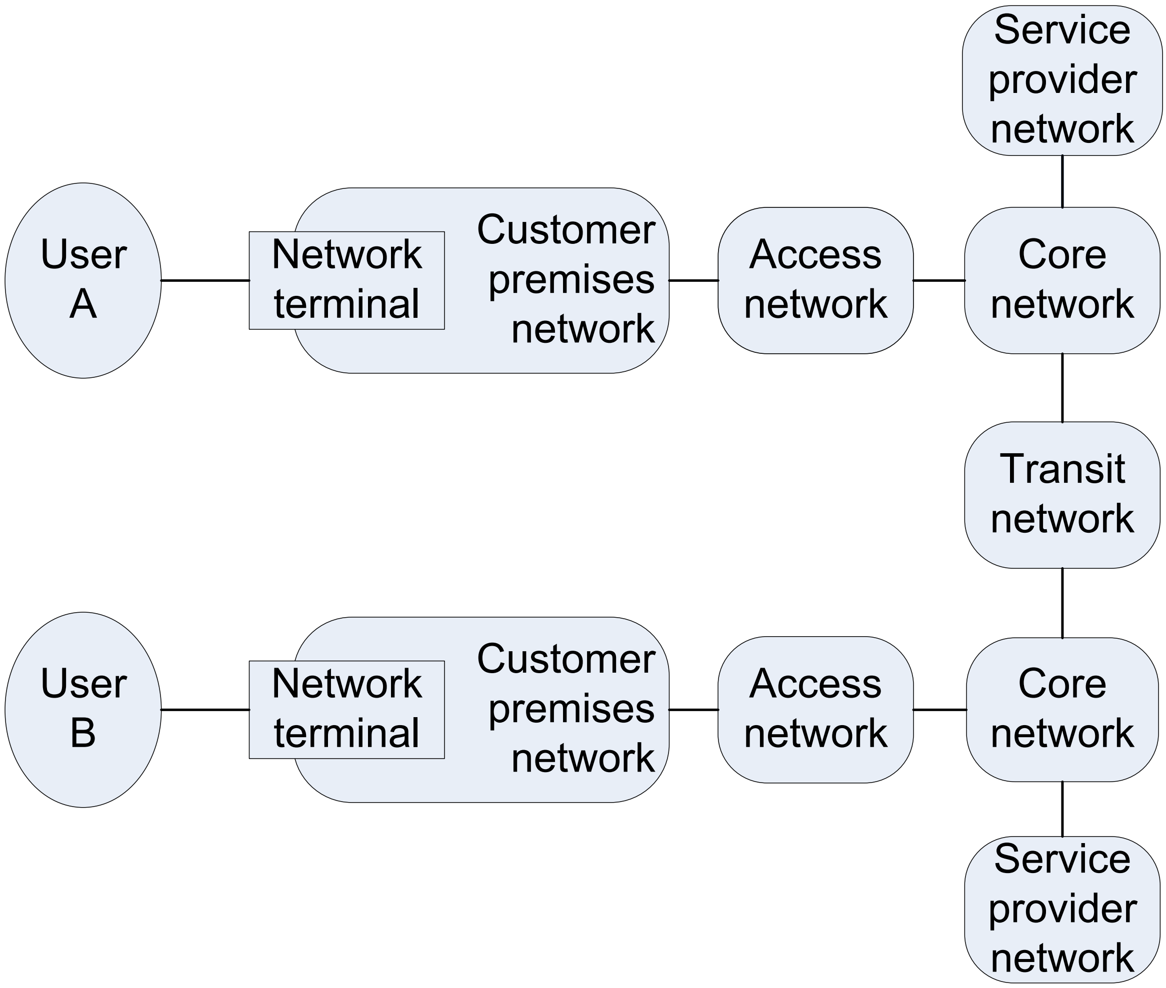

Figure 2. General reference model of contributions to end-to-end QoS.

On telecommunication systems interaction level we have–originating, transit, and terminating network [ITU-T E.755, 1996], respecting origination and destination of the calls. These networks are not necessary fixed –see "Multiple ingress/egress interdomain routing" [ITU-T E.360.2, 2002]. In this classification, Customer Premises Networks of A and B-users are originating and terminating, respectively.

Access Network: An implementation comprising those entities (such as cable plant, transmission facilities, etc.) which provide the required transport bearer capabilities for the provision of telecommunications services between a Service Node Interface (SNI) and each of the associated User-Network Interfaces (UNIs) Service Node is "A network element that contains one or several of the service control functions, service data functions, specialized resource functions and service switching/control function to provide a service in the context of GII (Global Information Infrastructure); Service Node Interface (SNI) is not described in this Recommendation; User-Network Interface (UNI): The interface between the terminal equipment and a network termination at which interface the access protocols apply [ITU-T, Y.101 2000].

Core Network: A portion of the delivery system composed of networks, systems equipment and infrastructures, connecting the service providers to the access network [ITU-T, Y.101 2000].

Core Network: An architectural term related to the part of an NGN (New Generation Networks) network, which is independent of a specific access technology [ITU-T Q.1707/Y.2804, 2008].

Service Provider Network: A network administered by a Service Provider.

3.2. Overall Telecommunication System Approach

Our Overall Telecommunication System Approach is in conformance with the general quality definition:

Quality: The totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs – (ISO 8402: 1986, 3.1), remains in (ISO 8402, 1994) and [ISO 9000, 2005].

The ITU-T quality definition is similar, which shows the stability of the concept:

Quality - The totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs. NOTE – The characteristics should be observable and/or measurable. When the characteristics are defined, they become parameters and are expressed by metrics [ITU-T E.800, 2008].

Based on the expression in [ITU-T E.202, 1992]:"In principle, the design of future mobile systems should take into account, the overall end-to-end transmission performance on all realistic connections", and overall blocking definition in [ITU-T E.737, 2001]. we propose the following overall telecommunication network approach definition:

Definition 3: Overall telecommunication network performance includes network performance of all connections' attempts in an overall telecom network, from all access-network-head-points to all access-network-end-points, in the time interval considered.

Note 1: For connection definition see “Telecommunication Network Subsystem” in Section 2.2;

Note 2: For connection attempt definition (call attempt, call demand and repeated call attempt) see [ITU-T E.600, 1993]:

- call attempt: An attempt to achieve a connection to one or more devices attached to a telecommunications network. At a given point in the network a call attempt is manifested by a single unsuccessful bid, or a successful bid and all subsequent activity related to the establishment of the connection;
- call demand: A call intent that results in a first call attempt;
- repeated call attempt; reattempt: Any of the call attempts subsequent to a first call attempt related to a given call demand. Repeated call attempts may be manual, i.e. generated by humans, or automatic, i.e. generated by machines.

Note 3: For network performance definition see [ITU-T E.800, 2008] (Section 1). For Network performance objectives for IP-based services see [ITU-T Y.1541, 2006].

Note 4: Overall telecommunication network may consists of several telecommunication networks, operated by different operators (see end-to-end QoS approach above).

An end-to-end approach to QoS parameters, in a multi-provider environment, mentioning overall QoS parameters, is described in [ITU-T E.860, 2002].

In our approach, the overall QoS parameters are aggregation of all end-to-end QoS parameters of all connections in the telecom system, in the considered time interval.

Based on the Definition 3 above and our understanding of telecommunication system described in Open Issue 1, we propose the following overall telecommunication system performance definition:

Definition 4: Overall telecommunication system performance, in the time interval considered, includes:

- all intended, suppressed and attempted connections, among all users/subscribers through the overall telecommunication network
- all intended, suppressed and attempted connections (not necessary telecommunication connections) between users/subscribers, from one side and network information servers, Network Service Providers and/or Network Administrations, from other side.

Note 1: For intended and suppressed connection definition, see [ITU-T E.600, 1993] – Call intent: The desire to establish a connection to a user. Note – This would normally be manifested by a call demand. However, demands may be suppressed or delayed by the calling user's expectation of poor Quality of Service performance at a particular time.

Open Issue 10: Some providers are now beginning to interconnect with each other via "QoS-enabled peering" in an attempt to offer QoS that spans the networks of multiple providers. However, in the absence of appropriate standards and established procedures for management, trouble-shooting, monitoring, etc., such interconnections are likely to be challenging and labour-intensive. Note however that large amounts of Provider Edge – Provider Edge or Customer Edge – Customer Edge probing raises scalability issues. [ITU-T E.800 Suppl. 8, 2009].

4. States' Models Scalability

States: An indication of an object's current condition that permits prediction of the object's future behaviour [ITU-T Q.1300, 1995].

Object: An intrinsic representation of an entity that is described at an appropriate level of abstraction in terms of its attributes and functions [ITU-T Q.1300, 1995].

The Network State expression is used often in ITU-T Recommendations, without explicit definition, for example: "State-Dependent Routing (SDR) path selection methods use the principle of routing connections on the best available path on the basis of network state information" [ITU-T E.360.2, 2002].

4.1. Network's Call/Connection Streams State

In ITU-T Recommendations state space analysis is used in the meaning of "call/connection streams" state:

State space analysis: Computation of end-to-end call/connection blocking probabilities could be based on a state space analysis of the network. For the purpose of computing the blocking probabilities, a vector, each of whose elements represents the number of calls/connections in progress of one of the call/connection streams in the network, is usually taken as the state of the network. In general, there are various ways of specifying network states and state space depending on the purpose of applications. Usually, it may be possible to specify a state space and state transitions in the space by considering the characteristics of call demand types and the call and connection level traffic controls employed. By analysing the steady-state probabilities of the network, the call/connection blocking probabilities of individual traffic streams may be computed. In some cases, the state probabilities have the product-form [ITU-T E.737, 2001].

The "call/connection streams" are requests. The term "request" is in the general meaning of "an act of asking politely or formally for something" [COED11] It is used as at least 18 451 times in ITU-T Recommendations in associations like: "request for service"; "call request"; "request associated with the original message"; "A request is a message that results in action by the…"; "request packet"; "connection request"; "handover request"; "request of transmission"; "channel request"; "facility request" etc.

We will use, in this paper, term "request" as a generalization of all these and following cases:

A call attempts and a call (explained above) are requests;

A session is a request:

Session: A temporary telecommunications relationship among a group of objects in the service stratum that are assigned to collectively fulfil a task for a period of time. A session has a state that may change during its lifetime. Session-based telecommunications may, but need not be, assisted by intermediaries. Session-based telecommunications can be one-to-one, one-to-many, many-to-one, or many-to-many [ITU-T Y.2807 2009].

Upper levels requests are thinkable also, because they may be paid separately: work, task, sup-packed, packed, project etc. Telecommunication models including request scalability are not known.

Every network state concept is facing a parameter's scalability problem by reason of real networks' complexity. For example in "call/connection streams" approach the micro-states number of an end-to-end telephone call model is from 10^8 to 10^{14} [Endaltsev et al, 1988].

Open Issue 11: Development of an appropriate approach to requests' definitions, requests, states description and requests' models scalability is an open issue.

4.2. Network's Aggregative Device State

In [Poryazov, 1991] other approach to the network state is proposed: The overall network model is considered comprising (nested) virtual devices on several service levels: (base virtual device, phase, stage, switching subsystem, terminals subsystem). The network state is considered as aggregation of the macro-states (e.g. mean traffic intensity) of these virtual devices. This allows states scalability in the model.

The "call/connection streams state" and "aggregative device state" approaches are not alternative. They are supplementary, because requests' and devices' states are interconnected.

This "aggregative device state" approach is advanced in [Poryazov, Saranova, 2006], where tuple concept for networks state is proposed. It is presented here in developed and abstracted, from the concrete model, edition applicable not only to a network, but to a telecommunication system's state also:

System Tuple Set

Full system's parameter set: consists of all parameters of the virtual devices (communication entities) composing the telecom network model.

A system tuple is a finite set of distinguishable (by name and/or position) parameters and their values, which fulfils simultaneously the three following requirements:

1. All parameters (parameters' set), of the system tuple, correspond to one considered (observed, modelled) system;
2. All the values of a system tuple parameters correspondent to the one and the same time interval of measurements or considerations;
3. The instant of beginning and duration of this time interval are elements of the system tuple set.

Remarks: 1. Our definition of system tuple is based on the tuple definitions in Computer Science (Relational Data Bases) and Mathematics. It is adjusted for real systems' measurements, modelling and simulation; 2. Every subset of a system tuple, we call "sub-tuple".

Static and Dynamic Parameters' Classification

The duration of the observed or/and modelled time interval may vary from:

- Years – see annual reports of Telecom Administrations and [ITU-D Database, 2010];
- Season or month ("A month is chosen because it is short enough that seasonal variations and growth will not significantly affect load behaviour during the time interval considered, and it is long enough to get adequate statistical significance" [ITU-T E.500, 1998]);
- week, day ("The three daily groups to be considered are: working days, week-end days (including most holidays), and yearly exceptional days (e.g. Christmas, Mother's Day, extraordinary events, etc".) [ITU-T E.500, 1998]);
- hours, minutes ("In fact, the daily peak traffic intensity for different traffic systems can occur during different read-out periods" [ITU-T E.500, 1998]), "Use of an hour or possibly 15-minute interval of time would facilitate support by existing operations systems" [ITU-T I.358, 2003].
- minutes, seconds ("In all sections where the evaluation of events is described, the measurement technique is based on a sliding-window with a 1 second (and x second for FFD OAM option) granularity of advance" [ITU-T Y.1711 2004].);
- instant of time (see traffic intensity definition in [ITU-T E.600, 1993]),

[ITU-T E.360.1, 2002]: "Capacity management must provide sufficient capacity to carry the expected traffic variations so to meet end-to-end blocking/delay objective levels. Traffic load variations lead in direct measure to capacity increments and can be categorized as:

1) minute-to-minute instantaneous variations and associated busy-hour traffic load capacity;
2) hour-to-hour variations and associated multihour capacity;
3) day-to-day variations and associated day-to-day capacity; and
4) week-to-week variations and associated reserve capacity."

In each non-zero time interval above, the values of the system's tuple parameters may be classified as static (constant, independent of time), stationary (in a steady state, e.g. variable but with near to constant mean) or dynamic (dependent of the time). The classification depends on time scale, parameter's values dynamic and system's model objectives.

A telecommunication system's state is presented and modelled with a system tuple, if the model considers a stationary state of the system (the predominant practice). In dynamic models, more system tuples are needed, as well as functions, describing transitions dynamic between system tuples.

Telecom system may consists of many networks. This gives rise to problems in observation co-ordinations: "Different measurement periods and principles for collecting traffic data may have been used in different networks and services, depending on the operator. This solution leads, however, to overlapping data collecting and processing, and increases the possibility of inconsistencies. This Recommendation presents some principles which facilitate collecting and handling of data for different purposes, in different networks and services, run by several operators" [ITU-T E.492, 1996].

Base Parameters' Set (Base Tuple)

There are many obvious dependencies in a System Tuple (the Full System's Parameter Set). For example, the sum of probabilities of outgoing transitions in every virtual switch devices has value one; in stationary state Little's formula (Y = F T) [Little, 1961] is in force for every virtual device; we assume most of devices with infinite capacity. As a result, there are sets of parameters (sub-tuples of 'base parameters'), with the following property: If we knew the values of the base parameters, we may calculate the values of all other parameters of the overset System Tuple. Several different base parameters' sets may exist. We call base parameters' set and correspondent values of these parameters "*Base Tuple".* Obviously, a Base Tuple is a sub-tuple of the System Tuple.

Open Issue 12: To find minimal Base Tuple, among all base tuples of a System Tuple. This is important, because a telecommunication system is modelled with a big number of parameters, making measurements, modelling and simulation, visualization and understanding too hard.

Open Issue 13: To find minimal Easy-to-Measure Base Tuple, among all base tuples of a System Tuple.

Values of many important parameters in telecommunication system is Hard-to-reach data [ITU-T E.360.1, 2002] and "The functions of a network management operations system include the following:…– calculating hard-to-reach status of destinations and providing this information (hard-to-reach information) to exchanges" [ITU-T E.411, 2000]; "one of the early things traffic managers should look at is the hard-to-reach data" [ITU-T E.360.7, 2002].

5. Parameters' Classification Based on Their Values' Establishing Method

In many Teletraffic Engineering (TE) tasks, especially in Telecommunication System Design, we have to use more than one different values of a parameter, in one consideration, even in a mathematical expression. For example: empirical, target and design values of the blocking probability parameter. This shows necessity of values classification and correspondent notation.

The parameters of the System Tuple and chosen base parameters' subset (Base Tuples) may be classified, according their values Establishing Method, in at the least seven groups:

Empirical values

Empirical values are results of measurements, observation, surveys in real systems. They are two types: Primary (direct) and derived (indirect, second level):

Primary performance parameter: A parameter or a measure of a parameter determined on the basis of direct observations of events at services access points or connection element boundaries [ITU-T I.350, 1993].

More generally, measurements for a primary QoS parameter are taken at specific measurement points. Such points are simply interaction points, where reference events or their outcomes can be observed, and may be located or not in the technical interface (e.g., when measurements are obtained from a sub-provider) [ITU-T E.860, 2002].

Derived performance parameter: A parameter or a measure of a parameter determined on the basis of observed values of one or more relevant primary performance parameters and decision thresholds for each relevant primary performance parameter [ITU-T I.350, 1993].

Once primary QoS parameters are obtained, parameters of second level can be derived as functions of these values…Indirect Parameters are defined as functions either of values of primary QoS parameters or of decisions taken on the basis of the latter [ITU-T E.860, 2002].

Forecasted values

Telecom system's design includes network performance modelling in a future environment, so of vital importance is forecasting not only of traffic and call data but also economic, social and demographic data. Forecasting methods and econometric models are given in [ITU-T E.506, 1992]. There are many papers on forecasting methods, but in ITU recommendations aspects of value forecasting are described in [ITU-T E.507, 1988], [ITU-T E.508, 1992] and [ITU-CCITT 1987].

Assumed values

In the complicated telecommunication systems' modelling, structures', business relationships', processes' and parameters' simplifying assumptions are unavoidable:

- "Independence assumption among components" [ITU-T E.737, 2001];
- "In the context of this Supplement, it is a reasonable basic assumption that a receiving provider, promising to deliver IP traffic with a defined quality of service, performs a service to the sending provider" [ITU-T E.800 – Suppl. 8, 2009];
- "Traffic models adopt simplifying assumptions concerning the complicated traffic processes. These assumptions are directly explained in the Recommendations on dimensioning". (pp.9) [ITU-T E.490.1, 2003];

- “The objective of this Recommendation is to provide possible methods which are useful for dimensioning the network for a given set of traffic demand assumptions and GoS objectives, particularly, call/connection blocking probability objectives” [ITU-T E.737, 2001];

Sometimes assumptions are “for further study”: “Assumptions for establishing objectives… The exact conditions or assumptions under which these worst-case objectives may apply are for further study“ [ITU-T I.358, 2003].

Assumptions may be hypothetical: “In order to evaluate the performance of a component, it is assumed that a hypothetical traffic is offered to the component. The hypothetical traffic variables such as arrival rate are derived from the traffic characteristics of the original traffic assumption, the performance of the other components and traffic routing among the components” [ITU-T E.737, 2001].

Assumptions are always important, but sometimes are “no longer realistic”: “The specific proposal for a throughput probe that appeared in previous versions of this Recommendation has been deleted, since some of the assumptions about maximum TCP window size settings and packet sizes are no longer realistic” [ITU-T Y.1540, 2007].

Target values

QoS objectives may be expressed by target values, thresholds and ranges set to QoS parameters [ITU-T E.860, 2002]. “The target values in this table are to be interpreted as design objectives” [ITU-T E.721, 1999].

“Network operators are using Grade of Service (GoS) parameters and their associated target values:

- as internal design objectives;
- to meet Quality of Service (QoS) objectives to customers; and
- to meet commitments to other network operators” [ITU-T E.726, 2000].

(GoS (grade of service) is one of the few ITU-T concepts not easy for grasping and using. It is: “a number of network design variables used to provide a measure of adequacy of a group of resources under specified conditions (e.g., GoS variables may be probability of loss, dial tone delay, etc.)” [ITU-T E.361, 2003]. . “NOTES: 1. The parameter values assigned as objectives for grade of service variables are called grade of service standards. 2 The values of grade of service parameters achieved under actual conditions are called grade of service results” [ITU-T E.600, 1993]. “The key point to solve in the determination of the GoS standards is to apportion individual values to each network element in such a way that the target end-to-end QoS is obtained”. [Iversen, 2010]. Term “GoS” is not mentioned in [ITU-T E.800, 2008])

Defining target values: “Target values are determined in order to improve the quality of a service within a specified period of time. Depending on the service aspect that is subject for improvement, target values are fixed for specific QoS parameters” [ITU-T E.802, 2007]. Many key performance parameters and their target values are described in [ITU-T E.671, 2000], [ITU-T E.802, 2007], [ITU-T G.1010, 2001] and other ITU-T Recommendations.

Threshold Values

“Derived performance parameters describe performance based on events which are defined as occurring when the value of a function of a primary performance parameter(s) crosses a particular threshold. These derived threshold events identify the transitions between the available and the unavailable states” [ITU-T I.350, 1993].

“Depending on the QoS parameter under consideration, the reference value can consist of a threshold value (e.g., the performance should be better than a minimum threshold) or of an acceptable performance range. The final determination of a specific reference value depends on the kind of parameter (e.g., whether it is based on network performance parameters or subjective aspects), the technology involved and the kind of verification methodology used” [ITU-T E.802, 2007].

Threshold values occur in many theoretical considerations. In Terminal Teletraffic Theory and Overall Teletraffic Theory thresholds are introduced in [Poryazov, 1991], [Poryazov, 2004], used in [Poryazov, Saranova, 2006] and extended to more parameters in [Saranova, 2008].

Administrative values

Some parameters’ values are determined or coordinated administratively. For example:

- The durations of busy and ringing tones are usually limited administratively.
- “The QoS parameter values administratively coordinated at the network-to-network interface include: committed information rate, transit delay, and frame loss ratio. Additional parameters including Bc, Be, frame size, and DLCI should also be administratively coordinated at the network-to-network interface” [ITU-T I.372, 1993].

Design values

Design values are values of design variables, e.g. in [ITU-T E.529, 1997]: “The objective of network dimensioning in this Recommendation is to determine the design variables for a given traffic load assumption to meet a given end-to-end GoS requirement in the most economical way”.

Design values are output of the design model, with input consists of empirical, forecasted, assumed, target, threshold and administrative values.

Sometimes design values may correct design model’s input values. For example, the design value of blocking probability may be lower than the target one.

Test values

Test values are values of design variables (“test parameters” [ITU-T Q.542 1993]), in the processes of a communication entity or its model testing (model verification and validation [?]). ”Routine tests, statistical tests, manual activities and/or other means may be used to verify proper operation of these functions...Testing may be manual or automatic" [ITU-T Q.542 1993].

In a summary, designing a telecommunication system we need at least one base system tuple of parameters, with several qualifiers for parameters characterization and at least seven qualifiers for parameters' values classification based on values' establishing method. Each parameter may be base or aggregative.

6. Causal Classification of Values

In [ITU-T E.425 2002] Network Effectiveness depends of three parts: Network Failures; User Failures (ineffective calls associated with the calling and called subscribers) and Completed Seizures. There is a note in the "Cause value categorization" section: "It is important to note that this classification is theoretical and that in practice, some cause values categorized as a user failure can be in reality a network problem". "Cause value" field in [ITU-T E.425 2002] contents 99 items. In [ITU-T Q.850 1998] there are 127 cause value numbers and other failures' sources, for example Network Service Provider.

Causal values' classification is necessary not only for network control and management. It is important for network modelling and design also. In models we have other sources causing values – the modellers. Some model variables have not corresponding objects in the modelled system, but may sometimes improve the adequateness of the models' behaviours. For example, see the parameter in the Bernoulli-Poisson-Pascal model ([Iversen, 2010]).

Open Issue 14: Causal qualifiers and causal scalability are necessary for performance modelling and presentation on different causal levels: from hundreds causes, in the system control and management plane, to several main causes in the Annual Reports Level.

7. Overall Telecommunication System's Parameters' Notation System

Open Issue 15: Developing of a telecommunication system's parameters' notation system, allowing parameters' and their values naming according to at least eight requirements:

- Multi-conceptual dynamic modelling of the system. In the traffic modelling concept there are virtual devices and their parameters (see "Full system's parameter set" above). For other concepts, used for telecommunication system description (see "Overall Telecommunication System Reference Model" above) there are other entities, processes and parameters, which need appropriate notation, but are outside the scope of this paper. Notation means for Inter-conceptual interactions are mandatory. Overall telecommunication system is an entire entity, so conceptual scalability of its models is very welcome.
- Functional Role of the characterized virtual device or participating entity (for communication entity, see above) in the functional structure of the model. For telecommunication network such functional roles are, for example: transmission, switching, storage, computing, decision, management and billing. Now, practically, only graphic notation of these entity's functions is used. In electronics there is letter notation, e.g. R is standing for "resistor", C – for "capacitor", T – for "transistor" etc.

- Parameters' Characterization. In almost every model of a complex system, a parameter's name is not enough and qualifiers are used. For some qualifiers in Teletraffic models see [ITU-T E.600, 1993].
- Service Position in the model, of the characterized virtual device or participating entity. For telecom network, for example, one may divide the following service levels: base virtual device, phase, stage, switching and other subsystems, terminals subsystem and network state (considered as aggregation of the macro-states of included virtual devices.).
- Space Position in the model, of the characterized virtual device or participating entity. Telecommunication systems are distributed all over the World, but every their entity influences their performance, so space position notation and space scalability are advantages.
- Parameters' Values' Establishing Classification
- Parameters' Values' Causal Classification
- Name Design Criteria. "Names with which human beings deal directly should be user-friendly. A user-friendly name is one that takes the human user's point of view, not the computer's. It is one that is easy for people to deduce, remember and understand, rather than one that is easy for computers to interpret." - This is the only one criterion addressed in [ITU-T, X.501, 2005], Annex J: "Name Design Criteria".

Development of such telecommunication system's parameters' notation system looks pretty but impossible. Our experience in overall telecommunication networks' (including terminals and users' behaviour) modelling shows a big usefulness and even unavoidability of a general notation system, when the modelled system tuple includes hundreds parameters, in the simplest homogeneous case.

The problem was realized in the preparation of an overall network simulation model [Todorov, Poryazov 1985]. An initial decision was used in [Poryazov, 1991] and tested in a model with heterogeneous terminals in [Poryazov 1992]. The notation system refers overall terminal traffic and overall network traffic modelling and is extended in [Poryazov, 2004] and [Poryazov, Saranova 2006]. Its main approaches are:

1. A set of Base Virtual Devices, each with a unique Functional Role is chosen (see "Functional Entity" in Section 3). Only graphic notation of functions is used for presentation in the conceptual reference models. The minimal set of used functions consists of: Generator (creates or copy requests); Terminator of requests; Modifier (combination of Generator and Terminator); Server (serves requests); Pointer or Director (shows the next virtual device); Switch (switches to the one of outgoing pointers). Every Server device has at least six parameters: Probability for direction the requests to it (P); Frequency (rate) of requests (F); Time for service (holding time) of a request in the device considered (T); Traffic intensity (Y); Traffic volume (V); Capacity of the device (N = number of servers).

2. The real devices are presented as a connected, by means of pointers, set of virtual devices. The overall network model is considered comprising (nested) virtual devices on five service levels: (base virtual device, phase, stage, switching subsystem, terminals subsystem).

3. Parameters' qualifiers as a part of the parameter's name are used for parameters characterization. The meaning of used qualifiers (e.g.: demand, offered, carried, blocked) is described in [ITU-T E.6001993].

4. Causal values classification is presented by reference model structures and causal qualifiers. Each service phase consists of:

- Successful branch of consecutive base virtual devices, corresponded to the successful (carried, completed) branch of the requests' way (correspondent to the "Normal" cause value 31 in [ITU-T E.425 2002]; and
- Failure branches, correspondent to the modelled failures. Each failure is presented as a base virtual device with its parameters.

Causal qualifiers participate in the device name with the first letter of modelled failure. Now "enter", "carried" (correspondent to the begin and the end of successful branch in the phase modelled), "abandoned", "blocked", "interrupted" and "not available" qualifiers are used. For example, "*Prad*" stands for "Probability for repeating the attempts after abandoned dialling cases).

5. Values' Establishing Method Classification is used for determination of second set of qualifiers in Network Dimensioning Task [Saranova, 2007] and [Saranova, 2008]. For example, *emp.crr.Ys* and *dsn.crr.Ys* means empirical and design values of the carried traffic intensity in the switching subsystem.

The used notation system has some advantages and disadvantages:

- It reflects current ITU-T terminology and enable:
- Semiautomatic virtual devices', their parameters' and values' naming;
- Working with big numbers (e.g. thousands) of names;
- More precise parameters and their values qualification and notation, allowing simultaneous usage of different values of a parameter in one consideration and mathematical expression;
- Easy for people deducing, remembering and understanding the names;
- Using the same names in administration's reports, mathematical expressions and computer programs;
- The names are longer than usually used ones.

The described notation system is only a development step of a general telecommunication system notation, fulfilling requirements stated in Open Issue 15.

Conclusion

1. The main current concepts in overall Quality of Service (QoS) considerations in telecommunication systems, in documents of the leading standardization organizations, are found and put together.
2. The current definition of Telecommunication does not correspondent to the: concept of QoSE – QoS experienced/perceived by customer/user; to the general concept of QoS; and to the current works of Human-Computer Interface Personalization. New definitions of Communication and Telecommunication are proposed.
3. The necessity of Scalable Models of Overall Telecommunication Systems is argued. The scalability of real systems is much better than the one of their models. The lack of methodology and useful models is described in several Open Issues formulated.
4. A Reference Model of a Telecommunication System, comprising seven subsystems, is proposed. ("Telecommunication System" is in European, not in a US understanding as "Telecommunication Network").
5. The necessity of Inter-Conceptual Interactions and Scalability in Overall Telecommunication Systems Models is argued.

6. The Overall and End-to-End Approaches to Telecommunication Network Performance are described. A General reference model of contributions to end-to-end QoS is proposed and described.
7. A definition of Overall telecommunication network performance is proposed.
8. A definition of Overall telecommunication system performance is proposed. It defers from Overall telecommunication network performance, because: 1. includes the all user-to-user connections in the overall network; 2. includes users' and subscribers connections (not necessary telecommunication connections) to Network and Service Providers.
9. Two Telecommunication System States' modelling supplementary approaches are described: the "call/connection streams state" and "aggregative device state".
10. The Network's Aggregative Device State approach, developed by authors, is presented in more details. It is influenced from Informatics and Mathematics and includes concepts as System Tuple Set, Base Tuple, and Minimal Base Tuple. Static and Dynamic Parameters' Classification is described, along with the duration of the observation intervals
11. Parameters' Classification Based on Their Values' Establishing Method is proposed, for the needs of design models, based on practice described in ITU-T Recommendations.
12. The necessity of Causal Classification of Values in Telecommunication Systems' Models is argued, based on "Cause value" field in Network Signalization.
13. The necessity of Overall Telecommunication System's Parameters' Notation System is argued and a set of requirements is listed. An initial step of such notation system, proposed and used by authors is described.
14. At least fifteen Open Issues for further study are formulated.

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