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TOWARDS USEFUL OVERALL NETWORK TELETRAFFIC DEFINITIONS

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Abstract. A detailed conceptual and a corresponding analytical traffic models of an overall (virtual) circuit switching telecommunication system are used. The models are relatively close to real-life communication systems with homogeneous terminals. In addition to Normalized and Pie-Models Ensue Model and Denial Traffic concept are proposed, as a parts of a technique for presentation and analysis of overall network traffic models functional structure; The ITU-T definitions for: fully routed, successful and effective attempts, and effective traffic are re-formulated. Definitions for fully routed traffic and successful traffic are proposed, because they are absent in the ITU-T recommendations; A definition of demand traffic (absent in ITU-T Recommendations) is proposed. For each definition are appointed: 1) the correspondent part of the conceptual model graphical presentation; 2) analytical equations, valid for mean values, in a stationary state. This allows real network traffic considered to be classified more precisely and shortly. The proposed definitions are applicable for every telecommunication system.

Keywords: Overall Network TrafficTheory, ITU-T Definitions, Virtual Circuits Switching.

ACM Classification Keywords:

1. Introduction

The first what we need for usable Overall Network and Terminal Traffic Theory, is a complete set of clear, precise and useful definitions, particularly for overall network characteristics.

State of the art: Expressions "offered traffic" and "demand traffic" are not found in "ETSI Publications Download Area" [http://pda.etsi.org/pda/queryform.asp] and in [ANSI 2001]. The ITU-T definition of offered traffic is not valid for real telecommunication systems [Poryazov 2005] and that one for demand traffic is simply absent, despite usage in ITU-T Recommendations of expression "demand traffic" three times, and of "traffic demand" – 50 times.

Objective of the research: To trigger discussions towards establishing stable fundaments of Overall Network Traffic Theory.

Methods used: Conceptual telecommunication network modeling, influenced by Structural Programming approach. The reasoning is illustrated with circuit switching network models, because:

1) They are relative simple;
2) We have an existing Overall Network Teletraffic Model, consisting conceptual and correspondent analytical models;
3) "…the teletraffic theory of the Internet with dimensioning methods is mainly the topic of the future." [Molnar 2006];
4) We are discussing base traffic concepts and definitions, which have to be valid in any telecommunication system.

All assumptions, notations and equations, not mentioned here, are explaneted in [Poryazov 2005] and, in more details, in [Poryazov, Saranova 2006].

2. Conceptual and reference models

2.1. Normalized structure of traffic models

In this paper three types of virtual devices are used: base, comprising base devices (enforsing group limitations on the comprised base devices, e.g. maximal sum of capacities) and aggregating base devices (used in the reasoning only).

2.1.1. Base Virtual Devices and Their Parameters

In the normalized models, used in this paper, every base virtual device, except the switches, has no more than one entrance and/or one exit. Switches, as a rule, have one entrance and two exits, but, as exception, may have more. The structural normalization is possible for every computer program [Bohm&Jacopini 1966] and therefore for every model presentable as a computer program (e.g. computer simulation model). We will use base virtual device types with names and graphic notation shown on Fig.1. For every device we propose the following notation for its parameters: Letter *F* stands for calling rate (frequency) of the flow [calls/sec.], *P* = probability for directing the calls of the external flow to the device considered, *T* = mean service time, in the device, of a served call attempt [sec.], *Y* = intensity of the device traffic [Erl].

2.1.2. The Virtual Base Device Names

In the conceptual model each virtual device has a unique name. The names of the devices are constructed according to their position in the model.

The model is partitioned into service stages (**d**ialing, **s**witching, **r**inging and **c**ommunication).

Every service stage has branches (**e**nter, **a**bandoned, **b**locked, **i**nterrupted, **n**ot available, **c**arried), correspondingly to the modeled possible cases of ends of the calls' service in the branch considered.

Every branch has two exits (**r**epeated, **t**erminated) which show what happens with the calls after they leave the telecommunication system. Users may make a new bid (repeated call attempt), or to stop attempts (terminated call attempt).

In virtual device name construction, the corresponding bold first letters of the names of stages, branches end exits above are used in the order shown below:

Virtual Device Name = <BRANCH EXIT><BRANCH><STAGE>

A parameter's name of one virtual device is a concatenation of parameters name letter and virtual device name. For example, "*Yid*" means "traffic intensity in interrupted dialing case"; "*Fid*" means "flow (call attempts') rate in interrupted dialing case"; "*Pid*" means "probability for interrupted dialing"; *Tid* = "mean duration of the interrupted dialing"; "*Frid*" = "repeated flow call attempts' rate, caused by (after) interrupted dialing". All expression "device modeling the service of **r**epeated attempts after **i**nterrupted **d**ialing" is sometimes notated with {rid}.

2.1.3. The Paths of the Call attempts

We consider call attempts generated from terminals and correspondent to content and signaling terminal traffics. In this paper, we ignore the internal network signalization.

Figure 1 shows the paths of the call attempts, generated from (and occupying) the A-terminals in the proposed network traffic model and its environment. *Fo* is the intent rate of call attempts of one idle terminal; *M* is a constant, characterizing the BPP flow of demand attempts (*dem.Fa*). In this paper we assume *M = 0.*

In the model in Fig. 1, some of the blocks are numbered. These are Reference Points, e.g. the input point of call attempts into the model is virtual switch with Reference Point 2 (RP2). Comprising devices (“a”, “s” and “b”) are notated with graphical blocks.

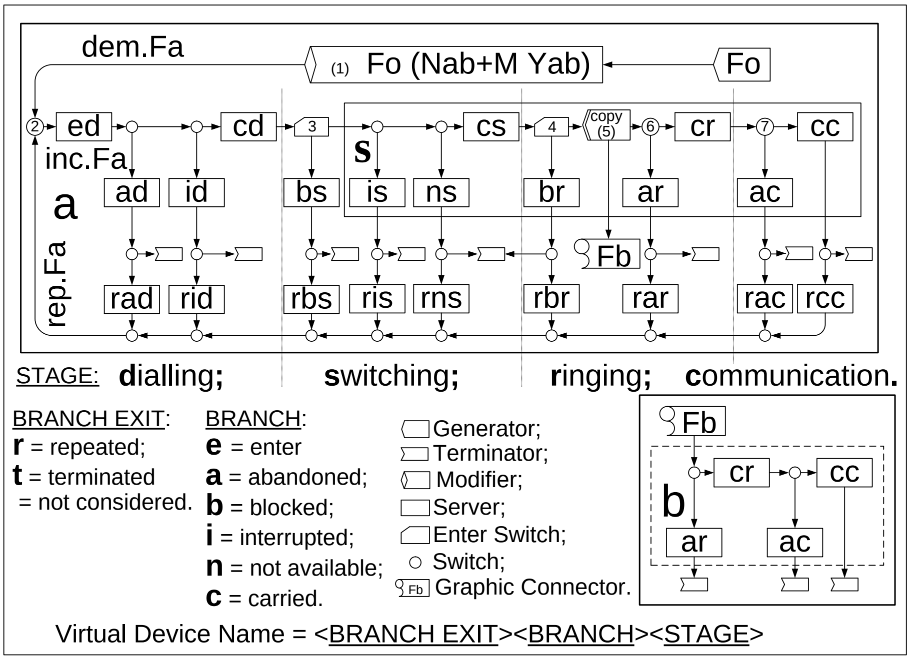

Figure 1. Conceptual model of the telecommunication system and its environment, including: the paths of the call attempts, occupying A-terminals (a-device), switching system (s-device) and B-terminals (b-device); base virtual device types, with their names and graphic notation. Some of switches, on the Carried Communication Branch are numbered as Reference Points.

2.2. Demand and repeated call attempts

2.2.1. The next definitions in [ITU E.600] are connected with demand traffic definition:

E.600, Definition 2.2: **call intent**: The desire to establish a connection to a user;

E.600, Definition 2.3: **call demand**: A call intent that results in a first call attempt;

E.600, Definition 2.4: **call attempt**: An attempt to achieve a connection to one or more devices attached to a telecommunications network;

E.600, Definition 2.5: **first call attempt**: The first attempt of a call demand that reaches a given point of the network;

E.600, Definition 2.6: **repeated call attempt; reattempt**: Any of the call attempts subsequent to a first call attempt related to a given call demand.

Following definitions above, we’ll use the following shortenings, as definitions:

2.2.2. Definition D2.2.1: “**demand attempts**” for the first call attempts, from all considered call demands, that reach a given point of the network. (The calling rate of demand attempts, generating from calling (A) terminals and incoming in the Reference Point 2 into the network model presented in Fig. 1, we note with $dem.Fa$);

2.2.3. Definition D2.2.2: “**repeated attempts**” are call attempts subsequent to first call attempts related to all considered call demands, that reaches a given point of the network.

2.2.4. The calling rate of these repeated attempts, generating from, and occupying calling (A) terminals and incoming in the Reference Point 2 into the network model presented in Figure 1, we note with $rep.Fa$. In this notation, the rate of all, incoming in the network, attempts (Fa) is:

$$Fa = dem.Fa + rep.Fa \, . \qquad (1)$$

The traffic of A-terminals, correspondent to Fa is notated with Ya .

2.3. Pie-Model concept

The Pie-Model concept is known through so called “pie-charts”. In pie-models all call attempts incoming to the network, e.g. in (RP2) in Figure 1, are distributed into branches with beginning RP2 and with end – the base virtual device considered, inclusively. The all virtual devices in the branch are considered as one device, aggregating them. The name of this aggregative device is the name of the last device in the branch, following from suffix “.p”, standing for “pie”. For example, the branch “carried communication” has last virtual device “cc” in the normalized model. The corresponding aggregation “pie-device” is named “cc.p” and has main parameters *Pcc.p*, *Tcc.p* and *Ycc.p*. These parameters may be expressed easy by means of normalized devices, e.g. for holding time (Tcc.p) we have (normalized base devices have suffix “.n”, standing for “normalized”):

$$\begin{aligned} Pcc.p &= (1-Pad.n)(1-Pid.n)(1-Pbs.n)(1-Pis.n) \\ &\quad (1-Pns.n)(1-Pbr.n)(1-Par.n)(1-Pac.n)\,. \\ Tcc.p &= Ted.n+Tcd.n+Tcs.n+Tcr.n+Tcc.n\,. \\ Ycc.p &= Fcc.p\;Tcc.p = Fa\;Pcc.p\;Tcc.p = (dem.Fa+rep.Fa)Pcc.p\;Tcc.p. \end{aligned} \qquad (2)$$

2.4. Ensue-Model concept

Let us consider the call attempts outgoing the device “carried switching” {cs.n} and incoming in RP4 in Figure 1. They have ensured continuation of their way in four possible branches. The set consisting of all base virtual devices, that may be occupied from the call attempts, after their leaving an appointed virtual device, we consider as an aggregative virtual device. The name of this aggregative device is the name of the appointed base device, following from suffix “.e”, standing for “ensue”[1]). The parameters of this “ensue device” may be expressed by means of normalized devices, e.g. for ensued traffic intensity ($Ycs.e$) and ensued holding time ($Tcs.e$) we have:

$$\begin{aligned} Ycs.e &= Ybr.n+Yar.n+Ycr.n+Yac.n+Ycc.n\,. \\ Tcs.e &= Pbr.n\;Tbr.n+(1-Pbr.n)\;Tb\,, \end{aligned} \qquad (3)$$

where Tb is the occupation time of the B-terminals (see Figure 1).

3. Effective traffic related definitions

Let us consider the following ITU-T definitions, copied from [ITU E.600] and commented by the author:

3.1. E.600, Definition 2.10: **fully routed call attempt; successful call attempt:** A call attempt that receives intelligible information about the state of the called user.

Comment: User’s states are, for example, “present” or “absent” and they are different from the terminal’s states, e.g. “not available”/”available” (in mobile networks) and “busy”/”free”.

3.2. E.600, Definition 2.11: **completed call attempt; effective call attempt:** A successful call attempt that receives an answer signal.

3.3. This definition refers rather the wanted terminal (responding equipment) state, because there are “calls on which an answer signal was received, although the called subscriber did not answer” [ITU E.422].

3.4. E.600, Definition 2.12: **successful call:** A call that has reached the wanted number and allows the conversation to proceed.

3.5. E.600, Definition 5.7: **effective traffic:** The traffic corresponding only to the conversational portion of effective call attempts.

3.6. Answer signal in effective call attempts (see E.600, 2.11 Definition) don’t means effective conversation, because: the user may absent (not answering condition); another user may repots that the wanted user is not near by; the quality of connection may be unacceptable, etc., so, an “abandoned conversation” case may occur. The referring to the “successful call” (see 3.4. E.600, 2.12 Definition) is more appropriate.

In view of mentioned and other discrepancies in the ITU-T definitions above, it is necessary to give new editions of the most of them:

3.7. Definition D3.1: **fully routed call attempt:** A call attempt that receives intelligible information about the state of the called terminal.

3.8. This means that fully routed attempts are reached RP4 in Fig. 1. In other words, they have created traffic *Ycs.p* and ensure ensued traffic *Ycs.e* with mean holding time Tcs.e (see equations (3)).

[1] ensue = happen afterwards; occur as a result [COD 99].

3.9. Definition D3.2: **fully routed traffic:** The portion of the traffic corresponding to the fully routed attempts, from the moment they reach the called terminal.

3.10. Definition D3.2 is in conformity with definition D3.1 and the value of the fully routed traffic is $Ycs.e$.

3.11. D3.3: **successful call attempt:** A fully routed call attempt that receives intelligible information about the state of the called user.

3.12. The successful attempt is reached RP6 in Fig. 1.

3.13. D3.4: **successful traffic:** The portion of the traffic corresponding to the successful attempts, from the moment they occupy the called terminal.

3.14. The B-terminal occupation happens in RP6. Following the reasoning in definitions D3.1 and D3.2, the value of successful traffic is $Yar.n + Ycr.n + Yac.n + Ycc.n$.

3.14. Definition D3.5: **effective call attempt:** A call attempt that has reached the called terminal and allows the communication with a user to proceed.

3.15. The effective attempt is reached the RP7 on Fig. 1 and a conversation (abandoned or carried) is occurring.

3.16. Definition D3.6: **effective traffic:** The portion of the traffic corresponding to the effective call attempts, from the moment of beginning the communication with a user.

3.17. Following the reasoning in definitions D3.1 and D3.2, the value of effective traffic is $Ycc.n$, because the abandoned communication is difficult to be accepted as “effective”. This is a strict definition. Some administrations might prefer a broad definition - to include the abandoned communications in definition also, because effective traffic is known as “cost effective traffic”. In this case, the effective traffic is $Ycr.e = Yac.n + Ycc.n$.

3.18. Definition D3.6 doesn’t contradict to E.600, definition 5.7. It’s only reformulated in order to reflect packet switching reality.

3.19. The (strict) effective attempts are moving only along the branch, corresponds to the {cc.p} (from RP2 to {cc.n}, see Figure 1) we call it “the *Carried Communication Branch*”. It’s parameters are: $Pcc.p, Tcc.p, Ycc.p$ (see equations (2)).

3.20. The “*ineffective attempts*” are all call attempts which are not effective.

4. Denial traffic concept

4.1. Every call attempt is generated with a will for success and it is moving in the Carried Communication Branch. In the normalized model every virtual switch, in the Carried Communication Branch, has two exits, so there are only two possibilities for a call attempt: 1) to continue its way towards {cc}; 2) to become ineffective and deflects of the effective way (to be failed in that switch point).

4.2. Definition D4.1: **denial traffic**: The portion of the traffic corresponding to the ineffective call attempts, created after call attempt deflection from the Carried Communication Branch.

4.3. In other words, denial traffic is served after the call attempt’s failure in a point of Carried Communication Branch.

4.4. The denial traffic is real traffic, a part of ineffective traffic, corresponding to the ineffective call attempts. In the model in Figure 1, denial traffic is served in 8 devices: {ad.n}, {id.n}, {bs.n}, {is.n}, {ns.n}, {br.n}, {ar.n}, and {ac.n} (the including of {ac.n} in the list depends on the accepted effective traffic definition, see 3.17 above). The blocking is only a cause for denial traffic appearance.

4.5. The denial traffic concept is a next generalization step, following a generalization tendency in ITU-T: “End-to-end connection, party, and multi-party set-up failure, …, can occur from a lack of resources due to insufficient dimensioning or failure from other errors. End-to-end failure from a lack of resources due to insufficient dimensioning can be considered as a special case of the set-up failure probability.” [ITU I.358].

5. Carried traffic concept

Let us consider a portion of the network on Figure 1, named “switching stage” (between the two vertical dotted lines). That portion of the network consists of four virtual devices: blocked switching {bs.n}, with traffic intensity $Ybs.n$; interrupted switching {is.n}, with traffic $Yis.n$; not switching (incorrect number, etc.), {ns.n} with traffic $Yns.n$; carried switching {cs.n} with traffic $Ycs.n$.

5.1. ITU concept for equivalent offered traffic [ITU E.501] is based on the carried traffic, defined in [ITU E.600]: E.600, Definition 5.1: **traffic carried:** The traffic served by a pool of resources.

5.2. E.600, Definition 5.5 doesn't reflect the difference between the parts of the served traffic: carried and denial traffics. The distinguishing is necessary for service assessment and optimization. The ratio carried/served traffic is a good efficiency indicator.

5.3. Obviously $Yis.n$ and $Yns.n$ are denial traffics, following of attempt's termination and possible repeated attempts. These traffics are real, they load switching system and must be taken into considerations in dimensioning, but it is a little forcedly to name them "carried"[2], better leave for them the name "denial".

5.4. There is a big distinction between carried traffic ($crr.Ys$) in the cases of circuit switching and packet switching networks. In the circuit switching, the carried traffic coincides with the traffic corresponded to the carried in the switching system attempts and the denial traffic ($Ycs.n + Ycs.e$, see equations (3)). In the packet switching networks, carried packets occupy switching system for a relative short time ($Tcs.n$ and correspondent $Ycs.n$).

The presented above gives grounds for a common, for circuit and packet switching networks, definitions, with illustrations based on the system presented on Fiure 1. These definitions are in force not only for switches.

6. Target traffic related definitions

In traffic engineering, many parameters have target values, which are interpreted as design objectives, see [ITU E.726].

6.1. The usual target value of blocking probability is zero (in our example, $trg.Pbs.n = 0$).

The traffic corresponding to this target value, in ITU-T recommendations is named "offered traffic": ITU E.600

6.2. The natural generalization of the target traffics is demand traffic concept. Since nobody demands unproductive attempt's occupation (and correspondent repeated attempts), the next definition is proposing:

Definition D6.2.1: **demand traffic**: The traffic that would be carried, in the overall network, from the demand attempts, if they all are served as current effective attempts. Consequently: $Pcc.p = 1$ and $rep.Fa = 0$.

6.2.1. Following definitions D2.2.1, D2.2.2, D6.2.1 and equations (2), putting $Pcc.p = 1$ and $rep.Fa = 0$ for the demand traffic ($dem.Ya$) of A-terminals, we receive:

$$dem.Ya = dem.Fa \; Tcc.p \, . \qquad (4)$$

6.2.2. The only difficulty, in evaluation of the demand traffic, through measurements in the real systems, is the estimation of $dem.Fa$, because it is connected with determination of repeated attempts flow.

6.2.3. Demand traffic is a dream target value for users and in the traffic management. Together with effective, carried and served traffics, it is useful for overall network performance evaluation.

6.2.4. The phrase "demand traffic" is used three times, without any definition, in the ITU-T Recommendations; "traffic demand" is used 50 times.

7. Conclusions

7.1. In addition to normalize and pie-models [Poryazov 2001], ensue model and denial traffic concept are proposed, as a parts of a technique for presentation and analysis of overall network traffic models functional structure. This allows real network traffic considered to be classified more precisely and shortly.

7.2. The ITU-T definitions for: fully routed, successful and effective attempts and effective traffic are re-formulated in order to avoid some discrepancies and to reflect packet switching reality. Definitions for fully routed traffic and successful traffic are proposed, because they are absent in the ITU-T recommendations.

7.3. A definition of demand traffic (absent in ITU-T Recommendations) is proposed. Together with effective, carried and served traffics, it is useful for overall network performance estimation.

7.4. For each definition are appointed:

1) the correspondent part of the conceptual model graphical presentation;
2) analytical equations, valid for mean values, in a stationary state.

[2] carry: 1. support or hold up, esp. while moving; 2. convey with one from one place to another; 3. have on one's person (carry a watch); 4. conduct or transmit (pipe carries water; wire carries electric current)…[COD 99]

7.5. The ITU-T definitions are needed a careful over-thinking for accuracy and completeness, because ITU is the base body for common fundamental concepts acceptation. Most of discussed in this paper terms are absent in [ANSI 2001] and ETSI definitions.

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