SOME QUALITY CHARACTERISTICS AND METRICES IN OVERALL TELECOMMUNICATION NETWORKS

Emiliya Saranova, Stoyan Poryazov

Abstract: More precise definitions of some ITU-T traffic concepts are used. On their base, three new more precise QoS traffic indicators are proposed and used for QoS characterization of a services delivered by a pool of resources (service phase concept). The quality of composition of two connected (sequentially or in parallel) service phases is presented as aggregation function of the qualities of the phases. Four different metrics are proposed. The results allow more precise prediction of service composition quality as function of sub-services quality. The approach is applicable for the overall telecommunication network QoS estimation.

***ITHEA Keywords**: Service composition, Causal aggregation, Quality of service composition, Quality metrics*

Introduction

The composition of informational services (especially in the internet) is an important topic from many years [Stegaru et al. 2012]. In the survey [Kondratyeva et al 2013] the quality of a composition as a function of the composed services' qualities is considered. Most of the metrics, for quality of composition estimation, use weighting coefficients proposed from the Network Administration. The objective metrics, based on direct analysis of flow, time and traffic parameters are rare. At the present, the state of the art is not very forwarded, in this direction [Otsetova, A., Saranova, 2017].

In this paper, the approach developed from authors in [Poryazov et al 2018a] and [Poryazov et al 2018b] is advanced for estimation of quality of service composition as an aggregation function of qualities of the service components (sub-services). More precise definitions of some ITU-T traffic concepts are used. On their base, three new more precise QoS traffic indicators are proposed and used for QoS characterization of a services delivered by a pool of resources (service phase concept). The quality of composition of two connected (sequentially or in parallel) service phases is presented as aggregation function of the qualities of the phases. Four different metrics are proposed. The results allow more precise prediction of service composition quality as function of sub-services quality. The approach is applicable for the overall telecommunication network QoS estimation.

Basic virtual devices

At the bottom of the structural model presentation, we consider “basic virtual devices” that do not contain any other virtual devices. Basic virtual devices, used in this paper, have graphic representations as shown in Figure 1.

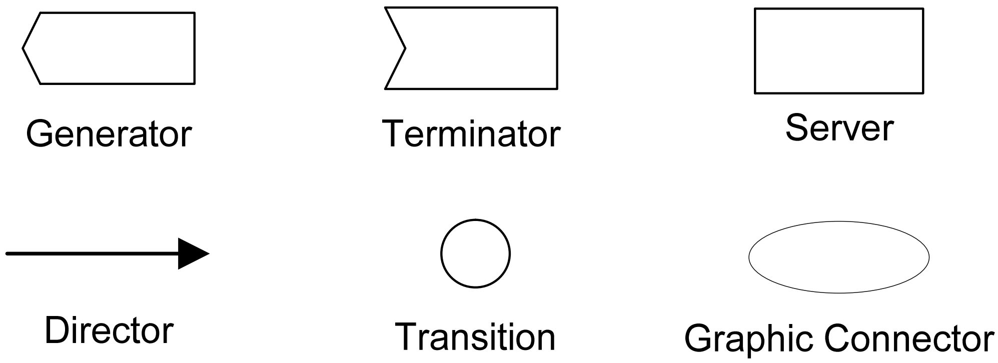

Figure 1. A graphical representation of the main basic virtual mono-functional devices used.

- *Generator* – this device generates calls (requests, transactions);
- *Terminator* – this block eliminates every request entered (so it leaves the model without any traces);
- *Server* – this device models the delay (the time duration of a service, the holding time) of requests in the corresponding device without their generation or elimination. It models also traffic- and time characteristics of the requests processing (c.f. Figure 2);
- *Director* – this device unconditionally points to the next device, which the request shall enter, but without a transfer or delay of it;
- *Transition* – this selects one of its possible outputs for each request entered, thus determining the next device where it shall go to;
- *Graphic Connector* – this is used to simplify the graphical representation of the conceptual model structure. It has no modeling functions.

The flows and main parameters of a basic virtual device (e.g. server) have the graphic representation as shown in Figure 2.

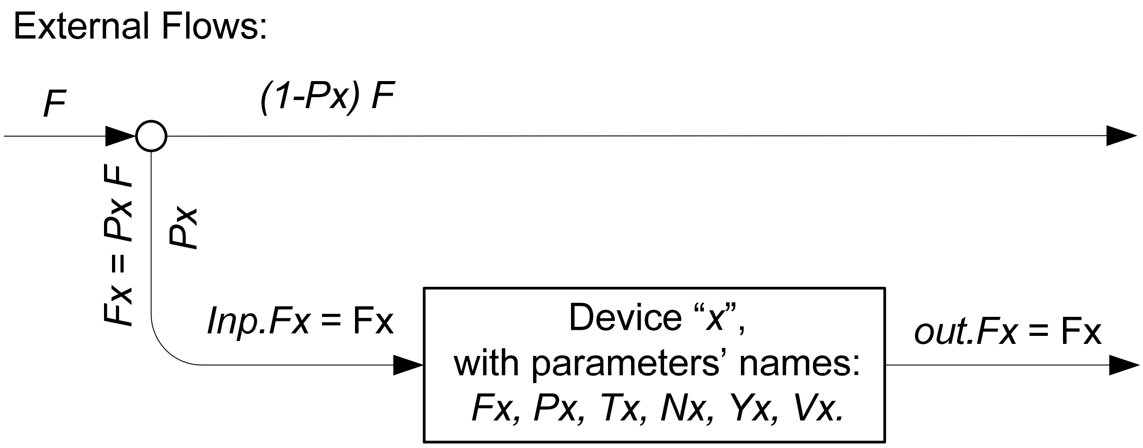

Figure 2. A graphical representation of a basic virtual device ***x*** and its main parameters. In stationary state $inp.Fx = out.Fx = Fx$.

Parameters of the basic virtual device x are the following (c.f. [ITU-T E.600, 1993] for terms definition):

Fx = Frequency (intensity or incoming rate) of the flow of requests (requests per time unit) to device x;

Px = Probability of direction of the requests towards device x;

Tx = Time duration of servicing of a request in by device x;

Nx = Number of lines (service places, positions, capacity) of device x;

Yx = Traffic intensity [Erlang];

Vx = Traffic volume [Erlang - time unit].

Stationary state

By assumption, every device, in the models, in this paper, is in a stationary state. So one may apply the Little's theorem [Little 1961] and for each device:

$$Yx = Fx\,Tx \tag{1}$$

In stationary state, input $(inp.Fx)$ and output $(out.Fx)$ flow intensities of a server coincide, because requests are not generated or terminated in a server. Obviously:

$$inp.Fx = out.Fx = Fx \tag{2}$$

Parameters' Qualification

In Fig. 2, one may see notations $inp.Fx$ and $out.Fx$. Traffic qualification is necessary and it is used in [ITU-T E.600, 1993], but without any attempt for including the qualifiers in the parameters' names. Since [Poryazov, Saranova 2006] we use up to two qualifiers as a part of the parameter's name. In this paper we use 'rep.' for 'repeated', 'ofr.' for 'offered', "srv"for 'served', "crr" for 'carried'etc. We expand the meaning of the traffic qualifiers to the other parameters determining the traffic, e.g. in our notations, $ofr.Ys = ofr.Fs\ \ srv.Ts$ means: 'the offered traffic intensity to the switching system is a product of the offered requests' frequency (rate) and the service time duration in the switching system'.

Service phase concept. Causal normalization

Based on the ITU-T definition of a service, provided in [ITU -T.E.800] (Term 2.14), i.e. "A set of functions offered to a user by an organization constitutes a service", we have proposed [Poryazov et al 2018b] the following definition of a service phase.

Definition 1: The Service Phase is a service presentation containing:

- One of the functions, realizing the service, which is considered indivisible;
- All modeled reasons for ending/finishing this function, i.e. the causal structure of the function;
- Hypothetic characteristics, related to the causal structure of the function (a well-known example of a hypothetic characteristic is the offered traffic concept).

Note that a service phase corresponds to service delivered by one pool of resources. We may present the service phase in device s by means of k+1 basic virtual causal devices, each representing a different reason for ending this service phase (Figure 3).

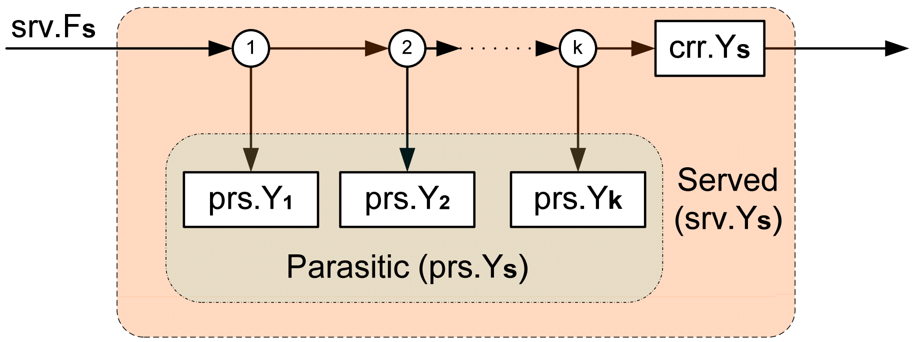

Figure 3. Traffic characterization of a service phase, represented as device ***s***, by means of ***k+1*** basic virtual causal devices.

In Figure 3, only one causal device represents successful completion of the service in device *s* – with carried traffic (*crr.Ys)*, whereas the remaining causal devices represent *k* different reasons for unsuccessful ending of the service – respectively with traffics $prs.Y_1, prs.Y_2,..., prs.Y_k$.

Generalizing, for more precise traffic characterization in a pool of resources, we propose the following definitions:

Definition 2: The Served Traffic in a pool of resources is the traffic, occupying (using) resources in the pool.

In Fig. 3, the served traffic in device *s* ($srv.Ys$) is the following sum:

$$srv.Ys = prs.Y1 + prs.Y2 + ... + prs.Yk + crr.Ys \quad . \qquad (3)$$

Definition 3: The Carried Traffic in a pool of resources is the traffic, which was successfully served in the pool (and carried to the next service phase).

In Figure 3, the carried traffic in device ***s*** is $crr.Ys$.

Definition 4: The Parasitic Traffic in a pool of resources is the traffic, which was unsuccessfully served in the pool.

In Figure 3, each of traffics $prs.Y_1, prs.Y_2,..., prs.Y_k$ is a parasitic one. Parasitic traffic occupies real resources of the pool, but not for an effective service execution.

In Definitions 2 and 3, the served- and carried traffic are different terms, despite the ITU-T definition of the carried traffic as “The traffic served by a pool of resources” ([ITU-T E.600, 1993], Term 5.5). We believe that this distinction leads to a better and more detailed traffic- and QoS characterization.

Causal aggregation in a service phase

The causal aggregation is understood as an aggregation of all cases in the model, corresponding to different reasons for service ending (referred to as unsuccessful cases).

Here a causal generalization is proposed, as an aggregation of all successful ($crr.Ys$) and all unsuccessful cases ($prs.Ys$).

$$prs.Ys = \sum_{i=1}^{k} prs.Yi \; ; \tag{4}$$

By Definition 2, the served traffic is a sum of the parasitic and carried traffic (c.f. Figure 1):

$$srv.Ys = prs.Ys + crr.Ys \; ; \tag{5}$$

$$srv.Fs = prs.Fs + crr.Fs \; . \tag{6}$$

By using the Little's formula we have: $prs.Ys = prs.Fs\ prs.Ts$ and $crr.Ys = crr.Fs\ crr.Ts$. Hence:

$$srv.Ys = srv.Fs\ srv.Ts = prs.Fs\ prs.Ts + crr.Fs\ crr.Ts \tag{7}$$

The causal generalization of Figure 3 is presented in Figure 4:

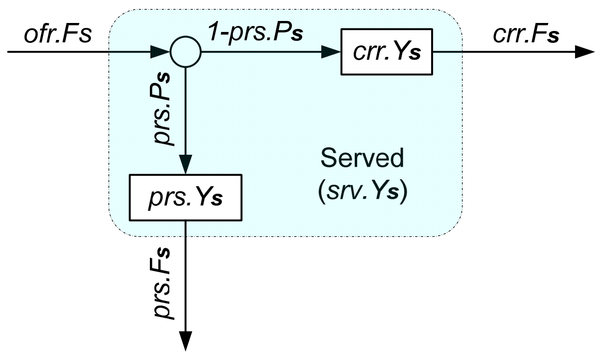

Figure 4. Causal generalized presentation of a service phase.

The causal generalized presentation of a service phase (Figure 4) consists of two virtual devices – one presents successful (carried) service and the other – unsuccessful (parasitic) service. $ofr.Fs$ is offered (incoming) intensity of requests; $crr.Fs$ and $prs.Fs$ are carried and parasitic respectively; $prs.Ps$ is the probability for parasitic service.

If we assume that $ofr.Fs$, $prs.Ps$, $prs.Tx$ and $crr.Fs$ are known, then directly from Figure 4 and Little's theorem, we receive:

$$prs.Fs = ofr.Fs\ prs.Ps \tag{8}$$

$$prs.Ys = prs.Fs\ prs.Ts = ofr.Fs\ prs.Ps\ prs.Ts \tag{9}$$

$$crr.Fs = ofr.Fs\ (1 - prs.Ps) \tag{10}$$

$$crr.Ys = crr.Fs\ crr.Ts = ofr.Fs\ (1 - prs.Ps)\ crr.Ts \tag{11}$$

$$srv.Fs = prs.Fs + crr.Fs = ofr.Fs \tag{12}$$

The service phase is considered as a device comprising carried and parasitic causal devices (c.f. Figure 4), so the served traffic intensity $srv.Yx$ is a sum of their traffics:

$$\begin{aligned} & srv.Ys = srv.Fs\ srv.Ts = prs.Ys + crr.Ys = \\ & ofr.Fs\,(prs.Ps\ prs.Ts + (1 - prs.Ps)\ crr.Ts) \end{aligned} \tag{13}$$

Therefore the mean service time of the phase ($srv.Ts$) is:

$$srv.Ts = prs.Ps\ prs.Ts + (1 - prs.Ps)\ crr.Ts \tag{14}$$

Quality factors and indicators of a service phase

There are many aspects of Quality of Service (QoS) [ITU -T.E.800], many factors influencing the QoS and corresponding indicators. We divide two types of factors' effects: degradative and terminative causing different effects. Degradative factors may cause degradation of the QoS, but the service is classified as successful. Terminative factors (i.g. interruption of the connection) cause termination of the service, which is classified as unsuccessful. A factor may be classified as degradative or terminative depending of its intensity, (i.g. noise, distortions, packet losses in speech communication, etc.).

In this paper we consider terminative effects only. Consequently, the quality indicators may be expressed in the concepts and terms of causal presentation of the services, considered in the previous two sections.

Following ITU-T approaches of traffic qualification and indicators definition ([ITU-T E.600, 1993] [ITU-T E.425]), and causal presentation of the services explained (c.f. Figure 4), we propose the following quality indicators:

Flow Quality (Q_f):

$$Q_f = \frac{carried\ requests'\ flow\ intensity}{served\ requests'\ flow\ intensity} = \frac{crr.F}{srv.F} \tag{15}$$

Traffic Quality (Q_y):

$$Q_y = \frac{carried\ traffic\ intensity}{served\ traffic\ intensity} = \frac{crr.Y}{srv.Y} \tag{16}$$

Time Quality (Q_t):

$$Q_t = \frac{total\ successful\ service\ time\ of\ requests}{total\ service\ time\ of\ requests} \tag{17}$$

The expression of the defined indicators using known parameters follows.

From (15), (10) and (12) follows

$$Q_f = \frac{crr.F}{srv.F} = \frac{ofr.F\ (1 - prs.P)}{ofr.F} = 1 - prs.P \tag{18}$$

From (16), (11) and (13) follows

$$Q_y = \frac{crr.Y}{srv.Y} = \frac{(1 - prs.P)\ crr.T}{prs.P\ prs.T + (1 - prs.P)\ crr.T} \tag{19}$$

Taking into account (14), from (19) follows:

$$Q_y = \frac{(1 - prs.P)\ crr.T}{srv.T} \tag{20}$$

Proposition 1: Numerically $Q_y = Q_t$ in a service phase.

Proof: From (17) and (20) follows:

$$Q_t = \frac{total\ successful\ service\ time\ of\ requests}{total\ service\ time\ of\ requests} = \frac{ofr.F\ (1 - prs.P)\ crr.T}{ofr.F\ srv.T} = Q_y \quad (21)$$

Quality aggregation of two consecutive service phases

Let Device x comprises two consecutively connected service phases named 1 and 2 (Figure 5)

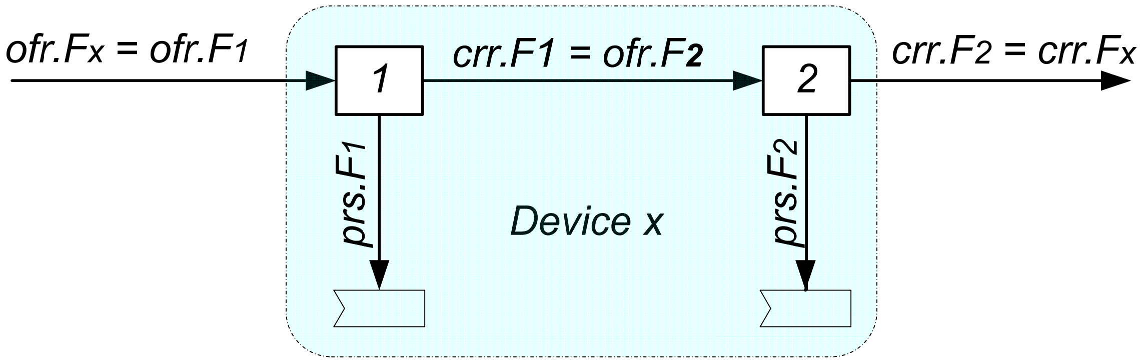

Figure 5. Two consecutively connected service phases named 1 and 2, and comprised in Device x .

We'll express the quality of the comprising Device x as function of its internal phases 1 and 2 (Figure 5). Obviously:

$$ofr.Fx = ofr.F1\ ;\ crr.F1 = ofr.F2\ ;\ crr.F2 = crr.Fx \quad (22)$$

By definition (15), the flow qualities (Q_{fx}, Q_{f1}, Q_{f2}) of Device x and internal phases 1 and 2 are:

$$Q_{fx} = \frac{crr.F_x}{srv.F_x} \quad (23)$$

$$Q_{f1} = \frac{crr.F_1}{srv.F_1} \quad (24)$$

$$Q_{f2} = \frac{crr.F_2}{srv.F_2} \quad (25)$$

Proposition 2: The flow quality Q_{fx} of the consecutively connected service phases is a multiplication of the flow qualities (Q_{f1}, Q_{f2}) of the phases:

$$Q_{fx} = Q_{f1} Q_{f2} \quad (26)$$

Proof: From (12), (22) and (24):

$$crr.F_1 = ofr.F_1\ Q_{f1} \tag{27}$$

From (12), (22) and (25):

$$crr.F_2 = ofr.F_2\ Q_{f2} \tag{28}$$

From (22), (23), (27) and (28) follows

$$crr.F_x = crr.F_2 = ofr.F_2\ Q_{f2} = crr.F_1\ Q_{f2} = ofr.F_1\ Q_{f1} Q_{f2} = ofr.F_x Q_{f1} Q_{f2} \tag{29}$$

From (23) and (29) follows (26).

Proposition 3: The traffic quality (Q_{yx}) of the consecutively connected service phases is a weighted mean of the traffic qualities (Q_{y1}, Q_{y2}) of the phases:

$$Q_{yx} = Q_{y1}\ \alpha_1 + Q_{y2}\ \alpha_2 \tag{30}$$

where:

$$\alpha_1 = \frac{srv Y_1}{srv.Y_x} \tag{31}$$

$$\alpha_2 = \frac{srv Y_2}{srv.Y_x} \tag{32}$$

$$\alpha_1 + \alpha_2 = 1 \tag{33}$$

Proof: By definition (16), the traffic qualities (Q_{yx}, Q_{y1}, Q_{y2}) of Device x and internal phases 1 and 2 are:

$$Q_{yx} = \frac{crr.Y_x}{srv.Y_x} \tag{34}$$

$$Q_{y1} = \frac{crr.Y_1}{srv.Y_1} \tag{35}$$

$$Q_{y2} = \frac{crr.Y_2}{srv.Y_2} \tag{36}$$

In the scheme in Figure 5, every served (carried or parasitic) request in devices 1 and 2 is served in comprising device x , therefore:

$$crr.Y_x = crr.Y_1 + crr.Y_2 \tag{37}$$

$$srv.Y_x = srv.Y_1 + srv.Y_2 \tag{38}$$

From (34), (37) and (38) follows:

$$Q_{yx} = \frac{crr.Y_1 + crr.Y_2}{srv.Y_x} = \frac{crr.Y_1}{srv.Y_x} + \frac{crr.Y_2}{srv.Y_x} \tag{39}$$

From (39), (35) and (36) follows:

$$Q_{yx} = \frac{Q_{y1}\ srv.Y_1}{srv.Y_x} + \frac{Q_{y2}\ srv.Y_2}{srv.Y_x} = Q_{y1}\ \alpha_1 + Q_{y2}\ \alpha_2 \tag{40}$$

From (38) and (40) follows Proposition 3.

Proposition 4: Traffic quality metrics of the consecutively connected service phases depends of flow quality metrics.

Proof: Expressing (31) and (32) by the parameters of devices 1 and 2, and using (11), (13), (15), (24) and (25) we obtain:

$$srv.Y1 = ofr.Fx\,[prs.P1\ prs.T1 + Qf1\ crr.T1] \tag{41}$$

$$srv.Y2 = ofr.Fx\,Qf1[prs.P2\ prs.T2 + Qf2\ crr.T2] \tag{42}$$

$$srv.Yx = ofr.Fx\,\{prs.P1\ prs.T1 + Qf1\,[crr.T1 + prs.P2\ prs.T2 + Qf2\ crr.T2]\} \tag{43}$$

Quality aggregation of two parallel service phases

Let two service phases are connected in parallel (Figure 6) and considered as a comprising Device x . An offered request may be served alternatively: with probability $P1$ in Service Phase 1 or with probability $P2$ - in Service Phase 2. Obviously:

$$P1 + P2 = 1 \tag{44}$$

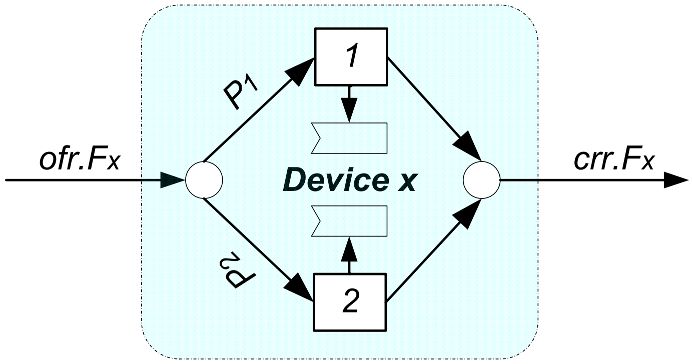

Figure 6. Two parallel connected service phases named 1 and 2, and comprised in Device x.

Proposition 5: The flow quality (Q_{fx}) of Device x depends from the flow qualities of two parallel connected service internal phases 1 and 2, (Q_{f1}, Q_{f2}) by the expression:

$$Q_{fx} = Q_{f1}\ P_1 + Q_{f2}\ P_2 \tag{45}$$

Proof: By definition (15):

$$Q_{fx} = \frac{crr.F_x}{ofr.F_x} \tag{46}$$

From Figure 6 follows:

$$crr.F_x = crr.F_1 + crr.F_2 \tag{47}$$

From (46):

$$crr.F_1 = Q_{f1}\ ofr.F_1 \tag{48}$$

$$ofr.F_1 = ofr.F_x\ P_1 \tag{49}$$

Therefore:

$$crr.F_1 = Q_{f1}\ crr.F_x\ P_1 \tag{50}$$

Analogously:

$$crr.F_2 = Q_{f2}\ crr.F_x\ P_2 \tag{51}$$

From (47), (50) and (51) follows:

$$crr.F_x = ofr.F_x\ (Q_{f1}\ P_1 + Q_{f2}\ P_2) \tag{52}$$

From (52) follows (46) – the Proposition 5.

Proposition 6: The traffic quality (Q_{yx}) of Device x depends from the flow qualities of two parallel connected internal service phases 1 and 2, (Q_{y1}, Q_{y2}) by the expression:

$$Q_{yx} = Q_{y1}\ \beta_1 + Q_{y2}\ \beta_2 \tag{53}$$

where:

$$\beta_1 = \frac{srv.Y_1}{srv.Y_x} = \frac{P_1\ srv.T_1}{srv.T_x} \tag{54}$$

$$\beta_2 = \frac{srv.Y_2}{srv.Y_x} = \frac{P_2\ srv.T_2}{srv.T_x} \tag{55}$$

$$\beta_1 + \beta_2 = 1 \tag{56}$$

Proof: By definition (16):

$$Q_{yx} = \frac{crr.Y_x}{srv.Y_x} \tag{57}$$

From (37) and (57) follows:

$$Q_{yx} = \frac{crr.Y_x}{srv.Y_x} = \frac{crr.Y_1 + crr.Y_2}{srv.Y_x} = \frac{crr.Y_1}{srv.Y_x} + \frac{crr.Y_2}{srv.Y_x} \tag{58}$$

From (58), (35) and (36):

$$Q_{yx} = \frac{crr.Y_1}{srv.Y_x}\ \frac{srv.Y_1}{srv.Y_1} + \frac{crr.Y_2}{srv.Y_x}\ \frac{srv.Y_2}{srv.Y_2} = Q_{y1}\ \frac{srv.Y_1}{srv.Y_x} + Q_{y2}\ \frac{srv.Y_2}{srv.Y_x} = Q_{y1}\ \beta_1 + Q_{y2}\ \beta_2 \tag{59}$$

Where, following (49) and analogous expression for $ofr.F2$ follows that:

$$\beta_1 = \frac{srv.Y_1}{srv.Y_x} = \frac{P_1\ ofr.F_x\ srv.T_1}{ofr.F_x\ srv.T_x} = \frac{P_1\ srv.T_1}{srv.T_x} \tag{60}$$

$$\beta_2 = \frac{srv.Y_2}{srv.Y_x} = \frac{P_2\ ofr.F_x\ srv.T_2}{ofr.F_x\ srv.T_x} = \frac{P_2\ srv.T_2}{srv.T_x} \tag{61}$$

Conclusion

The four metrics defined (26), (30), (45) and (53) are useful for QoS estimation of different parts of the telecommunication network as well as of the overall network (considered as consists of aggregated served and carried traffics).

For further work, estimation of composed QoS degradative factors is very important, because it is not investigated enough.

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