Comparison of Conceptual Models of Overall Telecommunication Systems with QoS Guarantees

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Abstract. Different approaches to conceptual modeling of overall telecommunication systems with QoS guarantees are discussed. Generalized Nets (GNs) are used as an alternative to the already existing conceptual models based on the Service Networks Theory. Two GN representations of a part of the Switching stage are proposed and their advantages and disadvantages are discussed.

Keywords: Overall telecommunication system · Generalized nets · Conceptual model · QoS guarantees

1 Introduction and Related Work

The field of our research includes complex overall telecommunication systems with Quality of Service (QoS) guarantees, taking into consideration: human factors; technical characteristics of the telecom network; the techno-socio-economic environment; QoS indicators, as a base for Quality of Experience (QoE) estimation. The characterization and estimation of QoE, especially in the context of multimedia (voice, video streaming) and Web services has been subject to increasing research interest in the last years. Characterization, estimation and management of the QoE are functions of many factors, but always are based on QoS indicators' values and are still open questions. The two main objectives of our work are creation of verified and validated computer models of:

- QoS prediction, in case of known other parameters;
- QoS guarantying (determination of the volume of necessary network resources, in case of known other parameters and target QoS).

We are fully agreed with the best available book in the field [5]: "A creation of a good conceptual model lays a strong foundation for successful simulation modeling and analysis" and "The state-of-the-art is such that we are not yet in

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a position to propose a unified definition of a conceptual model or a unified approach to conceptual modeling." The aim of this paper is to present some results of our conceptual modeling practice towards proposition of unified definition of a conceptual model. We use the conceptual modeling for the determination and explication of:

- The concept used in modeling. The telecommunication systems are very complex artefacts and many concepts are used in their investigation, e.g. belonging to mathematics, informatics, economics, sociology, psychology. Each concept may introduce its own terminology and conceptual models.
- The modelled structure (functional, temporal, spatial, financial etc.) of the system of interest. This includes Reference Points, in which the real system's and model's values of the parameters are objects of comparison in the models' validation.
- The assumptions and simplifications of the modelled system used in the model;
- The model specifications, used in discussions among modelers, model users, mathematicians and programmers (model implementers).
- A common base for modelling, verification and validation. Our conceptual model is used for parallel analytical and Informatical modelling, as well as for comparison of the results received from computer simulation (mutual verification of analytical and Informatical models) and measurements in the real system (model validation).
- A common base for forward and inverse modelling and simulation. A conceptual model is used for QoS prediction, and QoS guarantying tasks. This allows mutual verification of the forward and inverse models.

The three conceptual models, presented in this paper, are of one and the same telecommunication system. The first one (in Sect. 2), based on Service Networks Theory concepts including Queuing Theory devices, is briefly described. It is used for the creation of mathematical models of forward (QoS prediction) and inverse (QoS guarantying) tasks [6]. In Sect. 3, ordinary Generalized Net (GN) concepts are used. In Sect. 4 – an extension of the GNs. As a conclusion, the three conceptual models are discussed in Sect. 5.

2 Conceptual Model of Overall Telecommunication System Based on Service Networks Theory

The conceptual model includes user's behavior, a limited number of homogenous terminals; losses due to abandoned and interrupted dialing, blocked and interrupted switching, unavailable intent terminal, blocked and abandoned ringing and abandoned communication. The network traffic for the calling (denoted by A) and the called (denoted by B) terminals and user's traffic are considered seperately in their interrelationship. Two types of virtual devices are used: basic and comprising.

The basic virtual devices types, their names and graphic representation are shown in Fig. 1. There are six different types of basic virtual devices: Generator, Terminator, Modifier, Server, Enter Switch, Switch and Graphic conncetor. Every basic virtual device, except the Switch, has no more than one entrance and/or one exit. Switches have one or two entrances and one or two exits.

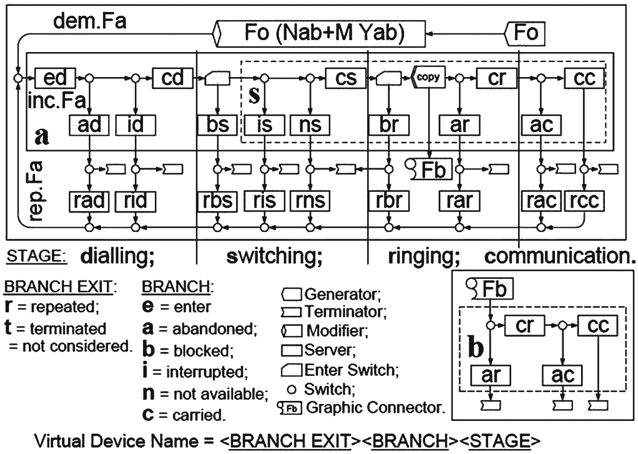

Fig. 1. Conceptual model of a telecommunication system.

Each of the basic devices is characterized by the following parameters: F - intensity (frequency, rate) of the flow [calls/sec]; P - probability of directing the calls of the external flow to the device considered; T - service time in the device of a call [seconds]; Y - intensity of the device traffic [Erlangs]; N - number of service places (lines, servers) in the virtual device (capacity of the device).

Three comprising virtual devices are considered in the conceptual model: **a** – virtual device that comprises all the A-terminals (calling) in the system. It is represented by a continuous line box in Fig. 1; **b** - virtual device that comprises all the B-terminals (called) in the system. It is represented by a dashed line box in Fig. 1; **s** - virtual device corresponding to the switching subsystem. Represented by a dashed line box in the **a**-device in Fig. 1.

3 Generalized Net Model of a Part of the Switching Stage

The theory of GNs [2] and their applications [3] provide alternative approach to the conceptual modeling of telecommunication systems. In this section an ordinary GN is used. The GN in Fig. 2 represents a part of the Switching stage from the conceptual model.

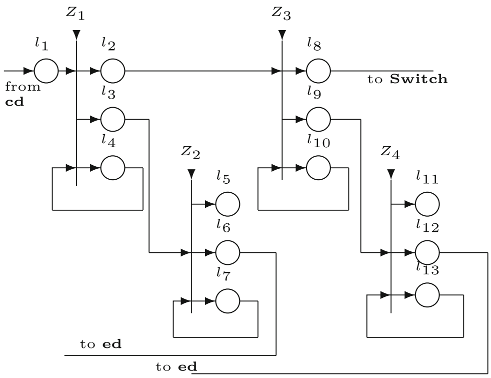

Fig. 2. Generalized net model of a part of the Switching stage.

The places in the GN model correspond to basic devices in the conceptual model as follows: l_1 corresponds to the Enter Switch deivice before the comprising virtual device s; l_2 corresponds to the Switch device at the beginning of the comprising virtual device s; l_3 corresponds to Switch device after the bs device; l_4 corresponds to bs; l_5 corresponds to the Terminator after bs; l_6 corresponds to the Switch after rbs; l_7 corresponds to rbs; l_8 corresponds to the Switch before the cs device; l_9 corresponds to the Switch after is; l_{10} corresponds to is; l_{11} corresponds to the Terminator after is; l_{12} corresponds to the Switch after ris; l_{13} corresponds to ris.

Five different types of tokens are used in the model. Tokens of type α represent the call attempts. They enter the net in place l_1 with characteristic *"volume, duration of service,call destination".* Token of type β stays in place l_4 in the initial moment. It is used to accumulate data about the bs device. Token of type γ stays in place l_7 in the initial moment. It is used to accumulate data about the rbs device. Token of type δ stays in place l_{10} in the initial moment. It is used to accumulate data about the is device. Token of type ϵ stays in place l_{13} in the initial moment. It is used to accumulate data about the ris device.

All tokens except the tokens of type α have initial characteristic: *"initial values of* $Y_{dn}, P_{dn}, F_{dn}, T_{dn}$", where dn denotes the corresponding device name. What follows is a description of the transitions.

$$Z_1 = \langle \{l_1, l_4\}, \{l_2, l_3, l_4\}, r_1 \rangle, \text{ where } r_1 = \begin{array}{c|ccc} & l_2 & l_3 & l_4 \\ \hline l_1 & W_{1,2} & W_{1,3} & W_{1,4} \\ l_4 & false & false & true \end{array}$$

and

- $W_{1,2} =$ "$Y_{is} + Y_{ns} + Y_{cs} < N_s$";
- $W_{1,3} = \neg W_{1,2}$;
- $W_{1,4} = W_{1,3}$.

When the truth value of the predicate $W_{1,2}$ is "true" the token α enters place l_2 without obtaining any new characteristic. When the truth value of the predicate $W_{1,3}$ is "true" the token α splits into two identical tokens one of which enters place l_3 and the other one merges with the β token in place l_4. In place l_3 the tokens do not obtain new characteristics. Token β in place l_4 obtains the characteristic *"current value of* Y_{bs}".

$$Z_2 = \langle\{l_3, l_7\}, \{l_5, l_6, l_7\}, r_2\rangle, \text{ where } r_2 = \begin{array}{c|ccc} & l_5 & l_6 & l_7 \\ \hline l_3 & W_{3,5} & W_{3,6} & W_{3,7} \\ l_7 & false & false & true \end{array}$$

and

- $W_{3,5}$ = "the current call is terminated (with a given probability)";
- $W_{3,6}$ = "the current call is repeated (with a given probability)";
- $W_{3,7} = W_{3,6}$.

When the truth value of the predicate $W_{3,5}$ is "true" the current token α enters place l_5 without obtaining any new characteristic. When the truth value of the predicate $W_{3,6}$ is "true" the current token α splits into two identical tokens one of which enters place l_6 and the other one enters place l_7 where it merges with the γ token. In place l_6 the tokens do not obtain new characteristics. Token γ in place l_7 obtains the characteristic *"current value of* Y_{rbs}".

$$Z_3 = \langle\{l_2, l_{10}\}, \{l_8, l_9, l_{10}\}, r_3\rangle, \text{ where } r_3 = \begin{array}{c|ccc} & l_8 & l_9 & l_{10} \\ \hline l_2 & W_{2,8} & W_{2,9} & W_{2,10} \\ l_{10} & false & false & true \end{array}$$

and

- $W_{2,8}$ = "the current call is carried (with a given probability)";
- $W_{2,9}$ = "the current call is interrupted (with a given probability)";
- $W_{2,10} = W_{2,9}$.

When the truth value of the predicate $W_{2,8}$ is "true" the current α token enters place l_8 without obtaining any new characteristic. When the truth value of the predicate $W_{2,9}$ is "true" the current token α splits into two identical tokens one of which enters place l_9 and the other one enters place l_{10} where it merges with the δ token. In place l_9 the tokens do not obtain new characteristics. Token δ in place l_{10} obtains the characteristic *"current value of* Y_{is}".

$$Z_4 = \langle\{l_9, l_{13}\}, \{l_{11}, l_{12}, l_{13}\}, r_4\rangle, \text{ where } r_4 = \begin{array}{c|ccc} & l_{11} & l_{12} & l_{13} \\ \hline l_9 & W_{9,11} & W_{9,12} & W_{9,13} \\ l_{13} & false & false & true \end{array}$$

and

- $W_{9,11}$ = "the current call is terminated (with a given probability)";
- $W_{9,12}$ = "the current call is repeated (with a given probability)";
- $W_{9,13} = W_{9,12}$.

When the truth value of the predicate $W_{9,11}$ is "true" the current token α enters place l_{11} without obtaining any new characteristic. When the truth value of the predicate $W_{9,12}$ is "true" the current token α splits into two identical tokens one of which enters place l_{12} and the other one enters place l_{13} where it merges with the ϵ token. In place l_{12} the tokens do not obtain new characteristics. Token δ in place l_{13} obtains the characteristic: *"current value of* Y_{ris}".

4 Representation of a Part of the Switching Stage with Generalized Nets with Characteristics of the Places

The model proposed in the previous section uses ordinary GNs. In one of the most recent extensions of the GNs – Generalized Nets with Characteristics of the Places (GNCP, [1]) – the places can also obtain characteristics. Here we propose a GNCP model of the same part of the Switching stage as the one in Sect. 3. For the sake of brevity, we use a reduced GNCP. The graphical representaion of the net is shown in Fig. 3.

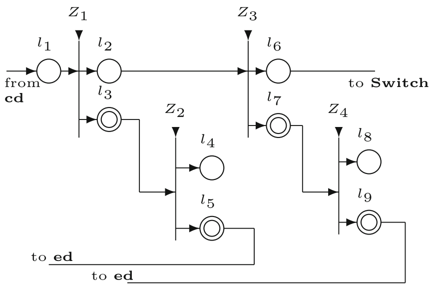

Fig. 3. GNCP model of a part of the Switching stage.

In the GNCP model only one type of tokens is used. The meaning of the places is the following: l_1 corresponds to the Enter Switch deivice before the comprising device S; l_2 corresponds to the Switch at the beginning of the comprising device S; l_3 corresponds bs; l_4 corresponds to the Terminator after bs; l_5 corresponds to rbs; l_6 corresponds to the Switch before the cs device; l_7 corresponds to is; l_8 corresponds to the Terminator after is; l_9 corresponds to ris. The places denoted by two concentric circles obtain characteristics when tokens enter them. These characteristics allow for accumulation of data related to the corresponding virtual device.

Tokens representing the call attempts enter the net through place l_1. They have the same characteristics as in the ordinary GN model. Places l_3, l_5, l_7, l_9 have initial characteristic in the form *"initial values of* Y_{dn}, F_{dn}, P_{dn}, T_{dn}*"* where *dn* denotes the device corresponding to the place as described above. In places l_2, l_4, l_6, l_8 the tokens do not obtain characteristics.

For completeness we give the formal description of the transitions.

$$Z_1 = \langle \{l_1\}, \{l_2, l_3\}, r_1 \rangle, \text{ where } r_1 = \begin{array}{c|cc} & l_2 & l_3 \\ \hline l_1 & W_{1,2} & W_{1,3} \end{array}$$

and

- $W_{1,2} =$ "$Y_{is} + Y_{ns} + Y_{cs} < N_s$";
- $W_{1,3} = \neg W_{1,2}$.

When the truth value of the predicate $W_{1,3}$ is "true" the current token enters place l_3 without obtaining new characteristic. Place l_3 obtains the characteristic *"current value of* Y_{bs}*"*.

$$Z_2 = \langle \{l_3\}, \{l_4, l_5\}, r_2 \rangle, \text{ where } r_2 = \begin{array}{c|cc} & l_4 & l_5 \\ \hline l_3 & W_{3,4} & W_{3,5} \end{array}$$

and

- $W_{3,4} =$ "The current call is terminated (with a given probability)";
- $W_{3,5} =$ "The current call is repeated (with a given probability)".

When the truth value of the predicate $W_{3,5}$ is "true" the current token in place l_3 enters place l_5 without obtaining characteristic. Place l_5 obtains the characteristic *"current value of* Y_{rbs}*"*.

$$Z_3 = \langle \{l_2\}, \{l_6, l_7\}, r_3 \rangle, \text{ where } r_3 = \begin{array}{c|cc} & l_6 & l_7 \\ \hline l_2 & W_{2,6} & W_{2,7} \end{array}$$

and

- $W_{2,6} =$ "The current call is carried (with a given probability)";
- $W_{2,7} =$ "The current call is interrupted (with a given probability)".

When the truth value of the predicate $W_{2,7}$ is "true" the current token α enters place l_7 without new characteristic. Place l_7 obtains the characteristic *"current value of* Y_{is}*"*.

$$Z_4 = \langle \{l_7\}, \{l_8, l_9\}, r_4 \rangle, \text{ where } r_4 = \begin{array}{c|cc} & l_8 & l_9 \\ \hline l_7 & W_{7,8} & W_{7,9} \end{array}$$

and

- $W_{7,8} =$ "The current call is terminated (with a given probability)";
- $W_{7,9} =$ "The current call is repeated (with a given probability)".

When the truth value of the predicate $W_{7,9}$ is "true" the current token α enters place l_9 without new characteristic. Place l_9 obtains the characteristic *"current value of* Y_{ris}".

5 Comparison of the Approaches and Conclusions

The conceptual model presented in Fig. 1 gives a clearer connection between the functions of the real system and their visual representations. It allows for easy understanding of the connections between the virtual devices and their functions. A downside of this approach is that it uses 7 different virtual devices. It shows the paths of the calls in the system but the calls are not presented in the model.

On the other hand, the GN models use less different components to describe the devices and the paths of the calls: places, arcs, transitions in the ordinary GN model in Fig. 2 and arcs, transitions and two types of places in the GNCP model in Fig. 3. That is why the GN representations are, in a sense, graphically simpler. However, users need special training in order to understand the paths of the calls and the connections between the analogues of the virtual devices in the net. The GNCP model has the simplest graphic representation. It has 4 places less than the GN model in Sect. 3, less arcs and, also, only one type of tokens is used while in the GN model in Sect. 3 we have five types of tokens.

In the telecommunication systems with virtual channel switching one call occupies all devices through which it has passed. With regard to this, it will be interesting to study a GN representation using one of the recently proposed extensions of the GNs – Generalized Nets with Volumetric Tokens – defined in [4]. In our future work, we intend to propose and study different GN analogues to the devices from the Service Networks Theory that would make the GN models more user-friendly.

The presented models of one aspect of a telecommunication system lead to the conclusion that a conceptual model may be invariant to the modeling sub-concepts and tasks, in contrast with considerations in [5]. This have to be taken into account in QoS related tasks.

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