Proceedings of the 2019 IEEE Conference on Big Data, Knowledge and Control Systems Engineering (BdKCSE)

Different Traffic Quality Aggregations for a Service Composition

Stoyan Poryazov
Institute of Mathematics and Informatics
Bulgarian Academy of Sciences
Sofia, Bulgaria
stoyan@math.bas.bg

Velin Andonov
Institute of Mathematics and Informatics
*Bulgarian Academy of Sciences*Sofia, Bulgaria
velin_andonov@math.bas.bg

Emiliya Saranova
Institute of Mathematics and Informatics
Bulgarian Academy of Sciences
Sofia, Bulgaria
emiliya@math.bas.bg

***Abstract*— The present paper studies the problem of the composition of traffic quality in a service composition. The causal structure is represented through causal virtual devices corresponding to parasitic, carried and served traffic. Causal composition and decomposition of traffic quality is represented graphically and analytically. A naming system of the virtual devices is proposed which takes into account the level of inclusion of the base virtual devices into the comprised. Different traffic quality aggregations are derived for service compositions in the cases of consecutively and parallel connected virtual devices.**

Keywords*— *service networks, causal structure; traffic quality, quality compositions.

I. INTRODUCTION

The importance of Quality of Service (QoS) indicators grows with the usage of the informational service networks and became a commodity in 2015 [1]. The QoS and Quality of Experience (QoE) are defined in different ways, but we will follow the definition in standardization documents such as the ITU-T [2]. The prediction of the overall network quality, as a function of qualities of composed services, is a foremost question in service networks design and maintenance. There are two main approaches of QoS aggregation – analytical (e.g. [3]) and simulational (e.g. [4]).

In the available literature the only traffic-like quality indicator considered is "throughput".

In our approach, services are presented as virtual devices and we use three QoS indicators: Flow Efficiency (Qf) Traffic Efficiency (Qy) and Time Efficiency (Qt) [5], applied to the causal virtual devices [6] and described in Section II. It is shown that Traffic Efficiency and Time Efficiency coincide numerically for a service device.

representation of a base virtual device such as server, buffer, switch etc. is shown in Fig. 1. Every such device named x has the following parameters:

The work was supported by the Task 1.2.5. of the National Scientific Program "Information and Communication Technologies for a Single Digital Market in Science, Education and Security (ICT in SES)" financed by the Bulgarian Ministry of Education and Science. The work of V. Andonov was supported by the Bulgarian NSF under grant DM 12/2 – "New Models of Overall Telecommunication Networks with Quality of Service Guarantees".

In Section III Consecutive Composition of virtual devices is considered and aggregation functions of introduced indicators are derived. In Section IV Alternative Composition of devices is considered. In the every of cases of consecutive and alternative compositions, the aggregation functions are completely different for Flow Efficiency and Traffic Efficiency indicators.

In the conceptual models of service networks we use base virtual devices [6]. A general representation of a base virtual device such as server, buffer, switch etc. is shown in Fig. 1. Every such device named x has the following parameters:

Fx – Intensity or incoming rate (frequency) of the flow of requests (i.e. the number of requests per time unit) to device x;

Px – Probability of directing the requests towards device x;

Tx – Service time (duration of servicing of a request) in device x;

Yx – Traffic intensity [Erlang];

Vx – Traffic volume [Erlang - time unit];

Nx – Number of lines (service resources, positions, capacity) of device x.

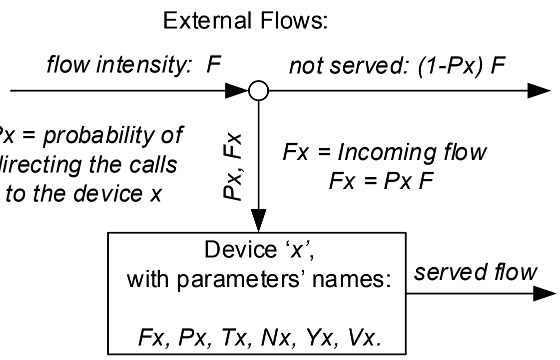

Fig. 1. Graphical representation of a base virtual device x.

The base virtual devices do not contain other devices. In our models of telecommunication networks we also use comprise virtual devices which include base virtual devices. An example of comprise virtual device is shown in Fig. 4.

978-1-7281-6481-6/19/$31.00 ©2019 IEEE

Some virtual device can have more than one exits (see Fig. 2). Each one of the *k* exiting arrows corresponds to one service line of the device x.

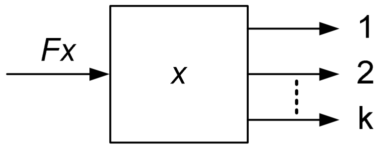

Fig. 2. Virtual device x with k service lines.

In the conceptual models of telecommunication systems the following types of base virtual devices are used: Director, Generator, Terminator, Server, Causal device, Enter Switch, and Switch. Their graphical representations are shown in Fig. 3.

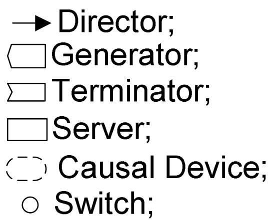

Fig. 3. Graphical representation of the base virtual devices.

Each type of the base virtual devices has specific function:

- Director – this device unconditionally points to the next device, which the request shall enter, but without transferring or delaying it;
- Generator – this device generates calls (service requests, transactions);
- Terminator – this block eliminates every request entered (so it leaves the model without any traces);
- Server – this device models the delay (service time, 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. Fig. 3);
- Causal device – virtual device defined for presentation of carried and parasitic service;
- Transition – this device selects one of its possible exits for each request entered, thus determining the next device where this request shall go to.

II. Causal Structure

The causal structure of the traffic composition/decomposition is represented graphically in Fig. 4.

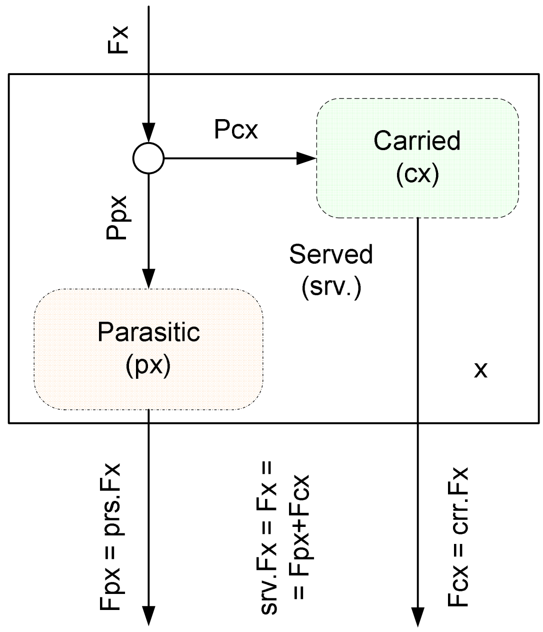

Fig. 4. Causal decomposition of the traffic in virtual devicex.

The virtual device cx and px are causal virtual devices. In general, the virtual devices can contain special causal devices corresponding to abandoned, interrupted, blocked, etc., traffic. That is why we call them generalized causal devices. The causal names of the generalized virtual causal devices are: c (carried or crr), p (parasitic or prs) and s (served or srv).

Qualifiers are used to characterize the parameters of the devices [6]. In the present paper we use the qualifiers crr. (carried), prs. (parasitic) and srv. (served). For instance, crr.Fx is the intensity of the carried flow of requests of the device x, prs.Fx is the intensity of the parasitic flow of requests of the device x (see Fig. 4).

For the causal decomposition shown in Fig. 4 the following equalities hold:

$$Ppx+Pcx=1 \tag{1}$$

$$srv.Fx=crr.Fx+prs.Fx \tag{2}$$

$$prs.Fx= FxPpx \tag{3}$$

$$crr.Fx = Fx(1-Ppx) \tag{4}$$

$$srv.Fx = Fx = Fpx + Fcx \tag{5}$$

A more detailed case of causal decomposition is presented in Fig. 5. Two different types of service of the requests in the causal device *Carried* (*cx*) are presented. They are denoted by *zero* and *real*. The requests which enter the zero device are serviced without delay, while the *real* device represents the *real* service of the requests with the corresponding delay.

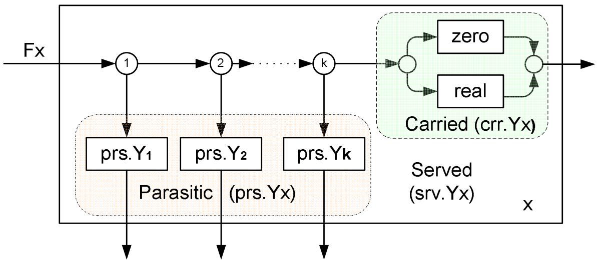

Fig. 5. More general causal decomposition in a virtual device x.

For the causal composition in Fig. 5 the following important equalities hold:

$$prs.Yx = prsY_1 + prs.Y_2 + \cdots + prs.Y_k. \quad (6)$$

$$crr.Yx = Yzero + Yreal\,. \quad (7)$$

For the base virtual device *x* shown in Fig. 4, we introduce the following quality indicators:

$$Qyx = \frac{crr.Yx}{srv.Yx} = \frac{Ycx}{Ycx + Ypx} = \frac{Fcx\,Tcx}{Fcx\,Tcx + Fpx\,Tpx}, \quad (8)$$

$$Qfx = \frac{crr.Fx}{srv.Fx} = \frac{Fcx}{Fcx + Fpx}\ , \quad (9)$$

$$Qtx = \frac{crr.Fx}{srv.Tx} = \frac{crr.Fx\,Tcx}{crr.Fx\,Tcx + prs.Fx\,Tpx} =$$

$$= \frac{Fx\,Pcx\,Tcx}{Fx(PcxTcx + PpxTpx)} = \frac{Pcx\,Tcx}{Pcx\,Tcx + Ppx\,Tpx} =$$

$$= \frac{\mathrm{Pcx\,Tcx}}{\mathrm{Tx}} = \mathrm{Qyx}. \quad (10)$$

Equation (10) shows that only the first two indicators shoud be determined for any device since *Qtx* quality indicator for any virtual device is equal to the *Qyx* indicator.

III. CONSECUTIVE COMPOSITION

Consecutive composition of virtual devices *1* and *2* within the comprise virtual device *x* is shown in Fig. 6.

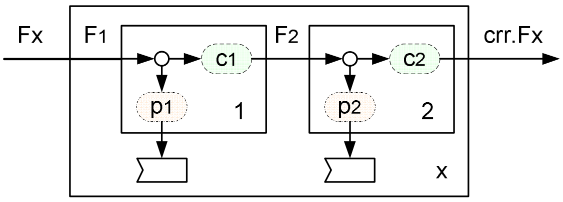

Fig. 6. Consecutive composition of virtual devices 1 and 2 within the comprise virtual device x.

The following equalities hold:

$$crr.F_1 = Fx(1 - P_{p1}) = F_{c1}. \quad (11)$$

$$crr.Fx = Fx(1 - P_{p1})(1 - P_{p2}) = crr.F_2 = $$

$$= Fc_2. \quad (12)$$

From (8) we have:

$$Qyx = \frac{crr.Yx}{srv.Yx} = \frac{crr.Fx\,rel.crr.Tx}{srv.Y_1 + srv.Y_2} =$$

$$= \frac{Fx(1-P_{p1})(1-P_{p2})rel.crr.Tx}{srv.Yx}\ . \quad (13)$$

Since the successfully serviced requests have passed through c1 and c2 we have:

$$rel.crr.Tx = T_{c1} + T_{c2}. \quad (14)$$

$$srv.Yx = crr.Yx + prs.Yx = prs.Y_1 + prs.Y_2 + crr.Yx = Y_{p1} + Y_{p2} + Y_{c1} + Y_{c2} = F_{p1}T_{p1} + F_{p2}T_{p2} + F_{c1}T_{c1} + F_{c2}T_{c2} = FxP_{p1}T_{p1} + Fx(1 - P_{p1})T_{c1} + Fx(1 - P_{p1})P_{p2}T_{\{p2]} + Fx(1 - P_{p1})(1 - P_{p2})T_{c2} = Fx\{P_{p1}T_{p1} + (1 - P_{p1})[T_{c1} + P_{p2}T_{p2} + (1 - P_{p2})T_{c2}]\}. \quad (15)$$

From (15), (14) and (13) we obtain

$$Qyx = \frac{Fx(1-P_{p1})(1-P_{p2})(T_{c1}+T_{c2})}{Fx\{P_{p1}T_{p1}+(1-P_{p1})[T_{c1}+P_{p2}T_{p2}+(1-P_{p2})T_{c2}]\}} =$$

$$= \frac{(1-\mathrm{P_{p1}})(1-\mathrm{P_{p2}})\mathrm{T_{c1}} + (1-\mathrm{P_{p1}})(1-\mathrm{P_{p2}})\mathrm{T_{c2}}}{\mathrm{T_1} + (1-\mathrm{P_{p1}})\mathrm{T_2}}. \quad (16)$$

In the above equation we have used the following equalities:

$$T_1 = P_{p1}T_{p1} + P_{c1}T_{c1} = P_{p1}T_{p1} + (1 - P_{p1})T_{c1}, \quad (17)$$

$$T_2 = P_{p2}T_{p2} + P_{c2}T_{c2} = P_{p2}T_{p2} + (1 - P_{p2})T_{c2}. \quad (18)$$

From (8) we have

$$Q_{y1} = \frac{F_{c1}T_{c1}}{F_{c1}T_{c1} + F_{p1}T_{p1}} = \frac{Fx(1 - P_{p1})T_{c1}}{Fx(1 - P_{p1})T_{c1} + FxP_{p1}T_{p1}} =$$

$$= \frac{Fx(1-P_{p1})T_{c1}}{Fx[(1-P_{p1})T_{c1}+P_{p1}T_{p1}]} = \frac{(1-P_{p1})T_{c1}}{T_1}. \quad (19)$$

$$Q_{y2} = \frac{F_{c2}T_{c2}}{F_{c2}T_{c2} + F_{p2}T_{p2}} = \frac{F_2(1 - P_{p2})T_{c2}}{F_2(1 - P_{p2})T_{c2} + F_2P_{p2}T_{p2}} =$$

$$= \frac{F_2(1-P_{p2})T_{c2}}{F_2[(1-P_{p2})T_{c2}+P_{p2}T_{p2}]} = \frac{(1-P_{p2})T_{c2}}{T_2}. \quad (20)$$

From (19) and (20) we have:

$$(1 - P_{p1})T_{c1} = Q_{y1}T_1, \quad (21)$$

$$(1 - P_{p2})T_{c2} = Q_{y2}T_2. \quad (22)$$

After substitution of (21) and (22) in (16) we obtain the indicator *Qyx* in the form:

$$Qyx = \frac{(1-P_{p2})T_1Q_{y1}+(1-P_{p1})T_2Q_{y2}}{T_1+(1-P_{p1})T_2}. \quad (23)$$

Or, after setting $w_1 = (1-P_{p2})T_1$ and $w_2 = (1-P_1)T_2$:

$$Qyx = \frac{w_1Q_{y1}+w_2Q_{y2}}{T_1+(1-P_{p1})T_2}. \quad (24)$$

Obviously, the sum $\boldsymbol{w_1 + w_2}$ is less than the denominator in (24).

In the following special cases, we have:

1. If $P_{p1} = 1; P_{p2} = 1$, we have $Qyx = 0; Q_{y1} = 0; Q_{y2} = 0$.
2. If $P_{p1} = 0; P_{p2} = 0$, we have $Q_{y1} = \frac{T_{c1}}{T_1} = 1$; $Q_{y2} = \frac{T_{c2}}{T_2} = 1; Q_{yx} = \frac{Q_{y1}T_1+Q_{y2}T_2}{T_1+T_2}$.
3. If $P_{p1} = 1; P_{p2} \neq 1$, we have $Q_{y1} = 0; Qyx = 0$.
4. If $P_{p2} = 1; P_{p1} \neq 1$, we have $Qyx = 0$.

For the second indicator *Qfx* using (9) we obtain:

$$\boldsymbol{Qfx = \frac{crr.Fx}{srv.Fx} = \frac{Fx(1-P_{p1})(1-P_{p2})}{Fx} =}$$

$$\boldsymbol{= (1-P_{p1})(1-P_{p2})}. \quad (25)$$

$$\boldsymbol{Q_{f1} = \frac{crr.F_1}{srv.F_1} = \frac{Fx(1-P_{p1})}{Fx} =}$$

$$\boldsymbol{= (1-P_{p1})}. \quad (26)$$

$$\boldsymbol{Q_{f2} = \frac{crr.F_2}{srv.F_2} = \frac{Fx(1-P_{p1})(1-P_{p2})}{Fx\,(1-P_{p1})} =}$$

$$\boldsymbol{= (1-P_{p2})}. \quad (27)$$

From (25), (26) and (27) we obtain:

$$\boldsymbol{Qfx = Q_{f1}Q_{f2}} \quad (28)$$

IV. ALTERNATIVE COMPOSITION

Alternative composition of virtual devices 1 and 2 is shown in Fig. 7.

In this case $\boldsymbol{P_1 + P_2 = 1}$. The following equalities can be easily verified:

$$\boldsymbol{crr.Fx = Fx[P_1(1-P_{p1}) + P_2(1-P_{p2})]}, \quad (29)$$

$$\boldsymbol{crr.Yx = crr.Fx\, crr.Tx}, \quad (30)$$

$$\boldsymbol{crr.Y_1 = FxP_1(1-P_{p1})T_{c1}}, \quad (31)$$

$$\boldsymbol{crr.Y_2 = FxP_2(1-P_{p2})T_{c2}}, \quad (32)$$

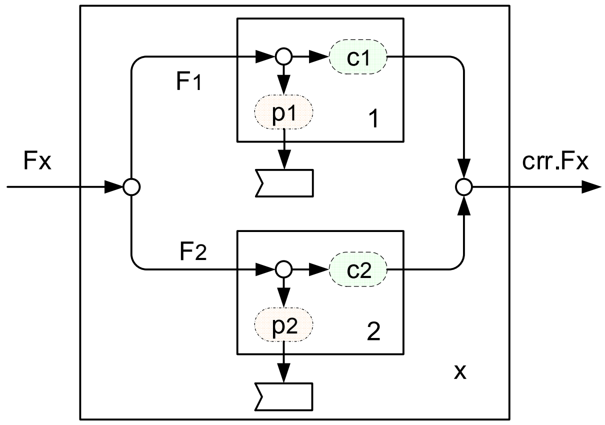

Fig. 7. Alternative composition of virtual devices 1 and 2 in virtual device x.

$$\boldsymbol{crr.Yx = crr.Y_1 + crr.Y_2 =}$$
$$\boldsymbol{= Fx[P_1(1-P_{p1})T_{c1} + P_2(1-P_{p2})T_{c2}]}, \quad (33)$$

Using the Little's formula *crr.Yx= crr.Txcrr.Fx* , (29) and (33) we obtain:

$$\boldsymbol{real.crr.Tx = \frac{Fx[P_1(1-P_{p1})T_{c1} + P_2(1-P_{p2})T_{c2}]}{Fx[P_2(1-P_{p1}) + P_2(1-P_{p2})]}}$$
$$\boldsymbol{= \frac{P_1(1-P_{p1})T_{c1} + P_2(1-P_{p2})T_{c2}}{P_1(1-P_{p1}) + P_2(1-P_{p2})}}.$$

$$\boldsymbol{srv.Yx = Y_1 + Y_2 = Fx(P_1T_1 + P_2T_2)}, \quad (35)$$

$$\boldsymbol{Qyx = \frac{Fx[P_1(1-P_{p1})T_{c1} + P_2(1-P_{p2})T_{c2}]}{Fx[P_1T_1 + P_2T_2]} =}$$
$$\boldsymbol{= \frac{P_1(1-P_{p1})T_{c1} + P_2(1-P_{p2})T_{c2}}{P_1T_1 + P_2T_2}}, \quad (36)$$

$$\boldsymbol{Q_{y1} = \frac{F_1(1-P_{p1})T_{c1}}{F_1T_1} = \frac{(1-P_{p1})T_{c1}}{T_1}}. \quad (37)$$

From (37), we have:

$$\boldsymbol{(1-P_{p1})T_{c1} = Q_{y1}T_1}. \quad (38)$$

Analogically,

$$\boldsymbol{Q_{y2} = \frac{(1-P_{p2})T_{c2}}{T_2}}. \quad (39)$$

From (39), we have:

$$\boldsymbol{(1-Pp_2)Tc_2 = Qyx_2Tx_2}. \quad (40)$$

$$Qyx = \frac{P_1 Q_{y1} T_1 + P_2 Q_{y2} T_2}{P_1 T_1 + P_2 T_2}$$

$$= \frac{w_1 Q_{y1} + w_2 Q_{y2}}{w_1 + w_2}, \qquad (41)$$

where we have set $P_1 T_1 = w_1$ and $P_2 T_2 = w_2$. Here, the sum of the weights in the nominator of (40) is equal to the denominator.

$$Qfx = \frac{crr.Fx}{srv.Fx} = \frac{Fx\left[P_1(1 - P_1) + P_2\left(1 - P_{p2}\right)\right]}{Fx}$$

$$= P_1(1 - P\_\{p1\}\}]) + P_2\left(1 - P_{p2}\right). \qquad (42)$$

$$Q_{f1} = \frac{crr.F_1}{srv.F_1} = \frac{Fx\left[P_1\left(1 - P_{p1}\right)\right]}{FxP_1}$$
$$= 1 - P_{p1}. \qquad (43)$$

$$Q_{f2} = \frac{Fx\left[P_2\left(1 - P_{p2}\right)\right]}{FxP_2} = 1 - P_{p2}. \qquad (44)$$

From (42), (43) and (44) we obtain:

$$Qfx = P_1 Q_{f1} + P_2 Q_{f2}. \qquad (45)$$

In the case of a system with blocking the following conditions are satisfied:

1. P_2 is the probability of blocking ($P_2 = Pb$).
2. $Q_{y2} = 0$ (the blocked requests are not served).
3. It is assumed that the blocked requests can be served with duration of the serviced (definition of *offered traffic*, see [ITU E.600]), i.e., $T_2 = T_1$.

Therefore, in this case

$$Qyx = \frac{P_1 T_1 Q_{y1}}{P_1 T_1 + P_2 T_2} = \frac{P_1 T_1 Q_{y1}}{T_1(P_1 + P_2)} = P_1 Q_{y1}$$

$$= (1 - Pb) Q_{y1}. \qquad (46)$$

From (37) and (46) we obtain:

$$Qyx = \frac{(1 - Pb)\left(1 - P_{p1}\right) T_{c1}}{T_1}. \qquad (47)$$

From (45) we have

$$Qfx = P_1 Q_{f1} = (1 - Pb)\left(1 - P_{p1}\right). \qquad (48)$$

The above equality shows that Qfx does not depend on P_{p2}.

V. Conclusion

The proposed approach to traffic quality indicators aggregation leads to new aggregation functions derived. It allows overall quality estimation in every service composition, considered as workflow.

In the future work, traffic quality indicators' aggregations of other composition patterns will be researched.

References

[1] Martín Varela, Patrick Zwickl, Peter Reichl, Min Xie, Henning Schulzrinne. (2015) From Service Level Agreements (SLA) to Experience Level Agreements (ELA): The Challenges of Selling QoE to the User. IEEE ICCW 2015, pp. 1741-1746, ISBN: 978-1-4673-6305-1, 978-1-4673-6304-4.

[2] ITU-T Recommendation ITU-T P.10/G.100 (11/2017). Vocabulary for performance, quality of service and quality of experience.

[3] Zheng, H., Yang, J. & Zhao, W. (2010). General probability distribution-based QoS analysis for web service composition. International Symposium on Web Intelligent Systems & Services (pp. 98-111).

[4] Gatnau, M., Catania, D., Cattoni, A. F., Ashta, J. S., & Mogensen, P. (2013). A Multi-QoS Aggregation Mechanism for Improved Fairness in WLAN. In Vehicular Technology Conference (VTC Fall), 2013 IEEE 78th (pp. 1-5). https://doi.org/10.1109/VTCFall.2013.6692041

[5] Poryazov, E. Saranova. User-oriented, Overall Traffic and Time Efficiency Indicators in Telecommunications. TELFOR 2016 International IEEE Conference #39555, November 22-23, 2016, Belgrade, Serbia , IEEE Catalog Number: CFP1698P-CDR, IEEE, 2016, ISBN:978-1-5090-4086-5/16, INSPEC Accession Number: 16603129, DOI: 10.1109/TELFOR.2016.7818729

[6] Poryazov S., Saranova E., Ganchev I. (2018) Scalable Traffic Quality and System Efficiency Indicators Towards Overall Telecommunication System's QoE Management. In: Ganchev I., van der Mei R., van den Berg H. (eds) Autonomous Control for a Reliable Internet of Services. State-of-the-Art Survey, Lecture Notes in Computer Science, vol 10768. Springer, Cham, DOI: https://doi.org/10.1007/978-3-319-90415-3_4, Print ISBN: 978-3-319-90414-6, Online ISBN: 978-3-319-90415-3. pp 81-103.