Agent Supported QoS Management

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***Abstract*— Nowadays, the rapidly developing science of services focuses on service management, which has to take into account the available resources and the user's wishes concerning the desired quality and costs. Quality of Service (QoS) management is perceived as a special aspect of distributed systems management. This area of management is concerned with finding appropriate QoS characteristics for the different system components in a distributed information system application and reserving the corresponding resources in such a way as to achieve the required functionality of the given application and to optimize the overall business organization performance. In this paper, we present a consistent set of concepts concerning QoS modelling for agent technology application and give an example of how that concept can be used.**

Keywords-service economy; Service Level Agreement; Service Level Objective; Quality of Service; agent technology.

I. INTRODUCTION

Nowadays, business organizations realize functionality as systems that are composed of services. This includes even mission critical processes of the business. Hence, the quality of such systems including their composition and services is increasingly important. However, it is a challenge to establish high quality in this context because the dynamics and distribution of functionality increase the potential points of failure. Different approaches exist to ensure quality, but they typically act within a restricted scope, such as network layer or software design. This paper presents the usage of Multi-Agent System (MAS) for Quality of Service (QoS) management and computerized network management. Thereby, it supports the selection of approaches to improve quality and finally helps to find a suitable solution for a given situation. The paper consists of two main parts. The first part covers a discussion on the service management, Service Level Agreement (SLA) construction and quality of service. Next, the applied agent technology is explained and the results of the application of agent system prototype for dynamic QoS management are presented and evaluated.

II. SERVICE SCIENCE

In literature, service science is an emerging trans-discipline that integrates marketing and behavioural science, operations research and management science, governance and political science, game theory and learning science, psychology and cognitive science, industrial engineering and system science, management of information systems and computer science, organization theory and administrative science, economics, law and historical science, foresight studies and design science [1]. The principal goal of service science is to catalogue and understand service systems, and to apply that understanding to advancing the service developers' ability to design, improve and scale service systems for practical business and social purposes. Services are considered as value co-creation that results from communication, planning, or other purposeful and knowledge-based interactions between distinct service system entities, such as individuals and business units [2]. The service science discipline is to establish service systems and value propositions as foundational concepts, to create data sets to understand the nature and behaviour of service systems and to create modelling and simulation tools for service systems. From the marketing and management science perspective, the services are intangible, heterogeneous, inseparable, and perishable. Services cannot be touched, transported or stored. Each service is unique, instantly generated, rendered and consumed. Services appear in relation to processes and Information Technology (IT) user needs, and the service provider implements these processes to enable the desired changes in the user world. Services require application of specialised competencies (knowledge and abilities) through actions, processes and performance to benefit. They involve a degree of influence of the service provider on the service recipient.

A. Service Management

Service management is defined as a set of specialized organizational capabilities for providing value to customers in the form of services. The service value consists of two principal elements: utility or fitness for purpose and warranty or fitness for use [3]. Utility is determined by the service's functionality and warranty is determined by service quality and performance. Utility is perceived by the customer from the attributes of the service that have a positive effect on the performance of tasks associated with desired outcomes. Service warranty is determined by sufficient capacity or magnitude and is defined in terms of continuity and security.

Nowadays, information technology supports service automation, which has a particularly significant impact on the performance of service assets, such as management, organization, people, processes, and knowledge. Advances in artificial intelligence, machine learning and rich-media technologies have increased the capabilities of software-based service agents to handle a variety of tasks and interactions. Automated systems present a good basis for

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improving service processes and they are a means for capturing the knowledge required for a service process. The automation of service processes helps to improve the quality of service, reduce costs and minimize the risks by reducing complexity and uncertainty of service management.

B. *Service Level Management*

The Service Level Management (SLM) approach was developed for years to combine the services providers' capabilities with service users' requirements. To manage service providers' responsibilities effectively, SLM implements Service Level Agreements (SLAs) with Operational Level Agreements (OLAs), and Underpinning Contracts (UCs) with third party suppliers [4]. OLAs is a non-contractual, service-oriented document describing services and service standards, with responsibilities and obligations where appropriate. The scope of issues considered within SLM is huge and the typical topics include: service performance against SLA, incident and problem reviews, business and customer feedback, issues' escalation and contract review summaries, service demand management, expected major changes which affect services, key business events over the service period, service improvement programmes, best practice assurance and standards' compliance. SLA is a basis for the specification and development of Information Technology (IT) service. It enables the monitoring of real time conformance of the service performance and related metrics to the SLA requirements. SLA supports service reconfiguration and adjustment to minimise SLA violations. By definition, SLA is an agreement, while the actual service is specified, designed and implemented in a technical context. There are some strong requirements for SLA modelling [5]. SLA is specified in a specific language, i.e., SLAng, RBSLA, to ensure integration of the SLA management framework with other IT systems for providing the service to the user. SLAs are described in a language that is technology neutral and platform independent. The management of SLAs and exchange of SLA specific information is automated to ensure a more proactive monitoring of the runtime service systems. There are different models of SLA lifecycle [6]. Generally, the SLA lifecycle covers the following stages of an SLA development: service and SLA template development, SLA negotiation, service preparation, service execution, assessment of SLA and the QoS, as well as assessment of the overall service, service termination and decommission [7]. SLA is a representation of all features a user should expect to receive via a service. An SLA is a concrete representation or codification of an agreement, which consists of the following sections:

- Purpose describing the motives behind the SLA creation.
- Parties involved in the SLA and their representative roles, i.e., provider and user.
- SLA validity period.
- SLA scope defining the services covered in the agreement.
- Restrictions to ensure that requested service levels will be provided.
- Service Level Objectives (SLOs) representing the levels of service that both the service user and the service provider agree on. They typically include a set of QoS indicators.
- Penalties for not meeting the agreed SLOs, such as getting discounts or having the right to terminate the contract.
- Exclusions specifying what is not covered in the SLA.
- Administration processes to assess the SLA objectives and describe the responsibility of the service provider [8].

According to [9], an SLA includes some guarantee terms, where each term codifies an obligation (see Figure 1). The performative aspects of the obligation are encapsulated by the QoS object, while service utility is captured by the business value. In order to ensure that obligations are met and the service is delivered as agreed, the service delivery must be monitored. Therefore, a set of monitoring policies is developed and implemented.

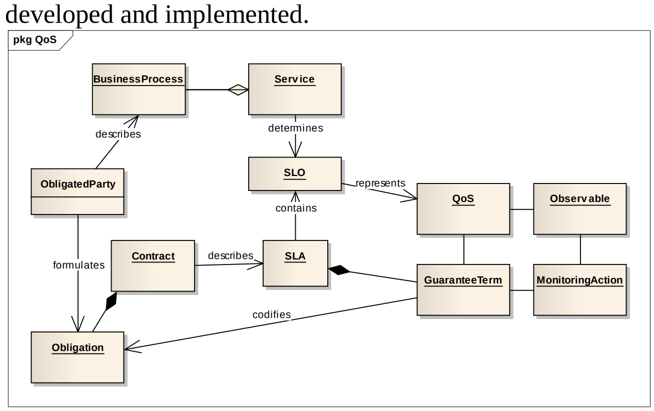

Figure 1. Service Level Agreement within Service Level Management.

Service Level Agreement (SLA) describes agreed service functionality, cost and qualities. An SLA is an agreement regarding the guarantee of a service. It defines mutual understandings and expectations of a service between the service provider and service users. It consists of sections describing the commitments to service quality and service levels that the service provider has to guarantee. SLAs contain Service Level Objectives (SLOs) that represent the Quality of Service (QoS) goals, e.g., storage, bandwidth or response time. Service providers need to comply with QoS requirements, specified in SLA and contracts, which determine the revenues and penalties on the basis of the achieved performance level.

C. *Quality Management*

Generally, in service science, quality can be considered in a few different ways [10]. On one hand, Quality as a functionality characterizes the design of a service and can be measured by comparing the service against other services offering similar functionalities. Quality as conformance, on the other hand, can be monitored for each service individually, and usually requires the user's experience of the service in order to measure the promise against the delivery.

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Quality as reputation is regarded as a general reference to a service's consistency over time in offering both functionality and conformance qualities, and can therefore be measured through the other two types of quality [10]. Thiadens analyses the product, the process, IT facilities and the business organization qualities [11]. Zeginis [12] proposed considered qualities as measurable and as unmeasurable. Measurable qualities could include accuracy, availability, capacity, costs, latency, provisioning-related time, scalability, whereas unmeasurable qualities cover interoperability of communicating entities, modifiability, security, as well as complementary dimensions, i.e., assertion-based monitoring, event-based monitoring, history-based monitoring. Service measure system contains information on the current system configuration and runtime information on the metrics that are part of the SLA. The system measures SLA parameters, such as availability or response time, either from inside, by monitoring resource metrics directly from managed resources, or from outside the service provider's domain, e.g., by analysing the client transactions.

D. Quality of Service

In a service contract or agreement, a service is defined by its context or functions, its terms and conditions, and is normally set by the agreement between the service user and the service provider. QoS is determined in relation to the fulfilment of the service agreement. According to the International Standard ISO/IEC 13226:1998 the QoS Framework is a structural collection of concepts and their relationships which describes QoS and enables the partitioning of, and relationships between, the topics relevant to QoS in information technology to be expressed by common means of description [13]. In ISO/IEC 10746-2, QoS is a set of qualities related to the collective behaviour of one or more objects. Depending on the established context and specified requirements, the QoS parameters may be of different kinds, e.g., a desired level of characteristic, a maximum or minimum level of a characteristic, a measured value, a signal to take an action, a request for operations, or the results of operations [13]. In the domain of service science and particularly in SLM, the QoS management functions are designed to assist in satisfying users' QoS requirements. The activities of QoS management include the establishment of QoS for a set of QoS characteristics, monitoring the QoS values, maintaining the actual QoS as close as possible to the QoS target, control of QoS targets, enquiry upon some QoS information and alerts in the case of events related to the QoS management [14]. Hardy considers three kinds of quality of service [15]. In the technical design, the intrinsic QoS which includes characteristics of the connection made through the network and provisioning the network accesses, terminations, and switch-to-switch links, relative to the expectations of the person who designs and operates the system. The perceived quality of service is what will determine whether the user will find the service acceptable when it is delivered, and the assessed quality of a service, which results when the user who pays for the service determines whether the quality of service was good enough to warrant its continued use.

III. APPLICATION OF AGENT TECHNOLOGY FOR QOS

Nowadays, the multi-agent systems (MAS) concern many aspects of human living. MAS can be successfully used in the transportation area [16][17] or in a hospital system [18]. The flexibility of MAS gives the opportunity to create a new type of intelligent system. Properties of agents are as follows: reactiveness, goal orientation, autonomy, adaptability, ability to communicate, capacity for cooperation and learning ability. Those properties of agents make this type of system distinguished and unique in IT. Agents are autonomic entities in the system, but through their learning abilities and communication skills they are able to create a complex system.

QoS may be used in a computer network as one of determinants of quality of a network. Actually, the QoS can be used to divide all network connections into specific groups, based on traffic flow definition: single transfer of information between computer units, like workstations, servers, etc., through the network. Each of this group has its own priority. Priority is used to calculate the portion of bandwidth which should be assigned to specific connections. This simple algorithm applies to management of traffic flows inside IT infrastructure. All models of QoS algorithm have the same common feature, i.e., static approach in defining the policy. The consistency of QoS policy is hard to achieve, because there is no possibility to track all changes of traffic flows in real-time by an administrator or even groups of administrators. In this situation, the static QoS will not be a sufficient solution from business perspective. The MAS for QoS [19] is a new approach to solve the problem of ad-hoc high priority business flows. The agents gather the users' requirements and based on those information they are capable of creating the optimal policy. Moreover, thanks to trend analysis, the agent is able to change the initial priority. The most important thing is that the agents notice the changes of users' requirements and react to them in real time. Agent, as the autonomic element in the system, can decide which traffic connection should be prioritized. Thus, a group of agents may create a system focused on ensuring users' satisfactions. It should be emphasized, that MAS was designed to solve complex problems, like managing the quality of network service in dynamic infrastructure, gathering and calculating huge amount of date, etc.

The approach presented in this section is the contribution of the authors only. Nevertheless, some of the parts of agent algorithm can be similar to other approaches due to open standard of QoS and agent's definition.

During the work on the prototype, we tried to find a similar approach to compare the effectiveness of these models, however without success. There are some of approaches how to use the MAS for QoS, like [20][21[22], nevertheless, they are not describing the real usage of MAS for QoS in simulated environment. Therefore, it is not possible to compare this model to any other, because each of them are focused on different aspects of managing the QoS. MAS for QoS can be divied into few elements: sniffer, analyser, generator and negotiator. Each of the elements is the independent part of the system. However, we must keep in mind that the analyser cannot work without data from sniffer subsystem. The sequence of agents' actions are sniffering the network traffic, analysing it, generating the new QoS policy. In case when an agent decides that some part of the traffic flows is important, the agent can negotiate higher preferences of that traffic flows with his neighbours. Due to a possible problem with MAS performance, we decided to implement some part of the agent into the database.

The policy is the output of agent's work and it is related only to the specific agent within MAS, so we can assume that the policy is created according to traffic flows which were observed by the agent in a proper time period. The policy is created by the agent on the basis of current traffic flows and the historical occurrences. Moreover, the policy includes the information on what portion of bandwidth and priority should be assigned to a particular traffic flow. The priority is used to distinguish the importance of traffic flows and this is the main factor in MAS for QoS. Taking into account that information, the agent is able to create the optimal policy. MAS for QoS has the possibility to use the network administrator's knowledge and creates the initial knowledge database, based on this information. Network administrator can furnish agent with information about critical traffic flows that have significant impact on business. Information defined by the administrator and observed by the agent is collected in the knowledge database.

In each company, we can distinguish at least one business process. Pall defined the business process as "the logical organization of people, materials, energy, equipment, and procedures into work activities designed to produce a specified end result (work product)" [23]. Business form is created by a set of processes forms – in the way which a business unit/units carries out the business. The business process can be described by a proper process flow. By means of the flow, the management can factorize the complex process. Moreover, priority is a common property of business processes.

Business process priority, as a common property of business processes, defines which business process has high impact on organization. However, managing processes and their priorities inside the company demands not only wide knowledge about all the processes but expert analytics skills too. Nowadays, management tries to do that with the help of expert systems, distributed analytic systems, etc. Multi-agent system is one of the examples of using analytic system to help user in decision making area.

A. *Case Study Description*

The MAS for QoS can be used in every computer network. However, the more complex the computer network is, the more efficient is the policy created by an agent. In our case study the computer network, closed test environment (Figure 3) consists of 5 routers, 12 workstations, 7 internal servers and more than 50 external servers. In our case study, the MAS is built by 5 autonomous agents. The MAS will achieve optimal results when agents will be installed on network devices only. Thanks to this approach all agents have the wide knowledge about traffic flows and all business flows inside the organization. Moreover, the agent can learn the habits of users and try to create a policy that reflects all users' needs. One of the most typical business flows (Figure 2) in an organization is creating a report for management. From organization's perspective the business flow is not complex at all. However, from a technical point view, the flow is more complex (Figure 3).

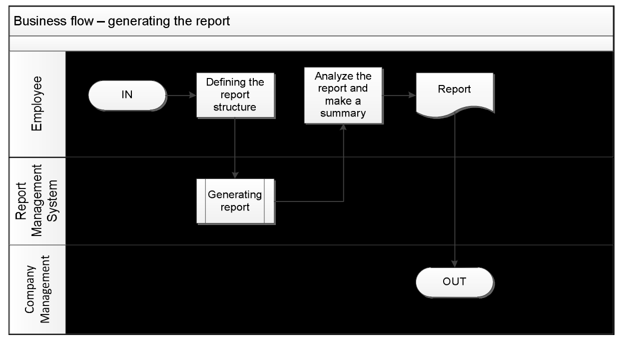

Figure 2. Business flow – generating the report.

The administrator is faced with prioritizing the connections inside an IT infrastructure. The common challenge for all IT infrastructure is the occurrence of multiple connections at the same time. Thus, generally it can be stated that many IT infrastructures face prioritizing the connections in real time. The priority is a percentage of bandwidth assigned to particular traffic connection. The higher the priority is, the more bandwidth will be assigned to the connection. To solve this problem the administrator can implement the QoS. Thanks to this solution, there is a possibility to create a static policy to assure that some connections will have a higher priority than others. Nevertheless, creating a static policy is a suboptimal solution, because the specific traffic/business flow may exist for a short period of time only. In the static policy, the common issue is not using the full available bandwidth. Moreover, continuously changing the policy can have significant impact on business and administrators' works. In such a case we can use MAS for QoS. Thanks to the flexibility of the MAS, there is an opportunity to manage the QoS for a computer network, especially in a highly dynamic environment. The new approach considers to use the historical and current information for creating the policy by agent and the human role can be reduced to minimum. Improving the computer network by MAS has an influence not only on the technology area but also on business processes built on it. The main goal of MAS for QoS is to adjust the traffic priority to actual users' needs. To perform appropriate tests a traffic generator was created. The generator generates the traffic, which reflects as far as possible the network traffic generated by employees or users in similar real network. Moreover, the test computer network (Figure 3) is very similar to computer network used in small companies. Despite the fact that the tests were done

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in test environment, the result of these tests can be compared with those that have been done in real environment, thanks to similarity of both environments and network traffics. The results shown in this section are presented from one agent perspective for better visibility. The realized test lasted 2 hours and during it agent noticed that 200 unique traffic flows occurred 5044 times and at least once the priority was changed for them. The agent, as an independent unit with the knowledge database of traffic flows, modified the priority of traffic flows 1781 times. It means that agent changed 26% of traffic flows priorities of total observed traffic flows during test. From business perspective, the agent can have significant influence on the business flows inside the company. The business flows describe all interaction between users, assets, etc. and have real impact on company profits. The longer the agent will work, the better the policy will be matched to the current needs of users and the quality of business flows will be improved.

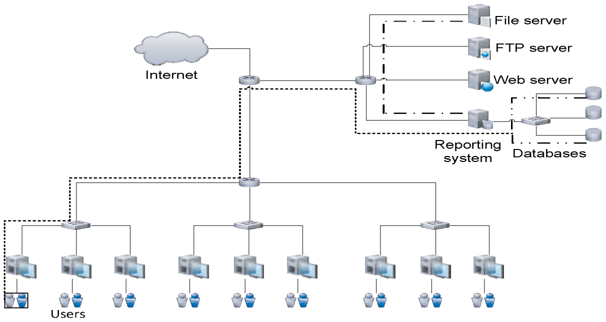

Figure 3. Business flow from technical perspective.

B. Research Results

In the prototype, the agent has the possibility to use traffic flows defined by an administrator. This information will be treated as the initial knowledge database by the agent. The agent can use the initial knowledge database in two ways: a defined priority of traffic cannot be changed or it is treated as the initial value, i.e., it can be changed by the agent over time. The first option might be used for traffic with real high impact on business flows. However, in this approach the agent reserves specific bandwidth for irrelevant traffic flow, which importance should be decreased over time. From business perspective this is a suboptimal allocation of resources, which could be used for increasing profits. A wrong allocation of network resources can disturb the businesses processes inside company. Internet surfing, connection to internal file servers or databases are all examples of those groups. The second option should be used in a dynamic environment, where there is a possibility of changing priorities of business flows. Both solutions can be adopted in every IT infrastructure, but only the second gives the opportunity to use the agent to improve and to create the most accurate policy to users' needs.

In Figures 4 and 5, it can be observed how the priority of traffic flow was changed over time for the same type of business flow – generating the report. The agent adjusted the priority to real usage and needs of users. Figure 4 presents how the priority was changed to the highest value and changed back to the lowest value (initial value for all traffic flows) over time. The traffic flow had a high priority, between 4 and 5, for over 1 hour. The situation is different on Figure 5. In the beginning of traffic occurrence, the agent decreased the priority of traffic flow to the lowest value and then increased it to a higher value. The agent used the priority value defined by the administrator as an initial value only. Unfortunately, as it was observed, using the initial value as the final could be the cause of creating a suboptimal policy. In such case, the agent will not take into account the current needs of users.

To summarize the example result, the agent registered 464 unique traffic flows and only 8 of them were defined by the administrator. The average priority with defined traffic flows is 2,17 and without defined traffic flows - 2.06. For 200 unique traffic flows the priorities were changed and the agent noticed 5044 occurrences of those traffic flows. For the rest of traffic flows (264), the agent did not change the initial priority value. 77 of unique traffic flows, which had not been defined by the administrator, had the highest priority at least once. It means that 16,6% of traffic flows had the highest priority value, so those connections had the biggest allocation of resources and they were the most preferable ones in a specific period of time.

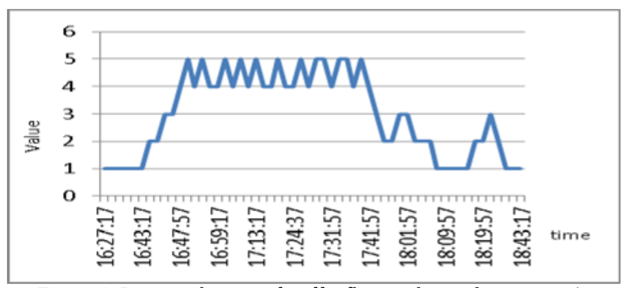

Figure 4. Priority changes of traffic flow without administrator's definitions.

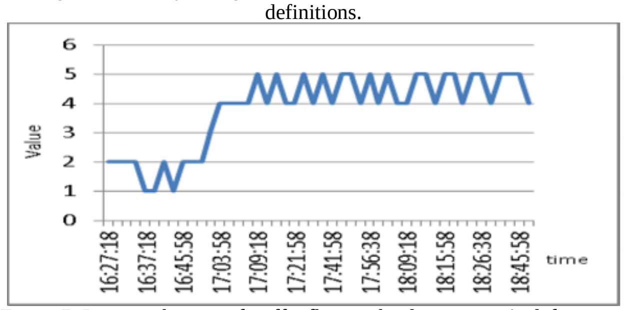

Figure 5. Priority changes of traffic flow with administrator's definitions.

Without the MAS for QoS, only 2 traffic flows defined by the administrator have a priority higher than 1. In the research of usage, it was attempted to prove that improving the quality of network connection can have significant impact on business processes. If the connection is faster than normal, the execution of business process can be finished faster than it was estimated in the beginning. Nowadays, there is no possibility that the administrator could create complex policy in a very short time. However, the

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administrator has an opportunity to use the MAS for maintaining the QoS in a computer network. The MAS for QoS guarantees that policies created by agents will be more adjusted to users' actual needs than created manually by administrator. Moreover, the biggest advantage of using MAS for QoS is the time in which the policy will be created. The administrator should have at least 10-30 minutes to create a policy while the agent needs only 3-5 seconds.

The test of MAS for QoS was performed on environment similar to the one which was presented in Figure 3. One of the biggest challenges is to protect the MAS for QoS against any abnormal traffic's behaviour, like maintenance or administrator traffic. The MAS for QoS distinguishes the network traffic and chooses the traffic used by users only. Moreover, the administrator of this system has the opportunity to define the traffic which should be analysed by agent. This approach allows to avoid any incorrect politics created by the prototype.

IV. CONCLUSIONS AND FUTURE WORK

MAS for QoS introduces a new approach on how to adjust the quality of traffic flows, which has real impact on the business flows inside a company. The quality in a network is especially important for the new generation of Internet applications, such as Voice over IP, video-on-demand and other consumer services. By introducing the dynamic quality for traffic flows, the MAS for QoS can change the network parameters for particular traffic flows in real time. Thanks to this approach, the agent is capable of changing the quality of connections only for those that really need it, based on his knowledge database.

The presented work will be further developed and extended. There are many alternative approaches for building scalable computer networks which could be used in MAS for QoS. Thanks to using different types of computer networks, we will have an opportunity to improve the agent's work - agent code optimization. More generally, more work needs to be done to improve an agent's statistical algorithms in the analytic module, which are used to generate the policies by the agent.

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