State of the Art in Service Management and QoS on Inter-Domain Service Provisioning

Technical Report

Fernando Matos, Paulo Simões, Edmundo Monteiro
CISUC, University of Coimbra
Pólo II, Dep. Eng. Informática
3030-290 Coimbra, Portugal
{ fmmatos, psimoes, edmundo}@dei.uc.pt

Despite all progress attained over the years in network management and service provisioning, there is still not a dissemination of advanced applications on the Internet. The main problem lies on the intrinsic heterogeneity nature of Internet. To provide an end-to-end service, several providers from different domains should connect their networks to establish links between customers or between customers and service providers. Almost certainly, the providers will have different equipments, distinct policies, and different goals. On today's service provisioning approach, when a customer requires for a service, such as video streaming, he must request and pay for the video to a content provider, using his Internet service provider (ISP) as access provider and paying for it as well. In this scheme the content provider can only guarantee the video will be transmitted with the desired requirements (e.g. high definition), but can not guarantee the video will be delivered to the customer as requested. This drawback happens because neither the ISP, nor the content provider, has guarantees from each other about their respective service provisioning capabilities (at least, not on real time). Another obstacle that arises from the same Internet heterogeneity context is the different providers' business view. Although they have the technical competence to offer end-to-end services with quality, there is still a lack of a business model to allow providers negotiate contracts for service provisioning in an automatic and on-demand fashion.

A more desirable approach for service provisioning in multi-domain environments would be a scenario where the customer requests and pays for the video to only one provider. This provider would be in charge to find and assembly several other services (published/offered by other providers) in order to compose the video provisioning path and deliver it to the customer with the requested requirements. It also would be in charge to establish contracts between those providers that own the services that are part of the whole video service and pay to them. Furthermore, monitoring and adaptation mechanisms would also be present to guarantee the customer receives the service with the contracted requirements. Otherwise, penalties would be imposed.

To accomplish the aforementioned scenario it is necessary the development of robust mechanisms to mediate interactions between providers, exchange and translate information, resolve conflicts due to divergence policies, and establish contracts in order to configure end-to-end (E2E) paths in multi-domain environments. To be possible to offer value-added services, these E2E paths should be assembled based on the customer service requirements, the quality of service (QoS) capabilities of each provider along the path, and the characteristics of the service content (if possible). Moreover, these mechanisms should support the following requisites [1]:

- on-demand: the services could be provisioned at the time a customer requisition takes place;
- automatic: lessening the human intervention during service configuration process; and
- dynamic: performing of dynamic service composition and adaptation due to modifications on policies, context and external factors.

Many solutions have been proposed to tackle some of those difficulties mentioned earlier and the majority of them are based on the Next Generation Network (NGN) paradigm, which proposes a clear separation between service related functions from transport and network related functions. Next Section presents what have been done so far concerning service provisioning for inter-domain environments using this NGN perspective.

1 Inter-domain service provisioning

NGN appeared as a novel promise to change how providers interact with each other and offer services to customers. Different from the traditional vertical service provisioning structure, where the customer is restricted only to his provider's portfolio, NGN brings a new market perspective based on its cornerstone: the separation of transport from service-related functions. This new paradigm allows service providers to cooperate in order to offer services beyond their domains without concerning about the network infrastructure. Besides, it facilitates providers to compose and offer their services as new value-added services. This situation generates a new market scenario, where providers may charge for these value-added services instead to charge for the network infrastructure. Some standardization groups have already proposed recommendations to accomplish this objective.

The 3rd Generation Partnership Project (3GPP) standardization body proposed an architectural framework called IP Multimedia Subsystem (IMS) [2], designed to deliver multimedia services for mobile users over UMTS technology. It facilitates the creation and deployment of services by the operators, since it offers common functions (*service enablers*) such as billing, presence and operation and management to ease the service implementation task. It was one of the first initiatives to deliver services over multiple domains, despite it was designed to mobile network.

In the context of fixed network, the Telecommunications and Internet converged Services and Protocols for Advanced Networking (TISPAN) group of ETSI proposed the TISPAN NGN specifications [3,4]. It uses the IMS core subsystem to handle Session Initiation Protocol (SIP) based applications and additional subsystems to handle non SIP-based applications. It provides an open architecture where application, control, and transport functions are provided by their respective layers.

Similarly to ETSI, ITU-T proposed its own NGN architecture recommendations that are currently maintained by NGN Global Standards Initiative (NGN-GSI) [5]. This architecture proposal is aimed to support the provisioning of content delivery and multimedia services and is composed of a Service Stratum and a Transport Stratum. The Service Stratum provides several functions to facilitate and enhance service deployment and provisioning such as user authentication, service discovery and session negotiation. The Transport Stratum provides functions to guarantee the IP connectivity between the service endpoints such as the resource and admission control functions.

The TeleManagement Forum (TMF) proposed a set of reference models, called New Generation Operations Systems and Software (NGOSS) [6,7], to implement a new generation of Operational Support Systems (OSSs) and Business Support Systems (BSSs). Its objective was to facilitate and automate providers' business processes to develop and deploy new services. Furthermore, it intended to act as a technological-neutral framework for service composition and management.

The Multi-Technology Operations System Interface (MTOSI) standard, supported by TMF, is an open interface to provide interoperability between providers through their OSSs [8]. It fully adopts the Service Oriented Architecture (SOA) philosophy and proposes the separation between business logic and transport functions and supports the specifications dictated by NGOSS. The MTOSI Implementation Lab aimed to produce an MTOSI implementation reference, in order to simulate and test real scenarios. It uses a Common Communication Vehicle (CVV), based on the concept of Enterprise Service Bus (ESB). It offers base functions to facilitate service provisioning among providers.

Although those recommendations are well-specified, have a wide acceptance on the research community, and some of them already have a reference implementation (e.g. MTOSI Implementation Lab [8]), they still need to incorporate some aspects to leverage the service provisioning process. Some of these aspects are how to mediate the business relationships between the involved parties and how to negotiate and deliver the E2E QoS in inter-domain scenarios.

2 Business Perspective

To fully accomplish the NGN intent it is necessary to fulfill several requirements such as service convergence, E2E QoS and security, just to name a few [9]. All aforementioned recommendations have proposed approaches to deal with these requirements. Some of them depict entire modules and describe how these modules interact with each other [3,5,8]. Even though these approaches offer plausible solutions for deployment of NGN architectures, they still lack solutions that guarantee those requirements in a business level. Due to the separation of service from technological related functions, providers found themselves in a position where they can offer innovative services and users can freely select their services. This situation led providers to observe their need for better, automatic and dynamic solutions to establish business relationships. It is an important concern since we are dealing with multi-domain environments with different provider business views. Furthermore, it is relevant to separate business-related functions from non-business ones [10] to guarantee independence of business process from service and network provisioning processes.

At [11] the authors presented a business view to define the relationships between the end-user and the service provider. It defines business processes that represent the operations related to service provisioning from the end-user authentication until the management of the service session. This business view can be used by providers to assure coherence between the processes of NGN services from the end-user perspective.

TM Forum IPsphere proposed a framework based on NGN principles to create and deliver services [12,13]. It allows providers to interact through a business layer, called Service Structuring Stratum (SSS), to locate, contract, initiate, operate, and terminate a service. This framework encompasses automatic service composition, and negotiation, leading to a flexible service provisioning infrastructure and yet permitting a coherent and promising business model. However, to the best of our knowledge, there is not a reference implementation so far.

The Global Business Framework (GBF) work [14] is a proposal of inter-domain on-demand service provisioning mediated by a business stratum. GBF contains a Business Layer (BL) where providers can publish, search, and offer services and exchange information to interact with each other. This information is represented by templates, called Element Specification Template (EST) and Service Specification Template (SST). These templates contain information about elements and services (composed of elements), respectively. Using the templates, providers can offer (and negotiate) services/elements to customer or other providers until they reach an agreement and sign a contract, which is represented by a Service Level Agreement (SLA). A provider called Service Owner (SO) is responsible to search for elements offered by other providers called Element Owners (EOs). SO uses these elements to compose a service with the requisites requested by the customer. Once the customer accepts the proposed service, SLAs are established between SO and customer and between SO and each contracted

EO. These SLAs are then used to monitor and guarantee that the service provisioning satisfies the agreed requirements.

3 E2E QoS

Although there are concrete proposals to provide inter-domain services over a business layer, such as IPsphere and GBF, they are still in early stages and much work must be done to guarantee important requirements. One of these requirements is provisioning of inter-domain services with E2E QoS. Several works dealt with QoS for service provisioning in an inter-domain context, proposing QoS solutions not only for lower layers (e.g. network layer) but also for higher layers (e.g. application layer). Some of these works concerned about QoS as the main problem to tackle, others only viewed QoS as one of the pieces of their whole proposal. However, integrated solutions to negotiate and provide QoS in a business viewpoint are still needed. The following paragraphs give an overview of different QoS solutions to E2E service provisioning.

Resource and Admission Control Sub-System (RACS) [15] of ETSI and Resource and Admission Control Functions (RACF) [16] of ITU-T are both resource and admission control solutions for their respective NGN framework specifications. Possibly the main difference is concerning the extent of the control region, since RACF acts on the access and core network while RACS acts on the access network and only on the border of the core network [17]. In spite of the mentioned difference, they have similar functionalities and do not conflict between them.

The End-to-end Quality of Service support over heterogeneous networks (EuQoS) [18] project developed a NGN architecture to manage the E2E QoS provisioning over multiple domains. This architecture defines a clear separation between application plane and control plane. The former plane is responsible to receive the service requisitions from the customer, perform AAA related functions and charge the customer. The latter plane is responsible to enforce the transport plane to provide the appropriate QoS according to the customer requirements. EuQoS also provides an interface to the customer that does not require application signaling protocols to request services.

Multi Access Service Everywhere (MUSE) project aimed to develop a multi-service access network [19]. It proposed a QoS architecture to allow users request for broadband services. This QoS architecture is composed of a data plane and a control plane. The data plane defines four DiffServ-based classes in which the user service request may fit. The control plane is responsible for the admission control and monitors the network and resource availability.

The TEQUILA [20], AQUILA [21] and CADENUS [22] triads are projects developed to reach the same objective: provide IP premium services over the Internet [23]. Although having the same objective, they focus on different aspects of the service provisioning. TEQUILA approach proposed service request negotiation between provider and customer in an intra-domain environment. This negotiation originates an IP connectivity described as a SLS that is used by a set of traffic engineering tools to acquire quantitative E2E QoS in a DiffServ-based IP network. AQUILA project developed a Resource Control Layer (RCL) over a DiffServ layer to control and monitor the resources. Through RCL, AQUILA offers the customer network services with different QoS characteristics based on pre-defined classes. In its turn, CADENUNS project proposed a framework composed of functional blocks. These functional blocks comprise operations such as service composition, authentication and mapping of QoS requirements to network resource. The interactions between the blocks permit service creation, negotiation and provisioning as well as the equipment configuration for proper QoS delivery.

MESCAL project [24] extended the work of TEQUILA to inter-domain context. It proposes an architecture to deliver E2E QoS across multiple domains using the concepts of local QoS classes (l-QCs) and extended QoS classes (e-QCs) to support the customer requirements. An l-QC expresses the inner delivering QoS ability of a provider, while e-QC expresses the delivering QoS ability of the local domain combined with l-QC or e-QC of neighbor domain providers. The MESCAL architecture uses a cascaded model to negotiate the SLSs. In other words, providers only negotiate with their neighbor domain providers. Traffic engineering algorithms are responsible to find appropriate combinations of l-QCs and e-QCs and bind them to create a service path provisioning.

ENTHRONE project [25] developed an architecture to provide multimedia services with E2E QoS over heterogeneous networks. This architecture is divided in four planes: a service plane where SLAs and SLSs are established between customers and providers; a management plane responsible to traffic and resource management; a control plane, where resource control and traffic engineering are performed and; a data plane, where DiffServ traffic control mechanism occurs to guarantee the E2E QoS. It defines a set of functional components, dispersed over the planes, that are responsible to offer service to the customer, negotiate the service QoS requirements and proper reserve and control the resources to assure the accorded QoS.

AGAVE project introduced the *Parallel Internet* concept which is a union of parallel *Network Planes* of network providers [26]. A *Network Plane* is a logical layer configured to route and forward traffic related to services with similar QoS requirements. These planes are used by service providers to guarantee the E2E QoS required by the customer. They can be created to support standard DiffServ-based QoS classes or to support specific requirements of service providers.

The previous mentioned projects proposed approaches for E2E service provisioning dealing a large spectrum of mechanisms to support QoS (e.g. QoS negotiation, path composition based on QoS requirements, resource reservation, etc). However, there are many other proposals that try to solve specific QoS related functions. Next, some works are presented divided by the QoS support mechanisms they try to tackle.

3.1 Service composition

In a multi-domain provisioning scenario, where the requested service may be a combination of several other ones, it is crucial that these parts be chosen properly in order to compose a service which satisfies the customer requirements. Moreover, considering providers wish to offer better value-added services, it is desirable to develop mechanisms that present enhanced service composition results concerning performance and QoS satisfaction. These results can be a set of service provisioning candidates, where they should be selected based on some criteria to provide the final service. Next, some works on service composition are presented.

At [27] the authors proposed a web service composition model that takes into account multiple QoS constraints. By using the customer QoS requirements, the model gets QoS metrics information to select service candidates to compose the service. It is defined a weight for each QoS metric. Once all service candidates are chosen and the weights are specified, a matrix is composed. Each row represents a service candidate and each column represents a QoS metric. After that, the QoS metrics are normalized using equations based on QoS constraints. Finally, a utility function is calculated to be used to choose the appropriate service candidates to compose the service. Although this work presents a solution to compose service based on QoS constraints, it does not present simulation results.

The work presented at [28] proposes a tree-based algorithm to select services to perform service composition, taking into account QoS criteria. To illustrate their proposal, the authors considered some QoS criteria (e.g. performance, cost, reliability, etc). Every service candidate has a value associated to each criterion. These values are normalized and a function is applied using the normalization values and weights defined by the customer for each criterion. The goal of this function is to calculate service scores that will be used during service selection. When all scores are calculated, a sorted binary tree is built, with the service candidates for a specific service function, using those scores as key nodes. At the end, the algorithm selects the right-most node since it has the greater value, and consequently the most appropriate QoS criteria composition. The authors also introduce a new service registry that keeps information about the services as well the information about which services are used by which costumer. At costumer side, service trees are maintained in a cache-based mechanism. At the end of the service provisioning, costumers send feedback information (e.g. QoS degradation) to the service registry about the service. The registry identifies which costumers are using the related service and sends the update information to them. This information is used to update their service trees and possibly perform a new selection. The problem with this approach is as the numbers of service candidates and customers increase, also increase the number of service trees in each customer and in the registry, consequently increasing the memory space required to store these trees and the compute time to perform the composition. The update information process time increases as well.

At [29], the authors propose a P2P approach to perform service composition based on QoS requirements. They define three generic abstractions (node, link and network) relating them to service management context: a node represents any service component; link represents a virtual connection between two nodes; and network represents a set of nodes and links that interact to provide an E2E service. This dynamically built network is called Virtual Private Service Network (VPSN). They also introduce the concept of Virtual Service Community (VSC) which is a community of service components that possess equivalent functionality and different QoS parameters. The idea is to build a VSPN which aggregates the service components selected to provide the global service. To accomplish that it is necessary to select the proper VSCs based on the service functional requirements. Afterward, in each VSC the appropriate node is selected based on the QoS requirements. Even so this proposal offer service composition considering QoS requirements, it does not take into account the service content characteristics. Moreover, it lacks for details of its functioning in a multi-domain scenario.

3.2 QoS negotiation

QoS negotiation can take action during service composition time as well after a possible combination of services is chosen to provide the customer requested service. At this time, some entity must negotiate the QoS parameters with all involved parties, and usually the result of this negotiation is a SLA contract to be signed between the parties. For the sake of organization, QoS negotiation proposals are presented in a different section from service composition.

At [30], the authors propose a distributed approach to be used for contract negotiation in a multi-domain scenario. It divides the negotiation requisition of an E2E service into several negotiations between neighbor domains. The result of these negotiation leads to an E2E service provisioning path. This approach takes into account four requirements during negotiation process: *i)* cumulative effects of QoS parameters (e.g. delay); *ii)* domain independence; *iii)* contract privacy and; *iv)* a global cost function (e.g. sum of contract prices). It uses dynamic programming principles to elaborate algorithms to handle QoS negotiations that cross multiple domains. As the previous mentioned work, this proposal does not take into account service content characteristics at performing the negotiation.

The work presented at [31] aimed to enhance the application-level QoS negotiation of IMS. It shows that additional mechanisms should be considered in order to handle media-rich services. The mechanisms are: i) user preferences; ii) network constraints and; iii) service profile. By using these mechanisms the authors proposed a model for dynamic negotiation and adaptation of QoS. They defined a generic QoS negotiation procedure comprising five phases that may be mapped into IMS. In spite of the model was designed aiming IMS architecture, it is possible to utilize some ideas, such as user preference and the generic QoS negotiation procedure in a higher-level QoS negotiation.

At [32] the authors proposed a framework to contract QoS specification, negotiation and monitoring. They considered three service types: task-oriented services, message-oriented services and streaming media services. Based on these services the authors defined common QoS characteristics (*e.g.* deadline, priority, integrity and so on) and observed how these characteristics relate with each other. They argue that it is possible to compose correct QoS specification for a required service in a way that two or more QoS characteristics do not conflict, thus facilitating the negotiation process. This specification is represented by an XML schema to provide flexibility and expressiveness. Although this work supports a negotiation mechanism, it only deals with the negotiation between customer and his provider. It does not tackle the negotiation between providers (inter-domain).

A web-service architectural solution to perform inter-domain SLS negotiation was proposed at [33]. In this work, logical QoS paths are established between known content servers (CSs) and predicted regions of content consumers (CCs), crossing IP domains. A path is an aggregated of pipes agreed between neighboring domains and represents one specific QoS class. When a CC request for a service, individual pipes (path between two neighboring domains) are negotiated and allocated for the service provisioning in a cascade fashion. The work defined a negotiation protocol composed of a set of messages that are exchanged by modules responsible to negotiate the SLS in order to establish the logical path. Web-service technology is used to exchange these messages and WSDL interface definitions to transfer the QoS parameters. A limitation of this proposal is that it is “semi” on-demand, since the logical QoS paths are established before any service request.

A framework to negotiate SLAs in inter-domain QoS service provisioning was proposed at [34]. Four entities that are involved during service negotiation and provisioning are specified: customer; service provider (SP); content provider (CP) and; network provider (NP). SP and CP may not be involved in a specific service requisition scenario. However, customer and NP will always be present at any scenario. As a result of a QoS service requisition by the customer, an SLA containing the QoS requirements is generated in order to be negotiated by the involved entities. The focus of the authors is on the inter-domain negotiation that occurs between NPs. When a NP receives an SLA concerning a QoS service requisition, it verifies if the source IP address of the service provisioning is on its domain. In this case it inspects the QoS requirements from the SLA to decide if it should accept or reject the QoS service requisition. Furthermore, the NP also negotiates the SLA with the neighboring NP, continuing this process until the destination IP address domain is reached. If the source IP address it is not on the NP domain, it forwards the SLA to the adjacent NP until it reaches the source IP address domain. Despite the authors present this negotiation approach as a viable solution for inter-domain provisioning they limit the negotiation to only one SP, not considering negotiation between several SPs (service composition).

Originally, WS-Agreement [35] does not tackle negotiation issues in its specification; rather it provides a language (based on XML schema) and a protocol for creation, establishment and monitor of agreements. At [36], the authors proposed an extension to WS-Agreement to handle negotiation between parties which may cause QoS modifications at runtime. They presented a new type of service level objective (SLO) that can be renegotiated based on some rules. These rules are specified in the SLA and determine the time interval that a SLO can be modified and the number of modifications this SLO can support. Furthermore, they enhanced the WS-Agreement protocol by adding new operations that allow the involved parties to renegotiate the SLO. After a service provisioning is on the course possible modifications on the involved parties may be performed in order to satisfy the QoS requirements. This modus operandi leads us to conclude that QoS requirements are not considered during service negotiation, rather the negotiation try to adapt the SLA according to some QoS violation during service provisioning.

3.3 QoS Policy Management

QoS policy management plays a strategic role in the provisioning of service with QoS in a multi-domain context. Since it is dealing with several providers with distinct business views, technical competencies, and services with specific purposes, it is important to have mechanisms to translate, aggregate and apply different QoS policies. Furthermore, the multi-domain environment is susceptible to frequent changes in the service provisioning due to the heterogeneity of the involved parties. In this case, QoS policy management can enhance the service and QoS expectations adaptation, applying rules related to expected and unexpected events. Following, some works on QoS policy management are presented.

At [37] the authors presented an architecture of policy-based QoS management in heterogeneous network in the ambit of NETQoS project [38]. The architecture intends to control the QoS management through event occurrences and policies associated to these events. Its functioning is based on the publish/subscribe principle, where a module called Context Manager (CM) receives subscriptions related to specific events. Every time an event occurs (e.g. an application launch or a policy violation), CM is informed of such occurrence and notifies the module which have subscribed for that event. Usually, the Policy Decision Manager (PDM) or the Policy Adaptation Manager (PAM) modules are the ones who are notified and take actions in order to fetch QoS policies related to the event. They use the policies to enforce or adapt QoS configuration at network and transport level entities. However, they did not detail how to apply this QoS configuration on inter-domain scenarios.

Still in the ambit of NETQoS project, the work presented at [39] proposes a hierarchical QoS policy framework for service management. The framework defines four policy levels: business policies; intermediate QoS policies; operational QoS policies and; configuration policies. The business policies are defined according to the actors (customer, service provider, network provider) and the relations between them. Moreover, they specify the QoS goals of the actors and are related to SLA objectives.

These business policies are translated to intermediate QoS policies which represent specific QoS parameters and procedures for network, service and application classes. In their turn, the intermediate QoS policies are translated to operational QoS policies of specific managed entities (router, gateway). At last, the operational QoS policies are translated to configuration policies of specific vendor equipments. The framework utilizes ontology to facilitate the policies translation process.

3.4 QoS monitoring

During service provisioning it is necessary to guarantee the customer receives the service with the agreed QoS requirements. Otherwise, the provider must be penalized if it is attested its responsibility at not accomplishing the requirements. In order to achieve those objectives, a QoS monitoring mechanism is essential to verify the QoS conditions on the service provisioning. The QoS monitoring gives support to the involved parties to analyze, evaluate, and adapt the service to make it in SLA accordance. Next, some works on QoS monitoring are presented.

The work proposed at [40] depicts an architecture to monitor service provisioning in order to guarantee agreed QoS expectations specified on the SLSs. Three main monitor modules are deployed in the architecture: *i)* node monitor (NodeMon) is a module that resides on network domain edges and is responsible to perform traffic measurement between any two edges of an AS; *ii)* network monitor (NetMon) is a module that performs intra-domain monitoring, using the reports received from the underlying NodeMons as input; *iii)* service level monitor performs customer/provider service level monitoring, auditing and reporting. The architecture performs a continuous monitoring, where traffic data are aggregated from the NodeMons and NetMons until they reach the service level monitors, which analyses the data to verify if the accorded QoS requirements are met. An on-demand monitoring is also performed by a module called customer service monitor (CustServMonitor). After receiving an alert message that can indicate QoS degradation, the CustServMonitor triggers the on-demand monitoring in order to discover which domain is responsible for this degradation. It uses the information recovered from the monitor modules already introduced. The authors state the monitor architecture provides support for the adaptation of service content due to

QoS degradation; however, they focus on media service only. It is not clear if it is generic to support other service types.

A reputation-based framework to support QoS monitoring at service provisioning is proposed at [41]. A trusted entity called Reputation Mechanism (RM) relies on customer reports to build a reputation system which may punish a provider in case it does not satisfy the advertised service SLA. Furthermore, it compares reports from different customers that are using the same service to diminish the probability of false feedbacks. If a trustful report shows the delivered QoS was lower than the advertised QoS, the provider reputation is downgraded and it may be forbidden to advertise its services. Besides, it would have to pay the penalties due to not achieving QoS fulfillment. To encourage customers to honestly report, a payment mechanism is also presented. This mechanism pays more for customers that send honest reports and pay less for those who send dishonest reports. The repudiation framework seems to attain good results based on the clients' feedbacks; however, it tackles only simple services between a provider and customer. It does not mention how to deal with composite services that is typical from inter-domain scenarios.

At [42], the authors proposed a knowledge-based system using ontologies to formalize and define QoS aspects. This formalization aims to facilitate the exchange of information by providers, concerning measurements and QoS requirements. There is an entity responsible for defining the QoS ontology, which comprises the thresholds for different service requirements, QoS characteristics, how to measure QoS characteristics, which units to be used, and the rules to apply when comparing the measurements (e.g. how to convert units). The service providers have to publish QoS information according to this QoS ontology. Another entity (evaluator) is responsible to gather the QoS information from providers, compare them to the SLAs, and warning the providers in case of no QoS service fulfillment. This evaluation can be available for customer and other providers for future service provider selection. Again, as occurred with the previous proposal, this work did not specify how the system would apply in inter-domain scenarios.

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