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Helmut Kneer
University of Zurich, kneer@ifi.unizh.ch

Harald Haeuschen
University of Zurich, haeeusche@ifi.unizh.ch

Kurt Bauknecht
University of Zurich, bauknecht@ifi.unizh.ch

TRADABLE SERVICE LEVEL AGREEMENTS TO MANAGE NETWORK RESOURCES FOR STREAMING INTERNET SERVICES

Helmut Kneer, Harald Häuschen, Kurt Bauknecht

Department of Information Technology IFI, University of Zurich, Winterthurerstrasse 190, 8057 Zurich, Switzerland
+41-1-635 4311
{kneer | haeusche | bauknecht}@ifi.unizh.ch

ABSTRACT

In recent years, supply and demand of streaming applications via the Internet (e.g., video-on-demand, live TV coverage, video conferencing) have increased. The idea behind streaming Internet services is to avoid a time-consuming download, and instead, make the user view streaming content in real-time without delay. However, today's Internet traffic is routed on a best effort basis without any support for guaranteed service provisioning. Missing traffic prioritization mechanisms to guarantee Quality of Service (QoS) and, additionally, the fact that traffic passes several Internet Service Providers (ISP) during transmission is very disadvantageous for the performance of streaming Internet services. Therefore, a solution is presented to enhance existing protocols with QoS mechanisms. Service Level Agreements (SLA) and Operational Level Agreements (OLA) between service providers and service customers are proposed to enforce service guarantees on an economic base and they serve ISPs and Content Service Providers (CSP) to efficiently manage network resources. The concatenation of such contractual agreements between ISPs enables end-to-end-based service provisioning with QoS assurance. A contracting protocol is introduced to control the settlement of contracts and user demands. With the help of service brokers, SLAs could even be traded in a marketplace established for efficient use of limited resources.

1. INTRODUCTION

Electronic business is flourishing through the recent development and introduction of multimedia applications that are streamed to end-customer hosts by means of Internet technology. Streaming means that continuous data is cut into single units (packets) and subsequently sent from sender to receiver. The sequence of these single packets is called stream [17]. The commercialization of streamed information [18] is a new branch in the world of electronic business since the global Internet provides an infrastructure to stream video, audio, or news-feeds from centralized servers to home users. Streaming, as a real-time service, requires strict transmission controls of network resources in order to provide Quality of Service (QoS) and deliver data packets reliably with respect to service parameters such as bandwidth, delay, latency, or error rate.

Current Internet technology is based on the Internet Protocol (IP) [15], which is widely used to connect networks of Internet Service Providers (ISP). However, IP is lacking any kind of QoS mechanisms, an indispensable feature for providing real-time streaming services for end-customers. Another difficulty with the provisioning of reliable streaming Internet services over IP networks is the data transmission along several independent ISPs that have no tools and mechanisms to control user demands (e.g., different QoS requirements, service requests at marginal hours). Existing protocols have been improved and new ones developed to fulfil some of the QoS requirements. An enhancement of the current Internet Protocol is given by IPv6 [6], which includes a flow label field and an extended Type of Service (TOS) field to differentiate service classes. Furthermore, the IETF developed an Integrated Services (IntServ) networking framework [4] with a per-flow reservation of network resources for single Internet applications by use of the Resource ReSerVation Protocol (RSVP) [3] as a signaling protocol. However, the support on a per-flow basis showed scalability problems with respect to a large number of flows and states to be kept in backbone routers. As a consequence, the IETF developed an architecture for Differentiated Services (DiffServ) [1] to support QoS in large IP networks. Instead of treating single flows, DiffServ handles IP traffic based on aggregated flows and fixed numbers of service levels. However, this approach is limited to a so-called DiffServ domain of an ISP with a number of routers delimited by ingress and egress routers. Although network capacities and bandwidth are growing steadily to satisfy customer needs, new solutions must be introduced to overcome the lack of any end-to-end based QoS mechanisms and inefficient use of available resources. Current protocols fulfil these requirements only partially.

The connectivity of different ISPs and the overall structure within the Internet requires contractual agreements among ISPs to guarantee QoS-based end-to-end communication. A Service Level Agreement (SLA)/Operational Level Agreement (OLA) is a contractual agreement between service customer and service provider and it comprises specifications of content and quality of a service. Additionally, the price for the service customer and the consequences for the service provider in case of service failure or service shortcomings are specified in the SLA/OLA. SLAs/OLAs are a means to guarantee on a contractual level the required QoS for an end-customer service. SLAs/OLAs are an essential part within the service level management of service providers and they enforce the management of network resources and thus improve customer satisfaction. The use of contractual agreements along a path of several ISPs requires the development of a contracting protocol, which controls the settlement of the contracts and user demands. With the introduction of service brokers, SLAs could even be traded in a marketplace. According to customer needs for specific times and services, a marketplace could serve to satisfy both service customer and service provider.

The paper is structured as follows. Section 2 describes an E-Commerce scenario with participating roles as basis for the use of SLAs/OLAs. Section 3 introduces the concept of SLAs and OLAs and it suggests a structure for the content of such contractual agreements. Furthermore, a contracting protocol is proposed to settle contracts among different business entities. Section 4 discusses the function of a service broker and how it can be used to trade SLAs in a marketplace. A SLA will be represented as a tradable digital good, enabling service providers to manage their resources efficiently.

2. E-COMMERCE SCENARIO

An E-Commerce scenario describes the situation between a supplier and a customer doing business over a physical distance by means of the Internet. Such a scenario specifies the exchanged goods and identifies the different business roles that are involved in performing the business and their relationships to each other [12]. Figure 1 shows an E-Commerce scenario of a streaming video application where single data packets of a video stream are transmitted from sender to receiver.

The sender is the provider of the content of the video stream and thus called Content Service Provider (CSP). The customer is the final receiver of the video stream, which pays money to use the service, and thus called end-customer. The scenario of Figure 1 demonstrates the possibility of n different CSPs communicating with k different end-customers since all these business entities are autonomous instances. The business entities, which deliver single packets of the video stream from CSP to end-customer are the so called Internet Service Providers (ISP). ISPs manage network infrastructure in form of hardware, software, and physical cable connections and they are interconnected with each other to span a communication network around the globe.

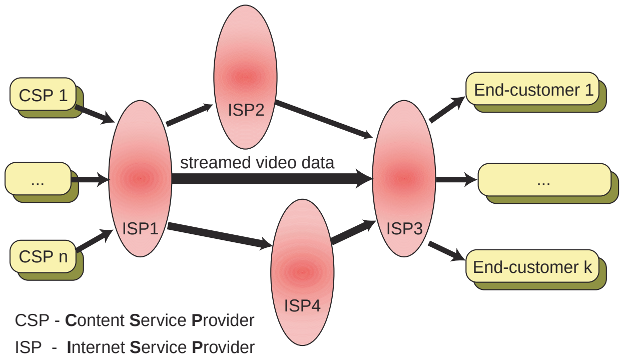

Figure 1: E-Commerce scenario of a streaming video application showing different roles and relationships

ISPs hold the most crucial part in the whole scenario since their responsible task is to receive data packets from precedent ISPs, route them through their own network, and deliver them to subsequent ISPs. Today's Internet is based on a best effort routing service with no rules to distinguish data packets in order to treat time critical traffic differently from other traffic. While a simple email service or a file transfer is not restricted to any time limits, real-time streams strongly depend on the delay between arriving packets. Exceeding the limit of delay between two or several arriving data packets results in an interruption and loss of received information, which is annoying for the end-customers and which can even result in financial losses in case of real-time news feeds or stock rates.

The idea in the E-Commerce scenario of Figure 1 is that the end-customer determines the service requirements by choosing parameters for the Quality of Service (QoS). The ITU-T [11] defines QoS as a concept for specifying how well an offered service is being performed and perceived by the end-customer. QoS can be specified by a number of parameters the end-customer negotiates beforehand and pays for hereafter.

From an economic point of view it is the end-customer that communicates only with a CSP to negotiate service conditions. It is also the end-customer that pays the CSP accordingly for the delivered service. The network infrastructure including the path that data follows from CSP to end-customer is of no interest to the end-customer and remains hidden. However, from a technical point of view, every service delivery (independent from its service requirements) requires the cooperation of several business entities (in Figure 1 this is CSP and up to four ISPs) in order to provide the service successfully to the end-customer.

3. CONTRACT-BASED RESOURCE MANAGEMENT WITH THE HELP OF SERVICE LEVEL AGREEMENTS

3.1. Overview

The E-Commerce scenario of the previous section illustrated a composition of different business roles in order to perform a service. E-Commerce service provisioning is a distributed task, which relies on the performance of every single entity. Service performance according to a pre-defined QoS can only be guaranteed to an end-customer, if every business entity along the path from CSP to end-customer fulfills its duties [12]. This requires the management of network resources of ISPs (e.g., bandwidth, access capacity, buffer, routers, etc.) and CSPs (e.g., video servers, hard- and software for compression, web access, etc.). Network resources need to be managed more efficiently in order to make the network run better, and be capable of supporting a wide variety of E-Commerce services.

Service Level Management (SLM) provides a concept to regulate on a contractual basis the management of resources for delivering a service with QoS restrictions [13]. SLM is the process of managing a delivered E-Commerce service in terms of quality, quantity, and cost. The ITIL standard [10] is an extensive framework for the whole IT service management based on modular components on a strategic, tactical, and operative level. It provides instructions to plan, execute, and support E-Commerce services. Service Level Agreements (SLA) and Operational Level Agreements (OLA) are an integral part of SLM to stipulate service conditions on a contractual basis between service providers and service customers. While SLAs define service conditions between an end-customer and the CSP, OLAs determine the supply of additional services between service providers in order to operate and fulfill SLAs. The combination of both SLAs/OLAs and mechanisms for the network management could result in a value-added service provisioning with QoS-based end-to-end communication.

3.2. Contracting Protocol

Our approach to combine business entities and make them cooperate is of decentralized nature. Several bilateral contracts in form of SLAs and OLAs are required between entities to enable a combined real-time service delivery. Therefore, a contracting protocol based on the exchange of XML documents was developed to show different steps of the contracting process. The single steps of the XML-based Contracting Protocol (XCP) are shown in Figure 2 and described below. Compared to the previously introduced E-Commerce scenario of Figure 1, the XCP is illustrated as a contracting process between one CSP, a single end-customer, and three intermediate ISPs.

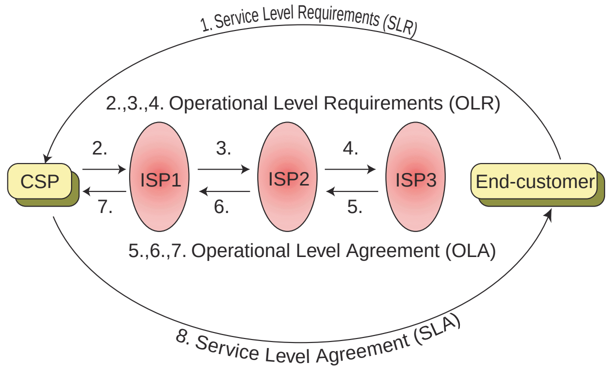

Figure 2: Contracting protocol showing a sequence of steps to result in bilateral OLAs and one SLA

In a first step, the receiver of the service (i.e. the end-customer receiving a video stream) defines the Service Level Requirements (SLR) in informal language and non-technical terms, which include service parameters to define the Quality of Service (QoS) (e.g., frame size, color depth, frame rate, price). The CSP who is the end-customer's responsible point of contact cannot guarantee the requested SLR at this point yet. After verifying its own resources required for the service delivery, the CSP needs to check (step 2) with one of its neighboring ISPs (in Figure 2 this is ISP1) whether it can provide the required resources to fulfill the SLR. At this point, the SLR need to be transformed into Operational Level Requirements (OLR) in form of technical expressions (e.g., bandwidth, packet delay, latency, loss rate) which can be directly interpreted by the succeeding ISPs. After verifying its own resources, ISP1 creates a new OLR to request the service with ISP2. This process of single and independent service requests continues until, finally, an ISP can deliver the service to the end-customer (in Figure 2 this is ISP3 as the end-customer's Access ISP). If an ISP does not agree with the required service conditions, it rejects the OLR and either another connecting ISP can be found or the SLR need to be redefined by the end-customer to fit the service conditions of all the ISPs.

If ISP3 can guarantee the service delivery to the defined conditions, it digitally signs the received OLR3 from ISP2, and thus, turns it into an Operational Level Agreement (OLA) (step 5 in Figure 2). The cascading process of signing OLRs goes back to the CSP with several OLAs between neighboring ISPs as a result. Consequently, the CSP can now sign a SLA that guarantees the end-customer a service under the previously defined conditions of the SLR. SLR and OLR are requests that are either rejected or accepted and signed by the ISPs in form of SLAs and OLAs. Several bilateral contracts were settled between all the involved business entities to enable a combined VoD service between end-customer and CSP. Therefore, the XML-based Contracting Protocol (XCP) was developed to show the feasibility of combined service provisioning.

The result of this approach as part of the Service Level Management (SLM) is the satisfaction of both end-customer and CSP as well as a well-structured network resource management for the ISPs to fulfill the service levels.

3.3. Content of SLAs and OLAs

SLAs and their underpinning OLAs are a means to establish business relationships between business entities and serve to enable the cooperation and responsibilities between entities according to predefined service parameters. SLAs and OLAs are negotiated and specified by both service provider and service customer before the service goes into operation. It defines service conditions and QoS levels for the performance of the delivered service.

For the implementation of SLAs/OLAs, several aspects concerning content and quality of the service have to be precisely specified. According to Hofmann & Schmitt [8] and ICS [9], SLAs/OLAs comprise different aspects that can be classified into four areas as illustrated in Figure 3.

There is no fundamental difference between the structure of a SLA and an OLA. However, since SLAs are signed between service provider and end-customer the language used for describing the contents of these four areas might be less technical and thus more informal. The content of OLAs should be precisely specified by numerical indications of service functionality, performance, monitoring, etc.

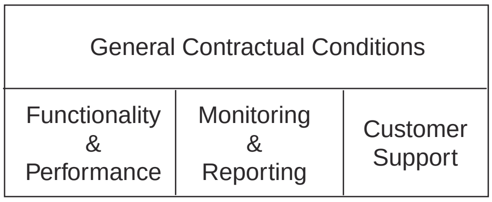

Figure 3: Content of SLAs and OLAs classified into four different sections

General contractual conditions describe a framework with general regulations for a business relationship between two entities. The following lists some general conditions that need to be defined as integral part of the contract.

Contract Duration – Every SLA/OLA should have a limit for the validity of the contract. The duration of the contract restricts the flexibility of the service and states formally the temporal availability of the service.

Contractual Determinations – It has to be specified under which conditions a change of the contract can be demanded by one of the two contractual partners. This protects business entities from unexpected service termination due to changing environmental situations.

Payment – The kind of payment for the service delivery needs to be stipulated. Possibilities include a fixed or variable price for the service, different payment mechanisms (i.e. credit/debit card, bank transfer, immediate pre-paid payments, etc.), charge sharing (sender/receiver pays according to a pre-defined ratio).

Non-Repudiation – Each contractual partner has to sign (digitally) the SLA/OLA and certify legally the obligation and liability for the service usage or delivery.

Service functionality and performance contains detailed specification of the mode of service operation as well as definitions of QoS parameters.

Service Functionality **–** The service has to be described entirely and precisely in detail as far as its content is concerned (aspects for the QoS are described in the following categories). The textual description of the service contains service requirements to be provided by the service provider. The more accurately and transparently service functionality is described, the clearer the expectations of the service customer and the less the disappointments during or after service operation.

Performance **–**Service performance is quantified by the response time of the service between sender and receiver. It reflects the rate for an end-to-end communication and determines how much bandwidth and network infrastructure (e.g., routers) the service provider has to supply in order to fulfill the customer's request. This aspect is described in technical terms within an OLA and in user-friendly, informal terms in case of a SLA.

Availability **–** The SLA/OLA contains the averaged availability of the service for the customer. Availability defines maximum number and period of a possible service outage. The higher the availability of the service the higher the price for the service customer.

Reliability **–** This aspect affects the physical quality of the transmission. The reliability is specified by a certain error rate (e.g., bit errors per day).

Security **–** Security aspects include confidentiality, integrity, and authenticity of data packets. Security mechanisms (i.e. cryptographic methods, passwords, public/private keys, watermarks, etc.) help enforce a secured service provisioning.

Service provisioning requires a monitoring service to inform the service customer about compliance with the contract. The area of monitoring and reporting defines customer-focused metrics and periods of notification to calculate and represent service levels and completion of the contract.

Service Indicators **–** SLA/OLA metrics have to be defined as well as its periodicity to measure service quality. This helps for the transparency of the service provisioning and consequently, the trustworthiness of the service provider and the business relationship with its service customer.

Notification **–** The periodicity and detail of the reporting of monitoring results (e.g., hourly, weekly).

Customer support contains regulations concerning support throughout the process of service provisioning. It covers actions to be undertaken by the service provider if service levels are not met as specified in the contract.

Liability **–** This aspect controls the liability of the service delivery and determines consequences for the service provider in case of service failure, service shortcomings, or even if a service delivery has been overdone. Service failure could for example result in reimbursements of service fees.

Recovery **–** The period of time that has elapsed before a failed/interrupted service has been brought back into operation. This includes existence and capability of contingency plans.

Reconciliation **–** Regulations to allow reconciliation in case of disputes.

User Support **–** Information and recommendations for the service customer in case of support queries or service failure. A Help Desk for example could provide such functionality for the service customer.

3.4. Implementing the Contracting Protocol

The process of sending out service requests and receiving corresponding answers in form of SLAs/OLAs or rejections is predestinated for the use of XML documents. As mentioned earlier, the whole contracting protocol is based on the exchange of XML documents and therefore labeled XCP (XML-based Contracting Protocol). SLR/SLA and their corresponding OLRs/OLAs are translated into XML documents as XCP exchange messages between business entities. XML is a perfect language to specify the content of SLR/SLA and OLRs/OLAs and it is suitable for structuring such a document hierarchically with markups in order to be processed automatically without human interaction.

Figure 4 shows the sequence of single XCP messages that are exchanged between the business entities according to the contracting protocol as described in section 3.2. It shows a cascading process of exchange messages starting from the top with a SLR from the end-customer to the CSP. That followed three consecutive OLRs from CSP over ISP1 and ISP2 to ISP3 before they are accepted and transformed into OLAs. The final SLA results as a consequence of a successful contracting process. In case one ISP rejects an OLR, a new ISP has to be identified in order to close the gap and form a continuous path from CSP to end-customer.

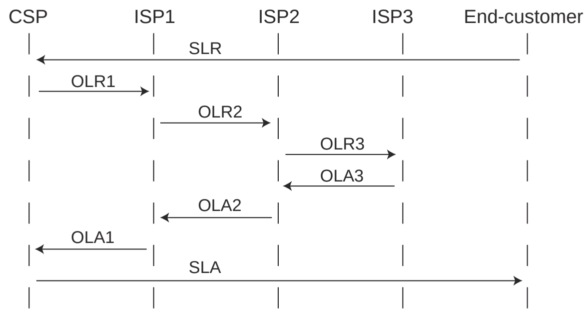

Figure 4: XCP exchange messages between the business entities

According to the XCP and the use of XML as the document language, there are five steps that are required for every ISP after receiving an OLR from a neighboring ISP.

1. Query to the ISP's resource database for any available network resources according to the requirements of the received OLR. The resource database contains information about availability of software and hardware resources. If services or network devices are down, it will be stored in that database. Also, the reservation of resources in advance will be available with the help of network management tools.
2. If resources are available, the received OLR is stored in a database (if possible, in an XML database). The received OLR is stored with a corresponding identification number to respond properly (i.e. with an agreement or rejection) to the request as soon as the availability of network resources of neighboring ISPs are clarified.
3. The received OLR is transformed into a new OLR that will be sent to the neighboring ISP. Since the whole contracting process of the XCP consists of several bilateral contracts, every business entity needs to sign two contracts for the service delivery to the end-customer. One contract with a preceding ISP, the other one with a succeeding ISP. In one contract the ISP is a service customer, in the other contract it is a service provider. Both contracts carry different identification numbers.
4. The new OLR is also stored in a database to keep reference for the expected reply. If the new OLR is rejected, it will be deleted from the database. In case of a positive answer, the corresponding OLA is stored instead.
5. The new OLR is sent to a succeeding, neighboring ISP to wait for a reply. The reply is either a confirmation in form of an OLA or a rejection. Consequently, the result of the reply needs to be communicated to the preceding ISP.

4. MARKET-BASED RESOURCE MANAGEMENT WITH THE HELP OF SERVICE BROKERS

4.1. Overview

Negotiation of SLAs/OLAs implies the end-customer to establish direct contact with the CSP at a definite time when he/she requires a service. However, this entails disadvantages and problems:

- Negotiation needs to take place for every individual business relationship, which can lead to an overload at the CSP's or ISP's servers. To some extent this could be reduced by mirroring services and contents at different locations with different service providers (e.g., Akamai[1]).
- In a distributed environment (as illustrated in Figure 1) it is difficult to utilize available resources in a balanced manner. It would be desirable to have a well-balanced network utilization even at marginal times of a day. This could be encouraged, for example, by use of differential pricing models [16], but this is not always flexible enough and nontransparent for the service customer.
- Service providers would prefer to administrate just a few SLAs/OLAs for services with large quantities of required network resources, since economic effort and risk are smaller.
- A reservation of a service in advance (i.e. a service will be provided at a future date) requires a well-working network resource management system. It is desirable for end-customers to be able to make reservations at any time, particularly for special events that are known in advance to obtain the required information at the right time.
- Every SLA/OLA is unique. Therefore, it cannot be re-sold easily if it is not required anymore.
- A service customer can never be certain that it will be possible to obtain a SLA/OLA at any given time for a requested service.

4.2. Service Broker

As an approach to solve the previously mentioned disadvantages and problems of the contracting process, the role of a Service Broker (SB) is introduced to act as a negotiator. To illustrate the concept of such a service broker and to keep the scenario as simple as possible, the service broker operates only between end-customer and CSP. However, service brokers as negotiators between ISPs are very well imaginable. The service broker represents a point of contact for end-customers if they request and negotiate a service with certain QoS requirements for the service performance. Furthermore, the service broker collects all the offers from CSPs and tries to match them in an optimal way. Service requests by end-customers could eventually be renegotiated and resubmitted to the end-customer in case of changes in price or QoS. In case of similar service requests concerning price or QoS parameters (i.e. several end-customers are interested in a real-time video stream of an Olympic competition), the service broker could collect these requests according to their local distances and gather them in a compound SLAs/OLAs with the end-customers and the CSP. To summarize, the role and functionality of a service broker ensures efficient utilization of available network resources in distributed environments.

Figure 5 shows the position and behavior of the service broker similar to the contracting protocol of Figure 2. However, compared to Figure 2, it is ISP3 that takes the role of the service broker, which is very well possible in a real-world scenario. The service broker takes a SLR from an end-customer, translates it into an OLR to transfer it to the CSP. The following steps (steps 2-7) are equal to the ones

[1] Accessible at URL: http://www.akamai.com

in Figure 2, with the particularity that there exists an OLA between service broker and CSP. Finally, service broker and end-customer settle the SLA with the required service conditions.

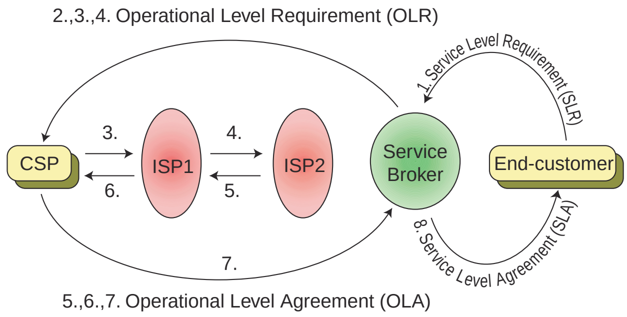

Figure 5: The service broker as negotiator between CSP and end-customer

In order to support the role of a service broker and the exchange of SLAs between service broker and end-customer (or eventually between other brokers), the contracting protocol as illustrated in section 3.2 requires further considerations:

- The SLA is turned into a negotiable digital good that can be renegotiated at will right up to the date of usage or after its validity has expired.
- A SLA can be formulated and issued at any time.
- When a service comes into operation, a SLA must be shown to proof correctness of service conditions. This way, the SLA serves to authorize the usage of specific resources.
- A platform is established where SLAs can be negotiated. Such a platform could be managed by service brokers.

Three conclusions can be drawn of the previous items in order to make the service broker work precisely and efficiently and particularly satisfying for both service provider and service customer: (1) a marketplace must be established where SLAs can be traded, (2) a certificate must proof existence and ownership of an SLA as prerequisites for the SLA to be traded correctly, (3) a transfer mechanism must enable the transfer of an SLA between seller and buyer as simply and securely as possible.

4.3. Trading SLAs

4.3.2. The Marketplace and its Participants

Trading SLAs requires a marketplace with several participants as modeled in Figure 6. It should be noted that the model focuses on the trading of SLAs assuming that in a similar and parallel manner corresponding OLA trading takes place between CSPs and service brokers.

- **CSP –** The business entity that provides the actual service. The CSP is responsible to the service broker for making sure that the service is available as described in the SLA, that it can be clearly identified, and that it meets all legal requirements. However, it is the service broker that holds responsibility to the end-customer for the service provisioning.
- **Owner/Seller –** The business entity that owns the SLA and holds the rights to trade it. Owner/seller of a SLA can be a service broker after reserving a service from a CSP (which was stipulated in form of an OLA). Owner/seller of a SLA can also be an end-customer trying to re-sell a previously purchased SLA.
- **Buyer –** The business entity that purchases a SLA and that will be the future owner and/or re-seller. Both end-customer and service broker could be possible buyers.

- **Trading System** – An institution that is responsible for the settlement of the transaction. It is required that all marketplace participants trust the trading system in order to execute SLA trading activities. There might be one or more trading systems present in a marketplace (compared to several certification authorities (CA) for public key infrastructures (PKI)). Such entities are proposed and used for other environments like digital ticket circulation [7].
- **Financial Institution** – An institution that is responsible for processing payment transactions. Also several financial institutions might be present in a marketplace (compared to several credit institutions for purchasing ordinary products).

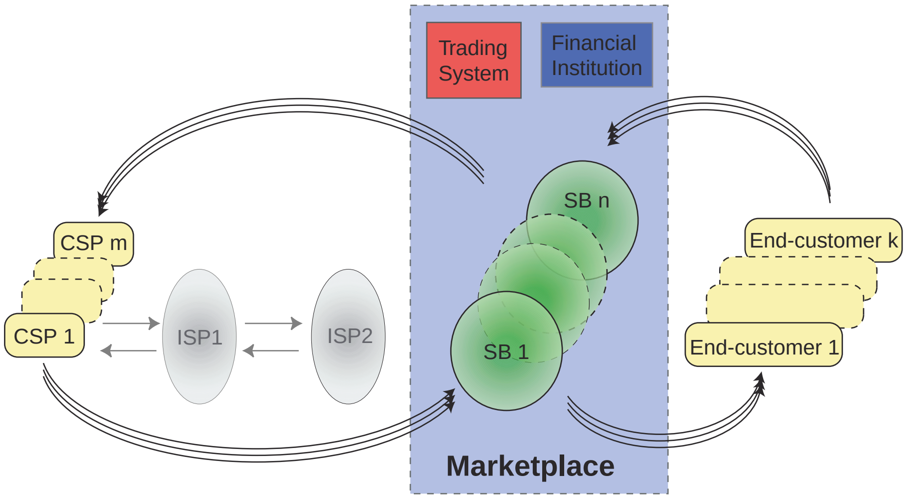

Figure 6: Participants in the marketplace for trading SLAs

4.3.2. SLAs as Tradable Digital Goods

The tradable SLA can be described with the help of an XML document [5]. The tradable SLA is essentially a certificate, which contains information about the content of the SLA, the issuer, the trading system, and the lawful owner of the SLA. Thus, the tradable SLA is an XML document named *SLACertificate* and divided into four sections as illustrated in Figure 7. The corresponding Document Type Definition (DTD) [2] is subsequently presented in Figure 8.

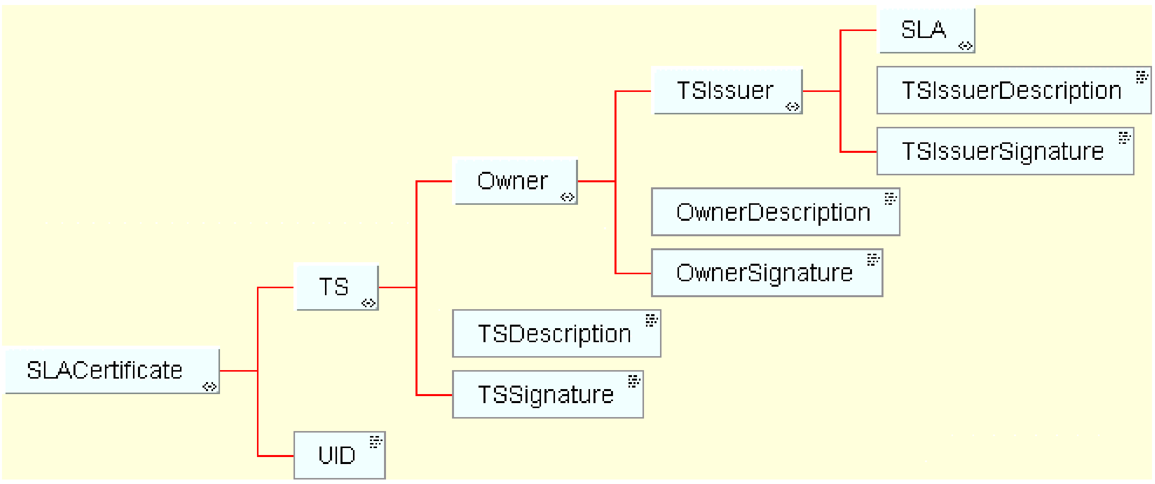

Figure 7: Graphical illustration of the XML syntax of a SLA certificate

- **SLA –** This section describes the content of the SLA according to section 3.3.
- **TSIssuer –** This section contains information about the issuer of the SLA, which is the trading system that signs the SLA at first. The issuer is always a trading system since it is a trusted entity to all marketplace participants. The issuer digitally signs its identifying information and the description of the SLA. This helps to identify modifications and prevents from fraud and unauthorized changes of the content. No information about the content of the SLA can be altered without the issuing trading system. However, the transfer of ownership can be executed by any other trading system.
- **Owner –** This section contains information about the owner of the SLA. The owner digitally signs his/her identifying information and the TSIssuer section. This digital signature verifies the lawful ownership and further on no changes can be made to the TSIssuer and SLA section without the owner's permission (for further information on digital signatures see [14]).
- **TS –** This section keeps information about the trading system, which has altered the SLA certificate last in order to sign its identifying information and the owner section. This trading system signs the whole SLA certificate at the end, which makes any kind of modifications impossible without any trading system.

```
<!ELEMENT SLACertificate (TS, UID)>
<!ELEMENT SLA (#PCDATA)>
<!ELEMENT TSIssuer (SLA, TSIssuerDescription, TSIssuerSignature)>
<!ELEMENT TSIssuerSignature (#PCDATA)>
<!ELEMENT Owner (TSIssuer, OwnerDescription, OwnerSignature)>
<!ELEMENT OwnerSignature (#PCDATA)>
<!ELEMENT TS (Owner, TSDescription, TSSignature)>
<!ELEMENT TSSignature (#PCDATA)>
<!ELEMENT TSIssuerDescription (#PCDATA)>
<!ELEMENT OwnerDescription (#PCDATA)>
<!ELEMENT TSDescription (#PCDATA)>
<!ELEMENT SLADescription (#PCDATA)>
<!ELEMENT UID (#PCDATA)>
```

Figure 8: Document Type Definition (DTD) for a SLA certificate

4.3.3. Transfer of Ownership

The main task of a SLA trading system, as a trusted entity, is to ensure secure transfer of SLA ownership together with the settlement of corresponding payments. A sequence of eight different steps is required to execute a transfer of ownership from a seller of a SLA to a buyer. Figure 9 illustrates the sequence of steps with the service broker as seller and the end-customer as buyer of a SLA.

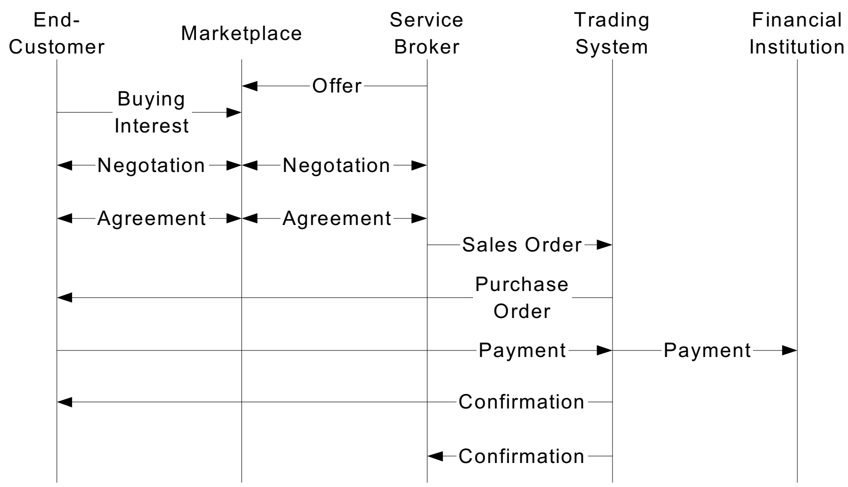

Figure 9: Transfer of ownership for a SLA certificate

1. **Offer:** The seller provides his/her SLA certificate to one or several marketplaces where it is to be offered for sale. These marketplaces are not only for trading SLAs, other goods can be traded, too. It is important that existing marketplaces (e.g., auctions, spot markets) are used for trading and negotiating. Only for the final transfer of rights of a SLA an additional mechanism is used.
2. **Buying Interest:** An interested service customer and potential buyer proceeds to the marketplace and selects a SLA. With the help of the trading system, the interested service customer can verify the validity of the SLA certificate, the seller's ownership, and the kind of SLA (e.g., QoS).
3. **Negotiation:** The potential buyer and seller negotiate the price for the SLA certificate. No additional protocols are used for the negotiation process. Negotiation is supported by standard mechanisms of the marketplace where SLAs are offered.
4. **Agreement:** Buyer and seller agree on a price for the SLA.
5. **Sales Order:** The seller signs the sales order as a means for confirming that he/she wants to sell the SLA for the negotiated price. The sales order is now forwarded to the trading system.
6. **Purchase Order:** The trading system sends the TSIssuer section of the SLA certificate to the buyer, who subsequently signs the owner section accordingly.
7. **Payment:** Payment is executed from the buyer via trading system to the financial institution.
8. **Confirmation:** After the financial institution confirms a successful payment transaction, the trading system finally signs the SLA certificate and sends it to the buyer. A confirmation statement goes to the seller about a successfully completed transfer of ownership.

As soon as the trading system receives a sales order (step 5), the status of the SLA certificate is set to 'being processed'. This ensures that the SLA cannot be sold again during the transaction process. While the certificate holds this status, both seller and buyer are able to revoke their interest to trade. However, once payment has been initiated (step 7) the status of the certificate is changed to 'being paid' and it is no longer possible for seller and buyer to revoke sales and purchase order. If the payment transaction is not successfully terminated the system reverts to the original status, i.e. the original owner remains owner of the SLA certificate.

The sequence of steps to transfer the ownership of a SLA certificate emphasizes the important role of the trading system during the whole process. It is a specific entity, which is trusted by all the participants of the marketplace. Such entities already exist for other purpose like PKI (e.g., SwissKey[2], VeriSign[3], GlobalSign[4]). The trading system performs the following tasks among others:

- Transfer of ownership of SLA certificates
- Processing payments
- Checking integrity, signatures, authenticity, and validity of SLA certificates
- Blocking or rejecting SLA certificates
- Storing of all the legally valid documents

5. CONCLUSIONS AND FUTURE WORK

The paper introduced an important step towards enabling QoS in streaming Internet applications with the help of SLAs/OLAs. Contractual agreements in form of SLAs/OLAs represent a possibility for both service providers and customers to negotiate and specify service requirements including the price. Pre-defined service parameters determine what service customers can expect and also what service providers have to deliver. Additionally, such contractual agreements were proposed to help both ISPs and CSPs to manage their network resources efficiently due to precisely formulated service conditions and penalties in case of service failure or shortcomings.

An enhancement of simple SLA negotiation is the trade in a marketplace. A marketplace for SLAs as digital tradable goods offers new possibilities to exchange and trade SLAs with reduced operating expenses for service providers and with a variety of transparent offerings and bargains for service customers. With the help of service brokers in a marketplace, utilization of network resources could be administrated more efficiently since supply and demand of services is matched optimally.

The realization of a marketplace to trade SLAs requires several security considerations that were not explicitly discussed within this paper. The cascading structure of digital signatures from issuer, owner, and trading system avoids fraud and theft of SLA certificates. The trading system as the only trusted party within the marketplace needs strong security mechanisms to be protected against malicious attacks and to guarantee its availability. Integrity of the SLA certificate as well as authenticity and non-repudiation of the traders are other indispensable security requirement that need further research.

The marketplace, as introduced in this paper, trades the content of the CSP directly to some end-customer. The service broker simply serves as intermediary negotiator between CSP and end-customer. In order to enhance the functionality of the service broker a business model could be envisaged where the service broker administrates the content itself and sells it to many end-customers with various service requirements. That way, content is transmitted to the service broker only once and re-traded from there. However, such a scenario raises legal questions dealing with copyright protection of digital content.

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[2] Accessible at URL: http://www.swisskey.com

[3] Accessible at URL: http://www.verisign.com

[4] Accessible at URL: http://www.globalsign.net

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