

Secure Collaboration Mechanism for SLA delivery among IPTV providers

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Abstract

Service Level Agreements (SLAs) specify the quality levels customers expect during service provisioning. A critical issue in this area is for service providers to effectively achieve the individual SLA optimization in terms of Quality of Service (QoS) metrics and price. In Mobile IPTV (M-IPTV) scenario, the personalized service provision and timely/on-demand delivery demands high quantity of available resources that a single provider might not be able to provide. Therefore, it is a growing interest in collaboration and resource sharing among IPTV providers to provide high quality services. We propose a protocol for secure M-IPTV service delegation to support SLAs of an IPTV provider through access control extension to different security domains using Single Sign-On (SSO) technique. Moreover, IPTV provider shares individualized policies within B2B environment to provide users with a consistent unified experience and a seamless logon. Therefore, this study demonstrates the efficiency of collaborative IPTV service when SLA is strictly considered in cases of limited resources of a single IPTV provider.

Keywords: *IPTV, Service Level Agreement, Access control, Single Sign-on, Multiple-attribute Authorization*

1. Introduction

IPTV dependencies have been analyzed from both consumer and supplier perspectives [1]. The ability to personalize content gives service providers the opportunity to create an attractive service aimed at instigates sales. Shin's [23] study based on logistic regression shows that the qualities of content and interactive services are user factors driving the adoption of IPTV.

IPTV services were originally targeted to fixed terminals such as set-top boxes used by different users; however, issues regarding requirements for mobility support were raised under the auspices of the Fixed-Mobile Convergence (FMC) trend. New personalized IPTV targets such as Mobile IPTV have been developed to enable users to transmit and receive multimedia signals including television, video, audio, text and graphic services through IP-based wired and wireless networks. These services also support QoS/QoE, security, mobility, and interactive functions of IPTV. Four M-IPTV approaches have been developed [20]: Mobile TV plus IP, IPTV plus Mobile, Cellular and Internet. Mobile TV plus IP is a convergence of broadcasting, telecommunications and computing. IPTV plus Mobile is dominated by Telco in an attempt to identify new sources of revenue. An outstanding activity in this field of IPTV plus Mobile is the Open IPTV Forum [16] initiative whose main goal is the development of open end-to-end

specifications to increase interoperability among providers. The cellular approach is represented by the Open Mobile Alliance [8] initiative, which defines an end-to-end framework for mobile broadcasts. The internet approach known as Internet TV or Web TV does not guarantee quality of service.

In multimedia services, security and privacy issues are areas of concern. Lian's [13] work provides a digital rights management scheme for convergent services through scalable encryption, adaptive decryption and transcoding.

In order to deliver a highly individualized and timely-on demand service, M-IPTV providers require secure and effective resource management strategies to guarantee the quality levels demanded by their customers. Service Level Agreements (SLAs) are the most common mechanism for establishing agreements between service provider and consumer about the quality of service (QoS). The key challenge for this study is SLA adaptation. When an IPTV provider lacks the capabilities and resources, it sends a SLA profile including attributes related to the user's policy to another IPTV provider effectively delegating the service provision. User Single Sign-On (SSO) [9] is a good method for accessing other systems in these types of situations.

In this work, based on Open IPTV Forum standardization for interoperability, we propose to support the SLA of an IPTV provider through access control extension to the security domains of different IPTV providers using SSO technique and individualized policies.

This paper is organized as follows. Section 2 discusses state of the art M-IPTV authentication methods, SSO approaches and SLA implementation scenarios. In Section 3, we introduce an M-IPTV framework and a secure service protocol. The performance evaluation is analyzed in Section 4, and research conclusions are presented in Section 5.

2. Related Works

2.1. M-IPTV Access Control

M-IPTV access control is a process by which the use of mobile multimedia resources is regulated according to a security policy, the result of which is a set of authorized interactions.

Three types of efficient service protection protocols regarding M-IPTV have been proposed: Data Rights Management (DRM) [13, 15], IP Conditional Access System (IP CAS) [26] and subscriber authentication technologies using the Authentication, Authorization and Accounting (AAA) mechanism [21]. DRM is a technology for controlling the rights to digital content using Conditional Access System (CAS) [3]. However, the use of specialized physical client security modules makes CAS unsuitable for M-IPTV. IP CAS is a technical implementation of CAS over IP network but with negative implications in quality and service. Subscriber authentication technologies utilizes AAA mechanism and ticket method based on One Time Password (OTP) counter and admissible bilinear map even when the service channel originates from a foreign network.

2.2. Single Sign-On

Single sign-on (SSO) allows a user to log in once and gain access to all systems without being required to log in again.

Different approaches for Web SSO implementation have been proposed including XML-Based [9, 10], One Time Password [24] and Kerberos [7, 11]. An XML-based SSO approach provides flexibility, extensibility and interoperability between environments to be integrated, in

addition to user authentication and access control using Security Assertion Markup Language (SAML) [17, 18], a standard specification ratified by the Organization for Advancement of Structure Information Standard (OASIS) [19]. The One Time Password method allows a user to use different passwords for each login in order to establish communication among applications without directly exposing the user's static password. Kerberos SSO implementation offers the ability to provide a single authentication in a user period and to cache the fact that authentication was successful. However, enterprise SSO makes the delegation of Kerberos credentials quite difficult.

An XML-based implementation combined with SAML has several advantages over Web SSO solutions, including the facilitation of site access among trusted security domains after a single authentication and the provision of distributed authorization.

2.3. Service Level Agreement

SLANg[12] is a XML-based SLA specification which integrates the non-functional features of contracts between independent parties with the functional design of a distributed component system for service provision. SLANg defines seven different types of SLA based on a service reference model, i.e., Application, Web Service, Component, Container, Storage and Network.

The approach used by Application SLAs is proposed in [14] to enable SLA-driven clustering of QoS-aware application servers which support application server technologies with dynamic resource management in order to adhere to application-level QoS requirements, e.g., timeliness, availability, and high throughput.

Web Service SLA [5] is intended for use as an enterprise server (or cluster) working as a web services provider for other enterprises. The current study proposes a QoS control mechanism that provides an effective differentiation of the service provided to consumers, reserving the processing capacity of the cluster for the preferred consumers during overload periods.

Dynamic Networking SLAs [2] can occur between a user and a Network Provider Agent to enable the use of dynamic and flexible bandwidth reservation schemes on a per-user or per application basis. The results of this study show that these schemes can be exploited to benefit both parties by achieving the highest individual SLA optimization in terms of QoS and price.

3. Proposal

3.1. M-IPTV Framework

We design a framework based on M-IPTV service provision in which a mobile subscriber wants to watch a TV program on his mobile phone. The IPTV provider must assure that the requested content is available prior authorizing the service. If the content is unavailable, the provider requests the service from another IPTV provider in order to avoid SLA violations.

This framework is a novelty solution that represents an identity federation in which users of one home IPTV provider are able to access, without further re-authentication, protected resources offered by another IPTV provider belonging to the federation. Moreover, the use of this type of system provides a mechanism to manage user authorization and to extend differentiated services to end users based on user attributes, i.e., age, gender and SLA analysis, provided by the home provider. Figure 1 shows the M-IPTV framework in which the participant entities are Subscriber, Mobile Communication Network and IPTV Provider Federation.

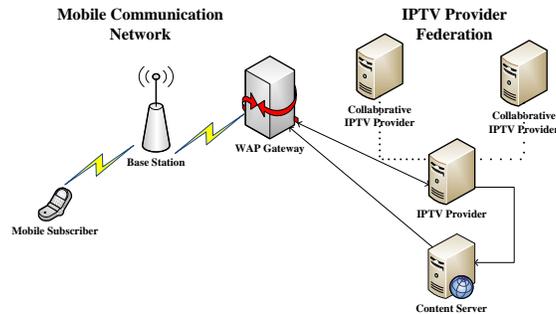


Figure 1. M-IPTV Framework

To provide access control based on user attributes, some important features must first be developed. First, IPTV providers must determine which user attributes (type and value) are useful for access control. Second, the protocol for service provision delegation must be defined.

The following sections describe the different components of the proposed framework.

3.2. Security Assertion Markup Language

SAML [17] is an XML-based framework for communicating user authentication, entitlement, and attribute information in order to allow business entities to make assertions regarding the identity, attributes, and entitlements of a subject or user and to share these assertions with other entities such as a partner company. The components of SAML [18] include assertions, bindings, protocols and profiles, the most important of which are assertions and protocols. Assertions provide statement information about a subject, i.e. authentication, attribute and authorization decision data. However, protocols defined by a number of requests/responses allow service providers to authenticate a subject or to receive assertions that meet particular criteria, i.e., the status of the user is valid to enjoy the service requested.

3.3 Architecture

The architecture, as shown in Figure 2, is based on a secure service convergence scheme composed of User, Distribution Networks and Content Provider [13]. Among them, User sends the M-IPTV service request using his mobile phone. The service request is transmitted over Mobile Communication Networks acting as Distributor Networks through the WAP Gateway in order to connect mobile domains to the wired Internet. The IPTV provider authenticates and authorizes mobile subscriber request, and the Content Provider processes the multimedia content including encoding, encryption, packaging and issuing the rights for access the content. The Mobile Phone decrypts and descrambles the content which is securely accessed by the mobile subscriber.

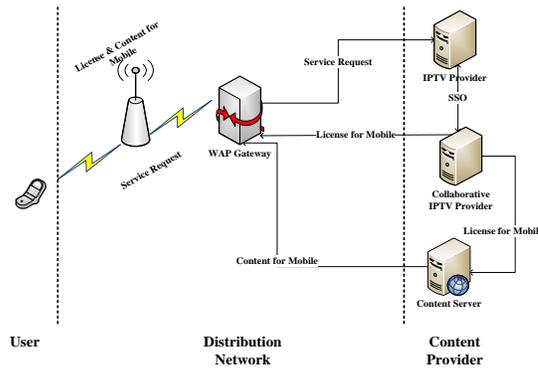


Figure 2. Architecture of M-IPTV Secure Service

We propose M-IPTV architecture for secure SLA-supporting service delegation, as shown in Figure 3. The IPTV provider receives the service request, authenticates the mobile user and assures that all resources required to deliver the desired service are available prior to authorizing the service. If any of these resources are unavailable, the provider negotiates with other IPTV providers to deliver the necessary service based on SSO and access control using SAML. Such a system provides interoperability between the environments to be integrated.

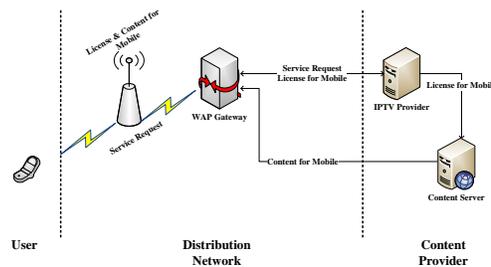


Figure 3. M-IPTV Architecture for Secure Service Delegation

3.4. M-IPTV Secure Service Delegation Protocol

When a customer wishes to use a service offered by an IPTV provider, a contract is required. The contract involves both functional and non-functional parameters regarding the service to be provided. SLA is the most common mechanism used to establish agreements on the QoS between a service provider and a service consumer.

The M-IPTV interaction process is shown in Figure 4. First, the user requests a service from the IPTV Provider. Second, the IPTV provider authenticates the user, checks the SLA to authorize the service and transmits the License to the user. Then, the Content Server transmits the content for Mobile.

The higher is the number of service requests, the higher will be the probability that the service provision to a customer is not successfully executed because of the IPTV provider's inability to meet the objectives of the SLA. To prevent such violations, the SLA needs to adapt during service provision using a flexible mechanism which enables run-time negotiation of the QoS guarantees with other IPTV providers. Finally, the home IPTV provider delegates the

service provision to a collaborative IPTV provider that guarantees the provision of the agreed service to the user.

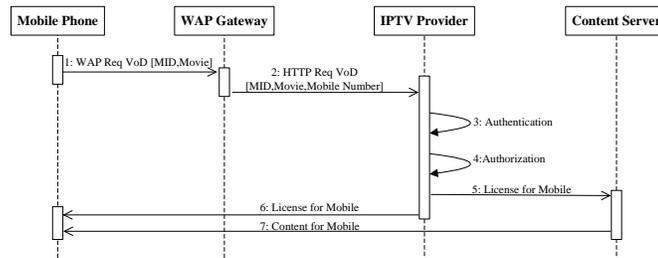


Figure 4. M-IPTV Service Delivery Protocol

In this work we propose a protocol that takes into account the dynamics of a scenario involving several IPTV providers. We remark that in such scenario there are several actors, in the role of IPTV provider. The main requirements are:

- Mobile subscriber authentication
- M-IPTV authorization based on the SLA profile
- Service delegation

Figure 5 illustrates the concept of the proposed protocol. The first step in this process is a user request for service from home IPTV Provider. The IPTV provider then authenticates the user, checks the SLA to authorize the service and predicts a lack of resources to deliver the desired service agreement with the SLA. The IPTV provider therefore redirects the service request to another IPTV provider. To provide flexibility, extensibility, and interoperability between the environments to be integrated, SSO and SAML provide seamless user access to both the home and collaborative IPTV security domains. The collaborative IPTV provider therefore requests SAML assertions from the home IPTV provider so that, the terms of the SLA, including the service description and the specific guarantee. Next, the collaborative IPTV provider analyzes the SLA profile and makes a decision regarding service provision. The IPTV provider delegate's service provision when the collaborative IPTV is able to comply with the SLA. Otherwise, the home IPTV provider continues to search for another IPTV provider to provide the desired M-IPTV service.

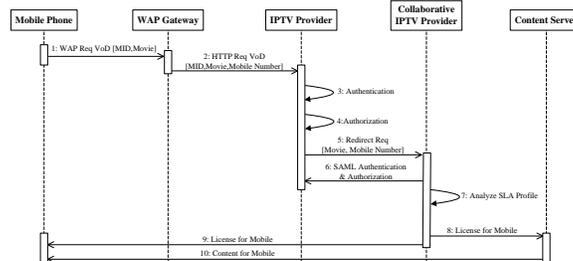


Figure 5. M-IPTV Secure Service Delegation Protocol

4. Performance Evaluation

The proposed protocol is analyzed according to M-IPTV access control requirements and Service Level Agreements.

4.1. M-IPTV Access Control Analysis

In this section we describe and analyze the M-IPTV access control requirements mobile user, cross-domain authentication, content security level, multiple attribute authorization, SLA and secure service delegation. Table 1 presents the results of the analysis.

Table 1. Analysis of the Proposed Scheme

	DRM	DCAS	Proposed scheme
Mobile User	X	✓	✓
Cross-domain authentication	X	x	✓
Content security level	Heavy	heavy	light
Multiple attribute authorization	X	x	✓
SLA	Not related	Not related	✓
Secure service Delegation	X	x	✓

The proposed architecture scheme allows for cross-domain authentication. Therefore, the IPTV provider is able to securely delegate M-IPTV service. Moreover, the IPTV provider and the collaborative IPTV provider authorize M-IPTV service based on analysis of user information such as age, gender, payment information, SLA profile, file access permissions such as read, write and delete and device information like type of terminal and special features.

4.2. Service Level Agreement

SLAs for Multimedia Internet Service are managed and controlled in [22] using a utility model based on the concepts of quality profile, quality-to-resource mapping, resource constraints, and utility function. These features provide a computationally feasible solution for admission control and quality adaptation that ensures the availability of sufficient resources to meet the minimum quality guarantee. Utility is defined as the satisfaction obtained from a service provider with regard to the system and network resources. From the perspective of IPTV provider, the higher is the utility of a request, the better it is for the business, although, a high utility value means higher quality resources. Therefore, under overload conditions without SLA adaptation, the IPTV provider may decide to discontinue a low utility service in order to provide a high utility service. Moreover, when the awaiting service requests are high utility, the provider may choose to provide service even when the SLA is violated, although, the service quality and reliability will be negatively affected. On the other hand, the IPTV provider may use a SLA adaptation technique to delegate low utility service in order to avoid service provision rejection. In this type of situation, the IPTV provider retains any resources that may prevent high utility service provision. The service delegation includes high utility service with SLA guarantees to assure excellent service quality for key mobile subscribers. In this way, mobile subscribers benefit from available and reliable M-IPTV service, and IPTV provider federations increase revenue while expanding their market segment.

The utility calculation depends on multiple SLA attributes, the utility values of which need to be normalized into a common utility space defined as the service utility. The service utility

describes the total satisfaction of n -attributes pre-configured into the SLA profile. The price $p_i(x_i)$ is different for each attribute and depends on the resource quality x_i . The service utility SU is defined as:

$$SU = \sum_{i=1}^n p_i(x_i), \quad (1)$$

and it is evaluated by the IPTV provider to determine the service utility. When service utility is high, the provider assesses of the resources needed to provide service according to the SLA. The existence of a mapping function $m(x_i)$ is assumed in order to associate the resource quality x_i with the resources required to provide that quality. Thus, the requirement SLA_i is met when resource R_i is greater than or equal to the amount of required resources. For a given R_i and x_i , SLA_i is calculated using:

$$SLA_i(R_i, x_i) = \begin{cases} R_i \geq m(x_i), 1 \\ R_i < m(x_i), \frac{R_i}{x_i} \end{cases}, \quad (2)$$

Therefore, for a request req the total percentage of SLA_{req} depends on the SLA of each n attribute as follows:

$$SLA_{req} = 100 \times \sum_{i=1}^n \frac{SLA_i(R_i, x_i)}{n}, \quad (3)$$

Although, the model of service utility and SLA adaptation supports any number of attributes, this section discusses performance after SSO authentication and authorization using a fast computing stream-based XML parser [4], i.e., GHPX, Xerces2 that does not affect the final outcome. In this work, performance is the rate at which data is delivered to the customer. Therefore, we assume that the IPTV federation provides the same SLA guarantees in terms of the QoS metrics offered.

Due to effects of the network, the media stream travels to the mobile phone with a speed different from the play rate of the client. In order to avoid mismatch between transference and play rate, the mobile phone is equipped with a buffer which stores data before it is played and while the content is being played back. When the buffer does not possess sufficient frames to smoothly display the content, it requests a throughput increment to guarantee SLA. In [6], the streaming-media workload is characterized by differentiating the inter-packet arrival times of audio and video streams depending on the buffer status, i.e., buffering time and regular time. During buffering, the inter-packet arrival time decreases to approximately four times the usual load interval, increasing the transference rate at the receiver buffer. This increase in the transference rate is caused only by a reduction in the inter-packet arrival time and not by increases in the sizes of the packets, resulting in an average bandwidth that exceeds the initial provision. The best approach for calculating the audio and video inter-packet arrival times during buffering intervals $IT_{Buffering}$ is to use an exponential distribution. For a given inter-packet arrival time x , the probability density function for the audio and video contents is

$$IT_{Buffering}(x \leq X) = 1 - e^{\left(\frac{-x}{\mu}\right)}, \quad (4)$$

Furthermore, during regular load intervals, the most suitable distribution is the cumulative normal distribution $IT_{regular}$, which describes the probability function distribution of positive, a

real-valued random variable x with an error function erf , the probability that the error of a single measurement lies between $-x$ and $+x$. This distribution is useful for determining the bit error rate of a digital communication system. The regular inter-packet arrival time $IT_{regular}$ for audio and video contents is defined as

$$IT_{regular}(x \leq X) = \frac{1}{2} \times \left[1 + erf\left(\frac{x - \mu}{\sqrt{2} \times \sigma}\right) \right] \quad (5)$$

Figure 6 shows the distribution of inter-packet arrival times. The audio inter-packet arrival time λ_a during buffering is less than or equal to 0.10 seconds compared to 0.3 seconds during the regular time. On the other hand, the video inter-packet arrival time λ_v during buffering is less than or equal to 0.02 seconds, compared to 0.05 seconds during regular time.

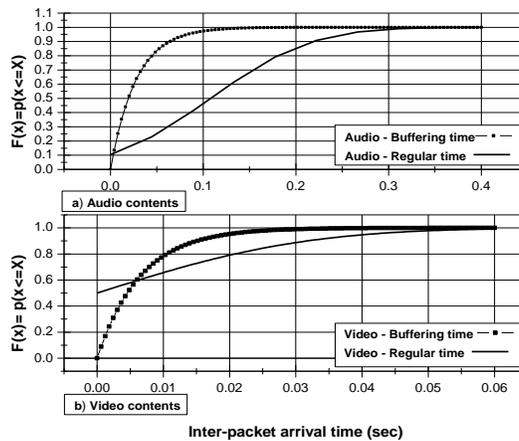


Figure 6. Distributions of Audio and Video Inter-Packet Arrival Times

We model the number of total delivered media packets $packet_{total}$ depending on the audio inter-packet arrival time λ_a and video inter-packet arrival time λ_v at time t as

$$packet_{total} = t \times \left(\frac{\lambda_v + \lambda_a}{\lambda_a \times \lambda_v} \right), \quad (6)$$

Figure 7 shows the cumulative volume of packets delivered in one minute using inter-packet arrival time and buffer status, i.e., buffering time and regular time. Theoretically, buffering occurs when there is some delay in the network, during which the IPTV provider modifies the transference rate in order to fulfill the user SLA. This is in opposition to regular time, during which the network conditions are good and packets are timely transmitted to user device to smoothly display the content.

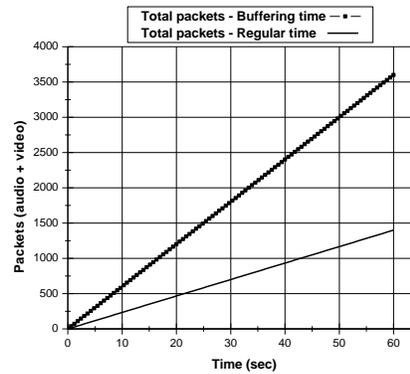


Figure 7. Total Media Packets (Buffering and Regular Time)

The media stream that uses buffering inter-packet arrival time is a result of several user demands whose service utilities are low. Therefore, under overload conditions, the IPTV provider discontinues the low service utility requests to employ resources that potentially degrade the performances of streaming servers and encourage networks to provide high utility requests.

Using SLA adaptation, an IPTV provider does not suspend service provisions. Thus, the IPTV provider delegates low utility M-IPTV requests to the IPTV provider federation in compliance with the user SLA. In this case, the IPTV provider federation applies a collaboration strategy for resource management in order to assure low utility M-IPTV service sharing revenues and costs, i.e., bandwidth consumption among collaborative IPTV providers.

We analyze the workload of the cumulative delivery of media content during buffering where a total of 3500 packets are delivered within a period of one minute by a single IPTV provider in the reference scenario and by three collaborators using adapted SLAs in the collaborative scenario, as shown in Figure 8.

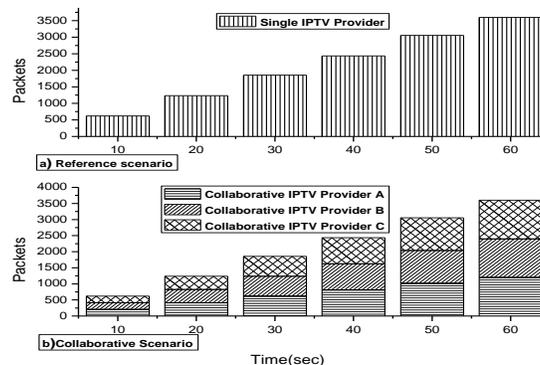


Figure 8. Low Utility Service Delivery Using Collaborative Strategy

In the reference scenario, a single IPTV provider sets the audio inter-packet arrival time λ_a to 0.10 and the video inter-packet arrival time λ_v to 0.02 seconds. In the collaborative scenario, the IPTV provider asks different collaborative providers to deliver only a part of the media content in order to consume limited resources at a low cost. In terms of throughput, each collaborative IPTV provider affects the inter-packet arrival time, to decreasing the transfer rate

and consuming less bandwidth. In the example using this approach, three collaborators agree to deliver the media content. Each of whom sets the audio inter-packet arrival time λ_a to 0.30 and the video inter-packet arrival time λ_v to 0.06 seconds.

A collaborative IPTV provider allocates capacity to provide a desired M-IPTV service with positive effects, revealing that the agreed transference rate is achieved by the IPTV provider federation. Such collaboration leverages existing infrastructure with regard to quality and performance, minimizing the probability of service suspension.

Considering that the media stream using buffering inter-packet arrival times is generated by several user demands whose service utility is high, overload conditions indicate that a single IPTV provider lacks the resources to totally or partially address all of these demands. Therefore, in Figure 9, we analyze a scenario in which a total of 3500 packets are delivered by a single IPTV provider in 60 seconds, in violation of the SLA. The IPTV provider uses SLA adaptation along with a collaboration strategy for resource management in order to deliver the media stream on time.

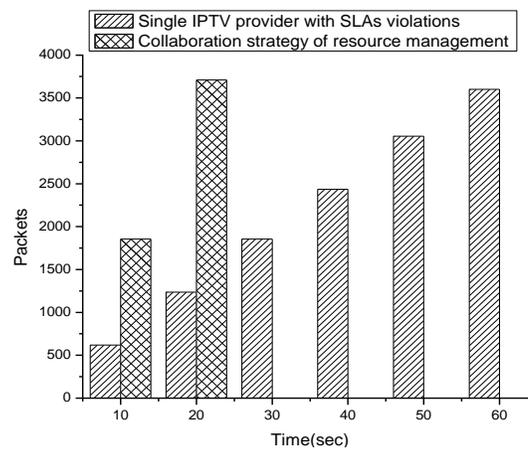


Figure 9. Comparison of Media Packets Volume Delivery

Due to the quality of resources, collaborators provide a better transference rate by decreasing the inter-packet arrival time, allowing the mobile subscribers to experience excellent stream quality. In this case, three collaborators deliver the stream media in 1/3 of the time that it would take a single IPTV provider. Figure 10 shows how the operation of the collaborative method in which the requests are delegated to a set of collaborators deployed across the IPTV federation. Each collaborative IPTV provider delivers equal amounts of media by adjusting the inter-arrival packet time and effectively reducing delivery time.

By analyzing both scenarios in which throughput is affected due to scarce resources and insufficient capacity, the use of an IPTV provider federation using SLA adaptation along with a collaboration strategy for resource management efficiently solves the problem of service suspension and service provision based on SLA violations.

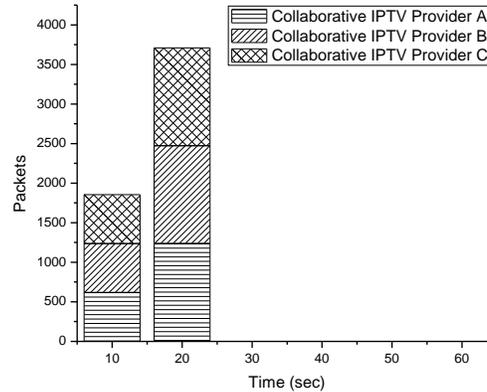


Figure 10. High Utility Service Delivery Using Collaboration Strategy

4.3. SSO Efficiency

In order to complete our analysis, we analyze the efficiency of the proposed access control technique, the main component of which is SSO. In the proposed method, this SSO extends access control to different collaborative IPTV provider security domains without requiring the user to repeat his log in. However, without SSO, mobile user is able to locate an IPTV provider who delivers M-IPTV service with SLA guarantees after multiple logons resulting in service provision rejection.

Our proposal does not re-authenticate the user when service provision delegation occurs. A collaborative IPTV provider gathers authentication and authorization information to determine analyze whether to accept or reject the service provision delegation. SSO aims to reduce the total response time determined by login speed, authentication/authorization, computing time, delegation time and SAML parsing time, complicating comparison analysis. We evaluate SSO efficiency by means of traffic overhead, i.e., the number of exchanged messages, secure service delegation protocols and multi logon protocols. The results of our analysis are summarized in Table 2.

Table 2. Number of Exchanged Messages

Protocol	Number of messages exchanged
M-IPTV service delivery protocol	5
Rejection protocol	3
M-IPTV secure service delegation protocol	7

The SSO traffic overhead to_{SSO} includes one service request and service delegation for each collaborative IPTV provider that agrees to deliver the service requested:

$$to_{SSO} = 5 \times iptv_{collaborative} + 2, \quad (7)$$

Moreover, Multiple Logon traffic overhead $to_{multipleLogon}$ is comprised of several rejection protocols until an IPTV provider delivers the service requested, as shown in the following equation.

$$to_{multipleLogon} = 3 \times iptv_{collaborative} + 5, \quad (8)$$

Figure 11 shows a traffic overhead computation. SSO traffic overhead increases depending on the number of collaborative IPTVs that agree to deliver part of the content. Multiple logons generate less traffic overhead: however, the waiting time to process M-IPTV service through the Multiple Logon process is increased because of the numerous authentication and authorization transactions.

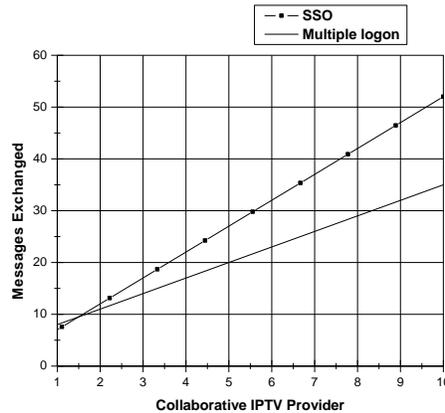


Figure 11. Traffic Overhead

The delivery time of a high utility service which employs a collaboration strategy along with the SSO access control mechanism is shown in Figure 12. The collaborative behavior of the IPTV federation dynamically balances service provision and efficiently delivers 100% timely-on requests. Moreover, the delivery time is reduced proportionally to the number of collaborative IPTV providers, saving up to 91% of the original time when ten providers contribute to provide service. The SSO traffic overhead does not affect delivery performance because secure collaboration is achieved prior to streaming.

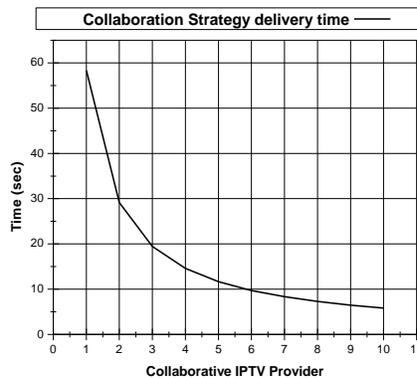


Figure 12. Efficiency of the Collaboration Strategy

5. Conclusions

In this work, the IPTV provider B2B scenario was analyzed in order to identify the access control and policies required for multiple-attribute authorization in the M-IPTV framework in order to for implement an effective resource management mechanism to guarantee the desired quality during service provision. We have proposed a new functionality to improve the flexibility of SLA management during service provision. The resulting protocol exhibits better performance with a higher rate of requests, i.e., when the capacity is limited, increasing the rate of accepted requests. This preserves the continuity of M-IPTV service provision.

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