End to end IP QoS assurance using policy based multi-agent SLA management systems.

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Abstract. The development of Internet as well overall communication technologies has created a very competitive communication market. In fact, there is no doubt that every company and perhaps every person in the world will have an Internet physical or wireless access via ISPs (Internet Service Provider). Thus the Internet became a very complex worldwide network which objective it to provide not only connectivity to end user but also services with a certain QoS (Quality of Service). Although, the effort made by each ISP to provide this QoS, it is not very easy to provide this QoS from access point of the customer to the destination point. The main difficulties are the negotiation process between ISPs in order to agree for the terms of collaboration and the deployment and management of the network in order to satisfy these agreements. It is recognized now that Policy-Based Networking became a key concept to facilitate the deployment of management strategy in IP based networks. Although, already existing solutions, they can operate only in a particular domain while the customer request for an end-to-end deployment. Thus, it is necessary to extend this approach in order to integrate mechanisms that permit satisfy end-to-end SLA (Service Level Agreement) upon a number of administrative domains. Thus the objective of this paper is to propose a solution that allow the interoperability between various policy domains. The approach is based on mobile agents to facilitate the negotiation between the different domains. Customer or ISP Policy Based Management System delegate to a mobile agents the responsibility to negotiate the terms of SLA on their behalf . The mobile agent negotiate according to a set of policies defined by the Customer or the initiating ISP.

1 Introduction

The Internet became at the centre of all communications between end users, customers and companies. It is clear that IP will be at the heart of many future services such as TV, Telephony, etc. Internet service providers are thus, seeking new way of doing business. While at the first time, the objectives was to provide more and more bandwidth to attract customers and allow them to user more and more complex services, the recent results have shown that it was not the more efficient approach as many customers where not satisfied by the provided service. In fact, customers do not have the same expectation from the network, some are asking just for mail service while others would like to use it for multimedia applications. The approach that is gaining now is the differentiation between customers so that the provided service is not the best one but the one that respond closely to customers' needs. Service Providers are therefore investigating opportunities for providing differentiated SLAs to their Customers to identify the terms of agreements concerning the quality of each provided service from the source access points to the destination access points. Quality can cover many aspects of the relationship and not only the quality in term of performance, for instance it includes quality of services, customer care, provisioning , security and particularly billing as all customers are concerned by the cost of a particular service use. These agreed terms are grouped in what is called SLA (Service Level Agreement).

Two main phenomena are appearing in the market. First, many ISPs start to provide QoS agreements to their customers and consequently SLA became a differentiation factor between provider. The competition market will be mainly focused on the capacity of an ISP to fulfil the agreed quality defined in the customers' SLAs. However, this is not an easy task as it is very complex to map customer's perception of a quality of service into operational performance parameters but possible because the ISP has control, over its own resources. Thus, it is necessary to provide to the customer a kind-of feed-back monitoring over its service to control the agreed terms. Some agreements have also to be set in the SLA in order to manage SLA violation.

Secondly, ISPs realize more an more that it is important to set up agreements with other ISP to offer broader services to the customer or simply providing more POPs(Point of Presence). However, this has a very big consequence over the SLA that can be agreed with the customer as in case of service spanning multiple domain there is not a central control over the resources and this is a big issue.

This necessitates a set of agreements between ISPs which can be seen as another type of SLA. ISP agree to fulfil agreed term for services that pass through its domain. Nowadays, this process is realized using fax or telephone and necessitates a certain delay time to verify and set up the network.

The objective of this paper is to investigate the possibility to automate this process so that the negotiation can be achieved in a shorter time if each ISP has already specified its business policy in term of cooperation with other ISPs. This suppose that ISPs have already installed a management system that is able to configure (and monitor) network equipments to provide certain classes of service (mainly we are concerned with DiffServ classes). The main focus is on the future strategies of ISPs to cooperate together in order to provide end-to-end services or value-added services based on agreed SLAs.

The complex aspects of this negotiation is the various as well as the semantic of parameters used in each domain. For instance, a gold service in one domain could be different from a gold service in another domain. This is identical to air companies. The Business class facilities of one company can be different from Business class facilities from another company. So if a customer has to take one flight from each companies to reach its destination then it will be difficult to assure him a company 1 Business like service from end-to-end. One solution could be to offer a company 1 Business like service, admit him in a Business class for the first flight and First class service in the second flight if we assume that the second company provides a better service called First Class.

The remainder of the paper is organised as follows: section 2 describes the background concepts for the purpose of this work. Section 3 presents the objectives of this work. The forth section presents the proposed framework for inter-domain policy based management using mobile agents. Section 5 describes the architectures of the different components of the framework. And finally a conclusion and intended future works.

2 Background concepts :

2.1 Policy Based Management

The Policy Working Group [14] of the Internet Engineering Task Force has accomplished a lot of work in this area and has mainly defined a scalable and secure framework for policy definition and administration [15][11]. The framework defines a set of component to enable policy rules definition, saving and enforcing [10].

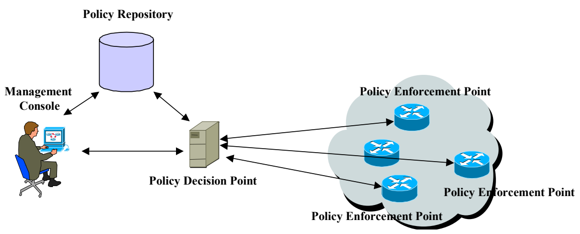

Figure 1 : Policy based management model

It identifies two primary main components by their functionality. The framework is comprised of a Policy Enforcement Point (PEP) that is a policy decision enforcer component and a Policy Decision Point (PDP) that is the decision-making component.

The management console is the GUI used by the administrator in order to introduce policies. Policies are defined according to high level strategy of the organization as well as according to SLA established with end-customers. Policy based management system require a global information model in order to capture all information needed to perform policies which means information about the network, the service, the customers, etc. Different models have been proposed such as DMTF (Desktop Management Task Force) Common Information Model or CIM that captures every notion that is applicable to all areas of management : system, network and users information as well as policy definition [17]. CIM is a kind-of implementation neutral schema for describing overall management information in terms of objects instances, properties, relationships, classes, and subclasses. It extends the existing instrumentation and management standards (SNMP, DMI, CMIP, etc.) using object-oriented constructs and design. DEN another initiative, which is an ad-hoc group of DMTF, has worked out a specification for modelling functionality and management of network elements and services.

2.2 Service Level Agreement (SLA) and Service Level Specification (SLS)

SLA is a formal negotiated agreement between two parties, sometimes called a Service Level Guarantee. It is a contract (or part of one) that exists between the Service Provider and the Customer, designed to create a common understanding about services, priorities, responsibilities, etc. [TMF 70]. Service Level Specification (SLS): Specifies handling of customer's traffic by a network provider [27]. Service Level Objective (SLO): Partitions an SLA into individual metrics and operational information to enforce and/or monitor the SLA [27].

2.3 Agent Technologies

Mobile agent technology is now a recognized concept for distributed systems management [1]. In fact, mobile agents are widely used to solve problems encountered in large scale distributed and real-time systems where the volume and complexity of the interactions make it difficult to implement classical client-server solutions. Generally, an agent can be considered as an assistant or helper, which performs routine and complex tasks on the user's behalf. In the context of distributed computing, an agent is an autonomous software component that acts asynchronously on the user's behalf. Agent types can be broadly categorised as static or mobile [2] [7]. The main motivation of the use of agent technology in this work is driven by the desire to automate the control and management processes related to policy negotiation between various administrative domains [3][6][8].

2.4 Objective of this work

Nowadays many ISP have provided a QoS IP infrastructure permitting new type of services such as: IP voice, Video, Virtual Private Network, etc. However, the provided services run only on a specific ISP infrastructure. In fact, it has been found to be very complex to deploy these services upon a set of multi-provider, multi-domain environment. When deploying such services, the configuration tasks are very complex because they are mainly performed through manual actions using faxes and telephone calls between the various organisations. This difficulty is exacerbated by the fact that each provided has its own definition of quality of service (premium, gold, silver, etc).Thus, the idea behind this work is to automate the negotiation procedure as well as the configuration procedures so that to offer rapidly new en to end services to customers based a negotiated SLA. The starting point of the overall process is a customer willing to use a service spanning several administrative domains. Each domain with its own strategy and goal but willing to cooperate together, to offer new end-to-end services and associated SLA. Each domain can use heterogeneous technologies for setting up its network. However, we assume that each organisational domain has deployed a Policy-Based Network Management System playing the role of Bandwidth Broker (BB) for this domain. The objective is then to enhance this BB with capabilities allowing him to negotiate with the customer and peer BB terms of SLA. The collaboration between the various domains will be based on a set of predefined agreements between these domains and represented by ISP to ISP SLA (I2I SLA). ISPs can negotiate cooperation on service per service base. The set of agreement ISP will agree on will be defined in the I2I SLA. These agreements are the formal negotiated terms between an ISP Provider and an ISP Customer for service delivery. It is designed to create a common understanding about services, priorities, responsibilities, etc. Similarly, end users connected to a particular ISP have agreed with this latter for Customer-to-ISP SLA.

When the service requested by a customer span a number of ISP, negotiation between ISP has to take place in order to assume to the customer the best deal for its request. For instance, if the ISP has connectivity with two other ISPs, there should be a process that allows searching for the best service (for instance, in term of QoS or Price) on a customer-based requirement defined by the SLA as described in the following figure :

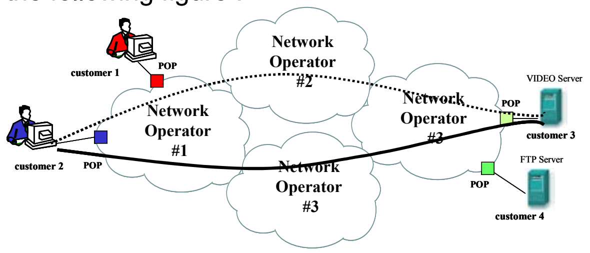

Figure 2 : End-to-end service spanning multiple domains

The contractual relationship between a customer and a particular ISP defining the set of services the customer is allowed to user as well as the terms of use of the services is represented by the Customer to ISP SLA.

ISP2ISP SLA and C2ISP SLA are different in the sense they do not address the same level of granularity of the services. C2ISP SLA has a fine granularity of service parameters while the ISP2ISP SLA has a wide granularity.

Thus it is necessary to enhance the PBM framework in order to take into account the multi-party process of policy based management. In fact, ISP establishes a set of agreement with others ISP in order to provide an end-to-end service to customer. Agreement between ISP will be based on ISP to ISP SLA that can change during time according to the business strategies. However, it is necessary to automate the interaction process between ISP Policy Based Management in order to hide the complexity of the end-to-end management. Inter-domain PBM have to provide facilities to adapt quickly to new changing strategy regardless the relation between a particular ISP and the other ISP. For instance, ISP can have different agreement with other ISP to provide connectivity to the same destination.

In this paper, we investigate the possibility to use mobile agents as flexible approach to PBM over multi-domain IP networks. The motivation to use mobile agents is the fact that negotiation between the customer and the ISP and an ISP and another ISP may be very complex. Thus, mobile agents can be a good approach to help to automatism all the negotiation process to avoid many interactions using a classical client server protocol. Hence, the philosophy of policy based management will help this approach as agent can themselves carry business policies so that the negotiation and the decision can be performed locally.

3 Negotiation of QoS parameters

In order to understand the problem, we takes the topology presented in the figure 2 as the use case. It presents four ISPs willing to cooperate in order to provide end-to-end services. We complete this figure with some network level information.

Now let suppose that the ISP1 is implementing the following quality of service strategy where 3 classes are defined :

1. Gold: Traffic in this category is allocated 50 percent of the available bandwidth.
2. Silver: Traffic in this category is allocated 30 percent of the available bandwidth.
3. Bronze: Traffic in this category is allocated 20 percent of the available bandwidth.

The three service are defined using the following QoS parameters : delay , jitter, packet loss and throughput which affect the customer traffic and are part of the negotiated SLA. At this point we didn't for simplification reasons the other parameters of the SLA such as : RFSD, MTBF, MTRS, MTTR that are probably in real word important properties in the SLA [28] :

If the customer request a service between his site a remote site, the delay that the customer's applications will see is the end to end latency introduced all along the network path due to queuing, processing or congestion. In our case we have to deal with the multiple domains. In this case the global latency is additive, ie : $D_{end\text{-}to\text{-}end} = D1 + D2 + ... Dn$

The jitter is the distortion of the inter-packet arrival times compared to the inter-packet times of the original transmission (i.e. delay variance). Jitter particularly damaging to multimedia traffic. In the case of a connexion spanning multiple domains delay variation accumulates on an RMS basis, i. e. *DVtot =sqrt[DV1 2 +DV2 2 +..... DVn 2];* where Dn is the mean one- way delay of Domain n and Vn is the standard deviation of the delay variation of Domain n

The loss is the failure of a transmitted packet to be received, usually because it was dropped at some point along the network path due to congestion. Thus when spanning multiple domains the loss probability accumulates on a probabilistic basis, i.e. LPtot = 1-[(1- LP1)*(1- LP2)*......(1- LPn)];

Let suppose that the objective of the ISP1 is to maintain the previous service in the following boundaries. The way the ISP divide its bandwidth and how it distribute it between different classes is independent from the requirements of the customers however, the ISP has to assess his choices in the middle term according to the network utilisation and the QoS failure in the network (monitoring loop).

Gold :

1. DSCP : EF
2. delay : Max = 10ms
3. jitter : Max = 1 ms
4. packet loss : Max 10-12
5. throughput : 500 Mbps

Silver :

6. DSCP : AF
7. delay : Max = 20 ms, Probability = 10-3
8. jitter Max = 5 ms, Probability = 10-3
9. Packet loss : Max 10-6, Probability = 10-3
10. throughput : 30 Mbps

Bronze :

11. DSCP : BE
12. Throughput : 20 Mbps

If these service have to be provided from end to end, the ISP can not assure that the networks in the path to the destination POP will assure these services. Thus there is a need to collaborate with remote ISP in order to verify what are the available service and how they fit with the provided services.

Thus we defines two types of SLAs : The Customer to ISP SLA and the ISP to ISP SLA.

3.1 C2ISP SLA Specification

The SLA between the customer and the ISP specifies the following information : **who** is the customer, **what** service he is willing to have, **when** he is willing to use it, from **where** he is going to use (and **how** to monitor the provided service for billing purpose and cash back in case of failure). We have used for that the approach described in the Internet draft : draft-somefolks-sls-00.tx which introduce four units :

Common agreements:

1. Description of the customer/provider/service
2. Time validity period (permanent or at certain date/time)

Topology agreements:

1. Service Access Points
2. Graph (describe the type of connexion the customer is going to set up 1-1; 1-M; M-1; 1-*; *-1 etc. At this point we consider only a point to point services

QoS agreements:

1. Traffic descriptor
2. Load descriptor
3. QoS parameters

The fourth is the monitoring unit including parameters concerning the monitoring of the service which is not yet considered in this work.

Traffic descriptor describes the packet streams of the customer for which the QoS unit attributes apply. This can be a DSCP, a TCP or UDP Source Port, a Destination Port, a Protocol, a Layer2Specification.

Load descriptor describes the type of load the customer is going to send or receive as well as the treatment to none conform traffic. These information will permit to set up the right leaky bucket policing of the traffic at customer ingress access routers. Excess traffic can be dropped, shaped or remarked.

The main parameters are :

Delay unit :
Max Delay to be seen by each conformant packet
Max Probability that this max delay is not respected,
Loss unit
Max Loss Probability defining the experience of end-to-end loss of conformant packets,
Max probability that this Max Loss is not respected,

Jitter unit
Max Jitter seen by each conformant packet
Mean Jitter seen by conformant flow

Based on these information, we have upgraded the domain information model with an object class representing the SLA_{C2ISP}. This is mainly composed by a set of attributes representing relationships to other object classes such as customer class, time validity period classes, SAP classes, Type of graph class, QoS unit class.

An example of an agreed SLA mainly based on the work presented in <draft-somefolks-sls-00.txt>allowing customer 1 to set up a video conference service with customer 2. Some modifications regarding this draft have been performed in order to highlight the previous QoS parameters in the SLA. Notice in this case that customer 1 and 2 are customers of the same ISP.

The instance object model for this example is presented in the following (Cost information was not represented in this initial model, it will be considered in future works):

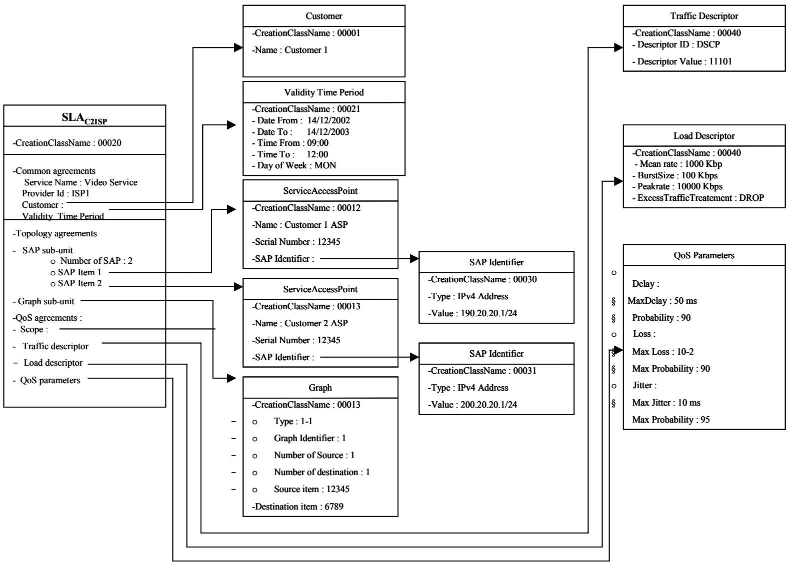

Figure 3 : Specification of the Customer to ISP SLA

4 Required Information models

When a service span a number of ISP, then the negotiation between the customer and the peer ISP has to be fulfilled in different manner as the ISP need to have more information about what collaborating ISP can offer.

The process can be performed in two different manners :

There could be an initial SLA negotiation between ISPs wishing to cooperate. This negotiation allows

the exchange of information concerning the capabilities of each ISP i.e. services are provided by the peer ISP (premium, gold, silver, etc), the minimum bandwidth to be allocated, the usage cost of this service, POPs, etc. Then each time a customer requests a new service the associated ISP has already enough knowledge about the different domains and the associated quality of service and cost to take a decision. When an allocation is realised with a remote ISP, interdomain resource usage and resources allocation information should be maintained. This approach will necessitate a regular update of information between the ISP so that any changes in one domain can be notified to others domains. For example, if one ISP changes its billing strategy, it has to notify the changes to the peer ISPs,

An other approach is to have a central repository containing information about all ISPs and ISPs don't have any a priori knowledge about other ISPs. When a service is requested, depending on the service access points required by the customer. If the destinations SAPs are outside his domain, he can request thus central repository to search for candidate ISPs. When this list is identified, the ISP negotiate with the remote ISPs. This scenario is similar to what a trader does for distributed applications. The central repository can a special VASP (Value Added Service Provider).

It is clear that the second approach is more flexible but in thus work we decided to use the first approach i.e. the ISP knows exactly his partners as well as their capabilities. But we plan to work on this special VASP in the future

4.1 Inter domain Information Model

The initial interaction between ISP permit to identify which networks are reachable by particular ISP (this can be learned implicitly through BGP for example or explicitly through the negotiation protocol) and what type of services the ISP is offering (qualitative information such as voice, video, data, premium, gold, silver, bronze).

In other to maintain theses information in the information model of the ISP, we have added new object classes such as :

Peer ISP class : represents the peer ISP that could be part of the service chain to the remote access point. It contains all the information that identify the remote ISP, its Points of Presence (POP) and exchange points (EP) with other ISPs.

Peer ISP service class : represents a description of the portfolio services provided by the remote ISP. This class permit to maintain detailed information about the quality of service provided by a remote ISP as well as its properties (cost, security, etc) for each service.

Peer ISP SLA : represents inter-domain SLA between the local ISP and the peeISP. It represents the agreed terms between two ISP concerning the delivery of a particular service. This SLA is very important when monitoring the quality of service of the provided service and identifying any violation of the agreed contact (it is not represent here due to paper size limitation).

4.2 ISP2ISP SLA Specification Model

An SLA between ISPs will have an aggregate structure comparing to the SLA between a customer and an ISP. The main differences concern the level of granularity of a service an ISP can ask to another ISP. For example while a customer can request a DS0 service, one ISP will have to ask for a more important service in term of bandwidth for example : a 1*T1 service (1,5Mb/s), N*T1 services, etc. It is up to the ISP to Thus the parameter N is important in the negotiation process between the ISP depending whether the ISP is willing to have all this bandwidth or not. Hence each ISP has to maintain a resources model that represent the resources that are available in time in its own domain and between ISP domain. Each time an ISP receives a request for a new service from the customer he has to verify whether there are enough resources at the time the service is requested. So he has to implement a forecast resource model, to calculate during time whether the resources will be available and request if needed from the peer ISP more bandwidth .

The proposed ISP to ISP SLA is as follow for a Video service trunk :

Common agreements :				
5 Provider Id :	ISP1			
6 Customer Id :	Customer1			
7 Service name :	Video Service			
8 Time Stamp :	012034557			
9 Time Validity Period				
	Time From :	09:00		
	Time to :	12:00		
	Date From :	14/06/2002		
	Date To :	14/07/2003		
	Days of the Week :	MONDAY		
Topology agreements :				
10 SAP sub-unit				
	Number of SAP	2		
	SAP Item 1	a.		
		Serial number :	12345	
		SAP Identifier:		
			Type :	Ipv4 Address
			Value :	190.20.20.1/24
	SAP Item 2			
		Serial number :	6789	
		SAP Identifier		
			Type :	Ipv4 Address
			Value :	200.20.20.2/24
11 Graph sub unit				
	Type :	1-1		
	Graph Identifier :	1		
	Number of Source :	1		
	Number of destination :	1		
	Source SAP Item :	Serial number :	12345	
	Destination SAP Item:	Serial number :	6789	
QoS agreements :				
12 Scope :				
	Graph Identifier :	1		
	Traffic descriptor			
		DSCP :	11101	
13 Load descriptor				

	Mean rate :	500 Kb/s	
	BurstSize :	1000Kb	
	Peakrate :	1,5 Mb/s	
	ExcessTrafficTreatement :	DROP	
14 QoS parameters			
	Delay :		
		MaxDelay :	50 ms
		Probability :	90
	Loss :		
		Max Loss :	10-2
		Probability :	90
	Jitter :		
		Max Jitter :	10 ms
		Probability :	95
	Service availability :	100%	
Cost agreement :			
15 Fixed cost 16 Variable cost	1. 100 UNIT/Mbps/minute		
SLA Violation			
This section should specify the term of agreements in case of non respect of the SLA			

5 Proposed architecture

After defining the various models necessary to maintain information about the resources and SLA, we propose hereby an agent architecture to help the realisation of the negotiation process between the various domains. The idea is to give enough autonomy to the agent in order to find the best service depending on the customer or the ISP criteria. The ISP SLA management system is also based on a set of agent but in this case the agent can also be realised as components as their roles don't necessitate any intelligence. The choice of agent approach is only motivated by a modular decomposition of the architecture. Thus, the agent architecture is deployed on the top of a policy based management system which control effectively the resource of an ISP domain (Figure 5).
SLA subscription (SSU) agent : this agent is responsible for the interaction with the customer agent for subscribing a new SLA. As a result it creates an SLAc2ISP objects in the common information model as well as related objects.
Inter domain SLA subscription (ISSU) agent : this agent is responsible for the processing of all SLA negotiation with peer ISPs. It uses an ISP agent to interacting with remote ISP. As a result it creates an SLAISP2ISP objects in the common information model as well as related objects.
SLA Admission Control (SAC) Agent this agent is responsible to:
- Interacts with the CN agent for the verification of the terms the new SLA with the available resources in the domain and between domains.
- Gets available resources in the domain with NRAM agent.
- Gets available resources in the inter domain with INRAM agent.
- Creates and sends new C2ISP SLA objects as well as related objects to NRAM agent.
- Creates and sends new ISP2ISP SLA objects as well as related objects to INRAM agent.
- The processing of all SLA negotiation with peer ISPs. It uses an IN agent to interacting with remote ISP.

Network resource allocation model (NRAM) agent : this agent keeps an up to date information about the available resources in the ISP network as well future resources allocation.
Interdomain network resource allocation model (INRAM) agent : this agent keeps an up to date information about the available resources between peer ISPs network as well as the future allocation of resource.
Policy generator (PG) agent : it main role is to convert accepted SLA into operational policies in the CIM.
Customer negotiation (CN) agent : is an agent that is instantiated by the customer for the purpose of negotiating end-to-end SLA with the connected ISP.
ISP negotiation (IN) agent : is an agent that is instantiated by an interdomain SLA agent for the purpose of negotiating end-to-end SLA with the connected ISP.
The Policy Decision Point (PDP) : is the decision-making component that takes as input policies that are saved in the CIM and take the related configuration decisions
Common Information Model Repository : is the database that contains a the instance of the CIM classes. In fact, it is a CIM object manager.

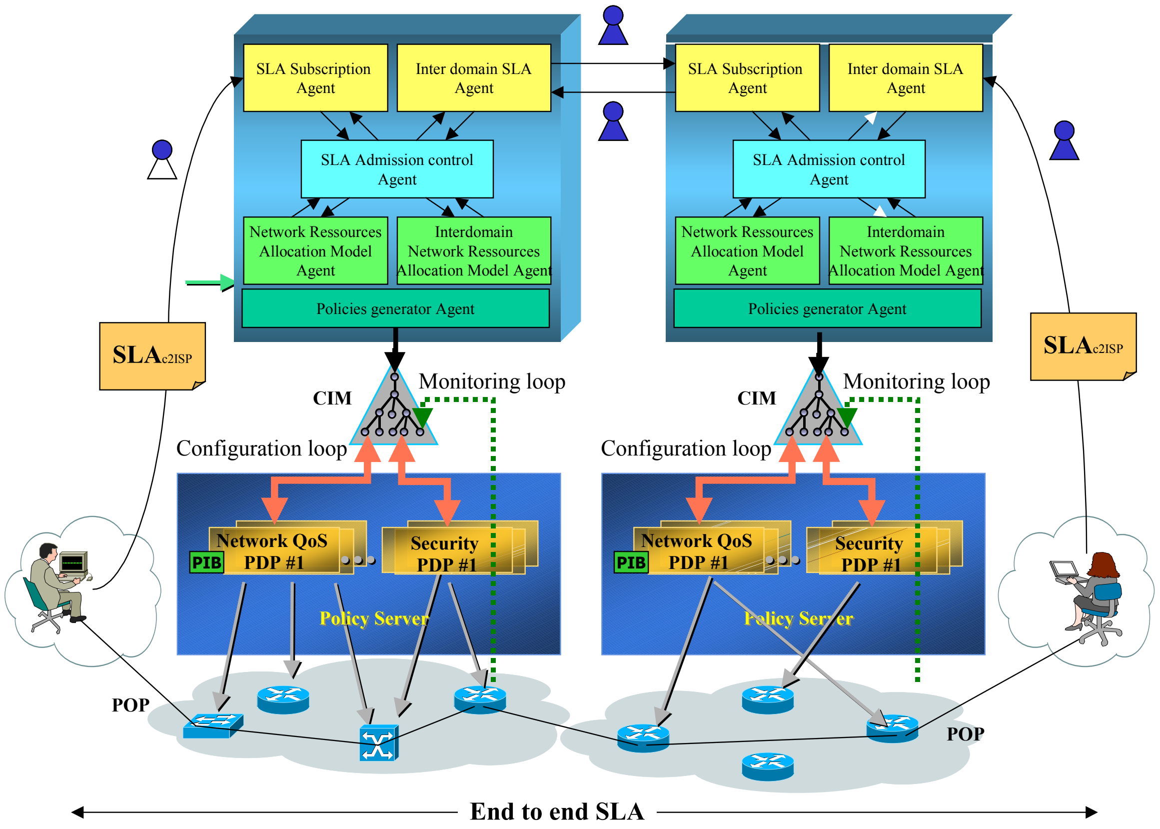

Figure 4 : Agent Based Architecture for SLA Management

5.1 Interaction Protocol between a Customer and an ISP

In the case where the service request by the customer can be fulfilled directly in the ISP domain, the interaction protocol between a customer and an ISP is based on agent interactions.

In order to represent these interact we have used the approach presented in [AUML]. The SLA negotiation protocol is composed of 6 services : ***Submit***, ***Refuse***, ***Accept***, ***Propose*** and ***Cancel*** which are self explained in the Figure 6.

The interaction diagram shows the scenario where the customer gives to its agent the authorization to negotiate remotely any proposal from the ISP which is different from the initial request. The customer can give a maximum and minimum range for the SLA parameters as well as a priority between these parameter.

Simple rules can be used to represent this policy :
IF proposed SLA <> requested SLA refused THEN start negotiation // agent can negotiate locally
Or IF proposed SLA <> requested SLA THEN stop negotiation, // agent can not negotiate and end of process.
Or IF proposed SLA <> requested SLA THEN request source, // agent can not negotiate, final decision is taken by the source.

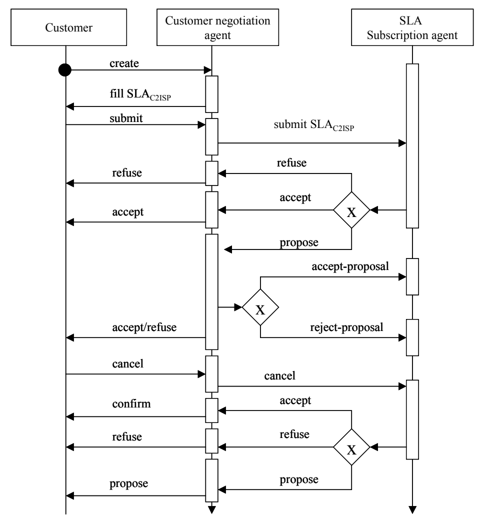

Figure 5 : Customer agent and SLA subscription agent protocol specification

In case of local negotiation, further rules can be specified :
<AgentBehaviour>
<SLABehaviour>
IF proposed SLA <> requested SLA THEN start negotiation // agent can negotiate locally
IF Negotiation THEN Priority BANDWIDTH > DELAY > JITTER
IF proposed BANWIDTH < BANDWIDTH THEN Refuse proposal
IF proposed DELAY between X, Y THEN Accept proposal

IF proposed JITTER between Z, T THEN Accept proposal
<SLABehaviour>
</AgentBehaviour>

5.2 Interaction Protocol between two ISPs

In the case where the ISP is not capable to satisfy form en-to-end the terms of services because the end points to not belong to its networks, the negotiation process is more complex.. In fact, the interaction protocol between an ISP SLA management system and another ISP is launched when a SLA request from a customer required the deployment of a service spanning multiples ISPs and the ISP didn't yet set up any agreement with the remote ISP for this particular service. This process can also be launched in case where the available resources allowed for the inter ISP communication are sufficient.

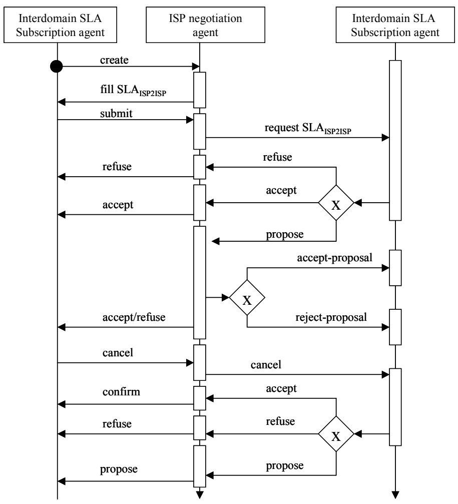

Figure 6 : negotiation protocol between an ISP agent an interdomain SLA subscription agent

As for the previous negotiation process, interaction between ISP domain necessitates almost the same steps. However, the ISP can not negotiate a strict value for SLS as the result will be mainly on aggregate, Thus the ISP will fix different rules for the negotiation agent. For instance, the ISP will fix different constraints rules such as max cost per Mb, min and maximum allocation bandwidth, maximum time to service, etc.

In this case study, we have added the parameter maximum bandwidth allocation the ISP is accepting. Hence, the agent should specify to the remote ISP whether he want to us it domain as a stub domain or as a final domain. If it is a stub domain, this means that the final access point is in a different network otherwise the remote site should be connected to the ISP domain.

To express these information, the requested SLA are represented in a using XLM so that they could be exchanged in a standard format.

5.3 Network resource allocation model :

The network resources allocation model agent is responsible for maintaining an up to date model of resources usage during time. In fact, the various SLAs accepted with customer defines a set of service that can be permanent or can be set up at a certain date/time. Thus this agent has the responsibility to respond to reservation request according to available resources.

In this table we presents one way to maintain this resources model using tables. We suppose that the ISP has set up a set of service (presented here as P for premium, S for silver and B for bronze). Each service has a certain amount of allocated bandwidth that decrease as much as new SLA are agreed.

The main difficulty here is to represent a forecasting model. A more efficient approach would a symbolic approach. But for simplification reason, we used tables at the moment. We suppose that minimum reservation slot is 1 hour. Each time an SLA is agreed its corresponding slot is marked.

Thus we have one table for the different existing service between peer SAPs and Nx365 tables, specifying for each day of the year the schedule of resources usage according to agreed SLA (supposing that the ISP allow reservation for N complete years, but can be also performed as a slicing table) :

Service ID : P12																								
Date : 12/05/2002																								
Time	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	18	20	21	22	23
Usage (%)	0	0	0	0	0	0	0	0	50	50	50	50	50	0	0	0	0	0	0	0	0	0	0	0

In this tables we have represented a schedule for a premium service starting from 12/05/2002 at 8:00 and finishing at 12:00 with a reserved bandwidth of 0,5 Mb/s and finishing on 12/05/2002 between SAP1 et SAP2.

Service ID : B12																								
Date : 12/05/2002																								
Time	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	18	20	21	22	23
Us-age (%)	0	0	0	0	0	0	0	0	0	50	50	50	50	0	0	0	0	0	0	0	0	0	0	0

This table shows the reservation of 50% of the bandwidth allocated to the Bronze service between SAP1 and SAP2. The ISP will accept any further reservation as much as the service is not fully used.

The same process apply also for inter-domain resource model and corresponding agent

6 Policies generation

When an SLA is accepted, the SLA subscription agent inform the policy generator agent of the decision so that this latter creates the corresponding policy rules in the CIM. These policies will be used by the PDP in order to realize the business strategy of the ISP.

Thus the policies are expressed in term of rules as described in [QOSF2]. The rules which are created according to the acceptance of an SLA. Policies are expressed in term of rules that have a condition part and an action part that should be executed in case of the condition part is verified. This expressed in the CIM model with three main classes as follow :

IF VendorPolicyCondition == True AND PolicyTimePeriodCondition == True THEN execute VendorPolicyAction.

However, from the SLA, several rules should be created as follow regarding the different agreement in the SLA :

Rule 1 : concerning the ISP commitment for the service delivery. Two parameters are important : the TimeValidityTime and the Agreed QoS. Thus the rule will be :

IF (PolicyTimePeriodCondition = (PolicyTimePeriod == TimeValidityPeriod)) == True THEN execute (VendorPolicyAction1 = (provide AgreedSAPs with AgreedService)) AND (VendorPolicyAction1 = (Start Accounting according to AgreedAccountingSchema)

VendorPolicyAction1 will be transformed by the PDP into a more precise action according to the underlying technology. Example, in case of DiffServ it will a particular mapping to a DiffServ Class. VendorPolicyAction2 can be a simple action for example in case of a flat cost or a complex action in case of a more complex billing schema (i.e. session duration, amount of exchanged data, etc).

Rule 2 : concerning the Customer commitment to send a traffic of a certain profile :The rule that constraint the Customer traffic will be :

IF Input Traffic From Customer 1 <> Customer1AgreedInputTrafic THEN Drop

At this stage of the work, we have only address simple rules but more work is necessary to address all the possible cases.

7 prototype implementation

The developed prototype for this system is based on Java as programming language, ObjectSpace™ Voyager ORB 3.0 [12] as mobile agent platform, . DiffServ over Linux [29] and OpenLDAP-2.0.23 [30]. DiffServ over Linux was used to specify various classes of services in the ISPs' domain, the OpenLDAP server was used to implement the common information model and finally Voyager ORB is used to develop the multi-agents SLA management system as well as the customer negotiation agent.

8 Conclusion and future work

While at the first time the Internet was used by none-professional, the requirements in term of Quality of service were not very strict. But with its wide acceptance by worldwide company as an alternative to their existing networks, this network has to evaluate into a more professional network. This means that Internet Service Providers have to provide to their customers contracts that specify the responsibility of the ISP in the delivering of the service and what the customer should pay for that service. In this context we have addressed the problem of assurance from end to end which the real problem nowadays as ISP are not able to control the end to end path from the customer access point to the desired destination point. In our proposal, we have introduced several aspect of negotiation : between a customer and an ISP and between ISP. We have proposed a multi-agent architecture to facilitate these interaction. The multi-agent system is built on the top of a policy based management system that each ISP will deploy in his own domain. The customer specifies the terms of the service he would like to set up as well as the maximum price we would like to pay. This information is described in a Customer to ISP SLA. He creates an agent to whom it delegates the negotiation activities but delimitates his responsibilities using policy rules. We have also defined a multi-agent architecture that ISPs should build on the top of policy based management system. This multi-agent system will provide the necessary components to allow SLA negotiation and management. These systems permit to verify whether it is possible to satisfy customer SLA and also to set up ISP to ISP SLA in order to negotiate the assurance of end to en path. When the customer agent presents the customer's requirement in term of QoS, the peer ISP determines the desired access point and eventually starts a negotiation process with all ISPs that need to be crossed to reach the destination points. Complex negotiation schema can be set up between ISPs and are automatically handled by agents. ISPs specify their cooperation strategy in term of policy rules and let the multi-agent system decide for registrations or rejection based on these policies. A lot of work still remain as we have to explore many negotiation schema that can exists in the real world. The mapping between the SLA level and the network level have done in a trivial scenario and need to be engineered in a better manner. It is also planned to study the impact of the ISP's strategy in term of QoS and pricing on their market share.

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