Adaptive Service Access Management for Ubiquitous Connectivity

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Abstract. This paper presents the Living Systems Adaptive Service Access Management Suite, a comprehensive middleware solution that enables adaptive connectivity management of nomadic end hosts across heterogeneous access networks while optimizing the way network performance and availability are managed.
The central concept is to describe how this is achieved by means of a distributed and autonomic middleware solution that combines end user requirements and service provisioning policies with network-facing management and control functionality.

1 Introduction

In today's highly competitive and converging Telecom markets, the presence of increasingly ubiquitous and heterogeneous communication and computing environments offers attractive business opportunities to operators, but also poses significant new challenges in many areas of communications and service management, especially in resource-limited access networks.

This is complicated by several factors. On the one hand, end users are becoming more demanding asking for new services to support a seamless and consistent experience across multiple access technologies, devices and locations. They expect to be always best-connected, i.e., anywhere and anytime access to the best available technology with the maximum capacity on offer, plus easy-to-use and problem-free services, all at ever lower prices. On the other hand, advanced end users devices enable a variety of ubiquitous deployment scenarios, but also pose significant challenges including of service usability and personalization. In addition, the widespread proliferation of multiple broadband access technologies such as cable, DSL, powerline, satellite, and wireless, is facilitating the entry of new service providers in both the fixed and mobile Telecom sectors.

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Therefore, operators need to find the means to lower operating costs while enabling the delivery of new and reliable services, by optimizing the way in which service performance and connectivity are managed.

This demands for a new kind of approach: a comprehensive policy-driven, autonomic solution spanning provider infrastructure and end-user devices, which builds adaptive control directly into the respective elements. This enables a shift of focus from technology toward the provisioning of next generation converged services. Most of the traditional client/server solutions are neither very effective nor entirely appropriate, due to a lack of capabilities required to handle the increasing dynamicity and diversity of heterogeneous access technologies. In this perspective, emerging solutions need to become increasingly "autonomic", meaning that their components should be able to self-configure, thereby dynamically optimizing their own operations according to the way their environment and usage model changes [1].

LS/ASAM, the Living Systems Adaptive Service Access Management Suite, is a comprehensive and innovative solution that enables effective delivery of next-generation ubiquitous services by dynamically combining end user requirements and service provisioning policies with network-facing management and control functionality. By automating selected low-level processes on both the users and operators sides and bringing more "personal intelligence" - users context and behavior awareness - and "network intelligence" - network services, content and resources awareness - throughout the whole service delivery chain, the LS/ASAM solution realizes *Adaptive Service Access Management*, ASAM. The central idea behind the ASAM vision is to use autonomic techniques that enable operators to efficiently manage and optimize resource utilization, performance and end user experience. This is achieved by transparently tuning service parameters while taking into account changes in both the client and network context.

This paper continues by first discussing in more details the ASAM core principles and then presenting the LS/ASAM Suite in terms of its conceptual foundation, including its architectural design and main features, as a means to realise the ASAM vision. Then, by selecting two of the most significant deployment scenarios, the main benefits of the LS/ASAM Suite are presented including a discussion of the distinctive characteristics. This before concluding the paper with some final remarks regarding ongoing and future work.

2 Managing Ubiquity

Due to the increasing deployment of multiple access technologies at the edges of networks, the management of ubiquitous communications and services is changing rapidly. Intelligence and specific management and control functions need to be migrated toward the edge of the network and even onto the customers' devices. In particular, *service access management*, i.e., the set of functions including the selection and maintenance of one of several available communication channels, is increasingly demanding:

– Fast and appropriate adjustment of the relevant connectivity parameters to a continuously changing network environment.
– The assurance of sufficient service quality and reliability, whose perception can vary from one user to another.
– In coordination with the aforementioned points, the optimisation of resource usage and reduction of operational costs.

Adaptive Service Access Management, ASAM, addresses these issues by providing the means to dynamically adapt the configuration and usage of available network access resources in a reliable and cost-efficient way. This is achieved by embedding specialized "intelligence" into complex multi-technology and multi-service access networks, including end user devices. The central concept is to deploy smart techniques allowing operators to efficiently manage and optimize resource utilization, performance and end user experience. This by transparently tuning service parameters (e.g., bandwidth, average delay), while taking into account changes in the context, including user preferences, Service Level Agreements, SLAs, user location, devices features, and network resources.

ASAM bases its adaptivity on the capability to autonomously observe, extract, understand and use context information to consequently modify its functionality. Information exchange and correlation between client devices and access nodes, as well as between access nodes even of different technologies, is at the core of this approach. In particular, through dynamic mediation between (often conflicting) requirements on the client and network side, capacity for given connections requests is allocated by taking into account the status of the whole service provisioning chain. This requires accounting for a variety of parameters characterizing the connection to be created and consequent required network resources, and existing policies both on the user and provider side.

For this to be realized, flexible and distributed monitoring, configuration and maintenance tools need to be smoothly interfaced and integrated within the evolving networking environment and pre-existing management systems. This is not an easy task, especially when considering that many operators must deal with a diverse mix of systems and processes that make it difficult to effectively monitor and tune service performance once already in the delivery phase. In this perspective, a new kind of management solution is needed. A comprehensive policy-driven and autonomic architecture, spanning basic infrastructures and end-user devices, which builds adaptive control functionality directly into the corresponding elements, enabling the shift of focus from technology to value-added services.

LS/ASAM is a comprehensive ASAM solution that addresses these challenges by making use of software agent technology [2]. Autonomous agents that adapt to changes in the environment, minimizing human intervention and service interruption, lie at the foundation of LS/ASAM and provide a powerful means to engineer a distributed and autonomic system that includes:

– Customizable and adaptive routines for automating and tuning repetitive information and control tasks.

- Coordination mechanisms enabling the spontaneous collaboration and dynamic aggregation of services.
- Abstraction of communication components to support context changes through adaptation of semantic grounding.

Although other approaches have been proposed in the literature that address part of the ASAM challenges, none, to our knowledge, is able to dynamically mediate between network and client requirements and accommodate resource allocation and consumption accordingly. In particular, the solution presented in [3], which is the closest one to LS/ASAM, supporting vertical handover in radio access networks. In this system, a dedicated decision module, placed within a concrete provider system, can communicate with various network devices, including client devices, to determine radio access network selection based on QoS parameters. Some degree of negotiation takes place, but only between entities within the network and excluding the client devices that remain passive.

3 The LS/ASAM Suite Architecture

The LS/ASAM architecture includes two main types of autonomic software components, as depicted in Figure 1, which communicate by relying upon the use of common interaction protocols and a shared semantics-based ontology defining all LS/ASAM concepts. These components are:

- *LS/CA, the Living Systems Connection Agent*, is a client component that can run on a variety of mobile end user devices (e.g., laptops, PDAs, smart phones) and provides mobile users with improved quality and reliability by optimizing service access through adaptive connection handover across multiple access technologies and dynamic mediation of service delivery parameters on behalf of the end user.
- *LS/SAM, the Living Systems Service Access Manager*, is a network component that can run on hardware located at the access nodes or at a network management facility. It dynamically optimizes resource allocation across heterogeneous network access domains with adaptive problem recovery and load balancing techniques.

These lightweight software components, i.e., they can live as processes in a Virtual Machine, can flexibly complement and extend many existing service management architectures, and are able to run on resource-limited devices and support asynchronous communication with intermittent network connections. By dynamically coordinating their actions and behavior, they enable adaptive communication service access by mediating between operator policies and end-users requirements and preferences.

3.1 The Living Systems Connection Agent

The LS/CA component provides adaptive service access by setting connectivity parameters according to the outcome of a mediation process to establish a

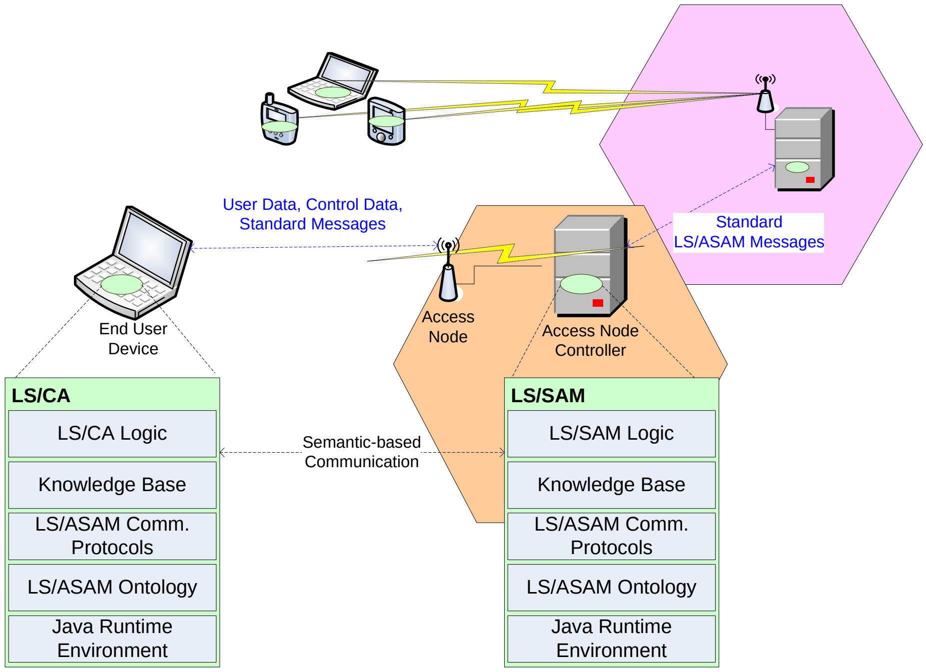

Fig. 1. An overview of the LS/ASAM architecture.

service access agreement based on the end user's requirements and the network provider's offering. This is determined by a set of factors including:

- Quality requirements of the applications and services running on the device the LS/CA is embedded in.
- Physical end user device status, e.g., battery power level, and properties, e.g., available network interfaces.
- Existing service provisioning conditions according to pre-defined subscription contracts/SLAs.

The LS/CA proactively manages and processes this information according to policies which capture end user preferences, e.g., minimising connection costs, maximising battery life when on-the-move, etc., and supports the following main features:

- *Seamless handover* and *session continuity*. This guarantees interruption-free service access across multiple technologies by allowing an LS/CA empowered device to maintain the same IP address for an entire session. This is achieved by making use of Mobile IP technology [4].
- *Secure communication*. Tight integration of the LS/CA with several third party VPN clients allows permanent secure connectivity. Furthermore, by integrating IPSec [5] and Mobile IP, the LS/CA ensures end-to-end encryption of all generated traffic (as an optional feature).

– *Connection adaptation.* This indicates automatic detection of available networks and selection of the preferred network adapter (access technology) based on service requirements and network conditions for improved reliability and QoS. This can trigger dynamic mediation between the LS/CA and the LS/SAM components.
– *Context-aware user support.* Through semantic service specifications, policy-driven decision making and dynamic information retrieval, the LS/CA improves end-user experience by directly addressing low-level issues (e.g., failure recovery, connection adaptation), while taking into account user policies and boundary constraints, i.e., context-based information and coordination with LS/SAM components as needed.

3.2 The Living Systems Service Access Manager

The LS/SAM component proactively monitors traffic and resources in the access node it controls, triggers appropriate actions (e.g., vertical handover, load balancing) according to the network status and current traffic conditions, processes incoming LS/CA calls for proposal and elaborate offers as appropriate - see Section 3.3. In particular, the two main distinctive features enabling LS/SAMs to optimize resource consumption at the access network level are:

– *Load-balancing.* Balancing traffic load across WiFi and cellular networks while considering the QoS needs of running services renders the network more resilient to traffic peaks. This is achieved by dynamic coordination between LS/SAMs that can hand over a certain number of connections to neighboring access nodes according to possibly several operator policies. The use of distributed constraint satisfaction algorithms [6] for LS/SAMs peer-to-peer orchestration enables effective load balancing by taking into account all existing constraints.
– *Congestion recovery.* Real-time and proactive detection, analysis and relief of congestion, reduces call dropping and increases service resilience and availability. Within an access node, once no new network connection can be accepted or the total requested bandwidth exceeds the total available one, i.e., packets are dropped, an LS/SAM can decide upon specific policies and existing SLAs (if any) whether and how to drop or hand over part of the traffic to neighboring access nodes.

LS/SAMs decisions and behavior are guided by the operator's policies that express service provisioning preferences with respect to a variety of aspects including, e.g., how to allocate traffic to balance out network utilization, how to treat specific users (i.e., connections) in case of congestion, how to adapt pricing schemes according to the user's subscription type. This requires dynamic management of information including:

– Traffic conditions and resources available within the access node the LS/SAM is controlling.

– Traffic conditions and resources available in other access nodes that a given portion of traffic can be handed over to, via dynamic LS/SAM-to-LS/SAM coordination.
– Existing service provisioning conditions according to pre-defined subscription contracts/SLAs.

3.3 Adaptive Coordination of the LS/ASAM Components

The mediation process conducted between the LS/CA and LS/SAM components consists of a sequential interchange formulated as a contract-net protocol [7] negotiation with the goal of determining the best connection parameters given the requirements of the end user, the offering of the network provider and the conditions of the transmission medium.

The requirements of the end user toward the provider are a combination of (i) the preferences of the end user formulated as user policies (e.g., minimising connection cost), (ii) the quality demands of the applications running on the end user device (e.g., a given application may require low end-to-end delay), (iii) the status of end user device resources (e.g., battery power, which can affect the selection of the transmission technology), (iv) the technologies supported by the end user device (e.g., only WLAN and UMTS network interfaces available), and (v) the conditions stated in the subscription contract (e.g., costs for using certain technologies).

The offering of the provider toward the end user is determined by considering (i) the properties of the provider network (e.g., diversity of network access technologies), (ii) the network status (e.g., distribution of traffic load, delay times), (iii) the capabilities of the network (e.g., mobility support, QoS control) and (iv) the provider policies, including business rules, that relate to the use of its infrastructure, pricing schemes, traffic prioritization mechanisms, etc.

Figure 2 illustrates the typical message exchange during a proposal setup sequence. The LS/CA sends a Call For Proposal (CFP) to one or several LS/SAMs requesting offers to set up a connection with specified constraints including quality requirements, or connection characteristics. The proposal offered by the involved LS/SAM is then determined as a function of the supplied client constraints on what a proposal may contain, provider policies and network state, which may relate to the instantaneous state and/or historical state data, and/or predictions about future state, optionally including reservations of network services.

The originating LS/CA waits a predefined duration to receive incoming proposals and/or rejections. Once the deadline is reached, the LS/CA begins to assess received proposals by considering (i) the set of quality requirements stated in the original CFP, (ii) the received proposal (or the relevant parameters stated in the proposal), (iii) the user policies, and (iv) the status of the end user device. The output of the assessment function is a value indicating the viability of the proposal. If no proposals are acceptable, the CFP can be revised and resent to the same or different LS/SAMs. This forms the basis of the mediation

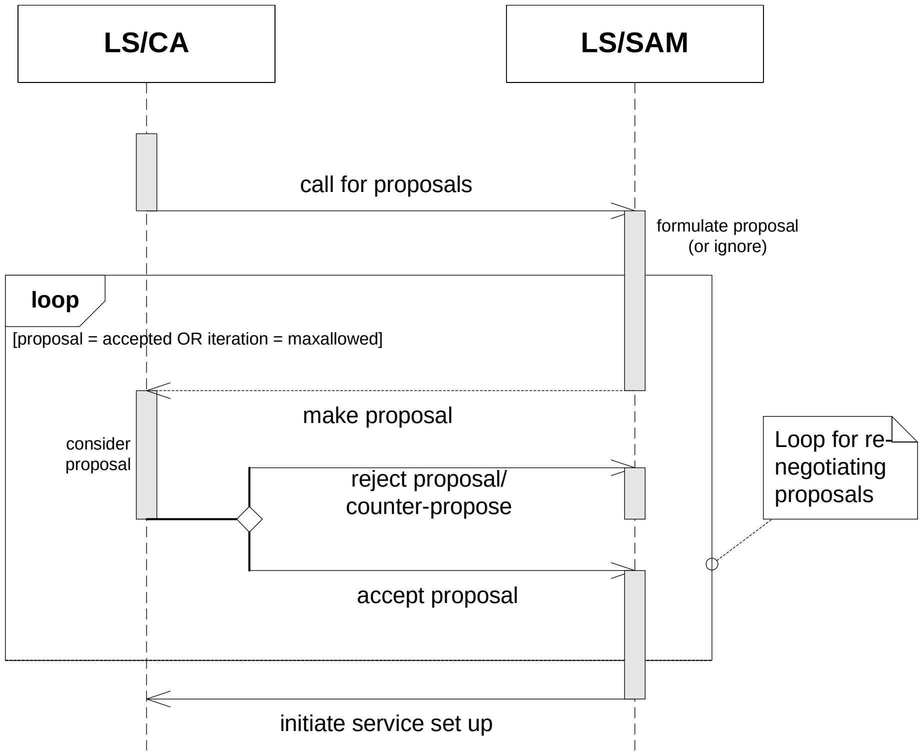

Fig. 2. Mediation process between the client and network LS/ASAM components.

process which may take place over several iterations. A basic protection algorithm is used to ensure that negotiation is convergent, thereby avoiding lengthy or endless iterations.

When, or if, a proposal is accepted the client device sends an accept-proposal message to the corresponding network provider. All other proposals that have been received are explicitly rejected by informing their source providers. The reason for rejection may be included in the message.

4 The LS/ASAM Suite in Action

Ubiquitous data connectivity and communications management are optimised transparently across multiple network access technologies by dynamic coordination of the LS/ASAM components according to the specific situations. In particular, different combinations of their features enable a variety of deployment scenarios. In the following, two of the most significant ones are presented including a discussion of the distinctive characteristics in relation to relevant work.

4.1 QoS Enforcement in Heterogeneous Access Networks

The notion of guaranteed data transmission quality with enforcement mechanisms, in particular for emerging QoS sensitive multimedia applications, e.g., voice or video over IP, is a key issue especially in converged networks [8]. While traffic prioritization is often not of paramount importance in core networks due to overprovisioning, QoS is an essential differentiator in limited-capacity wireless access networks for capacity and/or delay sensitive traffic such as voice or video over IP. While for cellular access technologies belonging to 2.5G, 3G and 3.5G, appropriate standards for QoS have been defined, few operators yet make widespread use of them. In addition, the WiFi world is supporting its technologies with specifications that directly account for QoS management.

In particular, when integrating different access network technologies, e.g., WiFi and UMTS, the quality of a connection may be degraded during vertical handover where (i) the connection needs to be re-established at the new access node, which is time consuming and during which no data can be transmitted, and (ii) if too many IP packets are lost, they must be retransmitted which can also be time consuming in the case of a large number of packets - again leading to service interruption.

Various approaches have been developed and proposed to address this problem. In [9], a reservation-based QoS model for integrated cellular and WiFi networks is defined and an adaptive mechanism to ensure end-to-end QoS is proposed. However, this model can only work by making the assumption that cellular/WiFi interworking is realized by relying upon a common and uniform reservation-based QoS architecture, which is not (yet) the case for most real network scenarios. Similarly, Song et al. [10] proposed an admission control mechanism for integrated voice and data services in cellular/WiFi networks. The main limitation of this approach though is that it does not account for video traffic.

To effectively provision QoS and optimize resource utilization for a variety of possible heterogeneous network scenarios, the LS/ASAM Suite relies upon the dynamic combination of specific mechanisms both at the client side (i.e., seamless handover, session continuity and connection adaptation) and at the network side (i.e., congestion recovery and load-balancing) that are compliant with dominant industrial standards, e.g., mobile IP or SIP/IMS, when supported, or technology-independent, whenever possible.

Unlike legacy systems and hardware-based solutions, the LS/ASAM components accommodate high-level service and user needs and preferences (including QoS requirements) by implementing coordination mechanisms and resource allocation algorithms that hide low-level access technology dependent processes. This is achieved by deploying an agent-based middleware architecture that provides users with a common and higher level of abstraction, which makes low-level network access heterogeneity transparent.

On the client side, basic QoS in terms of service availability and continuity is enforced by the LS/CA through automatic and policy-driven vertical handover, i.e., all traffic is switched from one network interface, according to existing constraints and user policies. Moreover, by continuously monitoring network conditions and device status and properties, the LS/CA exerts QoS and context-aware resource management by selecting the most appropriate access technology to be used for the running applications/processes. In addition, when appropriate, as detailed in Section 3.3, the LS/CA can also trigger negotiation with one or more LS/SAMs for different connectivity conditions.

On the network side, the key mechanisms deployed by the LS/SAM to enforce QoS provisioning are load-balancing and congestion recovery. Load-balancing can be triggered by LS/SAMs in order to redistribute traffic across several access nodes according to various criteria, including:

- Current utilization of resources at the access node, e.g., once the traffic overcomes a given threshold a certain portion of the supported connections might be handed over to neighbor LS/SAMs.
- QoS requirements of the running services, e.g., best-effort connections might be handed over to prioritize premium services for which charging might be based on service reliability guarantees (e.g., $\geq$95% non-disruption).
- Predictions of the network resources usage to minimize the probability of congesting an access node.

Analogously, whenever congestion occurs a specific part of the traffic at a given access node might be handed over to other LS/SAMs or selected existing connections (e.g., the non-premium ones) might even be dropped as appropriate. This enables relief of congestion and increases service resiliency and availability.

For example, assume a user that launches an IP-based TV program (e.g., a news channel) on a smart phone. During the launch of the selected application to render the video stream, the LS/CA determines the connectivity parameters (typically bandwidth and delay) for interruption-free high quality service provision. Because different access technologies offer different QoS assurances, the LS/CA might try to switch to a specific technology, e.g., UMTS, that better supports the QoS level needed for the video down-streaming. In addition, in the case of an UMTS connection, the LS/CA would set up a new Packet Data Protocol context requesting the UMTS QoS streaming class [11].

Figure 3 depicts the deployment model for this case. Each end user device is installed with an LS/CA component able to enforce QoS. The LS/CA must be aware of the different traffic categories available in each network access technology. During a vertical handover, the QoS class of the active network is mapped into an appropriate QoS class of the target network. There is one LS/SAM agent being deployed per access node, i.e., each LS/SAM agent is in charge of a specific access node and thus is up-to-date at all times regarding the status of that node. When planning load balancing and congestion recovery, the LS/SAM agent must be aware of the QoS classes supported by the different access technologies to minimize the risk of degraded service quality. This involves LS/SAM-to-LS/SAM coordination first to exchange information on current traffic load (or resource availability) and then to possibly take or hand over part of the communications/traffic[1].

[1] Peer LS/SAMs coordination is not described in this paper because of some pending patenting issues.

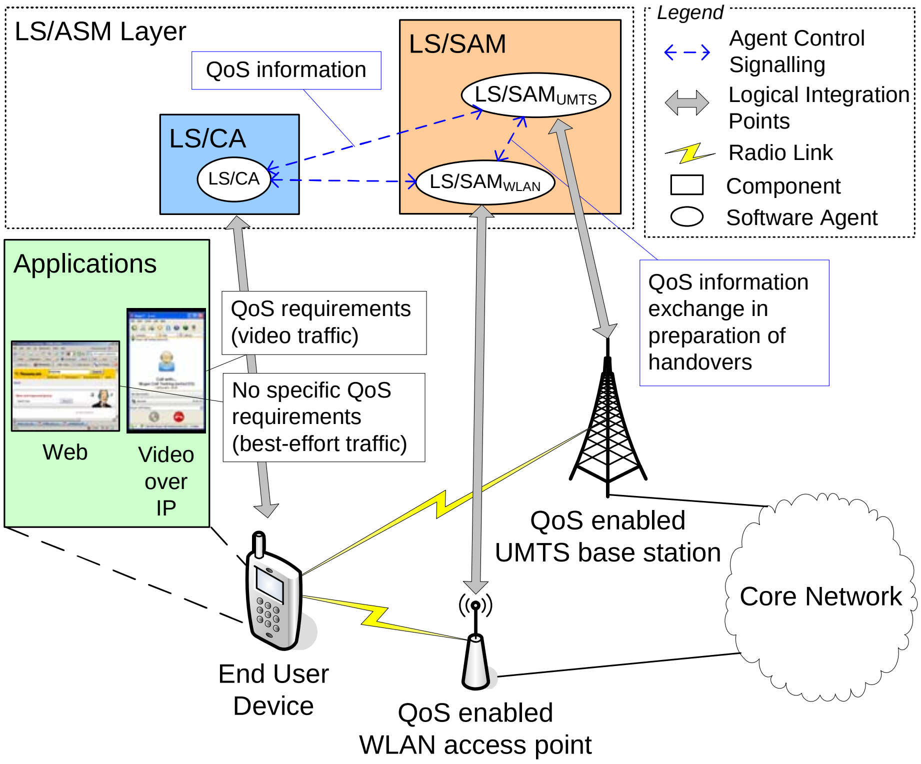

Fig. 3. Deployment model of the LS/ASAM Suite for QoS enforcement.

4.2 Integration with an IMS/SIP Framework

IP Multimedia Subsystem, IMS, initially developed by 3GPP and 3GPP2 as an IP core network architecture for cellular/wireless-based access to Internet services, is now evolving into a standard that provides a common framework to create and offer next generation converged network services [12]. IMS builds on the Session Initiation Protocol, SIP, that is mainly in responsible for delivering a session description to a user at its current location [13]. The key idea is to enable any kind of access (wireless or fixed) for any kind of media (including any combination of voice, text, image and/or video) supporting multiple devices and endpoints.

Because of the (at least initial) co-existence of IMS and non-IMS applications, the costs associated with moving to a full IMS-based network, and the inherent complexity of IMS (and its several standards, interfaces and protocols) most service providers and or operators are expected to migrate toward an IMS service framework iteratively.

One of the core issues to be addressed for successful adoption of IMS is the ability to face more aggressive bandwidth and latency demands, which implies increased QoS management and design capabilities on the bearer network [14]. In particular, IMS/SIP lacks traffic management capabilities and especially adaptive connectivity management and optimization mechanisms that can be regarded as key components for delivering ubiquitous quality-sensitive multimedia services.

In this perspective, the LS/ASAM Suite complements an IMS-based framework by ensuring the quality of delivered services at the bearer network level through its adaptivity mechanisms, leaving IMS/SIP to cope with call control and service deployment issues. As depicted in Figure 4 the LS/CA component directly interacts with the SIP client installed on the end user device. In this way, the SIP client is able to obtain information on the quality of the connection which is helpful to determine, for instance, the appropriate codec to use, and to request the LS/CA component to ensure a certain quality level (in particular, when explicit QoS class enforcement is enabled). On the network side, an LS/SAM agent integrates with each access node and, by means of load balancing and congestion recovery enables to provide a high level of service quality.

A simple use case is when one considers the collaboration between a SIP client and the LS/CA component to guarantee a level of quality required by a user to perform a video call. Upon launch of the SIP-based video calling application, the SIP client assesses the connection quality by means of the LS/CA component. The SIP client is aware of the quality requirements imposed by the video call service that are also variable according to the size and quality of the video picture. The LS/CA component can, in collaboration with the respective LS/SAMs, discover the quality offering at alternative access nodes and, based on that decide whether a handover to another access node needs to be triggered. Both end devices that participate in the video call must also agree on the codecs to be used for encoding and decoding the voice and video data. The LS/CA component delivers the necessary information to the SIP client to make its choice. Once the video call is established and running, it is the LS/CA agent's responsibility, in cooperation with the active LS/SAM agent, to preserve the quality of the connection and take appropriate measures if tolerance thresholds are violated. Depending on the mobility profile of the user, but also on the evolution of the network conditions, handoffs are unavoidable and thus need to be well planned and efficiently executed to minimize quality breaches.

The LS/CA does not affect the SIP call itself nor infringe any of the IMS/SIP standards. SIP is concerned with controlling the call execution while LS/ASAM takes care of connectivity. LS/ASAM is therefore complementary to IMS/SIP and benefits result even if only a small proportion of the entire network infrastructure (namely the access part) and end user devices are LS/ASAM empowered.

5 Discussion

The LS/ASAM Suite is a distributed and resilient system that exhibits high adaptivity to its network environment. This has been achieved by properly com-

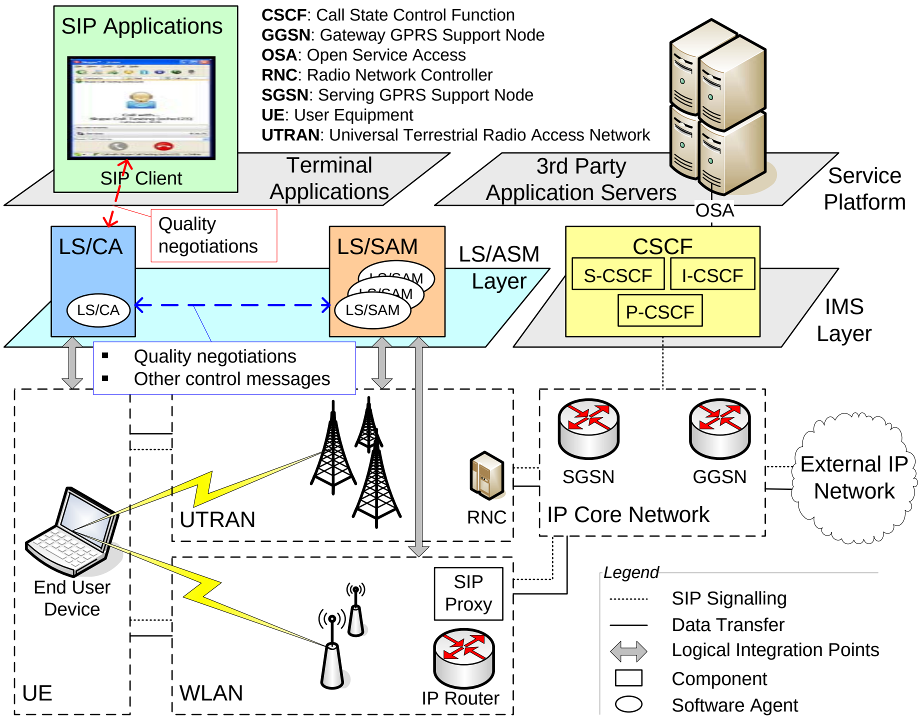

Fig. 4. Deployment model of the LS/ASAM Suite when integrating with an IMS/SIP-based architecture.

bining multi-agent systems concepts and technology with powerful resource allocation algorithms and reasoning strategies.

The central idea is that loosely-coupled distributed management functions and control methods can be well-modeled and implemented by making use of automated, goal-driven and proactive software entities. These lightweight components are able to operate on resource-scarce devices and support asynchronous communication with intermittent network connections. Moreover, according to the results of proactive monitoring information received from the environment within which they are embedded, the LS/ASAM components directly assist with autonomic management of network resources. They are able to configure themselves and dynamically optimize their operations according to the way their environment changes and in-line with operator and client user policies. They thus assist with the speed-up and automation of simple, tedious and repetitive service management tasks currently performed most commonly by human operators. The ultimate result of this is potentially substantial cost savings to the operator. In particular, by hiding low-level networking aspects that, especially in converged network scenarios, can continuously change due to end users mobility, the LS/ASAM middleware provides transparent service access in heterogeneous networks and becomes an essential complement to (bearer unaware) service delivery platforms.

However, to achieve the potential of autonomic management systems in todays' networks is not a straightforward task. Migrating intelligence and complex management functions toward the edge of the network reduces the degree of manual intervention needed, but increases somehow the complexity of the management system itself. The network has indeed to be adaptable, but at the same time stable and controllable. Therefore, populating the networking environment with autonomic software components requires more configuration and monitoring capabilities.

In this sense, middleware technologies for highly dynamic and heterogeneous networks are required to become able to monitor and control the middleware itself, by integrating with traditional quite static infrastructures often populated by legacy solutions and adapting to different operating systems and connection technologies. This is a challenging task that still requires additional investigation.

6 Conclusion and Future Directions

The system described in this paper has been implemented as a fully-functional prototype with accompanying system simulator for testing in isolation of real installation.

The deployment of a comprehensive ASAM solution like the LS/ASAM Suite is expected to bring important benefits both to the operators and to the end users. This includes:

- More effective resources utilization leading to enhancement of provisioned services, increased traffic capture and cost reduction.
- Improved customer satisfaction, through transparent problem recovery and proactive service level monitoring and adaptation.
- Tailored provisioning of services using user context, which also aids in the design of new services.
- Flexible introduction of specific policies to exert control over, for instance, differentiation of price plans.
- Simple rollout over existing infrastructure to protect and extend the lifetime of capital investments.
- Reduced complexity: simplify management of the entire path from the service platform to end user devices.

While most of these benefits have been largely confirmed by our LS/CA customers, our ongoing and future work includes more refined and extensive characterization of the LS/ASAM performance, especially on the network side, when adopting different user and operators policies, network allocation strategies and algorithms. As a matter of fact, while the LS/CA has been already successfully deployed in a variety of real-world scenarios, the adoption of the LS/SAM requires some additional work given the wide assortment of existing and upcoming service and network management architectures.

In particular, by simulating and analyzing the LS/ASAM Suite performance in a variety of networking scenarios and consequently refining the behavior of the various system components, we expect to better characterize and consequently improve performance and scalability. In addition, by means of selected testbed demonstrations and experiments we are assessing the feasibility and complexity of integrating LS/ASAM entities in specific service delivery frameworks.

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