QoS Path Selection Mechanism in a Hybrid Access Wireless Scenario: A Distributed Approach using Mobile Agents

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***Abstract*— The differentiated requirements of applications over this multitude of access networks need a mechanism for resource negotiation and management. The aim of the paper is to present an inter-domain end-to-end mechanism used for best path selection in a hybrid access WLAN-UMTS scenario, based on one-way delay estimation as the network parameter requested by the application and managed by mobile agents. Further, based on the obtained results, the paper proposed an extended mechanism using profiles, a set of aggregate parameters like bandwidth, delay, jitter, etc. The mechanism is called I-NAME (In-Network Autonomic Management Mechanism)and it is used for network resource reservation and management functions.

***Index Terms*— one-way delay, inter-domain path, mobile agents**

I. Introduction

Delivering multimedia traffic with quality of services guarantees over a heterogeneous multi-access domain is one of the major challenges of research in the area.

There are many discussions whether QoS resource reservation mechanisms are needed or not. One opinion is that the transmission medium will provide abundant bandwidth, thereby delivering also a kind of cheap QoS support automatically.

The other opinion is that no matter how much bandwidth the network can provide, new applications will be designed to consume them; therefore, mechanisms will still be needed to provide QoS support [1].

There are a number of factors and components that affect the performance of multimedia applications, and which are relevant in a resource management mechanism. By grouping all these influence factors, we consider the QoS problem has two major issues: network perspective with objective analysis, and application/user point of view, with a subjective perception.

From the network perspective, resource reservation refers to the service quality or level that the network offers to the application/user in terms of network's QoS parameters, including: delay, jitter, number of packets lost and throughput.

From the application/user perspective, resource reservation refers to the application's quality as perceived by the user, that is, the quality of the video presentation, the sound quality of a streaming audio, etc. The applications and users are grouped in the same category because of their common way of perceiving quality.

We developed two resource reservation approaches which assume the integration of two basic elements in the area of quality of services: vertical and horizontal.

The vertical QoS approach includes the intra-domain QoS resource reservation mechanisms that are already included in the last wireless standard architectures (i.e. IEEE 802.16, DVB-S, UMTS, IEEE 802.11 etc.). An intra-domain resource reservation process is simple if the resources are managed by a single entity or by a set of entities supporting a common negotiation protocol. The vertical approach suggests the separation of specific QoS parameters related to each networks' layers.

The horizontal concept is assuming the presence of an inter-domain QoS resource reservation mechanism in heterogeneous multi-access network architecture. This mechanism extends the intra-domain resource reservation mechanisms implemented in the wireless/wireline systems by interconnecting them. The second section of the paper presents an overview of current work within standardization groups, and briefly major achievements obtained by EU and NSF research projects. The third and the fourth paragraphs refer to the assumptions and the requirements needed by an inter-domain resource reservation mechanism.

Next we present the end-to-end path selection in an inter-domain WLAN-UMTS scenario based on one-way delay estimation using mobile agents.

The last paragraph concludes the paper.

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II. QOS MECHANISM DESIGN: OVERVIEW

There is little consensus on the precise definition of QoS. Researcher groups perceive and interpret QoS term in different ways [1] [2]. In order to group this point of views and to illustrate *ITU*, *ETSI*, and *IETF* perspectives, I will use the general QoS model presented in [3].

There are associated three notions of QoS approach, defined in the general model (1) intrinsic QoS, (2) perceived QoS, and (3) assessed QoS. Intrinsic QoS is determined by the transport network type and provisioning of network access. Perceived QoS reflects user's experience of using a particular service and user's expectations compared to observed service performance. The assessed QoS starts to be seen when the customer decides whether to continue using the service or not.

The *ITU* and *ETSI* perspectives to QoS related terminology are almost the same. Both organizations adopted the same definition of QoS concept, described first in [4] as *the collective effect of service performance which determine the degree of satisfaction of a user of the service*. QoS in the ITU/ETSI vision adheres mainly to perceived QoS rather than intrinsic QoS. IETF focuses on intrinsic QoS and does not deal with perceived QoS. QoS is understood by *IETF* as *a set of service requirements to be met by the network while transporting a flow* [5].

QoS is defined [6] [7] from two major points of view (1) *QoS from the point of view of the network*, and (2) *QoS from the point of view of the application/user*. From the network's perspective, the term QoS refers to the network's capabilities to provide the QoS perceived by the end user. From the end user's perspective, the term QoS is the end user perception of the quality of service offered in the network.

Concluding the different opinions presented, we *define* QoS concept as that parameters set that characterize the network capabilities [8] (intrinsic QoS/QoS from the point of view of the network) in order to satisfy the user requirements [9] (perceived QoS/QoS from the point of view of the application/user). That definition constitutes the basis of the project proposal.

A few steps have already been taken towards the accomplishment of the proposed inter-domain QoS mechanism. These steps are: (1) analysis of certain intra-domain QoS mechanisms, (2) testing of certain hybrid wireless IP architectures' co-existence, (3) testing of mobile agents' capabilities for the resource's management in wireless systems and (4) designing the basic schematic of the proposed inter-domain QoS mechanism.

The present knowledge stage in the area illustrates the concepts and QoS mechanisms development, starting with providing an intra-domain QoS support, and continuing with the need for the inter-domain QoS support provisioning. To the latest trends were added the possibility of using the mobile agents for inter-domain QoS support, which is the same idea suggested by this project. A set of three papers that mention the use inter-domain QoS mechanisms using mobile agents were selected to compare the current project [18-20].

A first inter-domain IP architecture, having similar characteristics with the one promoted by this project, is presented in [18]. The paper demonstrates the efficiency of a resource reservation scheme using mobile agents by increased allocated bandwidth, decreased dropping rate, and decreased blocking probability as compared to non agent-based resource management scheme. The hybrid wireless architecture integrates only wireless local area networks and 3G cellular systems. The project proposed a scalable QoS mechanism which integrates also satellite networks and wireless metropolitan area networks.

The usage of mobile agents for resource provisioning in telecommunications networks is suggested also in [19]. The article focuses on the possibility of the usage mobile agents for resource management. Mobile agents, in described system, are responsible both for splitting and for merging informational streams that are created between the source and the destination. This QoS mechanism is an in-traffic one, being closer to the intra-system QoS approach, but the suggested QoS mechanism is out off-traffic.

The paper [20] proposes a QoS mechanism in order to manage and allocate resources at a middleware layer, transparent to the system users. In context of a hybrid terrestrial-satellite system, the paper promotes a resource control mechanism based on a client/server paradigm. It suggests a multi-agent system composed by three basic typologies of agents. Each agent topology has allocated a specific task, dedicated for application control, user location, and system resources management. The paper suggests that a mobile agent platform is the solution for end-to-end QoS requirements of the future 4G heterogeneous scenarios.

The tested hybrid access wireless IP architecture intends to integrate the wireless spatial and terrestrial wide area networks, and the wireless metropolitan and local area networks. The inter-domain QoS mechanism requires (1) resources negotiation, (2) resources allocation, and (3) resources management in order to (1) creating, (2) maintaining, and (3) terminating end-to-end QoS sessions established between different wireless system categories. Provisioning the QoS support is a complex task, the available resources being (1) diversified, (2) distributed, (4) managed by different entities, and (4) negotiated by different protocols. All these requirements demand the knowledge of the network's context, the task allocated to the mobile agents.

The mobile agents can be defined as autonomous entities that act on behalf of their owners in order to accomplish the allocated tasks. The agents are placed in an environment where they can interact, and they acts based on the information provided. A set of characteristics recommends agents for resource reservation: (1) ability to communicate with other agents, (2) independent functioning, (3) reaction to the environment in which they are used, and (4) personalization.

Inside the suggested inter-domain QoS mechanism, mobile agents will act on behalf of the user in order to provide QoS support. The function of the mobile agents is to select certain class of services according to the negotiated inter-domain QoS parameters set.

It is obvious that a traditional approach of the QoS problems is not an appropriate solution. The idea of an exclusive centralized system that has control over users and resources, doesn't fit the actual need of a user located inside the heterogeneous wireless system. In conclusion, I can state that utilizing the mobile agents is the optimum solution for controlling and managing the inter-domain adaptive QoS for a hybrid access wireless IP medium.

A. Intra-Domain Reservation Mechanisms

There has been a significant amount of work in the past decade to extend the IP architectures and to provide resource management/QoS support for multimedia applications. IP networks are evolving from a best-effort service support model, where all transmissions are considered equal and no delivery guarantees are made, to one that can provide predictable support, according to specific QoS requirements. Furthermore, recent applications are associated with user interactions, and the ability to browse different scenarios at the same time. All these aspects made the researchers look for other solutions in order to assure a resource reservation management support.

A first approach on QoS provisioning support placed the mechanisms on the end-system, including source rate control, transfer rate adaptation, packet error control, and retransmission [2] [3]. Many of these mechanisms, from a QoS intrinsic perspective, can be categorized as adaptive applications [4].

Another approach on QoS provisioning is to provide a network mechanism for monitoring the parameters. In this case, the network node plays an active role in controlling end-to-end service quality. This requires additional traffic control mechanisms, such as admission control, traffic policing, classification and traffic scheduling. Also, IETF has proposed several service models and mechanisms to meet the demand for resource management: IntServ (Integrated Services), DiffServ (Differentiated Services), Proportional Services etc.

While the IntServ model can provide quantitative QoS guarantees to individual flows, the DiffServ model can provide qualitative guarantees to multiple aggregate flows. Eventually these two mechanisms could be combined for overcoming their limitations and to increase the scalability. Thus DiffServ model could be applied within core network, whilst the IntServ seems to be more suitable for access networks [5].

B. Inter-Domain Reservation Mechanisms

Based on the existing IntServ, DiffServ and their combinations, the implemented vertical QoS reservation mechanisms applied to a single-domain could be extended for inter-domain management. This task is more challenging due to heterogeneous aspects of both access and core networks. Proposed solutions are inter-domain end-to-end QoS signaling and resource management policies based on client/server architectures. These are covered by working groups of various standardization bodies and research projects. The NSF and EU have funded several research activities in the area of QoS support for multi-domain IP networks: LNS, AQUILA, CADENUS, TEQUILA and ENTHRONE [6]. They all strive to develop solutions for next-generation hybrid networks, by addressing service management, service definitions, network resource management, traffic engineering, network monitoring and inter-domain QoS support. Both centralized and distributed approaches are taken.

Current technologies are not appropriate for inter-domain cooperation and collaboration. This need was addressed by LSN (Large Scale Networks) project, focused on optical networking test-beds to develop the generalized multi-protocol label switching (GMPLS) protocol, inter-domain resource reservation and management, optical networking protocols and switches.

CADENUS project introduced traffic policies at different levels, starting from the translation of the service level agreement down to several commands for setting the network devices. The information was stored in databases, which were accessible from the entity that handled the resources.

In TEQUILA, the use of high-level policies was the key element in driving the traffic engineering algorithms. In particular, these policies are used for network dimensioning, traffic planning and dynamic control of resources (DiffServ over MPLS).

AQUILA did not use policies, but performed global management of the resources by using the resource control agents, which monitored, controlled and distributed the resources in the network [7].

To provide end-to-end QoS services in a scalable manner, ENTHRONE made resource provisioning in advance to fulfilling the individual customer services requests, by establish at aggregate level QoS enabled pipes [8] [9].

Delivering multimedia traffic with QoS guarantees over multi-domain is one of the major challenges of research in wireless IP hybrid networks. The trend towards automatic network management has lead to the definition of policies providing better control of system domains [10].

These domains can be composed of more than one access network, each with its capabilities, devices, and users [11]. Thus, policies are defined to control service provisioning and automate network resource configuration.

Resource management policies based on client/server architectures but using mobile agents have been identified in some research group activities:

A first inter-domain management mechanism discussed was [12]. This paper demonstrated the efficiency of a resource reservation scheme using mobile agents by increasing allocated bandwidth, decreasing dropping rate and blocking probability compared to non agent-based schemes. It proposed a scalable QoS mechanism which integrated wireless wide and metropolitan area networks.

The use of mobile agents for resource provisioning in telecommunications networks is suggested also in [13]. The article was focused on possibility of using mobile agents for resource management. Mobile agents were responsible both for splitting and for merging informational streams that were created between the source and the destination.

The paper [14] proposed a QoS mechanism in order to manage and allocate resources at a middleware layer, transparent to the system users. In context of a hybrid terrestrial-satellite system, the paper promoted a resource control mechanism based on a client/server paradigm. It suggested a multi-agent system composed by three basic types of agents. Each agent topology had allocated a specific task, dedicated for application control, user location and system resources management. The paper suggested that a mobile agent platform could be the solution for end-to-end QoS requirements of the future 4G heterogeneous scenarios.

III. Design Principles for a Proposed Inter-Domain Resource Reservation Management

Today's telecommunications world is increasingly characterized by a multiplicity of access technologies, fixed and mobile, as well as different flavors of both of them. These technologies have generally evolved from legacy independent architectures to heterogeneous access, with little real attempt to achieve inter-working.

Users expect to be able to connect to a broadband network, irrespective of time, terminal, location, and operator in order to access resources both in client-to-client sessions as well as centralized broadcast service delivery, and they also prefer to experience different access networks as one transparent single network.

Users have potential access to mobile networks, satellite networks, DSL fixed networks, digital terrestrial broadcast networks and more. Also, many mobile users' terminals today implement 3G, WiFi, WiMAX and Bluetooth interfaces, and the strategies for connecting to the IP networks behind these access networks generally result only in very simple selection of one of the available networks, often requiring user interaction and configuration tasks.

It is obvious that a traditional management is not appropriate, because the idea of an exclusive centralized system that has control over users and resources does not fit the actual need of a user located inside the heterogeneous wireless/wireline system any more, especially when some inter-access system tasks are required. These are almost undefined today. For example, 3GPP TS23.234 defines Integrated WLAN (I-WLAN)

Current trends could involve: globalness, in-network implementation, activeness, cost effectiveness, scalability.

a) Globalness. With the expected increase in number and scale of future networks, the mechanism intends to manage the inter-domain resources of an operator that integrates multiple users (wireless/wireline terrestrial and spatial wide area networks, wireless/wireline metropolitan, local, and personal area).

b) In-Network implementation. User terminals will implement multiple access technologies, but the subscriber still has to select one network. Today's management access mechanisms are generally limited to selecting a single path, considering alternative or even parallel paths to be used in case of transmission failures. Starting an application requires users to manually select, probably switch between different access networks and maybe also manually specify which applications may use which networks at which time. This consideration leads to the idea of network-based mechanisms [15], functions that are integrated into the to-be-managed networks and use all necessary and available means of the traditional control and network management planes.

c) Activeness. In mobile scenarios, conditions of the access networks change rapidly (inter-symbol interference, channel throughput, available radio resources, signal-to-noise ratio, etc.), making manual control useless. Moreover, the network can offer a significant increase in capacity and the user could reach higher throughput, more reliable connectivity or lower costs, if such control could be provided. Even if a subscriber has access to manual configuration and network selection, there is currently no advertised on alternative, heterogeneous network resources. This consideration requests for an active adaptable in-network control mechanism which reacts to changes.

d) Cost effectiveness. The mechanism must adapt to user's application requests and to network's changes by some means of quality control. Additionally, users still need a way to control network usage due to cost considerations. This reasoning illustrates a need for per-user/application costs evaluation where user's supported costs are taken into account. Cost effectiveness is also important for the future operator of the heterogeneous access network environment, i.e. how to improve today's situation with multiple independent and expensive "silo" solutions. Secondly, the operator wants to extend and optimize the coverage, which may lead to lower spectrum costs.

e) Scalability. The architectural active access environment enables users/applications to have simultaneous possibilities of connecting to several access networks at the same time, limited only by some near field radio issues. From the operator's point of view it is important that the business can grow without major network restructuring and cost. This means that the replacement of access system elements and network elements can be done as business grows without generating a major impact on the management mechanism.

IV. Inter-domain Best Path Selection Based on One-Way Delay Estimation using Mobile Agents

In order to realize a distributed inter-domain resource management, this paper proposes a network state-aware system by using mobile agents. The status of each network node is defined by a set of parameters, such as one-way delay, throughput, jitter etc.

The role of the mobile agents is to determine and to guarantee an end-to-end path selection according to a negotiated set of constrains.

However within this paper we are focused on the selection of the best path between the source and the destination in a

WLAN-UMTS scenario, based on one-way delay estimation only.

The goal is to have access to services that should be flexible, dynamic, personalized (from the user/application point of view) and optimized (from the network/operator perspective).

Mobile agents can be defined as autonomous entities that act on behalf of their owners in order to accomplish allocated tasks or even more abstract goals. A set of characteristics recommends agents for resource reservation: ability to communicate with other agents, functional independence, reactiveness to the environment in which they are used, and personalization.

When the term "mobile agent" is used, it refers to a process that can transport its state from one host to another. Mobile agents decide when and where to move next, saving theirs own state and resuming the execution on the new host from the saved state. The traditional use for mobile agents is to retrieve information for the user or for the network.

For this purpose we can use two approaches: the client-server model and the mobile agent model. In the first case, a client needing information from several servers, connects to each of them, makes a request and expects an answer. This approach works just fine, but generates a lot of traffic.

In the mobile agent model, the client sends a self-contained piece of software (the mobile agent) to do the work for it.

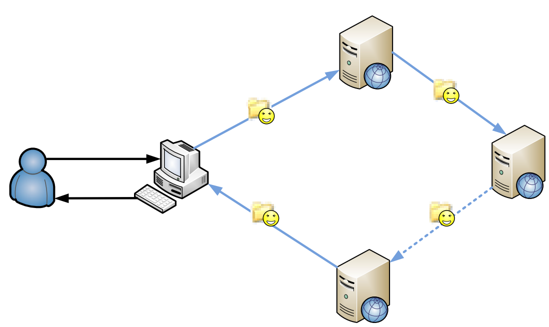

Fig. 1. The mobile agent concept model

This concept is illustrated simplified in Figure 1. The agent travels in the network, collects data and returns to the client. If in the first case the traffic generated from the client was "n" requests (where "n" is the number of servers), in this case the client generates only one request.

Another advantage of the second model is that the mobile agent has enough intelligence to return only the relevant information to the user, sparing him the time needed to search through the results.

In case of network resource reservation, the role of the mobile agents is to negotiate, collect, transfer and modify a parameter set based on users interaction according to network's availabilities and user's needs (see Fig. 2).

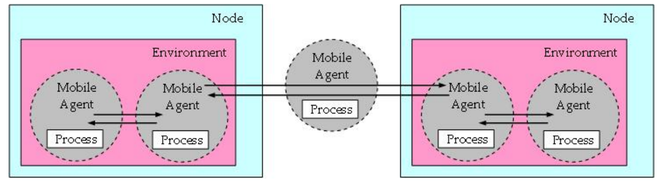

Fig. 2. Mobile agent message exchange

The parameter set could include requests for throughput, delay, jitter, packet loss, costs. Consequently, the methods for determining these parameters from different types of applications/networks have to be specified/available, as well as the conditions on which the mobile agents will act. Such a parameter set is required for making decisions regarding the parameter's distribution across the network.

The operator/network uses mobile agents to permanently test available links. In this way the network is aware of its QoS capabilities (delay, jitter, throughput) being able to accept/reserve resources asked by different users/applications. In the other approach the user/application proactively sends a mobile agent to test the network.

The agent travels across the network from source to destination and back, selecting the route based on an aggregate parameter set constraints.

If none of the possible paths meet the application parameter's constrains, the agent can set the application to run with lower resources (not to close the session).

For the tested scenarios we combine both approaches, meaning that the operator/network is self aware of its parameters (stored in the nodes), and the user/application sends a mobile agent before starting, including its parameter set constrains. The evaluation consists of selecting the best path to the destination in a hybrid access WLAN/UMTS scenario. As parameter constraint we selected the one-way delay estimation based on the use of mobile agents.

A. Simulation environment

The work was done using ns-2 simulation environment. We upgraded a mobile agent's extension to ns-2.28 as the initial one was designed for 2.1b9. We need this upgrade in order to run an all-in-one [1] hybrid access wireless architecture. The patch [17] allows us to use modules for several wireless and wired technologies, such as: IEEE 802.3 (Ethernet), IEEE 802.11b (WLAN), IEEE 802.15.1 (Bluetooth), satellite and UMTS.

B. Measurements and end-to-end delay evaluation in a WLAN/UMTS scenario

The work consists of an implementation of a resource management mechanism by using mobile agents to estimate one-way delay in a hybrid access UMTS-WLAN network architecture. The propagation one-way delay was evaluated by combining the effect of Uu (interface between UE and UTRAN) and Iub (interface between RNC and Node B) network interface parameters over the propagation delay.

The scenario simulates communication between a MN (mobile node) connected to WLAN network and a UE (user equipment) attached to UMTS network (see Figure 3.).

Our first step towards inter-domain resource management scheme has been to extract the one-way delay by using the mobile agents, as the first parameter in the aggregate parameter set.

The implementation of the resource management system was divided in two steps: first, the evaluation of the application’s global delay over UMTS links, in order to determinate the parameters, second, the estimation of the delay by using mobile agents, in order to select the best path to the destination.

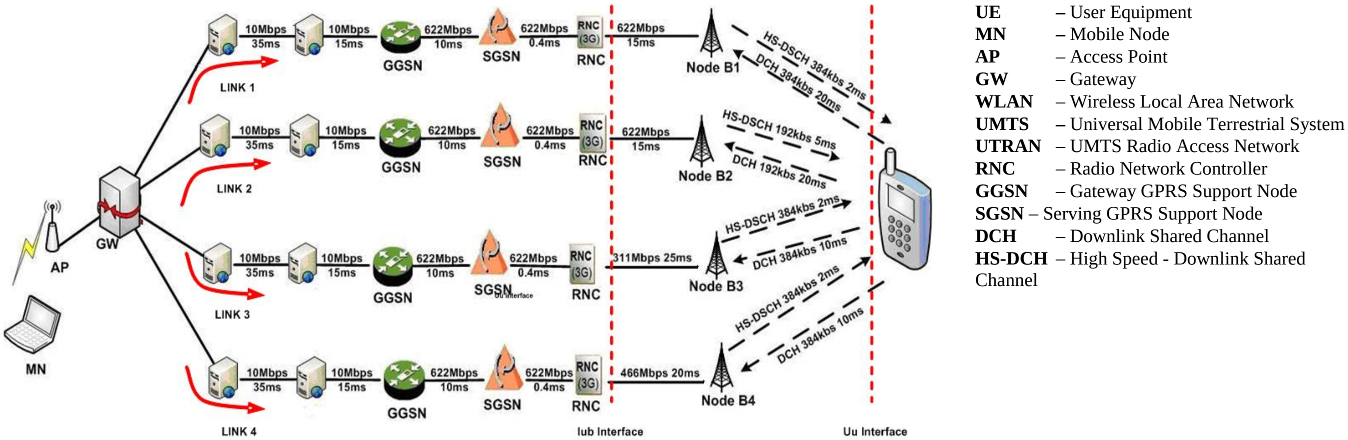

Fig. 3. The combined effect of Uu and Iub network interfaces parameters over one-way delay in a hybrid access WLAN-to-UMTS network architecture

For the UMTS Uu network interface we set up four links, having the following parameters (see Table I):

TABLE I
UU INTERFACE PARAMETERS

Channel	HS-DCH (uplink)		DCH (downlink)	
	throughput [kbps]	delay [ms]	throughput [kbps]	delay [ms]
LINK 1	384	2	384	20
LINK 2	192	5	192	20
LINK 3	384	2	384	10
LINK 4	384	2	384	10

We set up also the Iub interface parameters. The parameter sets are shown in the tables below (Table II, III and IV):

TABLE II
UMTS NETWORK PARAMETERS (LINK 1&2)

	Node 1	Node 2	GGSN	SGSN	RNC	Node B
throughput [Mbps]	10	10	622	622	622	
delay [ms]	35	15	10	0.4	15	

TABLE III
UMTS NETWORK PARAMETERS (LINK 3)

	Node 1	Node 2	GGSN	SGSN	RNC	Node B
throughput [Mbps]	10	10	622	622	311	
delay [ms]	35	15	10	0.4	25	

TABLE IV
UMTS NETWORK PARAMETERS (LINK 4)

	Node 1	Node 2	GGSN	SGSN	RNC	Node B
throughput [Mbps]	10	10	622	622	466	
delay [ms]	35	15	10	0.4	20	

After launching the application between MN and UE, mobile agents measure the one-way delays. These measurements are performed for each particular link of the network. Considering the parameters associated on network segments, measured one-way delays are stored in a database. Based on those measurements, the mobile agents estimate the one-way delay for each possible link between the source and the destination node in the network (see Table V).

TABLE V
ONE-WAY DELAY ESTIMATED BY MOBILE AGENTS FOR DIFFERENT SEGMENTS OF THE NETWORK

	WLAN segment [ms]	UMTS segment [ms]	ONE-WAY DELAY [ms]
LINK 1	271.443	1874.38	2145.823
LINK 2	271.443	4484.38	4755.823
LINK 3	271.443	2042.68	2314.123
LINK 4	271.443	1910.38	2181.823

In our case, the mobile agents select the best path to the destination in terms of minimum one-way delay as LINK 1, characterized by one-way delay of 2145.831 [ms]. Based on this calculation, we could guarantee the best path selection.

In a highly dynamic network environment, the link parameters are changing in time and consequently the network state changes too. Moreover, in a heterogeneous architecture there is no mechanism to guarantee an end-to-end QoS connection. Finally, the assumptions and requirements imposed to an inter-domain resource reservation request a distributed management mechanism.

The result obtained indicates the possibility of using mobile agents in order to select the best path to the destination, based on one-way delay estimations. By using mobile agents that perform periodical measurements of the network (in our case the one-way delay estimation), this method offers a method that overcomes the criteria imposed to an inter-domain resource management mechanism.

V. I-NAME (IN-NETWORK AUTONOMIC MANAGEMENT ENVIRONMENT)

Delivering multimedia traffic with QoS guarantees over multi-domains is a major challenge nowadays. The domains can be composed by more than one access network, each with its capabilities, devices and users. In this context, we define I-NAME (In-Network Autonomic Management Environment) as an environment performing in-network management and resource reservation tasks between network domains.

Working with profiles (aggregated parameter sets) it is flexible to the network conditions and users requests. It was designed as an end-to-end solution for managing resources, overcoming and accommodating different types of users (in terms of network technologies – access and transport). Hence, it is not a signaling mechanism because it reacts to the environmental network context.

I-NAME is not a routing mechanism, but it detects the best path to the destination considering users requests (as it was presented in the previous chapter of the paper). This is done based on the information collected and delivered to each node in the network through exchanged profiles.

I-NAME defines profiles as aggregate QoS parameter sets (throughput, delay, jitter, packet loss, etc.) and gives personalized access (from the user point of view) and optimized services (from the network/ operator perspective). I-NAME defines profiles, as the QoS parameter sets requested, supported, negotiated, and adopted in the message flow between network nodes. A first approach of these ideas was presented in [21-23].

Considering this, I-NAME defines four types of profiles needed to determine the path cost:

(1) Requested profile: includes application request for resources, generated by the SN (Source Node).

(2) Accepted profile: expresses the destination's availability for resources announced in the requested profile and it is generated by the DN (Destination Node).

(3) Negotiated profile: expresses the destination's possibilities for resources announced in the requested profile and it is generated by the DN.

(4) Adopted profile: contains the source's availability for resources announced in the negotiated profile and it is generated by the SN.

I-NAME message flow is based on the interaction and decision according to the information included in the profiles. The profiles should carry the network's capabilities from node to node in the path to the destination, but only the SN and DN could choose between different profiles in order to have a common view of the application requirements.

The implementation is based on two applications running simultaneously in each node: a client (I-NAME Client Application) and a server (I-NAME Server Application). On the path from the source to the destination the messages are passing through strategic nodes which recognize and further process the I-NAME message flow.

To add a request, I-NAME Client Application will send a Query Message to the Server Application that includes the Requested Profile. The Server Application will listen to a well known port and it will store a database including all the requests received. On the path from the source to the destination, the network will stamp in the Requested Profile its own capabilities.

The message is define as Query message with network profile, which is the same as the initial Query message, plus the network's additional influence. This means additional delay and jitter by each network segment or bandwidth limitations introduced on that path.

We call the path specific characteristics as the Path Profile. This could be modified by each network node, accordingly to the segment parameters passed by the Query Message through the path. Because of multiple paths, each time a new request reaches an intermediate node, the node will forward the best Path Profile to the next network node. (See Fig. 4)

When the Requested Profile reaches the destination node (containing the Client Application requests and network's capabilities mapped into the Path Profile), the I-NAME Server Application will answer with a specific message.

This message is generated in collaboration with the destination node, indicating its availability to support the Requested Profile. If the destination node answers by an Accepted Profile, it expresses the destination's availability for resources announced in the Requested Profile. Destination node sends a message indicating the acceptance for requested parameters. (See Fig. 5)

If the destination node answers by an I-NAME Negotiated Profile, it expresses the destination's possibilities for resources announced in the I-NAME Requested Profile. Destination node sends a message indicating the available possibilities for requested parameters. (See Fig. 5)

The answer sent back to the source node will record the best path to the destination. Thus I-NAME will assist low level routing (based on low level QoS parameter measurements and monitoring), managing in a distributed manner the network resources. (See Fig. 7).

A diagram implementing I-NAME algorithm is presented in Fig. 8.

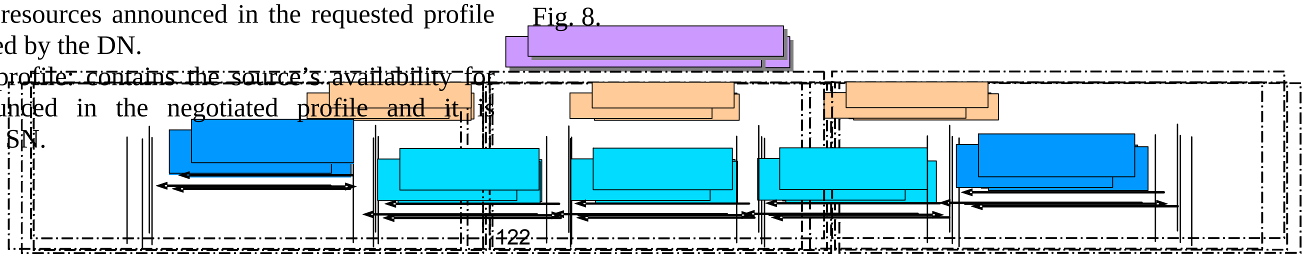

Fig. 7. I-NAME Adopted Profile Message Flow

Fig. 4. I-NAME Requested Profile Message Flow

VI. CONCLUSIONS

According to our investigations, the legacy heterogeneous networks are encountering difficulties in inter-domain end-to-end QoS resource management using traditional approaches (client-server or P2P solutions). As an alternative mechanism until the network architecture will include distributed QoS functionalities in each node, a mobile agent–based approach has been studied. We simulated a WLAN-to-UMTS scenario, involving ns-2.28 with all-in-one hybrid access wireless architecture. The paper presented the best path selection to the destination, based on mobile agent's one-way delay estimation. In the scenario, the one-way delay has been measured as the combined effect of Uu and Iub network interface parameters against propagation delay.

As the one-way delay is part of an aggregate set of parameters (together with throughput, jitter etc.) the mobile agents could perform even a more complex task. Although each technology might involve its own QoS mechanism, the paper proved that a single paradigm could be involved in path selection. Thus, any other combination of technologies (i.e. UMTS-to-WLAN, WLAN-to-satellite etc.) could take advantage of using mobile agents in a similar approach.

The proposed I-NAME mechanism completes the one-way delay with other QoS parameters in so called profiles. Hence, I-NAME is could bee seen as a monitoring algorithm and a scheme for self-management of the network resources.
Through these profiles, I-NAME adds predictions in the network, monitors and manages resources.

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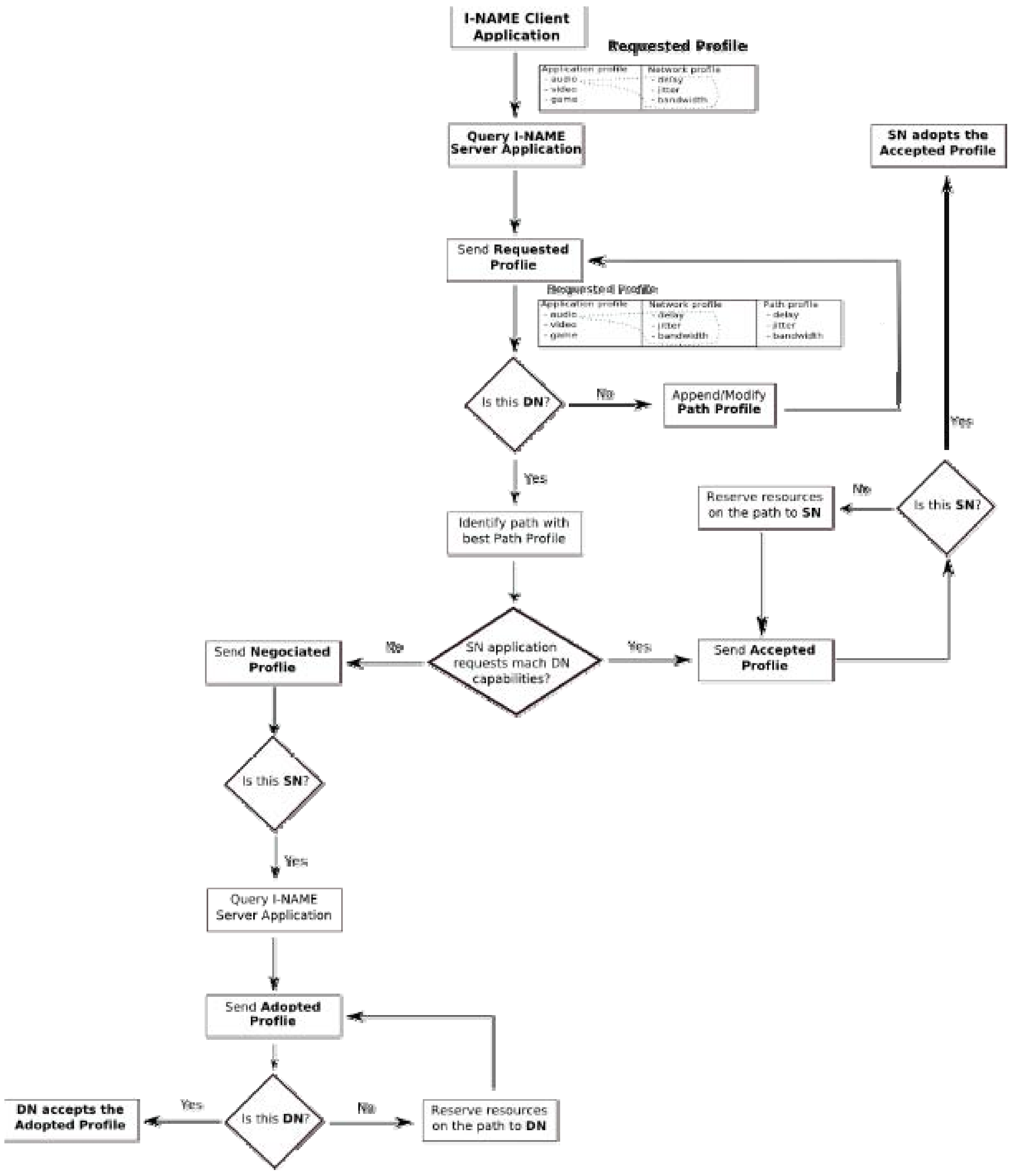

Fig. 8. I-NAME Mechanism Scheme

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