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An Overview of Intra-Domain QoS Mechanisms Evaluation

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Abstract – There has been a significant amount of work in the past decade to extend the IP architectures and to provide 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 QoS support. This paper includes the results obtained in order to provide a global analysis of the QoS parameters on four network layers, offers the mobility effect over the QoS parameters, especially in case of end-to-end delays introduced by handover procedure in different wireless access systems categories.
Keywords: intra -domain QoS access mechanisms, mobility, QoS parameters

I. INTRODUCTION

There are a number of factors and components that affect the performances of multimedia application. By grouping all these elements, we consider the QoS problem having two major perspectives: (1) network perspective (involving an objective analysis), and (2) application/user perspective (involving a subjective analysis).

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

From the application/user perspective, QoS 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 [1].

We developed two QoS approaches which assume the integration of some basic elements in the area of quality of services, like: (1) vertical QoS, and (2) horizontal QoS.

The vertical QoS approach includes the intra-domain QoS resource reservation mechanisms. The intra-domain QoS mechanisms are either already included in the last wireless standard architectures (i.e. IEEE 802.16, DVB-S, UMTS) or defined as extensions of the existing standard architectures (i.e. IEEE 802.11e).

An intra-domain resources reservation process is a simple one if the resources are managed by a single entity or by a set of entities supporting a common negotiation protocol. The vertical QoS approach suggests the separation of QoS aspects on each layer. Since each layer contributes to the offered quality of service, the vertical QoS approach supposes the extraction of the specific QoS parameters on each network layer. The QoS parameters' analysis is done from the network's perspective, of the support that the network guarantees to the applications.

The horizontal QoS concept is assuming the presence of an inter-domain QoS resource reservation mechanism in a hybrid access wireless IP network. The inter-domain reservation mechanism is an end-to-end QoS mechanism and represents the task of the project proposal.

Analyzed scenarios are accompanied by simulation conditions, graphical representation and simulation results. In our simulations we use ns-2.26 network simulator. These approaches will be presented in the next chapters of the paper.

II. INTRA-DOMAIN QOS RESERVATION MECHANISMS ANALYSIS

A. *Overview*

The intra-domain QoS reservation mechanisms were studied form the perspective of vertical QoS approach. The results we obtained provide a global analysis of the QoS parameters on four network layers.

Application layer analysis includes QoS facilities for SIP using COPS protocol. Transport, network and medium access layer analysis includes QoS provisioning mechanisms in wireless networks. TCP and UDP protocol performances at the transport layer level were analyzed in conjunction with the DSDV and AODV routing protocols use on the network layer.

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The effect of mobility and the number of mobile nodes for a wireless scenario were analyzed in the case of some real-time running applications. The analyzed QoS parameters were: throughput, number of lost packets, and average end-to-end delay [4].

B. *Application Layer QoS Analysis*

A scenario was made at the application layer's level, based on which QoS parameters' negotiation and signaling capabilities were added to the SIP user agents. The reservation requests sent to the access point in the DiffServ domain were transmitted by using the COPS protocol.
The messages sent in the network by the user agents with QoS capabilities and Q-SIP server's messages, were captured and analyzed. The following QoS parameters were analyzed: round trip time, inter-arrival jitter and cumulative number of lost packets.

C. *Transport Layer QoS Analysis*

The scenario presented in this chapter includes 10 MNs and we try to evaluate the efficiency on the transport layer. So, for TCP and UDP we switch between DSDV and AODV routing protocols. There are established four TCP or UDP connections for each scenario.
On the transport layer, UDP protocol is a connection less transport protocol. There is no confirmation of receiving data. It is more suitable in critical-time applications (real-time applications) than in no transmission error applications. This is obvious from our simulation: even we have a lower throughput, in case of UDP, the packet loss ratio is lowest.

Table 1. Simulations Results: TCP vs. UDP

Parameters	Protocols			
	TCP		UDP	
	DSDV	AODV	DSDV	AODV
Throughput [pcks/s]	155.24	156.92	77	77
Routing overhead [pcks]	59	37	60	42
Packet loss ratio [pcks]	84	120	1	1
Average end-to-end delay [ms]	378	366	7	3.5
Efficiency [%]	98.91	98.47	99.98	99.98

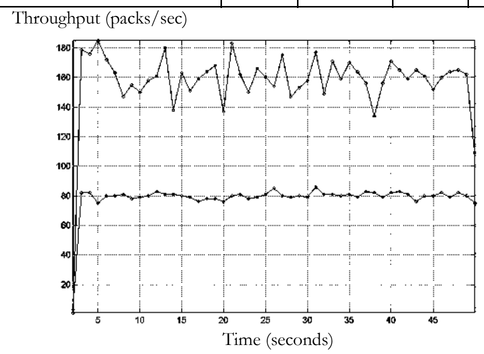

Figure 1. Graphical representation: TCP vs. UDP

D. *Network Layer QoS Analysis*

We evaluate the routing protocols DSDV, DSR and AODV performances. In order to communicate with a destination, a source needs to discover a suitable route for sending packets to that destination.
This work is done by a routing protocol. The problem of routing in a network has two components: route discovery and route maintenance [2].
The existing routing protocols in ad-hoc wireless networks can be classified as proactive routing protocols and reactive routing protocols. There are four ad-hoc routing protocols currently implemented for mobile networking in ns-2.26: one proactive routing protocol (DSDV) and three reactive routing protocols (DSR, AOVD, and TORA).
Considered scenarios were analyzed looking on the following parameters: throughput, routing overhead, packet loss ratio, average end-to-end delay, efficiency.
The first scenario of this section contains a wireless network with 10 mobile nodes (MNs). Wireless MNs are fixed. They keep the initial position during simulation. A FTP application between two MNs over a TCP transport protocol was set up. Simulation time is 50s. Assuming these initial conditions we switch the three routing protocols (DSDV, DSR and AODV) and than we increase to 20 the number of MNs. There are two distinct situations: (1) for the same protocol, which is the increasing effect of mobile nodes, and (2) which is most efficient routing protocol in each case.
In the second scenario we keep the initial network configuration with 10 mobile nodes (MNs). We study the influence of mobile node's speed on the parameters.
The key motivation behind the analysis of routing protocols on network layer is the reduction of the routing load and the effect of the network overloaded with routing information depending on the network type, running application and number of mobile nodes in the network [3].
High routing load usually has a significant performance impact in low bandwidth wireless links and we consider this aspect crucial on evaluating a link quality, hence the quality of offered services (QoS).

Table 2. Simulations Results: 10 MNs (scenario I)

Parameters	Protocols		
	DSDV	AODV	DSR
Throughput [pcks/s]	157.6	159.88	159.7
Routing overhead [pcks]	83	10	2
Packet loss ratio [pcks]	20	20	20
Average end-to-end delay [ms]	132	122	118

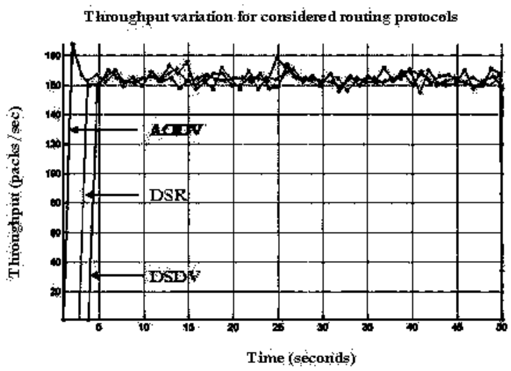

Figure 2. Graphical representation: 10 MNs (Scenario I)

Table 3. Simulations Results: 20 MNs (scenario I)

Parameters	Protocols		
	DSDV	***AODV***	***DSR***
Throughput [pcks/s]	157	159.86	159.6
Routing overhead [pcks]	221	20	2
Packet loss ratio [pcks]	20	20	20
Average end-to-end delay [ms]	138	125	142

Table 4. Simulations Results: different MNs speed (scenario II)

Parameters	Protocols			
	DSDV		***AODV***	
	15 m/s	***30 m/s***	***15 m/s***	***30 m/s***
Throughput [pcks/s]	87.64	38.74	112.5	98.9
Routing overhead [pcks]	70	80	23	23
Packet loss ratio [pcks]	41	25	40	40
Average end-to-end delay [ms]	165	164	146	198

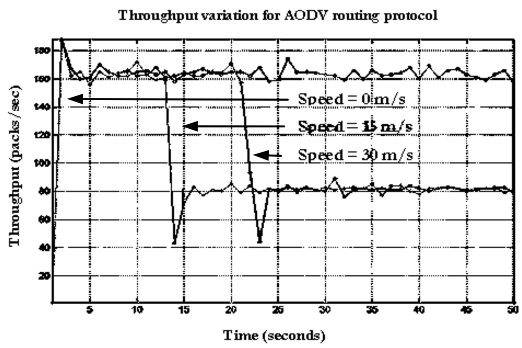

Figure 3. Graphical representation: different MNs speed (Scenario II)

Synthesizing results we demonstrate that: (1) AODV has the best performance even in a network with moving mobile nodes, (2) the higher the speed of mobile nodes the lower the throughput in the network, and (3) the lowest throughput in the network is not influenced by the number of packet loss, it is about de routing overhead.

E. *Medium Access Layer QoS Analysis*

An important part of the data link layer analysis consisted in medium access techniques study.

The DCF, PCF, and EDCF techniques were analyzed side by side. The DCF technique provides random medium access. The PCF technique provides access to a medium coordinated by an access point. The EDCF technique introduces a per-class QoS services differentiation by offering four traffic categories. The analysis showed a traffic stream efficiency increase when using the traffic priorities. The traffic scheduling mechanism offered transmission opportunities to every node in the network.

The analyzed QoS parameters were: throughput and transmission efficiency in the traffic priorities' context.

Following, we provide a general symmetric framework for analyzing the QoS efforts in 802.11 and the mechanisms in 802.11e that are designed to improve QoS in wireless networks. We introduce a number of key QoS mechanisms specific for the existing DCF and proposed EDCF operation mode, a method for supplying quality of service in IEEE 802.11 and IEEE 802.11a/b/g Wireless LANs.

In order to have support for the EDCF mode, a patch has applied to the simulator. We have used a data rate of 11 Mbps. The rate at which the PLCP header, which consists of 40 bits, is transmitted is 6 Mbps. The other important parameters that model the radio channel are the following: Slot Time: 9us; SIFS Time: 16us; Preamble Length: 96bits=16us; PLCP Header Length: 40bits; PLCP Data Rate: 6Mbps; Data Rate: 11Mbps.

We created a simulation scenario that involves a wired-cum-wireless network. There are two wired nodes, one of them being the root of the wired network, one base station and four mobile nodes. All the nodes are set up for hierarchical routing. This means that the network can be divided into routing domains (also known as regions or areas). All traffic flows between the wireless nodes will be coordinated by the base station. All the nodes are static, meaning that they have fixed positions within the simulated terrain. The ad-hoc routing protocol used is DSDV.

The simulation time is 10s. The following links have been defined in the simulation script: between the root and the base station there is a 100Mbps duplex connection, with a 2ms drop tail queuing system implemented; each wired node is linked to the root using a similar connection to the one presented above; between the wireless nodes and the base station we have defined independent traffic flows as will be presented shortly.

In the first scenario, four connections are created between one mobile node (node 4) and one wired node (node 1), all traffic having to pass through the base station (node 3) and the root (node 0).

Each connection uses a constant bit rate generator (CBR) as a traffic source, and each traffic flow has assigned a priority from 0 to 3 for the EDCF case. We have chosen to use 500 bytes packets which are spaced in time at different intervals for each traffic source, in order to obtain the desired bit rates.

We set the following priorities: 0-high priority, 3-low priority. In the second scenario, four connections are created between four mobile nodes (node 4 up to node 7) and one wired node (node 1), all traffic having to pass through the base station (node 3) and the root (node 0). In the same manner, each connection uses a constant bit rate generator (CBR) as a traffic source, and each traffic flow has assigned a priority from 0 to 3 for the EDCF scenarios.
The following tables present the results of the simulations.

Table 5. Simulations Results: DCF vs. EDCF (scenario I)

Traffic Analysis for the First Scenario		One Node/Four Traffic Flows – Sum of All Individual Data rates is Larger than available channel bandwidth			
		Different Data Rate		Same Data Rate	
		DCF	EDCF	DCF	EDCF
Traffic Flow 1	Average Throughput [kbps]	19.552	993.408	4,949.980	4,967.460
	Efficiency [%]	*1.96*	*99.34*	*99.00*	*99.35*
Traffic Flow 2	Average Throughput [kbps]	28.704	1,986.820	953.472	1,942.300
	Efficiency [%]	*1.44*	*99.34*	*19.07*	*38.85*
Traffic Flow 3	Average Throughput [kbps]	455.104	2,756.830	7.072	736.736
	Efficiency [%]	*11.38*	*68.92*	*0.14*	*14.73*
Traffic Flow 4	Average Throughput [kbps]	5,414.240	1,403.170	7.072	61.984
	Efficiency [%]	*67.68*	*17.54*	*0.14*	*1.24*
Total Throughput [kbps]		*5,917.600*	*7,140.228*	*5,917.596*	*7,708.480*

Table 6. Simulations Results: DCF vs. EDCF (scenario II)

Traffic Analysis for the Second Scenario		Four Nodes/Four Traffic Flows – Sum of All Individual Data rates is Larger than available channel bandwidth			
		Different Data Rate		Same Data Rate	
		DCF	EDCF	DCF	EDCF
Traffic Flow 1	Average Throughput [kbps]	953.472	993.824	1,507.170	4,967.460
	Efficiency [%]	*95.35*	*99.38*	*30.14*	*99.35*
Traffic Flow 2	Average Throughput [kbps]	1,736.800	1,986.820	1,495.520	2,039.650
	Efficiency [%]	*86.84*	*99.34*	*29.91*	*40.79*
Traffic Flow 3	Average Throughput [kbps]	1,817.090	2,627.460	1,616.990	520.416
	Efficiency [%]	*45.43*	*65.69*	*32.34*	*10.41*
Traffic Flow 4	Average Throughput [kbps]	1,558.340	1,339.940	1,440.610	66.144
	Efficiency [%]	*19.48*	*16.75*	*28.81*	*1.32*
Total Throughput [kbps]		*6,065.702*	*6,948.044*	*6,060.290*	*7,593.670*

QoS parameter analysis on medium access layer illustrates the benefits brings by 802.11e QoS extension, in fact EDCF vs. DCF medium access technique.
Analyzing simulation results we can extract the following conclusions: (1) traffic stream efficiency increase in case of using EDCF compare to DCF, (2) traffic priorities allow a high data transfer rate for the high priority traffic streams, and (3) EDCF realize a traffic balancing, offering transmission opportunities to each node in the network.

III. INTRA-SYSTEM MOBILITY MECHANISMS ANALYSIS

For the next generation technologies, mobility is more than a necessity, it's a requirement. In the context of QoS parameter analysis, a study was done on the effect of delays introduced by handover procedure.
Defining or characterizing the behavior of roaming mobile nodes involves two forms: seamless roaming and nomadic roaming. Also, depending on which layer the roaming occurs, we could define two major types of roaming: layer 2 roaming and layer 3 roaming.
Depending of the layer on each the handover procedure occurs and according with the application type, the handover procedure was tested for the following technologies: mobile IPv4, mobile IPv6, wireless LAN, and UMTS networks.
The analyzed QoS parameter was the end-to-end delay introduced by the handover decision. For the tested scenarios, we used ns-2 network simulator.
These studies offer the possibility of incorporating the additional delays introduced by the handover procedure to the global delays evaluation for a hybrid access wireless IP architecture.

A. *Mobility Analysis on Computer Networks*

A layer 2 network is defined as a single IP subnet and broadcast domain, while a layer 3 network is defined as the combination of multiple IP subnets and broadcast domains.
Layer 2 roaming occurs when a mobile node moves far enough that its radio associates with a different access point. With layer 2 roaming, the original and the new access point offer coverage for the same IP subnet, so the device's IP address will still be valid after the roam.
In order to demonstrate the handover concept for IEEE 802.11 wireless LAN, a simple wireless scenario was realized using the ns-2 simulator. The wired-cum-wireless scenario contains two wireless nodes, each of them communicating through its own AP. The fixed network is simulated by a simple connection between the AP's and UDP traffic is set between the two mobile nodes using a CBR application. The rate is set to 100 kbps. In order to make possible the handover process, one of the nodes moves from the coverage area of one AP to the other one. The maximum delay in communication indicates the initial handover moment. We can observe that the average delay is about 10ms smaller when the two nodes use the same AP.
Layer 3 roaming occurs when a mobile node moves from an access point that covers one IP subnet to an access point that covers another IP subnet. At that point, the mobile node would no longer have an IP address and default gateway that are valid within the new IP subnet.

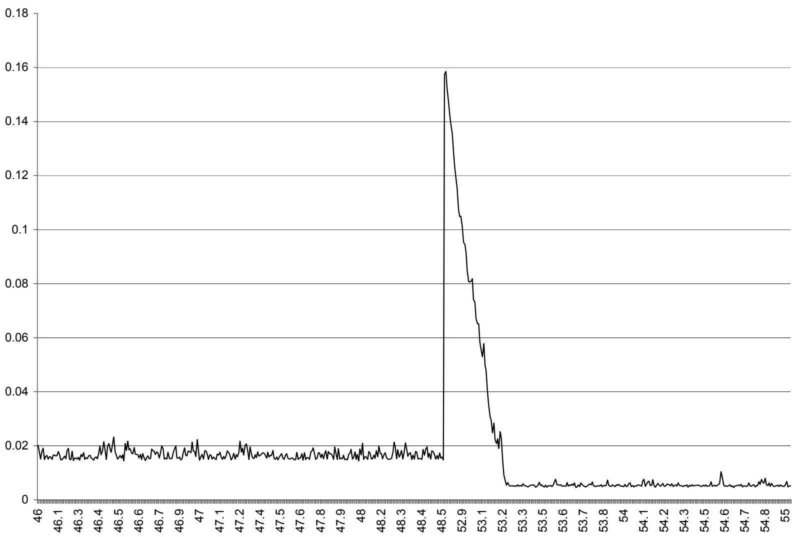

Fig. 4. End-to-end delay: IEEE 802.11 handover

All packets are sent to the HA. This is one of the disadvantages of mobile IPv4. This disadvantage of is solved by mobile IPv6 which uses the route optimization.

Comparing simulations results we observe that best performances are obtain in case of wireless networks handover process. That is because the handover decision is taken on layer 2 not on layer 3.

A layer 2 handover decision implies a less computational time on the mobile node vs. a layer 3 handover decisions.

To provide session persistence, it is needed a mechanism to allow a station to maintain the same layer 3 address while roaming throughout a network, mobile IP solution.

The mobile IPv4 is natively supported by the standard version of the ns-2 simulator, but there is no support for mobile IPv6 and an extension was patched. The effect on the end-to-end delay of the packets can be seen. Due to the fact that a triangular routing is used, the packets received by the mobile node while being in the visited network have a significantly larger delay compared to the ones received when it is in his home network.

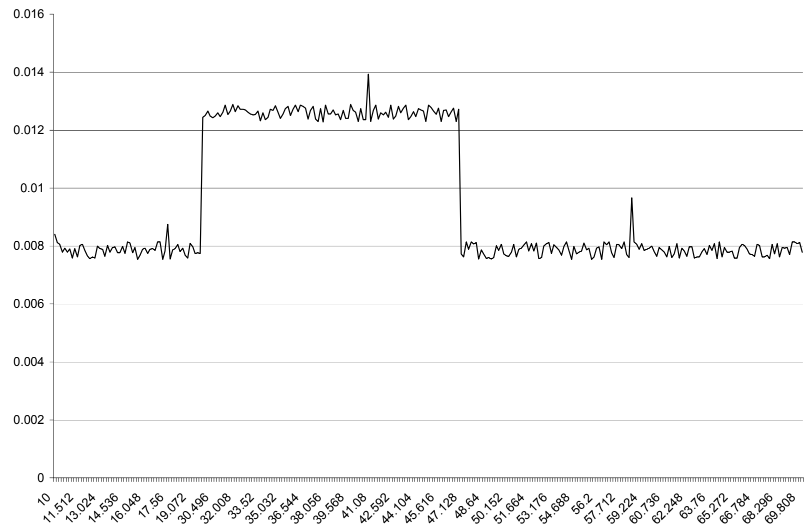

Fig. 5. End-to-end delay: IPv4 handover

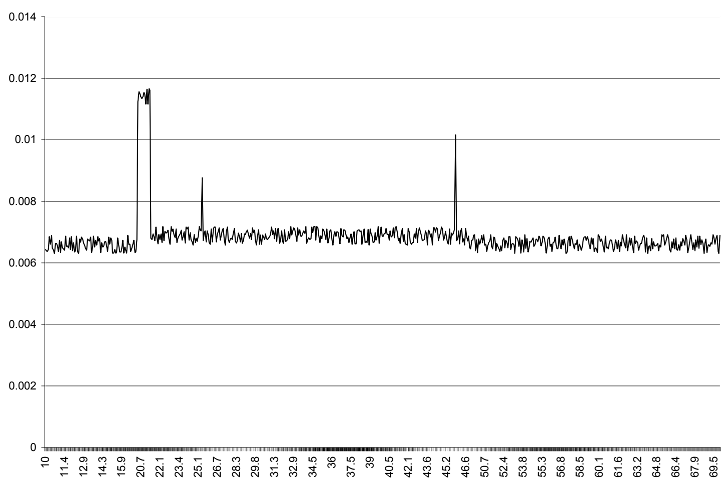

Fig. 6. End-to-end delay: IPv6 handover

In case of fixed networks, the route optimization algorithm used by IPv6 vs. IPv4 makes the handover transfer more rapidly. Hence, the end-to-end delay will be smaller in case of using IPv6 version.

B. *Mobility Analysis on Cellular Networks*

Like in all the other cellular networks, handovers are the basic means of providing mobility. For UMTS networks the idea is to reduce especially the number of handover failures compared to previous generation cellular communication systems.

The standard version of the ns-2 simulator doesn’t support UMTS system. Hence, an additional package had to be installed.

In case of delivering HTTP non real-time services, the information is encapsulated on TCP datagram (connection-oriented transfer protocol), the delay increases compared to real-time application case.

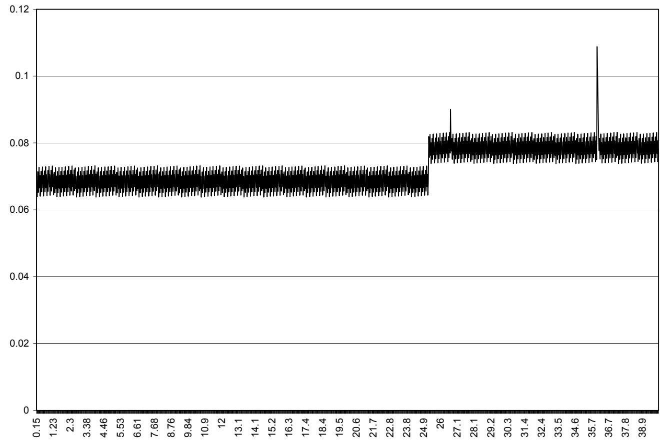

Fig.7 End-to-end delay: HTTP UMTS handover

Table 7. End-to-end delays for intra-system mobility

Network type		Fixed network		Wireless network	Cellular network	
Technology type		*IP core*		*WLAN IP core*	*UMTS IP core*	
Handover decision		*Layer 3*		*Layer 2*	*Intra-RNS handover*	
Protocol/Standard/Application		*IPv4*	*IPv6*	*IEEE 802.11*	*HTTP*	*CBR*
End-to-end delays	*min delay [s]*	0.007545s	0.00631s	0.004538s	0.269295	0.063795s
	max delay [s]	0.013936s	0.011662s	0.145834s	0.289065	0.108828s

IV. INTER-DOMAIN QOS MECHANISM

The intra-domain QoS reservation mechanisms were studied form the perspective of vertical QoS approach.

The heterogeneity of the access networks determined that the problem of providing services to be adapted to (1) the users’ needs and (2) to the network’s context. The endorsement of (1) the inter-domain end-to-end QoS signaling and of (2) the resource management policies based on client/server architectures in the context of having distributed systems for managing and adaptive controlling the resources, represent the possible solutions for an inter-domain QoS provisioning support [5], [7], [9].

The inter-domain QoS reservation mechanism suggests keeping the intra-domain QoS reservation mechanisms implemented in the wireless systems that intend to be interconnected. The alternative to the classical resource reservation method and QoS parameters transfer is the use of mobile agents [6], [8], [10]. The mobile agents shall act on behalf of the user in order to realize the QoS support.

Provisioning the QoS support is a complex task, the available resources being (1) diversified, (2) distributed, (3) managed by different entities, and (4) negotiated by different protocols.

The assimilation of the existent profiles is determined by the exchanged messages’ content between the mobile agents involved in the negotiation, reservation, and resource management process. The subject and the logical sequence of the messages that the mobile agents exchange will reflect the suggested inter-domain QoS mechanism’s characteristic features.

V. CONCLUSIONS

Two major conclusions could be highlighted at the end of this analysis: (1) from the network’s perspective, each layer contributes to the QoS parameters evaluation, and (2) from the application’s perspective, there should be a request for a QoS parameters set in order to guarantee the negotiated quality of service. The hybrid access wireless IP architecture intends to integrate wireless spatial and terrestrial wide area networks, and wireless metropolitan and local area networks. The hybrid wireless system resources are diversified, distributed, managed and negotiated by different entities, and the quality of services problem must adapt both the user requests and the network context.

The demands imposed to the inter-domain QoS mechanism recommend the use of mobile agents as an alternative to the classical method of resource reservation and QoS parameters transfer. In order to provide the quality of services, mobile agents act on behalf of the user. Inter-domain QoS support proposed by this mechanism needs the accomplishment of three phases: resource negotiation, resource allocation, and resource management. Each phase is associated to a corresponding specific profile. The purpose of the mobile agents is to determine the selection of a corresponding profile according to the negotiated set of QoS parameters.

These conclusions represent the starting point for the intra-domain QoS reservation mechanism design proposed to be developed.

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