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Mobility Mechanisms for Mobile/Wireless all-IP Networks

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Abstract – For the next generation technologies, mobility is more than a necessity, it's a requirement. Actual developed architectures dedicate a special attention to this aspect. Considering that, this paper analyzes the aspect reflecting the network capability, named mobility. We test and verify the mobile nodes availability to roam in different scenarios, for computer networks and cellular networks. All simulations scenarios were implemented using ns-2 network simulator and for the tested architectures we offer the end-to-end delay during the handover process. The results demonstrate how average end-to-end delay contributes to the QoS global evaluation for a wireless scenario.
Keywords: mobility, QoS support, end-to-end delay, ns

I. INTRODUCTION

The paper is structured on five chapters. The first chapter introduces the paper. There are a number of factors and components that affect the performances of multimedia application. Grouping all these elements, we consider that quality of services problem has two major perspectives: **network perspective** and **application/user perspective**. From the network perspective, QoS refers to the service quality or service level that the network offers to applications or users in terms of network QoS parameters, including: latency or delay of packets traveling across the network, reliability of packet transmission, and throughput.
From the user/application perspective QoS generally refers to the application quality as perceived by the user. That is, the presentation quality of the video, the responsiveness of interactive voice, and the sound quality of streaming audio.
We group applications and users are in the same category because of their common way they perceive quality [1]. Considering that, we evaluate mobility as a network parameter and analyze its contribution on delay of delivering packets for different wireless technologies. The results presented on this paper complete our work on QoS support for broadband wireless network and consolidate the layered QoS approaches separate QoS aspects on each layer [2].
We consider that parameters on each layer essentially contribute to the global QoS evaluation [3]. In our simulations we use ns-2.26 network simulator. A complete information regarding installation under different operating systems and specific parameter configuration for wireless scenarios is presented by the authors [4]. We offer description and graphical representations in all simulated cases.
The second chapter gives a perspective of mobility concept for different networks, illustrating the types of roaming and the correlations with network layers.
The third chapter presents the roaming process for **computer networks**, as layer 2 and layer 3 handover.
The four chapter presents the roaming process for **cellular networks**.
Chapter five will summarize and conclude our work on intra-system mobility evaluation.

II. GENERAL CONCEPTS ON MOBILITY FOR WIRELESS SYSTEMS

An integral concept for wireless systems is roaming. It is important to understand what roaming is, how and when it occurs, what types of roaming there are, and how these types differ. Mobility is the quality of being capable of movement or moving readily from place to place.
Defining or characterizing the behavior of roaming mobile nodes involves two forms: **seamless roaming** and **nomadic roaming**.
Seamless roaming is best analogized to a cellular phone call. There is no noticeable period of network unavailability because of roaming. This type of roaming is deemed seamless because the network application requires constant network connectivity during the roaming process. Seamless roaming is characteristic for cellular communications systems and assumes that mobile node roams between cellular base stations and maintains a permanent connection with the network.
Nomadic roaming is different from seamless roaming. Nomadic roaming is best described as the use of a wireless local area network environment.
The mobile node has network connectivity while seated at his destination and maintains connectivity to a single access point. When the user decides to roam, he interrupts the connectivity with the system. At a

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time, the mobile user roams from the initial access point to another access point.
This type of roaming is deemed nomadic because the mobile node is not using network services when he roams, but only when he reach his destination.
Also, depending on which layer the roaming occurs, we could define two major types of roaming: **layer 2 roaming** and **layer 3 roaming**.
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.
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.

III. MOBILITY ANALISIS ON COMPUTER NETWORKS

One of the most challenging issues in the area of wireless communication systems is the provision of fast and efficient mobility support.
Next generation applications running on wireless networks require an emerging need to both provide mobile nodes with the ability to remain connected while being truly mobile, and to quickly restore their connections during any kind of handover inside WLAN.
For IEEE 802.11 implemented wireless LANs, the handover process is known as break before make, referring to the requirement that a mobile node serves its association with one AP (Access Point) before creating an association with a new one.
This process might seem to be inefficient because it introduces the possibility for data loss during roaming, but it facilitates a simpler MAC protocol. IEEE 802.11 defines a layer 1 physical interface and a layer 2 data link layer access mechanism. Layer 2 roaming is natively supported for 802.11 mobile nodes.
As 802.11 is layer 3 unaware, some upper-layer solution is required for layer 3 roaming. Also, the type of application is directly correlated to its resilience during the roaming process.
Connection-oriented applications (TCP based) are more tolerant to packet loss incurred during roaming process because TCP requires positive ACKs, just as the 802.11 MAC does, hence any data lost during the roaming process will be retransmitted.
Connectionless applications (UDP based) are time critical and the packet loss incurred during roaming process might cause a noticeable impact to applications because UDP do not use retransmissions.

A. *Layer 2 Handover*

Depending of the decision of where to roam, the mobile node must decide which AP to roam to.
There are two different AP discovery processes: **preemptive AP discovery** (scanning the medium for APs before the decision to roam), and **roam-time AP discovery** (scanning the medium for APs after the decision to roam). Each discovery process can employ one or both of the following mechanisms: active scanning (the mobile node actively searches for an AP, waits for responses from APs and decides which AP is the best one to roam to), and passive scanning (the mobile node does not transmit any frames, listens for beacon frames on each channel and continues to change channels at a set interval).
In conclusion, there is no ideal technique for scanning. Passive scanning has the benefit of not requiring the client to transmit requests but runs the risk of potentially missing an AP because it might not receive a beacon during the scanning duration. Active scanning has the benefit of actively seeking out APs to associate to but requires the client to actively transmit requests.

A.1. *Scenarios and simulations results*

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 so-called wired-cum-wireless scenario contains two wireless nodes, each of them communicating through its own base-station (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. This situation could simulate for example a VoIP application. 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 scenario topology can be seen clearly in the next screenshots.

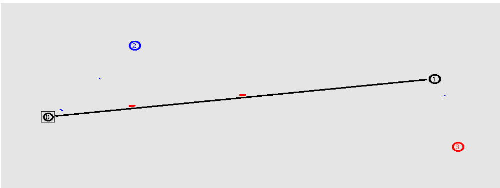

Figure 1. Mobile nodes positions before handover

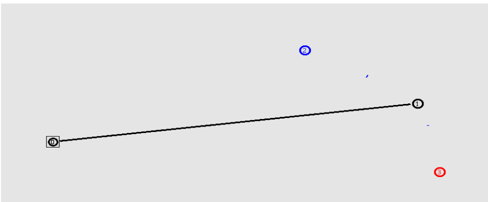

Figure 2. Mobile nodes final positions after handover

The end-to-end delay information is extracted from the corresponding trace file and the results are plotted in the graph presented below.

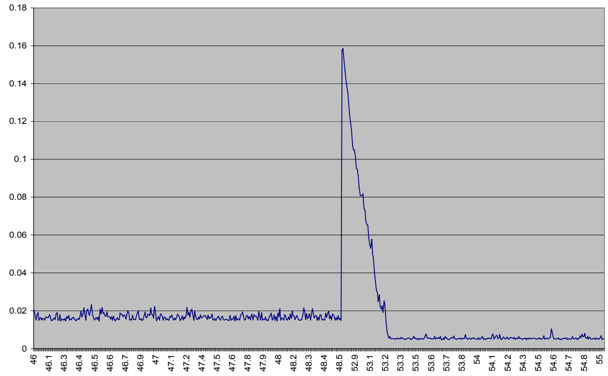

Figure 3. End-to-end delay representation in time [s] for IEEE 802.11 wireless LAN handover process

A.2. *Partial conclusions*

The maximum delay in communication indicates the initial handover moment. We can observe that the average delay is about 10 ms smaller when the two nodes use the same AP.

During the handoff procedure, we have some packets with very large delays (up to 160 ms), until the association with the new AP is achieved. Even though wireless LANs work over very high channel bandwidth, they show long network-layer handoff latency. This is a restraining factor for mobile clients using interactive multimedia applications such as voice over IP or video streaming.

For important and useful services like employing VoWLAN, the roaming latency (excessive latency and jitter, degraded voice quality) remains a challenge. New ways must, therefore, be examined for optimizing the time required to complete the inter-network APs transitions of wireless mobile nodes.

B. *Layer 3 Handover*

Layer 3 mobility is a superset of layer 2 mobility. In an 802.11 wireless LAN, the mobile node must perform a layer 2 roam, including AP discovery, before it can begin a layer 3 roam. Many applications require persistent connections with the network. 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.

The key components in a Mobile IP enabled network are: the mobile node (MN), the home agent (HA), the foreign agent (FA), Care-of address (CoA), Co-located care-of address (CCoA). There are three main phases of Mobile IP: agent discovery, registration and tunneling.

IEEE 802.11 wireless LAN's permit network mobility, but to properly implement and deploy a mobility-enabled WLAN, we must understand the nature of the applications. There are two versions of mobile IP: IPv4 and IPv6. The main difference between Mobile IPv4 and Mobile IPv6 is that the last one includes in the core protocol some features that were just extensions for Mobile IPv4. We can include here the route optimization and the reverse tunneling.

Beside that, Mobile IPv4 uses tunnel routing to deliver data-packets to mobile node, while Mobile IPv6 uses tunnel routing and source routing with IPv6 Type 2 routing headers; the FA is used in Mobile IPv4 to de-capsulate the packets for the MN, while in Mobile IPv6 the packets are de-capsulated by the mobile node itself, eliminating the need for FA. If in Mobile IPv4, agent discovery is used for mobile detection, Mobile IPv6 uses IPv6 router discovery.

Similarly, Mobile IPv4 uses ARP to determine the link layer address of neighbors while Mobile IPv6 uses IPv6 neighbor discovery and is de-coupled from any given link layer.

B.1. *Scenarios and simulations results*

For the layer 3 handover section were design two similar simulations for Mobile IPv4 and Mobile IPv6.

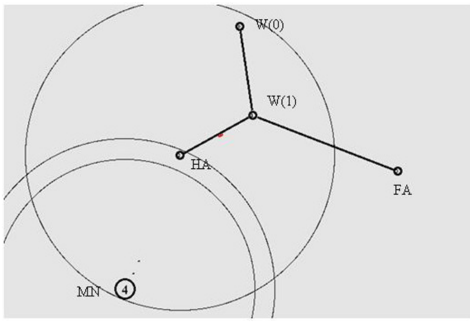

Figure 4. The mobile node in the home network

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.

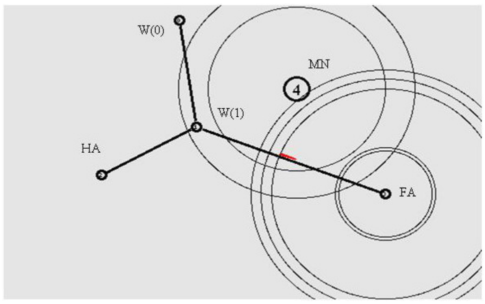

Figure 5. The mobile node in the visited network

The end-to-end delay is extracted from the two trace files (corresponding to Mobile IPv4 and Mobile IPv6) using an .awk script and plotting them we obtain the two graphs below.

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. Practically, all the packets are sent to the HA, and from here to the FA, which routes them to the MN. This is one of the disadvantages of Mobile IPv4.

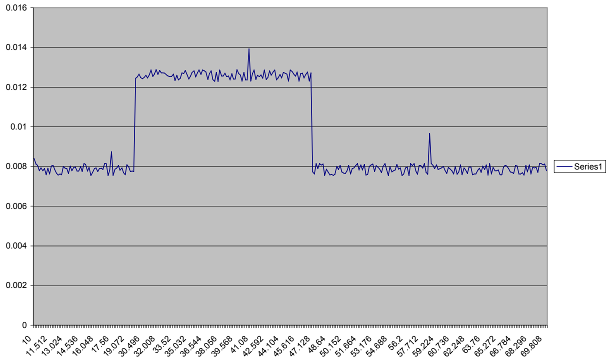

Figure 6. End-to-end delay representation in time [s] for Mobile IPv4 scenario

This disadvantage of is solved by Mobile IPv6. As discussed in a previous paragraph, Mobile IPv6 uses always the so called route optimization. So, as can be seen in the Figure 7, the difference between delays of the packets received in the foreign network and the ones received in the home network is not so large. This is due to the fact that, after the binding list and the binding cache are updated, the packets follow the shortest path to the destination without using the HA.

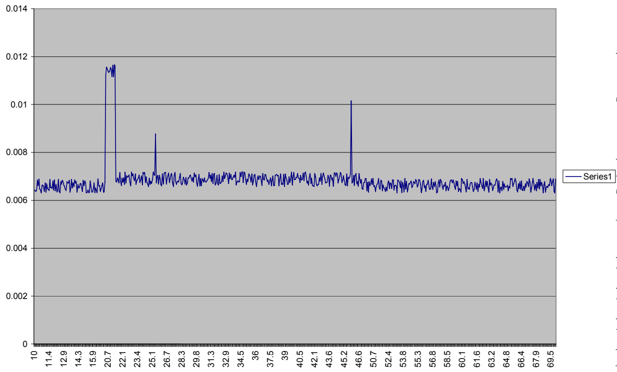

Figure 7. End-to-end delay representation in time [s] for Mobile IPv6 scenario

Only the first packets sent after the node has entered the foreign network have larger delays, because they follow the path through the home agent, until the Binding List is updated by the correspondent node. In fact, for this short period of time, the Mobile IPv6 actions exactly like Mobile IPv4 in order to route the packets.

B.2. *Partial conclusions*

The Mobile IP is generally used for nomadic mobility, although just theoretically it can be used for seamless mobility. The main reasons are the large delays, especially for the Mobile IPv4 version.

The Mobile IPv4 has several disadvantages: the triangular routing which means large delays for the packets; a HA may become a traffic and performance bottleneck and potential long handoff delay due to the registration process.

Some of these problems are solved by the Mobile IPv6 protocol (which introduces the route optimization as an alternative for the triangular routing), or by some "micro-mobility" management protocols, the Hierarchical MIP or Cellular IP.

IV. MOBILITY ANALYSIS ON CELLULAR NETWORKS

The UMTS architecture has been specified in order to offer higher flexibility to users than 2G networks could support.

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

Handovers can be classified in hard, inter-system and soft and softer handovers. Hard handover is the handover type where a connection is broken before a new radio connection is established between the user equipment and the radio access network. Inter-system handovers are necessary to support compatibility with other system architectures. Soft and softer handover are the CDMA specific handover types implemented in the UMTS system.

A.1. *Scenarios and simulations results*

The standard version of the ns-2 simulator doesn't support UMTS system; hence an additional package had to be installed.

The need was to extend the simulator to support UTRAN (new mobile nodes, layers and protocols), non-ad-hoc communication and routing for UE mobility. Then, as UMTS can be modeled as an all-IP network whereby all the transactions are based on IP protocols, with these entire modifications one can simulate a whole UMTS network by putting agents and applications on top of the nodes.

Two types of traffic are set between two mobile nodes. First a CBR application type is simulated with a rate of 13kbps, and then a HTTP connection with 64kbps. One of the mobile nodes stays fixed, while the other moves from one NodeB to another, performing the handover. Two screenshots of the scenario are presented below.

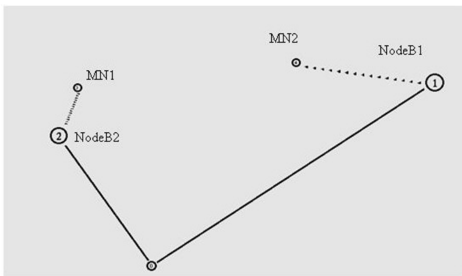

Figure 8. The mobile node before the handover process

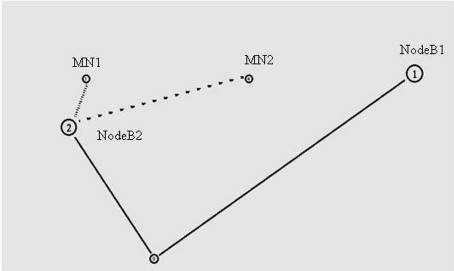

Figure 9. The mobile node after the handover process

The end-to-end delay is a very important parameter in handover analysis. This information is extracted from the trace file and then is plotted.

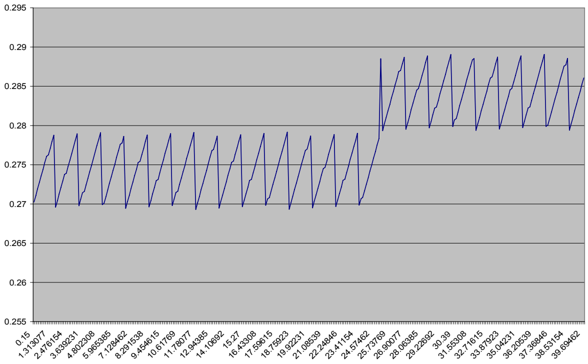

Figure 10. The end-to-end delay in a CBR UMTS application

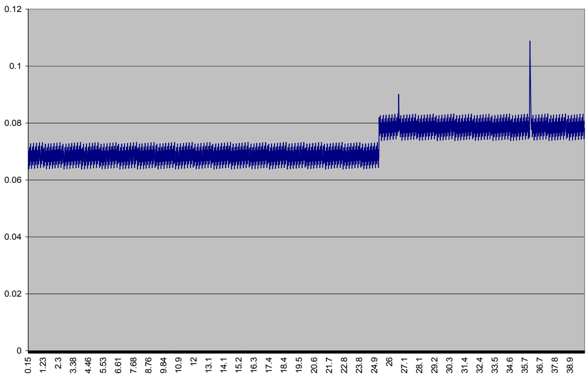

Figure 11. The end-to-end delay in a HTTP UMTS application

A.2. *Partial conclusions*

The delay is larger after the handoff, because the two mobile nodes don't communicate through the same NodeB anymore. Compared to the previous scenarios, the handover process has a minimum effect on the communication. This is normal, if we think that the cellular networks are designed to support a practically seamless handover for the mobile users.

V. CONCLUSIONS

The paper presents an intra-system mobility evaluation for different wireless technologies: computer networks (fixed and wireless networks) and cellular-based networks. The paper offers a complex simulation environment by using existing and patched modules for ns-2 network simulator.

There was simulated the handover processes for mobile IPv4, mobile IPv6, WLAN, UMTS. Also, there are tested best-effort and critical in time applications modeled by HTTP and CBR sources. Each scenario is accompanied by partial conclusions. Mobility as a network parameter and its contribution on delay of delivering packets is a good indicator of the network capabilities.

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 (WLAN) not on layer 3 (IPv6 and IPv4).

A layer 2 handover decision implies a less computational time on the mobile node vs. a layer 3 handover decisions. In case of fixed networks, the route optimization algorithm used by IPv6 version vs. IPv4 version makes the handover transfer more rapidly. Hence, the end-to-end delay will be smaller in case of using IPv6 version.

Evaluating the end-to-end delay for cellular networks we observe that in case of CBR application modeling critical in time applications over UMTS, the results are similar with IPv6 case.

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

We promote a layered QoS philosophy that separate QoS aspects on each layer, and each layer's parameters essentially contribute to the global QoS evaluation.

One of these parameters is end-to-end delay introduced by the handover process. Simulation results and conclusions presented in this paper complete and consolidate our work and vision related to the QoS layered approached which includes a complex analysis over different TCP/IP layers for wireless scenarios: study of medium access techniques, routing and transport protocols.

All work is done form the QoS perspective [2], [3].

Table 1. End-to-end delays for intra-system mobility on different wireless technologies

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

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