MULTINET: Enabler for Next Generation Pervasive Wireless Services

O. Lazaro[1], A. Gonzalez[1] L. Aginako,[2] T. Hof[3]., F. Filali[4], R. Atkinson [5], S. de la Maza[6], P. Vaquero[7], B. Molina[8], J. O´Flaherty[9], R. Mazza[10]

[1]Innovalia Association, [2]Euskaltel, [3]Thales Communications, [4] Institut EURECOM, [5] University of Strathclyde, [6] TRIMEK, [7] SOLUZIONA, [8]UPV, [9]MAC, [10] Wind

Abstract— Pervasive services provided to the enterprise require from increased speed, performance, degree of personalization, ubiquitous access and reliability. 4G broadband wireless systems and multihoming technologies provide a working framework where such challenges could be met. In the context of a user driven broadband multimedia service and heterogeneous multiple-flow communication network supported system, this paper presents the MULTINET architecture as an enabler for next generation service delivery. The paper will discuss the main entities involved in the system, the main functionality supported and performance. The paper will also highlight initial architecture set-ups and evaluate benefits and drawbacks of the proposed configurations to meet the identified QoS requirements.

***Index Terms*—Ubiqutous Services, Multihoming, NGN, MCoA**

I. Introduction

With the advent of 4G systems the use of heterogeneous communication systems in a transparent manner will effectively facilitate the deployment of ubiquitous services. The availability of multiple communication networks allow data communications and services, providing mobility to users with improved performance connectivity technology, facilitating seamless and intelligent mobile broadband communications at a lower cost, either in terms of battery power consumption or price. This strategic objective is developed by providing European large enterprises and SMEs with the necessary mobile broadband technology to support the Always Best Connected (ABC) paradigm communications. The heterogeneity and multiplicity of networks, available at various locations will enhance the user experience in terms of improved service performance, perceived Quality of Service (QoS) and reduced costs.

This is achievable by means of the MULTINET communication system which will be capable of providing the network and application functionalities so that multiple simultaneous networks can be seamlessly handled to optimize communications in multiple dimensions; while sustaining the existing mobile industry and attracting new business revenue.

The capabilities provided by MULTINET will facilitate high quality mobile broadband multimedia communication services at optimum cost, tailored to the communication requirements. The MULTINET technology provides the necessary networks and application functionality enhancements for seamless data communication mobility in a scenario where the user can benefit without intervention from simultaneous transparent network connectivity among the available access networks.

Current broadband applications provided to the enterprise account for Mobile Office applications (PIM, email, messaging…), will evolve in the near future into a Mobile Workforce (Sales Force, Field Engineers, Logistics…). However, to unveil the full potential benefits of broadband communications to the enterprise it is necessary to develop the IP and network connectivity management functionality which grant access to strategic information assets, i.e. realizing the Mobile Enterprise Applications - ERP, CRM, SCM, PLM. This demands that a more intelligent and flexible use of the available wireless infrastructure is achieved meeting these requirements.

Based on the scenarios described in [2] a number of common needs have been identified as drivers for next generation service enablers. The common needs include:

- Need to Accelerate Transmission at users indication.
- Need to Autonomously Redirect Established Sessions
- Need to Set Up Preferences
- Need for Ubiquitous Access
- Need for Reliability

Current IP-based wireless broadband communication systems suffer from limitations in the aforementioned aspects. It has been only recently that new mechanism to handle multiple IP addresses and managing mobile nested networks were proposed [3]-[8]. Bearing all these requirements in mind and the new emerging multihoming technology, the following paper presents a MULTINET architecture and some initial conclusions on most suitable IP and flow management configurations analyzed.

The paper is organized as follows. Next Section will present the MULTINET reference architecture. Afterwards, some working assumptions will be presented and the main issues regarding IP configurations in a multi-homed environment will be discussed within the scope of the proposed architecture. Finally, the main conclusions will be drawn and future lines of research detailed.

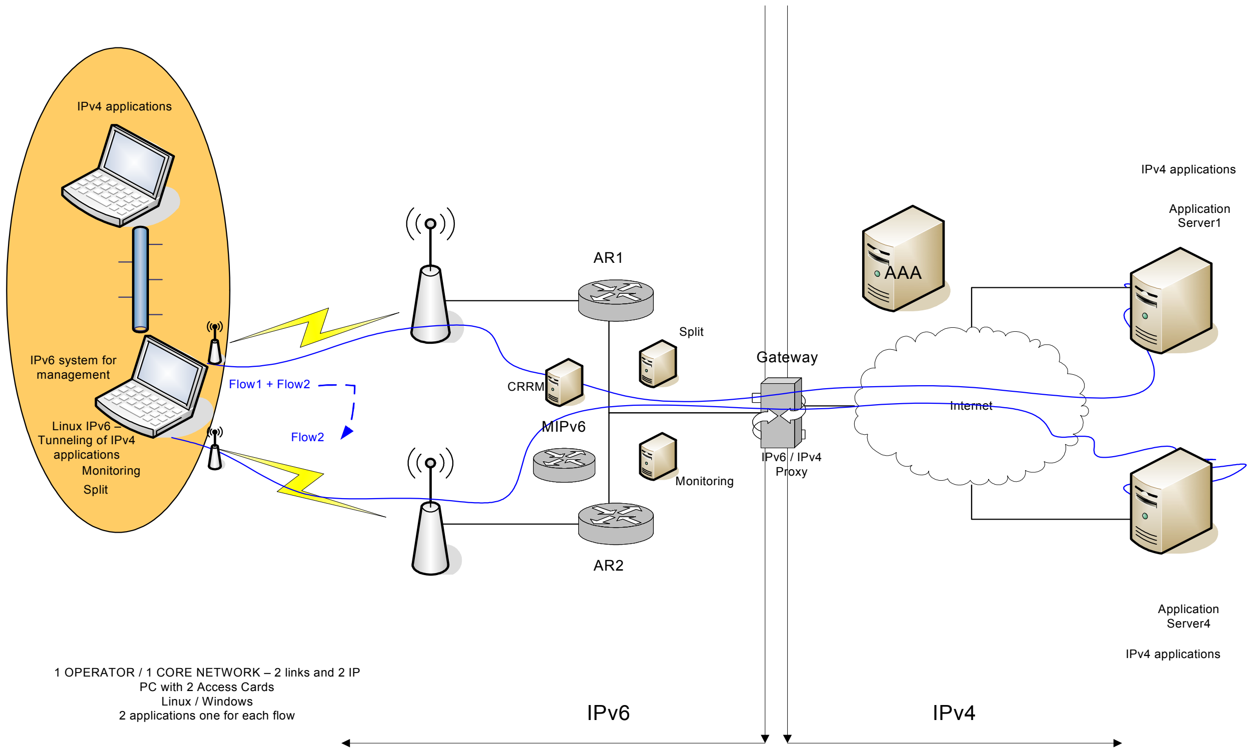

Figure 1 – Multinet Reference Model

II. MULTINET REFERENCE ARCHITETURE

The previous Section has presented the main issues and scenarios addressed by the MULTINET system. The MULTINET reference model is intended for user-driven network-supported approaches to next generation services.

Next generation communication systems will be characterized by a number of wireless communication systems that will cooperate in a seamless manner. Thus, the number of possible network parameter configurations and ultimately the number of options presented to the user will increase significantly.

It is generally acknowledged that early identification, adoption and continuous evaluation of user-requirements in technology development processes is advantageous in terms of succeeding in developing sustainable advanced communication services and applications from a business perspective. Thereby, user is put in control of the communication experience. However, this paradigm shift implies in many cases that complex decisions are left to the end user. Hence, it is necessary that mechanisms are in place to ease the decision making process for technology illiterate end-users.

MULTINET advocates an approach where the user is in control of the communication process and expresses their communication needs through simple commands, e.g. increased speed, increased reliability, increased QoS. These dynamic needs are translated into network level commands through appropriate middleware functions and decisions are supported through advanced network algorithms. The development of such middleware allows that the user is leveraged from complex network configurations through interaction with simpler interfaces. This approach supports wider adoption of next generation services.

This approach follows the experience gained through complex mobile communication systems such as UMTS, where the set of most common configuration parameters supported by the Network Operators are defined and agreed in advance in order to optimize network performance and QoS provision. In this way, it is possible to reduce uncertainty and work with a manageable degree of complexity.

The reference model adopted by the MULTINET project is depicted in Figure 1 MULTINET targets following key features:

- **Use of wireless access networks.**
- **Seamless perception of the user to network connection**. The ABC (Always Best Connected) paradigm targeted by Multinet frees the user from selecting a particular network, as it is the system's intelligence decides the most suitable access network. Nevertheless, the user can have access to a configuration facility which represents an input for the corresponding decision algorithm.
- **Flow management support.** Traditional services such as Internet browsing, multimedia services and file downloads are already supported by wireless networks (GSM, GPRS, WLAN), MULTINET targets broadband multimedia service delivery supported on flow management basis (flow split and handover) taking advantage of the various networks interfaces available to the nomadic user in their network.

The MULTINET reference model defines an open access platform supporting IP-based multi-media services, endowed with the desired functionality in terms of:

- Multihoming
- Load balancing
- Dynamic bearer selection
- Service-aware best-connection and QoS intelligence

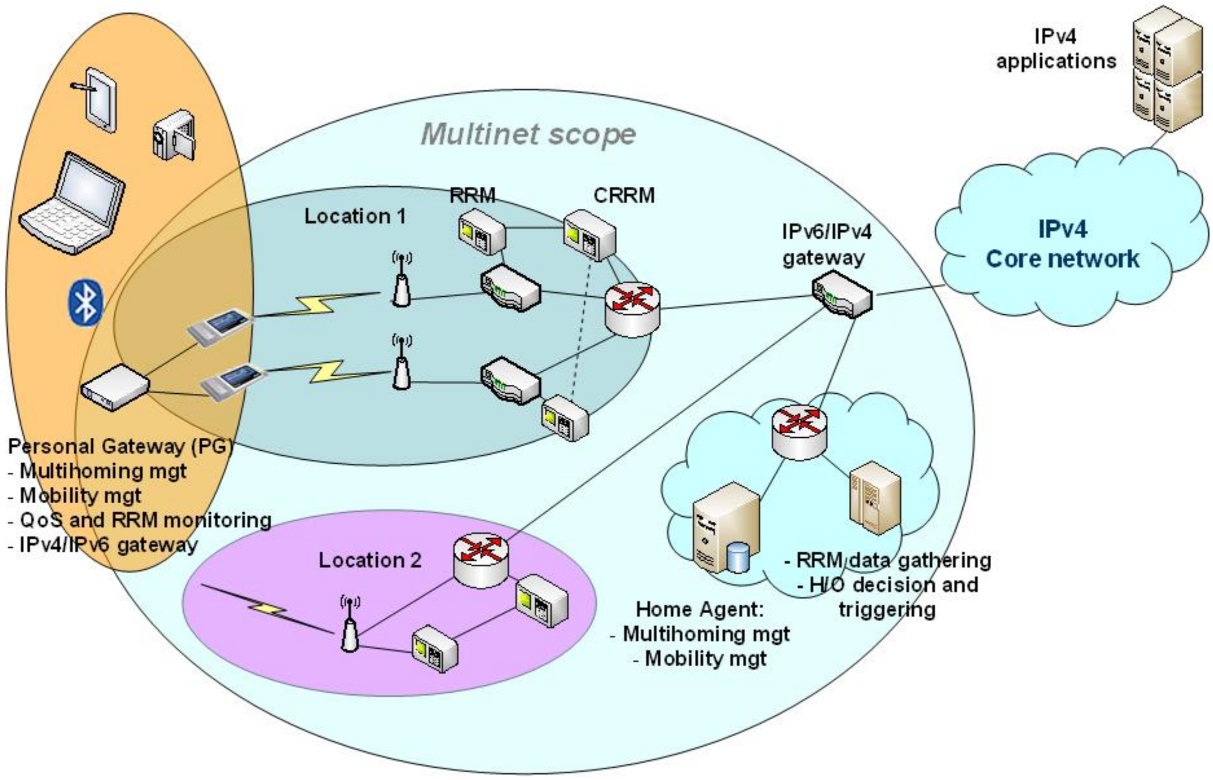

Figure 2 – MULTINET Architecture

It is worth noting that the MULTINET approach does not put additional requirements on the application side. With this respect the proposed reference model decouples "standard" windows-based applications from the advanced MULTINET functionality. This reflects on the development of a Personal Gateway as will become apparent in the following Sections.

One important feature in the reference model above is the fact that a Common Radio Resource Manager is capable of optimizing load balancing and dynamic bearer decisions for each flow. Furthermore, these decisions are based on user initiated service-aware QoS requirements.

The user environment is split into two domains:

- **User devices.** The user device tends to be a simple device, a common laptop, PDA where changes in the applications are avoided or minimized. This allows the use of a Windows platform and common applications. The network driver also runs a common IPv4 stack if required, so less demanding requirements are put on the terminals. This separation is particularly relevant when we consider mobile workforces that normally cooperate in the field and where it is advantageous also to coordinate the communications of the various devices involved in a particular task transparently to the working team.
- **The personal gateway (PG).** The PG allocates part of the workforce team communication environment intelligence. The PG represents a multimode device that permits the use of both many access networks simultaneously or switch from network to network. It provides at least functionalities for mobility, multihoming and IPv4/IPv6 translation support.

The **Access Router (AR)** represents the external router of each access network; this means that any packets arriving from a different network must traverse this AR for establishing contact with any of the nodes located in this access network. This is typically the case of a Corresponding Host (CH) contacting the Mobile Host (MH) through the interface of the PG connected to the AR. As the Multinet platform comprises several wireless access network, each of them will have an access router. It is assumed that all ARs are communicated where other entities – Common Radio Resource Management, Monitoring Manager, Split Manager - are also attached.

The **Common Radio Resource Management (CRRM)** provides supports to the PG in order to determine the best access network (AN) for a given application and in the handover process, since the PG cannot optimally fulfill this process autonomously due to lack of overall knowledge of network conditions.

The **Monitoring Manager** is responsible for collecting information about how the radio resources are being used. It implies inspecting at a flow-level QoS performance. This entity is also responsible for security mechanisms. The Multinet platform handles the split of a flow for service delivery to various IPs related to a single user device. Thus, fractional network bandwidth could be exploited. Without flow splitting individual service performance suffers in terms of both delay and throughput, since there may be insufficient resources to satisfy all service flow QoS requirements. Furthermore, within broadband wireless networks lack of flow-splitting functionality also translates into overall system performance degradation, since each services contends for the resources available and this impacts negatively on already established network connections. The **Split Manager** is responsible for managing multiple flows belonging to the same session. Thus, the corresponding host only perceives a single, high bandwidth flow.

III. MULTINET FUNCTIONAL ARCHITECTURE

The previous Section has presented the main components of a reference MULTINET architecture and the main entities. One of the most relevant features of the MULTINET architecture is the capability of the PG, as an extension of the devices and applications attached to it, to benefit from simultaneous connections to various communication networks. This situation demands that the means to identifying the user devices, sessions and flows operating over the PG are identified univocally. To satisfy this requirement various options exist based on the entity which is in control of the configuration process. The aim of this Section is to present the functional aspects related the MULTINET approach in this context and discuss some associated implications. Current research work focus on Multiple Care of Address and flow distribution aspects. However, discussion in this Section mainly focuses on implications from IP address configuration perspective for user and application identification.

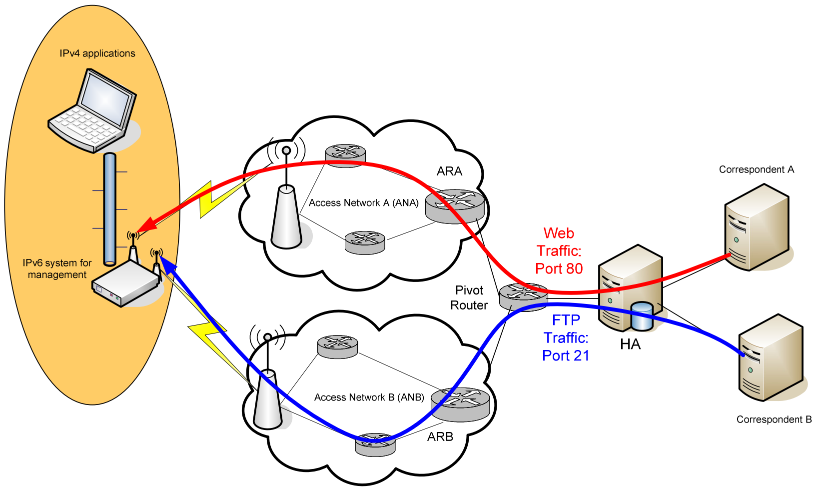

Figure 3 – Multiple IP

A. Multiple IP Address Approach. Network-Centric

The MULTINET functional architecture is based on IP address management supporting Mobile IPv6, through Multiple IP address based solution that is network-centric. Alternatives to such configuration and associated drawbacks are discussed in [9][11]. To facilitate discussion we will consider two access networks, ANA & ANB with associated IP address blocks [a1 … an] and [b1 … bn] respectively. The presence of an intelligent server is also assumed, which is in charge of controlling and diverting data flows accordingly. Its location in the architecture diagram below suggests that it executes access network selection in conjunction with the Network Intelligence Server, based on port addresses. Due to its location in the network it is referred to as the pivot router. As we will discuss later in the paper, for a multiple IP address solution, this component operates as a traditional router, forwarding packets based on destination IP address.

The network operator provides standard telecoms and Internet services in addition to the Multinet solution. The Multinet solution must not interfere with pre-existing IP solutions for non-Multinet users either in the core or access network. Non-Multinet users attached to access network ANA, for example, must be able to communicate with, and hence route to, other users in the Internet and also access network ANB. Thus, any packet within ANA with a destination address associated with ANB will be forwarded to ANB via the pivot router.

The approach taken by the MULTINET project entails that the MN sends binding updates to the MIPv6-based HA. The idea is that the BUs register multiple CoAs with the home agent: one per interface. Unlike a user-centric approach, no port information is associated with each CoA registration; therefore, the HA will have total discretion in mapping flows (via port addresses) to CoA and hence ANs. An intelligent network element, e.g. the CRRM, could generate a mapping policy on a node per node basis and send the policy to the HA, as shown in Figure 3.

This approach enables the network to retain control of the direction of flows in the following manner. The CRRM could operate intelligent network selection algorithms that generate a policy which informs the HA to forward all web traffic (port 80) over ANA and all FTP traffic (port 21) over ANB, for example. The HA would then implement the policy by mapping all port 80 traffic to CoA a1 and port 21 traffic to CoA b1.

B. Performance evaluation of the CRRM module for WLAN

In the previous Section it has become apparent that the MULTINET architecture relies importantly on a CRRM and the NSA to determine the flow to port mapping. This entails that intelligence in the network should not be handicapped by propagation delays of network policies, excessive overheads and that relevant information is passed to the core decision engine, the NSA, of the MULTINET system.

This Section presents some preliminary studies on the CRRM performance, data estimation accuracy and overheads that will be substantiated in the final version of the paper with initial test-bed results currently being obtained.

The CRRM operation can be described as follows. CRRM collects measurements from the different access points of the subnetworks. Measurements could be collected periodically or when the WLAN's RRM receives a measurement request from the CRRM module.

The measurements collected by the WLAN's RRM concern mainly the available resources in terms of bandwidth at each access point connected to the available access routers. The measurements are sent back to the CRRM.

The tool used for bandwidth availability estimation is called wimeter (wireless meter tool). Wimeter captures and analyzes on real-time all frames going to or coming from an access point in order to estimate the traffic load and to compute the available bandwidth. To this end, our tool incorporates new sophisticated methods to split the duration of a measurement period between defer, backoff, busy, and free timeslots. One important result that we got from the analysis is that the estimated bandwidth is a function of the size of data packets expected to be sent during the free period as well as the link-layer capacity of the sender and the receiver stations as 802.11 uses a link-layer rate adaptation technique to enhance the reception and transmission quality. The observations made based on extensive real experimentations show that wimeter is able to capture almost all frames and provide an accuracy estimate of the available bandwidth in a very dynamic fashion. The reader can find in [10] extensive details about the functionalities of wimeter as well as the theoretical features that it includes.

To illustrate the performance of wimeter to estimate the available bandwidth efficiently, we show hereafter real-experimentation results conducted for a scenario of a single CBR traffic.

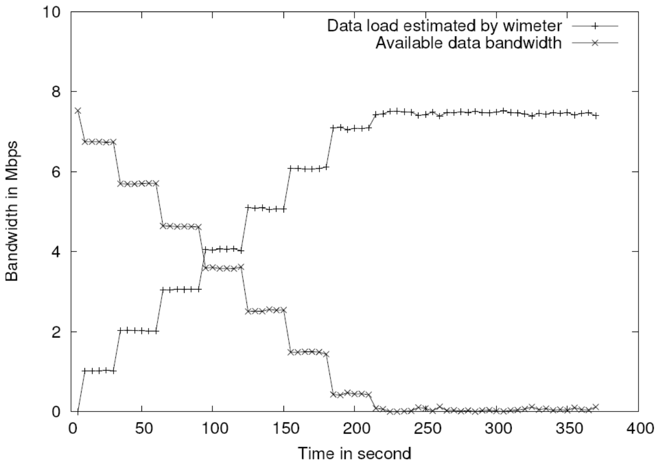

Figure 4 The variation of the available bandwidth computed by wimeter when the source rate increases from 0Mbps to 11Mbps

Figure 4 depicts the results obtained for a scenario where there is only one source which is increasing its sending rate from 0 to 10Mbps. As we can see, when the source sending rate increases, wimeter is always able to capture the new behavior of the source and to correctly estimating the source throughput as well as the available bandwidth. Furthermore, the available bandwidth drops to 0 when the data throughput is close or bigger than the saturation throughput (7.4Mbps). Hence, when the source sending rate is 8Mbps, 9Mbps, 10Mbps, and 11Mbps, the data throughput and the available bandwidth remains constant.

Note also that the overall bandwidth (including control and management packets) is very close to the data throughput which means that the overhead induced by control and management packets (such as DHCP, ARP, and MAC beacon packets) is very low.

IV. Conclusions

This paper has presented the MULTINET approach to enable next generation ubiquitous services. MULTINET reference architecture facilitates a user-initiated network-supported approach, which relies on the availability of a Personal Gateway with support capabilities for mobility management of nested networks, multihoming and IPv4/IPv6 translation for mobile working force applications. The advantages of MCoA and a network centric IP configuration on the MULTINET scenarios have been presented and a preliminary solution based on a Common Radio Resource Management scheme and Multiple Care of Address capabilities discussed. Current work is focusing on extending the analysis on estimator accuracy and solution scalability performance estimation.

Acknowledgment

This work has been partly funded by the European Commission through IST Project MULTINET: Enabler for Next Generation Service Delivery (No. IST-2005-027437). The authors wish to acknowledge the Commission for their support. We also wish to acknowledge our gratitude and appreciation to all the MULTINET project partners for their contribution during the development of various ideas presented in this paper.

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