Enhancing Naming and Location Services to support Multi-homed Devices in Heterogeneous Environments

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Abstract— **The growth of the Mobile Internet is being fuelled by the development of heterogeneous devices which have several wireless interfaces. This brings new challenges which require a critical examination of current Internet Infrastructure with a view to providing better support for mobility, multi-homing and virtual networking. This paper considers a recently published solution to the multi-homing issue, and based on that proposes enhancements to support the core location and naming servers with the introduction of the Master Locator and the Enhanced DNS.**

Keywords-component; multi-homing; the Master Locator; the Enhnaced DNS; the Y-Comm framework.

I. INTRODUCTION

The growth of the Mobile Internet continues apace. Mobile handsets and laptops will soon have several wireless interfaces including 3G, WLAN 802.11 a/b/g and Ultra Wide Band systems with WiMax and Long Term Evolution (LTE) as the newest wireless technologies being developed and deployed. Consumers will expect these devices to seamlessly maximize the use of these networks using vertical handover techniques [1]. In the near future, therefore, a significant number of peripheral networks attached to the Internet will use wireless technology. This emerging trend also raises several issues for the core of the Internet as it represents a significant network evolution with more support for mobile environments being a key requirement of future networks.

Support for mobility will also require the development of location systems within the Internet. Present mobility management techniques such as Mobile IP [2] are proving inadequate and need to be enhanced. Mobile devices with several interfaces bring the issue of multi-homing to the fore. Multi-homing in wired systems tends to be confined to core network infrastructure such as routers and gateways. However, with mobile heterogeneous devices becoming ubiquitous, multi-homing issues need to be addressed.

The issue of multi-homing has been investigated by different research efforts such [3][4][5][6]. In a recent work, the Y-Comm group has introduced a novel addressing scheme to deal with multi-homing and support vertical handover [7].

The authors argued that the current location systems will not be able to effectively operate in the multi-homed, heterogeneous environments such as 4G systems, and thus, there is a need to enhance some existing network entities such as the Home Location Register (HLR) [8], by introducing the concept of the Master Locator (ML). In addition, the proposed addressing scheme attempts to improve overall network security by the introduction the idea of scope for servers [10] [11].

With regards to the location systems, it is believed that, as huge number of multi-homed, mobile devices move and change their addresses, this will raise a serious management challenge to current naming servers such the Domain Name Server (DNS) [9][15] as they have to cope with a large number of frequently-changing available addresses. This paper investigates the effect of multi-homed environments on the DNS servers and in the context of the proposed addressing scheme; it suggests some enhancements to cope with the situation. The rest of the paper is outlined as follows: Section 2 looks at the multi-homing issue and its impact on the DNS and HLR services. Related work such as the Y-Comm framework and the recently proposed addressing scheme are described in Section 3. For the addressing the problem of multi-homing, the proposed solution in Section 4 is mainly related to enhancing the current DNS and HLR services. Section 5 describes current work to develop a testbed for implementing the proposed solutions. The paper concludes in Section 6.

II. PROBLEM DEFINTION

In future heterogeneous environments, a mobile node (MN) will have multiple interfaces which will enable it to join different peripheral networks. Current addressing schemes such as IPv4 and IPv6 [14] identify the network interface card (NICs) rather than the node itself. Consequently, a multi-homed node will have multiple addresses; however, there is nothing to indicate that these addresses are collocated on the same node. The authors in [7] highlighted the challenges of

this situation in terms of routing and QoS, then as a potential solution, a novel addressing scheme has been proposed. This section investigates the impact of the multi-homing issue on current naming and location systems such as the DNS and the HLR.

A. The DNS Concerns

The DNS is a key player in Internet communication; it is responsible for resolving human- friendly domain names to IP addresses. Also, the DNS defines a hierarchical naming space that helps in identifying and locating the resources in the Internet. Since Next Generation Networks (NGNs) such as 4G systems will be IP-based, the operation of the DNS should be incorporated into future NGNs.

Currently, the DNS database holds all resource names and maps them to the corresponding IP addresses. However, with multi-homed nodes, a node will have more than one entry in the DNS database each with a different IP. This means the node is accessible over multiple networks each with different characteristics in term of coverage, QoS and security. Therefore, in the case of access requests by a multi-homed node to a multi-homed server, the DNS cannot just do a load balancing and use round-robin techniques to decide which address to use because the characteristics of the different routes/networks leading to the server have to be considered when choosing the address. This situation indicates the need for major changes to the DNS operation, which will be introduced later as an Enhanced DNS (eDNS) server.

B. The HLR Concerns

The concept of the HLR has been mainly used by cellular networks such as GSM, TDMA and CDMA [8] to hold subscribers' information. This works fine in homogeneous environments where the MN roams within the same technology; thus, the HLR is capable of tracking the MN's movement and consequently delivering mobile calls. The problem in heterogeneous environments is that, a multi-homed node might join and handover between different technologies with separated HLRs. However, there is no coordination between these different entities, thus, the MN's mobility will not be tracked and the calls cannot be delivered. Additionally, the open and dynamic nature of heterogeneous systems as in 4G networking implies that the MN does not initially have a contract with a single network or operator rather an agreement with a central management entity in the core network to use the peripheral networks of different operators; thus, the MN cannot consider a single operator as a home network and consequently, the concept of the HLR does not fit with the multi-homed, future and heterogeneous networks. To deal with this situation, a generic, cross-operator location system called the Master Locator will be introduced later in this paper.

III. PREVIOUS WORK

This section briefly looks at related work as well as the recently proposed addressing scheme as introduced in [7].

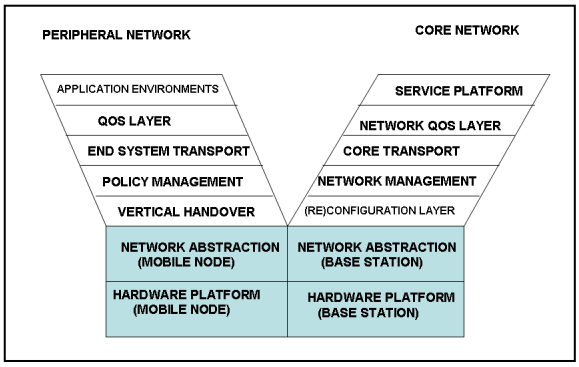

Figure 1. The Y-Comm framework

A. The Y-Comm Framework

Y-Comm [12][13] is a 4G, communication architecture to support vertical handover for multi-homed nodes in heterogeneous environment. The architecture has two frameworks:

- The Peripheral framework deals with operation on the mobile terminal.
- The Core framework deals with functions in the core network to support different peripheral networks.

As shown in Fig 1, the two frameworks share a common base subsystem consisting of the hardware platform and network abstraction layers. Both frameworks diverge in terms of functionality but the corresponding layers interact to provide support for heterogeneous environments.

To support multi-homed nodes, the Network Abstraction Layer (NAL) contains the drivers of different networks and thus provides a common interface that supports different networking technologies. Additionally, issues such as network operability and overlapping are addressed by this layer.

B. Location/Node ID addressing

One approach to tackle the multi-homing issue is to use the concept of a Location_ID/Node_ID address scheme, where the Node_ID identifies the node irrespective of its network interfaces. This concept was originally investigated in [5] and has also been recently pursued in the development of the Identifier Locator Network Protocol or ILNP [16]. ILNP attempts to use DNS facilities to support mobile devices. These efforts while sensible introduce major new functionalities such as mobility management to DNS services which because of frequent accesses can potentially overload the DNS. The approach taken in this paper extends the HLR concept through the introduction of a Master Locator to deal with the mobility of end devices.

C. A Recently Proposed Addressing Scheme

Recently, the Y-Comm group [12][13] has proposed a novel addressing scheme in [7], which is an enhancement of the Location/Node identifier concept. In order to maximize network operation, this new scheme changes the Location_ID/Node_ID format to Location_ID/ NetADMIN/ Node_ID format, shown in Fig 2.

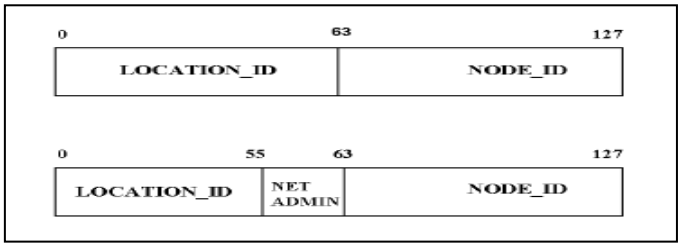

Figure 2. The Address Format

The new NetAdmin field performs network administering tasks as follows:

- The Scope Field (SF): it is a 2-bit field, responsible for defining nodes' accessibility. The value 00 represents a local service which could be accessed only from within the same machine, so remote devices will not even know about these services. The value 01, indicates LAN scope in which the node is only accessible by other devices on the same LAN. The value 10 signals that only machines on the same site are allowed to access the server. The value of 11 denotes that the device can be globally accessed
- The Static (S) field: this 1-bit long field indicates that the node is static or mobile.
- The Multicast (M) field: when it is set, this bit indicates whether the address represents a multicast group rather than a unicast address.
- The Interface Number Field (INF) is a 4-bit field used to address up to 16 virtual or physical network interfaces. Where the address 0 defines any-cast address, 0xF is a broadcast address and 0x1 is the primary interface. More details about these fields and their functions are found in [7].

This paper is about proposing enhancements to the networking infrastructure via an enhanced DNS and the Master Locator in order to implement the new address format.

IV. THE PROPOSED SOLUTIONS

In addition to making major modifications to current location and naming services, the authors believe that, in order to tackle the afore-explained problems, there is an urgent need to define an operational model to specify how the Master Locator (ML) and the eDNS cooperate. However, before proceeding in explaining the new model, a brief description of future network structure as proposed in [17] is presented in this section.

A. *Future Network Architecture*

As previously mentioned, the future Internet might be viewed as composed of a super fast core network with attached slower peripheral networks. These networks will be connected to the core network via Core End-Points (CEPs) as shown in Fig 3. Each peripheral network can be represented as a domain which is managed by technology-dependent entities such as Base Station Controllers (BSCs), and as a result the CEP can also be viewed as an Administrative domain which control these domains.

To provide security and QoS–related functions as well as to support vertical handover, different network entities should operate in the Administrative-domain such as the Centralized AAAC server (CA3C) and Centralized QoS Broker (CQoSB). These in turn interact with the Domain A3C server (DA3C)

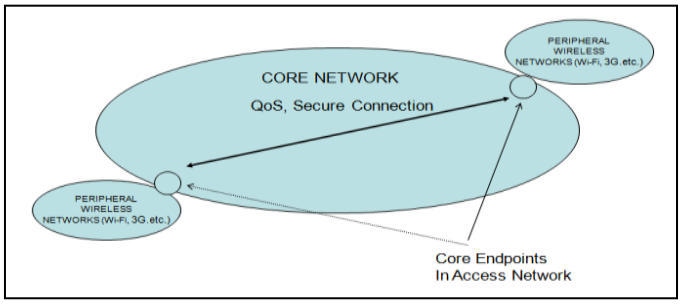

Figure 3. Future Internet Architecture

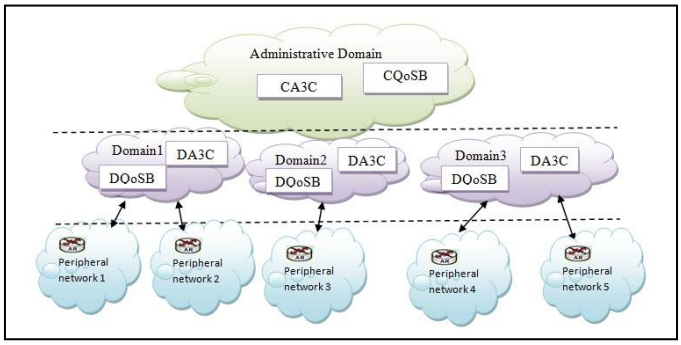

Figure 4. Network Hierarchical structure

and the Domain QoS Broker (DQoSB) in each domain. More details about the functions and structures of these entities could be found in [17].

B. *New Requirement for Supporting Naming and Location services in Heterogeneous Environments*

As mentioned previously, the concept of a Master locator, which is located in the core network, is used to tell corresponding nodes about the networks to which mobile node is currently connected. The corresponding node therefore polls the Master locator to find out the various networks to which the mobile device is currently attached. These ideas are compatible with mobility management mechanisms in commercial mobile networks which use the concept of the Home Location Register (HLR).

In order to choose the best connection between two end-points, in this multi-homed environment, it's necessary to know about the QoS of each network, the mobility of the device and the mapping between the Location_IDs and the relevant network interfaces. In our proposed solution, this functionality is achieved by evolving the HLR concept to the ML which is responsible for tracing the MN over different networks. In a heterogeneous environment, an Internet name will now map to same Node_ID but with several Location_IDs. In order to help the CN to choose the best connected network, it is necessary to enhance the DNS to provide added support. However, in order to achieve this, the eDNS and the ML need to cooperate and interact with other components in the network such as the CQoSB at the CEP.

Fig 5 shows these ML-eDNS interactions, the model describes the transactions, needed for initiating a connection between the CN and the MN as follows:

- Msg 1: The CN asks the eDNS server for MN's address(es).
- Msg 2: The eDNS uses the MN's name to look up in its database and since the MN is a multi-homed device, its name will be resolved to different addresses which share the Node_ID part, and this implies that the MN is accessible over different routes/ networks. However, the eDNS cannot define the best route for the connection request as it does not keep track of the QoS of the different networks. Therefore, the eDNS returns the MN's Node_ID and the address of the ML that manages the mobility of MN.
- Msg 3: The CN polls the ML to find out the different networks to which the MN is currently attached. The ML approaches the CQoSB in the related CEP to get QoS-related information about these networks. In addition, the MN also informs the ML about which networks it is using and the related interface numbers, this information is cached in the ML.
- Msg 4: A list of MN's Location_IDs along with their QoS specifications is then passed to the CN, which chooses the MN's route and thus the corresponding Location_ID.
- Msg 5: At this stage, the CN has MN's Node/Location IDs and it can start the procedure for setting up the connection in term of QoS signaling and resource allocating.

Fig 6 shows the case of a stationary destination node (SN) with a single Location_ID, this implies that either the SN has a single interface or is multi-homed within a single domain. In this situation, the CN uses the location_ID without referring to the ML.

C. The Structure of the Enhanced DNS (eDNS)

The section above showed that the eDNS's response depends on the status of the node whether it was mobile or stationary. This implies that it is crucial for the node to declare its status to the eDNS; this could be achieved using the address format including whether or not it is stationary as well

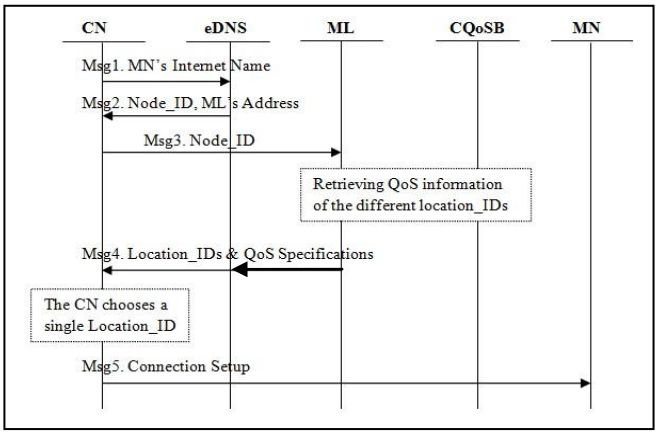

Figure 5. The Connection Initiation Model in case of mobile node

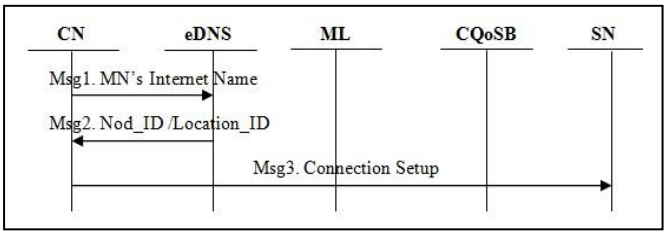

Figure 6. Connection Initiation Model in case of stationary node

TABLE I. THE EDNS RECORDS

Internet Name	Node_ID	S	M	SF	Location_ID	ML's Address
Name1	Node_ID1	1	0	01	Location_ID1	ML- Add
Name2	Node_ID2	1	0	10	Location_ID2.1 Location_ID2.2	ML-Add
Name3	Node_ID3	0	0	11	Location_ID3	ML-Add
Name4	Node_ID4	0	0	10	Location_ID4.1 Location_ID4.2 Location_ID4.3	ML-Add

as whether it is a multicast node and its related scope. This discussion highlights the need for major enhancements to the current DNS server; table I shows required fields that need to be added to DNS records.

As shown in the table, based on the value of the S Field and the Location_IDs, the eDNS's response changes; the first two entries indicate two multi-homed, stationary nodes (S= 1); however, the first is multi-homed in the same domain (one location_ID) while the second is stationary with respect to both domains (two Location_IDs). Similar discussion goes for the last two entries indicating two multi-homed, mobile nodes (S= 0). The other columns are included in the eDNS records for security purposes such as the SF which indicates the destination's accessibility. This means that whenever the MN joins a new network, this has to be registered to the eDNS.

D. The Structure of The Master Locator

The Master Locator is responsible for managing and tracking the MN's mobility between different network operators in the heterogeneous environment. The mobile node informs the ML of its movement in the case of a handover. The ML stores this information and then passes it to the CN to choose the best route to the MN.

For effective tracking of MN mobility, we also propose an additional 4-bit field, called the Mobility Vector which is used as a hint of how mobile the node is on a given network. When a mobile node has moved to a new network, its mobility field is set to 15 (0xf). For every second that the mobile remains in the specified network, the mobility field is reduced by one until it becomes zero. The mobility field is used to distinguish between mobile environments with small coverage such as a WLAN hotspot and a large coverage system such as an UMTS network. This will help the CN to decide which network will be suitable to send different types of data. Sensitive data that require a secure and reliable channel with little packet losses would use the UMTS network, while video data may choose the more unreliable channel as it is more tolerant of packet loss. Table.2 shows the structure of the Master Locator.

As shown in Table II, the ML stores the different Location_IDs, the corresponding interface given by its INF, the mobility vector and QoS specification of each network to which the MN is attached.

TABLE II. THE MASTER LOCATOR RECORDS

Node_ID	Location_ID	INF	Mobility Vector	QoS Specifications
Node_ID1	Location_ID1.1	INF1.1	Value1	QoS1
	Location_ID1.2	INF1.2	Value2	QoS2
Node_ID2	Location_ID2.1	INF2.1	Value3	QoS3
	Location_ID2.2	INF2.2	Value4	QoS4

V. A PROPOSED TESTBED

In order to explore this further, a new testbed composed of mobile devices and linux routers capable of supporting 3G using OpenBTs [18] as well as WiFi network is being constructed at Middlesex University. This would be used to implement the new addressing scheme along with the eDNS and the ML to evaluate their performance.

VI. CONCLUSION AND FURTHER WORK

This paper re-examines the Internet Architecture with a view to urgently addressing problems resulting from moving towards future, heterogeneous and multi-homed environment. It proposed major enhancements to some networking systems such as the HLR and DNS by introducing the ML and the eDNS to adopt a new addressing scheme that deals with the multi-homing and supports the concept of scopes that has been used by Y-Comm's Ring-Based security model.

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