Usage of IPv6 in Selected 3G and 4G Architectures

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Abstract

This paper looks into usage of Internet Protocol version 6 (IPv6) in two different network architectures defined by the Third Generation Partnership Project (3GPP) and the Moby Dick research project. These two architectures seem to have similar goals but fairly different approach to reach them. The 3GPP architecture has a clear telecom background with backward compatibility requirements towards circuit switched networks. Still, Internet Protocol (IP) is seen as the base protocol for future connectivity also in the 3GPP architecture. The Moby Dick architecture has more straightforward approach. It takes physical- and data-link layer transmission functionalities of different access network as given, and exchange all existing higher-level tasks by fully IP-based mechanisms. The Moby Dick architecture is based on using enhanced Mobile IPv6 and also more the Internet oriented than the 3GPP architecture.

1 Introduction

Since early days the communication has highly concentrated on voice and text. In telecom network voice and Short Message Service (SMS) have been the most popular services. However, the Internet has now shown that many other services can also appeal to people. Services like peer-to-peer file sharing and peer-to-peer gaming are already today generating far more traffic in global backbone network than ordinary web surfing. Bringing this type of services to mobile environment seems to offer great potential and even further interesting usage scenarios. Unfortunately today's Internet is not very mobile as connectivity is often bound to end of a cable or, in best case, inside a small Wireless Local Area Network (WLAN) hot spot. On the other hand bringing an advanced service support to today's voice oriented telecom mobile networks is not an easy task either.

Globally different forums, companies and societies seem to have common view that IP is the protocol that will enable new possibilities for future communications. Depending on the viewpoint, this may mean bringing voice on top of IP to enable Voice over IP (VoIP), or improving underlying IP support to enable new service concepts. Good examples of different viewpoints behind these examples are the Internet society and the telecom industry, as both are constantly searching for solutions to enable greater service selection based on the usage of IP.

Next step towards higher mobility seems to be interworking between different access technologies, i.e. network convergence. Again, IP seems to be the common nominator behind the access technology convergence. Using IP as the common underlying connectivity technology between different networks enables more seamless mobility between them.

2 Short Introduction to IPv6 and Mobile IPv6

The Internet Engineering Task Force (IETF) started work on the Next Generation Internet Protocol (IPng) in the early 1990s and in September 1995, officially delivered the core protocol of IPv6. The most significant characteristic of IPv6 is that it substitutes 32-bit IP version 4 (IPv4) addresses with 128-bit addresses. In addition to larger address space, IPv6 provides built-in improved support for Quality of Service (QoS), security, and mobility. IPv6 eliminates the need of private IP address spaces and Network Address Translators (NAT) due to its huge IP address space, i.e. every terminal can be allocated one or even several global IPv6 addresses. Thus, with IPv6 we can get rid of NAT and private address space maintenance. More generally speaking, IPv6 supports better 'always-on' and peer-to-peer type applications than IPv4 and improves this way users possibility to communicate more seamlessly. [1]

The generic problem with IP mobility is that when an IP node moves to a new access network, it has to change its IP address to reflect the new point of attachment. Changing the IP address seen by the transport and the application layers every time a Mobile Node (MN) moves to a new network may be a solution to infrequent roaming, but not to mobility in general. Mobile IPv6 solves the mobility problem by managing the correlation between a changing IP address (Care-of-Address) and the static home address. The transport and application layers keep using the home address, allowing them to remain ignorant of any mobility. The home address is naturally routed to the Home Agent (HA), which maintains the mapping from the home address to the current Care-of-Address (CoA). The HA will tunnel packets to the MN at its current point of attachment by the CoA. As the MN moves from one network to another, and its CoA changes, it will inform the HA of the new binding. [1]

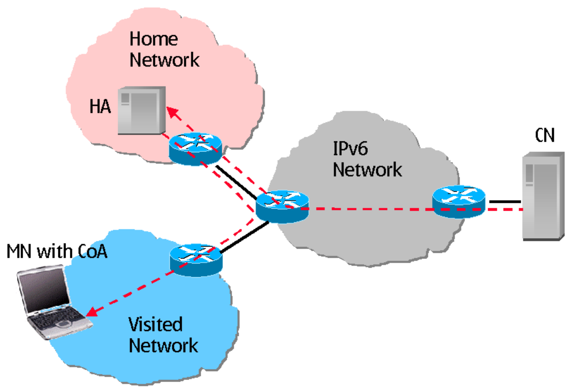


Figure 1: Mobile IPv6 functionality

3 Third Generation Partnership Project

The Third Generation Partnership Project (3GPP) is a standardization forum that was established in December 1998. The original target of the 3GPP was to work on technical specifications over a 3rd Generation mobile system (3G). Since then the work has widen to include the maintenance and development of the well known Global System for Mobile communication (GSM) including evolved radio access technologies (e.g. General Packet Radio Service (GPRS) and Enhanced Data rates for GSM Evolution (EDGE)). [1] In practice this means that also the maintenance work of the GSM standardization has been gradually moved from the European Telecommunications Standards Institute (ETSI) to the 3GPP since 1998 [3].

When established, the 3GPP decided to provide new specifications on yearly basis and the first specification release was named as Release 1999. Main work on Release 1999 was finalized in a year. Next the 3GPP started to work on Release 2000. This release was also planned to include so called All-IP (All Internet Protocol) that was later, more or less, renamed as IP Multimedia Subsystem (IMS). During year 2000 it was seen that the development of Release 2000 could not be completed within year. This realization was followed by decision of splitting Release 2000 into Release 4 and Release 5. [3]

It was agreed that Release 4 would be completed without All-IP, or IMS as it was now called. With this division the 3GPP was able to complete Release 4 in March 2001. However, changed required due backward compatibility where still made as late as September 2002. The most important new functionalities in Release 4 included the Mobile Services Switching Center Server (MSS) - Media Gateway (MGW) concept, IP transport of core network protocols, Location Service enhancements for Universal Mobile Telecommunications System (UMTS) and multimedia messaging, and IP transport for user plane. [3]

The standardization of the IMS was started in Release 5. The IMS is defined as access agnostic IP-based core architecture that interworks with both voice and data networks for fixed and mobile users. The 3GPP standardizes the IMS to provide the most important core functionalities of future IP networks. The content of Release 5 was widely debated during the work and finally it was decided that some IMS work items would be moved to next release named Release 6. Content of Release 5 was officially frozen in March 2002 but there are several changed been made to this release since then. [3]

The 3GPP work has continued with Release 6 and lately also with Release 7. However, this paper will discuss on the specification work already done to the existing 3GPP releases and concentrate mainly on the 3GPP Release 5 IMS functionality and IPv6 usage.

4 IPv6 in 3GPP Architecture

Since early days, the 3GPP has included IP as an integral part of its long-term architecture strategy. This targeted wide use of IP in the architecture is often referred as the All-IP architecture. It means that IP would be used as main protocol on both user- and transport layer of 3GPP architecture. Furthermore, the 3GPP has also been driving usage of IPv6 as main IP version in future architecture. The best example of IPv6 support requirements is the IMS specification work started in Release 5 [7]. In addition, option to use IPv6 on user layer has already been specified in earlier 3GPP releases within several steps. It is usually seen that full support to use IPv6 on user layer was required by Release 1999. To be able to use IPv6 on the user layer, all involved network elements, including e.g. Serving GPRS Support Node (SGSN), Gateway GPRS Support Node (GGSN), Radio Network Controller (RNC) and Domain Name Server (DNS), have to support IPv6 as specified [8] [9]. [10]

The main high-level functionality of the 3GPP IMS architecture is the capability to enable peer-to-peer connections between terminals using IP. Legacy Circuit Switched (CS) telephony technology has enabled peer-to-peer connections as basic functionality but this has not been possible with IP-based applications. By allowing IP-based applications to have peer-to-peer connectivity, IMS will indeed create new service possibilities that have not seen earlier even in the Internet ecosystem. Central enabler of peer-to-peer IP services within the IMS is Session Initiation Protocol (SIP). Core functionality of the SIP has been specified in the IETF Request For Comments (RFC) 3261[11]. [3]

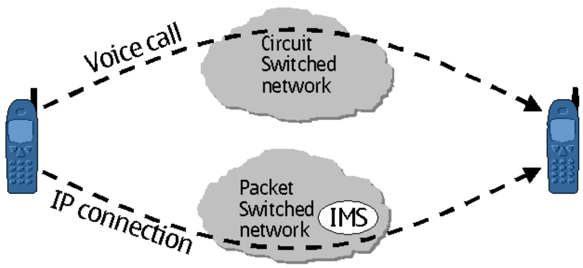


Figure 2: IMS enabling peer-to-peer connectivity

The IMS functionality can be seen similar to Mobile Services Switching Center (MSC) functionality in CS networks. Both architectures are providing mechanism to call to another person based on phone number or other address information. Where MSC works in CS network, IMS provides same functionality for Packet Switched (PS) environment. This comparison is illustrated in Figure 2. In addition, the 3GPP IMS architecture and functionalities are shown in the Figure 3

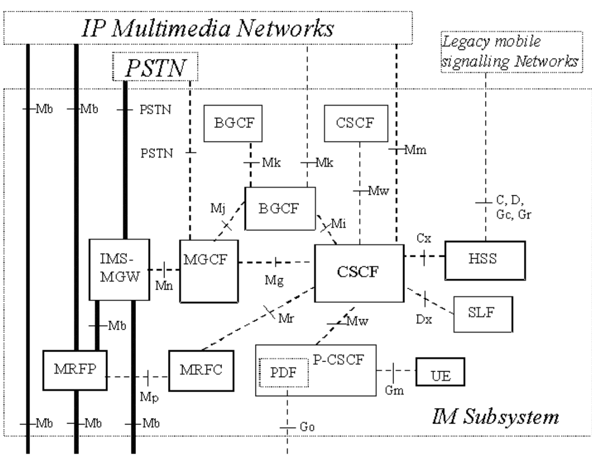


Figure 3: IMS system architecture and entities [12]

The 3GPP Release 5 specification is highly based on using IPv6 addressing with IMS. In the 3GPP Release 5 IP multimedia call control protocol specification [13] it has been stated that all IMS entities are allocated IPv6 addresses in accordance with the constraints specified in the architectural specification [7]. Also, in the same IP multimedia call control protocol specification [13], it has been stated that for the purpose of access to the IMS, User Equipment (UE) is assigned with IPv6 prefixes in accordance with the constraints specified in the architectural specification [7].

However, as further stated in the 3GPP Release 5 architectural specification [7], IP transport between network elements of the IP Connectivity services, e.g. between RNC, SGSN and GGSN and IP transport for the circuit switched domain can be provided with both IPv4 and IPv6. This means that routing between network elements can still be done with IPv4 and no IPv6 support is required at layer 3. This way the 3GPP states that it is just so called user layer, which is supposed to utilize IPv6. Figure 4 illustrates how the IPv6 user layer is defined. Lower IP layer, responsible of IP connectivity between elements can still utilize IPv4 as previously.
The 3GPP states that Release 5 architecture shall make optimum use of IPv6 [7]. The 3GPP specifications design the IMS elements and interfaces to exclusively support IPv6. However, early IMS implementations and deployments may use IPv4. In case IPv4 is used, the guidelines and recommendations in TR 23.981 [14] should be followed. Similarly, the 3GPP specifications also design the UE to exclusively support IPv6 for the connection to the IMS. The UE shall support IPv6 for the connection to the IMS. However, UEs may in addition support IPv4, which allows for the connection to early IMS that use IPv4 only; in this case the guidelines and recommendations in TR 23.981 [14] should be followed again. [7]

Originally, only usage of IPv6 was allowed for the IMS and for UEs connecting to it. This requirement was later on lightened to allow also IPv4 in early launches as described in [7]. A reason for the original 3GPP requirement to use IPv6 was the complexity seen to arise from the need of interworking between IP versions and possible future transition mechanisms required if IPv4 would be allowed. Also, as IMS is supposed to offer peer-to-peer service capability with globally unique addressing, usage of IPv6 with much larger address base was seen as clear requirement. Using IPv4 could simply not allow providing dedicated IP address for all the end-user terminals. However, it was later on noted that elements that are not directly specified under the 3GPP work, e.g. firewalls, are not offering IPv6 capabilities at required level and operators seem no to be willing to upgrade their existing network to IPv6 capable. As a result, allowing the deployment of IPv4 based IMS; lead the 3GPP to be forced to give also guidelines for IPv6 and IPv4 interworking. These guidelines are now stated in TR 23.981 [14].

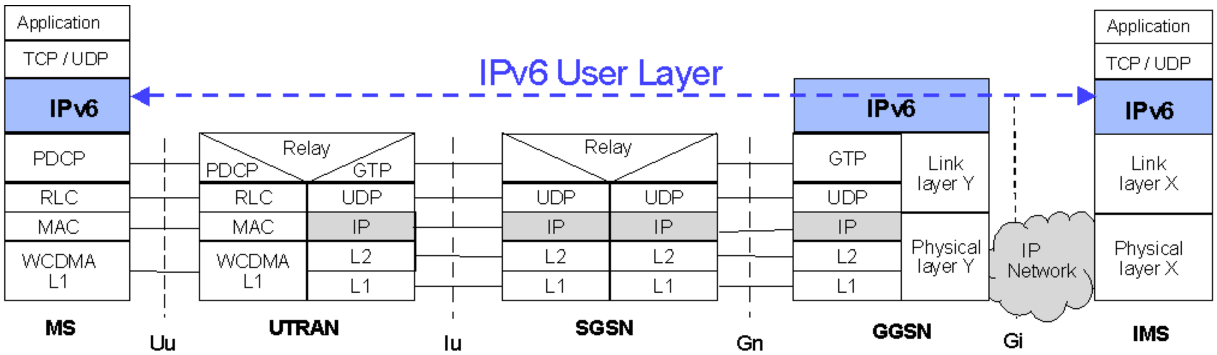


Figure 4: Usage of IPv6 as specified in the 3GPP

5 Moby Dick Project

Moby Dick was three year European Union (EU) Information Society Technologies (IST) project finished in December 2003. Project name Moby Dick comes from the wording “Mobility and Differentiated Services in a Future IP Network”. The main objective of the Moby Dick project was to study and test IPv6 based and QoS enabled mobility architecture comprising Universal Mobile Telecommunications System (UMTS), Wireless Local Area Networks (WLAN) and Wired Local Area Networks (LAN) based on Ethernet. This mobility paradigm is illustrated in Figure 5 below. [4]

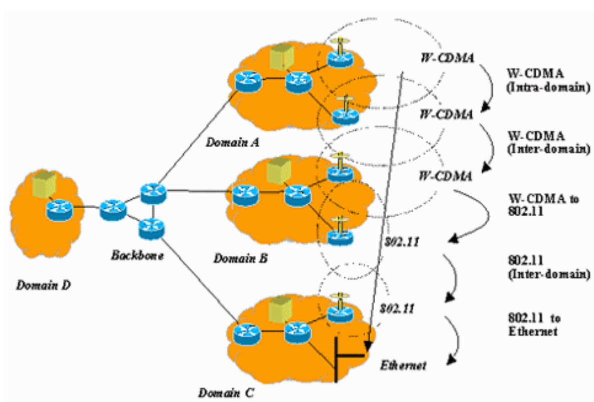


Figure 5: Mobility paradigm of the Moby Dick [4]

The Moby Dick project can be seen to fall under Fourth Generation (4G) research studies that search evolution of 3rd Generation mobile systems. It incorporates UMTS integration towards other wireless infrastructures, including especially WLAN. A further, important aspect of the Moby Dick project was the mobility between wireless and fixed IP networks. The Moby Dick work was based on the Internet paradigm, meaning that the IETF standardization work was the baseline for the Moby Dick project work [4].

Other Moby Dick technical key issues included [4]:

- Definition of a common architecture integrating QoS, IPv6 mobility, and Authentication, Authorization, Accounting and Charging (AAAC) with respect to wireless issues.
- Implementation and evaluation of an IPv6-based end-to-end technological approach to fulfill the requirements of present and future mobile communication services.
- Implementation and evaluation of QoS models (e.g. Differentiated Services) in highly dynamic and heterogeneous network topologies.
- Definition of a suitable charging concept, which would enable permanent mobile IP-based services on a large scale.

Wireless Europe magazine described in its January 2004 issue [6] how the Moby Dick project maps with the 3GPP standardization work. This very high level alignment is presented in the Figure 6. It shows how the Moby Dick project is seen to base on IPv6 and has similar scope with the 3GPP work but no direct connection to it.

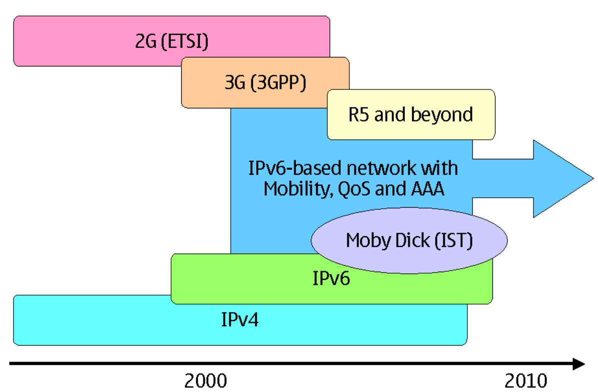


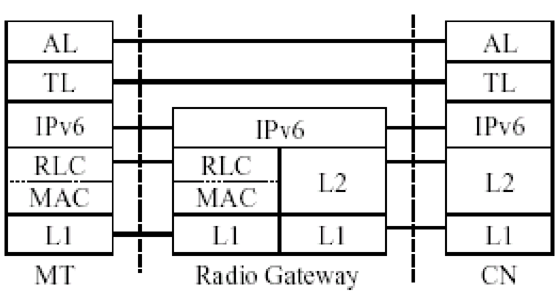
Figure 6: Alignment of 3GPP and Moby Dick [6]

The development work of seamless converged mobile network architecture, started in the Moby Dick project, is now continued further in the next IST program within Daidalos (Designing Advanced Interfaces for the Delivery and Administration of Location independent Optimized personal Services) project. Daidalos project was started in November 2003 and it is planned to continue until April 2006. [5]

6 IPv6 in Moby Dick Architecture

Moby Dick work group saw that the 3GPP and the 3GPP standardized 3rd generation network architecture are carrying two much legacy when providing backward compatibly towards circuit switched networks. This has lead to a sophisticated, complicated and quite expensive network architecture were mainly core network is IP-based. As the Internet biased engineers, Moby Dick project saw that large part of elements and protocols could be dropped if backward compatibility and saving of already made investments would not be such a high priority. [15]

The Moby Dick project ended up with an architecture where the IP layer was directly on top of the lower radio interface protocol stack, including layers 1 and 2. As an example, in a case of the provided test bed UMTS access, the Time Division - Code Division Multiple Access (TD-CDMA) interface with only the Radio Link Control (RLC) protocol between Layer 3 IPv6 and Medium Access Control (MAC) would exist as shown in the Figure 7. From a higher protocol stack perspective, this means that all the data transmission is on pure IPv6 end-to-end. Also any tunneling protocol, e.g. GPRS Tunneling Protocol (GTP) used in the 3GPP architecture, is not used in the Moby Dick architecture. This should offer simplified inter-technology handovers, as stated by the Moby Dick working group. Similar protocol stack would be used also with WLAN connectivity. [16]



AL: Application Layer, TL: Transport Layer (e.g. TCP, UDP, etc.), L1: Physical Layer, L2: Link Layer, MAC: Media Access Control, RLC: Radio Link Layer

Figure 7: Protocol stack towards the UMTS [16]

In the Moby Dick architecture, Radio Gateways (RG) are providing interface between wireless and fixed networks. All the routing will take place in the fixed network and all required servers will also run on fixed network side. None of the UMTS specific elements are used behind the Radio Gateways in Moby Dick architecture. This means that the 3GPP-specific elements such as RNC, Home Location Register (HLR), Visitor Location Register (VLR), MSC, GGSN and SGSN are not part of the architecture. These are partly replaced by fully IP-based functionalities and elements including Mobile IPv6 (MIPv6) Home Agents (HA) and -Access Routers (AR), AAAC servers, Paging Agents (PA) and QoS Brokers. The resulting architecture is illustrated in the Figure 8 below. [16]

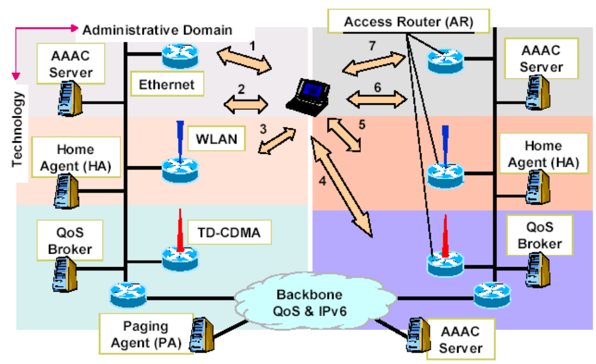


Figure 8: Moby Dick architecture [17]

Mobile IPv6 was an important part of the whole Moby Dick architecture and project. There was a separate work group to study mobility in addition to two other work groups with more specific topics being AAAC and QoS. In the Moby Dick final project report the key result was stated to be Mobile IPv6 capability to provide seamless mobility on heterogeneous network architecture with only slight enhancements [17].

These different enhancements to basic Mobile IPv6 were studied by analytically [18] and simulation based [19]. Enhancements were basically needed to be able to provide uninterrupted voice services for users in micro mobility environment [16]. While the basic MIPv6 provides required mobility for macro mobility (i.e. inter-domain handoffs), enhancements were needed for intra-domain mobility (i.e. micro mobility) [16]. In studies [18] and tests bed [17] it was clearly shown that by using just MIPv6 there is considerable delay when the Access Router is changed. This delay was in the range up to 10 seconds, which is unacceptable for real time services like voice. Delay was significantly reduced using Fast Handover based on the make-before-break approach instead to break-before-make of basic MIPv6 [17].

An example signaling of the Moby Dick implemented fast intra-domain handover mechanism is illustrated in Figure 9 and the message sequence for the example is listed in Table 1. In this example also QoS and AAAC message flows are shown. The Moby Dick project was able to confirm that both QoS and AAAC functionalities are possible along implemented MIPv6 based fast handover mechanism [17].

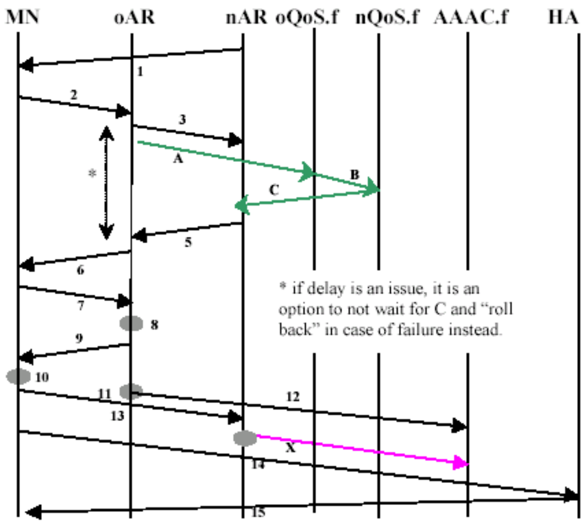


Figure 9: Moby Dick fast intra-domain handover [17]

Table 1: Moby Dick fast intra-domain handover [17]

No.	Message
1	Router Advertisement
2	Router Solicitation for Proxy
3	Handover Initiate
A	QoS message A
B	QoS message B
C	QoS message C
5	Handover Acknowledge
6	Proxy Router Advertisement
7	Handover Execute
8	Start Bicasting (& Timer)
9	Handover Execute ACK
10	Leaving Old Link
11	Bicasting Timer Expired
12	Accounting Data
X	Accounting Start
14	Binding Update
15	Binding ACK

The Moby Dick project was able to prove that IPv6 based mobility in heterogeneous network environment is possible with required performance level. In addition to pure convergence and mobility architecture, the project group was also able to add some level of AAAC and QoS support to the test bed implementation. However, as a technical research project the Moby Dick does not solve questions of business models and relationships between different operators and service providers. These topics were clearly not in the scope of the Moby Dick project but should be solve before this mobile Internet architecture can be provided in a profitable way. The Moby Dick successor the Daidalos project will take a further look to these required economic and business models [5].

7 Conclusion and Summary

This paper evaluated the usage of IPv6 in the 3GPP and the Moby Dick network architectures. In general, it was noted that the 3GPP architecture development is based on offering backward compatibility and continuation towards CS connectivity, where as the Moby Dick project was searching more full IP type architecture solution without legacy support requirements. The Moby Dick project was clear three-year research project as the 3GPP is a highly industry driven standardization work with future continuation plans. The 3GPP architecture has long telecom background, as the Moby Dick architecture is more Internet biased, even though both architectures are re-using the IETF specified protocols.

The 3GPP work has a clear ambition towards all-IP architecture but it will most likely take some time to reach this goal. Already today the 3GPP is promoting usage of IPv6 and this can most clearly be seen in core IMS specification and requirements. IPv6 has also been optionally available in transport parts of the architecture for some time. Mobile IPv6 has no role in the 3GPP architecture at the moment. As fully opposite, the Mobile IPv6 usage is a central part of the Moby Dick network architecture. A major part of the Moby Dick project was composed of the research to provide enhanced hand-over functionality on top of basic Mobile IPv6 as answer to micro mobility requirements faced.

Short summary of the 3GPP and the Moby Dick architecture comparison is available in Table 2 below.

Table 2: Comparison of 3GPP and Moby Dick

3GPP Architecture	Moby Dick Architecture
Telecom oriented	Internet oriented
Industry standardization	Research project
IPv6 preferred	Mobile IPv6 based
Both circuit and packet switched functionality	Fully packet switched approach
CS connectivity	No CS connectivity
Detailed specifications	No specifications

Acronyms

3G Third Generation
3GPP Third Generation Partnership Project
4G Fourth Generation
AAAC Authentication, Authorization, Accounting and Charging
AR Access Router
CS Circuit Switched
CoA Care-of-Address
DNS Domain Name Server
EDGE Enhanced Data rates for GSM Evolution
ETSI European Telecommunications Standards Institute
EU European Union
GGSN Gateway GPRS Support Node
GPRS General Packet Radio Service
GSM Global System for Mobile communication
GTP GPRS Tunneling Protocol
HA Home Agent
HLR Home Location Register
IMS IP Multimedia Subsystem
IP Internet Protocol
IPng Next Generation Internet Protocol
IPv4 IP version 4
IPv6 IP version 6
IST Information Society Technologies
LAN Local Area Network
MAC Medium Access Control
MGW Media Gateway
MIPv6 Mobile IPv6
MN Mobile Node
MSC Mobile Services Switching Center
MSS MSC Server
NAT Network Address Translator
QoS Quality f Service
RG Radio Gateway
RNC Radio Network Controller
SGSN Serving GPRS Support Node
SMS Short Message Service
TD-CDMA Time Division - Code Division Multiple Access
UE User Equipment
UMTS Universal Mobile Telecommunications System
VLR Visitor Location Register
VoIP Voice over IP
WLAN Wireless Local Area Network

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