

OMEGA ICT project: Towards convergent Gigabit Home Networks

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Abstract— Gigabit home networks represent a key technology to make the Future Internet success a reality. The OMEGA European project [1] aims to define and demonstrate such networks. Consumers will require networks to be simple to install, without the need of any new wire. To achieve this, gigabit radio links and wireless optics communications will provide wireless connectivity within the home and its surroundings. Power-line communications potentially combined with robust RF will provide a home backbone “without new wires.” To make this network ubiquitous, seamless and robust a technology-independent MAC layer will ensure its global control and provide connectivities to any number of devices the user wishes to connect to it in any room in a house or a flat. In order to make this vision come true, substantial progress is required in the fields of optical-wireless and RF physical layers, in protocol design, and in systems architectures.

Index Terms— Home Area Networks, Network Convergence, Business cases.

I. INTRODUCTION

The future Internet will require an extremely high-bandwidth “core” and “access” network, along with the associated developments in transmission and switching that are required to achieve this. User expectations are high; the future Internet must be as simple to use as other utilities (gas, water, and electricity), high-capacity mass storage and other devices must plug in and work; “no new wires” should be required; and access to information should preferably be wireless. Services must be also portable and personalised, seamlessly following the consumer from place to place and device to device at any time, with no delay or interruption of service. In the absence of such an easy-to-install and easy-to-maintain HAN, the consumer is required to have information technologies (IT) skills that are a major barrier to mass market broadband penetration.

The future HAN must also enrich the lives of consumers, for example by allowing visual communications with their friends or relatives, by enabling interactive experiences through entertainment, by assisting the consumers in maintaining their independence as they age, for example by offering remote healthcare and by allowing them to communicate with their family to reduce any sense of isolation they may have. In essence they must have the ability to control their virtual as well as their physical environment.

A. The OMEGA vision for a gigabit home area network

Given that FTTH access promises symmetric data rates of at least 100 Mbit/s, this implies a HAN supporting Gbit/s data transmission and a latency time in the millisecond regime. It implies that the performance of the HAN must be high enough to maintain several services simultaneously, each with very different requirements. Furthermore, it must be low-cost and easy to be manufactured in volume.

The OMEGA home network aims to deliver Gbit/s capacity and low latency within the home and to the access network, with either wireless transmission or transmission using existing wired home infrastructure, thus enabling access to and the development of new and innovative services.

Figure 1 illustrates the network concept. Data enters the home and is routed by the home gateway. The gateway in turn is connected to OMEGA hardware, which can deliver Gbit/s data transmission. Room-area communications is provided through ultra wide band (UWB) radio and broadcasting by use of visible-light communications (VLC).

To extend UWB penetration, the gateway can also use lower frequency RF to connect to terminals, or use power-line communications (PLC) beyond state of the art 100 Mbps net to connect to OMEGA bridges within the house. Bridges can alternatively or complementarily be networked by means of high speed radio backbone, leading to the first hybridization of wireline and wireless connectivities.

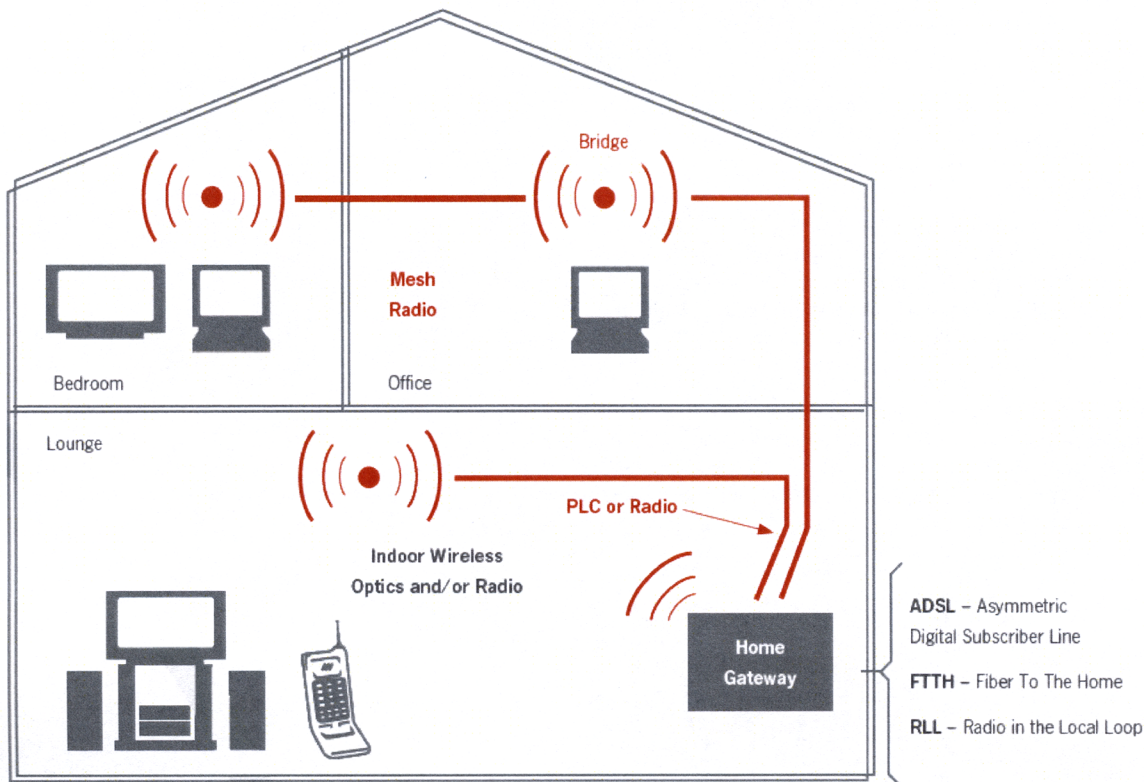


Figure 1: Gigabit home area network – OMEGA

II. USAGES AND BUSINESS CASES FOR GIGABIT HOME NETWORKS

A. Market status

For access networks, the deployment of broadband access (xDSL and beyond) will exceed 100 million subscribers in Europe in the near future [2]. The majority of the connections will approach the Shannon limits of xDSL technology, with ultimate native asymmetry and limited (~50Mbit/s) downlink. Optical fibres outperform xDSL in terms of data rate and fibre-to-the-home (FTTH) deployments are growing within Europe at rates depending on the economic models and financing in each country, and are expected to reach a maximum 10 % penetration by 2010. At the end of 2007, the number of FTTH subscribers in Europe was already exceeding one million and the number of FTTH passed homes was around 5 millions [2].

Products such as the Telefónica Home Gateway and Orange Livebox are early, highly successful examples of convergence, and the emergence of efforts such as the Home GateWay Initiative [3] and work within the ITU [4] shows the importance of HANs and the demand for convergent services.

B. Impact

OMEGA will demonstrate a proof of concept UBB HAN and evaluate roll-out scenarios that create mutual benefits for

society and industry. The disruptive capabilities of such a network will open up new business opportunities for the entire value chain, from manufacturers to network operators, service and content providers up to the end users.

The goal of the OMEGA project is to provide significant contributions to standards especially in the fields of convergence layer, power line and wireless optic communications. These objectives are shared by a strong consortium of major companies and institutions, ranging from manufacturers, network operators R&D centres and the academic domain. This vertically integrated group of contributors has the knowledge to ensure that outcomes from OMEGA take into account the requirements of all the 'stakeholders' in the industry.

In terms of impact on the European society the OMEGA project addresses several important challenges. Firstly it will ease and encourage the development of new advanced communication services to the benefit of both the society and industry. The expected impact for the citizen is the availability of new services due to UBB penetration to the device. From a societal perspective, OMEGA will enable the emergence of a new 'level of experience' of communication, entertainment and instant services.

Minimising power consumption due to home electronic devices is a major expectation. The OMEGA network will provide the lowest power consumption connection (of the several possible) to a device, due to the efficient cooperation that the integrated approach will bring. In addition there is the potential to 'build-in' energy consumption as a core parameter in the new protocols and techniques that OMEGA will develop.

C. Business models

According to market analysts, more than 50% of US houses with a home network are equipped with a router or residential gateway. This market is addressable from operators and service providers aiming to offer converged gigabit home access using a dedicated multi-service gateway.

In addition, 50% to 60% of the customers are interested in streaming PC videos to TV set in other rooms or to a primary TV set equipped with DVR. Therefore an increasing interest from telecom and media operators as well as from service providers appears towards the business opportunities arising in the home environment.

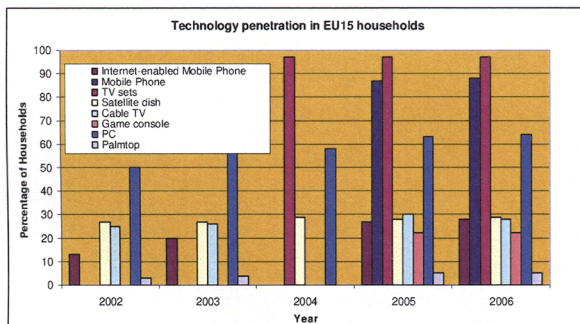


Figure 2: Average values of technology penetration in EU15 countries

As different technologies appear in European home environment (Figure 2), the opportunities for converged home networking services are high and especially those related to TV streaming to other devices, content storage and content acquisition/downloading.

On the other side, services such as home automation and browsing/chatting using TV sets are of limited interest mainly to the high penetration of PCs and its dominance as the Internet access terminal (Figure 3).

In Figure 4, the situation in EU15² in terms of PC-based internet penetrations, the average number of persons per dwelling and the total number of dwellings per country is illustrated. It can be denoted that using these parameters, a classification of countries in terms of HAN potential can be occurred: countries with large internet penetration per household and an average number of 2.5 persons per dwelling and countries with moderate internet penetration with more than 3 persons per dwelling. This first classification can be

² EU15 corresponds to the 15 countries composing the European Union from January 1st 1995 to April 30th 2004.

further elaborated by using financial, economic and social characteristics, in order to get a better insight of HAN potential.

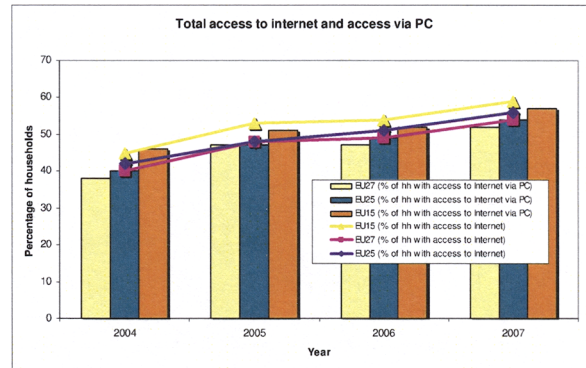


Figure 3: Access to Internet and PC-based Internet access in EU15, EU25 and EU27 countries. PC-based Internet access dominates in the home environment.

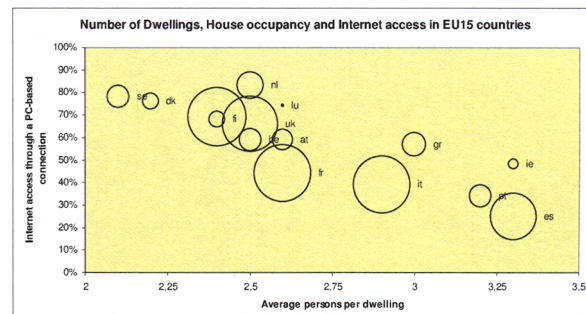


Figure 4: A classification of EU15 countries in terms of internet penetration, average number of persons per dwelling and total number of HAN market potential (number of dwellings)

OMEGA will also permit to address market segments of the access networks that are not strictly home network. Indeed, its generic low cost technology will make it easy to be on board to solutions for business enterprise solutions, as well as hot spot infotainment and electronic kiosks.

III. CHALLENGES FOR TRANSMISSION TECHNOLOGIES

The general objective of the OMEGA is to distribute in all rooms 1 Gbit/s over heterogeneous technologies. Three main technologies without need of new wires in the home will be investigated and optimised in order to meet this challenging target: radio, power line communications and wireless optics.

The challenges to be faced by these technologies in order to build a successful Gigabit Home Network concept depend on their respective maturity and current deployment.

A. Radio communications

Current and future services and contents in home networks put diverse demands on the underlying transmission technology.

Due to the trade-off between data rate and coverage range inherent to radio systems, only a mixture of different radio technologies trimmed to the different classes of applications can fulfil all the requirements to the desired extent. To avoid inefficient and cumbersome solutions with coexistence problems as experienced today, OMEGA will integrate various appropriate radio devices into a converged heterogeneous radio network, which meets the customer's demands with respect to quality of service, reliability, throughput, ubiquity, and self-configuration. In addition to the crucial aspect of convergence at the radio layer, advanced PHY, MAC, and cross-layer mechanisms will be developed, [5]-[6].

B. Power line communications

Current PLC standards provide throughput below 200 Mbps and over a maximum of 30 MHz, see [7]. OMEGA aims to increase the current frequency range for power line communications up to 100 MHz, a bandwidth for which the channel capacity exceeds 1 Gbps, see [8]. A tight investigation of medium impairments as well as electromagnetic compatibility in this enlarged spectrum will help to define advanced modulation schemes based on multi-carrier approaches that best fit this wider communication pipe containing a higher number of carriers.

C. Optical wireless communications

OMEGA aims to combine optical wireless communications techniques in order to provide a range of communications channels, which together can provide robust optical wireless communications. Infrared optical wireless will be used to provide Gbps line-of-sight communications, while visible light communication will provide broadcast coverage at lower data rates, see [9].

IV. CONVERGENCE LAYER

Much research work has been carried out addressing the convergence of heterogeneous networks, and many European collaborative projects have developed complex software architectures. All these efforts have in common that they assume that IPv6 as a minimum common factor for next-generation networks. Many open and lightweight middleware architectures have been designed to handle QoS, resource management, and security aspects in heterogeneous networks, again assuming heterogeneous IPv6 networks, [10]. Making this assumption makes it easy to achieve such architectures within a single research project. But, on the other hand, working at such a high OSI level of the protocol stack does not offer control of other key aspects, such as energy consumption and optimal use of the network resources. Some research on integrating PLC and WiFi in a home control network at lower levels has been undertaken, but the low target data rate has made this effort relatively straightforward and limited impact.

The OMEGA project aims to enable the cooperation of communication technologies by developing an inter-MAC convergence layer located between layer 2 (MAC) and layer 3 (Network Protocol), with the main idea of switching between access technologies as proposed in [1]. This approach is totally new because, to the best of our knowledge, there have not

been any research efforts so far, concerning the convergence of wired (PLC) and wireless (radio and HWO) technologies in the challenging scenario of a multimedia and high-data-rate HAN.

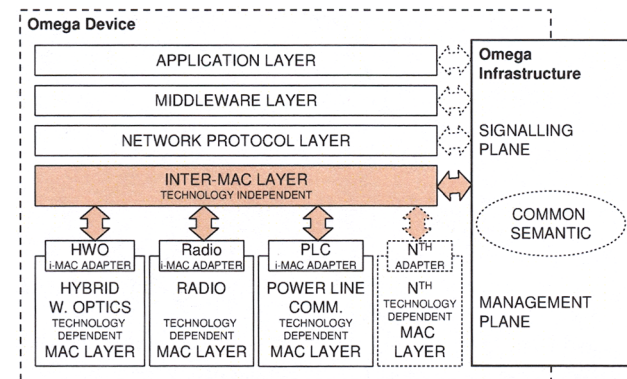


Figure 5: Inter-MAC Reference Architecture

The OMEGA project will pioneer a new method of inter-MAC convergence, identifying the advantages and the limits of such an approach in terms of performance, reliability, stability, backward compatibility, costs, and potential impacts onto existing standards.

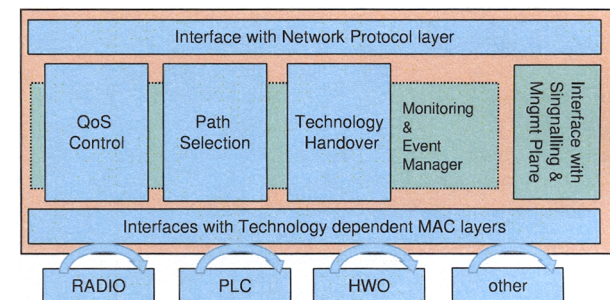


Figure 6: Convergence at MAC layer: the Inter-MAC functionalities.

The *QoS Control* manages the resource allocation of specific flows guaranteeing QoS parameters: Bandwidth, Delay, Jitter, Loss Ratio and Error Ratio. Different classes of service can be handled by the Inter-MAC that translates them in Ω -compliant service requirements. The QoS Control performs a complete scan over all MACs to estimate which of them can handle the specific flow belonging to that class of service.

The *Path Selection* selects all the possible paths to connect two or more nodes among various networks. It considers multi-hop solutions and takes care of load balancing techniques. Load balancing is needed whenever the QoS parameters could not be assured using only one available path. Existing solutions for multi-hop routing are tailored for homogenous networks and thus not suited for the heterogeneous home gigabit architecture. Implementing multi-hop connection in the home heterogeneous environment is novel, and will be undertaken by this functional component. This will consider factors including class-of-service

identification, policy-based routing table derivation, dynamic bandwidth allocation, protection, reservation, priority routing, and priority queuing.

In order to provide access to different communications systems an efficient vertical *Technology Handover* mechanism is required. A technique that uses the common semantic to describe the available channels and chooses between them will be developed. The technology handover switches between two different technologies and is recalled whenever a network congestion, link failure or device mobility occur.

The *Monitoring & Event Manager* represents the link-up point for the functionalities described above. Its task is to trigger decisions, based on Signalling & Management Plane information. Since every Inter-MAC functionality is related to each other, if Monitoring & Event Manager detects that a particular link of the Home Network cannot support the service class imposed by QoS Control, then it will trigger Path Selection module in order to choose a better link. So, information produced from monitoring and event manager will be used by Inter-MAC to cast its main functionalities.

The *Interfaces with Technology dependent MAC layers* interrogate the underlying MAC layers using special Inter-MAC adapters. The adapters provide the information in a proper and compatible format with the data obtained from the *Interface with Network Protocol Layer*. The adapters receive as input parameters that are different for every MAC (technology-dependent information), and translate them to give in output always the same specifications (technology-independent information). This interface has two main tasks. The first one is to provide a complete set of basic common functionalities: medium sharing, channel allocation, back-off algorithm, duplexing, flexible access, prioritized access, error handling and frame aggregation. The second purpose is re-utilizing this set of basic functions and the information received by the adapters to implement the enhanced Inter-MAC features previously described.

The *Interface with Network Protocol layer* allows the Inter-MAC to communicate with upper layers. It has to be intended as a standard interface, aiming to not modifying the existent interaction with the IP layer.

The *Interface with Signalling and Management Plane*. The key role of the Inter-MAC is to conveniently translate the information received in order to re-arrange data and to implement the functions previously introduced. Inter-MAC provides a set of management plane elements that can be accessed by the other layers to optimize their own functionalities. Signalling plane elements are used to establish and release connections as well as to set QoS parameters.

A successful project will develop a future-proof scalable inter-MAC layer that will provide the 'glue' for the OMEGA network and developments after the completion of the project.

V. CONCLUSION

In this paper, we describe a project that will have a number of significant outcomes. It will provide a substantial consumer "pull" for next-generation broadband by enabling the sharing of large-date user-generated content, which will, in turn, raise the expectation for higher data rates.

Among all aspects investigated in the FP7 OMEGA project, this paper focuses on future usages and business cases for the Gigabit Home Networks as well as on the convergence among heterogeneous transmission technologies to be used in future Home Networks.

Home Area Networks based on the OMEGA concepts will give the possibility of delivering new high-bandwidth services to the user throughout the home, by offering access to novel "emotional" experiences or virtual services.

ACKNOWLEDGEMENT

The research leading to these results has received funding from the European Community's Seventh Framework Programme FP7/2007-2013 under grant agreement n° 213311 also referred as OMEGA.

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