ICT-MobileSummit 2009 Conference Proceedings
Paul Cunningham and Miriam Cunningham (Eds)
IIMC International Information Management Corporation, 2009
ISBN: 978-1-905824-12-0

Poster Paper

Criteria and Factors Affecting Home Networks Deployment: Evidence from the ICT-OMEGA Project

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Abstract: Home networks (HNs) will play an important role in the widespread adoption of broadband services. The OMEGA project aims to provide the next generation HN combining several diverse wireless and wireline technologies. In the world of converging heterogeneous HN, a system designer needs to be aware of many technical, economic, social as well as other issues related to the deployment of broadband services and their relative importance. In this paper the methodology of pairwise comparison is used as a roadmapping tool in order to quantify the importance of these critical issues and to define the critical factors that should be taken into account for service deployment over gigabit home networks as in case of ICT-OMEGA Network. The approach is part of the AHP (Analytic Hierarchy Process), which is applied in three levels (objective-criteria-factors). The High Definition Television and Voice over IP services are addressed and these services are decomposed in general characteristics and quantitative or qualitative technological aspects that will be prioritized. For this reason an online survey platform, including the building of the corresponding algorithm, has been developed and illustrated.

Keywords: Home Networks, HDTV, VoIP, pairwise comparison, Analytical Hierarchy Process, roadmap.

1. Introduction

The future Internet will require an extremely high-bandwidth “core” and “access” network, along with the associated developments in transmission and switching.. Home networks (HNs) play a critical role in achieving broadband penetration, as they act as the last network segment that enables the provision of end-to-end services. Traditionally, in-building networks, for instance in corporate or academic settings, have a tenfold higher bandwidth than their access points to the telecommunication infrastructure. Given that fibre-to-the-home (FTTH) access promises symmetric data rates of at least 100 Mbit/s per household, this implies HNs supporting Gbit/s data transmission and a required latency time in the ten millisecond regime. These performance criteria will ensure that no bottleneck will be present for end-to-end HN services (such as High Definition Television –HDTV and Voice over IP – VoIP) and that the HN will have the necessary capacity for delivering local services such as instant access to mass media storage. In addition, the performance of the HN 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. All these combined challenges define the objectives of ICT-OMEGA, an Integrated research Project financed within the 7th EU R&D framework programme [1].

The OMEGA project aims to incorporate three technologies, namely the optical wireless, radio and Power Line Communications (PLC) into a single inter-MAC layer. This is a challenging task and requires the network designer to be aware of many technical, economic and social issues starting from the application down to the physical layer. In this paper, indicative results concerning the critical issues affecting the deployment of broadband services over the next generation HNs and specifically the OMEGA network are presented. These results have been obtained through a number of surveys conducted using the Analytical Hierarchy Process framework and a pairwise comparison methodology which is used to quantify the importance of each service technology aspect.

2. Methodology

The methodology used is mainly based on the pair wise comparison method [2], [3] which is a vital part of the Analytical Hierarchy Process (AHP), often used for technology evaluation. The impact of technologies under focus is calculated as a composite index called Technology Value [4]. The Hierarchical Modelling of an AHP model is developed in three discrete levels, which is depicted in Figure 1. On the first level the *objective* for evaluating technologies is defined. In OMEGA case the objective is the prioritization of critical issues regarding the deployment of broadband service over the next generation HNs and specifically the OMEGA network. The second level is to determine the criteria for the technologies assumed. A Criterion is a general attribute of a technology, for example Service Performance which is an important criterion in VoIP and HDTV services. A list of technological factors is identified for each criterion. A *factor* is an indicative characteristic than can be quantified and characterizes the criterion to which it is part. For example Achieved Bit Rate could be a representative factor of Service Performance. These factors could be either quantified in terms of numerical values (for example in the case of the achieved bit rate in Mb/s) or using a six-point qualitative scale (Excellent - E, very good - VG, good – G , acceptable – A, poor – P, unacceptable – U).

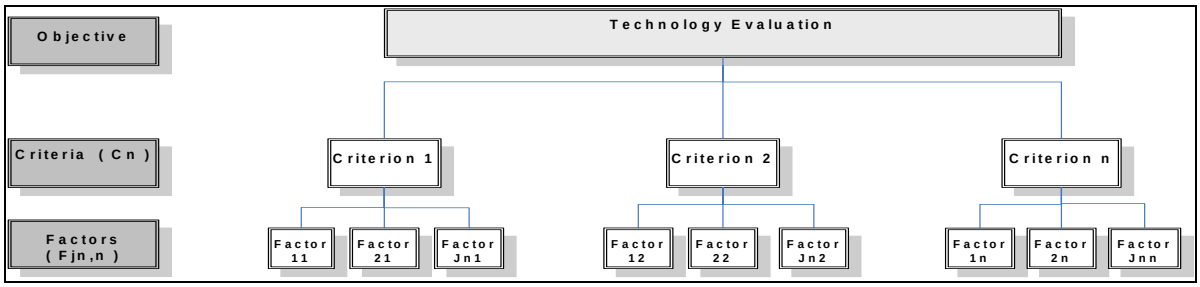

Figure 1: The generalized hierarchical model developed for evaluating technologies

The importance of each criterion is identified through a series of pairwise comparisons, that user is asked to perform. More specifically, experts are asked to fill a table containing the upper triangular elements A_{ij} of a $N \times N$ matrix $\mathbf{A}=[A_{ij}]$ where N is the number of criteria. The experts fill out the elements A_{ij} with $i<j$ by allocating values between 0 and 100, signifying therefore the relative importance of criterion i compared to criterion j. For example if an expert assigns $A_{ij}=60$ this implies that according to his/her point of view, the weight of criterion i is 60% when compared to the weight of criterion j which is 40%. The same process is carried out for the factors of each criterion separately. Using the elements of $\mathbf{A}$, a new $N \times N$ matrix $\mathbf{P}=[P_{ij}]$ is calculated where $P_{ij}=A_{ij}/(100-A_{ij})$ for the upper diagonal elements ($i<j$), $P_{ij}= (100-A_{ij})/A_{ij}$ for the lower diagonal elements ($i>j$) and the diagonal elements P_{ii} are set equal to 1. The elements of P_{ij} represent the relative importance of criterion/factor i compared to criterion/factor j. The eigenvalues and eigenvectors of matrix $\mathbf{P}$ are calculated and the eigenvector $\mathbf{x}=[x_k]$ associated with the maximum eigenvalue [5] is estimated. The weight w_k of criterion k is then estimated using:

$$w_k = x_k \left[\sum_{l=1}^{N} x_l \right]^{-1} \quad (1)$$

The same procedure is followed to estimate the weights of the factor of each criterion. It should be denoted that the matrix P_{ij} must be consistent and some indexes are used for qualifying the consistency of an array. More specifically, the consistency index and the consistency ratio are determined as follows [3]: C.I. = (λ_{max}-n)/ (n-1), where n is the rank of matrix $P_{ij,}$ and C.R.=C.I./R.I, where R.I. is the random index, specified by a principal random consistency index array. A value of C.R. less than or equal to 0.1 is acceptable. Larger values require the expert to reduce the inconsistencies by revising judgments.

3. Survey Design and Results

The pairwise comparisons were conducted by a web-based survey/roadmapping platform incorporating the AHP framework. User/experts log on to the platform and fill out the questionnaires that have been set up. Detailed instructions and examples are provided to helping users. The platform has been developed and maintained by the University of Athens in .NET® framework. The user interface is illustrated in Figure 2 [6]. The data supplied by users are saved in a database and the survey designer can perform the pair wise comparison in order to estimate the weights that signify the importance of criteria and factors.

Figure 2: Home Page of Online Survey Tool

Three surveys regarding the OMEGA Network, the HDTV and VoIP services have been designed and set up for the purposes of ICT-OMEGA project as discussed and presented in the following paragraphs. A number of ten experts from the project consortium have been participated for a period of one month. A detailed description of the methodology, the criteria/factors as well as the findings and conclusions can be found in [7]

3.1 The Omega Network Survey

Table 1 presents the criteria and factors associated with the OMEGA network. Most of these are self explanatory while others are explained in the footnotes. The survey results show that when designing the OMEGA Network, social acceptance issues are the most important criteria to take into account. Experts have assigned an importance approximately 25% which is 5 percent units higher than the next important criterion. This is an indication that system designers realize that the importance of user satisfaction in term of no strictly technical needs. Note that as it is depicted in Figure 6, under this criterion, security/privacy issues are the most important ones followed by health issues with assigned values of 45% and 37% respectively. The design – integration of equipment to the rest of the home environment seems to be a minor concern, compared to the aforementioned factors. The system performance, flexibility and OAM criteria seem to be of similar importance to the experts. Surprisingly enough, the experts believe that the economic/business aspects of HN are less important than all other criteria. This can be attributed to their main technical background. The economic/business criterion would be the most important one from a user point of view. Furthermore it is interesting to note that there is not a single criterion that is significantly more important than the others as shown in Figure 3.

Table 1: Relative Importance of factors, under each criterion, for Omega Network

Criterion 1: System Performance		20.6 %
Factor 11	Coverage	26.5 %
Factor 12	Maximum bit rate	26.1 %
Factor 13	Ease of use	24.9 %
Factor 14	Network congestion probability	22.5 %
Criterion 2: Economic/business		17.1 %
Factor 21	Installation First Cost	19.8 %
Factor 22	OAM - Operation Administration and Maintenance	19.8 %
Factor 23	Cost of multi-technology extenders[1]	14.9 %
Factor 24	Cost of Omega Gateway[2]	15.5 %
Factor 25	Cost of OMEGA Legacy Device Adapter (OLDA)[3]	14.7 %
Factor 26	Cost of End Connectivity components	15.2 %
Criterion 3: OAM (Operation Administration and Maintenance)		19.3%
Factor 31	Ease of installation/maintenance	19.7 %
Factor 32	Ease to upgrade legacy devices	15.2 %
Factor 33	MTBF-Mean Time Between Failure	18.4 %
Factor 34	MTBR – Mean Time Between Replacement	18.0 %
Factor 35	MTTR – Mean Time To Repair	12.8 %
Factor 36	Interchange ability[4]	15.9 %
Criterion 4: Social acceptance		24.3 %
Factor 41	Security/Privacy	44.4 %
Factor 42	Health issues	36.4 %
Factor 43	Design – integration to home environment	19.1 %
Criterion 5: Flexibility		18.8 %
Factor 51	Compatibility with "No new wires" approach	57.2 %
Factor 52	Scalability[5]	16.5 %
Factor 53	Upgradeability[6]	13.2 %
Factor 54	Compatibility with previous solutions/ legacy systems	13.2 %

[1]As shown in Table 1 and Figure 4, it is not yet clear which the decisive performance measure is for the HN. Coverage, maximum bit rate, usability and network congestion probability have more or less the same weight, but coverage and bit rate slightly overrun the other twos. In contrast, the compatibility with the "no new wires" approach, as it is shown in Figure 7 seems to dominate the system flexibility issues with a weight of 57%. This is an indication that experts tend to think that installing new cables such as fibers inside the house won't be acceptable from a user point of view. Scalability is marginally the second more important factor while upgradeability and compatibility with previous solutions/legacy systems have the same weight of 13.2%.

Operation Administration & Maintenance (OA&M) and Economic/Business criteria seem to be the least important ones with similar weights 19% and 17% respectively. As it is presented in Figure 5, Ease of Installation is the most important factor (20%), followed by Mean Time Between Failure (19%), Mean Time Between Replacement (18%) and Interchange-ability (16%). The rest of factors belonging to OA&M (Easy of upgrade legacy Devices and MTTR) give, altogether, a weight of 28%. Regarding to economic/business aspects, as it is presented in Table 1**Error! Reference source not found.**, the most important factors are clearly the OA&M and first installation cost, with a value of 20% each. This indicates that in the mind of the designer, the installation and maintenance cost will be the most important concerns for the user, especially since a "no-truck roll-out" approach is foreseen.

[1] Extender is used to extend the Gbps home network coverage or to interconnect different devices that cannot communicate directly.
[2] Boundary element between the Gbps home network and the access network.
[3] OLDA can act as an OMEGA proxy for non OMEGA devices.
[4] If system components are interchangeable with same or similar components made by manufacturers commonly available in electronic stores, if they are made-to-order by the original manufacturer or if they have to be specifically redesigned
[5] If the system can adjust itself automatically according to changes-Note: easy to use extenders, all devices are compatible with wifi etc.
[6] If additional adjustments or hardware/software modification are required except from the replacement of existing components with the new ones.-Note: ability to support future Broadband services

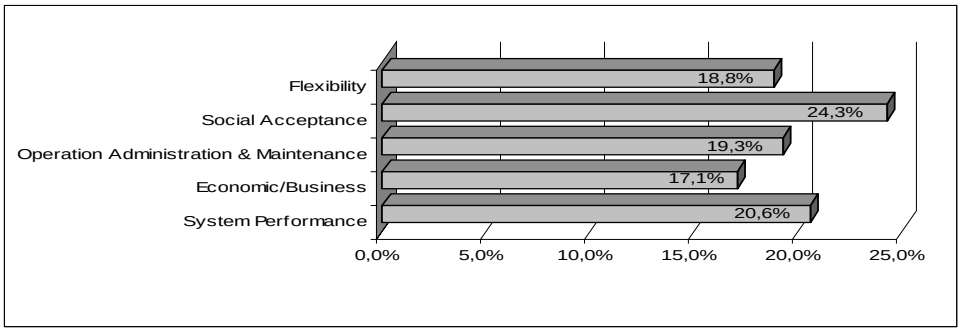

Figure 3: Related weights of OMEGA network criteria.

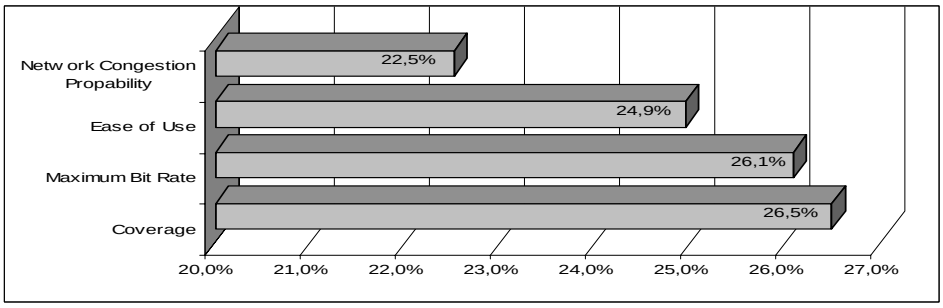

Figure 4: Related *weights of OMEGA network factors for system performance.*

The rest of the factors concerning the components used (e.g. OMEGA Gateway, etc) have similar importance ranging from 14% to 16%. Adding up the cost of individual components one sees that overall, the cost of components far the critical issue totalling a 60% weight. This is a clear indication that, in HN, component costs of is more critical than in metro or core networks.

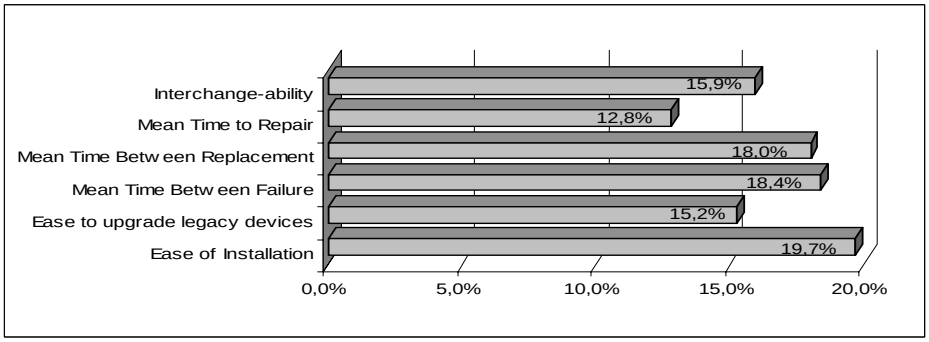

Figure 5: Related weights of OMEGA network factors for OA&M

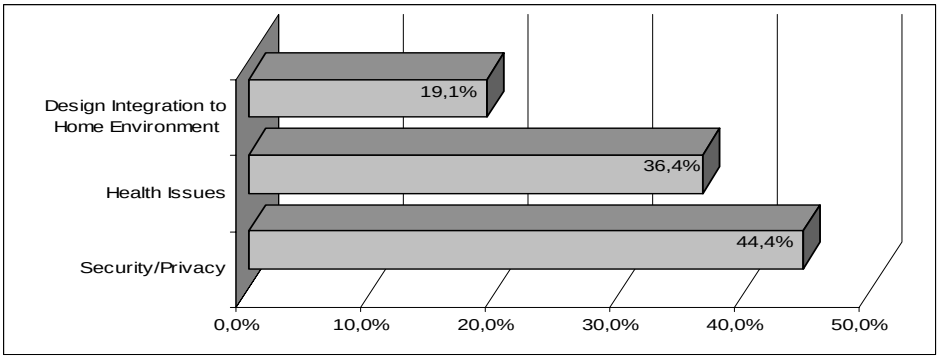

Figure 6: Related weights of OMEGA network factors for social acceptance

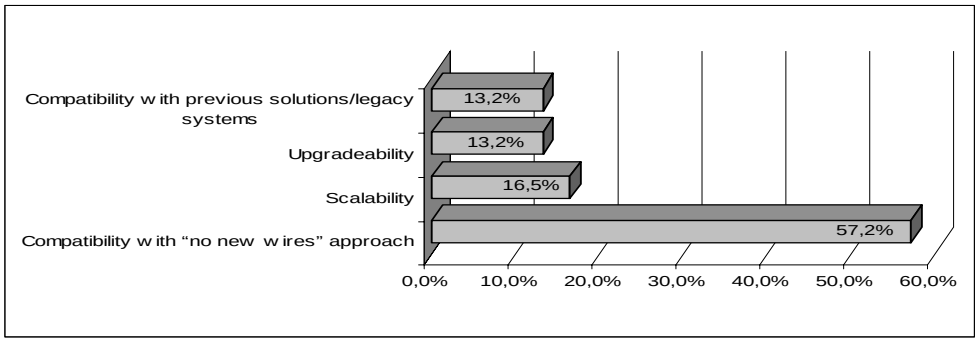

Figure 7: Related weights of OMEGA network factors for flexibility

3.2 HDTV and VOIP Surveys

The criteria and factors assumed in the HDTV and VoIP surveys are shown in Table 2 and are identical in the most part for these two services, the only difference being in the factor of the service performance [7]. In the case of HDTV, the degradation of picture is additionally defined as a factor whereas in the case of VoIP, the degradation of sound is replaced by the degradation of voice. According to the opinion of the experts, mobility and service performance are of equal importance for HDTV, while for VoIP, service performance is more important than mobility.

Table 2 and the following figures depict the relative importance of factors under each criterion for HDTV and VoIP. For the mobility criterion, outage probability turns out to be the one that experts valuate more, in both HDTV and VoIP technologies, as it is shown in Figure 8-Figure 10. This is not surprising since outage probability greatly determines the level of user satisfaction. Concerning which mobility type is more important, experts seem to believe that mobility inside the home is more important than home-to-home and home-to-WAN mobility. Regarding service performance factors, as it is presented in Figure 9, achieved bit rate is weighted as the most important one for HDTV (25%). However, as Figure 11 shows, the most important factor for VoIP is quality degradation of voice with a value of 26%. Moreover, adaptability to different conditions follows for both services (17%-HDTV, 22%-VOIP). Concerning VoIP, perceived delay and achieved bit rate follow closely (21%, 18% respectively). The rest of factors have similar values for HDTV ranging from 13% to 16%.

Table 2: Weights of Criteria and factors, under each criterion, for HDTV and VoIP Technologies

		HDTV	**VoIP**
Criterion 1: System Performance		50 %	55.7%
Factor 11	Home Mobility	19.9 %	16.6 %
Factor 12	Home to Home Mobility	15.4 %	15.6 %
Factor 13	Home to WAN Mobility	19.5 %	15.2 %
Factor 14	Room/Device handover	14.3 %	14.3 %
Factor 15	Outage Probability	30.8 %	38.4 %
Criterion 2: Service Performance		50 %	44.3 %
Factor 21	Achieved Bit Rate	24.7 %	18.2 %
Factor 22	Quality degradation of picture	14.8 %	-
Factor 23	Quality degradation of sound	15.0 %	-
Factor 24	Quality degradation of voice	-	25.5 %
Factor 24	Perceived Delay	15.5 %	21.1 %
Factor 25	Adaptability to different conditions	16.9 %	22.4 %
Factor 26	Availability of lower class services	13.1 %	12.9 %

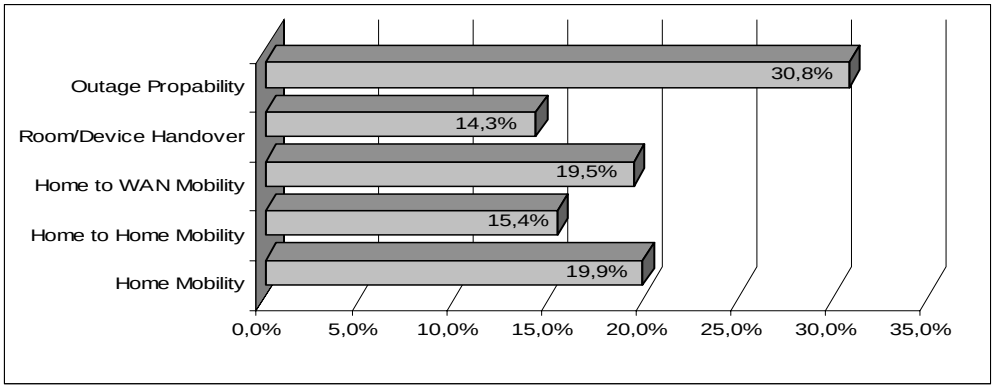

Figure 8: Related values of HDTV factors for mobility

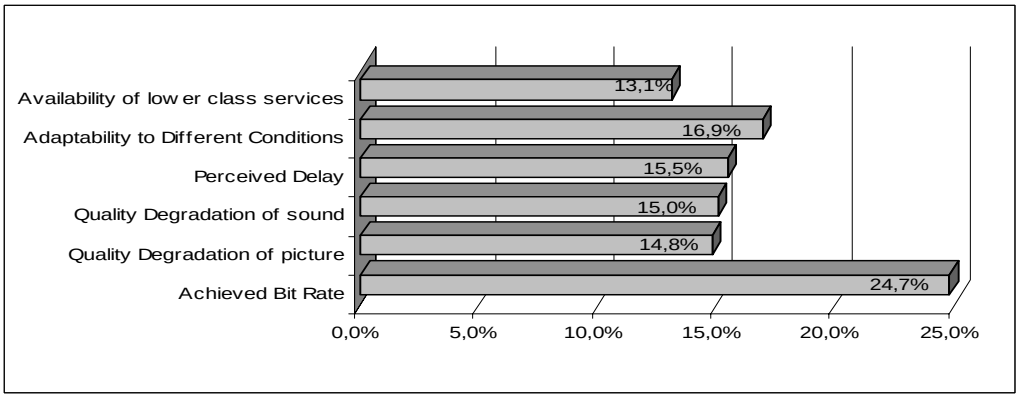

Figure 9: Related values of HDTV factors for service performance

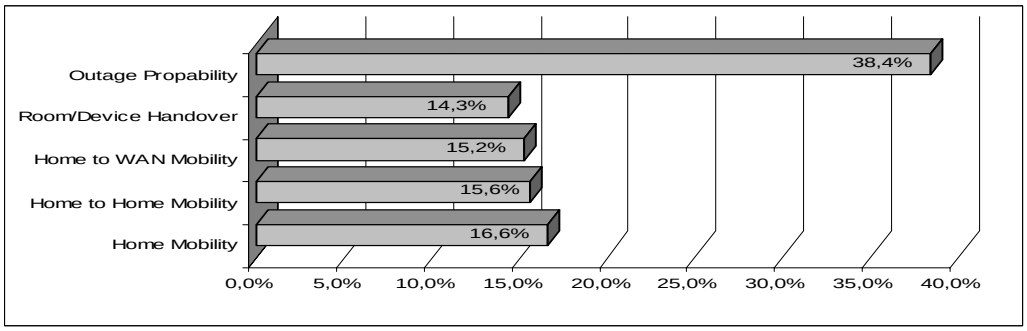

Figure 10: Related values of VOIP factors for mobility

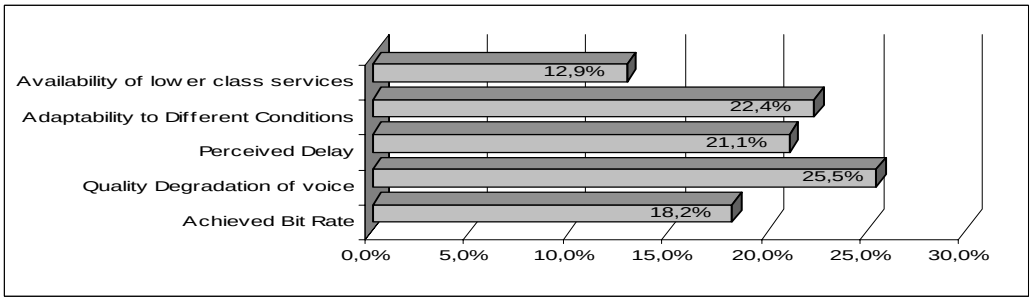

Figure 11: Related values of VOIP factors for service performance

4. Conclusions

In this paper, the first results concerning the importance of various issues of HN from a system designer and integrator point of view are presented. These results are drawn from a series of surveys conducted on-line within the consortium of the OMEGA project. The various aspects for the OMEGA network are highlighted and issues related to HDTV and

VoIP are also examined. Regarding the widespread adoption of next generation HNs, experts seem to believe that social acceptance is the most important criterion and specifically the security/privacy and health issues seem to be the dominant factors for social acceptance. Regarding system performance which is the second most important criterion, the experts did not single out a performance measure. The HDTV and VoIP surveys revealed that service performance and mobility have approximately the same weight and the outage probability is the dominant performance measure. These results are a first step towards a roadmap for HN, a goal that will be addressed within the OMEGA project using the AHP methodology.

Acknowledgments

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. Authors would like to thank the experts participated in the aforementioned surveys as well as the people working on the Workpackage 1 of ICT-OMEGA. They would like also to appreciate the valuable contribution of Ms. Kelly Papadogeorgaki and Mr. George Kakaletris, both from the University of Athens, Greece to the design, development and maintenance of the survey/roadmapping platform.

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