Forecasting the Diffusion of Gigabit Home Networking In Europe

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ABSTRACT

The steady growth of broadband penetration and the ongoing progress in networking technologies have increased the importance of home networks in the provision of high quality internet services. Market stakeholders have cooperated to evolve home networking towards an integrated, converged Gigabit technology, which will completely change the Home Area Networks (HANs) landscape and will enable a wave of possibilities. As Gigabit HAN technologies have just been launched in the market, there is a necessity of studying their future penetration. However, the lack of historical data on which such a forecast could be based presents a barrier that existing literature has not successfully addressed. The present paper attempts to analyze and forecast the diffusion of Gigabit HANs by suggesting a novel approach that overcomes the limitations of previous works. The proposed methodology is based on historical analogies and employs an objective and statistically reliable approach to investigate the degree of analogy and influence between services that drive the diffusion of broadband and home networking. The data used in this work were extracted from Eurostat's database and the final results, in terms of expected HAN penetration, are quite optimistic.

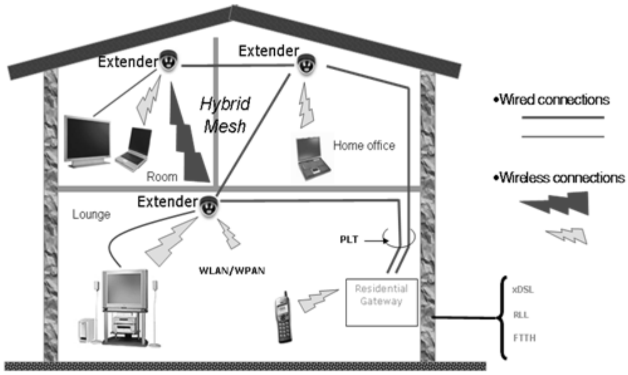
Keywords: Forecasting, Gigabit HANS, Home Networking, Innovation Diffusion, Pre-Launch

INTRODUCTION

The explosive growth of Internet and the widespread diffusion of broadband technology have led to a steady rise in the importance of home networking and Home Area Networks - HANs. Since the birth of the idea, home networks are continuously evolving and they are becoming an increasingly essential component of modern households. From the simplicity of a couple of telephone lines and a data modem to provide Internet connectivity, we have moved to complex home networks that are the centers for high quality online data and video services. This development clearly entails enormous

DOI: 10.4018/ijtd.2014070103

Figure 1. A future home network (Javaudin et al., 2008)



global opportunities. For instance, according to (Transparency Market Research, 2013), the cumulative expected growth in the home networking device market is USD 46 billion from 2010 to 2018 as the growth prospects of tablets and other devices in home networks necessitate additional connectivity options. Apart from the economic realm, home networking is expected to produce increased societal benefits by enabling services such as telemedicine and remote collaboration. It can also contribute to worldwide sustainability by making it easier for employees to telecommute and by allowing for better control of home appliances, heating/cooling systems, sprinkler systems and more.

Despite of the optimism of experts from the telecommunications and entertainment markets however, today's reality in the field of HANs is still ridden by several problems and obstacles that hinder further progress. More specifically, the current home networking environment is a complex mix of heterogeneous technologies and devices, all operating independently of each other and certainly not offering the set of services originally imagined (Ericsson, 2009). This imposes a barrier in the adoption of technology inside homes and a lot of frustration on the part of the users that try to deal with the pain of management and debugging of home services (Edwards et al., 2011). Existing home networks are far from fulfilling the user expectations of high Quality of Experience, advanced home services and ubiquitous access to home network resources while within or out of the borders of the house (Accenture, 2008).

Industry pundits, realizing these problems, envisioned a future home network, which they are calling the "smart home", or the "connected" home (Eurescom, 2009). It entails a set of computers, consumer electronics, mobile devices and sensors that seamlessly collaborate through wired, wireless, or a combination of such networks, to share content and enrich the home user experience through advanced services. It will be built around the residential gateway, which will link together the range of devices in the home and connect them with the Wide Area Network (WAN). The gateway will be connected to networking hardware capable of delivering high bit rates by using wired or wireless technologies such as Ultra Wide Band (UWB) or Visible Light Communications (VLC). To extend coverage throughout the home, the gateway may also use low frequency RF to connect to terminals, or use Power Line Communications (PLC) or Wi-Fi to connect to network bridges around the house. The idea is illustrated in Figure 1.

A more detailed description of such future home network will be given in the next section.

Presently, recent advances in standardization efforts and in networking technologies have brought HANs on the verge of a complete transformation, towards this direction of the envisioned future home network. We are getting very close to the marketing of integrated, converged Gigabit home networking solutions, which will succeed current technologies, completely changing the HAN landscape and enabling a wave of possibilities for all stakeholders in the home networking market (Broadcom, 2013a; Broadcom, 2013b). Following the above considerations, the necessity of studying the evolution of home networking and its future penetration into the market becomes obvious. However, since such novel solutions have yet to appear on the market, any forecasting attempt meets a certain barrier which is the lack of relevant historical data, on which it could be based. In the methodology – literature review section of this paper, an analysis is provided on the limitations of traditional approaches to overcome this barrier, along with an elaboration of a novel methodology that aims to overcome these limitations.

The analysis is performed over the European region and is quite valuable, as it can provide significant insight to home networking stakeholders in supporting their technical and commercial decision process. Telecommunications operators and equipment vendors can exploit the information to support their business planning. Investors and businesses need the information in order to assess the viability of home networking ventures. Finally, regulatory authorities need an estimation of the market's potential size before determining telecommunications policy. The full extent of the importance of successful diffusion forecasting to telecommunications business and policy agents is beyond the scope of this article. The reader is referred to Mcburney et al. (2002) for an elaborate analysis on the subject. As far as the literature of forecasting is concerned, the research performed in this paper contributes by proposing an alternative approach to forecasting without historical data, which constitutes an improvement over earlier works dealing with the same issue.

The rest of the paper is structured as follows: the following section provides an overview of the present state of home networking, its limitations and barriers with respect to adoption and describes the way stakeholders reacted to these problems and how they envisioned the future of home networking. It also highlights the motivation and goals of the present work. The methodology section describes the method followed in the present work, along with a review of the relevant literature. Then, the next section analyzes the data used in the forecasting process and it is followed by a section that details the derived results and provides a discussion of the findings. Finally, in the last section our conclusions and thoughts for future research are presented.

HOME NETWORKING: CURRENT STATE AND FUTURE DEVELOPMENTS

Today's home networks enjoy a widespread diffusion in the market. In the Western, economically developed, world home networks are already present in the majority of households. For example, in the Unites States according to recent findings (The Diffusion Group, 2013), 84% of broadband households already employ a home network. In Europe, similar reports estimate their diffusion at about 50% of households (European Technographics©, 2012). However, consumers face a vast heterogeneity in all home network related aspects. Homes typically consist of several digital devices like HDTVs, media players, digital cameras, mobile phones, music players and digital photo frames. In these devices content can be delivered in a wide variety of formats. And on top of that, in order to deploy the actual home network, there exist many available networking technologies to choose from (such as Ethernet, Wi-Fi, PLC, Optical Wireless, Bluetooth), each with its own transmission protocols, adapters and configuration utilities. As a result, modern homes consist of several unconnected subsystems which conform to different standards. For example, there may be cable television and security and telecommunication subsystems which are not interconnected and are individually controlled (Ericsson, 2009).

This state of things leads to user frustration and significant monetary costs for companies. For example, in year 2002 when the idea of home networking was relatively new, Parks and Associates found that home network devices were the single most returned category of items at consumer electronics stores in the United States (Scherf, 2002). In 2010, over 25% of all wireless access points were returned, despite most presumably functioning as intended (Pogue, 2010). Data indicates that only 5% of consumer electronics product returns worldwide are due to actual technical failure (Accenture, 2008). It is evident therefore that the current state of home networks functions as a barrier to adoption of new technology (such as home automation systems). Indeed, consumers in the United States regularly cite technical complexity as the primary disincentive to adding new networked devices in their homes (Edwards et al., 2011).

In order to unleash the full potential of home networking, market stakeholders have realized that these limitations must be overcome. A vision of the future home network was formed according to which, home networks must be simple to install, preferably without any new wires, and easy enough to use, so that information services can be just another utility as, for instance, electricity, water and gas are today. In addition, they must be low-cost and easy for massively manufacturing. Devices must comply with plug-and-play specifications and access to information should be effortless and intuitive. Services must be portable and personalized, following the consumer from place to place and device to device at any time, with no delay or interruption of service. The home network should function seamlessly, integrating different wired and/or wireless transmission technologies. Moreover, its performance must be high enough to simultaneously maintain several services, each with very different requirements. As a consequence, bandwidth is a very important consideration. Given the fact that Fiber to the Home (FTTH) access promises symmetric data rates of at least 100 Megabit/sec, the envisioned home network must support Gigabit/sec data transmission and a latency time in the millisecond regime (Javaudin et al., 2008). Such performance can ensure that no bottleneck will be met for end-to-end WAN services and that the home network will have the capacity for local services, such as instant access to mass media storages which are themselves being “fed” continually by the access network.

At present we are getting very close to the vision described in the preceding paragraphs. The first step in this evolution process was the forming of alliances by industry companies, mainly service providers, consumer electronics and mobile device companies. Their goal was to promote interoperability between devices and converged services. Such alliances include the Universal Plug and Play Forum (http://www.upnp.org/), the Digital Living Network Alliance (http://www.dlna.org/) and the Home Gateway Initiative (http://www.homegatewayinitiative.org/). At the same time, home networking technologies have quickly evolved, especially in the fields of optical-wireless and Radio Frequency (RF) physical layers, in protocol design, and in systems architectures. Data rates that exceed the Gigabit/sec can now be attained by various technologies. As a result of the achieved progress, the future of home networking is beginning to take shape.

The emerging model of the new home network is that of an integrated, converged solution that combines a large and heterogeneous set of different networking technologies and achieves data rates in the Gigabit/sec area. It will be built around the residential gateway. The gateway links together the wide range of devices in the home and communicates with the outside world. Inside the home, the gateway will be connected to networking hardware, which can deliver Gigabit/sec data transmission most probably by using Line-of-Sight (LOS) 60 GHz RF or LOS optical-wireless links. Room-area communications can be provided through Ultra Wide Band (UWB) and broadcasting by use of Visible Light Communications (VLC). To extend penetration, the gateway can also use low frequency RF to connect to terminals, or use PLC or Wi-Fi to connect to network bridges within the house.

Marketing developments are starting to pave the way for the advent of the envisioned home network. For example, Gigabit enabled home networking equipment using the HomePlug AV2 standard was launched since June 2013 according to chipset vendors (Broadcom, 2013b). Furthermore, MoCA 2 - enabled modems, routers and access-points that deliver Gigabit per second throughput have been announced since the beginning of this year (Broadcom, 2013a). As a result of the combined efforts for standardization and interoperability and for the development of home networking technologies, we are getting very close to the marketing of integrated, converged Gigabit home networking solutions, along the lines of the previous paragraph.

In the next section, the details of the methodology followed along with a review of the relevant literature are described in detail.

METHODOLOGY: LITERATURE REVIEW

In this section, a literature review will be presented, followed by the methodology proposed by the authors. One of the main central themes of the innovation field is the mathematical modeling of diffusion for new products and services, for different types of innovations and under different assumptions. Summarizing the main findings of the diffusion of innovations theory - DOI (Rogers, 2003), it is assumed that the diffusion of an innovation in a social system can be described by a bell-shaped curve, depicting the frequency of adoption against time and an S-shaped curve, when the cumulative number of adopters is plotted. During the introduction stage and as the innovation is introduced into the social system the rate of adoption is relatively low. This is followed by the take-off stage, described by a high rate of adoption, until the peak of the bell curve is reached, which corresponds to the inflection point of the cumulative adoption. After that time the rate of adoption decreases again, until the saturation level of the market is asymptotically met. At this time, the maximum number of adopters is reached, together with the end of the life cycle of the innovation, which is usually replaced by its descendant generation, or by another substitute product.

The Bass model (1969) is one of the most widely used models to describe diffusion, following the early work of Gompertz (Gompertz, 1825; Rai, 1999). Among the most characteristic contemporary efforts to capture diffusion dynamics are the logistic family models, represented by the Fisher-Pry or linear logistic model (Fisher & Pry, 1971). All of the above models are capable of providing S-shaped curves, describing the technology diffusion among social systems at the aggregate level. However, as derives by the corresponding literature of modeling and forecasting of innovation diffusion, no criteria have been established for the selection of the most suitable model in a given study and different diffusion processes can be better described by different models. For example, in the case of mobile telephony, the Gompertz model adequately described diffusion in India (Singh, 2008), while the logistic model worked well for Portugal (Botelho & Pinto, 2004) and the Bass model yielded the most accurate results for Korea (Kim & Kim, 2004). Additionally, these models do not differ significantly when tested using Greek data (Michalakelis et al., 2008). The analysis of this work is based on the logistic model, since it is especially applicable to technology-driven adoptions where new superior technology displaces old technology (Vanston, 2004) as will happen with the new solutions in home networking.

The formulation of the logistic model is described by the following differential equation:

$$Y\left(t\right) = \frac{S}{1 + e^{(-a-b\cdot t)}} \quad (1)$$

Where $Y(t)$ represents the total penetration at time t and s is the saturation level, or otherwise the maximum expected cumulative penetration of the innovation considered. Parameter a determines the timing of the diffusion process, and parameter b measures the relative growth rate. Estimation of the diffusion parameters, S, a and b, is achieved by using past diffusion data of the considered innovation and applying suitable techniques, such as Ordinary Least Squares (OLS), Nonlinear Least Squares (NLS) or Maximum Likelihood Estimation (MLE).

Apart from the selection of a suitable model to estimate the diffusion process of an innovation, one of the major constraints faced in this paper is the lack of historical data from which analyses can be made, as forecasting has to be performed prior to sales introduction. Among the common approaches to overcome this problem is to perform consumer surveys in order to gauge the consumers' propensity to adopt a certain technological product (Robertson et al., 2007). Other approaches are the panel consensus method (Eskin, 1973), which assumes the existence of experts with suitable knowledge and experience to evaluate the uncertain effects of the future and the well-known Delphi method (Wright, 1998), which is a refinement of the panel consensus but with no group meetings, thus eliminating personalities' influential effects. Finally, the historical analogy approach can be used, which assumes that similar products exist that have preceded the product under consideration and their diffusion data can be used, possibly after suitable transformation, to forecast the current innovation.

Since there is no historical diffusion data regarding integrated, converged Gigabit home networking solutions (for simplicity we will just use the term home networking henceforth), an estimation of their future diffusion, as described above, cannot be performed. To overcome this problem, an approach similar to historical analogies was adopted, aiming to provide estimates of the diffusion parameters. More specifically and according to the proposed methodology, the parameters of the logistic model are estimated by suitably combining the corresponding parameters of similar services for which data is available. This combination of services is based on appropriate assumptions which are described later in this section. Several similar approaches exist in literature transferring insights from diffusion of existing products to new ones, in order to forecast their market development. For example, Bähr-Seppelfricke (1999) defines a general set of product attributes and forecasts a product's diffusion based on its combination of product attributes. Easingwood (1989) finds that there are different classes of products and each class is stated to have a distinct diffusion curve so that a new product's diffusion can be forecasted by identifying its affiliated class. Thomas (1985) gives a framework for forecasting which is based on the Bass model. A more sophisticated method has been proposed by Bayus (1993), where he attempted to forecast the diffusion of HDTV. More recently, Vanston (2002) provided forecasts regarding the demand for high speed digital access at the household level in the United States. The approach followed in the present work is inspired by these efforts. However, these works suffer from a main limitation: they are based on experts' opinions or are employing simple ad hoc averages to determine the weight of each similar product/service to the diffusion of the product under study. In this paper, a more sophisticated and statistically reliable approach was adopted to estimate the weight of each similar service's contribution to the expected diffusion of home networks.

The analogy hypothesis, on which the present work is based, is the following: home networking adoption will be driven by users' demand for internet services. Users are expected to desire the building of a robust home network so as to be able to enjoy their favorite TV shows, perform video calls, play online games, surf the web etc., from their household connected devices. Therefore, demand for this kind of internet services/activities is expected to drive home networking adoption and these services diffusion data can be used as proxies for the diffusion of home networking as a whole. This approach can be implemented after applying some suitable transformation over the data, in order to reflect the contribution of each service to the total home network diffusion. In other words, their individual diffusion processes, if appropriately combined, can reveal very important information for the diffusion of home networking itself. According to the methodology proposed in this paper, by estimating the diffusion characteristics of these services and combining (weighting) them appropriately, the diffusion characteristics and parameters of home networking can be in turn estimated. Appropriate weighting has the meaning of defining the weights as directly proportionate to how much each service will drive home networking adoption, instead of simply averaging them. This leads to a further argument regarding the estimation of each service's weight, according to which internet services are expected to influence home networking diffusion in quite the same way they have influenced broadband diffusion. Thus, services having a stronger impact on broadband adoption will quite probably have a stronger impact on home networking adoption as well. Estimation of each service's impact on the adoption process of broadband is performed by the means of a multiple regression analysis. The results of this analysis reveal how much each service influenced broadband adoption and, following our analogy, can be used for weighting them appropriately for the case of home networking.

The proposed methodology has not been used earlier in the literature; it is therefore a novel approach to determining the weights of analogous products or services in a forecasting process where no actual diffusion data exists. The analysis performed in this work not only provides estimates regarding the future diffusion of home networking but also addresses one of the limitations in the literature of innovation forecasting, regarding the lack of historical data. Thus, instead of relying on subjective expert experience which can impose a level of bias, or performing unreliable consumer surveys, or even calculating ad hoc averages, regression analysis constitutes an objective, statistically reliable and sound approach to investigating the degree of analogy between similar products and the product to be forecasted.

DATA

In the context of the methodology described in the preceding section, thirteen internet services were selected to be used as analogous to home networking. The diffusion data for these services was extracted from Eurostat's database for the years 2003-2011 in thirty-three European countries, on an annual basis. These services were selected because they represent a wide variety of services that are enabled by broadband. Thus, the analysis will not be narrowed and in addition there is high data availability for these services to allow the drawing of statistically significant results. Selected services are presented in Table 1, where the first column contains the acronym of each service, in accordance to the acronym used by Eurostat and the second column its description. Table 2 shows the countries for which the historical data was used in the forecasting process. They consist of the total of the twenty-seven European Union countries plus Iceland, Norway, Croatia, FYROM, Turkey and Serbia. Data regarding broadband diffusion in each of these participating countries during the same period of 2003-2011 was also extracted from Eurostat.

RESULTS AND DISCUSSION

According to the developed methodology, a multiple regression analysis was performed over the data in order to investigate the strength of the relationship between each of the considered services and broadband adoption[1]. Each year's broadband diffusion level was combined with the diffusion levels of all the services in the same year to form an observation. This was performed for all years and for all countries, providing a cluster of 297 similar observations, which was used as input to the statistical software, in order to draw conclusions about Europe as a whole.

The common concern of multicollinearity in regression analysis, which occurs when the independent variables are related to each other, was resolved by following the stepwise regression approach, rejecting any independent

Table 1. Services used to forecast home networking diffusion

Service acronym	Service description
I_IUEM	Sending/receiving e-mails
I_IUGM	Playing/downloading games, films, music
I_IUGOV	Interacting with public authorities
I_IUIF	Finding information about goods and services
I_IHIF	Seeking health information
I_IUHOLS	Travel and accommodation services
I_IUNW	Reading/downloading online newspapers/news
I_IUPH	Telephoning or Videoconferencing
I_IUSOFT	Downloading software
I_IUWEB	Watching Web TV
I_IUBK	Internet banking
I_IUJOB	Job search or sending an application
I_IUSELL	Selling goods or services

Table 2. Countries considered in the forecasting process

Belgium	Estonia	Italy	Hungary	Portugal	Sweden	FYROM
Bulgaria	Ireland	Cyprus	Malta	Romania	UK	Turkey
Czech Rep.	Greece	Latvia	Netherlands	Slovenia	Iceland	Serbia
Denmark	Spain	Lithuania	Austria	Slovakia	Norway	
Germany	France	Luxemburg	Poland	Finland	Croatia	

variables (e.g. services) that were not significant at least at the 5% level. The results of the regression analysis are presented in Table 3, Table 4, and Table 5.

The analysis provided only six services out of the thirteen, as derived by the R-squared coefficient of determination (Table 4), explaining almost 94% of the variability in broadband diffusion. These six services will serve as cor-

Table 3. Summary output

Independent Variable	Coefficient	Standard Error	t-Stat	P-value	VIF
I_IUGOV	0.449	0.0732	6.14	0.00	3.576
I_IUIF	0.502	0.0714	7.04	0.00	3.894
I_IUNW	0.360	0.0805	4.48	0.00	3.229
I_IUPH	0.422	0.0733	5.76	0.00	1.994
I_IUWEB	0.760	0.0793	9.57	0.00	4.041
I_IUSELL	0.564	0.1246	4.53	0.00	2.834

Table 4. Goodness of fit

Standard Error	**7.135**
R-Squared	93.9%
R-Squared (adjusted)	93.7%
Observations	297

Table 5. Analysis of variance

Source	**Degrees of Freedom**	**Sum of Squares**	**Mean Square**	**F-Stat**	**P-value**
Regression	6	134568	22428	346.98	0.00
Residual Error	290	18745	65		
Total	296	153313			

responding variables for the next steps of the forecasting process. The adequacy of the model is validated, since each service's regression coefficient has a zero P-value (Table 3), which means it is statistically significant at the 5% level. Furthermore, from the analysis of variance (Table 5) it can be observed that the P-value of the regression is also equal to zero. This shows that the regression as a whole is significant. The variance inflation factors (VIF) indicate that the degree of multicollinearity among the remaining independent variables is small.

Since the regression is judged as significant, it is of interest to examine the partial effect of each of the six services to broadband adoption. Observation of the regression coefficients indicates that the service with the largest impact is web TV (0.76). Broadband diffusion is also fueled by the need of consumers to use internet as a marketplace, either to collect information about products and services (0.50) or to sell directly to other consumers (0.56). Finally, slightly smaller is the impact of the three other services – interacting with public authorities (0.45), performing calls and video calls (0.42) and reading online news (0.36).

As already mentioned, since the six selected services account for almost 94% of broadband diffusion they can be used to predict home networking, omitting the other seven. According to the next step of the developed methodology, each service's weight on the calculation of home networking will be proportionally large to its regression coefficient obtained from the preceding analysis. The results are shown in Table 6.

Table 6. Calculation of services weights

Service	**Regression coefficient**	**weight**
I_IUGOV	0.449	0.147
I_IUIF	0.502	0.164
I_IUNW	0.360	0.118
I_IUPH	0.422	0.138
I_IUWEB	0.760	0.248
I_IUSELL	0.564	0.184

Table 7. Services diffusion characteristics

Service	Model parameters			R-squared
	S	A	β	
I_IUGOV	0.859	-2.398	0.462	97.08%
I_IUIF	0.960	-2.793	0.404	99.71%
I_IUNW	0.936	-3.697	0.375	98.94%
I_IUPH	0.968	-3.431	0.566	99.63%
I_IUWEB	0.917	-3.177	0.521	99.64%
I_IUSELL	0.813	-3.031	0.485	99.26%

Each service, *i,* has a weight (*weight*$_i$), which derives from the regression coefficients according to the below formula:

$$weight_i = \frac{R_i}{\sum_{j=1}^{6} R_j} \quad (2)$$

where R_i is the regression coefficient of service *i.* Equation 2 is used for the calculation of weights in order to assign a weight to each service that is directly proportionate to the service's impact on broadband diffusion.

As argued in the methodology section, the diffusion of home networking will be produced by the appropriate weighting of the diffusion of the selected services. Having calculated the weights, the next step in the forecasting process is to estimate each service's diffusion characteristics (saturation level S and diffusion speed parameters, a and b). This is achieved by applying the logistic model on the actual diffusion data of each of the six services that remained after the correlation analysis. The services diffusion curves follow the anticipated S-shaped curve, as many other high-tech products and services, and their diffusion level has already reached the point where the estimation of the coefficients of the logistic model can produce quite accurate results. The estimation process was performed on the average diffusion of each service in the European area for the years 2003-2011 and the results are presented in Table 7, while the corresponding graphical depiction is illustrated in Figure 2.

The R-squared coefficient of determination is very close to 100%, for all the considered

Figure 2. Diffusion of services driving home networking

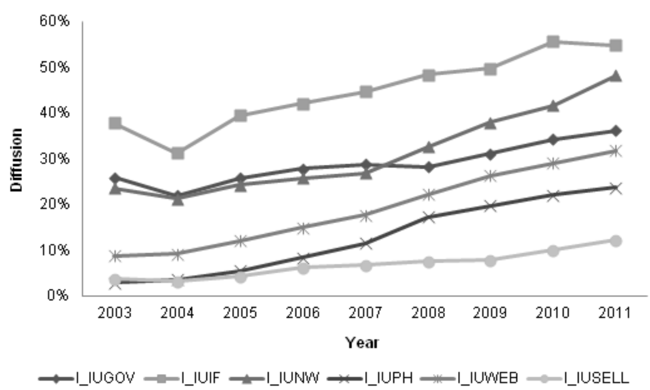


Table 8. Home networking diffusion characteristics

S	0.905
a	-3.069
b	0.475

services, which means that the logistic model provides very accurate estimation results and it can adequately describe the actual data.

The final step of the forecasting process is to calculate the diffusion parameters of home networking and produce its expected diffusion path. The diffusion parameters of the logistic model (S, α, b) that will describe home networking diffusion are calculated by weighting of the corresponding coefficients that describe services diffusion. This notion is expressed mathematically by the means of the following formulas:

$$S = \sum_{i=1}^{6} S_i \cdot weight_i \quad (4)$$

$$\alpha = \sum_{i=1}^{6} \alpha_i \cdot weight_i \quad (5)$$

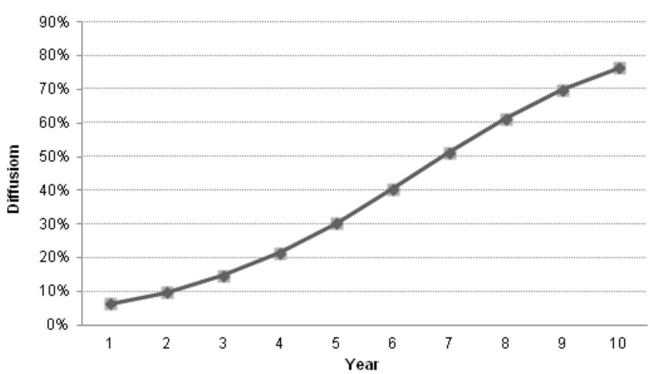
$$b = \sum_{i=1}^{6} b_i \cdot weight_i \quad (6)$$

In the above equations S_i, a_i, b_i and $weight_i$ are the diffusion characteristics and weight of service *i*. The results are illustrated in Table 8.

According to the estimated parameters, the diffusion of home networks will have a high penetration rate, as indicated by the value of *b*, which expresses the speed of diffusion. In addition to this, the value of saturation level *S*, at a level of 0.905 shows that home networks are expected to meet a high penetration, as almost the whole population will enjoy the corresponding services. Further analysis of the diffusion parameters indicates that, given the current market dynamics, saturation is expected to be met in about 14 years' time after the initial launching. In addition and since the symmetric logistic model is used to forecast the process, the inflection point of the diffusion will be met in about 7 years after the initial launching. As a general outcome, HANs seem to be a promising investment, since their prospects in terms of expected penetration are quite optimistic.

In order to graphically illustrate the estimated diffusion path of home networking, a plot is produced based on the estimated parameters appearing in Table 8. The resulting graph is presented in Figure 3 and it represents the

Figure 3. Average European home networking diffusion as a percentage of population



expected diffusion of integrated, converged, Gigabit home networking solutions at the end of each year after its initial launch (labeled as year 1, since there is no certainty about the launching date). It corresponds to the average diffusion of the thirty-three participating European countries.

According to the results, the diffusion of home networking is expected to be rapid and reach the level of about 80% of the European population in nearly ten years after launching. Forecasting beyond this ten year horizon is both risky and redundant, since in the first years after the launching of any product, actual market data can be used to train the diffusion models and produce more accurate forecasts than in the pre-launch phase.

As a final note in discussing the results of the present work, some limitations are identified, which in turn indicate valuable extensions to the proposed methodology and directions for future work. The main limitation, of either the proposed approach or any other alternative, is that if the product itself imposes substantial differences as compared with its similar ones, or with the factors that are assumed to influence it then it may lead to large inaccuracies in the penetration estimation process. Moreover, the methodology does not take into account the effect of planned promotions over expected sales. Usually, the introduction of a technological innovation into the market follows certain marketing actions which prepare the market to know the product and its characteristics seeking to influence the initial number of adopters, however without knowing the actual effects over diffusion.

Another limitation of this work is that it does not explicitly incorporate competition and competitor actions. With many new product introductions, there is a tendency for competition to intensify its marketing efforts in promoting existing products. These efforts may substantially affect the new product sales and forecasts should anticipate competitor reactions and their probable effect on the new product sales. In addition, the pricing scheme will definitely affect the number of adoptions, especially during the introductory stage of the diffusion. Thus, the elasticity of price over demand is another aspect that needs attention and should be considered in the analysis, as it may have substantial effects over the diffusion shape of home networking.

CONCLUSION

This paper is devoted to the development and evaluation of a methodology seeking to forecast the evolution of integrated, converged Gigabit home networks and their diffusion process in the European area. The contribution of the work is not limited only to the estimation of the future diffusion of home networks but it also addresses a gap in the relevant literature of innovation forecasting regarding the lack of historical data and it extends the approach of historical analogies by providing a better understanding of the underlying processes involved in the diffusion process. The proposed methodology proceeds with sophistically aggregating the diffusion process of each service that boosts adoption, instead of just averaging the underlying factors driving the diffusion of an innovation or relying on subjective opinions and possibly unreliable consumer surveys. Thus, a statistically reliable approach is developed, for investigating the degree of analogy between similar products and the product under study and estimating the contribution of each underlying factor to the total diffusion phenomenon. The methodology that was developed in the present paper can be refined and improved by addressing the limitations discussed in the previous section, which could be the subject of future works. As a final direction for further research, it would be of great interest to integrate the results of this forecast in a broader technical and economic analysis regarding possible rollout scenarios of home networking solutions in the European area. The forecasted diffusion can be used as a critical input in the construction of models aiming to study the potential profitability of different scenarios of stakeholders' involvement in the booming home networking market.

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ENDNOTES

[1] All estimations and statistical analyses were performed using Minitab and Datafit statistical software.

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