Technoeconomic Evaluation of the Major Telecommunication Investment Options for European Players

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Abstract

This article summarizes the major results from European projects drawing final conclusions and recommendations from the technoeconomic evaluation of three telecommunications market studies. It presents an analysis addressing a wide range of crucial telecommunications questions debated today. The business cases are: seamless mobile IP service provision, 3G mobile virtual network operators (MVNO), and fixed networks for broadband IP services. Extensive market analysis has been carried out for modeling demand, penetrations, and tariff structures for new mobile services and broadband services as an input to the business cases. Results show that over a 10-year study period, UMTS business is profitable in most cases for established operators with reasonable market share. The 3G MVNO business case is profitable under typical conditions when MVNO yields about 10 percent penetration, depending on the country type. Provision of fixed broadband services with a fiber to the curb solution is viable in dense urban and urban areas, but not in suburban environments, while fiber to the home is viable only in dense urban areas, despite the selection of protocol (ATM vs. Ethernet). Furthermore, broadband wireless access (BWA) systems, in dense urban and urban areas, show quite promising economic results.

The telecommunications market is continuously expanding across Europe, following the European Union liberalization directives and measures toward broadband provision for all. Anticipation for substantial return, primarily due to new information communication technologies (ICT) services, encourages the entry of new players into the marketplace. Nowadays, a number of new advanced services are increasingly offered to consumers, yielding new business opportunities for both users and service providers.

Today, network operators are facing the challenge of how to expand the existing access network infrastructure into a broadband access network, wireless or fixed. Strategies for enhancing and upgrading the traditional network, in a cost-effective and flexible enough way to serve a complex set of customer demands, are crucial for operators, service providers, and equipment manufacturers [1]. In a competitive environment changes in access network infrastructure have to be viable in the usual economic sense (i.e., by leading to higher penetration or a reduction in annual charges). Due to increased pressure to minimize costs and maximize revenues, a large variety of access network architectures must be rigorously examined in order to determine the most appropriate ones for different area types and service demand profiles. Thus, technoeconomic evaluation in telecommunication network projects is required in order to derive suitable introduction strategies.

The objective of the technoeconomic analysis presented and discussed hereafter is to identify economically viable implementation strategies for effective use of enhanced technologies, taking into account profitability and technical requirements. An analysis of different telecommunication studies is presented, including technoeconomic assessment of the key factors influencing the life cycle costs and value of the network. The rest of the article is structured as follows. The methodology and tool used for the analysis are outlined along with a general model description. The market analysis with demand evolution studies for both mobile and fixed broadband services is then illustrated. Finally, the main results from the selected cases are analyzed and discussed, and conclusions and recommendations are drawn.

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The net present value (NPV) describes today's value of the sum of resultant discounted cash flows (annual investments, running costs, revenues, etc.), or equivalently the volume of money expected over a given period of time. If the NPV is positive, the project is acceptable, and it is a good indication of the profitability of an investment project, taking into account the time value or opportunity cost of money, which is expressed by the ***discount rate***.

The internal rate of return (IRR) is the interest rate resulting from an investment and income (resultant net cash flow) that occur over a period of time. If the IRR is greater than the discount rate used for the analysis, the investment is profitable. The IRR gives a good indication of the value achieved with respect to the money invested.

The *cash balance* (accumulated discounted cash flow) curve generally goes negative in the early part of the investment project because of initial capital expenditures. Once revenues are generated, the cash flow turns positive, and the cash balance curve starts to rise. The lowest point in the cash balance curve gives the maximum amount of funding required for the project. The point in time when the cash balance turns positive represents the ***payback period*** for the project.

Methodology and Tools

This article is based mainly on the work within the projects IST-TONIC [2] and Celtic-ECOSYS [3]. These projects study various upgrade or deployment scenarios for both fixed and wireless telecommunication networks (with special focus on the mobile sector). These projects are precursors in the investigation of the economic side of telecommunications networks and services deployments [4–7].

The modeling was carried out using the technoeconomic tool, which is an implementation of the methodology developed by a series of EU cooperation projects in the field. The tool has been extensively used for several technoeconomic studies by major European telecom organizations and academic institutes [4–7].

The core of the model is its database with the cost figures of the various network components and their evolution over time. These figures are constantly updated by compiling data from the major European telecommunication companies. The output of the database is the cost evolution of the components over time. A dimensioning model (geometrical for fixed networks models or a radio link budget based for mobile networks models) is used to calculate the number of network elements for the defined set of services and network architectures. The infrastructure costs of the network are calculated using the dimensioning model, which involves input parameters such as subscriber density, cable and duct availability in the center of the city (which indicates the degree of reusability of existing infrastructure), and so on.

Finally, the future market penetration of these services and the tariffs associated with them, which have been calculated through market forecasts and benchmarking, are incorporated into the tool. The tariff policy of operators could be taken into account by modifying the tariff level in conjunction with the expected penetration of the services offered.

All these data are included into the tool in which the user can develop a discounted cash flow (DCF) financial model that calculates revenues, investments, installed first cost (IFC), as well as cash flows and other financial results for the network scenarios and architectures for each year of the study period. For the final technoeconomic evaluation of the network solution, critical financial indexes, such as net present value (NPV) and internal rate of return (IRR), can be calculated in order to decide about the profitability of the investment. A more analytical description of the methodology and the earlier versions of the tool can be found in [8].

The detailed bottom up construction of the technoeconomic model allows us to minimize errors during model development and to calculate intermediate results. The detailed modeling, including equipment, installation, operational cost structures, and even marketing costs, ensures a significant correlation between technoeconomic models and real situations. In addition, it must be noted that telecom operators very often resort to plain DCF analysis when assessing their business cases. Therefore, all the selected cases have been studied over a 10-year period, from 2002 to 2012. As for the calculation of the discounted cash flows, a discount rate of 10 percent has been selected, reflecting average values for the telecom industry. Taxes have not been included since they vary among countries depending on different economic and regulatory factors. But since this traditional approach is often unable to capture the flexibility of the decision makers to adapt and revise their decisions in response to unexpected market developments, sensitivity and risk analysis has been carried out for the improvement of the analysis. Following the identification of the network infrastructure, service and traffic characteristics for different metropolitan areas have been defined.

Scenario Description

In this article the network areas have been examined taking into account parameters such as subscriber density, loop lengths, and geographical and market characteristics. Using statistical data from operators, results from this article can be exploited in many countries for similar areas. Mean source traffic figures have been used for dimensioning and structuring standard tariffs such as connection tariff, access tariff, service provider tariff, traffic tariff, transaction tariff, and charge for content.

Cost Evolution Model

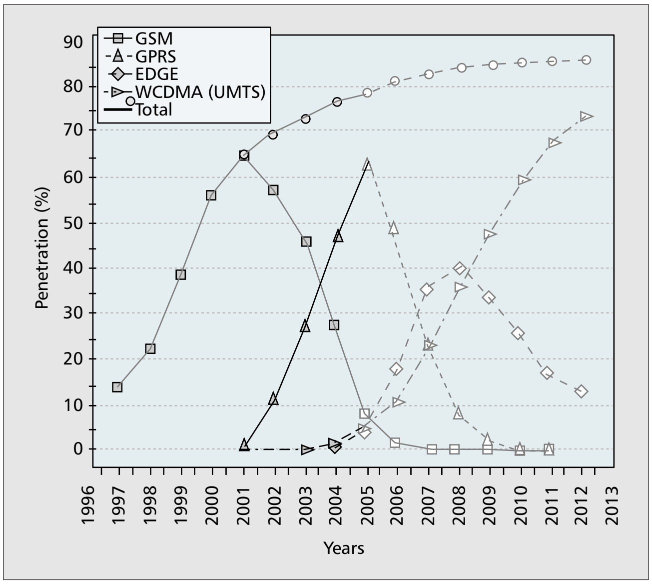
In the past a prediction of cost trends could be based on information and statistical data referring to previous years. Today, quick technical innovation and consequent insufficient historical data make predictions extremely difficult.

The predecessor of TONIC project, the RACE-TITAN project proposed a prediction model for price evolution based on Wright's empiric law: "*Each time the cumulated units production doubles, the unit cost decreases of a constant percentage*" [7, 9]. The advantage of the model is that it can be used when only a few observations are available and even if historical costs are partially or totally absent. The learning curve expressing this empirical law is

$$P(t) = P(0)\cdot\left[\frac{1}{n(0)}\cdot\left\{1+\exp\left[\ln\left(\frac{1}{n(0)}-1\right)-\frac{2\cdot\ln(9)}{\Delta T}\cdot t\right]\right\}^{-1}\right]^{\log_2(K)}. \quad (1)$$

The value of $n(0)$ reflects the relative accumulative volume and should be equal to 0.5 according to statistical data for components that exist in the market and their price is expected to be further reduced due to aging rather than due to production volume (i.e., very old products, many years in the market). From estimations in industrial telecommunication network components, $n(0)$ could be 0.1 for mature products and 0.01 for new components in the market.

$P(0)$ is the component's price in the reference year 0, ΔT is the time for the accumulated production volume to grow from 10 to 90 percent, and K is the learning curve coefficient. K is



■ Figure 1. *Subscriber penetration forecasts for different mobile systems for Western Europe (solid lines represent real data, dotted lines forecasts).*

the factor that causes reduction in price when the production volume is doubled. The K factor as well as the actual or forecast ΔT can be obtained from the production industry, mainly the suppliers. All the above described values have been extensively used for the evaluation of telecommunications investment projects [4–8]. Similar cost evolution models have been used in all cases presented hereafter.

OA&M Approach

The operation, administration, and maintenance (OA&M) approach is divided into three separate components as follows:

1 *The cost of repair parts*
2 *The cost of repair work*
3 *The operation and administration cost for each service cross-related to the number of customers or to the number of critical network components.*

The formula for calculating OA&M cost is given by [7, 8]

$$(OA\,\&\,M)_i = \frac{V_{i-1}+V_i}{2}\cdot\left(P_i\cdot R_{class}+P_l\cdot\frac{MTTR}{MTBR}\right)+OA, \qquad (2)$$

where V_i is the equipment volume in year i, P_i is the price of cost item in year i, R_{class} is the maintenance cost percentage for every cost component, P_l is the cost of a single working hour, MTTR is the mean time to repair, and MTBR is the mean time between repairs for the cost item in question. The first term into the parenthesis represents the cost of repaired parts, the second term represents the cost of repair work, while OA represents the operation and administration cost. In order to implement the calculation of the OA&M cost, classes for MTTR and MTBR are defined in the database of the technoeconomic tool as well as values for P_l and P_i.

Market Analysis

Demand modeling and broadband forecasts are essential inputs to all business case analyses. Therefore, demand models and forecasts for different access technologies in the fixed and mobile network have been developed in the project. In addition, models have been developed for forecasting the total broadband penetration in Europe. Forecasts have been made from 2005 to 2012 based on a four-parameter logistic diffusion model [10] which is recommended for long-term forecasts as well as for new services [11]. The model and values employed are based on a compilation.

The demand model is defined by the following expression:

$$Y_t = \frac{M}{(1+\exp(a+bt))^c}, \qquad (3)$$

where Y_t is the demand forecast at time t and M is the saturation level of the penetration, which is estimated *a priori*. The parameters a, b, and c are be estimated by a stepwise procedure, attempting to value these parameters using nonlinear regression and data from external reports and market surveys [12].

Specific forecasts are developed for three country groups: the Nordic countries (e.g., Finland, Norway), large Central European countries (e.g., France, Germany), and Southern European countries (e.g., Greece, Portugal). For the mobile network, the market share evolution and penetrations are modeled for Global System for Mobile Communications (GSM), General Packet Radio Service/high-speed circuit-switched data/enhanced data for GSM evolution (GPRS/HSCSD/EDGE), Universal Mobile Telecommunications System (UMTS), and wireless LAN (WLAN). A specific model is developed to predict the fixed network service penetration and market share between asymmetric digital subscriber line (ADSL), very-high-rate DSL (VDSL), fixed wireless broadband, and cable modem/hybrid fiber coaxial (HFC), described hereafter.

Mobile Market Demand Evolution

The forecasts of the total mobile subscribers and mobile subscriptions predict very similar penetration levels between the three country groups studied, as described later. The TONIC-ECOSYS market analysis has applied comprehensive forecasting methods on the following mobile system generations:

- Second generation (2G) — Digital mobile systems such as GSM
- 2.5G — GPRS, EDGE
- Third generation (3G) — UMTS (wireless code-division multiple access, WCDMA) including combined 3G/public WLAN users

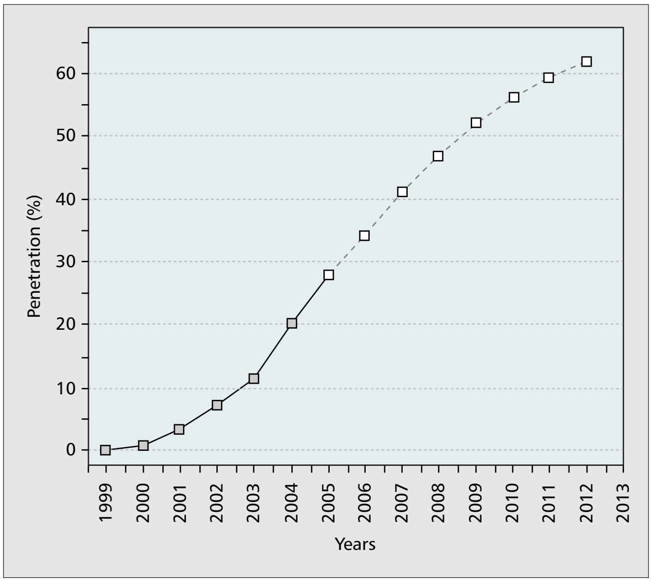
The forecast models take into account substitution effects between mobile system generations quantifying the forthcoming turning point for GSM penetration and later upcoming turning point for 2.5G. Decrease in 2G and 2.5G are caused by the rapid growth of UMTS (and WLAN) especially from 2005 onward (Fig. 1). The analyses show that UMTS-WCDMA and WLAN penetration in Southern Europe will be delayed compared with the penetration in other European country groups. In addition, the Average Revenue Per User (ARPU) is also lower in these countries.

Broadband Demand Evolution in the Fixed Network

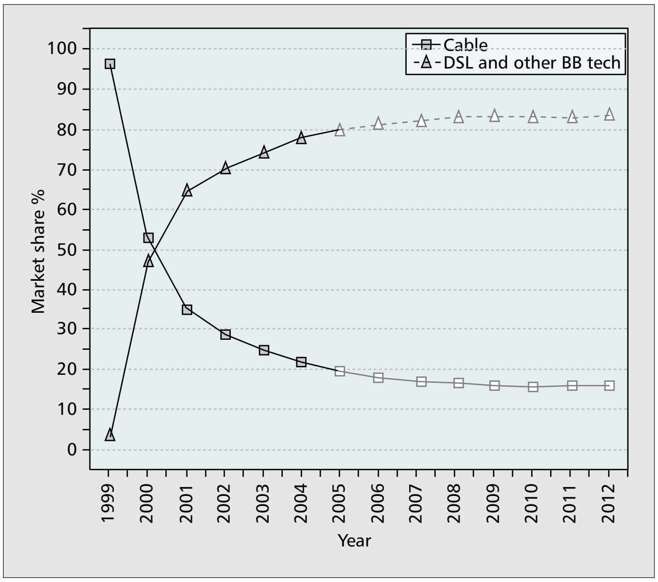
Specific models are developed to forecast broadband subscriptions and broadband traffic generated in the fixed network. Both the business and residential markets are covered. Forecasts for fixed access technologies have been developed for the technologies:

- HFC
- ADSL
- VDSL
- Other broadband technologies: LMDS, satellite, and so on

A battle is taking place between incumbent operators, new operators, and cable operators in Western Europe. The fast evolution of broadband services in Germany, Sweden, and Denmark is especially speeding up broadband demand in



■ Figure 2. *Long-term broadband penetration residential market, Western Europe (solid lines represent real data, dotted lines forecasts).*



■ Figure 3. *Predicted market share evolution between cable modems (HFC) and DSL + Other broadband technologies (solid lines are real data, dotted lines forecasts).*

Europe in general. Germany and France reached 2 million DSL accesses at the end of 2001, while in 2005 France reached 4.5 million. In some countries the cable operators have rather high broadband market shares since they started broadband deployment earlier than the incumbent operators. Forecasts showed that DSL access technology would be the dominant technology within a short time in Europe, and this was the situation in 2005. However, in areas where cable networks exist, competition is intensive and broadband penetration is higher than normal. The situation in Europe is different from North America, where forecasts show that cable modem technology based on HFC during the next years will still have more than 50 percent of the market [13]. Fixed wireless broadband access based on technologies like LMDS is rather expensive at the moment.

The saturation level *M* in the demand model (Eq. 3) has been estimated based on coverage for broadband in various countries in Europe. In non-dense rural areas, the expenses to roll out broadband are high due to low sharing of infrastructure costs. Migration between technologies is modeled so that VDSL and fixed wireless broadband are taking market shares from ADSL and cable modem. The penetration forecasts for the broadband technologies are worked out by multiplying the predicted market share with the total broadband penetration.

Figure 2 shows the long-term Western European residential broadband subscription forecasts as calculated with the model presented in Eq. 3. The demand is expressed in terms of percentage of total number of households. The figure shows a penetration of nearly 28 percent at the end of 2005.

Figure 3 shows that the market share for cable modems (HFC) starts with nearly 100 percent in 1999, but during the first two years loses about 40 percent of the market. The long-term forecasts show saturation for cable modem on a 20 percent level. These forecasts contradict the long-term forecasts from various consultant companies, which predict higher cable modem penetration based mainly on North America conditions, where cable modems already have a sizable presence.

The broadband country group forecasts show that broadband penetration is growing faster in the Nordic and Central European countries than in the Southern European countries. The delay in broadband penetration is estimated to be between two and three years.

Results and Discussion

UMTS–WLAN Case Study

This study focuses on seamless mobile IP service provision and network solutions, enabling seamless handover between 3G mobile and WLAN networks. The analysis assesses two major deployment scenarios, the first in a "large" Western European country (France, Germany, Italy, UK), and the second in a "small" in terms of population Nordic country. The country characteristics are presented in the Table 1. The overall size of the surface area is not the sum of all the sub-areas because certain areas (e.g., lakes, mountain tops etc.) are not taken into account and thus do not need to be covered. The technoeconomic analysis was performed for a 3G operator both with and without a public WLAN operation for hot spot broadband coverage. The impact of network roll out pace and license cost have also been analyzed.

Six basic scenarios have been investigated, supplemented with risk analyses and additional studies on effects for example by infrastructure sharing and co-operation with mobile virtual network operators (MVNOs). All the scenarios start the network deployment in the year 2002 from the dense urban areas and continue toward the less populated areas. The full rollout to rural areas takes 10 years in the large country, which is the same in the case of a small country under the slow rollout scenario. In the case of a small country with fast rollout, the deployment is completed in three years, reflecting strict regulation as initially in Sweden.

In order to determine the impact of the various services on network dimensioning and revenue for the operator, service classes in terms of bandwidth and quality of service (QoS) have been defined. Each bandwidth class (narrowband, wideband, and broadband) is characterized by an average bit rate, which corresponds to the average air interface capacity required by a subscriber when using the given service. There are four QoS classes as defined by the Third Generation Partnership Project (3GPP): conversational, streaming, interactive, and background. The main characteristics of each class are indicated in Table 2.

For simplification of the analysis, the interactive and background service classes have been combined, considering that their requirements on the network were similar enough, and therefore would not have any serious impact on network

Country type	Large	Small
Area size	370,000	330,000
Area dense	185	17
Area urban	2,960	264
Area suburban	37,000	3,300
Area rural	303,400	264,000
Population dense	50,000	50,000
Population urban	4000	4000
Population suburban	1000	1000
Population rural	40	3
Total Population	65 M	5,5 M

■ Table 1. *Population covered in large and small country examples*.

dimensioning and revenue expectations. Lastly, services are divided into circuit-switched and packet-switched services. Based on these criteria, a total of 11 service classes have been defined and used. Depending on whether or not the operator owns only a UMTS network or both a UMTS network and a WLAN component, the service set is not the same. Especially in the selected scenarios, the "broadband" services are assumed to be available only if the operator provides also the WLAN access. These classes are listed in Table 3 with examples of the services they encompass. The nominal data rate is equivalent to the average bit rate in the air interface during a session including overhead.

Usage, in terms of average minutes per day, differs depending on whether the customer has a professional or a residential profile. The average busy hour consumption per user per service class is assumed to be 30 percent of the total daily consumption for professionals and 20 percent of the total daily consumption for residential customers. Residential customers pay for their own subscription or opt for prepaid formulas, which may lead them to restrict somewhat more their consumption with respect to business users. In other words, price sensitivity for residential users is greater than for business users. It has been assumed that residential users have both post-paid and prepaid contract subscriptions. Evaluation of the residential segment share is based on observation of the current share of prepaid formulas and an estimation of contract-based residential subscriptions in the market. The estimated breakdown between residential and professional/business subscriptions in both a large and a small country has been assumed to be constant (80/20 percent residential/business).

The network capacity dimensioning and busy hour modeling start with total subscriber penetration estimations. Subscriber penetrations in both market segments, business and residential, have been taken into account. Predictions for distribution of the subscriptions between market segments are utilized to get the market sizes for business and residential service classes. These market sizes are assigned to the service classes in the model so that the penetration percentages refer to the respective market size, either business or residential.

In addition to dimensioning for capacity, the model is designed in such a way that certain coverage requirements are fulfilled. For UMTS, the geographical parameters are set in a way that the area covered is inhabited by more than 80 percent of the population. This coverage requirement is in line with most national regulators' obligations for UMTS. Rollout is assumed to be progressive, starting in dense urban and urban areas for service availability in 2003, and then extending to suburban areas.

For the WLAN component, only the country type currently determines the number of sites. The high capacity WLANs are constructed only for indoor hot spot areas where the expected demand is high. These hot spots include airports, railway stations, hotels, congress and exhibition halls, shopping centers, stadiums and arenas. Because advanced services, which are not yet adopted on a massive scale, have been considered, it has been observed that coverage is the main dimensioning criterion, which determines the roll-out cost.

The main financial results for each case defined are illustrated in Table 4. The study shows that the UMTS business cases can be positive for operators with substantial market share (~30 percent) in both large and small European countries. This was contrary to the pessimistic view dominating the industry analysts' reports in the early years of this decade. The payback periods are generally around seven years, which is not considered too long against the magnitude of the project.

In the five larger European countries (France, Germany, Italy, Spain, and the United Kingdom) the average license fee is €4 billion. A license cost of €6 billion has been retained in this model for the large country case (around 65 million population), slightly below the extreme license costs in the United Kingdom and Germany. For a small country, a fee of €6 million has been applied, an amount more related to the situation of Nordic countries (small countries in terms of population). The impact of high license fees does not threaten any large country business case, but a lower fee (20 percent of high license fee = €1.2 billion) would gain one year in terms of payback period, and clearly stronger results. Especially for sparsely populated small country cases, the UMTS rollout benefits substantially from the investigated infrastructure sharing approach, and in the case of extremely strict network rollout obligations, sharing is inevitable to secure the case financially.

The technoeconomic modeling shows that network investments play a minor role compared to operational costs, but the most critical factors are the usage and tariff levels; thus,

Class	Conversational	Streaming	Interactive	Background
Characteristics	Delay and jitter controlled Constant bit rate Some bit errors allowed	Jitter controlled Near constant bit rate Some bit errors allowed	Enables question/answer exchange Low or no tolerance of errors Variable bit rate	No time constraint Low/no error tolerance Variable bit rate
Examples	Voice, video telephony, videoconferencing	Video, audio	Web browsing, interactive email	FTP, email downloading as background task

■ Table 2. *Quality of service classes (Source: 3GPP 3G TS 23.107).*

Circuit/packet switched	Bandwidth class	Quality of service class	Sample services	Nominal data rate (kb/s)	Supporting network
Circuit	Narrowband	Conversational	voice call	16	UMTS
Circuit	Wideband	Conversational	video call, enhanced m-commerce	100	UMTS
Packet	Narrowband	Conversational	voice over IP	16	UMTS
Packet	Wideband	Conversational	video call, games	100	UMTS
Packet	Broadband	Conversational	video conf.	227	UMTS /WLAN
Packet	Narrowband	Streaming	on rich call (e.g., audio clips)	16	UMTS
Packet	Wideband	Streaming	rich call (incl. video clips)	100	UMTS
Packet	Broadband	Streaming	Near video-on-demand	227	UMTS/WLAN
Packet	Narrowband	Interactive/Background	short msg., WAP	1.7	UMTS
Packet	Wideband	Interactive/background	Email, Internet	8.2	UMTS
Packet	Broadband	Interactive/background	Large file transfer, applications	107	UMTS/WLAN

■ Table 3. *Service classes for UMTS-WLAN business case.*

the revenue side. The ARPU is not forecast directly, but it is based on the modeled service provisioning, subscriber penetrations, and price level evolution. Mobile ARPU shows clear but not dramatic growth, due to the provided UMTS functionality and capacity, touching the €50 limit in 2008. As migration to mass market mode takes place, bringing accelerated price erosion, the ARPU figures start to decline again toward the end of the study period, but this does not prohibit the UMTS business profitability.

The highest risk generally associated with the 3G business case is the possible delay of the UMTS breakthrough. The foreseeable reasons for the delay of the UMTS are general lack of demand, lack of interest, or useful applications and services, lack of willingness to pay for telecom services (especially mass market mobile data services), unavailability of equipment, too high price level, and weak economic position of the interested parties, or a combination of these, coupled with unwillingness to take the risk of initiative by the players. The results of the sensitivity analysis show that the business cases turn negative if the delay is more than three years. However, a low probability of a long delay can be observed because infrastructure has been readily available, the rollout and upgrades were already established by many European operators in 2003, and the availability of dual mode UMTS/GSM handsets seems satisfactory in relation to the penetration from 2004 on. As the analysis performed is related to an incumbent operator investing heavily in UMTS, the case of Telecom Italia can be used as a reference, where ambitions to drive UMTS growth is spurred by the rapid take-up of 3G in 2005, as the penetration was reported to have increased from 5 to 13 percent in one year.

This analysis' results suggest that the UMTS service portfolio, with realistic ARPU levels against the history data, will bring the investigated cases up to positive results within an economically feasible period. In general, heavy investment projects like the UMTS case should be viewed with a more far-reaching sight than as nowadays often analyzed. This brings a suggestion to the investing operators to avoid looking too much into temporary conjectures relating to short-term economic trends, but to utilize more robust long-term modeling, taking into account all the different factors of the business case.

Delay in UMTS launch and take-up clearly diminishes the positive prospects calculated for the UMTS license holder. This is due to the high irreversible investments already made, or about to be made, in the license acquisition and network buildout because of the license rollout requirements. The technoeconomic model demonstrates how the UMTS launch

Scenarios	NPV (M€)	IRR	Payback period
Small country with slow rollout, without WLAN provision	635	39%	6, 3
Small country with slow roll-out, providing WLAN service	690	39%	6, 4
Small country with fast rollout	98	12%	8, 1
Large country with high license fee, without WLAN provision	5,639	19%	7, 1
Large country with high license fee, providing WLAN service	6,703	20%	7, 0
Large country with lower license fee	9,754	40%	5, 9

■ Table 4. *Summary of main results from evaluated basic scenarios.*

Country type	Large		Small	
MVNO type	Operator-like	Service-oriented	Operator-like	Service-oriented
NPV (M€)	111	332	259	28
IRR	12%	15%	40%	14%
Payback period (years)	8.2	7.7	5.0	7.6

Table 5. *Summary of the basic results for the full MVNO case [14].*

will substantially increase the revenues from the early adopters migrating to the new system with a richer service portfolio. These growing revenues will be postponed in case of delayed UMTS launch and take-up, eroding the UMTS case. On the other hand, the subsequent fourth-generation (4G) technology is putting pressure, as a considerable delay may shorten the life cycle of the UTMS and especially its "cash cow" period.

As the delay is demonstrated to be a common concern for the UMTS stakeholders and can be tackled by concrete measures, the general recommendation for players in the areas investigated is not to postpone the necessary investments and development for full UMTS service provisioning. Not only the telecom operators are at stake, but also the value chain and partnering modes are richer and more vital than with the much narrower 2G approach. The take-up of new services will happen only if they are developed and provided in an attractive way. UMTS currently offers the best and most efficient platform for the totality of 3G services (enhanced video calls, fast Internet access and file transfer, etc.), and the only possible one for many of them. When the full breakthrough of 3G happens, those players with successful entry in 3G markets will benefit most.

It has been claimed that the rise of public access WLANs will have large impact on 3G businesses by cannibalizing potential 3G revenues. It is then often said that revenues diverted away from 3G networks by WLAN type stand-alone networks are a big risk, since the latter are supposed to be much more cost effective. The case studies indicate that this view does not apply in the main Western European business players, and that 3G and WLAN are essentially complementary within a total mobile data services portfolio. WLAN is, at least in the beginning, representing only one service category of 3G-service provision, namely Mobile Intranet/Extranet Access. This category is especially suitable for workers on the move who have a need to access corporate intranets and the Internet remotely. Such workers are also likely to be the main users of public WLAN services. By combining a public WLAN service with their 3G services, operators will be able to offer a seamless mobile data communications solution for the business user. Results show that WLAN revenues are small compared to the whole 3G revenues, so the economic figures in most cases are not significantly influenced.

Mobile Virtual Network Operator Case Study

As there are a number of firms already doing business or interested in entering the mobile sector, which have been left without a 3G license and on the other hand, license fees may act as an economic burden for the "winning" companies, a new business channel to enter the mobile market and participate in the 3G era is the MVNO channel. This business case focuses on the MVNO business opportunity, and it is based on IST-TONIC [2] 3G business cases presented in the previous section, in terms of business analysis, estimated services, market conditions, and so on. From the initial technoeconomic study [14] and the associated reports about companies that have expressed their interest to enter the market, several MVNO business profiles can be foreseen:

- Telecom operators, for whom MVNO offers a complementary service to fixed wireless access services, and the business focus is on network operations.
- Power companies or utilities in general, which benefit from large customer bases but lack service innovation, and they probably focus on network operation.
- TV and multimedia content providers, for whom MVNO offers strong service differentiation and penetration possibilities due to special entertainment services. Thus, their focus is service provisioning.
- Car/food/retail industries with a large customer base and high value brand name but without additional service offerings and coverage. Their MVNO case is probably focused on low price customer provisioning.

The similarities in business profiles lead to a grouping of two main MVNO business profiles that have been investigated:

1 The *operator-like MVNO* with a telecom or utility background, without a mobile license but widely known as an operator. This kind of MVNOs take advantage of several issues such as initial market share and lower training costs, aiming to complement/expand other services such as fixed broadband services. Such examples are B2 in Sweden, Kingston in the United Kingdom, and One.Tel in the Netherlands.

2 The *service-oriented MVNO* is a high brand value and large customer base company, aiming to expand its business in the mobile area such as BSkyB, Virgin Group, Value Telecom, Ford, and General Motors in UK. Therefore, it targets to gain customers from every MNO and thus, the churn effects must be taken into account as key element in this case. Several advantages (e.g., marketing costs) and pitfalls (e.g., leased lines costs and personnel costs) must be taken into account as key elements in this case.

Nowadays, the MVNOs form partnerships with infrastructure owners or rent network resources and focus on developing their own service offerings, essentially in content and portals. An MVNO has control over switching and authorization. The MVNO concept separates the radio infrastructure from the intelligent components of the network, such as the databases.

There are different scenarios for an MVNO approach and consequently different architectures for the MVNO, spanning the full MVNO approach, with its own SIM card, network selection code and switching capabilities as well as a service center but without spectrum, to a wireless Internet service provider (ISP) without its own core network, which is basically an Internet portal providing wireless IP services.

In the analysis outlined hereafter, only the full MVNO has been tracked. Four scenarios based on the previously described UMTS case definition of large and small country have been studied. These scenarios also differentiated in the market shares due to different competition environment:

- Operator-like MVNO in a large country with a market share of 8 percent at the end of the study period

- Service-oriented MVNO in a large country with a market share of 6 percent at the end of the study period
- Operator-like MVNO in a small country with a market share of 12 percent at the end of the study period
- Service-oriented MVNO in a small country with a market share of 4 percent at the end of the study period

The main economic results for the four basic scenarios are illustrated in Table 5.

These results show that MVNO companies can be profitable. It can be observed that the investments are more or less proportional to the population. Interestingly enough, for the small country the investment per customer is almost triple that for the large country due to the coverage obligations and population density (Table 1). The main difference between the MVNO types is due to the different market shares and associated usage levels in the service oriented scenarios (30 to 50 percent higher than in the operator oriented scenario).

The usage level is one of the most critical parameter for the MVNO business case. An increase in usage translates only as greater revenues, while the corresponding increase in costs is minimal and related to core network elements. The MVNO service oriented case can be profitable only for companies targeting the high-end segment of customers and gaining high penetration.

The price for interconnection between an MVNO and a mobile network operator (MNO) is based on data from operators and reports. This parameter could be the turning point for this business case, and the MVNO must negotiate hard with the MNO in order to keep the interconnection costs as low as possible. On the other hand, the national regulating authorities in telecommunications should protect the new companies and ensure that the interconnection price level will boost the overall competition. From the other parameters, only operations, maintenance, and marketing costs are seen to have a significant impact on the business case. However, most of these costs are quite inelastic since they are related to personnel costs, and the operator does not usually have much leverage to reduce them significantly. The marketing cost in some cases is of major importance.

The MVNO case in the 3G era has been shown to be profitable in both large and small countries. The MVNO entry to 3G business represents a profitable option for both the MNO and MVNO. Furthermore, as new technologies and new services appear, and m-commerce, location-based commerce, and short-range commerce are continuously developed, the MVNO for 3G becomes a viable and win-win situation for all actors. The initial presence of the MVNO in the 2G is mandatory for a successful business in the emerging 3G market. A business case for a new MVNO without a brand name does not look lucrative. Marketing and entry costs in general can be a burden for a potential MVNO, but this can be overcome by a high brand firm or an already operating company. The results also show that it is potentially very profitable for an MVNO to expand its services by providing broadband services via WLAN.

Fixed Broadband Access Network Case Study

The "economics of fixed networks for broadband IP services" business case analyzes the provision of next-generation services in urban areas. Technoeconomic analysis of telecommunication systems and services, combining the economical and business aspects with comprehensive technical parameters modeling, has not been widely published for fixed broadband access apart from the technoeconomic analysis in [4] and a discussion of installation costs in [15]. The business case discussed below analyzes how close to the customer fiber can be profitably deployed and how important the actual choice of technology is (Ethernet or asynchronous transfer mode, ATM).

Technoeconomic evaluations have been carried out for a number of different access deployment scenarios:

- Fiber to the cabinet (FTTC)
- Fiber to the home/office (FTTH/O)
- Hybrid fixed and wireless access

The FTTC and FTTH/O deployment scenarios are analyzed for three different types of generic urban areas: dense urban, urban and suburban.

Basically, two network technologies are compared for FTTC and FTTH/O deployment, which are using ATM or Ethernet as a layer 2 protocol. The hybrid fixed and wireless deployment consider a new LMDS Ethernet-based system that can handle the same service set as does the FTTC solutions. Realistic migration alternatives have been analyzed with respect to profitability and risk profiles.

FTTC solutions for dense urban and urban areas result in a positive business case (positive NPV) with a payback period between nearly four and six years [4]. The positive result for dense urban and urban areas is mainly driven by the existing infrastructure in terms of ducting systems, the short total connection distance to the customers, and the housing structure as well. The most important variables influencing the business case are tariffs, customer penetration, the network operations costs and the access equipment costs. The total investments for point-to-point Ethernet compared to point-to-multipoint ATM FTTC architectures focusing on both business and residential market are in general on the same order.

The results show that the choice of technology (Ethernet or ATM) has almost no effect on the cost level and profitability of the cases. For the suburban area, an FTTC solution is too expensive due to heavy infrastructure investments.

Only the dense urban area case is profitable for both FTTH/O architectures and technologies, with payback periods of 5.5 years for the ATM PON solution and around 7 years for the Ethernet point-to-point solution. For the urban and of course much more for the suburban area, an FTTH/O solution is too expensive; therefore, other access technologies should be considered, like hybrid fixed and wireless access.

Sensitivity analysis has been carried out in order to rank a number of selected uncertainty assumption variables according to their impact on the NPV. In a "traditional" approach, each of the selected parameters is changed on a one-by-one basis by the same percentage up and down. This is basically wrong, as some variables are inherently more uncertain than others. Instead, 5 and 95 percent have been chosen as lower and upper limits, respectively, for each variable, and probability density functions have been applied to all parameters [16].

The most influencing variable is the wholesale ARPU, as was expected (generated from annual tariff). It reflects the degree of competition within the value chain. If the operator gets less than the assumed 60 percent, it has the greatest impact at all. The 5 and 95 percent confidence limits are 40 and 80 percent, respectively. The second most influencing variable is the total penetration. The variation was set between plus and minus 20 percent of the default penetration. A reduction in total penetration results not only in lower revenues but also lower costs due to less investment needed. The network operations variable, defined by 20 percent of the accumulated investments, is the third most influencing variable. The confidence limits are 10 and 30 percent, respectively.

The uncertainty in access equipment costs has been modeled by changing the time constant ΔT of the production volume curve (Eq. 1).The default value is 10 years. The 5 and 95 percent confidence limits are 5 and 15 years, respectively. The impact is far less dramatic than for the variables listed above. For ΔT, the values 5, 10, and 15 years correspond to price reductions of 69, 59, and 47 percent, respectively, during the whole study period. Sales and marketing costs are assumed to be 5 percent of the total revenues. A uniform distribution from 2.5 to 7.5 percent has been used to give confidence limits of 2.75 and 7.25 percent, respectively. The impact is small because of the small default value.

Similar assumptions have been used and an extensive risk assessment has been performed on the different fixed network scenario and business cases. The FTTC deployment scenarios have small risk for urban and dense urban areas. The FTTH/O deployment scenario is highly risky, especially in the urban area. Furthermore, in an extensive approach, by using the new broadband wireless access (BWA) system, which is Ethernet-based and designed for multidwelling housing structures, in combination with VDSL in dense urban and urban areas, the analysis shows quite promising economic results (3.5 years payback period in dense urban and almost 5 years in urban areas). In contrast, in suburban areas, the business case is not attractive at all. The main reason for this is that BWA access terminal (receiver) design is optimized for a fairly high number of customers. In general, the new BWA option seems to yield somewhat better results than the FTTC solutions. This is mainly due to the very smooth scaling behavior of BWA. Apart from suburban areas the full coverage is easily achieved with a limited number of required access points. Later on, as the capacity requirements grow, new access points can be deployed on demand, or new solutions under the umbrella of WIMAX systems could be found.

Conclusions and Recommendations

This article has presented a technoeconomic evaluation of three selected business cases addressing a wide range of crucial telecommunications questions debated today in connection with an extensive market analysis.

Several conclusions and remarks can been drawn from results. First, as far as the market study is concerned, there is a substantial demand for broadband services in the fixed network and new services in mobile networks. The broadband business breakthrough is happening now. The players have to act and compete for market shares now if they want to survive. DSL technology is expected to be the dominant platform for broadband delivery, especially in Europe. Given the right regulatory conditions, local loop unbundling (LLUB) will be the real enabler for efficient competition and service development. The regulators should stimulate competition and competitive environment in the first mile.

In the "UMTS+WLAN" case, long-term sight with comprehensive modeling, as in IST-TONIC [2], is needed to get sound economic forecasts and recommendations for extensive UMTS business cases. The cases studied here are generally positive, but service provisioning and take-up delay should be fought back as a potential eroding factor for the business case. Prompt investments in UMTS are justified and needed throughout the extended value chain.

Authorities should smooth the obstacles for the UMTS rollout and business, by avoiding requirements leading to uneconomic structures, in the current financially challenging situation. Models for infrastructure sharing and bandwidth sharing with MVNOs, for example, should be considered. This is also in the interests of the society in terms of advanced mobile services for citizens and companies. The delay of the UMTS breakthrough in Europe would mean that Europe may lose the benefits from the leading position in the world concerning mobile service infrastructure and more widely from a most developed information society.

Results suggest that 3G and WLAN will be complementary within a total mobile data services portfolio. While WLAN services will not be substitutes for 3G services, they can become a strong source of competitive differentiation, and therefore mobile operators should offer WLAN services to their customers, either by themselves or through partnering.

Regarding the MVNO case, as new technologies and new services appear, the virtual operator path for 3G becomes a viable and profitable situation in both large and small countries. Since the market share has a critical impact on the profitability, the initial position of the MVNO in the 2G era is important for a successful business in the emerging 3G market. As marketing and entry costs in general will be a burden for a potential MVNO, the business case for a new MVNO without a brand name does not look lucrative. In addition, profitability options are offered by the provision of supplementary broadband services via WLAN. In conclusion, due to the great impact of interconnection price and usage levels, the MVNO case is "on a tightrope" between market share and usage and the battle will be more critical for companies aiming to be involved in the 3G market without having a telecom background, since they must target the high-end segment of customers and gain high penetration.

As far as the "fixed broadband access network" case is concerned, the access network is the most expensive part in deploying a new network platform. FTTC architecture is a profitable deployment strategy for dense urban and urban areas for services beyond 2 Mb/s. FTTH/O architectures and technologies are only profitable in dense urban areas. However, the FTTH/O architecture enables an easy bandwidth upgrade and is therefore most future-proof.

Whatever the selected technology of layer 2 (Ethernet or ATM), there is no impact on the cost level and profitability of the cases. The hybrid fixed and wireless access system, focusing on the multidwelling market segment, is a realistic alternative and possibly a complementary solution in urban areas. In some cases political actions are required if the ambition is to provide the broadband services in all rural and noncompetitive areas.

Concluding, investments in telecommunication technology can develop a new market area and expand traditional options for new players. Any business modeling should be accompanied by technoeconomic evaluation in order to give readers insights into the financial perspective and viability of a telecommunication investment project.

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