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## Deliverable number 11

## *Final results on seamless mobile IP service provision economics*

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**Abstract:**

This deliverable presents the final techno-economic results on network solutions for seamless mobile IP service provision enabling seamless handover between 3G mobile and WLAN networks. Investment and operating cost structure are identified, as well as the breakdown of revenues. Analysis concerns two major deployment scenarios, the first in an average "large" European country, and the second in a "small", typical Scandinavian-type of country. The techno-economic analysis was performed for a 3G operator with and without a WLAN component for hot spot broadband coverage. Sub-scenarios are also developed for analysing the effect of network roll out pace, and also the impact of the license cost as well.

Main conclusion are that 3G operators may slightly benefit by deploying high QoS Wireless LAN for broadband services, but the economic results are much more sensitive to license fee level and roll out pace. In general the investigated European UMTS cases are seen as positive prospects within the TONIC framework and basic assumptions.

**Keyword list:** UMTS, mobiles, 3G, WLAN, Hiperlan2, Wireless IP, techno-economics

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# 1. EXECUTIVE SUMMARY

This deliverable contains the final techno-economic results of the work achieved by TONIC Business Case 1 (BC1) “seamless mobile IP service provision economics”. BC1 regards core and radio network infrastructure, market development and business modelling aspects of mobile IP service provision, which enables seamless handover between Third Generation (hereinafter 3G) mobile systems and wireless local area networks (hereinafter WLAN). The main objective of the deliverable is to elaborate and evaluate network and economic elements connected with the use of UMTS-WLAN infrastructure for mobile service provision.

The studies have been undertaken for large and small European country-profiles, in accordance with different demographic, economic and regulatory national portraits. They refer to an incumbent 3G mobile network operator, with already a solid customer base and Second Generation (hereinafter 2G) mobile infrastructure, facing the strategic decision of adding public WLAN infrastructure on its own mobile network to strengthen its broadband service portfolio in hot spot areas. These areas may include airports, hotels, conference centres and university campuses, being chiefly characterized by their number of access points, customers served and capacity available. The service portfolio aims at business (notably post-paid) and residential (notably pre-paid) customers alike. Typical services being proposed are mobile commerce, video conference, voice-video call, video-on-demand, mobile gaming and file transfer, each with different requirements in terms of bandwidth (narrowband, wideband, broadband), quality of service (conversational, streaming, background-interactive), switching mode (circuit, packet) and supporting network (UMTS, WLAN). Services are grouped in classes according to these requirements.

A comprehensive model embracing network and traffic dimensioning, cost evaluation, service characterization, market modelling and revenue forecast has been implemented. The model takes an operator viewpoint and aims to simulate six different network scenarios in the study period from 2002 to 2011. The model, running on Excel, accommodates key financial outputs such as Net Present Value, Internal Rate of Return and payback period for 3G investment appraisals. The six evaluated scenarios are: a small country with slow network roll-out with or without WLAN add-on, a small country with fast network roll-out, a large country with high license fees with or without WLAN add-on, and a large country with low license fees.

Market forecast is implemented through a four-parameter, non-linear S-shaped predictive procedure suitable for long-term analysis of the take-up of new telecommunication services. Customer segmentation sees a constant average of 20% business customers and 80% residential customers over the study period. Market penetration rates, on-line usage time patterns and overall capacity demand per service class have been modelled born in mind a number of market segment-related technological, e.g. equipment restrictions, and subscription, e.g. price levels, constraints. The typical business usage time for any given service class in comparison with its residential usage time is measured through multiplying-factors which, depending on the service under consideration, vary between 1.5 and 2.5 times the residential usage time values. The overall amount of traffic generated by all users is calculated from the penetration rate of the service class in question, the respective market size, the average daily usage time of each service class per user and the average bit rate of each service class for usage time. WLAN demand forecast basically relies on mobile personal computer adoption patterns in Western Europe over the studied period, assuming that implementation costs are basically driven by the inter-connection with leased or DSL lines.

The generic network architecture model envisaged for seamless mobile IP service provision is based on an IP core network, enabling users to benefit from a common set of services offered through different access systems, whether wired or wireless. This deliverable covers aspect connected with UMTS-WLAN inter-working wireless access only. Details on capital and operational expenditure, roaming capabilities, quality of service and equipment requirements related to different parts of the network infrastructure are duly specified. While WLAN access is primarily aimed at hot spot areas, the UMTS network dimensioning, in large and small countries alike, assumes a deployment which is started in dense urban areas, being progressively extended to urban, sub-urban and rural areas as demand for broadband mobile services rise. There are also terms stated in the UMTS licence that may affect the pace of rollout and the geographical area to be covered. The issue of shared infrastructure among various network operators is also addressed, concluding that shared infrastructure may substantially reduce upfront investments at various levels of the network. A shared radio network is looked upon as not interesting in dense or urban areas, or for 3G operators drawing a substantial 2G subscriber base in Large country type. In sparsely populated countries (country type Small), the TONIC model leads to a remarkable 14 % savings on investments.

With a direct impact on revenue levels, the pricing schemes for UMTS/WLAN service provision look primarily at the amount of megabytes transferred per service class, with lower tariffs for WLAN (due to cheaper technology investments) than for UMTS. But heed is also taken, however, to other schemes, such as flat rate tariff regimes. Subsequent tariff erosion patterns are applied over the studied period. The ARPU development during the study period for both UMTS and total mobile subscriber base, resulting from all the modelled factors, is presented and critically compared with the history data and other studies.

The study leads to a positive prospect on the economics of European UMTS operator in all basic cases. The license and investment costs are not seen too high for making profitable business in the long run, as the license period is in most cases as long as 20 years. Yet the technology generations emerging afterwards have to be taken into account. The pay back periods are generally near 7 years, which is not to be considered too long against the magnitude of the project. The risk of delayed UMTS deployment and take-up, which can ruin the business case economically, should be fought back in all frontiers.

This deliverable concludes that the often expressed concern about the rise of public WLAN to the detriment of 3G is not justified. Instead, it indicates the economic profitability of WLAN notably as a complementary, rather than competing, solution for 3G operators towards broadband mobile service provision. Under the nominal assumed scenario WLAN is expected to boost UMTS multimedia usage by 8%, and to generate 6% of the combined UMTS-WLAN revenue stream in large countries, with additional overall investments and operating costs of just 1% and 4% in excess respectively. For small countries, the additional investment and operational costs are 2% and 5% respectively, resulting in a similar UMTS-WLAN revenue composition. In related terms, a 3G operator in a large country with high license fees is expected to see the Net Present Value of its investment up by 18% thanks to WLAN service provision. In a small country with a slow network rollout the Net Present Value premium for WLAN usage is estimated at 9%. This stems from the fact that small countries are prone to higher investment levels per inhabitant in newly established networks.

Thus, results show that companies operating WLAN services as mobile virtual network operators can benefit from higher revenues, as WLAN may serve as an additional service for its existing customer base.

# 2. LIST OF ACRONYMS

| | |
|---|---|
| 3G | Third Generation (mobile systems) |
| AAA | Authentication, Authorization, Accounting |
| AP | Access Point |
| APC | Access point Controller |
| ARPU | Average Revenue Per User |
| ASP | Application Service Provider |
| BAN | Brain Access Network |
| BAR | BRAIN Access Router |
| BMG | BRAIN Mobility Gateway |
| BRAIN | Broadband Access for IP Based Networks (IST-1999-10050) |
| BS | Base Station |
| BSC | Base Station Controller |
| BSS | Base Station Subsystem |
| BTS | Base Transceiver Station |
| CAPEX | Capital Expenditures |
| CSCF | Call State Control Function |
| DFS | Dynamic Frequency Selection |
| DHCP | Dynamic Host Configuration Protocol |
| DLC | Data Link Control |
| DNS | Domain Name Server |
| EDGE | Enhanced Data for GSM Evolution |
| EIRP | Equivalent Isotropic Radiated Power |
| ETSI | European Telecommunications Standards Institute |
| EU | European Union |
| FDD | Frequency Division Duplex |
| FP | Flexibility Point (level in the TONIC tool description of network architecture) |
| FW | Firewall |
| Gb | Interface Gb between BCS and SGSN |
| GGSN | Gateway GPRS Support Node |
| GMSC | Gateway Mobile Switching Center |
| GPRS | General Packet Radio Service |
| GRAN | Generic Radio Access Network |
| GSM | Global System for Mobile communications |
| GSN | GPRS Support Node |
| HIPERLAN | High Performance Radio Local Area Network |
| HLR | Home Location Register |
| HSCSD | High Speed Circuit Switched Data |
| HSS | Home Subscriber Server |
| IP | Internet Protocol |
| IRR | Internal Rate of Return |
| IST | Information Society Technologies |
| Iu | Interface between RNC and Core Network |
| Iu-bis | Interface between Node B and RNC |
| Iur | Interface between RNCs |
| IWU | InterWorking Unit |
| LAN | Local Area Network |
| MAC | Medium Access Control |

| | |
|---|---|
| MGCF -> | Media Gateway Control Function |
| MGW | Media GateWay |
| MIND | Mobile IP based Network Developments (IST-2000-28584) |
| MIP | Mobile IP |
| MSC | Mobile Switching Center |
| MT | Mobile Terminal |
| MVNO | Mobile Virtual Network Operator |
| Node B | UMTS Base Station and Base Station Node |
| NPV | Net Present Value |
| NSS | Network Subsystem |
| NVOD | Near Video on Demand |
| OMA | Open Mobile Alliance |
| OMC | Operations & Maintenance Center |
| OPEX | Operating Expenditures |
| PBP | Pay Back Period |
| PDN | Packet Data Network |
| PHY | Physical Layer |
| PLMN | Public Land Mobile Network |
| PSTN | Public Switched Telephone Network |
| QoS | Quality of Service |
| RNC | Radio Network Controller |
| SGSN | Serving GPRS Support Node |
| SIM | Subscriber Identification Module |
| SIP | Session Initiation Protocol |
| SMS | Short Message Service |
| TDD | Time Division Duplex |
| TONIC | Techno-economics of IP Optimized Networks and Services |
| TRX | Transmitter-receiver |
| TPC | Transmit Power Control |
| UMTS | Universal Mobile Telecommunication Service |
| URAN | UMTS Radio Access Network |
| USIM | User Service Identity Module |
| UTRAN | UMTS Terrestrial Radio Access Network |
| VLR | Visitor Location Register |
| VOD | Video on Demand |
| WAP | Wireless Applications Protocol |
| W-CDMA | Wideband Code Division Multiple Access |
| WLAN | Wireless Local Area Network |
| WP | Workpackage (within an IST project) |
| WPAN | Wireless Personal Area Network |
| WRC | World Radio Conference |

# 3. INTRODUCTION

## 3.1 Background - TONIC research target

Uncertainties with respect to take-up rate for mobile services, regulators relaxing license requirements, asset write-downs and shelved launches are today's breaking news about telecommunications sector. These have persuasive impact on opinion: Will 3G gloom stay at this stage for a long time?

It is also said, very often, 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 efficient.

TONIC research, thanks to its comprehensive and quantitative approach, moderates and the stand alone impact of WLAN networks, demonstrating that it is much more a completing than a competing technology. Therefore a comprehensive model for UMTS operator's business case was created. An "incumbent" operator, having a 2G infrastructure and customer base already there, has been selected for this study case. The TONIC model aims for holistic view combining demand development estimation, technology rollout, cost modelling, services classification, pricing and revenue forecasts. By these means it is possible to have a consistent picture, where changing of one factor is reflected in others. To have benchmarks or boundary values for different parameters (like ARPU, end-user price level, penetration, etc.) it is possible to have reality checks for feasible inputs. This is important, as the information is at this stage still very fuzzy. The model gives also possibilities to "simulate" scenarios with different input values, and make risk and sensitivity analyses with several interdependent variables. In the model, the UMTS economics has been separated from the 2G businesses to get a focused view on the effects of UMTS demand, rollout and service provisioning on the costs and revenues of the operator. However the underlying 2G/2.5G network, providing e.g. antenna site infrastructure and seamless handovers (where limited WCDMA coverage) has been taken into account. In this study the 3G UMTS case is looked within a quite large time span (years 2002 – 2011). This reflects the fact that UMTS is a long haul endeavour and opportunity. Also taking into account that the licenses are in most cases for 20 years. On the other hand, keeping in mind the pace of emerging new technologies, it is considered that ten years describe well enough the 3G window of opportunity for the operators. The research question is to demonstrate how a 3G operator can come off in the competition in given country demographics, economical constraints and regulatory conditions.

## 3.2 Document outline

This document presents research results on TONIC business case two entitled "Seamless Mobile IP Provision" in a comprehensive way. After having described in chapter 4 and 5 our general assumptions and type of services, market demand in chapter 6 is analysed and quantified accordingly to retained service classes. It is also developed in this part a WLAN stand- alone business case that unveils possible economical imbalances for WLAN pure players. Full description of network architectures and cost elements are given in chapter 7, while dimensioning process is explained in chapter 8, with its capacity and coverage principles. Benefit from possible infrastructure sharing in UMTS deployment is detailed in chapter 9 for small and large country cases. Before presenting in chapter 11 financial results for basic cases with different scenarios in terms of roll out pace and license fee level, end user pricing and revenue forecasts are calculated. It is shown that these forecasts diverge from other market studies. Finally, last chapters are dedicated to following simulations resulting from TONIC business modelling: impact of MVNO on MNO, sensitivity analysis and risk analysis, the latter being implemented for analysing the impact of a delayed penetration of UMTS usage.

# 4. GENERAL ASSUMPTIONS

Following the definition of appropriate service sets, and taking into account demand scenarios established within TONIC Work Package 1, the business case group developed a model for the dimensioning of the network and service resources, encompassing both the 3G mobile and WLAN (Hiperlan/2) components. The tariff structures defined in Work Package 1 are applied to compute key economic indicators such as Net Present Value, Internal Rate of Return, and payback period. The economic indicators are calculated from pre-tax cash flows.

The techno-economic modelling by TONIC provides a business case analysis in the sense that it answers the question, "Is the given business scenario profitable or not, under the defined circumstances?" This approach takes into account direct investments (CAPEX) OA&M[1] costs (OPEX), and revenues.

This case study spans the timeframe from year 2002 to 2011. Unless otherwise stated for specific modelling scenarios, cash flows are discounted using a 10% discount rate. This rate represents an average of the different discount rates most commonly used by telecommunication operators in Europe. The techno-economic modelling was carried out using the TONIC tool, developed by the TONIC project using the TERA tool as its basis. This tool is an implementation of the techno-economic modelling methodology developed by a series of EU co-operation projects in the field.

## 4.1 Technologies studied

In the network scenario to be modelled, the UMTS network uses WCDMA/FDD[2] technology (Release 99 in the first years of the study period, then through Release 4's MSC Server concept towards an all-IP core network as standardised in 3GPP Release 5 specifications). The WLANs are assumed to be based on enhanced Hiperlan/2 technology. The inter-working of these networks and the ability to seamlessly move among them is developed by the IST projects BRAIN[3] and MIND[4]. The purpose of TONIC Business case 1 is to evaluate the economic implications if the BRAIN technology were implemented on a nationwide scale.

## 4.2 Selected country types

The modelling focuses on two area scenarios: a large European country (population 65 million) characterised by France or Italy, for example, and a small European country (population 5,5 million) exemplified by Scandinavian countries like Norway or Finland. The models are not exactly representative of any defined country, but rather share typical demographic characteristics of these countries. The countries differ on several points, in addition to their geographical and demographic features. Firstly, the operator in the large country is assumed to have significant license costs (around 90€/inhabitant for large country vs. 2€/inhabitant for small country Secondly, the UMTS subscriber saturation level is estimated to be higher in the Nordic country type – 95% versus 90% in the large country type. Terminal subsidies are 300€ per new subscriber in both type of countries.

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[1] Operation, Administration & Maintenance
[2] Wideband Code Division Multiple Access/Frequency Division Duplex
[3] http://www.ist-brain.org/
[4] http://www.ist-mind.org/

## 4.3 Selected operator characteristics and scenarios

The business case is evaluated from an incumbent 3G mobile network operator point of view. UMTS roll out pace and license fees level have such a big impact that different scenarios have been studied according to these parameters. Combination with WLAN is an option for the operator to supplement its infrastructure and service portfolio.

UMTS rollout is assumed to begin in 2002, and the services are available as of 2003. The WLAN network deployment is started in 2003 and services are launched in 2004. This time frame is in keeping with the anticipated large-scale availability of Hiperlan/2 products, and particularly the possibility of seamless handover between this type of system and UMTS networks. The high capacity WLANs are constructed only for indoors hot spot areas where the expected demand is high. These hot spots include airports, railway stations, hotels, congress and exhibition halls, shopping centres, stadiums and arenas.

Six scenarios are analysed in the report:

- Small country with slow roll out, without WLAN services
- Small country with slow roll out, providing WLAN services
- Small country with fast roll out
- Large country with high license fee, without WLAN services
- Large country with high license fee, providing WLAN services
- Large country with lower license fee

All the scenarios start the network deployment in year 2002 from the dense urban areas and continue towards the less populated areas. The full rollout to rural areas takes the whole study period in the Large country and Small country with slow roll out scenarios, but is completed in three years in the Small country with fast roll out case.

Revenues are calculated only as the customer is in the coverage area of the built UMTS network, outside which the traffic going to 2G network and that usage not counting on the UMTS business case revenues.

Sensitivity studies with respect to parameters such overall mobile penetration, market share, equipment costs, tariffs and license fee level are implemented. Risk analysis is also performed for assessing effect of shift in time of the UMTS penetration.

# 5. SERVICE CLASSES

The following list gives an idea of the variety of services to be made available to the customer by UMTS complemented with WLAN. More detailed discussion about the different services can be found in the TONIC Deliverable 1.

1. Internet access
2. IP information services (news, weather, sports, stock quotes, airline schedules, etc.) [Service and content provider functions needed inside or outside the operator network]
3. Corporate Intranet access
4. WAP access [WAP Gateway and WAP portal]
5. Push services (subscription-based information services, advertising)
6. Personal information management
7. Scheduling and Groupware
8. Integration with desktop applications
9. Text Messaging (SMS; instant messaging)

10. Group Chat
11. Presence service
12. Multimedia Messaging (e.g. pictures, audio- and video clips)
13. Personal and Group Storage services
14. Unified messaging services for access to universal message box for e-mail, voice-mail, and faxing, with ability to forward to another terminal
15. E-mail
16. Fax
17. File Transfer
18. Mobile commerce, (m-commerce), mobile banking, shopping
19. Mobile gaming (incl. real time audiovisual)
20. High bit-rate, non-interactive, multimedia applications for multicast video, audio, and music streaming
21. Rich call; Multimedia file or stream exchange between mobile terminals during conversation (photos, streaming audio - and video clips)
22. Telephony (IP telephony with also access to legacy PSTN)
23. Mobile video telephony (multimedia conversation)
24. Mobile videoconferencing
25. Remote video surveillance/monitoring
26. Video-On-Demand (VOD)
27. Digital TV
28. Pay Per View, or Near-Video-On-Demand (NVOD)
29. Localised Content Service (e.g. services available nearby)
30. Network Provider Discovery
31. Localisation Service (e.g. “navigation” systems, guidance to target; localisation of customer or patient)
32. Business’ and organizations’ professional information sharing applications (mobile sales personnel, access and update to databases and business applications, telemedicine, repair supervision and other, in many case multimedia, communication).
33. Virtual wallet applications (used with vending machines, in shops, etc.; may be connected to credit cards too)
34. Telemetry (e.g. alarm systems, remote control of devices, e.g. sauna stove)

In order to determine the impact of the various services on network dimensioning and revenue for the operator, we have defined service classes in terms of bandwidth and quality of service. Each bandwidth class - narrowband, wideband and broadband - is assigned an average bit rate, which corresponds to the *average air interface capacity required by a subscriber, when using the given service*.

There are four Quality of Service (QoS) classes:
- Conversational
- Streaming
- Interactive
- Background.

The main characteristics of each class are indicated in Table 1 (Source: 3G TS 23.107):

*Table 1: Quality of Service Classes as defined by 3GPP*

| Class | Conversational | Streaming | Interactive | Background |
|---|---|---|---|---|
| Characteristics | Delay and jitter controlled<br>Constant bit rate<br>Some bit errors allowed | Jitter controlled<br>Near constant bit rate<br>Some bit errors allowed | Enables question /answer exchange<br>Low or no tolerance of errors<br>Variable bit rate | No time constraint; Low/no error tolerance<br>Variable bit rate |
| Examples | Voice, video-telephony, video-conferencing | Video, Audio | Web browsing, interactive e-mail | FTP, E-mail downloading as background task |

For simplification, we combined the Interactive and Background service classes, considering that their requirements on the network were similar enough, and therefore not having any serious impact on network dimensioning and revenue expectations. Lastly, services are divided into circuit-switched and packet-switched services.

Based on these criteria, we defined 11 service classes. 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. Indeed, the “broadband” services are assumed to be available only if the operator has the WLAN component.

These classes are listed in Table 2 with examples of the services they encompass:

*Table 2: Service classes for TONIC Business Case 1.*

| Circuit / packet Switched | Bandwidth class | Quality of Service class | Sample services | Nominal data rate (kbps)* | 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 | 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 | WLAN |
| Packet | Narrowband | Int_backgr | short msg., WAP | 1.7 | UMTS |
| Packet | Wideband | Int_backgr | E-mail, Internet | 8.2 | UMTS |
| Packet | Broadband | Int_backgr | Large file transfer, appl. | 107 | WLAN |

*average in the air interface during a session, overhead included

Usage, in terms of average minutes per day, differs depending on whether the customer has a professional or residential profile. Lastly, the average busy hour consumption per user per service class is assumed to be 30% of total daily consumption for professionals and 20% of total daily consumption for residential customers.

For practical reasons we will use in our following analysis about services classes the acronyms like follows Table 3:

*Table 3:Acronym of Service class characteristics*

| **Acronyms** | **Characteristic** |
|---|---|
| CS | Circuit Switched |
| PS | Packet Switched |
| NB | Narrowband |
| WB | Wideband |
| BB | Broadband |
| Conv | Conversational |
| Stream | Streaming |
| Int_backgr | Interactive background |

# 6. MARKET AND DEMAND FORECASTS

## 6.1 Introduction

Demand forecasting is an essential step in business modelling since both volumes and pricing assessments make the essential calculation of forecasted revenues. Technology penetration, market segmentation and demand in volume per services classes have been in depth investigated in this chapter. It covers aspects connected with market assumptions on mobile subscriber penetration and technology-generation development over the study period above.

The referred market studies have been applied with a critical attitude. We have tried to dig into the basic dynamics of the mobile market, taking into account both the history data from former generations and the rich service portfolio and completely new opportunities brought in by the 3G standards. We try to avoid looking too shortsightedly on the current downturn, which is to our view more the normal state of uncertainty and fear before the take off. The declining ARPUs are not telling that there is no potential anymore for lucrative new services and respective revenue opportunities, but only that the old era of mobile associated mainly to voice has come to its stagnation before new wave. We discuss the ARPU forecasts separately linked with our end-user price modeling, in the Chapter 10. By building a complete model with all the aspects, we benefit a good frame of reference for reality checks of our assumptions, concerning e.g. capacities, price levels or consuming patterns for different service categories. We do not go to too much of details anyhow, like to try to figure out the distinctive “killer applications”, but we look the opportunities at a classified but not individual service level, taking all the time into account the different segments of residential and business markets.

As noted above, against the diverse new service concepts, we see no evidence that the high revenue potential would have disappeared from the market. When is the 3G mature to take wind is another question. We pay attention to the technology and market development, which are contributing to the migration pace towards UMTS, also in the Risk analysis Chapter 11.10.

The market forecast procedure used in the TONIC model, as an input towards the revenue evaluation of Chapter 10, is detailed in Section 6.3, with the mathematical modeling associated to each forecast being also specified. Section 6.4 contains an overview of the mobile subscriber penetration rates in Western Europe in the timeframe 1997-2010, as well as our estimations for the market share and subscriber base development trends for 2G, 2.5G, 3G and 3.5G mobile systems over the study period. Section 6.5 describes the mobile subscriber segmentation assumed in the model according to typical service usage or payment profiles for large and small countries. Section 6.6 breaks down the overall market demand for 3G mobile service provision into a number of service classes characterized by different requirements in terms of bandwidth, quality of service, switching mode and supporting network. Typical usage time patterns per service in each market segment are also described, as well as the evolution of WLAN deployment throughout hot spot areas. Section 6.7 explains how user traffic generates, taking into account aspects such as the market share of the concerned 3G operator, typical daily usage patterns per user, market penetration rates and average bitrate requirements per service class. Section 6.8 lays down a preliminary approach towards the assessment of the WLAN service provision value chain, and the business case modeling of a stand-alone WLAN operator within a 3G mobile framework.

A list with a number of studies referenced in this chapter follows in Section 6.2.

## 6.2 Relevant reference studies

- WLAN Revenue Opportunities for 3G Operators. The UMTS Forum, Issue September 2002
- Fostering an application driven business with Nokia. Nokia Networks White Paper.
- TONIC tool, UMTS-WLAN business model, version 14th. October 2002.
- OVUM Forecasts: Global Mobile Markets 2001-2005 (February 2001)Jupiter: Wireless Market to take off in 2003 (April 2001)
- OVUM Cellular voice and data forecasts (March 2001)
- Strategy Analytics: Mobile Communications Service – Europe 2000-2005 (August 2000)
- Forrester, Europe's UMTS Meltdown (December 2000)
- Strategy Analytics Industry Report, Global Cellular Data Applications, Revenue, & 3G Migration (December 2000).
- IDATE: Mobile Data Services (Europe only, October 2002)
- OVUM: Global Wireless Market 2002-2006 (July 2002)
- Yankee Group: European Cellular Forecast (October 2001)
- Forrester: 3G 's Belated Break-Even (September 2002)
- Analysys Research: Western European Mobile Forecasts and Analysis 2002-2007 (September 2002)

## 6.3 Mobile market forecasting model

The TONIC project uses a logistic model to perform demand forecasts. This model is recommended for long-term forecasts and for new services. To achieve a good fit, a four-parameter model including the saturation level is used.

The model is defined by the following expression:

$$Y_t = M / ( 1 + \exp (\alpha + \beta t))^{\gamma}$$

where the variables are as follows:

$Y_t$ : Demand forecast at time t

M : Saturation level

t : Time

$\alpha, \beta, \gamma$ : Parameters

The parameters $\alpha, \beta, \gamma$ cannot be estimated simultaneously by ordinary least-squares regression since the model is non-linear in the parameters. Instead, a stepwise procedure is used to find the optimal parameter estimates.

The logistic model is used for the total mobile penetration as well as for the different mobile technology generations. The parameters are estimated for each generation separately. For UMTS subscriber penetration model, different Saturation level parameter M values are used for “Small country” business cases (M=95%), and for country type “Large” (M=90%). The other parameters are the same for both country types.

## 6.4 Forecasts for different mobile technology generations

In the early TONIC period (2001), many of the market analysts and consultancy penetration estimations for the UMTS were showing early UMTS brake through[5]. After the early UMTS predictions the slowdown of the telecom industry affected the published reports as first to postpone the UMTS brake through and then also the growth in revenues.

In the above-referred newer studies, the forecasts cont very much on the assumption of UMTS delay. This potential risk factor for UMTS business case is discussed more in the Risk analysis chapter 11.10. We see no grounds in delaying the UMTS penetration in that extent, as the technology is maturing, UMTS is providing superb service potential and the license holding operators have widely made their decisions on UMTS launches. These decisions are also seen feasible in the economic sense by the TONIC analysis. Thus the prevailed downturn in the business is seen as biasing the recent reports. (See also the ARPU discussions and referred studies in the chapter 10.5.2.).

From the critical analysis of the market studies , history data from 2G and most recent development we derive forecasts for different mobile generations presented below.

The total mobile subscriber penetration is not of much controversy between studies as the trend has been clear and in Western Europe we are already considerably near the saturation. In the country types studied mobile subscriber penetration will be over 80% in 2005. Based on this information, we have made the following assumptions about the average mobile subscriber penetration for Western Europe:

*Table 4: Subscriptions and subscribers assumptions for total mobile penetration (%)*

| **Penetration/year** | **2005** | **2010** | **Saturation** |
|---|---:|---:|---:|
| Subscribers | 82 % | 90 % | 95 % |
| Subscriptions | 101 % | 120 % | 130 % |

Subscriber penetrations were selected as the basis for calculations in the TONIC model, as it describes better the real usage amounts and spending, which are related to amount of users rather than amount of subscriptions the individuals’ usage is split into. Also, especially within pre-paid contracts, there are dormant subscriptions not generating any traffic or revenue.

[5] For the early TONIC period market forecasts, see the TONIC Deliverable 2 (Demand models and preliminary forecasts for IP services).

Based on existing information on penetration rates from 1997 to 2002 and on the above-mentioned assumptions, we applied a logistic model to generate penetration rates from 1997 to 2010, as shown in Figure 1.

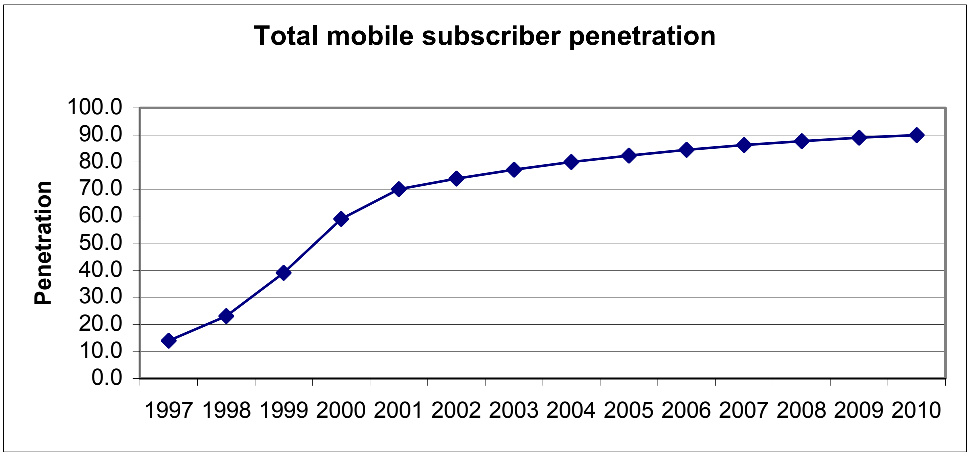



*Figure 1: Estimated total mobile subscriber penetration in percentages for W. Europe, 1997-2010.*

The total subscriber penetration in Western Europe is split into four mobile system generations, namely 2G, 2.5G, 3G and 3.5G, as defined in the chapter 6.1 above. Assumptions about the relative market share for each of the systems were discussed above.

These assumptions are presented in the Table 5.

*Table 5: Market share assumptions for different mobile systems*

| **Technology** | **2000** | **2002** | **2005** | **2010** |
|---|---|---|---|---|
| *2G* | 100 % | 84 % | 50 % | 0 % |
| *2.5G* | 0 % | 15 % | 30 % | 30 % |
| *3G* | 0 % | 1 % | 18 % | 50 % |
| *3.5G* | 0 % | 0 % | 2 % | 20 % |

A logistic model was also applied to estimate the percentages for the different generations for the years 2001-2010, as illustrated in Figure 2.

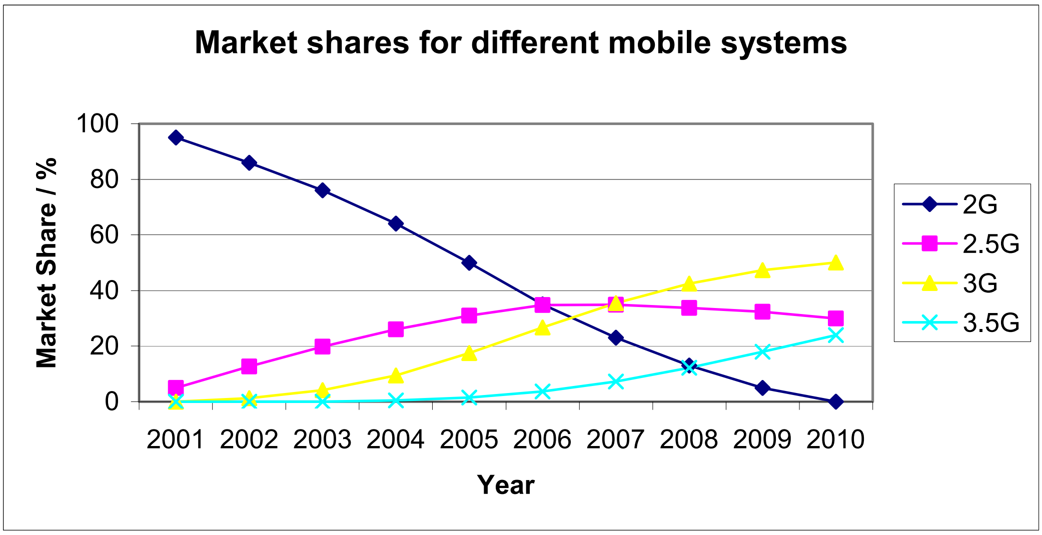



*Figure 2: Shares of different mobile systems for Western Europe.*

Based on the assumptions for the evolution of the total subscriber penetration combined with the assumptions regarding each of the mobile systems, we have calculated the penetration forecast for the four different mobile generations. These penetrations are shown in *Figure 3*.

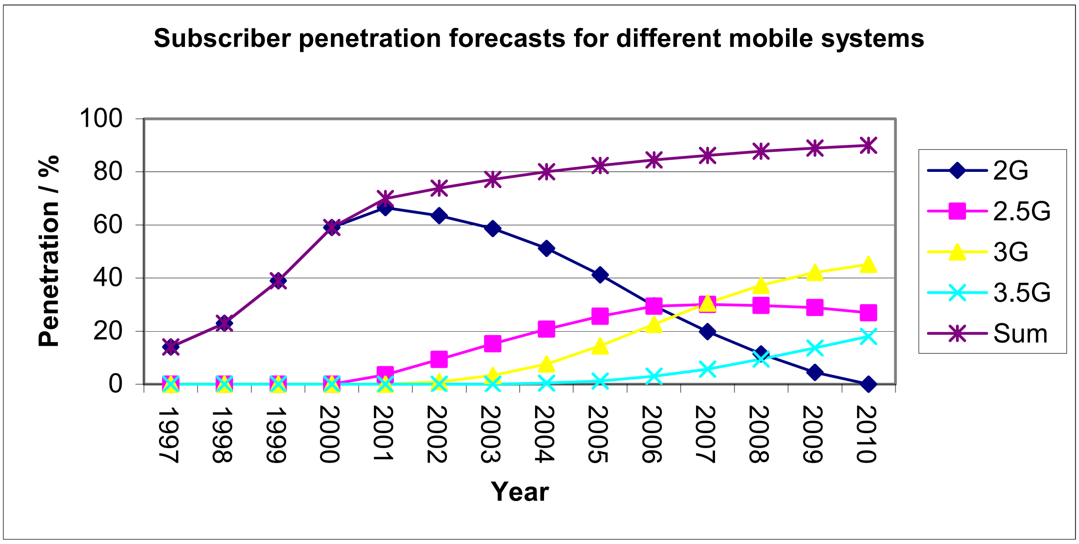



*Figure 3: Subscriber penetration forecasts for different mobile systems for Western Europe*

As mentioned above, we chose to take into account the number of subscribers rather than subscriptions in our business cases studies. Indeed, the common understanding of ARPU and costs per customer are related to this quantity. While some subscribers' possession of several SIM cards may lead to increased consumption, the growing proportion of so-called "dead" SIM cards tends to push consumption down, leading to great uncertainty as to the real number of active contracts. Moreover, the saturation level in terms of subscribers is well identified, but there is no way to predict this level for subscriptions.

The following Figure 4 depicts the subscriber penetration curves for 3G and 3.5G services, which form the basis for the subscriber numbers used in the business case:

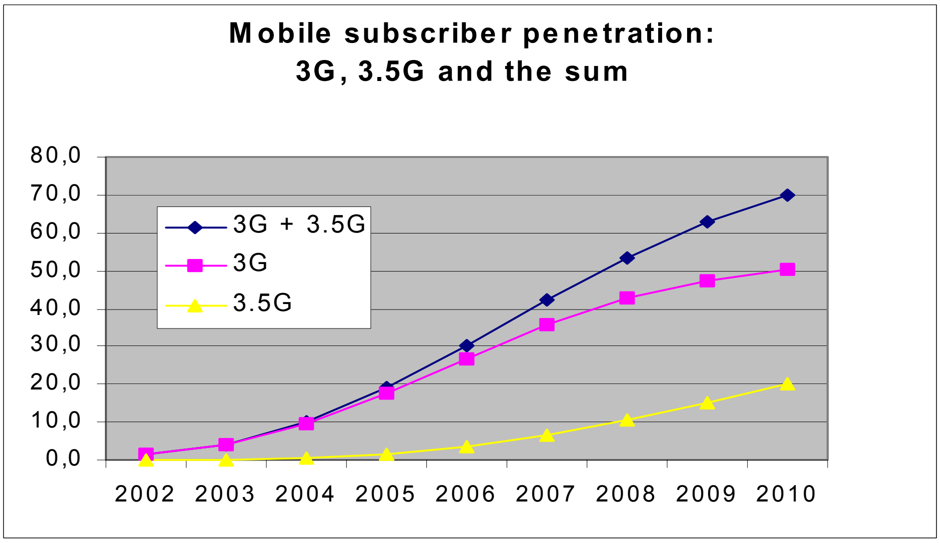



*Figure 4: Mobile subscriber penetration rates (%) for 3G, 3.5G and their combination.*

## 6.5 Market segmentation

Market demand considers business and residential (or private) chief market segments, with the purpose of evaluating the number of subscribers belonging to each segment. This market segmentation is based on the following premises:

The business user does not pay for the subscription, rather the employer pays. While usage is geared primarily toward work-oriented issues, some allowance is made for leisure uses (music, gaming…); this assumption leads to usage patterns which can at times resemble those associated traditionally with a residential customer. We have assumed that 100% of business users have post-paid contract subscriptions, although in some countries a small percentage uses pre-paid.

The residential customer pays for the subscription or opts for a pre-paid formula, which may lead him to restrict somewhat more his consumption with respect to a business user. In other words, price sensitivity is greater than in the case of the business user. We have assumed that residential users have both post-paid contract subscriptions, and pre-paid. Special focus is given to the share of these two formulas.

Evaluation of the residential segment share is based on observation of the current share of pre-paid formulas and an estimation of contract-based residential subscriptions in the market. The estimated breakdown in residential and professional subscriptions in a large and a small country is indicated in Table 6 and Table 7. As indicated, a constant 80-to-20 residential-to-business ratio has been assumed.

*Table 6: Market segment evolution large country*

| | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|
| Residential L | 80% | 80% | 80% | 80% | 80% | 80% | 80% | 80% | 80% | 80% |
| Business L | 20% | 20% | 20% | 20% | 20% | 20% | 20% | 20% | 20% | 20% |

*Table 7: Market segment evolution small country*

| | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|
| Residential S | 80% | 80% | 80% | 80% | 80% | 80% | 80% | 80% | 80% | 80% |
| Business S | 20% | 20% | 20% | 20% | 20% | 20% | 20% | 20% | 20% | 20% |

The market segmentation figures above seem to prove a good average for Western Europe as a whole in terms of 2G-to-3G market developments in the timeframe 2001-2011. Table 8 introduces real data on pre-paid and post paid subscriptions (which in practise may be regarded as residential and business subscriptions respectively) from the mmO2 Mobile Service Group operating in the United Kingdom, Germany, The Netherlands, Ireland and Isle of Man. The group as a whole shows a 65% of pre-paid, 35% of post-paid subscriptions in the first quarter of year 2002, which is in accordance with the JD Power and Associates survey '2002 UK Mobile Telephone Customer Satisfaction Study' giving for the whole UK the same distribution of 65% pre-paid, 35% post-paid. Also other operator information affirms the same general patterns. This is in line with the TONIC average assumption of 80% and 20%, born in mind that part of the post paid contracts are business (company pays) and part residential. The above mentioned UK Mobile Customer Satisfaction Study also highlighted that contract customers used their mobile services more and spent EUR61 per month compared to EUR28.14 for pre-paid customers. Combined with other information (e.g. TIM in Italy reports three times the residential ARPU for the business segment), this has led to the higher penetrations for certain services and higher usage amounts for the business users (see the business/residential Service Class estimations next page in Table 8: Example of real 2G mobile customer base (Source: mmO2 Group, May 2002)).

*Table 8: Example of real 2G mobile customer base (Source: mmO2 Group, May 2002)*

| | Customers at 31.Dec.2001 | Net additions during period | Customers at 31.Mar.2002 | Out of total |
|---|---|---|---|---|
| O2 UK | | | | |
| Pre-pay | 7601 | -59 | 7542 | 68.04% |
| Post-pay | 3474 | 68 | 3542 | 31.96% |
| Total | 11075 | 9 | 11084 | 100.00% |
| | | | | |
| O2 Germany | | | | |
| Pre-pay | 1785 | 127 | 1912 | 49.14% |
| Post-pay | 1871 | 108 | 1979 | 50.86% |
| Total | 3656 | 235 | 3891 | 100.00% |
| | | | | |
| O2 Netherlands | | | | |
| Pre-pay | 1070 | -48 | 1022 | 81.43% |
| Post-pay | 231 | 2 | 233 | 18.57% |
| Total | 1301 | -46 | 1255 | 100.00% |
| | | | | |
| O2 Ireland | | | | |
| Pre-pay | 807 | 17 | 824 | 69.83% |
| Post-pay | 355 | 1 | 356 | 30.17% |
| Total | 1162 | 18 | 1180 | 100.00% |
| | | | | |
| Manx | | | | |
| Pre-pay | 23 | 3 | 26 | 55.32% |
| Post-pay | 20 | 1 | 21 | 44.68% |
| Total | 43 | 4 | 47 | 100.00% |
| | | | | |
| mmO2 Group | | | | |
| Pre-pay | 11286 | 40 | 11326 | 64.88% |
| Post-pay | 5951 | 180 | 6131 | 35.12% |
| Total | 17237 | 220 | 17457 | 100.00% |

## 6.6 Demand development and usage amounts per Service Class

The penetration rates (within the concerned market segment) are estimated in Table 9 for each service class. An overall representation is provided in . The basic principle laying down this approach is that not all subscribers use all service classes, as subscriptions may restrict the usage to certain classes only. Also, the user equipment might allow a limited number of applications. The price for some service classes may exclude certain users altogether.

It is assumed that all-IP technology-based packet switched (PS) voice and video telephony is utilized from 2004 onwards, taking over gradually as the handsets are upgraded from the usage of circuit switched (CS) services. It is also assumed that IP Multimedia Subsystem (IMS) services, related to 3GPP release 5 standards, are implemented in such a way that (multi)media gateways (MG) can also support voice calls between the PS domain handsets and traditional CS telephony networks.

The so-called "Broadband Service" classes require bandwidths which realistically are only provided by the WLAN technology, being geographically restricted only to hot spots such as airports, etc. WLAN implementation as part of the ubiquitous mobile network in combination with UMTS is thought to be available for users from year 2004 on. Therefore, the various broadband service classes show zero usage before then. WLAN as a separate technology is naturally available well before, but not as a complementary technology for UMTS WCDMA access with full roaming capabilities, or at least with some level of inter-system mobility handovers. This will mean common access control and charging, as well as capability for dual mode (UMTS/WLAN) terminals. The restriction by narrower geographic scope is likely to affect the figures, as well as the positive impact on usage resulting from a potentially much lower price for the transfer capacity used.

*Table 9: Market penetration by service class*

| Service | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|
| NB_conv_CS_bus_penetr | 0% | 100% | 90% | 80% | 70% | 60% | 40% | 30% | 20% | 10% |
| WB_conv_CS_bus_penetr | 0% | 10% | 30% | 40% | 50% | 50% | 50% | 40% | 30% | 30% |
| NB_conv_PS_bus_penetr | 0% | 0% | 10% | 20% | 30% | 40% | 60% | 70% | 80% | 90% |
| WB_conv_PS_bus_penetr | 0% | 0% | 0% | 10% | 20% | 30% | 40% | 50% | 60% | 60% |
| BB_conv_bus_penetr | 0% | 0% | 5% | 8% | 10% | 15% | 20% | 22% | 24% | 25% |
| NB_stream_bus_penetr | 0% | 50% | 60% | 70% | 80% | 90% | 100% | 100% | 100% | 100% |
| WB_stream_bus_penetr | 0% | 40% | 40% | 50% | 60% | 70% | 80% | 90% | 100% | 100% |
| BB_stream_bus_penetr | 0% | 0% | 5% | 8% | 10% | 15% | 20% | 22% | 24% | 25% |
| NB_int_backgr_bus_penetr | 0% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| WB_int_backgr_bus_penetr | 0% | 50% | 60% | 70% | 80% | 90% | 100% | 100% | 100% | 100% |
| BB_int_backgr_bus_penetr | 0% | 0% | 5% | 8% | 10% | 15% | 20% | 22% | 24% | 25% |
| NB_conv_CS_res_penetr | 0% | 100% | 90% | 80% | 70% | 60% | 40% | 30% | 20% | 10% |
| WB_conv_CS_res_penetr | 0% | 10% | 30% | 40% | 50% | 50% | 50% | 40% | 30% | 30% |
| NB_conv_PS_res_penetr | 0% | 0% | 10% | 20% | 30% | 40% | 60% | 70% | 80% | 90% |
| WB_conv_PS_res_penetr | 0% | 0% | 0% | 10% | 20% | 30% | 40% | 50% | 60% | 60% |
| BB_conv_res_penetr | 0% | 0% | 0% | 5% | 6% | 7% | 8% | 9% | 10% | 11% |
| NB_stream_res_penetr | 0% | 50% | 60% | 70% | 80% | 90% | 100% | 100% | 100% | 100% |
| WB_stream_res_penetr | 0% | 40% | 40% | 50% | 60% | 70% | 80% | 90% | 100% | 100% |
| BB_stream_res_penetr | 0% | 0% | 5% | 5% | 6% | 7% | 8% | 9% | 10% | 11% |
| NB_int_backgr_res_penetr | 0% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| WB_int_backgr_res_penetr | 0% | 40% | 40% | 50% | 60% | 70% | 80% | 90% | 100% | 100% |
| BB_int_backgr_res_penetr | 0% | 0% | 5% | 5% | 6% | 7% | 8% | 9% | 10% | 11% |

It should be noticed that the usage times presented are average subscription values, born in mind the service penetration rates of Table 9 above.

Thus, the average business usage time for a NB_conv_CS-like service in year 2005, for instance, is estimated at 7.31 min/day (on-line usage). The average residential usage time for the same service, also in year 2005, is estimated at 2.92min/day, that is, 2.5 times lower. This business-to-residential usage ratio holds more or less constant over the timeframe under consideration, from 2003 to 2011.

*Table 10: Usage times for business service segments (2003-2011)*

| | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|
| Usage_NB_conv_CS_bus | 4.33 | 6.04 | 7.31 | 9.47 | 9.74 | 10.00 | 10.00 | 10.00 | 10.00 |
| Usage_WB_conv_CS_bus | 0.54 | 0.76 | 1.10 | 1.42 | 1.46 | 1.50 | 1.50 | 1.50 | 1.50 |
| Usage_NB_conv_PS_bus | 0.00 | 9.06 | 11.69 | 15.63 | 16.31 | 17.00 | 17.00 | 17.00 | 17.00 |
| Usage_WB_conv_PS_bus | 0.00 | 1.06 | 1.46 | 2.13 | 2.43 | 2.75 | 3.00 | 3.25 | 3.50 |
| Usage_BB_conv_bus | 0.00 | 1.21 | 1.83 | 2.84 | 3.41 | 3.75 | 3.75 | 3.75 | 3.75 |
| Usage_NB_stream_bus | 0.32 | 0.56 | 0.80 | 1.21 | 1.41 | 1.63 | 1.80 | 1.98 | 2.15 |
| Usage_WB_stream_bus | 0.22 | 0.38 | 0.55 | 0.83 | 0.97 | 1.13 | 1.25 | 1.38 | 1.50 |
| Usage_BB_stream_bus | 0.00 | 0.60 | 0.82 | 1.18 | 1.34 | 1.50 | 1.63 | 1.63 | 1.75 |
| Usage_NB_int_backgr_bus | 1.95 | 4.53 | 7.67 | 12.79 | 14.61 | 15.00 | 15.00 | 13.50 | 12.00 |
| Usage_WB_int_backgr_bus | 0.65 | 1.81 | 3.29 | 5.68 | 8.76 | 12.00 | 13.50 | 15.00 | 16.50 |
| Usage_BB_int_backgr_bus | 0.00 | 4.53 | 7.67 | 11.36 | 14.61 | 15.00 | 15.00 | 15.00 | 15.00 |

*Table 11:Usage times for residential service classes (2003-2011)*

| | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|
| Usage_NB_conv_CS_res | 1.73 | 2.42 | 2.92 | 3.79 | 3.89 | 4.00 | 4.00 | 4.00 | 4.00 |
| Usage_WB_conv_CS_res | 0.22 | 0.30 | 0.44 | 0.57 | 0.58 | 0.60 | 0.60 | 0.60 | 0.60 |
| Usage_NB_conv_PS_res | 0.00 | 3.63 | 4.68 | 6.25 | 6.52 | 6.80 | 6.80 | 6.80 | 6.80 |
| Usage_WB_conv_PS_res | 0.00 | 0.42 | 0.58 | 0.85 | 0.97 | 1.10 | 1.20 | 1.30 | 1.40 |
| Usage_BB_conv_res | 0.00 | 0.48 | 0.73 | 1.14 | 1.36 | 1.50 | 1.50 | 1.50 | 1.50 |
| Usage_NB_stream_res | 0.13 | 0.22 | 0.32 | 0.48 | 0.56 | 0.65 | 0.72 | 0.79 | 0.86 |
| Usage_WB_stream_res | 0.09 | 0.15 | 0.22 | 0.33 | 0.39 | 0.45 | 0.50 | 0.55 | 0.60 |
| Usage_BB_stream_res | 0.00 | 0.24 | 0.33 | 0.47 | 0.54 | 0.60 | 0.65 | 0.65 | 0.70 |
| Usage_NB_int_backgr_res | 1.30 | 3.02 | 5.11 | 8.52 | 9.74 | 10.00 | 10.00 | 9.00 | 8.00 |
| Usage_WB_int_backgr_res | 0.43 | 1.21 | 2.19 | 3.79 | 5.84 | 8.00 | 9.00 | 10.00 | 11.00 |
| Usage_BB_int_backgr_res | 0.00 | 3.02 | 5.11 | 7.58 | 9.74 | 10.00 | 10.00 | 10.00 | 10.00 |

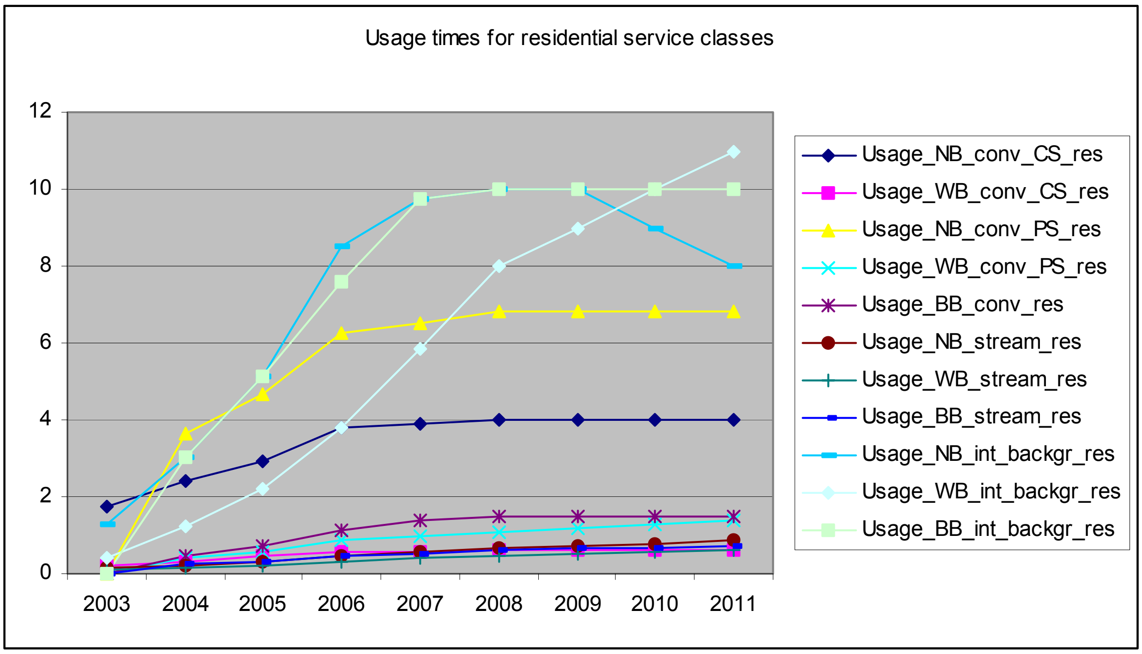



*Figure 5: Evolution of usage times (minutes per day) for residential service classes in the timeframe 2003-2011*

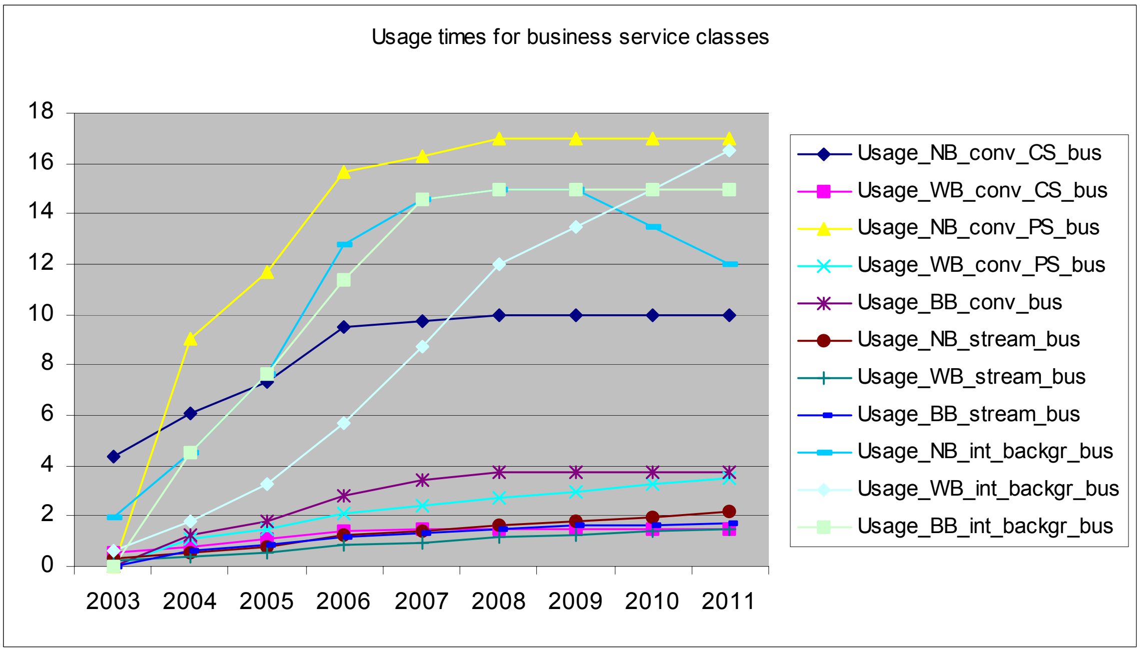



*Figure 6: Evolution of usage times (minutes per day) for business service classes in the timeframe 2003-2011*

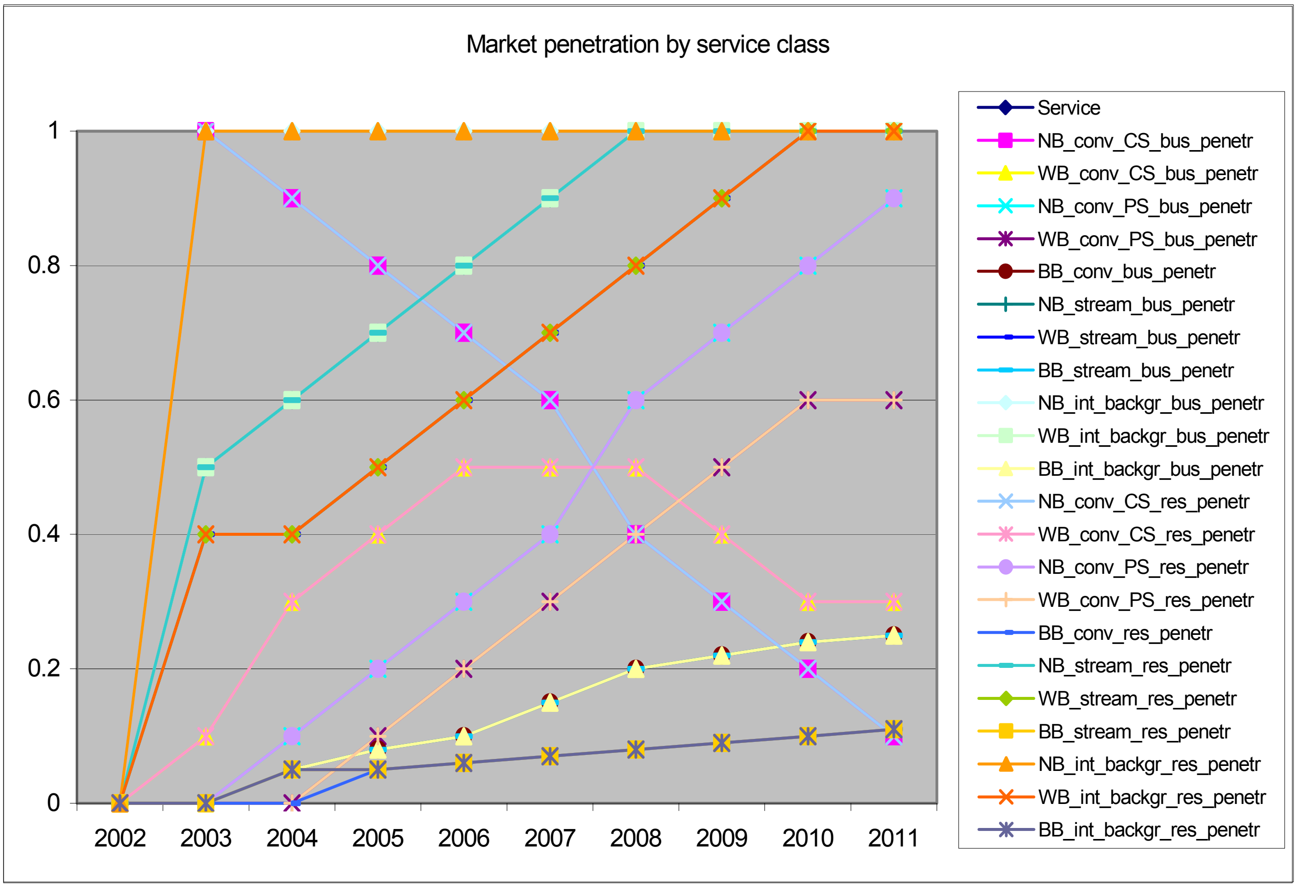



*Figure 7:Penetration rates for all service classes (out of the yearly total UMTS penetrations)*

The characteristics of WLAN deployment and its traffic demand (in Mb/month) are specified in Table 12 next page taking into consideration key site locations such as airports, hotels, conference centers, cafes and educational establishments. The timeframe under consideration is 2003-2011.

*Table 12: Assumptions for WLAN deployment and traffic demand in the timeframe 2003-2011*

| **WLAN sites** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** |
|---|---|---|---|---|---|---|---|---|---|
| **airports** | 5 | 10 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| APs per site | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| capacity available | 1000 | 2000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 |
| custs simul | 2000 | 4000 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 |
| **hotels** | 350 | 1000 | 1250 | 1500 | 2000 | 2500 | 2500 | 2500 | 2500 |
| APs per site | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| capacity available | 10500 | 30000 | 37500 | 45000 | 60000 | 75000 | 75000 | 75000 | 75000 |
| custs simul | 21000 | 60000 | 75000 | 90000 | 120000 | 150000 | 150000 | 150000 | 150000 |
| **conference centers** | 7.5 | 12.5 | 15 | 20 | 22.5 | 22.5 | 22.5 | 22.5 | 22.5 |
| APs per site | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| capacity available | 150 | 250 | 300 | 400 | 450 | 450 | 450 | 450 | 450 |
| custs simul | 300 | 500 | 600 | 800 | 900 | 900 | 900 | 900 | 900 |
| **Cafes** | 0 | 250 | 400 | 500 | 500 | 600 | 600 | 600 | 600 |
| APs per site | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| capacity available | 0 | 5000 | 8000 | 10000 | 10000 | 12000 | 12000 | 12000 | 12000 |
| custs simul | 0 | 10000 | 16000 | 20000 | 20000 | 24000 | 24000 | 24000 | 24000 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Educational establishments** | 25 | 40 | 55 | 60 | 70 | 80 | 80 | 80 | 80 |
| APs per site | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| capacity available | 750 | 1600 | 2200 | 2400 | 2800 | 3200 | 3200 | 3200 | 3200 |
| custs simul | 1500 | 3200 | 4400 | 4800 | 5600 | 6400 | 6400 | 6400 | 6400 |
| **Others** | 125 | 150 | 165 | 170 | 175 | 200 | 200 | 200 | 200 |
| APs per site | 3 | 4 | 5 | 6 | 7 | 7 | 7 | 7 | 7 |
| capacity available | 3750 | 6000 | 8250 | 10200 | 12250 | 14000 | 14000 | 14000 | 14000 |
| custs simul | 7500 | 12000 | 16500 | 20400 | 24500 | 28000 | 28000 | 28000 | 28000 |
| **total sites** | 512.5 | 1462.5 | 1900 | 2265 | 2782.5 | 3417.5 | 3417.5 | 3417.5 | 3417.5 |
| total Aps | 1615 | 4485 | 5925 | 7100 | 8850 | 10765 | 10765 | 10765 | 10765 |
| total capacity built (end of y.) Mbps | 16150 | 44850 | 59250 | 71000 | 88500 | 107650 | 107650 | 107650 | 107650 |

## 6.7 Estimation of generated total traffic

Estimation of generated total traffic by the users start with total UMTS subscriber penetration forecasts. The operator's market share is a fraction of this subscriber penetration. Then subscriber distribution into the two market segments, business and residential, is taken into account to get the market sizes for the business Service classes and the residential Service classes in the model.

Penetration percentages (inside the respective market segment) are estimated for each of the Service classes, as described in the previous chapter. As to figure out the generated load or capacity demand by the users, the total daily usage time of all the services within a class has been selected as the most comprehensible measurement.

For the total generated capacity demand estimation we need to combine three aspects:

- Penetration percentages for each Service class, and respective market sizes
- The average daily usage time of each Service class per user
- The average bit rate of each Service class, during the usage time

To estimate these, all the applications attached to each Service class should be considered.

### 6.7.1 Generated peak load

In addition to the revenue calculations per each Service class presented in the next chapter, the target in the capacity demand part Figure 4: Mobile subscriber penetration rates (%) for 3G, 3.5G and their combination. of the model is to provide for the network dimensioning and feasible capacity rollout schedule. We start by estimating the traffic and resources needed in the WCDMA or WLAN air interface, leading, by further dimensioning calculations, first to the base station capacity needed and from that to most of the other network resources.

The user bit rate for interactive and background Service classes, for example, is estimated from average file transfers during sessions. In the narrowband (NB) case, we consider:

average file (typically e-mail) size is 13.4 kbit (1.7 kbytes),

time to transfer one file through air interface (average packet size 896 bits, Peak Bit Rate = 32 kbit/s, mean time between packets within packet burst = 0.24s) is 3.6 s.

Time between file transfers is estimated to be 12 s.

This leads to a mean user bit rate of 13.4 kbit / (12 s+ 3.6 s) = 0.86 kbit/s.

In the wideband (WB) case, it is estimated that:

average file size (email with possible attachment) is 53.6 kbit (6.7 kbytes);

time to transfer one file through air interface (with average packet size 896 bits, Peak Bit Rate = 384 kbit/s, mean time between packets within packet burst = 0.02s) is 1.2 s.

Time between file transfers is estimated to be again 12 s.

This leads to mean user bit rate of 53.6 kbit / (12 s+ 1.2 s) = 4.06 kbit/s.

For the broadband (BB) case, the estimation is that average file size is 0.5 Mbit (62.5 kbytes). Using similar reasoning as for NB and WB cases, the average user bit rate is estimated to be 50 kbit/s.

For the BB case, it has been assumed that the WLAN standard Hiperlan 2 (5 GHz) is well established in the date when the UMTS-WLAN combination is launched in this model, i.e., beginning of year 2004.

The peak load during "busy hour", together with coverage requirement, determines the network dimensioning. The "busy hour" refers to the period, when the demand for the resources within a cell is at the highest. For this purpose, the capacity demand values for different service classes are calculated in the model for busy hour usage. If entertainment applications dominate, then the main peak hour may be in the evening, but if corporate applications and work related use dominate, then it will be during office hours. In the model, the peak load per service is calculated by assuming a certain percentage of the daily usage to take place in the main busy hour considering all services[6]. Applying the busy hour factor, which is different for the business and residential service classes, does this. The current assumption is that business usage contributes more to the actual busy hour. Anyhow, the busy hour multiplier is set to a high value (30%/20%) to guarantee a safe throughput in all occasions.

Below, we give an example for calculating the capacity demand values for a given service class, e.g. NB interactive or background:

The average, or mean, user bit rate for the service class is estimated by utilizing information on average user activity of the applications under the class and the capacity provided in the WCDMA air interface. In NB interactive background case, the suggested result at this point is 0.86 kbit/s.

In the data transfer application case, the "Data Traffic Overhead Multiplier" is applied to take into account transmission overhead. In this case, the multiplier has been chosen to be 2. As output, we get the bit rate of the service class session in the air interface.

Because the air interface allows only a limited number of simultaneous sessions at a certain bit rate, and the sessions are initiated randomly (Poisson process), we have to apply the Erlang formula to add the statistical overhead that has to be reserved. For each service class, we calculate the number of sessions ("channels") that fit into the available carrier capacity (2 * 1920 kbit/s) in one cell. Due to the statistical distribution, the effect of Erlang formula is much higher for high bit rate services, than for low bit rate, where it can even decrease the effective load, because of the allowed 2% blocking. The resulting Average WCDMA Bearer Capacity Demanded by the service Class is then multiplied by the Average Usage Time (in hours) given for each service Class. This is further treated with the Busy Hour Multiplier to get the share of the capacity demand falling into busy hour. The resulting Busy hour capacity demand per service user is now available for dimensioning purposes.

[6] In fact, the busy hour for business and residential markets probably will not coincide, but because the favourite applications and thus usage patterns for 3G are not yet known, we do not have accurate information on their actual occurrence.

The following Figure 8 summarizes the procedures described above:

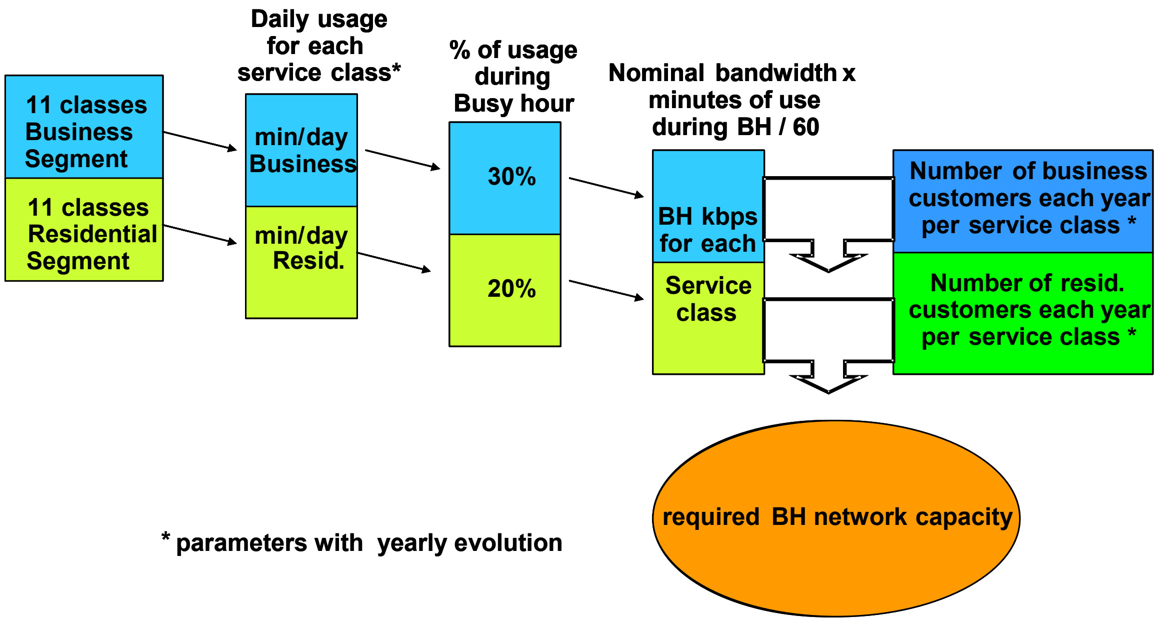



*Figure 8: Procedure for calculating the required busy hour network capacity.*

The capacity demand breaks downs in megabits per second (Mbit/s) by different criteria are provided next page in the Table 13.

*Table 13: Total busy hour traffic load by traffic type and combined traffic classes in Mbit/s*

| Traffic type | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|
| UMTS CS | 203 | 745 | 1 839 | 3 891 | 5 225 | 5 630 | 5 242 | 4 251 | 3 695 |
| UMTS PS | 26 | 236 | 1 194 | 4 069 | 8 611 | 16 355 | 24 020 | 32 648 | 39 170 |
| WLAN (BB) | 0 | 76 | 347 | 1 043 | 2 486 | 4 253 | 5 715 | 7 152 | 8 428 |

| Traffic classes | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|
| Conversational & Streaming | 219 | 935 | 2 906 | 7 573 | 13 055 | 20 608 | 27 304 | 34 307 | 39 900 |
| Interactive & Background | 10 | 121 | 474 | 1 429 | 3 268 | 5 630 | 7 673 | 9 744 | 11 393 |

The total busy hour traffic load is distributed to the base stations according to the population distribution to different area types during the busy hour. This leads immediately to the network dimensioning, see chapter 8.

## 6.7.2 Generated accountable end-user traffic

The end-user charging should reflect the generated busy hour load by the user, because that is source of the network capacity need and related costs. There are though also other costs, which are not traffic related, as general customer related costs and e.g. coverage build out costs. The pricing model used in the TONIC study takes into account the traffic amount per Service class and some non-traffic related pricing, but do not differ the charge according to time of day. So for the revenue calculations we are not looking at the peak load as with the dimensioning calculations, but the total amounts of megabytes (MB) per each Service class.

They are calculated from the same information as the peak load figures, but we do not need the busy hour share of the load but calculate over the whole billing period.

In the following Table 14, the monthly-generated chargeable megabytes (MB) per user are presented by market segment.

*Table 14: Total monthly billed MB amount per user in different market segment*

| User segment | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|
| Business Subscriber | 24.16 | 41.79 | 65.84 | 106.12 | 131.52 | 163.29 | 181.35 | 200.64 | 213.07 |
| Residential Subscriber | 9.97 | 17.32 | 27.56 | 44.82 | 56.18 | 70.31 | 79.81 | 90.05 | 95.68 |
| All subscribers average | 12.81 | 22.22 | 35.22 | 57.08 | 71.25 | 88.91 | 100.12 | 112.17 | 119.16 |

## 6.8 Low QoS WLAN stand alone business case perspective

Emergence of wireless ISPs  is expected to grow . Their differentiation factor may reside in their ability to catch the best hot spots such as airports or hotels that are supposed to be the most frequented and generate the highest traffic level.

Recent past taught us that Public WLAN business was insecure since pure players failed in US. Key difficulties contributing to those business failures were the existing two standards to face- Home RF and 802.11b-, the lack of existing customer base to market new product (MobileStar had only 5 000 regular subscribers), absence experience of roaming. As a result, the business model shows no scale effect on the roll out. Main conclusion from this is that leased or DSL lines are the killer costs in the WLAN business. Closed integrated model for all necessary roles, with no customer base was the reef. Hot spot operator installs networks, network operator negotiates with sites owners, invests, manage equipment; WLAN service provider is not network proprietary, it offers to customers a "transparent" access to internet/intranet with high bandwidth, managing billing of customer and reverse billing to the hot spot operator.

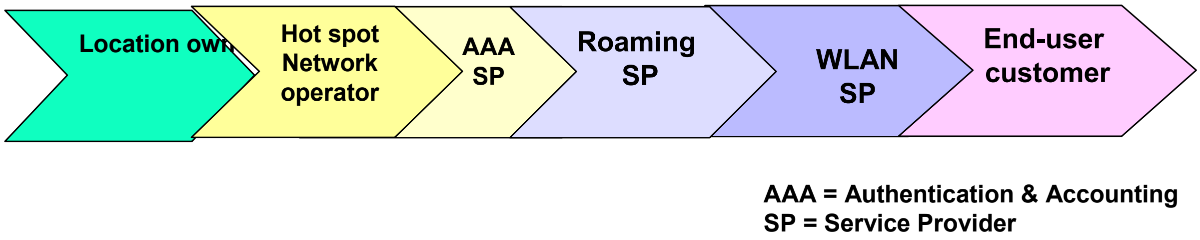



*Figure 9: WLAN Value Chain*

In fact, a hot spot operator can mix two approaches, install networks directly and aggregate existing hot spots with its own hot spots. This combined role corresponds to cases where the site owner wants to install the equipments (Universities, airports and some hotels)

A hot spot operator can also have two commercial channels: Via WLAN service provider or becoming WLAN service provider itself, via direct selling to end users with payment means like scratch cards, credit cards, or billing directly its own customer base.

Various combinations are possible. However we have simplified the business modelling below, considering only one WLAN operator without own hotspots and offering revenue sharing with landlords.

### 6.8.1 Modelling independent wireless ISP business case

#### 6.8.1.1 Introduction

This independent WLAN operator case study aims to investigate if an economical viability is possible given the fact it operates in a very fragmented market. Positive context is that the business case for offering WLAN public access services has many benefits, principal among them being that WLAN need only be deployed in places where there are sufficient potential users; moreover, most of these users are likely to comprise a well-defined user segment. For example, according to the Air Index of Airport Performance survey, 70% of business air travellers carry a laptop. Therefore, WLAN access in airports has a large addressable market and services can be made highly context-specific, time-sensitive and personalised to meet the precise requirements of business air travellers (an added bonus being that these users also generate high ARPU). Automated check-in, connecting flight information and entertainment and m-commerce applications could all be provided via a WLAN service. In order to take full advantage of this opportunity, a great deal of development work is required to provide a WLAN service management layer for profiling and billing customers. From an applications perspective WLAN technologies may provide a means to experiment with applications in advance of full 3G deployment, in order to determine which applications are likely to be the most successful. In particular, WLANs can be used to test location- or context-specific data services. They may also provide the necessary data rates to enable bandwidth-intensive services to be deployed well in advance of 3G. In some cases, it will be possible to exploit the bandwidth of WLANs to offer services that 3G will be unable to provide, due traffic congestion in hot spots. But economical success of independent WLAN operator is at stake and positive business model are still unproven. Our following investigations tend to confirm this point.

#### 6.8.1.2 Demand and revenues expected

Since Wi-Fi usage is mainly PC centric, we based our demand assumption on PC sales forecasts in large European country and calculated an average.

*Table 15: Laptop penetration and volume*

| | 2 002 | 2 003 | 2 004 | 2 005 | 2 006 | 2 007 |
|---|---|---|---|---|---|---|
| Thousand Laptops in one large country | 3 960 | 5 140 | 6 540 | 8 160 | 10 000 | 12 000 |
| % penetration Laptop/Population | 7% | 9% | 11% | 13% | 17% | 5% |
| % of Laptop WLAN enabled in the industry | 10% | 50% | 75% | 100% | 100% | 3% |
| Laptops "WLAN enabled" (renewal every 4 years) | 201 | 1 233 | 2 276 | 3 660 | 5 500 | 6 750 |
| % of Laptop WLAN enabled | 5% | 24% | 35% | 45% | 55% | 75 % |

- Assumption is that if 100 % of laptops with WLAN capabilities are potentially connected on hot spots, only 30 % are really using them on public hot spots.
- Market share is supposed to grow up from 5 % in 2003 to 20% in 2006.

Pricing model adopted for Low QoS WLAN services is monthly flat rate or "pay as you go" with unlimited access. On a monthly basis, we calculated an estimated 20 euros ARPU. This amount comes in addition to other mobile or ISP bills paid by consumers. Given the fact WLAN coverage will remain very limited when compared to mobile network, this price is about the maximum level consumer is willing to pay. We deducted revenues per year as showed in next chart (Figure 10).

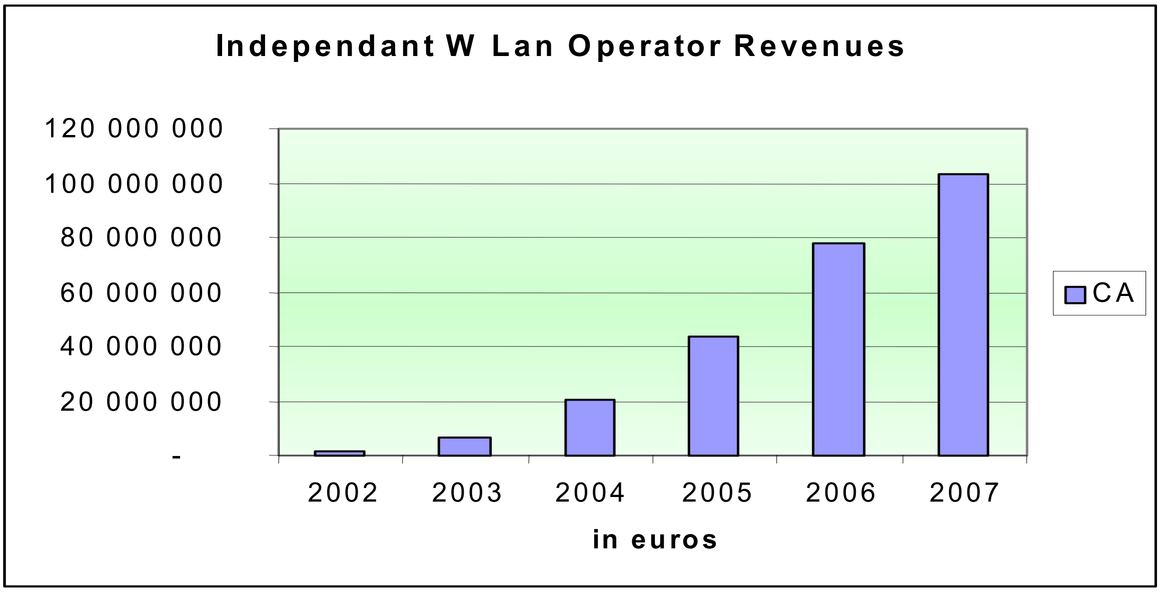



*Figure 10: Independent WLAN operator revenues*

### 6.8.1.3 Dimensioning and Capital expenditures

The considered independent WLAN operator operates on a number of hot spots distributed mainly on airports and hotels, the most promising areas for WLAN services. Figure 11 describes presence in hot spots:

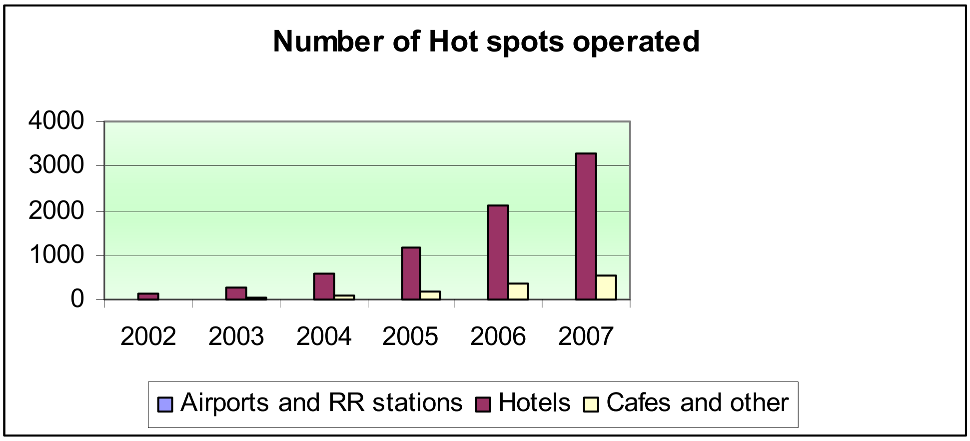



*Figure 11: Presence in hot spots*

WLAN Network components are described in Figure 12.

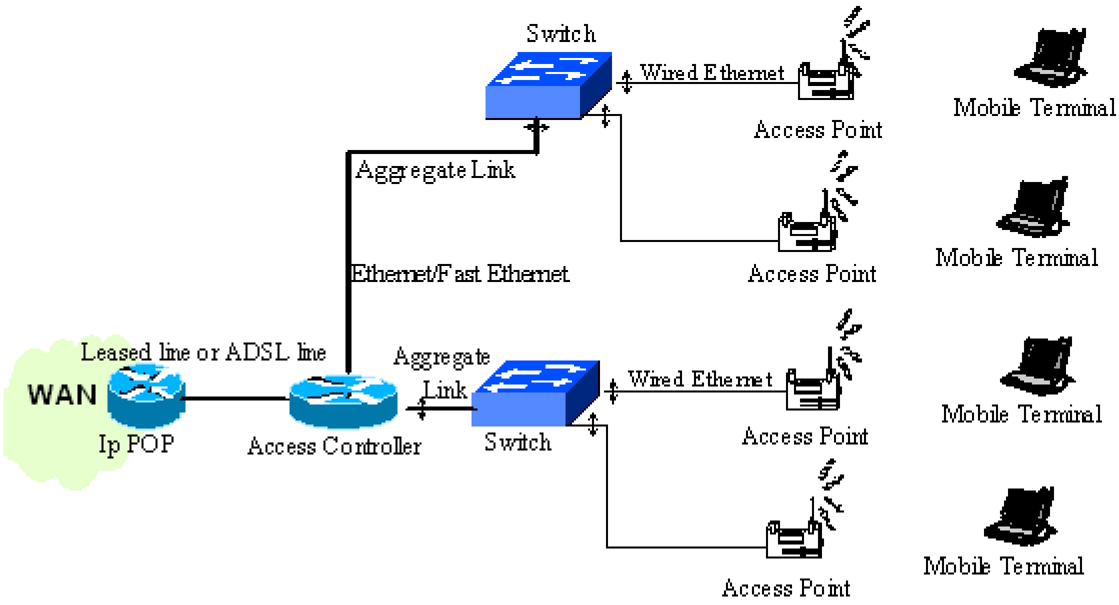



*Figure 12: WLAN access network*

Remark: Part of Access controller on some hotspots need a second switch.

Investments including all necessary equipments are described in below cake Figure 13. Access points and access controllers are the biggest bulk with 86 % of total investments, they include their installation costs.

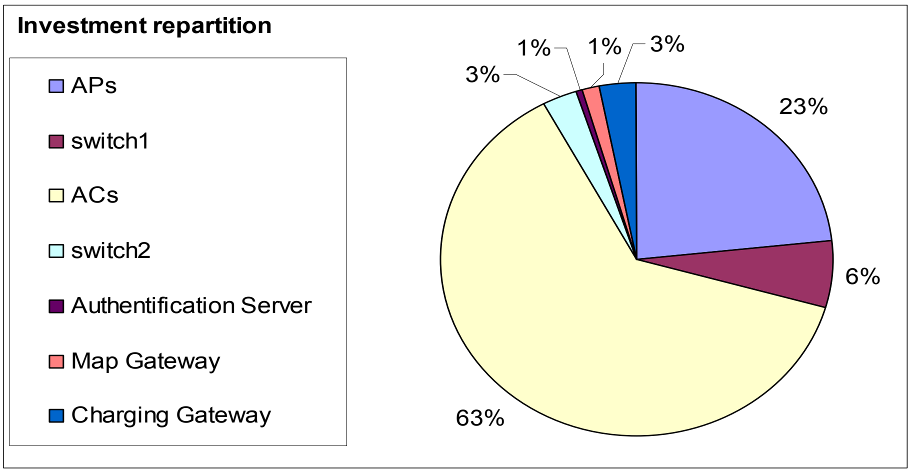



*Figure 13: Investment split-WLAN stand alone business case*

Total amount of investment is accounting for around 100 millions euros.

#### 6.8.1.4 Operating expenses: Revenue sharing with sites owners and backhaul costs are significant burden in an Independent WLAN operator business case

One of the greatest commercial challenges for WLAN service providers is the need to backhaul the traffic from the hotspot onto the core network. This is typically done via leased circuits, fibre-optics, microwave radio links and DSL solutions that are increasingly being considered for this task. The problem is that leased lines, fibre-optic cables or DSL lines with sufficient dimensioning are extremely expensive to deploy and as such are usually rented from the incumbent telco.

In our calculations, we have chosen to build the backhaul with professional 1 Mbps downstream DSL lines based on France Telecom Turbo DSL offer, anticipating a 15% price decrease each year until 2007. Despite this price cut, since we had to multiply by 3 in average the number of 1 Mbps DSL connections on hot spots for having a decent data rate, backhaul costs are accounting for almost half of operating costs with a cumulated amount of 130 millions euros over the studied period, as compared to cumulated revenues of 255 millions euros.

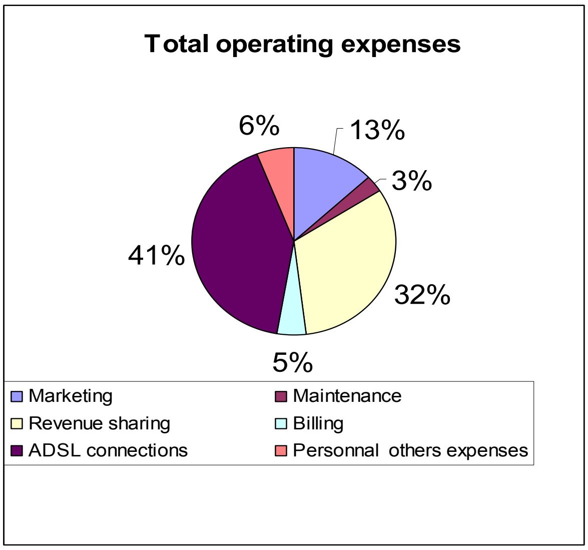



*Figure 14: Cumulated operational expenses*

Regarding the revenue sharing with site owners, we have considered various percentages depending on the frequentation of sites. Average level is of 25 %, but maximum is of 40 % and occurs on the most frequented sites, so where revenues are the higher.

#### 6.8.1.5 Results

Summary of profit and loss accounts are presented for each year in Table 16, all numbers are discounted with a 10 % discount rate:

*Table 16: profit and loss account – WLAN stand alone business plan*

| | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|
| Revenues | 1 679 487 | 6 498 508 | 20 675 166 | 43 873 877 | 77 757 524 | 103 483 290 |
| | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
| Marketing | 9 000 000 | 7 000 000 | 8 000 000 | 8 000 000 | 5 000 000 | 4 000 000 |
| Maintenance | 245 507 | 437 128 | 777 476 | 1 383 104 | 2 313 855 | 3 998 875 |
| Revenue sharing | 671 795 | 2 599 403 | 8 270 066 | 17 549 551 | 31 103 010 | 41 393 316 |
| Billing | 100 769 | 389 910 | 1 240 510 | 2 632 433 | 4 665 451 | 6 208 997 |
| ADSL connections | 7 519 857 | 12 344 399 | 21 050 063 | 26 603 562 | 30 504 375 | 32 738 472 |
| Personnal others expenses | 2 202 451 | 2 483 264 | 2 799 880 | 3 156 865 | 3 559 365 | 4 013 184 |
| Total Costs | 19 740 380 | 25 254 105 | 42 137 996 | 59 325 514 | 77 146 057 | 92 352 844 |
| *Investment* | *100 000 000* | | | | | |
| Amortization | 16 666 667 | 16 666 667 | 16 666 667 | 16 666 667 | 16 666 667 | 16 666 667 |
| Prof/Losses | - 34 727 559 | - 35 422 263 | - 38 129 497 | - 32 118 304 | - 16 055 199 | - 5 536 221 |
| Cash flows | - 118 060 892 | - 18 755 597 | - 21 462 830 | - 15 451 638 | 611 468 | 11 130 445 |
| Cumulated cash flow | - 118 060 892 | - 136 816 489 | - 158 279 319 | - 173 730 957 | - 173 119 489 | - 161 989 044 |

Cumulated cash flows are staying negative all over the studied period and break even is reached only late 2006.

Economic viability is not at the horizon under current market conditions, this is mainly imputable firstly to the revenue sharing agreements between the operator and site owners, secondly to the backhaul costs.

A 50 % cut in backhaul costs and revenue sharing would not turn in positive the business case but only reduce losses to 50 Millions euros in term of cumulated cash-flows.

A 50 % raise in ARPU (30 euros monthly in average) would have similar effect, contracting losses to 35 millions euros.

#### 6.8.1.6 Conclusion

Our independent WLAN operator business case can hardly be improved at the time being if we want to keep wise assumptions in terms of revenues and costs. This leads us to the conclusion that site owners may have much better perspectives if they operates themselves their areas with the support of Wireless network providers. Hotels and airport/airways companies in this case will bill directly their customers on a pay per hour or day basis, avoiding big issue of multiple roaming agreement set up.

### 6.8.2 Possible threat: Extended WLAN coverage with roaming capabilities

Announcement of recent trials with up-graded 811.B versions are reporting fundamental change of this technology: until now, WLAN was only used as an access network in some hot spots. But if it will allow in the future a real full coverage of a city, this would be clearly a threat for UMTS revenues: not only revenues from traffic in hot spots could be captured but also a significant share of all data revenues.

*Roam AD* Corporation operates a 3 square kilometre fully-functional demonstration network in the heart of Auckland CBD, New Zealand. The demonstration network was completed in May 2002.

This should be followed with a metropolitan-wide (100 km2) Cellular Wi-Fi network that provides end-users with secure non line-of-sight mobile broadband connectivity to the Internet, office networks and the PSTN.

Threat in the public arena was overstated since WLAN were remaining a nomadic technology rather than a mobile one: limited range of each base station meant it was unlikely to provide the same breadth of coverage as the 3G networks. But high proportion of revenues could be diverted away from 3G networks since pure WLAN operators may be able to offer a full coverage in cities.

# 7. NETWORK ARCHITECTURES AND COST ELEMENTS

## 7.1 Background

While UMTS networks are currently in the deployment stage, WLANs have already been launched for commercial service in such hot spots as airports and major hotel chains in the United States and many European countries. These WLANs, based on the IEEE 802.11b standard, operate in the unlicensed 2.4 GHz band. The area (range: 100-150 meters) is covered by a radio Access Point (AP) which is connected to an Internet backbone via a high-speed wireline data link. The users in the coverage area share the peak capacity, around 11 Mbps.

Although these systems are technically mature, quite well advanced from a market viewpoint, and have industry backing from major players (Lucent, Cisco, 3Com, Nokia among others), they are not the only solution for broadband wireless coverage. Other systems using the 2.4 GHz band include Home RF and future Bluetooth products, which are geared toward the residential market, with the potential to upgrade to higher bit rates. Another version of the IEEE standard, called 802.11a, will operate in the unlicensed 5 GHz band and is expected to offer better performance in terms of capacity - up to 54 Mbps raw data rate - while avoiding the congestion problems expected to arise in the 2.4 GHz band.

In addition to these “Wireless Ethernet” 802.11 standards, the ETSI HiperLAN/2 (High performance Radio LAN) standard is expected to give rise to products within the next year. This standard, which will also operate in the unlicensed 5 GHz band and offers a data rate similar to that of 802.11a, is a potential competitor to the IEEE standard. While their physical layers are similar, these two standards differ in the MAC layer, 802.11a retaining its Ethernet nature with a connectionless mode and HiperLAN/2 establishing connection-oriented links which are specifically adapted to the type of content in terms of bandwidth, latency, error rate, etc.

It is also recalled that most UMTS operators in Europe have received, in addition to paired 5 MHz frequency bands, a 5 MHz unpaired band allocated to Time-Division Duplex (TDD) operation. This resource can also be utilized for high-capacity indoor coverage of hot spots, where it offers the advantage over WLAN of being in a licensed band, managed such that no competing and/or interfering system can operate in the same band. It is also better adapted to asymmetrical data flows than the FDD resource. In near future also the WCMDA/FDD mode can offer data optimised asymmetric capacity with HSDPA (High Speed Downlink Packet Access) technology.

One issue, in all cases, is seamless handover between the WLAN or TDD resource and cellular mobile systems, UMTS in particular. This issue has not appeared crucial for current WLAN systems, which require the user to authenticate him/herself when starting a session, but it has been addressed extensively by certain UMTS equipment manufacturers and is also of key importance in the BRAIN/MIND architecture, which will be the focus of this TONIC business case.

## 7.2 Reference architecture and terminology

TONIC Business case 1 explores the techno-economics of a network infrastructure based on an IP core network enabling users to receive a common set of services through different access technologies. Such a concept for the provision of seamless IP services is illustrated in Figure 15.

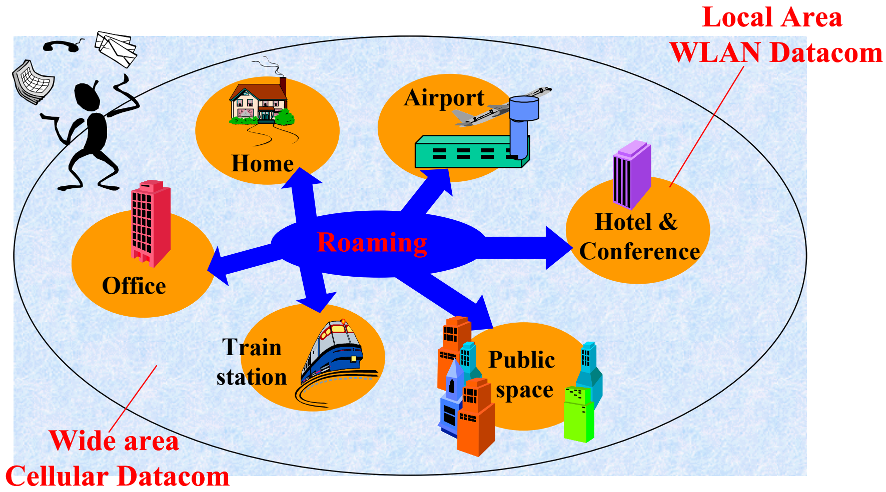



*Figure 15: Concept for seamless IP provision*

The network architecture modelled for the purpose of TONIC techno-economic studies is comprised of two wireless access systems, UMTS and WLAN. Since the UMTS-WLAN standardization is an ongoing process and only recently (August 2001) ETSI published the requirements and architectures for inter-working between WLANs and 3G networks main sources for TONIC were the IST projects BRAIN and MIND, as well as the 3GPP and ETSI working groups.

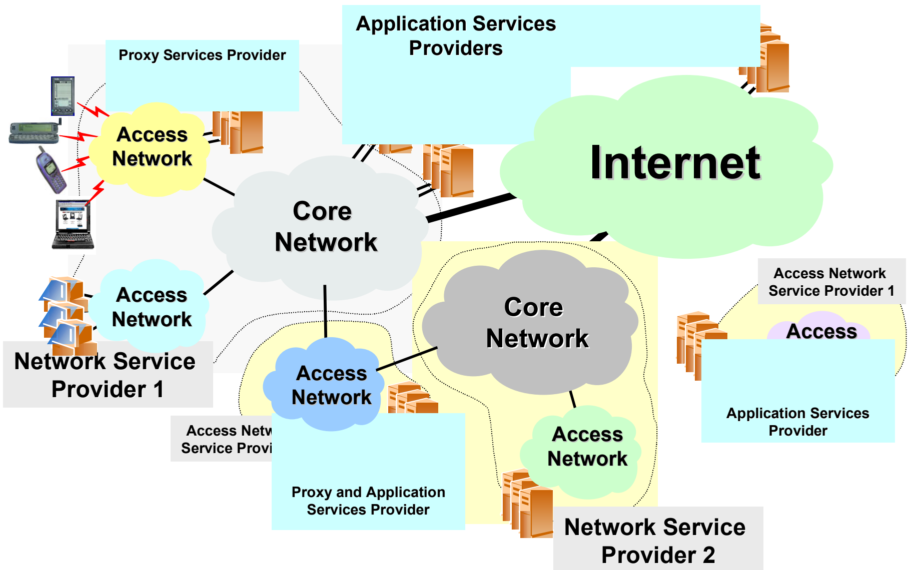



*Figure 16: Generic Network Model*

This generic network model -Figure 16 - described in comprises the following elements:

- **Access Network (AN):** a network that connects end-users' terminals. It can be based on wired or wireless technologies; could be mobile or fixed; private or public; etc. For example, the access network could be based on HIPERLAN/2, UMTS, GSM, etc. ***The TONIC business case focuses on access via UMTS and WLANs, with emphasis on HIPERLAN 2.***
- **Core Network (CN):** an IP backbone used to interconnect access networks. It can host connections with the servers/networks maintained by application service providers and

also a connection with the Internet. It is possible for an access network to be connected to two or more different core networks. ***The TONIC business case will take into account the transmission costs arising from the forecasted traffic load on the IP backbone, but does not consider the cost of build out of the IP transmission infrastructure.***

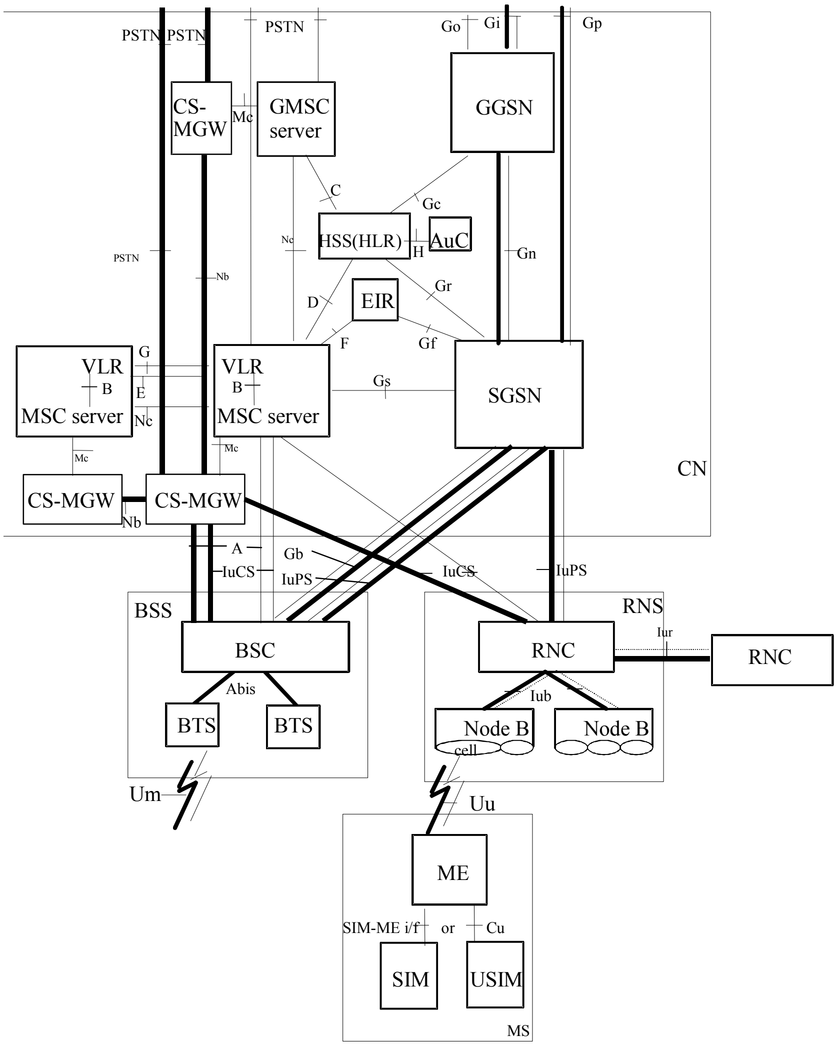
- **Network Service Provider (NSP):** an organization that offers network services to end-users. It runs its own core network and one or more access networks. ***The TONIC business case will be carried out from the standpoint of a Network Service Provider.***
- **Access Network service Provider (ANP):** an organization that owns an access network and offers network services to end-users. The access network can be connected to one or more core networks –this is the case, for example, of a network in an airport that offers specific services like flight information and also provides access to Internet through different providers- or it can be isolated –this is the case, for example, of a network in conference exposition that only offers conference specific information or services. ***This entity may be considered to provide revenue to the core network but, as a competitor to the Network Service Provider, subtracts revenue on the access level. For simplification, the net result will be considered null.***
- **Application Service Provider (ASP):** an organization that provides application services to end-users, including traditional IP services like e-mail, web access or more advanced ones like m-commerce, value added information/content services, location based services, IP-telephony, videoconference or video-on-demand. Application servers can be directly connected to an access network, to the core network or they can be accessed through the Internet. Provided content may be produced by the ASP itself or by connected Content Providers. ***ASP functions may be provided by the NSP or by a co-operating or independent player. It provides revenue to the core network and, in the case of bundled service offerings, a revenue sharing scheme is envisaged. The net result is positive revenue for the Network Service Provider.***
- **Proxy Services Provider (PSP)**: an organization that offers auxiliary services related with the adaptation of network protocols and applications to a particular access network. For example, a PSP can offer simple services like Web proxies or e-mail relays, or more complex ones like transcoding proxies that act as intermediaries between application servers and client devices, in order to adapt the information to the heterogeneous capacities of user terminals (in terms of bandwidth, resolution, color depth, etc). Mobility management functions (i.e., foreign agents) are also supposed to be offered by a PSP. ***This entity is assumed to have no impact on the cash flows to or from the Network Service Provider.***
- **Customer equipment**: in some cases, the operator may decide to subsidize the cost of the terminal or necessary add-on module. ***While this expense relates to the final link in the technical part of the network, it will be included among the sales and marketing expenses within the TONIC business case***.

## 7.3 UMTS Network basic configuration (UMTS Release 5)

The basic configuration of a Public Land Mobile Network (PLMN) supporting GPRS and the interconnection to the PSTN/ISDN and PDN is presented in Figure 17. This configuration presents signalling and user traffic interfaces which can be found in a PLMN. Implementations may be different: some particular functions may be handled in the same equipment and then some interfaces become internal interfaces.

In the basic configuration, all the functions are considered to be implemented in different equipment. Therefore, all the interfaces within PLMN are external. Interfaces A and Abis are defined in the GSM 08-series of Technical Specifications. Interfaces Iu, Iur and Iub are defined in the UMTS 25.4xx-series of Technical Specifications. Interfaces B, C, D, E, F and G require the support of the Mobile Application Part of the signalling system No. 7 to exchange the data necessary to provide the mobile service. No protocols for the H-interface and for the I-interface are standardized. All the GPRS-specific interfaces (G-series) are defined in the UMTS 23-series and 24-series of Technical Specifications. Interfaces Mc, Nb, and Nc are defined in UMTS 23.205 and in the UMTS 29-series of technical specifications.

From this configuration, all possible PLMN organisations can be deduced. In the case when some functions are contained in the same equipment, the relevant interfaces become internal to that equipment.




Legend:
Bold lines: interfaces supporting user traffic;
Dashed lines: interfaces supporting signalling.
NOTE 1: The figure shows direct interconnections between the entities. The actual links may be provided by an underlying network (e.g. SS7 or IP): this needs further studies.
NOTE 2: When the MSC and the SGSN are integrated in a single physical entity, this entity is called UMTS MSC (UMSC).
NOTE 3: A (G)MSC server and associated CS-MGW can be implemented as a single node: the (G)MSC.
NOTE 4: The Gn interface (between two SGSNs) is also part of the reference architecture, but is not shown for layout purposes only.

*Figure 17: Basic Configuration of a PLMN supporting circuit and packet switched services and interfaces .*

## 7.4 Basic components of the mobile system

### 7.4.1 Core Network (CN) entities

#### 7.4.1.1 The Home Subscriber Server (HSS)

The HSS is the master database for a given user. It is the entity containing the subscription related information to support the network entities actually handling calls/sessions. A Home Network may contain one or several HSSs: it depends on the number of mobile subscribers, on the capacity of the equipment and on the organisation of the network. As an example, HSS can provide support to the call control servers in order to complete the routing/roaming procedures by solving authentication, authorisation, naming/addressing resolution, location dependencies, etc. The HSS is also responsible for supporting the call control and session management entities of the different Domains and Subsystems of the operator as shown in the next figure.

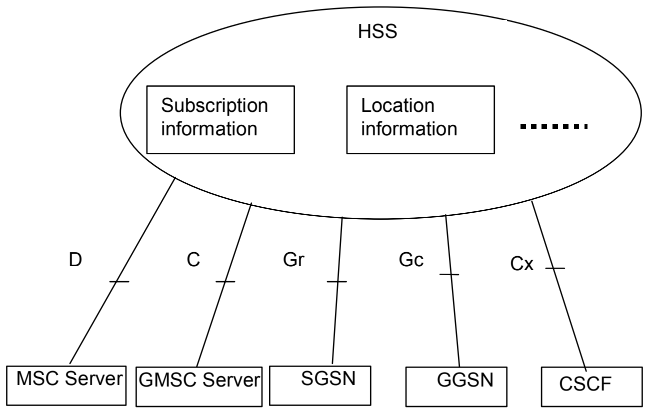



*Figure 18: Example of a Generic HSS structure and basic interfaces*

HSS may integrate heterogeneous information, and enable enhanced features in the core network to be offered to the application & services domain, while at the same time masking the heterogeneity.

#### 7.4.1.2 Home Location Register (HLR)

The HLR can be considered a subset of the HSS that handles the following functionality:

- The functionality required to provide support to PS Domain entities such as the SGSN and GGSN, through the Gr and Gc interfaces. It is needed to enable subscriber access to the PS domain services.
- The functionality required to provide support to CS Domain entities such as the MSC/MSC server and GMSC/GMSC server, through the C and D interfaces. It is needed to enable subscriber access to the CS Domain services and to support roaming to legacy GSM/UMTS CS Domain networks.

#### 7.4.1.3 The Visitor Location Register (VLR)

A mobile station roaming in an MSC area is controlled by the Visitor Location Register in charge of this area. When a Mobile Station (MS) enters a new location area it starts a registration procedure. The MSC in charge of that area notices this registration and transfers to the Visitor Location Register the identity of the location area where the MS is situated. If this MS is not yet registered, the VLR and the HLR exchange information to allow the proper handling of calls involving the MS. A VLR may be in charge of one or several MSC areas. The VLR also contains the information needed to handle calls set up or received by the MSs registered in its data base (for some supplementary services, the VLR may have to obtain additional information from the HLR).

#### 7.4.1.4 The Authentication Centre (AuC)

The Authentication Centre (AuC) is an entity which stores data for each mobile subscriber to allow the International Mobile Subscriber Identity (IMSI) to be authenticated and to allow communication over the radio path between the mobile station and the network to be ciphered. The AuC transmits the data needed for authentication and ciphering via the HLR to the VLR, MSC and SGSN which need to authenticate a mobile station. The Authentication Centre (AuC) is associated with an HLR, and stores an identity key for each mobile subscriber registered with the associated HLR.

#### 7.4.1.5 The Equipment Identity Register (EIR)

The Equipment Identity Register (EIR) in the GSM system is the logical entity which is responsible for storing in the network the International Mobile Equipment Identities (IMEIs), used in the GSM system.

#### 7.4.1.6 SMS Gateway MSC (SMS-GMSC)

The SMS Gateway MSC (SMS-GMSC) acts as an interface between a Short Message Service Centre and the PLMN, to allow short messages to be delivered to mobile stations from the Service Centre (SC). The choice of which MSCs can act as SMS Gateway MSCs is a network operator matter (e.g. all MSCs or some designated MSCs).

#### 7.4.1.7 SMS Interworking MSC

The SMS Interworking MSC acts as an interface between the PLMN and a Short Message Service Centre (SC) to allow short messages to be submitted from Mobile Stations to the SC. The choice of which MSCs can act as SMS Interworking MSCs is a network operator matter (e.g. all MSCs or some designated MSCs).

#### 7.4.1.8 The Mobile-services Switching Centre (MSC)

The Mobile-services Switching Centre (MSC) constitutes the interface between the radio system and the fixed networks. The MSC performs all necessary functions in order to handle the circuit switched services to and from the mobile stations. In order to obtain radio coverage of a given geographical area, a number of base stations are required; i.e. each MSC would thus have to interface several base stations. Several MSCs may be required to cover a country. The Mobile-services Switching Centre is an exchange which performs all the switching and signalling functions for mobile stations located in a geographical area designated as the MSC area. The main difference between a MSC and an exchange in a fixed network is that the MSC has to take into account the impact of the allocation of radio resources and the mobile nature of the subscribers.

When needed, the MSC can be implemented in two different entities: the MSC Server, handling only signalling, and the CS-MGW, handling user data. An MSC Server and a CS-MGW make up the full functionality of an MSC.

#### 7.4.1.9 MSC Server

The MSC Server mainly comprises the call control (CC) and mobility control parts of a MSC. The MSC Server is responsible for the control of mobile originated and mobile terminated CS

Domain calls. It terminates the user-network signalling and translates it into the relevant network – network signalling. The MSC Server also contains a VLR to hold the mobile subscriber's service data and CAMEL related data.

#### 7.4.1.10 The Gateway MSC (GMSC)

If a network delivering a call to the PLMN cannot interrogate the HLR, the call is routed to an MSC. This MSC will interrogate the appropriate HLR and then route the call to the MSC where the mobile station is located. The MSC which performs the routing function to the actual location of the MS is called the Gateway MSC (GMSC). When needed, the GMSC can be implemented in two different entities: the GMSC Server, handling only signalling, as defined bellow, and the CS-MGW, defined above. A GMSC Server and a CS-MGW make up the full functionality of a GMSC.

#### 7.4.1.11 The Interworking Function (IWF)

The Interworking Function (IWF) is a functional entity associated with the MSC. The IWF allows interworking between a PLMN and fixed networks (ISDN, PSTN and PDNs). The functions of the IWF depend on the services and the type of fixed network. The IWF is required to convert the protocols used in the PLMN to those used in the appropriate fixed network. The IWF may have no functionality where the service implementation in the PLMN is directly compatible with that at the fixed network. The interworking functions are described in TS Technical Specifications 29.004, 29.005, 29.007 and 09.09.

#### 7.4.1.12 Serving GPRS Support Node (SGSN)

The location register function in the SGSN stores two types of subscriber data needed to handle originating and terminating packet data transfer:

- subscription information
- location information

#### 7.4.1.13 Gateway GPRS Support Node (GGSN)

The location register function in the GGSN stores subscriber data received from the HLR and the SGSN. There are two types of subscriber data needed to handle originating and terminating packet data transfer:

- subscription information
- location information

#### 7.4.1.14 Border Gateway (BG)

The Border Gateway (BG) is a gateway between a PLMN supporting GPRS and an external inter-PLMN backbone network used to interconnect with other PLMNs also supporting GPRS. The role of the BG is to provide the appropriate level of security to protect the PLMN and its subscribers. The BG is only needed in PLMNs supporting GPRS.

### 7.4.2 The Base Station System (BSS)

The Base Station System (BSS) is the system of base station equipment (transceivers, controllers, etc...) which is viewed by the MSC through a single A or Iu-CS interface as being the entity responsible for communicating with Mobile Stations in a certain area. Similarly, in PLMNs supporting GPRS, the BSS is viewed by the SGSN through a single Gb or Iu-PS interface. The functionality for the A interface is described in GSM 08.02 and for the Gb interface in TS 23.060. The functionality for the Iu-CS interface is described in TS 25.410 and for the Iu-PS interface in TS 23.060. The radio equipment of a BSS may support one or more cells. A BSS may consist of one or more base stations. Where an Abis-interface is implemented, the BSS consists of one Base Station Controller (BSC) and one or more Base Transceiver Station (BTS). The split of functions between BSS and CN for a Iu interface is described in the 25-series of UMTS Technical Specifications. The split of functions between BSS and CN for a A/Gb interface is described in the 08-series of GSM Technical Specifications. The split of functions between BSS and CN for a Iu interface is described in the 25-series of UMTS Technical Specifications.

#### 7.4.2.1 Base Station Controller (BSC)

A Base Station Controller (BSC) is a network component in the PLMN with the functions for control of one or more BTS.

#### 7.4.2.2 Base Transceiver Station (BTS)

A Base Transceiver Station (BTS) is a network component which serves one cell.

### 7.4.3 The Radio Network System (RNS)

The Radio Network System (RNS) is the system of base station equipments (transceivers, controllers, etc...) which is viewed by the MSC through a single Iu-interface as being the entity responsible for communicating with Mobile Stations in a certain area. Similarly, in PLMNs supporting GPRS, the RNS is viewed by the SGSN through a single Iu-PS interface. The functionality for the Iu-CS interface is described in TS 25.410 and for the Iu-PS interface in TS 23.060. The radio equipment of a RNS may support one or more cells. A RNS may consist of one or more base stations. The RNS consists of one Radio Network Controller (RNC) and one or more Node B. The split of functions between RNS and CN is described in the 25-series of UMTS Technical Specifications.

The distinction between the BSS and the RNS is that the former refers to 2G systems and the latter to 3G. The BSS is the legacy GSM/GPRS Radio network which allows the following modes:

a) A / Gb mode, e.g. for pre-Release 4 terminals, for Release 4 terminals when connected to a BSS with no Iu interface towards the Core Network.
b) Iu mode (i.e. Iu-CS and Iu-PS ), e.g. for Release 4 terminals when connected to a BSS with Iu interfaces towards the Core Network

Other modes (e.g. A/Iu-PS or Iu-CS/Gb) are supported by RNS which allows FDD and TDD modes.

#### 7.4.3.1 Radio Network Controller (RNC)

A Radio Network Controller (RNC) is a network component in the PLMN with the functions for control of one or more Node B.

#### 7.4.3.2 Node B

A Node B is a network component which serves one cell.

### 7.4.4 The Mobile Station (MS)

The mobile station consists of the physical equipment used by a PLMN subscriber; it comprises the Mobile Equipment (ME) and the Subscriber Identity Module (SIM), called UMTS Subscriber Identity Module (USIM) for Release 99 and following. The ME comprises the Mobile Termination (MT) which, depending on the application and services, may support various combinations of Terminal Adapter (TA) and Terminal Equipment (TE) functional groups. These functional groups are described in GSM 04.02.

Figure 19 illustrates the UMTS network architecture modelled.

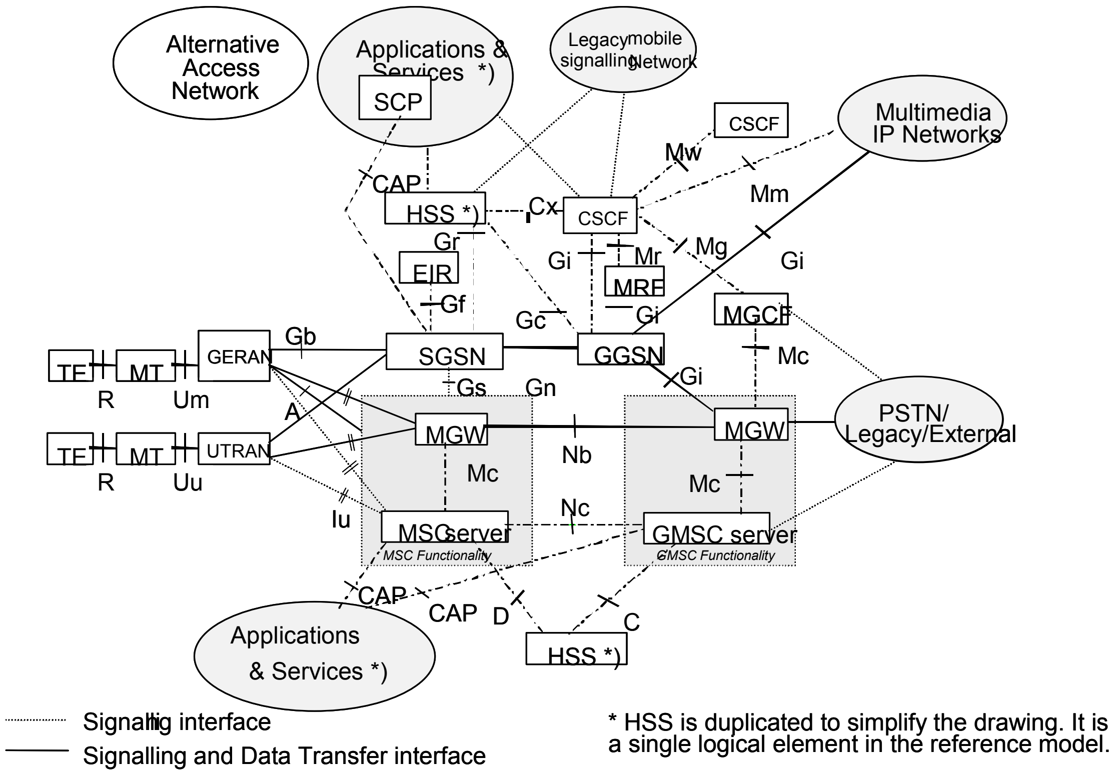



*Figure 19:Network Architecture (Source: 3GPP)*

## 7.5 BRAIN WLAN architecture [18]

The key elements of the network architecture are listed below with their basic functions:

- **Mobile Node (MN)**: Mobile terminal: IP host with one or more IP addresses and a single interface and possibly more than one simultaneous radio link with different BRAIN Access Routers. Two main types of terminal could be considered: type one is a small laptop/PDA with Hiperlan and UMTS PCMCIA cards, type 2 is an advanced UMTS handset with a Hiperlan card.
- **Access Point (AP)**: first air interface with mobile ; typical AP range = 25-35 m. Raw capacity = 54 Mbps; useful capacity = approximately 20 Mbps;
- **Access point controller (APC)**: 1 per site ; each is assumed to control up to approximately 9 APs.
- **Access Router (BAR)**: an IP router with multiple wireless and wired interfaces.
- **Access Network (BAN)**: data transmission infrastructure and control entities for routing and determining user access
- **Mobility Gateway (BMG)**: special purpose IP router hiding any BRAIN-specific routing functionality
- **Roaming Interworking Unit (IWU)**: same functionality as an RNC.

The architecture is illustrated in Figure 20.

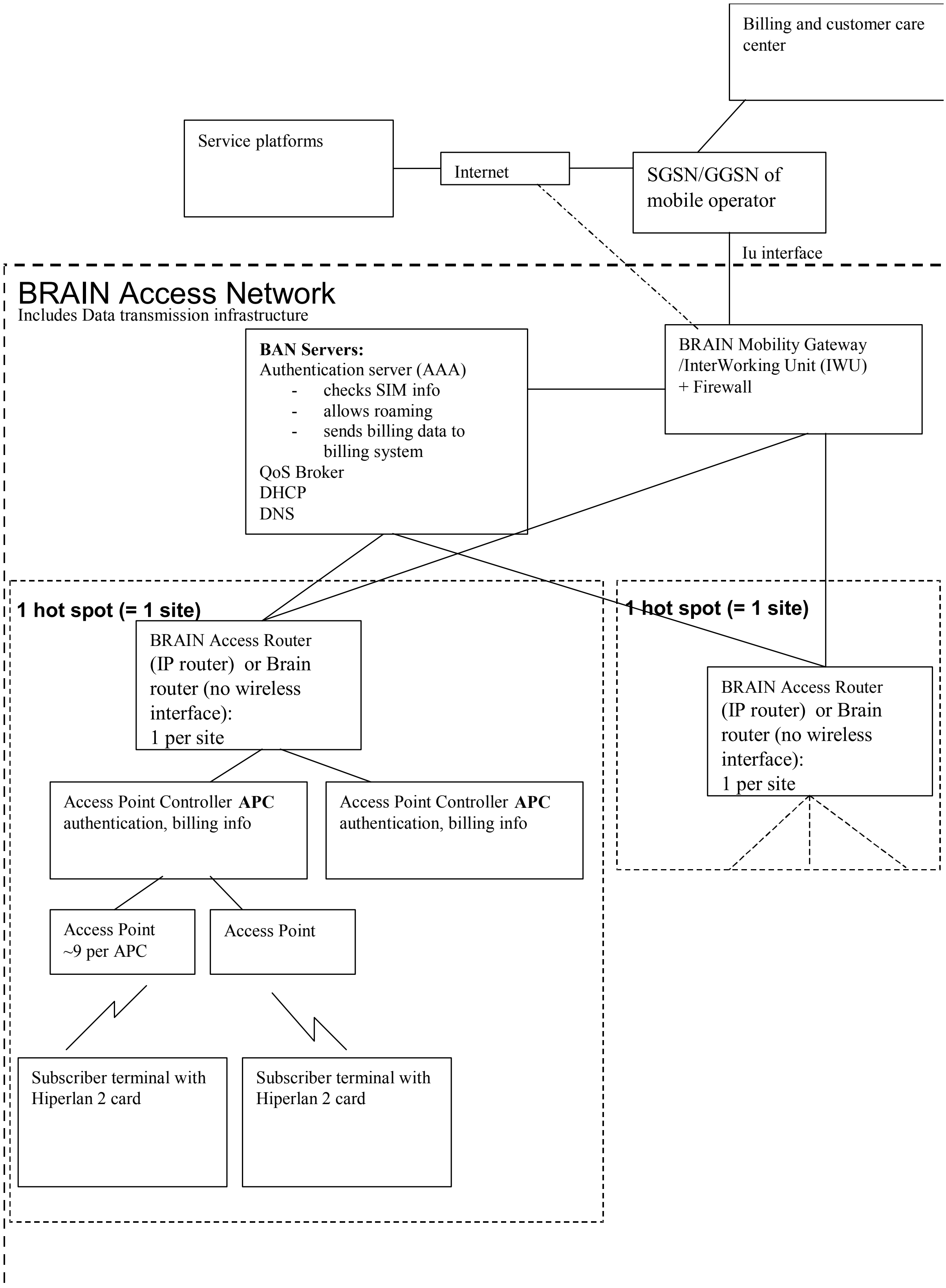



*Figure 20: Hiperlan2 architecture*

## 7.6 Interworking of UMTS and WLAN : The operator's view

As mentioned previously, the inter-working standardization is an ongoing process and the first standards are expected to be published in 2002. ETSI and 3GPP have published the requirements for interworking. There are two fundamental approaches : loose inter-working and tight inter-working.

UMTS incorporates a new generic radio access network, the UMTS Radio Access Network (URAN). The URAN may include several different realizations, of which the UTRAN (UMTS Terrestrial Radio Access Network) is one. The Iu interface forms the boundary between UTRAN and the UMTS core network. By connecting the BRAIN architecture to the Iu interface, BRAIN will form a complementary realization of the URAN concept for broadband data services. UMTS interworking will provide BRAIN with roaming support using the UMTS mobility infrastructure.

A BRAIN realization of URAN should provide the same logical interface to the higher layers, i.e., layers belonging to the non-access stratum, as UTRAN. Hence, no changes in higher layers should be required. UMTS authentication, security and location management can be used over HIPERLAN/2. UMTS bearer setup requests should be mapped to the corresponding HIPERLAN/2 DLC connection by the convergence layer. convergence layer. A USIM (User Service Identity Module) may be needed in a HIPERLAN/2 terminal supporting UMTS interworking. Handovers within a BRAIN subsystem should be invisible to the UMTS core network. Handovers between UTRAN and BRAIN, in case of dual mode terminals, should be supported via the core network.

The different forms of UMTS-WLAN roaming and interworking are important and it would be wrong to conclude that one method is the only way. The choice of interworking method is likely to be based on the background of the operator. Obviously, it would be impossible to consider all the possible backgrounds of operators but they can be classified into two rough categories, those with a legacy UMTS background and those which are WLAN oriented. There are further possible distinctions with the relative independence of the network operators.

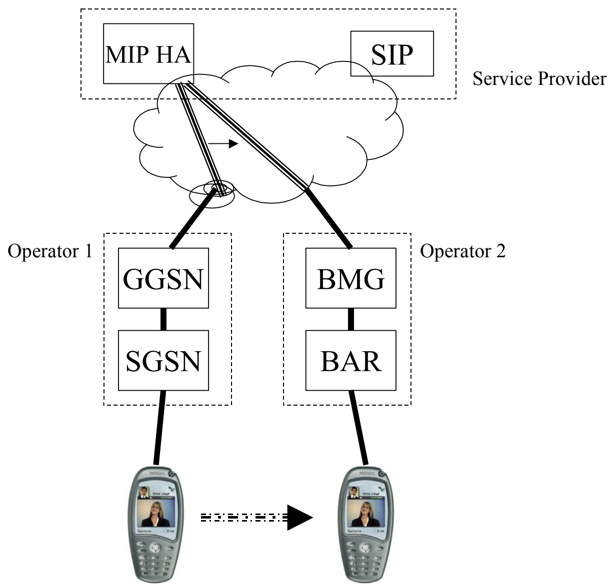



Figure 21: The No Coupling Architecture.

With the no-coupling approach Figure 21, the two operators can be completely independent; this is the only coupling option that allows this. As the coupling gets tighter, the level of independency is reduced. In the tight coupling cases, it is only really feasible that a single operator is running both networks.

From the legacy UMTS operators' viewpoint, they have already invested in a UMTS network, and want to get the most value out of their existing infrastructure; this will be an evolutionary rather than a revolutionary step. To this end, a tight integration would be ideal as it would enable the operator to provide increased services to the user without a clear differentiation of aspects of service. It also allows the operator to keep close control of customers.

From the WLAN operators' viewpoint (no legacy UMTS network), the restrictions placed on tight integration within a UMTS dominated network may not make sense. This is where we will see either a loose coupling or no-coupling approach (the traditional Internet view of different service providers, freedom to build one's own service portfolio). Other alternatives would be for a tight integration but with the UMTS being tied into the BRAIN core network.

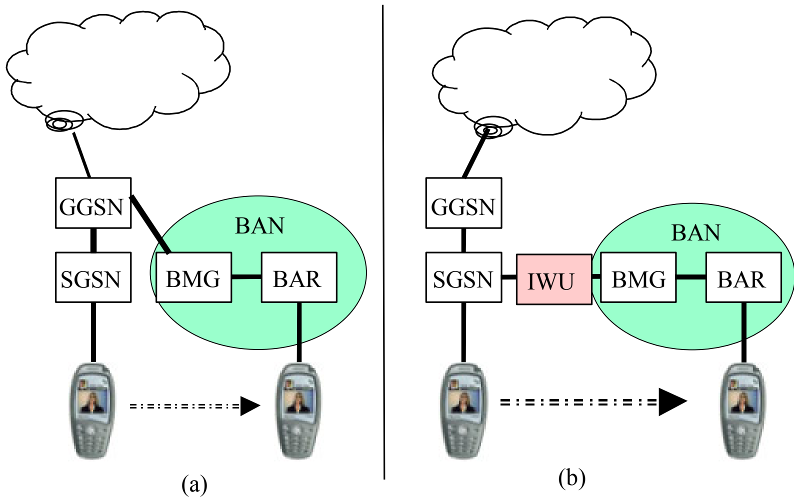



*Figure 22: Tight Coupling Architecture (a) Access via the GGSN; (b) Access via the SGSN.*

*Table 17: Summary of Coupling vs. Characteristics.*

| *Characteristic/ Coupling* | No-Coupling | Loose Coupling | Tight Coupling (GGSN) | Tight Coupling (SGSN) |
|---|---|---|---|---|
| *Handover Speed* | Slowest as longest path update route | Faster as shorter updates | Faster | Fastest |
| *Security* | Unknown | Good | Good | Good |
| *Context Transfer* | Slowest | Faster | Faster | Fastest |
| *Operators* | Ideal for independent | Trusted Partners | Single/Trusted Partners | This would really be for a single operator and is a complex issue with regards to its applicability in all cases, |
| *QoS* | Complete Renegotiation | Complete Renegotiatio n | Some Renegotiation | Minimal Renegotiation |
| *Triggers for handover* | Could come from a number of sources outside of the current network. | Could come from external and internal sources | Will come from current network or MN | Will come from current network or MN |
| *IWU (Interworking Unit)* | Not required | AAA–HLR interaction | AAA-HLR interaction | Full interaction between BRAIN and UMTS protocols |

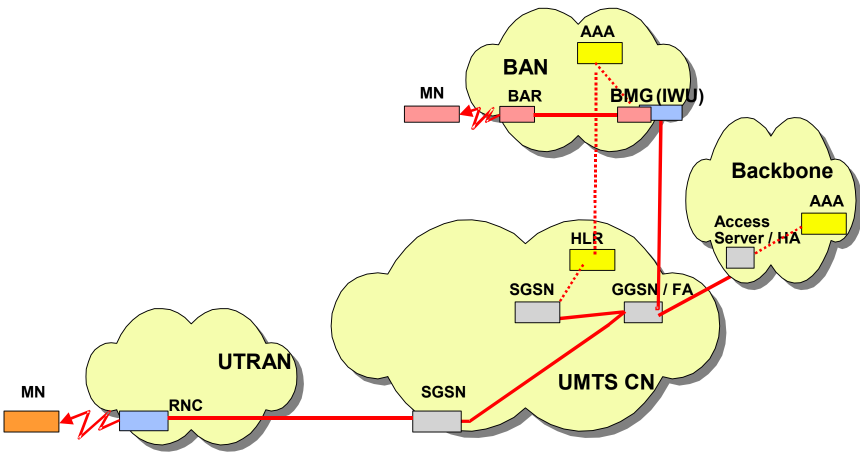



*Figure 23: Tight Integration at GGSN and HLR level*

Assumptions and requirements for BANs are specifically important for the design of network topologies. One of these states that a BAN may have multiple interconnections with a fixed network and that it may be connected to more than one fixed network. BAN should include multiple BMGs for the purpose of avoiding sub-optimal routing to and from MNs and preventing the occurrence of bottleneck, monolithic BMGs. Therefore, it is essential to include multiple BMGs in some cases of network topologies.

It should be noted that the BAR is the last downlink network layer hop before MNs. BARs use Access Points (APs) (H2 model) to control the wireless link and together form a single IP entity. As far as the BAR is concerned, AP is a “logical” unit with its elements, in particular the AP Controller (APC) (or more correctly Central Controller – CC), which manages one or more Aps. However the structure of the AP with parameters such as the number of APs is transparent to the BAR. The particular structure of the AP determines the wireless link scenario were the RF aspects are controlled by APs thus incurring the conclusion that the number of APs maps into the number of wireless cells. Another important issue is the relation of AP to the protocol layer structure inside the BAR. It is considered that the AP “fits” below the IP2W sublayer and this is seen as a network interface. This facilitates the possibility of having more network interfaces inside the BAR where each interface is dealt with a separate AP or another element from a different wireless link technology[7].

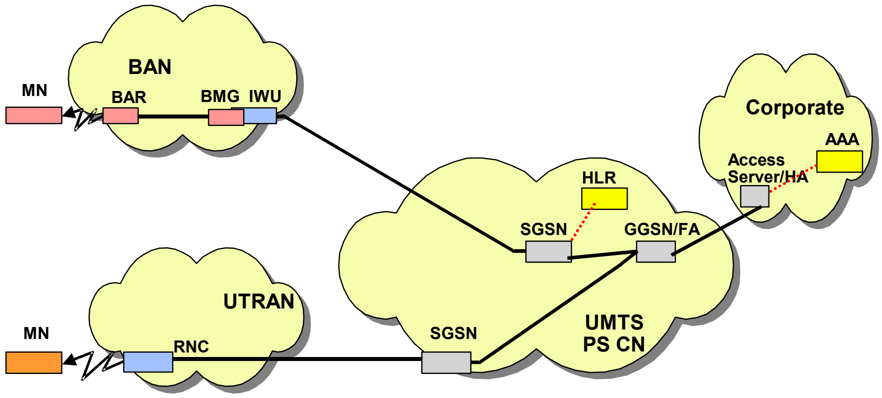



*Figure 24: Access to UMTS via the Iu interface (via SGSN)*

## 7.7 Network Scenarios

They are listed in Table 18 to Table 21:

*Table 18: Small Company Scenario*

| | |
|---|---|
| *Description* | Company internal private WLAN |
| *Scale* | small office building with a few workers (< 50). |
| *Mobility*<br>*UMTS roaming* | Mobility is low.<br>They are not particularly concerned with vertical handovers to UMTS etc. |
| *QoS / applications* | They use it for internal mail and video-mail, www browsing. |

[7] Multiple wireless interfaces per BAR would probably result in a scenario where the BAR is the crossover router.

*Table 19: University Campus Scenario*

| | |
|---|---|
| *Description* | Campus-wide private WLAN |
| *Scale* | A large university campus – many buildings spread over a few km. (~10,000 users)<br>Normal density of 0.25 users/$m^2$, but maximum up to 32* this. |
| *Mobility*<br>*UMTS roaming* | Mobility – often none, occasionally medium (walking). Note that many users may change location 'simultaneously' (end of lecture hour)<br>They are not particularly concerned with vertical handovers to UMTS etc. |
| *QoS / applications* | Priority of lecturers over students.<br>Email, download of lecture notes, multicasted lectures, on-line games |

*Table 20: Conference centers*

| | |
|---|---|
| *Description* | Mix of different access – public WLAN hot spot, offering access to Internet, public WANs (UMTS, GPRS), possibly specialised system on trains, private WLAN (small company network scenario) |
| *Scale* | 500 m square, 1000 users |
| *Mobility*<br>*UMTS roaming* | Most users are walking-speed mobility, |
| *QoS / applications* | Needs to be billable |

*Table 21: Global Network Scenario*

| | |
|---|---|
| *Description* | Global telcos network<br>Many different access technologies<br>Public network + private networks run as a service by the telcos for 3rd party. |
| *Scale* | Full mobile subscriber base with over 80 % penetration in Population |
| *Mobility*<br>*UMTS roaming* | Full range of mobility<br>Vertical handovers required between different access run by operator (e.g. HIPERLAN/2 to UMTS). Inter-operator handovers less critical, though also desirable. |
| *QoS / applications* | All applications<br>Needs to be billable |

Among these different network scenarios, TONIC focuses on that of the Global Network, ensuring nationwide coverage. The UMTS network covers in the end practically all of the population, and WLAN coverage of hot spots is rolled out progressively.

Table 22 shows the number and type of hot spot coverage for the Scandinavian-type country:

*Table 22: TONIC WLAN rollout scenario for a country of ~5 million inhabitants.*

| | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|
| **WLAN sites** | | | | | | | | | |
| airports | 3 | 5 | 6 | 7 | 8 | 8 | 8 | 8 | 8 |
| APs per site | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| Hotels | 43 | 68 | 86 | 99 | 105 | 111 | 114 | 117 | 117 |
| APs per site | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Conference center | 3 | 5 | 6 | 7 | 8 | 8 | 8 | 9 | 9 |
| APs per site | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Café | 0 | 93 | 154 | 198 | 228 | 247 | 259 | 265 | 265 |
| APs per site | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Educational centers | 9 | 15 | 22 | 25 | 26 | 28 | 29 | 30 | 30 |
| APs per site | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Others | 31 | 49 | 62 | 71 | 77 | 83 | 90 | 93 | 93 |
| APs per site | 3 | 4 | 5 | 6 | 7 | 7 | 7 | 7 | 7 |
| total sites | 89 | 235 | 336 | 407 | 452 | 485 | 508 | 522 | 522 |

Note that this rollout is solely based on coverage. The model evaluates the total traffic requirements for broadband services to be handled by the WLAN component and checks that the capacity installed is sufficient. If it is not, then the dimensioning rules call for the addition of Access Points, and recalculates the number of leased lines required.

## 7.8 Cost components

The costs include both investments, i.e., capital expenditures, and operating expenditures.

## 7.9 Investment (CAPEX)

The cost components are the equipment units described in sections 7.3- 7.5. They are listed in Table 23, according to the network level in the network architecture. Price degradation has been applied upon the presented reference prices after the Reference price year.

*Table 23: The main cost components utilised in the model.*

| NW level | UMTS COMPONENTS | Ref. price year | Capacity increment ksubs. | Incremental price (k€) | WLAN COMPONENTS | Ref. price year | Capacity increment | Incremental price (k€) |
|---|---|---|---|---|---|---|---|---|
| 3 | Middleware/ serv. platforms:<br>- multimedia msging<br>- mobile Internet<br>- location-based serv<br>- streaming<br>- m-commerce | 2001 | 10 | 150 | | | | |
| 3 | UMTS MSC upgr. | 2001 | 500 | 2000 | | | | |
| 3 | UMTS OMC | 2001 | 1000 | 7000 | | | | |
| 3 | UMTS Billing Syst. (partly legacy syst. used) | 2002 | 1000 | 12000 | | | | |
| 3 | UMTS HLR/AuC | 2001 | 1000 | 7000 | | | | |
| 3 | UMTS MSC Server | 2001 | 1000 | 3000 | | | | |
| 3 | UMTS CPS | 2002 | 1000 | 15000 | | | | |
| 3 | UMTS HSS | 2002 | 1000 | 6000 | | | | |
| 3 | UMTS Multimedia GW/circuit switched | 2001 | 1000 | 1000 | WLAN_OMC | 2004 | 4000 APs | 200 |
| 3 | MM GW/ IP | 2001 | 1000 | 2800 | | | | |
| 3 | Edge router | 2002 | 2.5Gb | 250 | Edge router | 2002 | 2.5Gbps | 250 |
| 2 | DNS | 2000 | 1/SGSN | 15 | | | | |
| 2 | Firewall | 2000 | 1 per GGSN | 70 | WLAN Mobility Gateway/IWU | 2004 | 1Gbps | 571 |
| 2 | GGSN (serves also WLAN in tight IW) | 2001 | 1000/ 1Gbps | 800 | WLAN Bandwidth QoS Broker | 2004 | 500 APs | 300 |
| 2 | SGSN (serves also WLAN in tight IW) | 2001 | 1000/ 1Gbps | 2500 | | | | |
| 1 | RNC | 2002 | 250 Mbit/s | 1500 | WLAN Brain Access Network | 2004 | 1Gbps | 90 |
| 0 | UMTS Node-B | 2001 | cover. /capa | 70 | WLAN Brain Access Router | 2004 | 1 per site | 4 |
| 0 | Node-B site installation | 2001 | 1 per nodeB | 35 | WLAN Access Point Controller | 2001 | 9 APs /APC | 8.5 |
| 0 | Node-B site buildout (when no 2G site) | 2000 | depending | 100 | WLAN Access Point | 2002 | acc. to plan | 1 |
| 0 | | | | | AP installation | 2001 | perAP | 0.2 |

## 7.10 Operating cost items (OPEX)

Operating cost items include the following:

- Leased Line Costs for UMTS and WLAN: the number of leased lines is calculated according to the downlink capacity needed, as this direction is considered to be the most demanding.

- UMTS terminal_subsidies: as mentioned, these subsidies differ from one country type to the other, they are assumed to be 150 € in the "large" country and 40€ in the small country.
- Employee and Training Costs: training costs are incurred essentially during the deployment year. Employee costs are related to customer service (hot line, customer care), technical staff and administrative staff.
- Marketing Costs: these costs include advertising sand sales costs.
- Site Rental for UMTS and WLAN base stations, including power supply.
- Hosting Costs for WLAN Mobility Gateway (including firewall and DNS) and Bandwidth Broker.
- Maintenance for all equipment: the annual maintenance cost is estimated to be 5% of the investment cost.

# 8. UMTS NETWORK DIMENSIONING AND ROLL-OUT

The UMTS network dimensioning is a two-fold task. On the other side there are certain coverage requirements, set by operator's business plan and possibly also by the license agreement. Then there are the capacity needs driven by the provided services and their market demand. Within these constraints, the operator designs its roll-out plan in the particular country. It is updated, when needed, following the market development.

In the TONIC model there have been implemented certain parameterised roll-out schedules for different country types, governing the build-out periods of different types of areas towards the full coverage of the country at least in the end of the study period. In addition, the capacity requirements for the radio network, as well as for the core network, are modelled so that the investments for the capacity needed by the customers in each covered area are made one year before the actual need. In this process, the safety margins have been taken into account.

The UMTS revenues are dependent on the network rollout, as the 3G usage is calculated only if the user is in the coverage area of the UMTS network. Otherwise the service is not available, or, when possible, the service is provided through GSM/GPRS network, which revenue is not counted.

## 8.1 Key assumptions

### 8.1.1 Area types and country specific roll-out plans

The TONIC business case 1 focuses on two country types "Large" and "Small" as presented in the chapter 4. Within these country types we have one basic roll-out schedule for Large country and two scenarios for Small country, named as "Fast" and "Slow". Fast roll-out reflects stringent requirements dictated by the license agreement, and the slow one more market driven approach. The Large country schedule is comparable to the Small country Slow roll-out, meaning full coverage only in the end of the study period.

The building of the network starts in all cases from the densest urban areas and continue towards the suburban and then the rural areas. Different areas are classified as "dense urban", "urban", "sub-urban" and "rural" areas. Division into these classes in Large and Small country cases is presented in the following subchapters.

#### 8.1.1.1 Large country

The Large country surface area (370 000 km$^2$) and total population (65 M in the beginning) is divided into area types with the following characteristics, and roll-out schedules:

| | |
|---|---|
| • Dense urban | |
| - Size (km$^2$) | 185 |
| - Number of inhabitants per km$^2$ (during busy hour) | 50 000 |
| - Start year of the build-out | 2002 |
| - Start year of the operation | 2003 |
| - Duration of the building period (years) | 1 |
| • Urban | |
| - Size (km$^2$) | 2 960 |
| - Number of inhabitants per km$^2$ (during busy hour) | 4000 |
| - Start year of the build-out | 2003 |
| - Start year of the operation | 2004 |
| - Duration of the building period (years) | 2 |
| • Sub-urban | |
| - Size (km$^2$) | 37 000 |
| - Number of inhabitants per km$^2$ (during busy hour) | 1000 |
| - Start year of the build-out | 2004 |
| - Start year of the operation | 2005 |
| - Duration of the building period (years) | 3 |
| • Rural | |
| - Size (km$^2$), (some uninhabited areas not included) | 303 400 |
| - Number of inhabitants per km$^2$ (during busy hour) | 40 |
| - Start year of the build-out | 2005 |
| - Start year of the operation | 2006 |
| - Duration of the building period (years) | 7 |

#### 8.1.1.2 Small country

The Small country surface area (330 000 km$^2$) and total population (5.5 M in the beginning) is divided into area types with the following characteristics, and two roll-out schedules:

| | Slow | Fast |
|---|---|---|
| • Dense urban | | |
| - Size (km$^2$) | 17 | “ |
| - Number of inhabitants per km$^2$ (during busy hour) | 50 000 | “ |
| - Start year of the build-out | 2002 | 2002 |
| - Start year of the operation | 2003 | 2003 |
| - Duration of the building period (years) | 1 | 1 |
| • Urban | | |
| - Size (km$^2$) | 264 | “ |
| - Number of inhabitants per km$^2$ (during busy hour) | 4000 | “ |
| - Start year of the build-out | 2003 | 2002 |
| - Start year of the operation | 2004 | 2003 |
| - Duration of the building period (years) | 2 | 1 |
| • Sub-urban | | |
| - Size (km$^2$) | 3 300 | “ |
| - Number of inhabitants per km$^2$ (during busy hour) | 1000 | “ |
| - Start year of the build-out | 2004 | 2003 |
| - Start year of the operation | 2005 | 2004 |
| - Duration of the building period (years) | 3 | 1 |
| • Rural | | |
| - Size (km$^2$), (some uninhabited areas not included) | 264 000 | “ |
| - Number of inhabitants per km$^2$ (during busy hour) | 3 | “ |
| - Start year of the build-out | 2005 | 2003 |

| | | | |
|---|---|---|---|
| - | Start year of the operation | 2006 | 2004 |
| - | Duration of the building period (years) | 7 | 2 |

### 8.1.2 Capacities of network elements

#### 8.1.2.1 Radio network

For the WCDMA coverage and capacity, only one 2*5 MHz FDD carrier is assumed, as in most large countries only two carriers are granted per licensed operator and the second one is reserved for the micro layer.

Radio network modelling is done with three-sector UMTS base stations (Node-B:s) so that site coverage area is 2 * (cell range)$^2$. Average cell ranges used in the model are based on studies on the most advanced technical solutions and are:

- Dense Urban: 0.57 km
- Urban: 0.89 km
- Suburban: 2.11 km
- Rural: 6.36 km

The elements in radio network, with price information, are presented in the chapter 7.

#### 8.1.2.2 Core network

As a broad view, the network elements of the core network, holding also for RNC:s, are added according to their transmission capacity and the traffic going to/coming from the users, i.e. through base stations. Some elements, like the service provisioning middleware, are driven by the subscriber amount

The elements in core network, with capacity and price information, are presented in the chapter 7.

## 8.2 Coverage requirements

### 8.2.1 Radio network coverage calculation

Given the average cell ranges, it is possible to calculate the amount of needed base stations for coverage build-out of different area types.

For the Small country type, with lower population density, the network is mostly coverage driven throughout the study period. As contrary to Large country, where – given the usage amounts of the UMTS services – the additional base stations are needed in the dense urban areas after a couple of years operation and also in sub-urban in the later phase. Anyhow, as the base estimations for usage amounts might be somewhat cautious, the UMTS network is mostly coverage driven, save the dense urban areas.

### 8.2.2 Regulatory requirements for the coverage

The optimal roll-out of the UMTS network is driven by the market demand development. In the first phase, as the demand is still low, it is cost efficient to build only the most dense areas, where the utilization degree of a base station can be got to feasible level. Also the constraints in acquisition and building process set some practical limits on the roll-out time-table. It is also feasible to build certain areas for full coverage first, rather than spots of coverage here and there.

This market driven planning is though not possible in every case. There have been different kind of frequency licensing procedures in Europe and thus the conditions might vary substantially. Auction type of spectrum awarding, with high license fees is supposed for the Large country, but negligible license fees combined with stringent service rollout requirements are modelled for the Small country type (fast roll-out). The license fee used for Large country basic case is 6 billion €.

For Large country, the rollout requirements differ country by country, but the presented roll-out schedules we have used, reflecting the combined licensing data, lead to: 50% population coverage at the end of 2004, 80% population coverage at the end of 2006, and at least 50% surface area coverage at the end of 2008.

As in some Nordic countries, specially Sweden, there have been introduced by the regulator very fast roll-out schedules, we have modelled, for comparison, two schedules, very fast and a slower one. In the fast rollout, virtually 100% coverage is achieved by the end of 2004. In the slower scenario the rollout is smooth and the large rural area build-out is not completed before the year 2011, although the urban, suburban and part of the rural area (e.g. main roads) is covered already by year 2006. In the current economic situation of the telecom sector, also the tight regulatory requirements have been taken into new consideration within EU and the European countries.

## 8.3 Generated load and capacity requirements

The population distribution into different area types and the usage penetration of different Service classes indicate the load in each cell. Given the capacity figures of the base stations, it is now possible to calculate if the coverage build-out is enough to give the needed transceiver capacity. If the current build-out does not provide for it, the amount of base stations is increased accordingly (note what was stated in the beginning of chapter 8.1.2 about the used carriers.)

## 8.4 Cost calculation

Non discounted investments are for the whole study range not more than about 1.9 B€, partly due to a long roll-out period and degrading equipment prices. When the license fee is left out, the investments consist of base stations (45%), site build out (20%, with one third of the sites new), switching, routing and control centres (23%) and new billing systems and other OSS plus software (11%). The backhaul and transport is modelled as leased line costs thus calculated within the Running Costs.

### 8.4.1 Radio and core network element cost calculation

The elements in radio and core networks, with capacity and price information, are presented in the chapter 7. The cost calculation is mostly quite straightforward, as combining this information with the user traffic transmitted through the base stations in different areas. Capacity is rolled out one year ahead by purchasing and installing enough amounts of each element to cover the growing traffic load generated by the increasing number of UMTS users. Most of the time the investments to radio network equipment, representing bulk of the costs, are dominated by the coverage roll-out plan.

### 8.4.2 Transport cost modelling

Transport costs were first coarsely modelled with the TONIC tool, by using average traffic amounts between nodes and rigid update patterns for the links. These results were validated using the optimising methodology described below. The results were found to be within reasonable limits coinciding with the optimal results, confirming the usability of the model calculation. This is probably due to the un-optimal links being compensated by using average traffic amounts.

A methodology for the calculation of transport costs due to leased lines have been set-up between Core Sites, being an important indicator to validate the results obtained in TONIC model of BC1. A non-optimised method is to assume that the traffic between each pair of Core Sites is supported through the direct leased lines. The optimised approach is to take advantage of the available bandwidth in leased lines to route traffic between other pairs of Core Sites. In this optimised method, traffic between Core Sites can be router by other Core Sites, which can result in lowering the capacity (and the cost) of the direct leased lines. For this purpose, it is used a heuristic based on Lagrangean Relaxation with Sub-Gradient Optimisation; this technique has been exploited in contexts, see chapter 13 References [1],[2].

The study assumes two scenarios: -small country and -large country, which are characterised by their geography and demography parameters, with direct implications on the network architecture level, traffic requirements and its distribution across the network.

All of these settings allow building a model using a dedicated software tool, named PT Plan MPLS, which implements the above mentioned heuristic algorithm (based on Lagrangean Relaxation with Sub-Gradient Optimisation). PT Plan MPLS[8] was developed by Institute of Telecommunications (IT) and PT Inovação (The R&D branch of Portugal Telecom) [1].

- Appendix A contains all development of transport cost optimisation that have been performed for TONIC calculations
- Appendix B contains all development of access dimensioning optimisation that have been performed calculations

# 9. INFRASTRUCTURE SHARING – RESULTS FROM TONIC MODEL

## 9.1 Background and current situation

A number of European regulators have expressed support for infrastructure sharing, but only with the imposition of certain limits. Following request of the operators, certain regulators in European countries have adopted positions in the debate over the sharing of infrastructures, specifying what types of agreement are likely to receive authorization.

The UK regulator, in an information note of May 2001, explicitly encouraged the sharing of sites, and indicated that he would be examining the infrastructure sharing agreements on the basis of respect for the right of competition.

On 5 June 2001 the German regulator defined in a communiqué the technical conditions under which infrastructure sharing agreements could be set up (sharing limited to sites, passive elements, and radio networks, subject to the condition that the two operators control their own software networks).

The Netherlands defined a position on 19 July 2001, which reconciled the British position (respecting the right of competition) and the German (independence of operators in line with the licences issued). The press release associated with the adoption of this position is presented as an appendix.

The European Commission declared itself in favour of the sharing of infrastructures, at least with regard to means which would favour the launch of UMTS, particularly in the communiqué of 20

[8] PT Inovação kindly authorized the use of this software tool for this study.

March 2001, while still showing a preoccupation with the avoidance of agreements which could be anti-competitive, as Mr. Mario Monti, European Commissioner with responsibility for competition, made clear in his speech in Barcelona on 11 September 2001.

On 12 June 2001 British Telecom and Deutsche Telekom announced the signing of a non-binding draft agreement, confirmed on 21 September by a formal agreement between mmO2 and T-Mobile, their respective mobile phone subsidiaries, regarding the sharing of infrastructures in Germany and the United Kingdom, which it is reckoned will save 25 to 30% of the costs of constructing networks.

The German telephone operator E-plus (KPN Group) and Group 3G (Telefonica/Sonera) announced on 14 September 2001 that they had signed a co-operation agreement for the construction of a third-generation UMTS mobile phone network in Germany. This agreement makes provision in particular for the sharing of radio network sites and active elements (base stations and RNC)

MMO2 (British Telecom), through the medium of their Dutch subsidiary Telfort Mobile and KPN Mobile, announced on 8 November 2001 that a co-operation agreement had been signed regarding the deployment of their 3G network in the Netherlands. This agreement is open to other Dutch 3G operators, and makes provision in particular for the sharing of radio infrastructure elements excluding the network core, being intended to pave the way for a definitive agreement before the end of 2002.

Others infrastructure sharing deals have been concluded during the 2002 first semester: Orange, which holds one of Sweden's four UMTS licences, has joined the network-sharing partnership between fellow licence holders Europolitan Vodafone and the Hi3G consortium, which is owned by Swedish firm Investor and Hong Kong-based conglomerate Hutchison Whampoa.

## 9.2 Technical Solutions for the Sharing of Infrastructure

In schematic terms, there are five levels of infrastructure sharing. In the presentation set out below it is presupposed that each level implies the sharing of the preceding level, although this condition is, of course, not always necessary. More complex combinations of the different sharing levels could be implemented by the operators; it is accordingly theoretically possible, for example, to amalgamate levels N1 and N3 without amalgamating level N2.

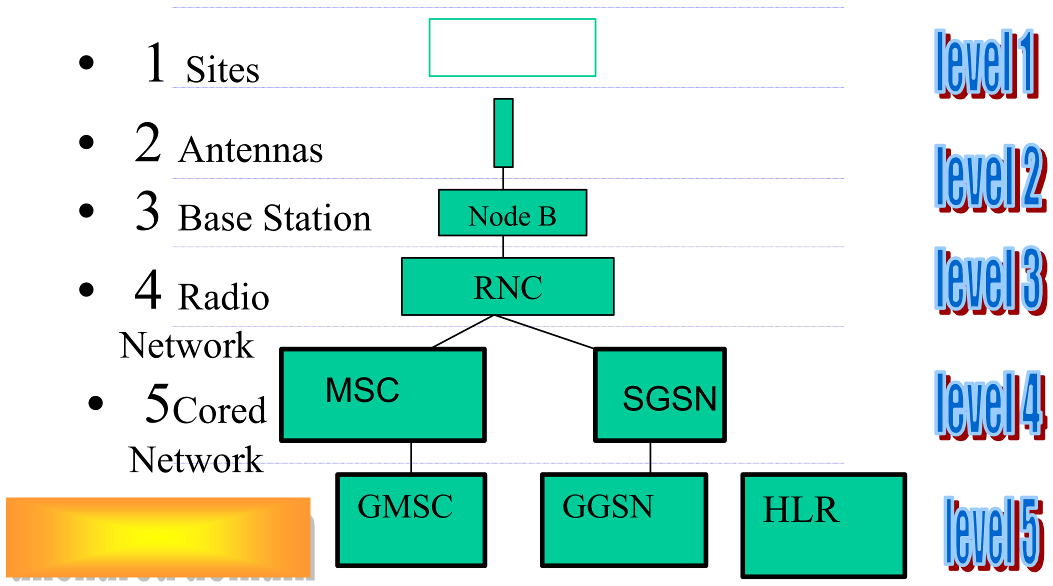



*Figure 25: Infrastructure sharing level*

See appendix C for entire description of network sharing level.

## 9.3 Geographical dimension of infrastructure sharing

The infrastructure sharing agreements can be applied to a fraction of the territory covered by the licences. A distinction can therefore be made between three cases:

Case 1 - The sharing agreement relates to the zones taken into account under the coverage obligations of the licence for the two operators in the agreement;

Case 2 - The sharing agreement relates to one zone taken into account under the coverage obligations of the licence for one of the operators, but exceeding the obligations of the other;

Case 3 - The sharing agreement relates to coverage areas exceeding the coverage obligations of both the operators.

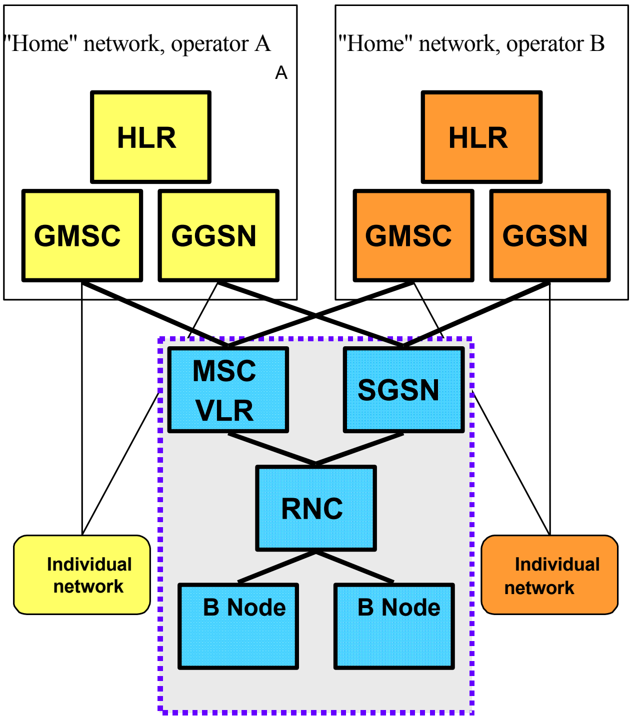



*Figure 26: Diagram showing the principle of network core sharing*

It can be readily appreciated that the three cases should give rise to examination under different criteria with regard to the respecting of the operators' commitments (case 1), the rules of competition (case 2), and the maximisation of collective benefit (case 3).

Apart from this, the "depth" of the agreement on the technical level may vary as a function of the zones, and in particular of their financial potential. It is possible to conceive of agreements on level 1 in a dense area, and level 3 and 4 agreements in less dense areas.

"Geographical" agreements can also give rise to a genuine territorial division of the networks.

This approach is manifested by selective deployments into certain geographical zones and roaming movement agreements within these zones in such a way as either to offer coverage identical to that provided for, but at least with regard to cost (case 1), or to expand the offer to a global service coverage provided for in the commitments, still at low cost, or to augment the global coverage provided for while minimizing the additional costs (problematic with regard to universal coverage).

Such a division of territory is "at the limit" of the sharing of infrastructures, since each operator has possession of their network with a reciprocal roaming movement agreement, but in reality there are no shared elements other than those necessary for interconnection. Each operator is in fact in an MVNO situation on the part of the network deployed by the other operator. In this respect, this approach will be studied in greater detail within the scope of the report on the MVNO.

## 9.4 Industrial availability of shared equipment

The availability of shared equipment seems to vary depending on the equipment suppliers and on the way in which this sharing possibility is provided for in their initial hardware conception.

Accordingly, a number of industrial concerns have announced that they may be ready very rapidly (a matter of a few months), depending on the demand from the operators.

Nokia are forecasting that their shared equipment at level 4 will be available in 2002. Ericsson have stated that they are ready to respond rapidly to operator demand for levels 4 and 5, and have proposed a number of solutions to operators in Germany and Sweden.

It is nevertheless likely that initially there will only be single-manufacturer solutions available. Even if the technical solutions being forecast make use of interfaces standardised by 3GPP, the level of inter-operability of the sharing solutions for infrastructures from different suppliers will depend on the effective availability of the technical functional performance provided by the equipment units as a whole.

## 9.5 The German and Dutch positions with regard to this classification

From the technical point of view, the German and Dutch regulators have accepted the sharing of infrastructures up to level 4 as defined above, and exclude level 5. They have nevertheless submitted the approval of agreements compatible with these technical devices to a more detailed examination with regard to their effect on competition between operators.

The criterion applied is that each operator must retain control within their "software" network over their own data traffic and over the use of their own frequencies, in order to retain mastery of all the components, which determine the quality of their networks and the supply of services.

In addition to this, anxious to preserve the spirit of competition, they have imposed on the operators the restriction of an exchange of technical data which is strictly necessary, and the German regulator has likewise made provision for separate operations and maintenance sectors. Coverage obligations will not to be infringed in Germany: 25 % of the population by the end of 2003. All agreements must be submitted to to RegTP for inspection. It is clearly indicated that no exclusive coverage contract will be allowed.

Regulators have excluded level 5 (sharing network cores), taking the view that this would imply the sharing of frequencies, and that the existence of a network specific to each operator is no longer verified, the operation of the sharing principle accordingly being converted into what is virtually a process involving the concentration and reduction of the number of operators. This concentration would therefore be incompatible with the aim of increasing the number of operators of mobile networks in competition over a given territory.

It may also be noted that, from the point of view of the consumer, if this "concentration" at the level of infrastructures can be translated into the maintaining or increasing of the number of offers of independent services (MVNO agreements), the "concentration" on the infrastructures is not "ipso facto" incompatible with maintaining competition which is of benefit to the consumers.

## 9.6 Techno-economic analysis of infrastructure sharing

The analysis elements set out below are essentially the result of a qualitative approach. Essentially, a precise quantitative approach of the financial impact of the decision to share networks on the financial situation of an operator would require the involvement of detailed models of the business plans of operators based on in-depth discussions of the various hypothetical situations to be taken into account, which would exceed the time-frame defined for the work of the group. As well as this, the probable sensitivity of the results to the hypotheses relating in particular to the specific situation and strategy of each operator would render such an exercise relatively complex, and the exploitation of the results particularly delicate.

## 9.7 Impact of infrastructure sharing in the investments

### 9.7.1 Investment economies in the network sharing sector

All things being equal, the sharing of infrastructures between operators undeniably leads to a reduction in the investment incurred by each operator in the sharing sector. The scale of this investment saving is difficult to determine, however, inasmuch as it appears to depend in particular in the level of sharing and the geographical strategy of deployment which is opted for.

In diagrammatic form, the investments for the deployment of a 3G network can be divided as follows in Figure 27.

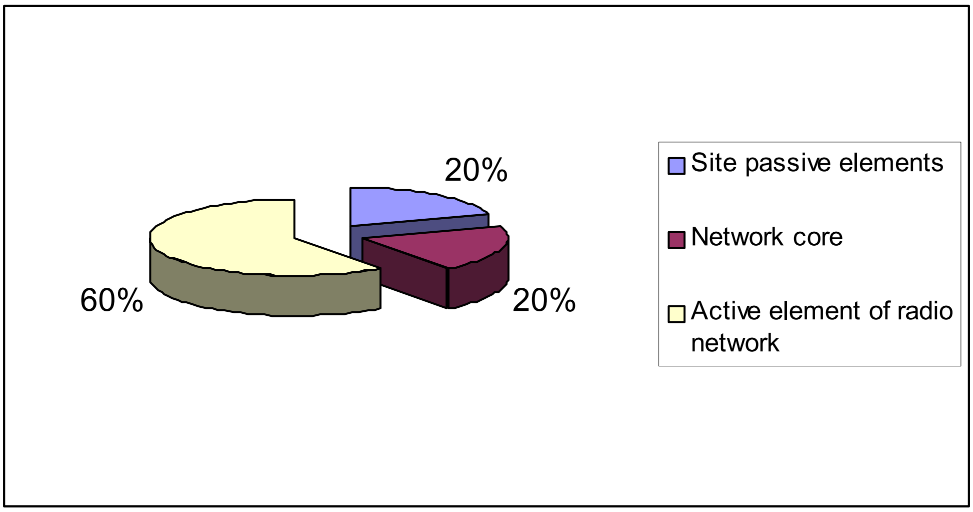



*Figure 27: Cost break down Analysis for a UMTS network*

The savings on investments achieved within the scope of an infrastructure sharing agreement must therefore be appreciated according in particular to the level of sharing opted for, and its geographical scale.

According to GITEP TICS, the sharing of sites, including antennae (levels 1 and 2 combined in accordance with the delineation adopted heretofore), would allow on average for 20 to 30% savings on the network investment costs (CAPEX).

Also according to GITEP TICS, the sharing of the radio network (including the sharing of sites, levels 1 to 4 inclusive) would in general allow for savings from 25 to 45%, or 5 to 20% additional savings in relation to single sharing of levels 1 and 2. Finally, the sharing of active elements (levels 1 to 5 inclusive) would allow for a maximum saving of 10% above the savings already achieved from the sharing of the four foregoing levels.

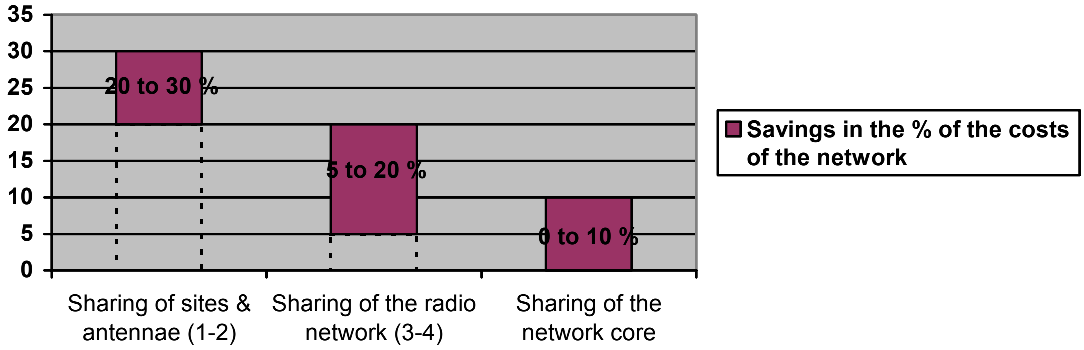



*Figure 28: Theoretical investment savings associated with the sharing of infrastructures by two operators*

### 9.7.2 Infrasharing will also generate costs

This overall assessment of the investment savings must nevertheless be qualified if, during the period, the mutual relationship of the operators within the network constitutes only a transitional phase, followed by the removal of the relationship.

In the longer term, and on the assumption that the UMTS encounters the anticipated success, it is probable that operators would be led to separate the networks which were initially operated on a shared basis, in order to meet the need to increase capacities, in order to establish greater differentiation or to become more independent from other operators within the framework of very sharp competition. Such a process of reduction of the mutual relationship is nevertheless likely to be carried out on the technical level while still sharing the sites (level 1).

Over the duration of the relationship, additional costs could be incurred associated with the move from a sharing relationship to the cancellation of that relationship with regard to radio equipment.

The benefit derived from the process of moving from the sharing relationship to its removal would therefore probably be greater, all other things being equal, the longer the sharing lasts. There is essentially a minimum period for sharing, from which the operation is profitable overall in terms of the updated cumulative total of the investments. This period, however, depends on the specific conditions of each agreement, the dynamics of the market as a whole, and the position of each operator on the market.

### 9.7.3 Infrasharing as a mean to fulfil coverage requirements with lower costs

In the very short term, one of the main points of interest, if not the only one, in the sharing of infrastructures is the ability for operators to spread over a period of time the investments required for achieving their objectives in terms of coverage, by sharing their preliminary deployment operations in such a way as to reduce their initial investments, and undertaking, during the period of the relationship, the additional investments required for the final separation of the networks depending on the developments within the market.

This spreading process would seem to be a determinant element in a context in which the rapidity of the deployments of the networks, the success of the launch of the services, and the amount of taxes and levies incurred with the obtaining of licences, lead to high financing requirements over the first few years.

The agreements on sharing infrastructures should therefore allow for the financial risk on the part of the operators to be reduced at a time when the uncertainty of success of the UMTS is high among investors and based on the models for earnings projected by the operators themselves.

The savings on investments in the short term thanks to the sharing of infrastructures could therefore be put to advantage in order to facilitate the achievement of the objectives of coverage, and even to speed up the deployment of UMTS networks, within a difficult financial context, provided that the industrial availability of the equipment is effectively ensured such as to allow the implementation of sharing solutions.

## 9.8 Interest tempered by not insignificant technical constraints

Sharing infrastructures requires a level of co-ordination, or even co-operation, between the operators, which becomes closer and closer the more the level of sharing increases.

This co-operation arrangement then introduces a considerable number of constraints on the activity of the operators involved in the sharing arrangement, and therefore limits their room for manoeuvre. These constraints induced by the co-operation must accordingly be taken into account in the assessment of the technical and financial interest which sharing may have for each operator.

These constraints affect in particular the operational elements involved in the deployment and exploitation of the networks, and may have an impact on the capacity of operates to establish differentiation between themselves in terms of services or quality of services.

Some elements are set forth on the following pages to assist in analysing the technical constraints to which the operators will be subjected, depending on the level of sharing provided for.

Constraints can be seen to grow at each level, with a jump between levels 2 and 3 (sharing of active elements of the radio network) and between levels 4 and 5 (sharing of network core elements), which indicate a fundamental difference in the type of infrastructure sharing and in the type of constraints associated with it.

### 9.8.1 Level 1

In the event of sharing of sites, account needs to be taken of the constraints associated with:

- The qualification of the sites to be shared (electro-magnetic compatibility, coverage models, site area, 2G-3G optimisation);
- The installation of equipment units on the shared site (access and security, site engineering, timetable for the deployment of the operators);
- The operation and maintenance of the equipment (action taken on site, monitoring and controlling the network equipment units, etc.).

The development towards separated networks is leading to a search for new sites which will allow for one operator to be accommodated.

### 9.8.2 Level 2

In the event of sharing of antennae, account needs to be taken of the constraints associated with:

- The need to make joint choices, influencing the quality of service (techniques for establishing differentiation in reception and transmission, radio-electric planning, antenna architecture, use of TMA (Tower Mast Head Amplifier);
- Installation of joint antennae;
- The influence on radio-electric planning of the linearity of antenna amplifiers on a number of frequency bands;
- Taking into account the radio-electric planning for 3 dB of loss incurred by the shared antenna coupler, with a view to the separation of the equipment connected to it.

The development towards separate networks consists simply of removing the double function of the antenna in order to revert to the preceding level.

### 9.8.3 Level 3

In the event of sharing of base stations (mode B), account needs to be taken of the constraints associated with:

- The use of B node supported by at least two carriers (a substantial distance between the frequency bands of the operators involves an additional level of technical complexity);
- The adaptation of the software configuration in order to manage mobile information deriving from several operators (it will be necessary in particular to synchronise the modifications to the software);
- A risk of ending up with single-manufacturer solutions (due in particular to the problems of inter-operability at the level of B node - RNC links);
- Potential conflicts with regard to quality levels deriving from the services offered (sharing power);
- The operation and maintenance of the active elements being shared

The development towards separate networks consists of removing the double function of the B nodes in order to revert to the preceding level.

### 9.8.4 Level 4

In cases of sharing base stations controllers (RNC), account needs to be taken of the same types of constraints as for the sharing of the B nodes, which are still pertinent in the case of the RNC, and the additional constraints associated with:

- The management of the separation of the functions specific to the RNC (radio access configuration, management of the performance and quality of the radio services);
- Inter-operability between equipment units deriving from several different manufacturers (software and hardware configuration);
- Inter-operability between the shared RNC and the RNC retained under individual control, linked by means of the Iur interface in order to guarantee the handover (soft handover);
- The operation and maintenance of the active elements being shared.

The development towards separate networks consists of removing the double function of the RNC in order to revert to the preceding level.

### 9.8.5 Level 5

In the event of sharing of network cores, account needs to be taken of the additional constraints associated with:

- The choice of dimensions of the shared equipment (B node, RNC, MSC, SGSN), in order to support the traffic associated with the offering of services from each of the operators;
- The establishing of the dimensions of the backbone package and the management of the quality of the service;
- The need to support homogenous intelligent network protocols in order to ensure the continuity of client services for each operator when they are moving through the shared network;
- The management of billing tickets;
- The installation, operation, and maintenance of the shared active equipment units.

The development towards separate networks consists of removing the double function of the shared network cores in order to revert to the preceding level.

## 9.9 Sharing the radio network is of less interest in the most dense areas

Interest in sharing infrastructures depends on the geographical area under consideration, and in particular on the density of population and of the traffic hoped for. In general terms, it may be considered that sharing infrastructures which goes beyond the sharing of sites is of less interest in the most dense areas.

In effect, in very dense areas the difficulty in finding new sites and the environmental constraints justify a considerable interest in sharing sites, but do not provide any incentive to go any further in the sharing of infrastructures.

Conversely, in less dense areas the deployment of infrastructures is established in coverage software of such a nature that the small volume per operator can justify the installation of a shared infrastructure.

The Figure 29 shows a summary of these considerations:

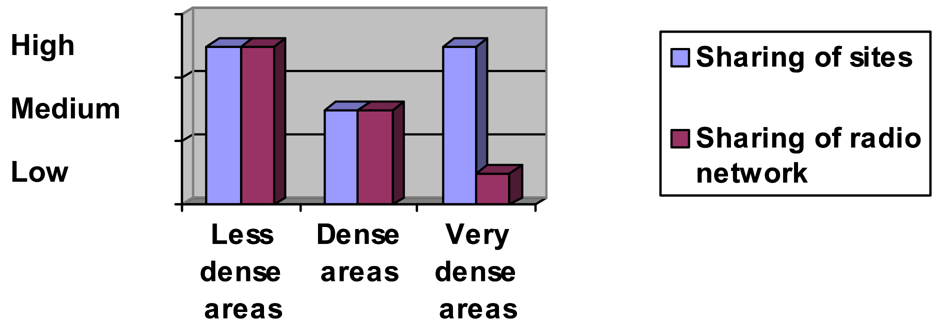



*Figure 29: Interest in the sharing of infrastructures as a function of population density*

The deployment of the networks is in general implemented first of all in very dense areas in order to reach as many consumers as possible, which tends to limit the interest in sharing infrastructures (beyond the sharing of sites), at least in the first phase of deployment.

## 9.10 Sharing the radio network is of less interest to UMTS operators who have acquired a significant 2G body of subscribers

The last variable with regard to the attractiveness of sharing infrastructures for an operator is associated with prior presence on the mobile phone market. Essentially, each 2G operator can assume that a certain number, of greater or lesser significance, of their 2G customers will move with them to the 3G network. The increase in load on their network will probably be more rapid than on those of incoming operators who can only count on newcomers to their networks and services.

It follows that the "time frame" during which the sharing of UMTS infrastructures is financially advantageous may transpire to be substantially narrower for a 2G/UMTS operator than for a UMTS operator. We have seen earlier that the time aspect of sharing may call the financial interest into question. Logically, it would seem that a 2G operator with a large body of subscribers will therefore have less incentive to share than an operator who is a new arrival.

If the sharing of infrastructures allows for a different sharing arrangement to be implemented for an operator's investments, by reducing the initial investments, it will nevertheless not in itself, in a difficult financial context, resolve all the problems associated with the financial viability of the operators.

## 9.11 Harmonisation desirable at European level of the conditions for sharing infrastructures between operators

The introduction of the third generation of mobile networks has been marked by a substantial disparity in the conditions, particularly financial, for the issue of authorizations within Europe.

In this context, it would seem to be important for the most coherent approach possible to be adopted in Europe with regard to the question of infrastructure sharing.

In this respect, it is of value to examine the degree to which the approaches adopted by Germany, the Netherlands, and the United Kingdom are compatible with the conditions of issue in other countries.

## 9.12 An opportunity but not a miracle solution

The sharing of infrastructures between operators is an indicator as to why better sharing during the investment period is to be favoured, so contributing towards reducing the initial financial burden on the operators. This will not, however, resolve all the problems associated with the financial viability of the projects or of the operators themselves.

## 9.13 Small country case

As indicated one of the best infrastructure scenario, from level 1 to level 5, cannot be determined in a quantitative way. We have chosen a level 4 infrastructure sharing and implemented it in TONIC model. This high level was chosen to maximize impact on economic criteria. Referring to the very likely additional costs for acquiring those new "share enabled" access network equipments and also for not having optimal site plan since network are shared, we estimated a 12 % extra cost for the small country case. Assumption taken is that 20 % of network is shared with another operator.

Gains obtained from infra sharing are presented on chart Figure 30:

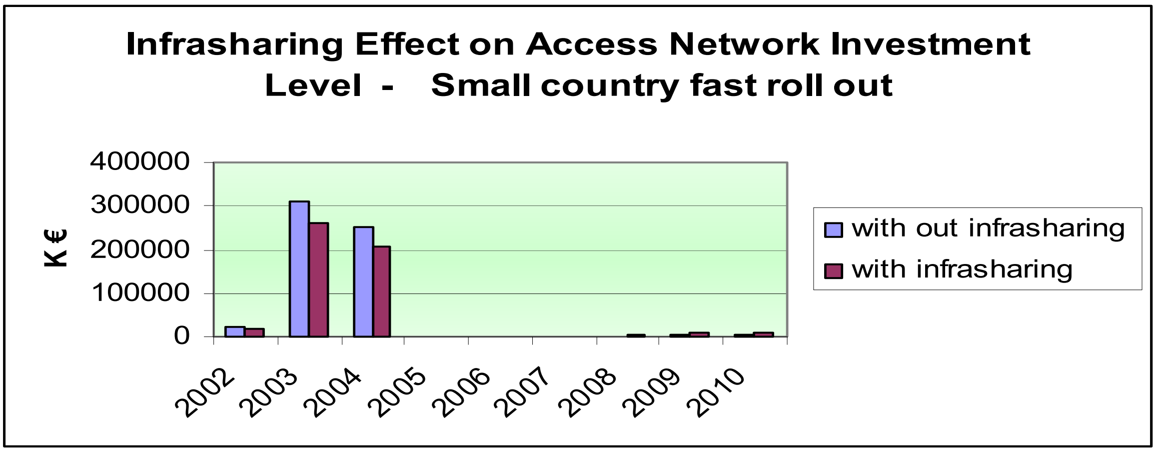



*Figure 30: Infrasharing Effect – Small Country fast roll out*

In this case it results as a remarkable 14 % saving on investment in term of discounted investments. This has huge impact on economic criteria like NPV and IRR as shown on Table 24.

*Table 24: NBV and IRR gain with infrasharing*

| | Without Infrasharing | With Infrasharing | Gain |
|---|---|---|---|
| NPV | 96 Meuro | 269 Meuro | x 2,8 |
| IIR | 12 % | 17 % | + 5 points |

## 9.14 Large country case

In large country case extra cost for getting "share enabled" equipment and adjusted suite plan is estimated at 9 %. Assumption taken is that 20 % of network is shared with another operator.

Gains obtained from infra sharing are presented on chart Figure 31:

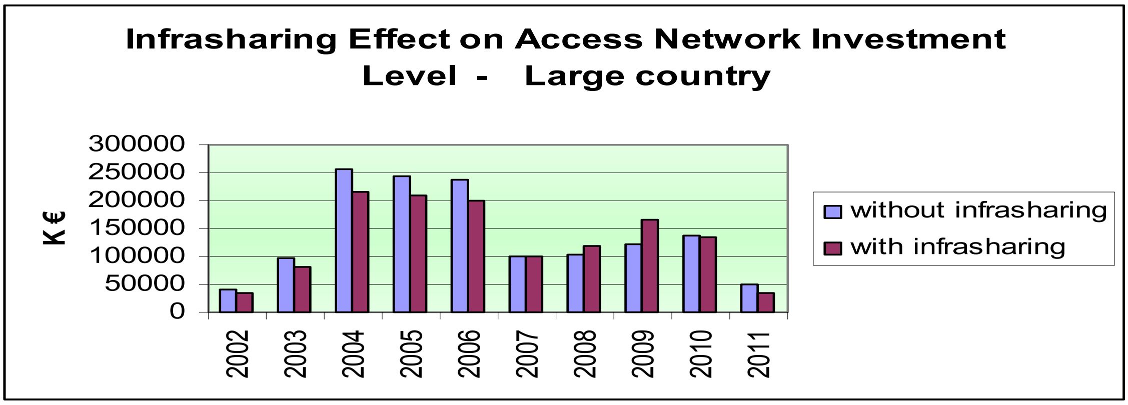



*Figure 31: Infrasharing effect on access Network Investment – Large country*

In this case, infra sharing has negative impact during 2008 and 2009: additional cost of equipment is not balanced by the volume effect, i.e. the number of access network equipments saved.

Effect on economical criteria is much lower than in small country case as shown in Table 25: NPV and IRR gain with Infrasharing –Large Country case

*Table 25: NPV and IRR gain with Infrasharing –Large Country case*

| | Without Infrasharing | With Infrasharing | Gain |
|---|---|---|---|
| NPV | 5 639 Meuro | 5 719 Meuro | +1,5 % |
| IIR | 19 % | 19 % | + 0 points |

## 9.15 Conclusions resulting from TONIC simulations

Infra-sharing opportunity is not likely to be taken by incumbent for strategic reason as explained above. On top of that, considering technological risks and related estimated costs subject to uncertainties on one side and the limited benefit we calculated in our model minus 2 points of IRR only- on the other side, our conclusion is that most incumbent will have to withdraw such projects or limit them to site sharing only, under environmental pressure.

# 10. END-USER PRICING AND REVENUE FORECASTS

## 10.1 Introduction

Pricing is a difficult issue at this phase of the 3G emergence, as different new tariff schemes are just to be brought out. Compared to the old era of mainly voice and then SMS, the new mobile data services bring many new possibilities in charging policy. Starting from pure monthly flat rate or transmission volume based, to different kind of packages based on bit rates, minutes, packet amount, Mbytes, subscribed or used services, content, etc.

## 10.2 Different pricing models

The aim of the end-user pricing is get best possible revenue out of the 3G investments. This means among other things that the network resources should be utilized optimally, implying that each service revenues should be proportional to the load generated to the critical resources, especially the air interface capacity during the peak period. This with the condition that the value-adding component of the service, which is not related to the traffic resources, is handled separately (revenues/costs). In practice this is hardly possible to implement as a clear-cut method.

The price cannot grow linearly to e.g. bit rate or monthly MB quota. To boost the usage the volume discounts are needed. On the other hand there are limits for the spending of individual users. So the pricing can be seen as optimisation question to get the maximum revenue per user without too high load on the resources. Especially in the beginning of the rollout, when e.g. the radio resources might be sparse, it is important to guide the customers to certain kinds of usage patterns, so that the quality of all services is sustained on a sufficient level. This might mean even raising tariffs when the user is crossing certain traffic amount. However the actions of the competitors bring an element difficult to count in for the optimal pricing strategy.

## 10.3 Selected pricing principles

In the TONIC model the end-user monthly charging is in the first place based on the transferred Mbytes. Each service class has its own tariff per MB, which is degrading as the bit rate of the service class increases. On the other hand, with the interactive/background traffic the user is paying only for the active sending and maybe receiving of the user data packages, not for constant bit rate channel as with conversational traffic, so it is assumed that the price level per bit is higher. WLAN tariffs are supposed to be clearly lower per MB compared to UMTS, due to cheaper technology with more capacity but restrictions on availability. Tariff erosion is naturally included in the modelling.

The model gives freedom for simulation with different pricing plans, which may consist of combination of a traffic related part and a traffic independent part for each service class. It is possible to introduce e.g. a plan, where there is an average flat rate for the service class users and an additional traffic related tariff, or even a pure flat rate model.

In the basic business cases the emphasis is still on the MB based tariff, as the costs of the network are clearly related to the provided traffic. Anyhow the added value of the services is included as giving higher than pure bit transfer price estimates.

## 10.4 Estimated end-user price levels and price erosion

*Table 26: MB based price level estimation (euro)*

| | | |
|---|---|---|
| UMTS | Narrow band Conversational - Circuit switched | 1.30 |
| UMTS | Wide band Conversational – Circuit switched | 0.65 |
| UMTS | Narrow band Conversational - Packet switched | 1.30 |
| UMTS | Wide band Conversational – Packet switched | 0.65 |
| WLAN | Broad band Conversational | 0.20 |
| UMTS | Narrow band Streaming | 1.00 |
| UMTS | Wide band Streaming | 0.50 |
| WLAN | Broad band Streaming | 0.15 |

| | | |
|---|---|---|
| UMTS | Narrow band Interactive and Background | 6.00 |
| UMTS | Wide band Interactive and Background | 1.50 |
| WLAN | Broad band Interactive and Background | 0.25 |

The MB based price level estimation is presented in Table 26. Notice that tariff presented is the average of different services in the class; the price per bit for individual services may differ significantly. For example narrowband interactive/background services are supposed to include many services where the value is not so dependent on the amount of transferred bits, but on other use factors. In addition to MB based price, the basic tariff parameter values include one traffic independent element for each user. This reflects the services like currently in 2G networks the SMS, where the added value is clearly mainly elsewhere than in the transmission of bits. It is set to 7€ per month in the beginning, reflecting the current SMS and that kind of data services spending. Price erosion applies also on these revenues, leading in effect a decreasing weight of this revenue element.

## 10.5 End-user price and usage benchmarking against the ARPU estimations from the market studies

As the end-user pricing and usage figures of each Service class lead to certain level of revenues per average user, it is necessary to benchmark the results against the ARPU estimations from the market studies, complemented with TONIC judgement on mobile market potential and user behaviour based on experience from previous technology generations projected on TONIC scenarios. This should ascertain that the calculated ARPU outcomes are on a realistic level considering the foreseen consumer and business spending patterns.

### 10.5.1 Definition and calculation of ARPU in the TONIC model

The UMTS revenues in the TONIC model are dependent on the network rollout, as the 3G usage is calculated only if the user is in the coverage area of the UMTS network. Otherwise the service is not available and the demand is not fulfilled, or the usage goes seamlessly to the GSM/GPRS network, which revenues are not counted.

The ARPU figures are usually counted plainly as the operator's mobile revenues divided by the amount of mobile subscribers. This might cause some confusion in the current new situation where the operator would provide several systems (2G and 3G) simultaneously, and we want to separate the revenues from subscribers of different systems. According to knowledge from previous mobile generations the first migrates are clearly spending more than the latecomers. An oppositely affecting factor within European 2G/3G migration is that in the beginning much of the usage, and thus revenue, goes to the 2G network as the 3G coverage is lacking, but the roaming between 2G and 3G is provided. In the TONIC model both of these factors are taken into account in the cost and revenue calculations; but for the reference to the commonly presented ARPU figures, the revenue calculation not taking into account the special user profile in the first two years and the start-up coverage limitations, is presented. This ARPU graph reflects the smooth development of ARPU (demand) for the users migrated to UMTS, as if the full UMTS coverage were there. It is much the same for all country and rollout cases, and is presented in the Figure 32 below. We can see that the UMTS users ARPU (without WLAN revenues) reaches 66 € /month in the years 2007 and 2008, but start to reduce after that, as the UMTS penetration grows over 50% of all mobile subscribers and the price erosion starts to outweigh the usage growth per UMTS user.

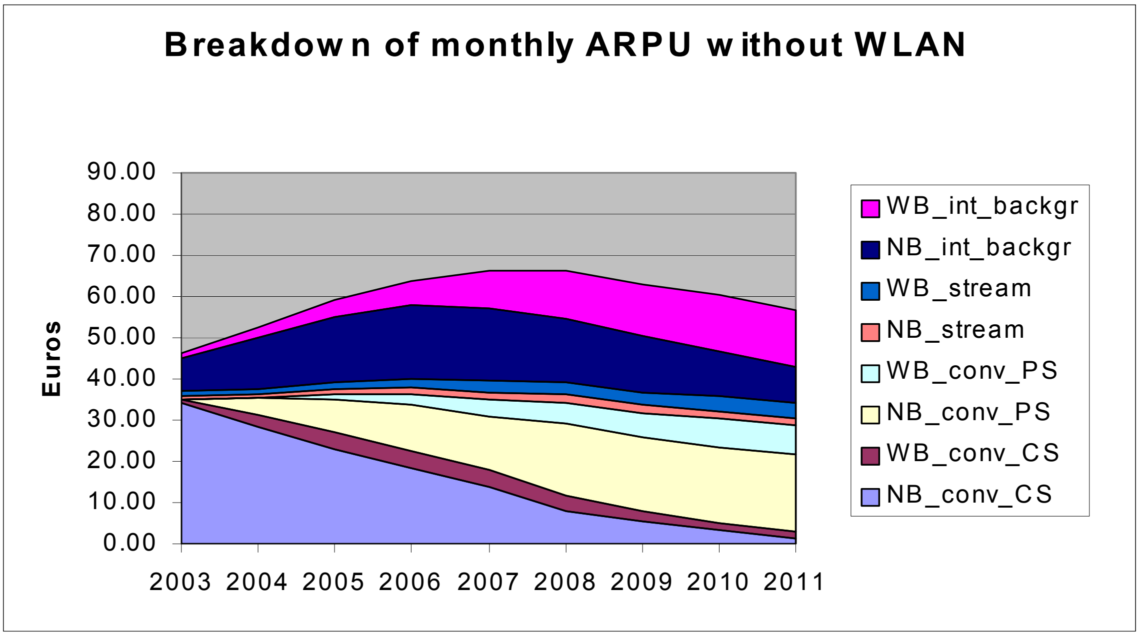



*Figure 32: Breakdown of monthly ARPU without WLAN / UMTS subscribers only*

To figure out the development of the total mobile ARPU, as being the common perception of ARPU measurement, we have to take into account customer bases of all mobile generations (2G, 2.5G and 3G). This is modelled in TONIC as 2G having only usage of CS voice (NB_conv_CS) and 2.5G also narrowband interactive and background packet switched Service classes (NB_int_backgr). The SMS related revenues are included to the NB_conv_CS class in the presentation. The market share of the operator is supposed to be the same in all mobile generations. The generic mobile ARPU development is presented in the Figure 33. It can be noted that the monthly ARPU touches the 50 € level in the years 2008 to 2010, as the UMTS penetration brings new services and usage, but start to reduce after that, because the price erosion starts to outweigh the usage growth per mobile user propelled by UMTS services.

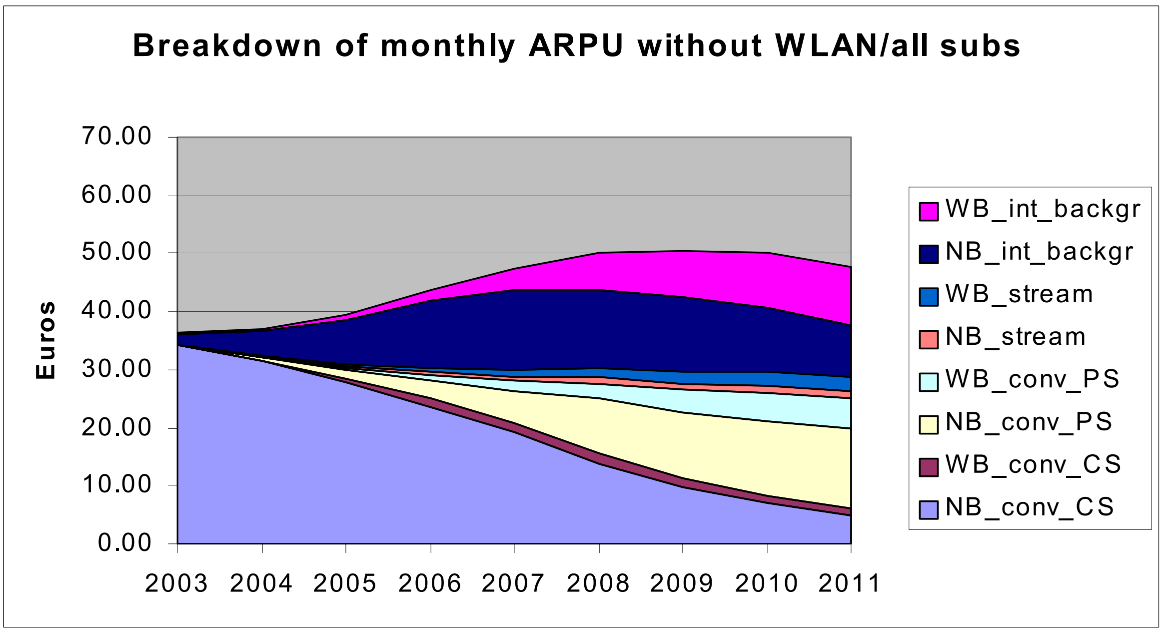


*Figure 33: Breakdown of monthly ARPU without WLAN / all subscribers*

## 10.5.2 Comparison to estimations based on market studies

In the early TONIC period (2001), the market analysts and consultancy ARPU estimations for the UMTS era were showing steep slope of increase at the point where the UMTS brake through was foreseen to take place[9]. After the first UMTS predictions the slowdown of the telecom industry affected the published reports as first to postpone the UMTS brake through and then also to level out the steep growth. The reports reflecting the latest trends suggest even all the time lowering ARPU:

IDATE: Mobile Data Services - Oct. 2002 (Europe only)

- Overall ARPU including data services : from 30 € in 2002 to 35 € in 2007 (data representing 30%).
- Mobile data usage penetration in 2007: UMTS 10 %, GPRS 38%, GSM (SMS) 32 %

OVUM: Global Wireless Market 2002-2006 - July 2002.

- 3G penetration will grow from 3% in 2005 to 27 % in 2007
- ARPU remains flat and stays at 28 € - 7 € of which are data revenues

Yankee Group: European Cellular Forecast -Oct 2001

- Data ARPU grows from 6 € to 13 € in 2006
- Global ARPU reaches 36 € in 2006

Forrester: 3G 's Belated Break-Even - September 2002

- Only 10% of European mobile users will use UMTS in 2007
- Industry wide payback delayed until 2014

**Analysys Research:Western European Mobile Forecasts and Analysis 2002-2007 – Sept.2002**

- Return to the ARPU levels of 2000 (over 37€) is not reached by 2007

In the referred newer studies there have not been put enough attention on the UMTS market separately - as a new business case starting from zero penetration. We see that the ARPU decline trend due to saturation of 2G market cannot be projected to the 3G market, because the decline is much related to the impact of low-end users, not effecting the 3G case for several years. The prevailed downturn in the business seems to be reflecting too much in the reports. As TONIC models the 2G and 3G as separate cases, it can fully take into account their different life-cycle phases indicating clearly different spending patterns.

The TONIC estimations based on total picture of the business cases led to ARPU levels, which we consider realistic against the history of mobile market generations before 3G: Certain percentage of the customers (especially the business segment) are in a position to spend on mobile telecommunications well over 60€ per month and willing to do so, if interesting and useful services are available; these are the first migrates. The low-end users, entering last to the UMTS phase, though have limited spending patterns. Taking both of these

[9] For the early TONIC period market forecasts, see the TONIC Deliverable 2 (Demand models and preliminary forecasts for IP services).

aspects into account, and also the tariff erosion caused by growing competition, we can foresee that

1) the UMTS users ARPU can go considerably high in the middle of the study period, as the UMTS subscribers are still a selected proportion of the users; degrading after that, when the customer base widens towards low-end users
2) the total mobile ARPU cannot grow as high as the previous, but anyhow the UMTS is trailing the general ARPU level up, though the price erosion factor forces the ARPU downwards again in the end of the study period

Based on presented factors we conclude that the TONIC ARPU results, based on thorough business modelling, are not outside the realistic frame of market potential and behaviour.

# 11. RESULTS

## 11.1 Cost structure

### 11.1.1 Time distribution of investments and running costs

The yearly investments and running costs for four basic scenarios are illustrated in Figure 34.

Acronyms meanings are like follows:

- [LC_High_Wye] stands for " Large Country case with High license fee and WLAN"
- [SC_SlowWye] stands for "Small country case with slow roll out and WLAN"
- [[LC_High_Wno] stands for " Large Country case with High license fee and no WLAN"
- [SC_SlowWno] stands for "Small country case with slow roll out and no WLAN"

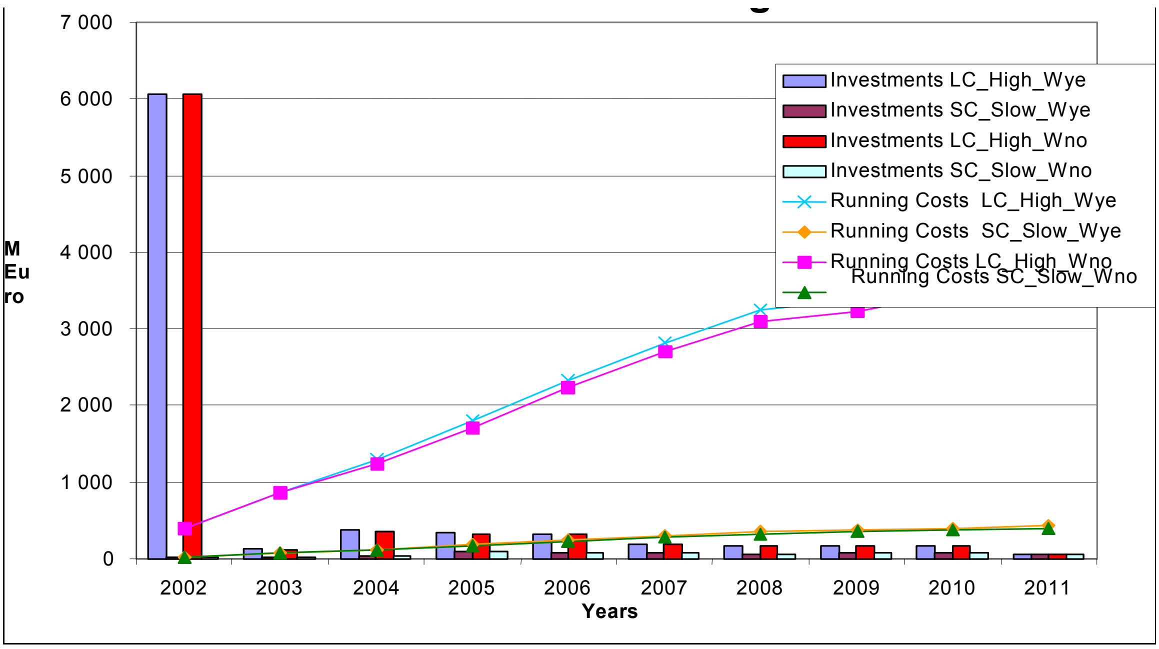



*Figure 34: Non-discounted investments and running costs for basic scenarios (Large Country case with High license fee and WLAN). Early investments in 2002 are dominating in large country case because of the payment of UMTS license fees whose amount is of 6 billion euro under the High assumption.*

### 11.1.2 Large country case

In large country case with WLAN presence, cumulated operating costs are around 23,250 million euros as total cumulated investments are of 7,993 billions euros, including license fees. Cumulated investments equal then roughly 1/3 of cumulated operational costs. WLAN operating costs are representing only 3,5 % of total costs.

UMTS equipments are installed progressively according to license coverage requirements-80 % population covered in 2006- and capacity needs (see next graph Figure 35).

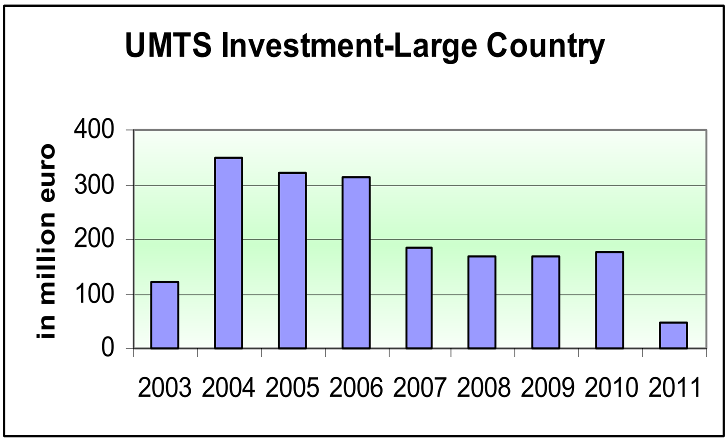



*Figure 35: Large Country - UMTS investment outside license fees*

Figure 36: Total investments excluding license fees reaches 2 billions euro in large country case, while WLAN investments accounts only as 4 % of the whole.
As usual access network costs are dominating, representing almost ¾ of the whole, if we include WLAN since it is considered fully as an access network.

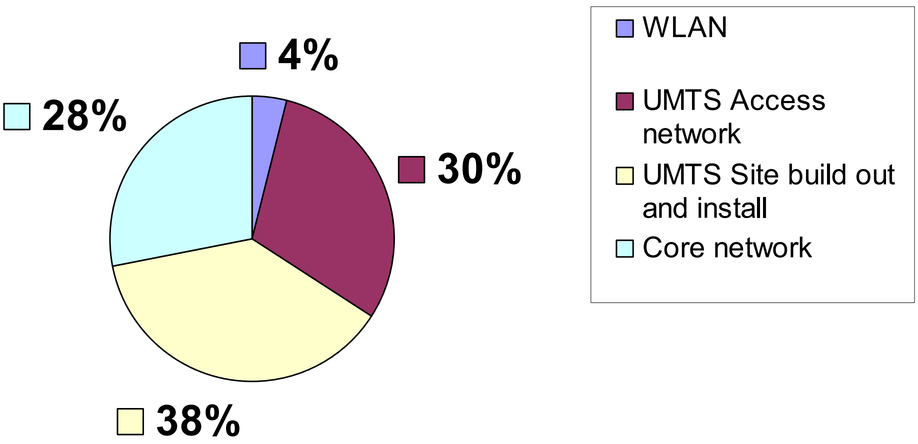



*Figure 36: Cumulated Investment breakdown-Large country case*

Same breakdown is presented in next cake Figure 37 for operational costs of which items have been simplified as follows: Lease Line and Internet Costs, Terminal Subsidies, Employee costs, Marketing, Site Rental and all WLAN costs. Those later have been grouped for having the proportion of additional costs related to WLAN presence. Employee costs are reaching almost half of operational costs because we assume all functions such as maintenance, Customer Relationship Management, IT costs, billing and so on are NOT outsourced like it is the case at various extend in reality.

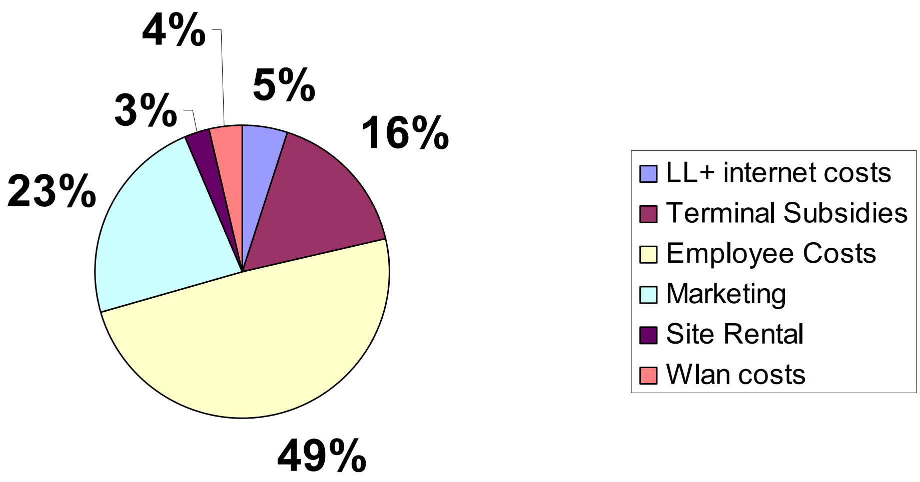



*Figure 37: Operational cost breakdown- Large Country*

Marketing costs are coming in second position because of the necessary strong mass media communication that is needed to impulse new mobile multimedia services. Usually, marketing costs are concentrated on the first years of business plan. TONIC model assumption is that new UMTS network will not have to be publicised for itself when it is launched, but services will have to be continuously advertised. So marketing costs are a function of total inhabitant: 9 euro per year and per inhabitant.

Terminal subsidies have been estimated at a relatively high level, those are coming at the third rank, since no take up can occur when terminal costs are a first barrier that most consumers cannot cross. 300 euro per terminal subvention will then have to be supported by the operator. This amount includes dealer or operator's own points of sales commission.

### 11.1.3 Small country cases

In small country case, we see on graph Figure 38 like in large country case the weak impact of WLAN on investments. Running cost curves are similar, cumulated costs differ only by 4 %.

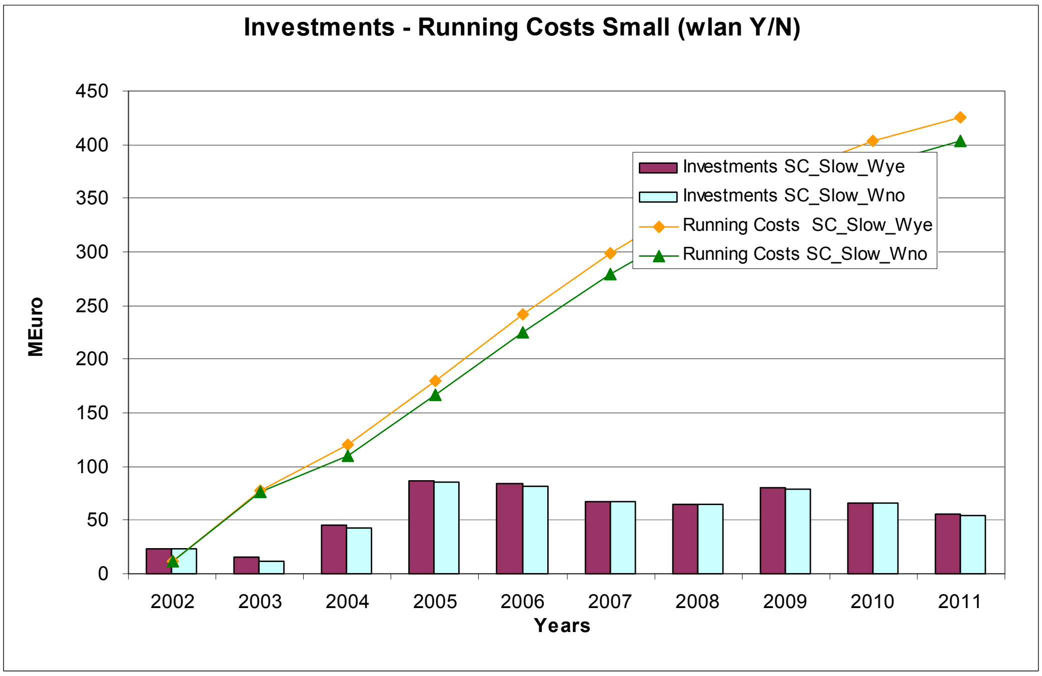



*Figure 38: Investments and Running costs Small Country case WLAN Yes/No*

Same curves and histograms are much more unparallel on next graph Figure 39: one first scenario with a fast roll out meaning that full coverage is achieved in 2004 and a second one with a very progressive rollout. Cumulated investments are cut by 14 % in slow rollout case since this one benefits much more of equipment price erosion. On operational costs side, same slow rollout case has 18 % less cumulated running costs than in fast roll out case.

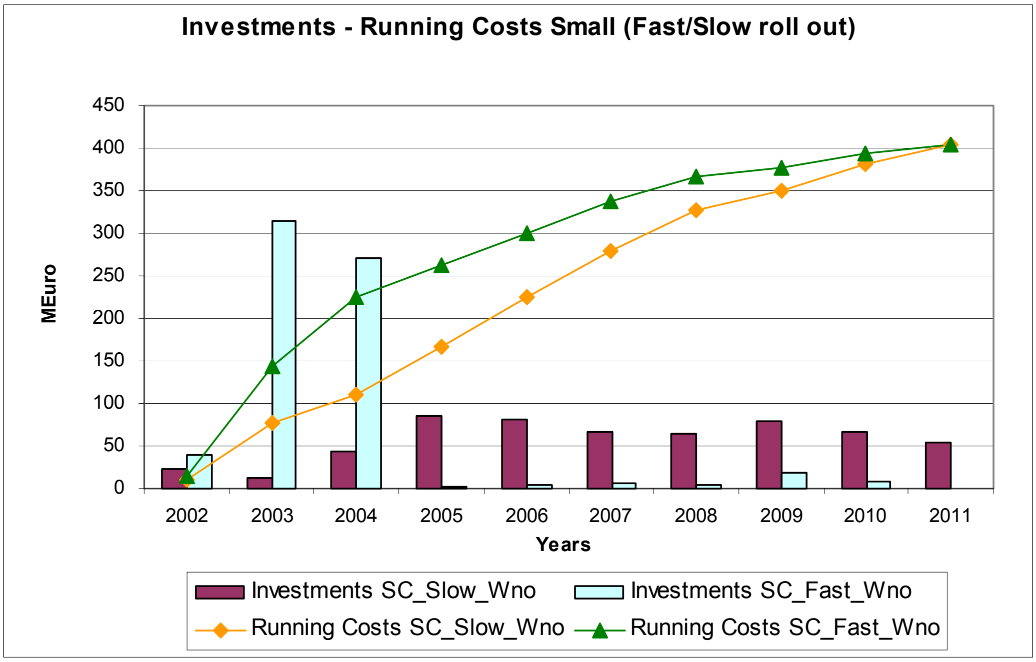



*Figure 39: Investments and Running costs Small Country case-Fast/Slow roll out*

Investment split for Small country case Figure 40 shows that access network and site build out with installation costs represents 91 % of the whole. This result can be explained by the fact typical Nordic countries have less dense areas compared to large country. WLAN accounts only for 1 %.

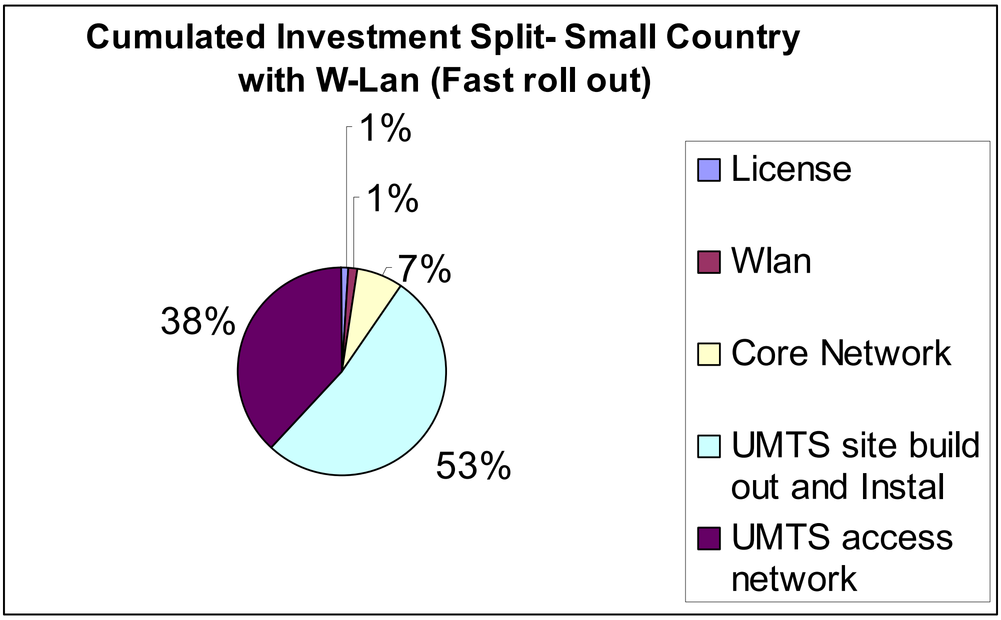



*Figure 40: Cumulated Investment split – Small Country case (fast roll out)*

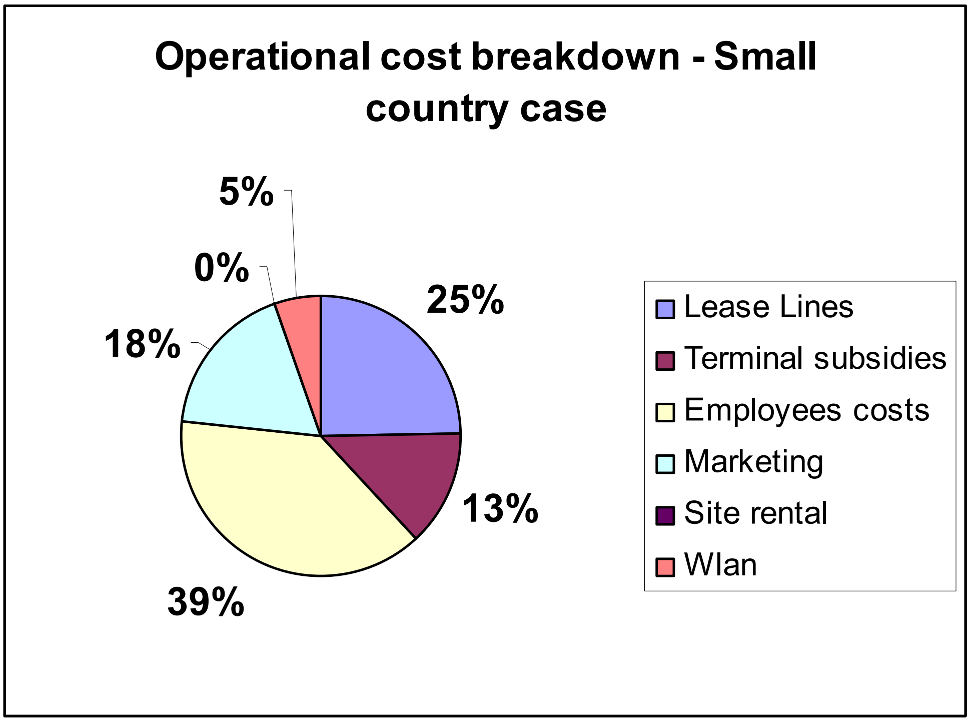



*Figure 41: Operational cost breakdown – Small country case*

Operational cost breakdown for small country case (Figure 41) reflects also differences with large country characteristics: lease lines costs are proportionally higher that in large country because of the higher distance between core and access network. WLAN cumulated operational costs are in same range than in large country case.

## 11.2 Revenue structure

### 11.2.1 Revenue segmentation in large country case

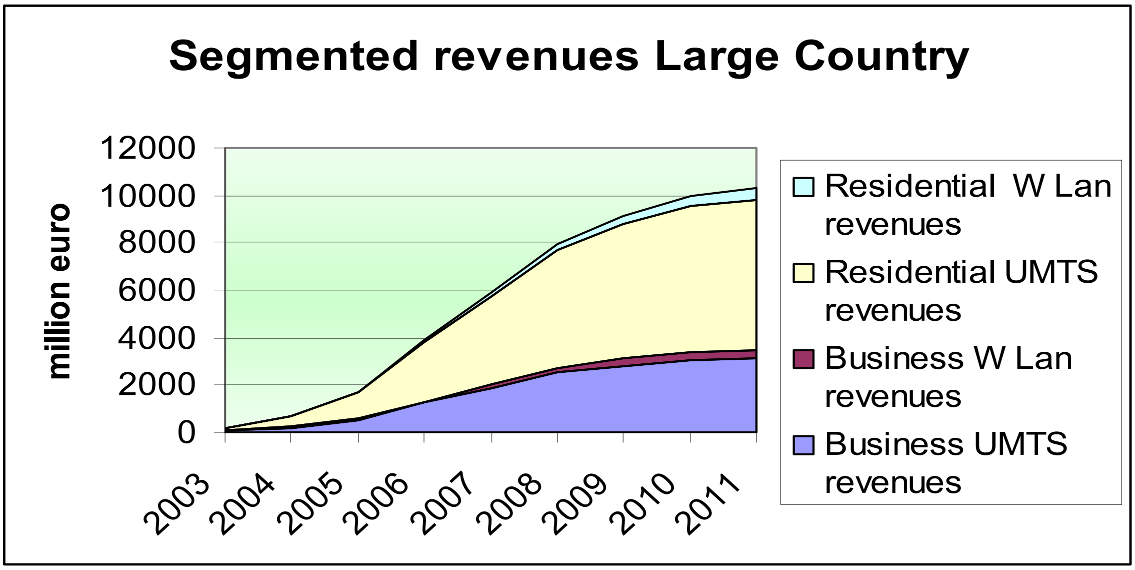



*Figure 42: Revenue segmentation-Large country case*

Figure 42: Revenues streams start on 2003 for UMTS and 2004 for WLAN. WLAN revenues are representing respectively for residential and business segments less than 9 % and 5 %. Those are corresponding to the whole broadband service classes and also a fraction of wideband service classes. Revenue mix between residential and business segment is resulting from volumes of customers in each segment multiplied by the ARPU. As explained in chapter 6.5 "Market segmentation", if business customers are a fraction of only 20 % of the whole customer base on the studied period, their ARPU is much higher (x 5).

### 11.2.2 Revenue segmentation in small country case

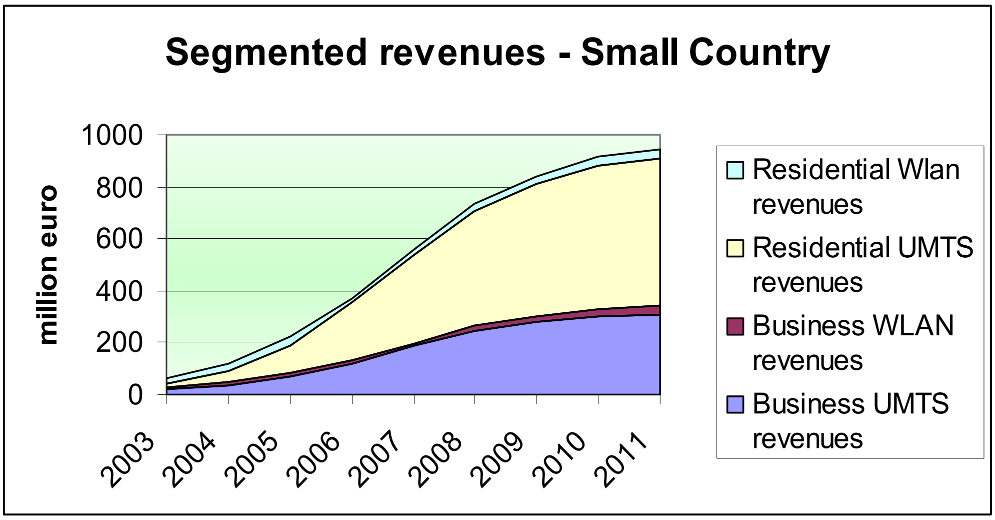



*Figure 43: Revenue segmentation – Small country case*

Figure 43: WLAN revenues are, in small country case, representing respectively for residential and business segments less than 11 % and 8 %.

## 11.3 Economics of basic scenarios

Six basic scenarios have been analysed describing different country and conditions.

These are listed with their acronyms and meanings like follows:

- [LC_High_Wye] stands for " Large Country case with High license fee and WLAN"
- [SC_SlowWye] stands for "Small country case with slow roll out and WLAN"
- [[LC_High_Wno] stands for " Large Country case with High license fee and no WLAN"
- [SC_SlowWno] stands for "Small country case with slow roll out and no WLAN"
- [[LC_Low_Wno] stands for " Large Country case with High license fee and no WLAN
- [SC_Fast_Wno] stands for "Small country case with fast roll out and no WLAN"

Compared cumulative cash flows are shown in next chart. Peak funding of small country cases are not easily visible because of the scale effect. Deepest peak funding on Figure 44 (red and dark blue curves) are related to the large country case with high license.

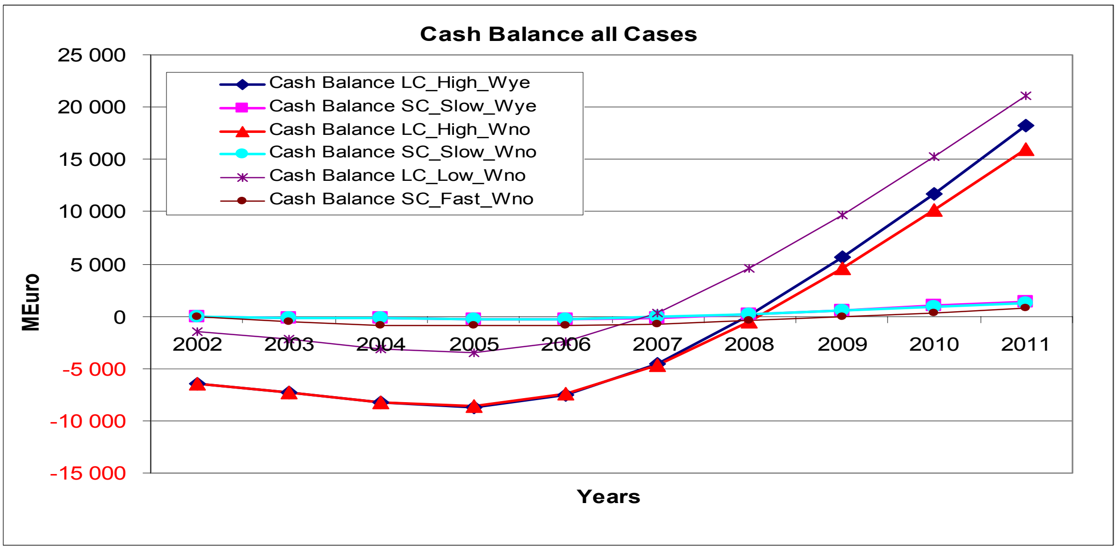



*Figure 44: Compared cash balances of six basic scenarios*

### 11.3.1 Small Country with slow roll-out, without WLAN provisioning

This chart combines cash-balance curve with revenue, investment and operating cost histograms on the whole period.

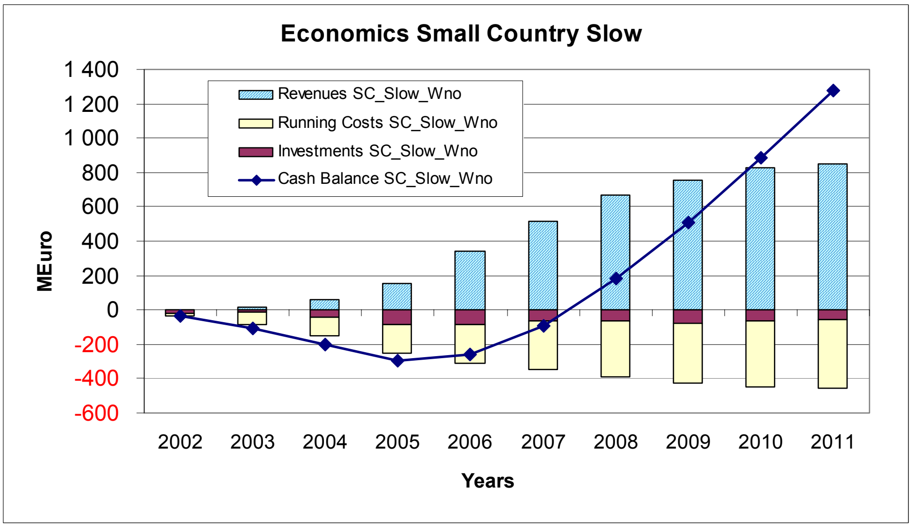



*Figure 45: Economics Small Country Slow*

Figure 45: Cash-balance break-even point is situated near 2007 year's end; peak funding is of 300 million euro. The slow roll out option makes a distribution of investments all over the period.

### 11.3.2 Small Country with slow roll-out, providing WLAN service

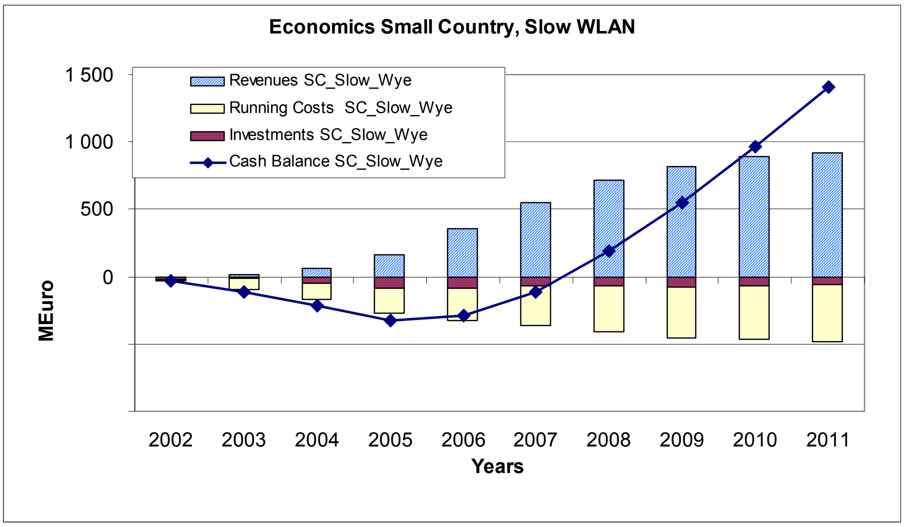



*Figure 46: Economics Small Country with slow roll out providing WLAN services*

Results do not much differ from 12.3.1 since WLAN effect is not sensible on general economics of studied business case.

### 11.3.3 Small Country with fast roll-out

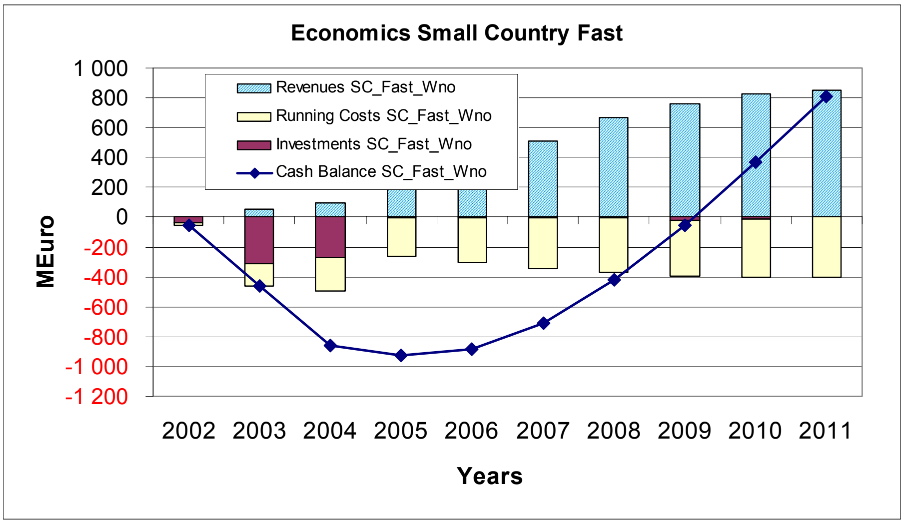



*Figure 47: Small country case with fast roll out without WLAN*

Figure 47: Much more sensible is the roll out effect. If the operator decides or is obliged to fulfil tough license coverage commitments, achieving then within two years a full coverage, we see that peak funding is almost multiplied by 3 and pay back period is lengthened of almost two years.

### 11.3.4 Large Country with high license fee, not providing WLAN service

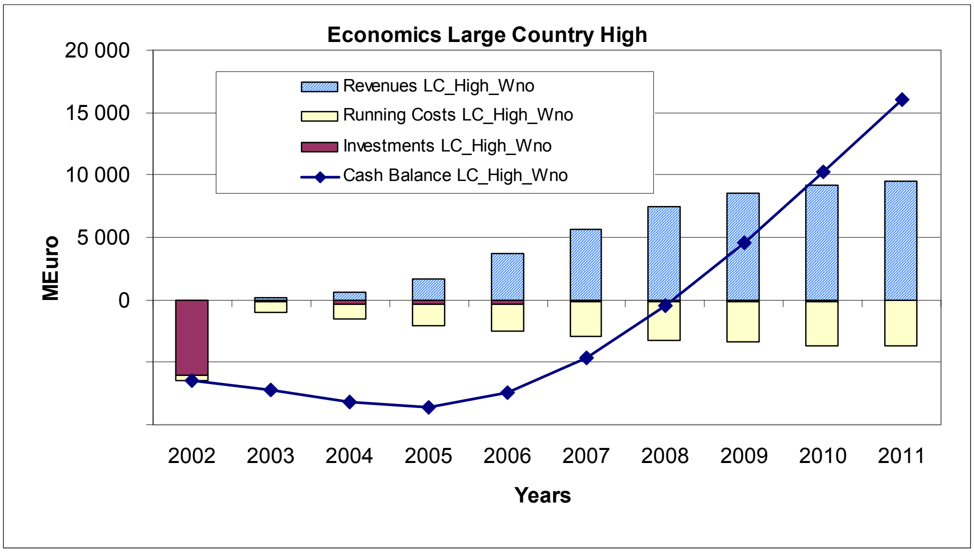



*Figure 48: Large country case with High license fee, not providing WLAN*

Figure 48: Despite the 6 billion euro license burden, this case remains positive and pay back period is of less 7 years.

### 11.3.5 Large Country with high license fee, providing WLAN service

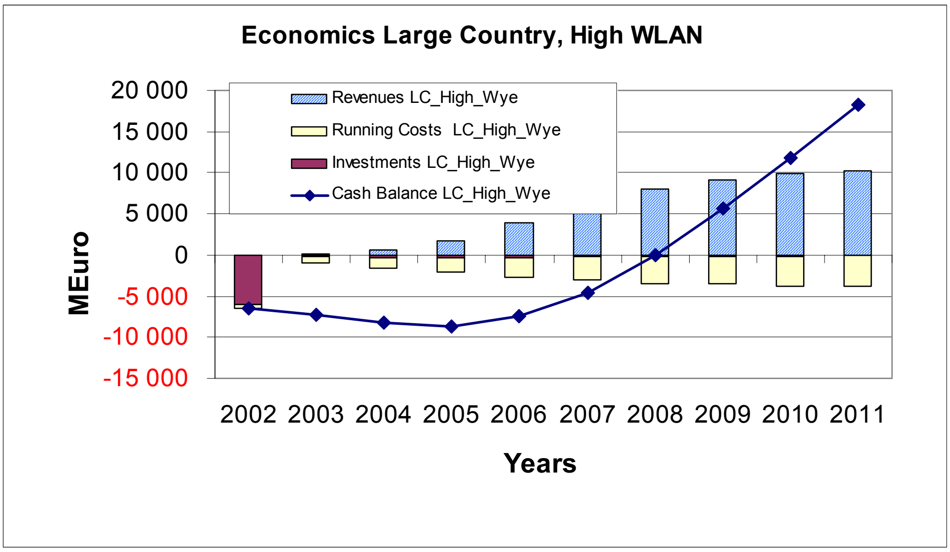



*Figure 49: Large country case with high license fees, providing WLAN*

Figure 49: WLAN presence improves slightly economics in terms of pay back period but we will see in chapter 12.5 that it has an impact on NPV.

### 11.3.6 Large Country with lower license fee

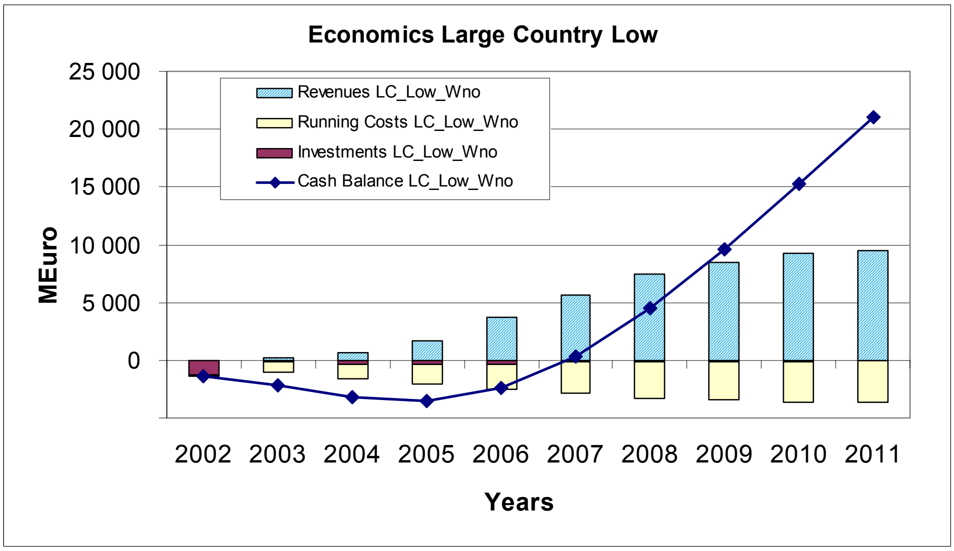



*Figure 50:Large country case with lower license fee, not providing WLAN*

Figure 50: Released from license burden, large country business case is improved. Pay back period is shortened of one year and peak funding divided by two.

## 11.4 Regulatory and license impact

The 3G licensing conditions set by most country regulators ruled that all license winners must build their own networks and they specified a date by which network rollout must be complete and services launched. However, most regulators are relaxing these conditions in order to achieve their key objective of ensuring a competitive 3G market that benefits operators and, more importantly, customers.

The huge cost of 3G has led the majority of operators to begin discussions with their domestic competitors to share networks in order to reduce 3G build out costs (see chapter 9). Fines for delayed network launch dates are also being wavered by regulators. Spanish operators were contracted to launch 3G commercial services by August 2001. In April, the regulator announced that it was moving back the launch date to the fourth quarter of 2002, after it became evident that network build out would not be completed by any operator this year and that 3G handsets would not be available in massive volumes until mid 2003 either.

After excessive spending on 3G licenses, operators are coming to terms with the financial burden they have laden themselves with and are taking positive steps to reduce the overall cost of 3G in other areas. For the most part, regulators are working in harmony with operators to ensure that the financial burden of 3G does not prohibit delivery or take up of services. But governments from UK and Germany both excluded to reconsider or repay part of license fees they cashed arguing it would lead to inextricable legal issues.

Auctions and beauty contest in European countries resulted in very different costs of license. These are list in next table. In most countries, licenses were paid in one off payment just after operators have been selected or won thee auctions, other countries have combined this with annual payments. Exception is Sweden, where fees are entirely based on revenues.

License duration is generally of 15 years as our studied period spreads over 10 years. This means one third of license costs is not counter balanced by revenues raised during the five last years that are out of the business plan.

*Table 27: Average 3G Licence Cost in different countries*
*(Source: Mc Kinsey Report to European Commission-June 2002)*

| | Average 3G License price per Unit (million euro) | | Average 3G License price per Unit (million euro) |
|---|---|---|---|
| Austria | 139 | Italy | 2 433 |
| Belgium | 188 | Luxemburg | 14 |
| Denmark | 133 | Netherlands | 544 |
| Finland | 25 | Portugal | 100 |
| France | 620 | Spain | 863 |
| Germany | 8 350 | Sweden | % revenues |
| Greece | 162 | UK | 7 220 |
| Ireland | 83 | | |

In the five larger European countries, i.e. France-Germany-Italy-Spain –UK, average license fee is of 4 billion euro. This average is of 85 million euro for small country.

We retained in TONIC model for large country case a license cost of 6 billion euro, so a bit under the extreme license costs in UK and Germany and for small country 6 million euro, this amount being more related to the situation of Nordic countries.

## 11.5 WLAN impact

### 11.5.1 WLAN is of interest when combined with mobile services

The WLAN initial demand was for wireless local networks for offices, hospitals, university campuses and similar closed environments but, more recently, the major drive has been for public access WLAN networks.

A number of major operators have announced plans to deploy WLAN access networks in areas of high user demand such as airports, railway stations, convention centres, hotels and cafes. There has been much concern expressed that the rise of public access WLANs will impact on 3G by cannibalising potential 3G revenues. After carrying out a number of studies, it has been concluded that this view is wrong and that 3G and WLAN are essentially complementary within a total mobile data services port-folio. However, there continue to be reservations and a further examination of the WLAN/3G issue has been undertaken, now looking at the business value of WLANs for public 3G operators.

Thus, WLAN impacts on only one service category of 3G service provision, namely Mobile Intranet/Extranet Access. This category is specifically defined as being for workers on the move who have a need to access corporate intranets and the Internet remotely. Such workers are likely also to be the main users of public WLAN services. By combining a public WLAN service with their 3G service, operators will be able to offer a seamless mobile data communications solution for the business user.

Public WLAN gives operators the opportunity to expand both overall market size and competitive position for data services. Public WLAN service could also provide competitive differentiation for 3G operators. Public WLAN services lack a number of essential elements which can be provided by a mobile operator. These elements include: an existing billing mechanism which can easily accommodate WLAN; user authentication and fraud control mechanisms; roaming; and customer care. Previous attempts to launch public WLAN services, notably in the USA, have failed because of the stand-alone nature of the WLAN technology. Public WLAN services make a natural extension to the services offered by a mobile operator.

Although it represents a small percentage of total 3G revenues, the Mobile Intranet sector is significant as it is a primary service offering for the corporate sector. According to the UMTS Forum's forecasts, over the next three years, the number of business users of public WLAN services will rise to 20 million. Of these, some 5.3 million are likely to use WLAN to access services that are also supported by 3G… in other words they will be both WLAN and 3G users. The 20.5 million users are expected to generate $2.8 billion in service revenues by 2005, making a combined 3G/WLAN market opportunity of $12 billion.

Also, there is a risk for 3G operators who do not choose to participate in the WLAN market. While WLAN services will not be substitutes for 3G services, they can become an additional source of competitive differentiation. There are already strong indications that vendors and operators are recognising the key advantages that offering a combined WLAN/mobile service can offer. In Austria, mobile operator One has integrated WLAN with its GSM network, to deliver a service targeted at skiers seeking information on snow conditions. Swedish vendor Ericsson has recently signed a contract with Danish GSM operator TDC to integrate WLAN access points into the latter's GSM network. Meanwhile, other operators starting to roll out

WLAN access include T-Mobile and Telia. As operators evolve to 3G, combining WLAN with their mobile voice and data offering will become ever more important.

### 11.5.2 WLAN impact in TONIC results

WLAN services combined with UMTS are slightly adding value to UMTS business case in our TONIC simulation as shown in next graph describing large country case:

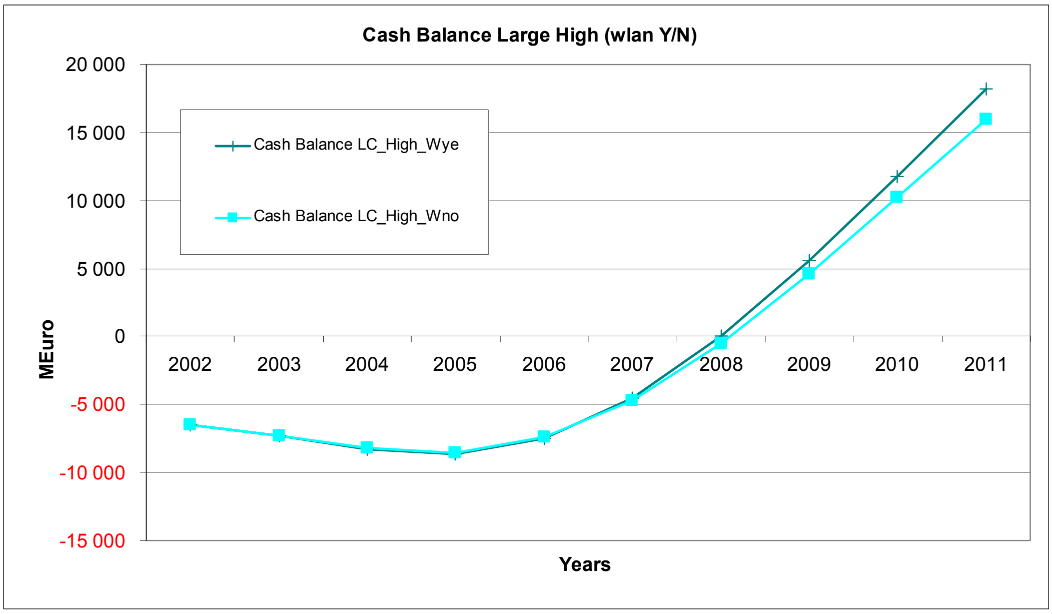



*Figure 51: Cash Balance Large Country, High License fees, With or without WLAN presence*

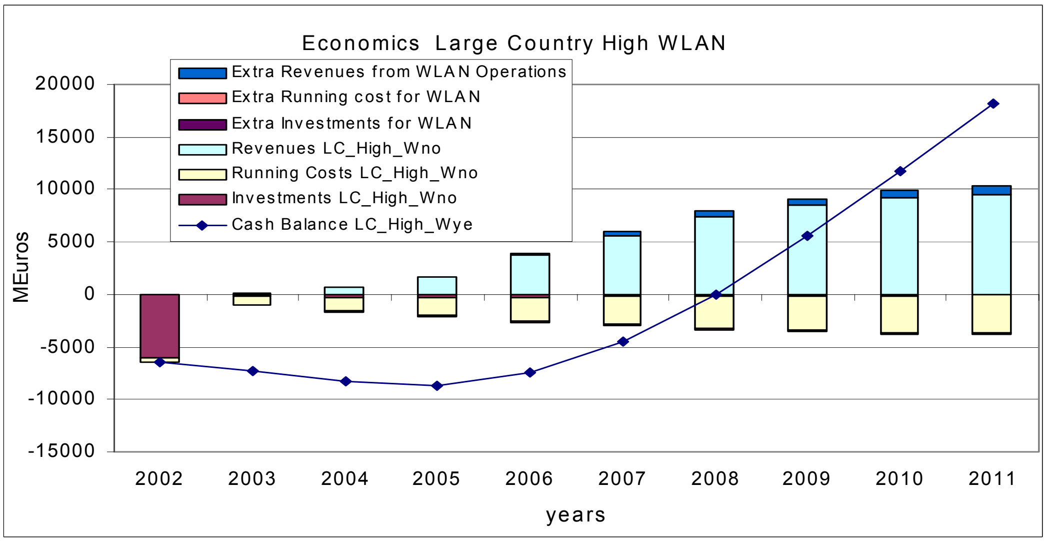



*Figure 52: Impact of WLAN presence in Large country case*

Key TONIC assumption is that WLAN usage will boost UMTS multimedia usage by 8 % while cannibalisation effect is of 6 %. We thus consider that the later are in analyst literature largely overstated as indicated in previous chapter. This synergy is illustrated on the two next charts (Figure 53 and Figure 54).

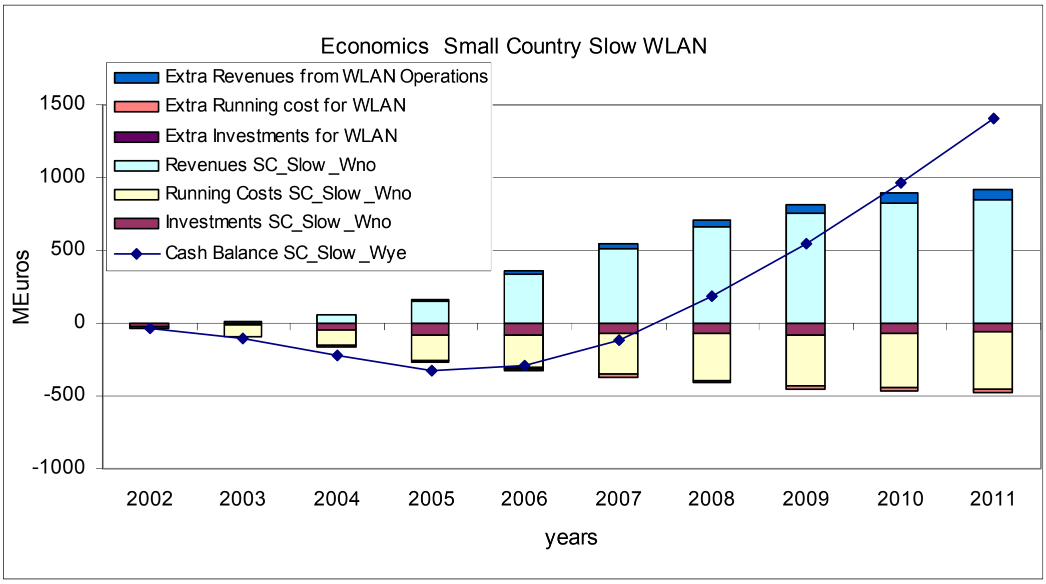



*Figure 53: Impact of WLAN presence in Small country case*

Additional investment is of 1 % while 6 % of total revenues are generated from WLAN services and additional operational costs are limited to 4 %.

Same statement on small country case has less favourable figures: Additional investment is of 2 % while 6 % of total revenues are generated from WLAN services and additional operational costs are limited to 5 %.

WLAN impact on profitability is resumed in next table with NPV and IRR numbers:

*Table 28: WLAN impact on profitability*

| Scenarios | NPV (M€) | IRR | PayBP |
|---|---|---|---|
| 1 Small Country with slow roll-out, without WLAN provisioning | 635 | 39% | 6,3 |
| 2 Small Country with slow roll-out, providing WLAN service | 690 | 39% | 6,4 |
| 4 Large Country with high license fee, not providing WLAN service | 5 639 | 19% | 7,1 |
| 5 Large Country with high license fee, providing WLAN service | 6 703 | 20% | 7,0 |

WLAN positive impact is more sensitive in large country case than in small country case in terms of NPV and IRR because we have in small country case proportionally more investment, i.e. more hot spots to install as compared to the number of users.

## 11.6 Impact of taxation

All cash flows in studied business cases were calculated before taxation of profits. One reason for this approach is that percentages of tax on profit are still very different among European countries, so a standard percentage is not easy to determine. One other reason is that in many cases mobile activities are only part of activities of an incumbent operator. Under this condition, profits and losses are consolidated at the group level. However, since all business cases are positive in this study and then are generating potential taxable profits, it is necessary to analyse the impact of taxation.

TONIC model calculated tax on profits with the general common legal rule among European countries allowing that losses are deductible during five years. Tax rate on taxable income that equals to yearly profit is of 30 %.

Impact on NPV and IRR for large country case [high license fee with WLAN] and small country case [low roll out with WLAN] - is resumed in table below:

*Table 29: Impact of Taxation on profitability*

| ***Large Country*** | No Taxation | Taxation |
|---|---|---|
| Net Present Value (M euro) | 6 703 | 3 529 |
| Internal Rate of Return | 20 % | 16 % |

| ***Small Country*** | No Taxation | Taxation |
|---|---|---|
| Net Present Value | 690 | 447 |
| Internal Rate of Return | 39 % | 31 % |

Taxation is very significant especially in terms of NPV: it almost halves NPV results in large country case. Actually, only part of all cumulated losses is effectively deduced from the first year tax bill: around 2 billion euro losses are deducted as total losses account for 3 billion. This happens because of the limit of 5 years for deducing losses.

## 11.7 MVNO impact to a MNO (UMTS) Operator

This part of the study is based on the assumption that the **UMTS operator (without WLAN operation)** will serve a MVNO (Mobile Virtual Network Operator) operator through its network. The MNO operator will have additional cost for operating more customers but the benefit will come from the interconnection cost that the MVNO operator will pay in order to use the UMTS network.

The adoption of the appropriate price for the interconnection price between MVNO and MNO has been based on data from operators and reports. As the base value has been selected a price of 2 Euros per Mbyte during the busy hour and 0.5 euros per Mbyte for the traffic occurs outside the busy hours. But since such a value is only based on current situation in the 2,5G market, sensitivity analysis has been carried out for the improvement of the assumptions in deliverable 9. The situation where the interconnection cost is 3 Euro (50% increase) yield to negative NPV and non-acceptable IRR and payback period for the MVNO case. This could be the turning point for this business case and the MVNO must have hard negotiation with the MNO in order to keep the interconnection costs as low as possible. In the other hand the regulators should protect the new companies and ensure that the interconnection price level will boost the overall competition. In this study, we present that the overall interconnection price (2 Euro) yields to a good profit for the MNO operator.

More details about the technical infrastructure as well as the network implementation of a MVNO operator could be found in deliverable 9.

The modelling focuses on two area scenarios: a large European country characterised by Germany and France, for example, and a small European country exemplified by Scandinavian countries Norway and Finland.

Furthermore, the MVNO business profile that has been selected for this study is the **operator-like MVNO**. The MVNO could be a telecom operator or a infrastructure owner (e.g. power company) without a mobile license but well known as an operator aiming to complement/expand other services such as fixed broadband services (B2-Sweden, Kingston-UK, One.Tel-Netherlands, etc.). This is the **Operator-like MVNO** business profile.

The MVNO network will start offering services in 2004 and the profits of MNO network increase from that year and after. The main economic results for the two basic scenarios are illustrated below in next table. These results show that companies aiming to operating UMTS services can be benefited from an acceptable NPV and IRR figures when they operating an additional MVNO network as well.

*Table 30: Summary of the basic results (MVNO impact to MNO). (LC= Large country, High=High licenses fees, Wno=without WLAN, Impact=with a MVNO)*

| Country type | Large | | Small | |
|---|---|---|---|---|
| | LC High Impact | LC High Wno | SC Slow Impact | SC Slow Wno |
| NPV (MEuros) | 9,825 | 5,639 | 1,278 | 635 |
| IRR | 23.4% | 18.8% | 53.2% | 38.6% |
| Rest Value (MEuros) | 3,606 | 3,479 | 255 | 239 |
| Pay-back period | 6.8 | 7.1 | 6.0 | 6.3 |
| Investments (MEuros) | 7,432 | 7,308 | 381 | 363 |
| Running costs (MEuros) | 23,007 | 22,561 | 2,396 | 2,329 |
| Revenues (MEuros) | 55,682 | 46,475 | 5,602 | 4,182 |
| Revenues-Running | 32,675 | 23,914 | 3,206 | 1,853 |

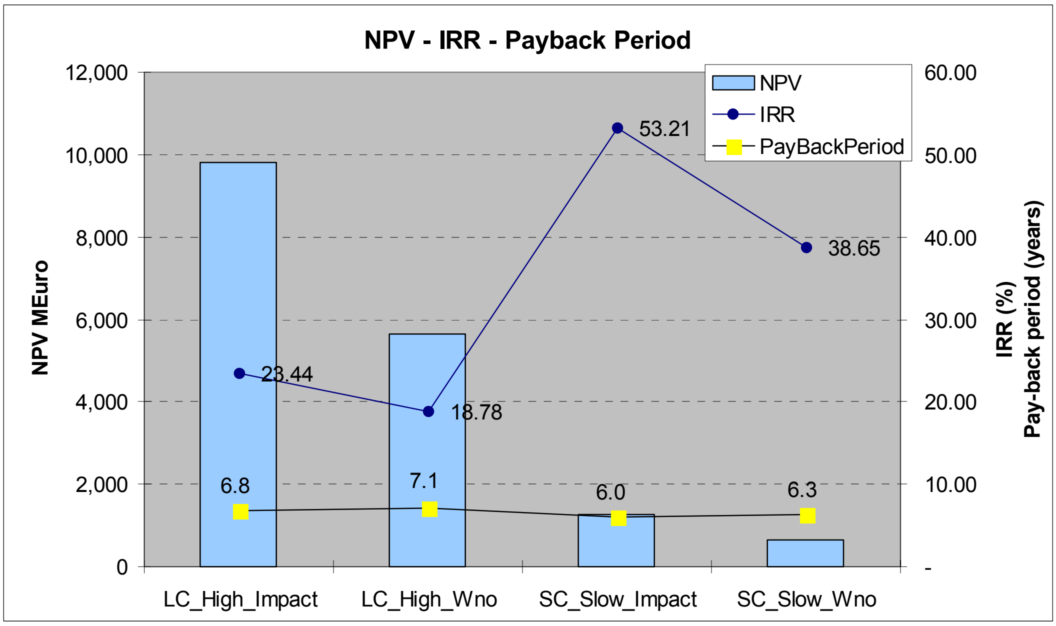



*Figure 54: Basic financial Indexes for all cases.*

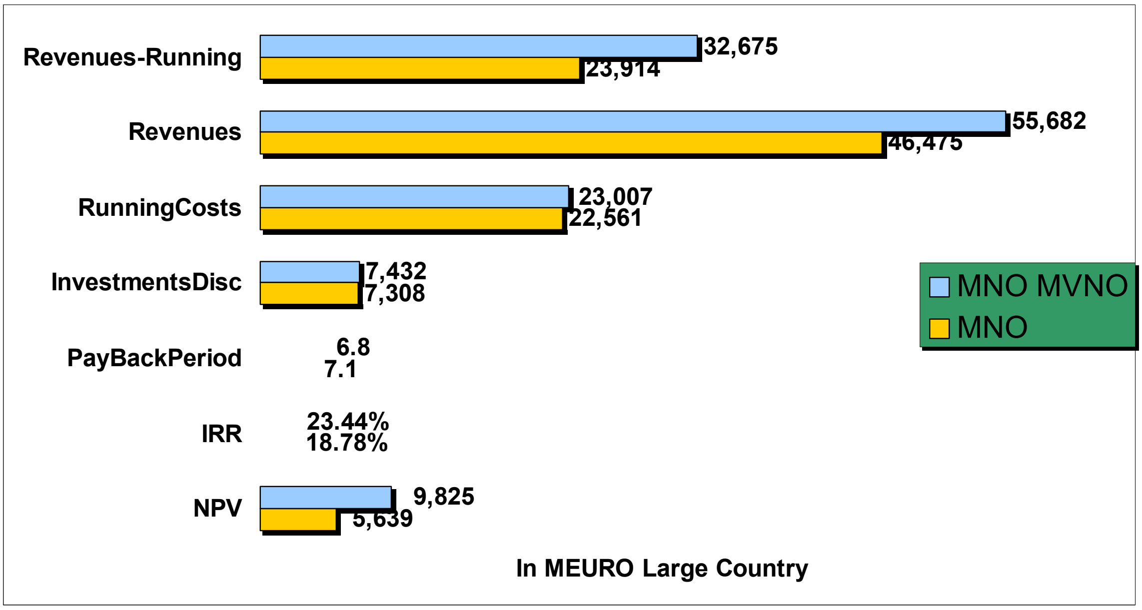



*Figure 55: Basic financials Large country*

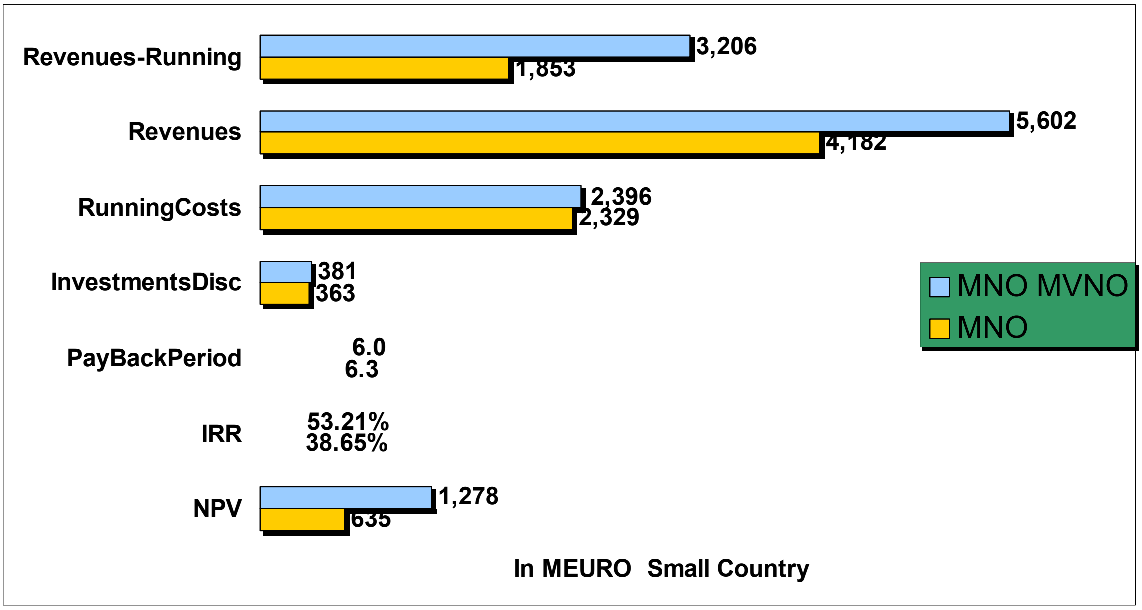



*Figure 56: Basic financial Indexes for a Small Country.*

Figure 57 and Figure 58 illustrate the investments, running costs, revenues and non-discounted cash balance for each combination of scenarios and profiles studied. Note that the Y-axis scales differ considerably between the two country types.

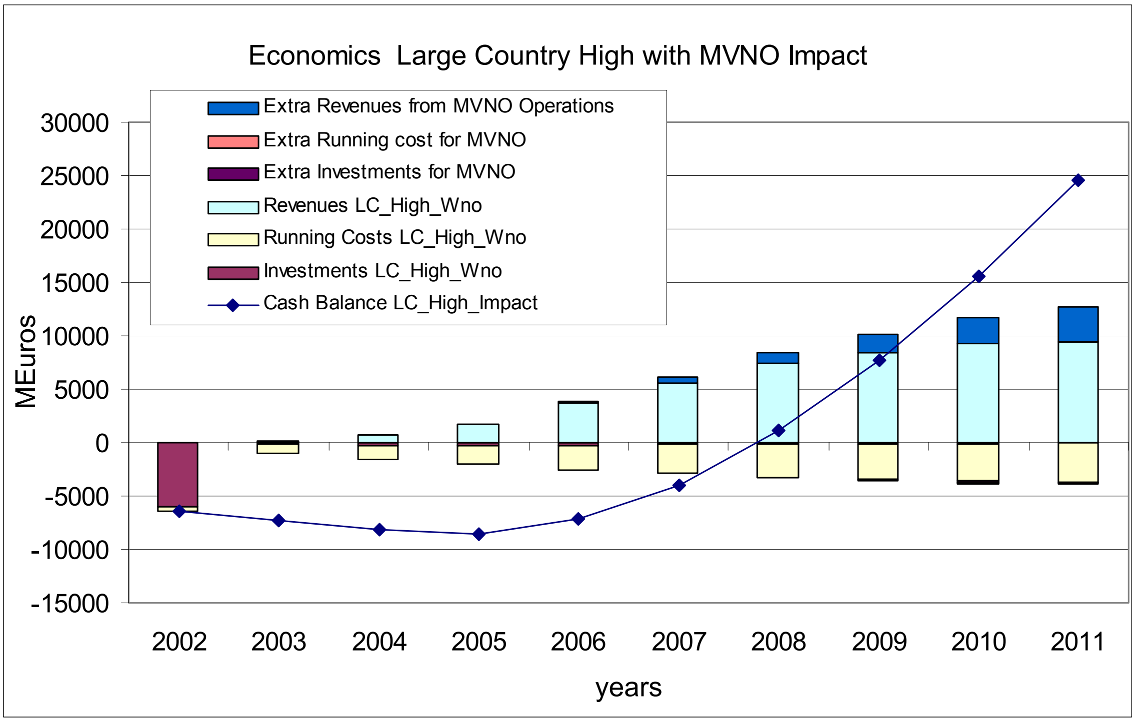



*Figure 57: Cash flow curves under nominal assumptions in large country for UMTS operator without WLAN and an operator-like MVNO (LC= Large country, High=High licenses fees, Wno=without WLAN, Impact=with a MVNO).*

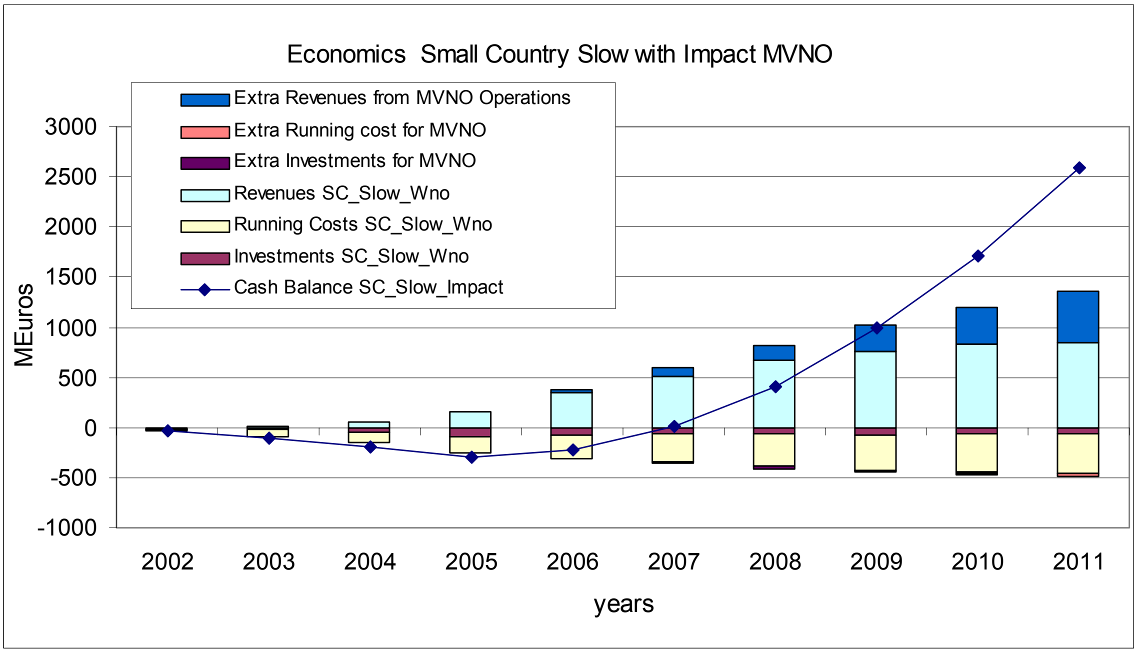



*Figure 58: Cash flow curves under nominal assumptions in Small country for UMTS operator without WLAN and an operator-like MVNO (LC= Large country, High=High licenses fees, Wno=without WLAN, Impact=with a MVNO, Slow=Slow implementation of UMTS ).*

Looking from Figure 54 to Figure 57, it can be observed that the revenues stream (for the MNO) from the MVNO operation is much more than the required investment and operation cost. The logical explanation for this is that the Operators are going to build UMTS networks that can serve more than the expected customers due to regulation implications. This obligation is based on the necessity to offer coverage and therefore to buy equipment that is not fully utilised.

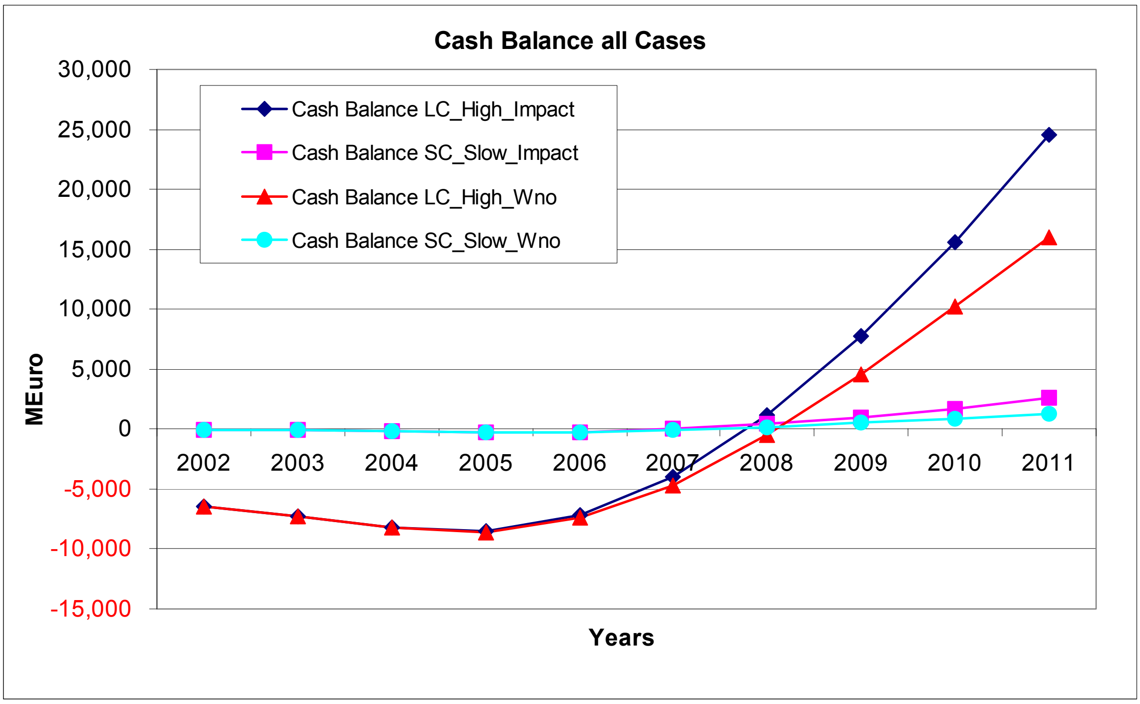



*Figure 59: Cash balance curves for all cases (LC= Large country, High=High licenses fees, Wno=without WLAN, Impact=with a MVNO, Slow=Slow implementation of UMTS )*

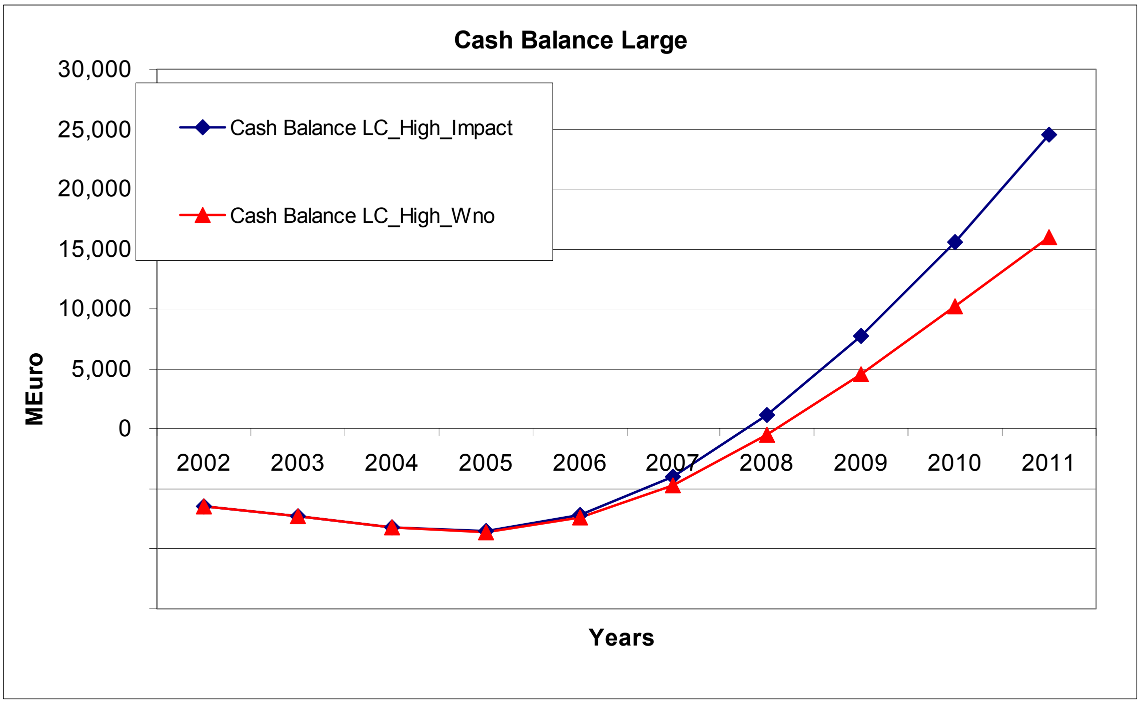



*Figure 60: Cash balance curves in a Large Country (LC= Large country, High=High licenses fees, Wno=without WLAN, Impact=with a MVNO, Slow=Slow implementation of UMTS).*

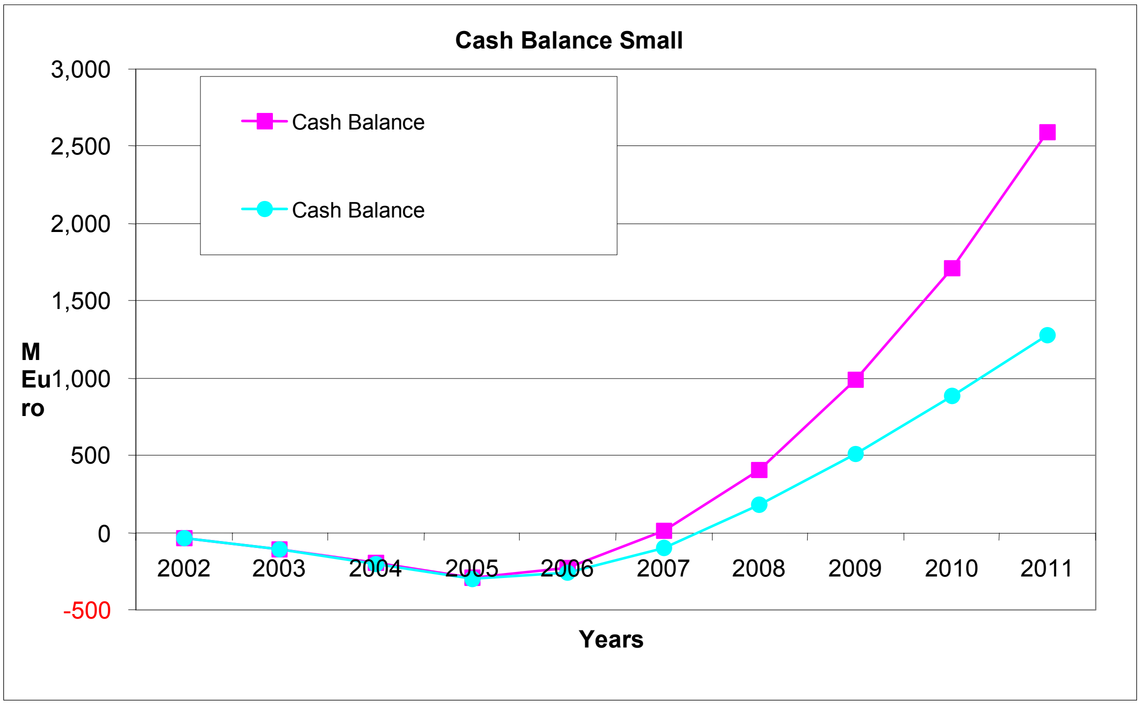



*Figure 61: Cash balance curves in a Small Country(LC= Large country, High=High licenses fees, Wno=without WLAN, Impact=with a MVNO, Slow=Slow implementation of UMTS)*

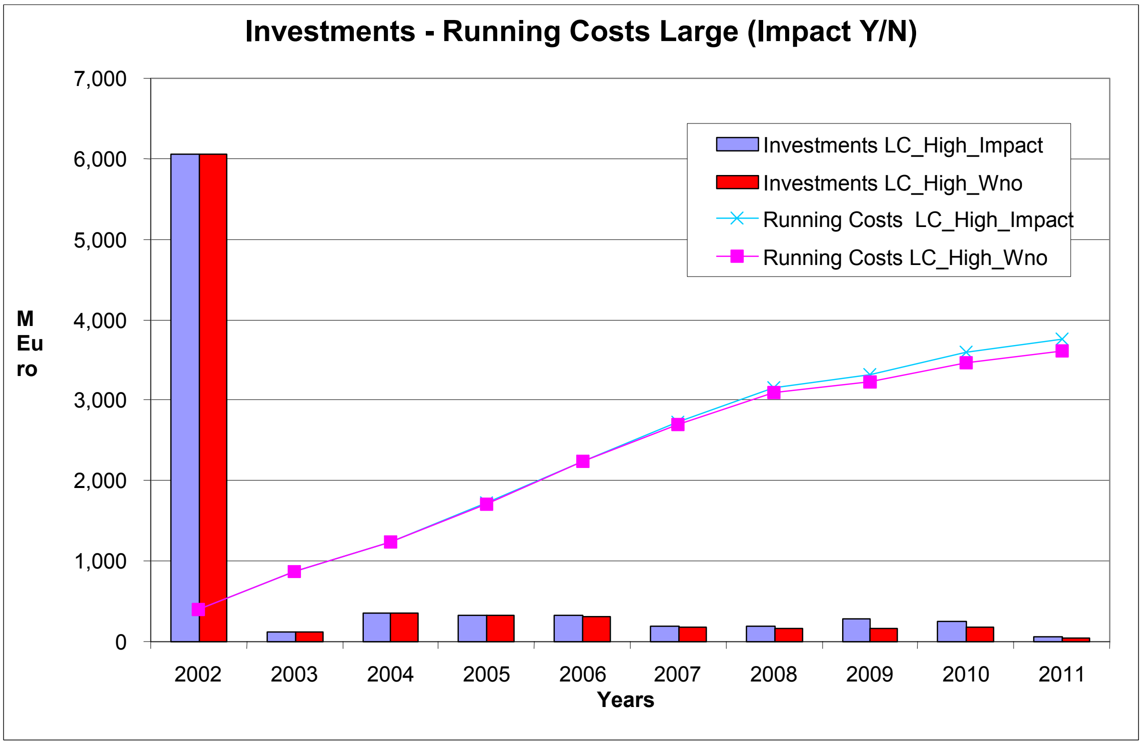



*Figure 62: Investments and running costs in a Large Country (LC= Large country, High=High licenses fees, Wno=without WLAN, Impact=with a MVNO, Slow=Slow implementation of UMTS).*

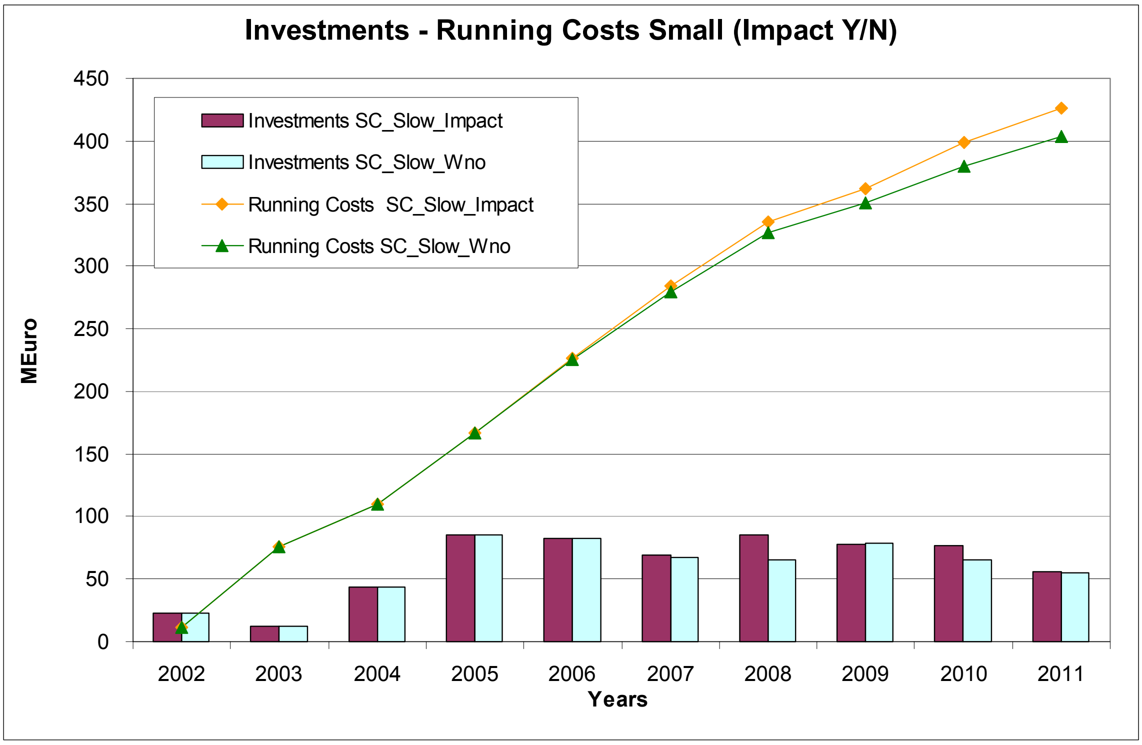



*Figure 63: Investments and running costs in a Small Country (LC= Large country, High=High licenses fees, Wno=without WLAN, Impact=with a MVNO, Slow=Slow implementation of UMTS).*

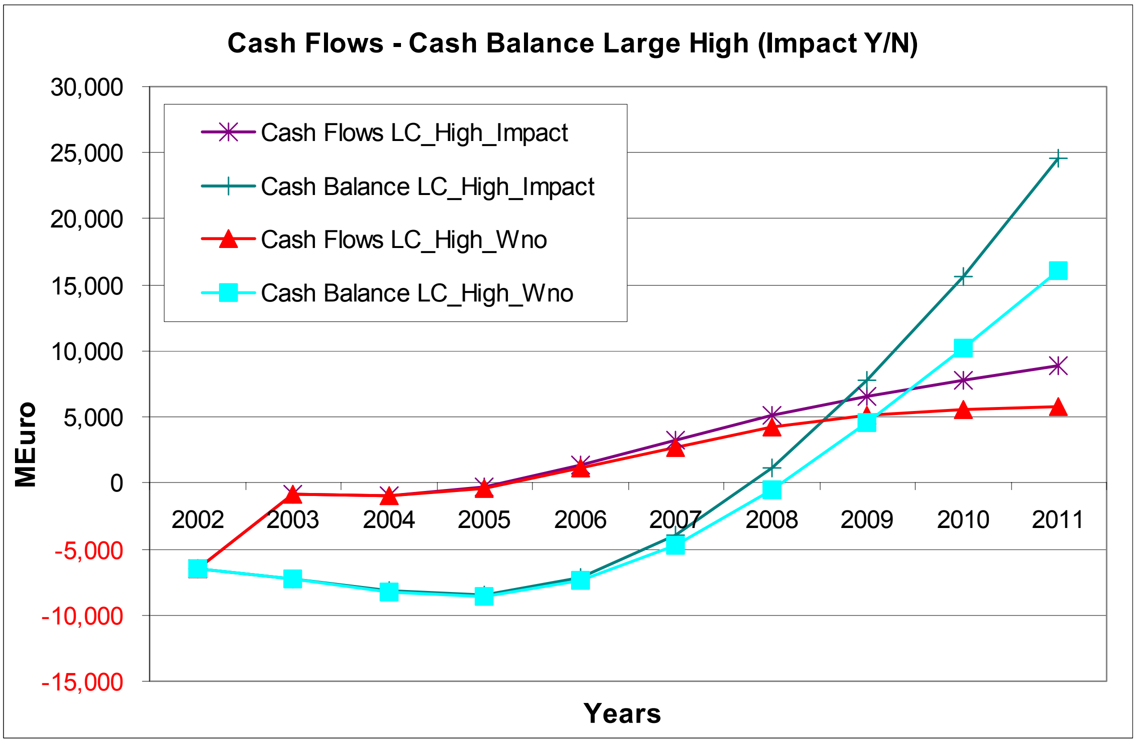



*Figure 64: Cash balance and cash flows for in a Large Country (LC= Large country, High=High licenses fees, Wno=without WLAN, Impact=with a MVNO, Slow=Slow implementation of UMTS)*

In addition in our case the MNO's market share remains 30%. It is logical to assume that MVNO will gain some customers from its MNO operator. We calculate the impact of MVNO if 5% of MNO potential customers in a large country will be MVNO customers in the future. So in this case a part of the MVNO customers came from the potential MNO share. Of course the MNO will select the MVNO, and will make special agreements, so that as many as possible of the MVNO customers are out of the competitors share and not from its own potential customers but this case should be investigate since the 3G battle will take place in a competitive environment (see next figure). This market share's losses influent positive the running cost since fewer customers must be served via this network. Furthermore the revenues and NPV values are greater than in the basic case (without MVNO) due to the interconnection cost.

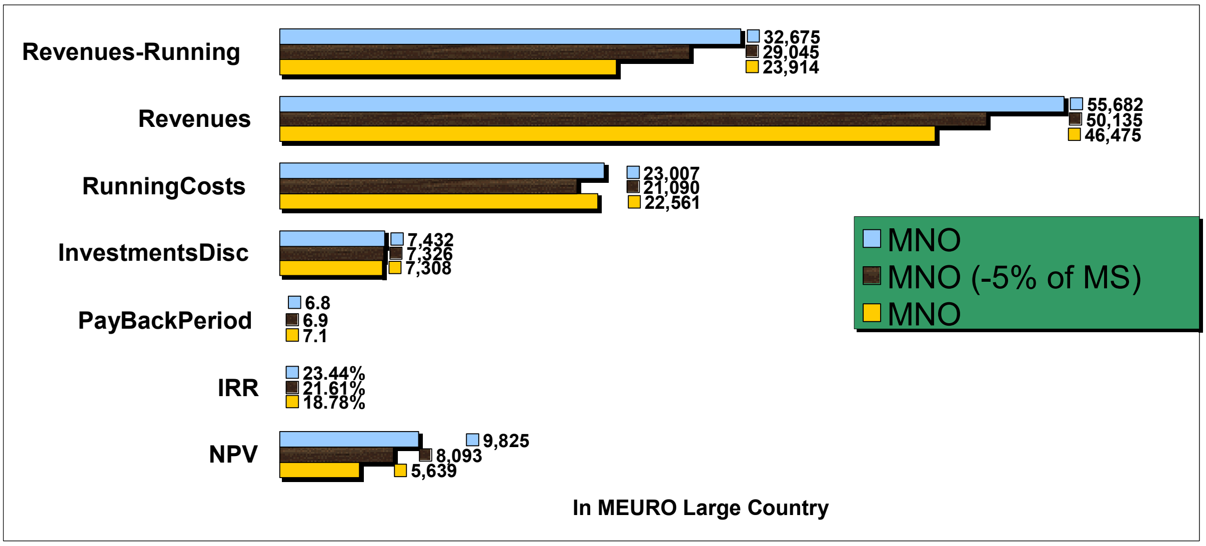



*Figure 65: Basic financial Indexes for a large Country (including impact on MNO Market Share).*

In conclusions, MVNO has a positive impact to MNO even if takes market share from his own customers. MNOs have many benefits from their "marriage" with MVNOs and can overcome any strict coverage obligations or even pessimistic market forecasts.

## 11.8 MVNO as a WLAN operator

This study illustrates the benefits of a operator-like MVNO from operating a WLAN network. High interconnection costs limit MVNO from offering of additional broadband services. An option is the implementation of its own WLAN network in hot spots rather than paying the MNO for operating its customers. In this scenario, an Operator-like MVNO & WLAN operator has been studied both in a Large and small European country.

The main economic results for the four basic scenarios are illustrated next page. Results show that companies aiming to operating WLAN services as MVNO operators can be benefited from more-than-acceptable NPV and IRR figures. In more detail, operators investing in MVNO rollout benefit from more or less the same payback period and rather interesting economic figures. The WLAN MVNOs are benefited from larger revenues stream since the WLAN operation will act as additional service for its existing customers. This occurs due to better usage patterns of their customers and associated consumption and they have to pay only some small additional investments. The WLAN operation could be the logical step for a MVNO since the investments are minimal and the additional potential revenues are in the scale of Meuros. In the large country the NPV is almost 3 times more than in the basic case (without WLAN) and in the small 30% greater. This occurs due to the greater number of potential customers that an operator can serve in a large country.

*Table 31: Summary of the basic results.*

| Country type | Large | | Small | |
|---|---|---|---|---|
| | OL | OL WLAN | OL | OL WLAN |
| NPV (MEuros) | 111 | 328 | 259 | 322 |
| IRR | 11.68% | 14.18% | 39.77% | 38.22% |
| Rest Value (MEuros) | 48 | 116 | 5 | 139 |
| Pay-back period | 8.2 | 8.1 | 5.0 | 5.7 |
| Investments | 144 | 194 | 55 | 141 |
| Running Cost | 23,070 | 24,042 | 3,080 | 3,092 |
| Revenues | 25,192 | 27,035 | 3,950 | 4,241 |
| Revenues-Running | 2,122 | 2,993 | 870 | 1,148 |

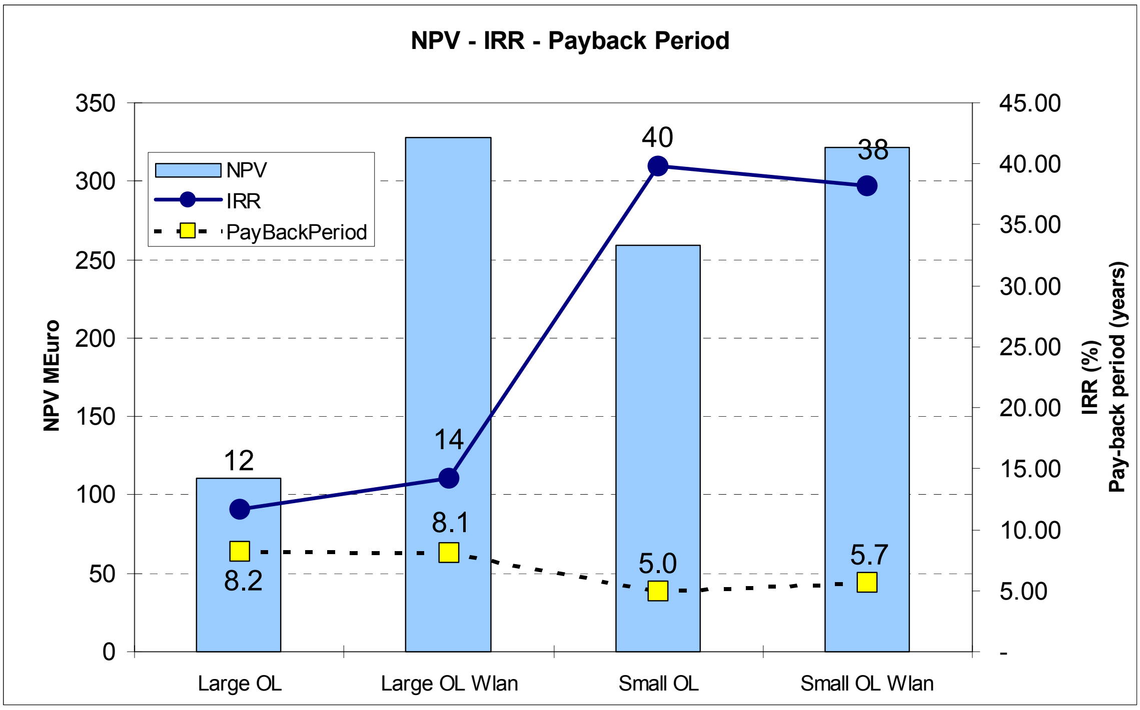



*Figure 66: Basic financial Indexes for all cases (OL=Operator-like).*

Following figures illustrate the investments, running costs, revenues and non-discounted cash balance for each combination of scenarios and profiles studied. Note that the Y-axis scales differ considerably between the two country types. In addition the cash balance curves for bath case are illustrated.

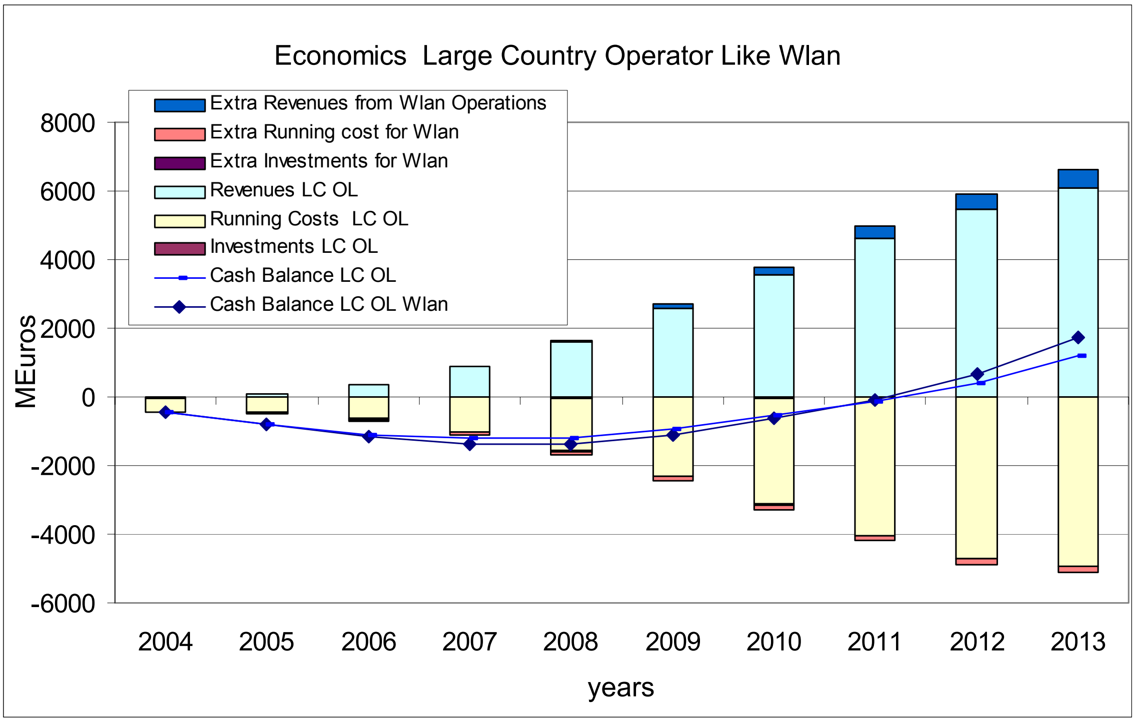



*Figure 67: Cash flow curves under nominal assumptions in large country for an operator-like MVNO (LC= Large country, OL=Operator-like).*

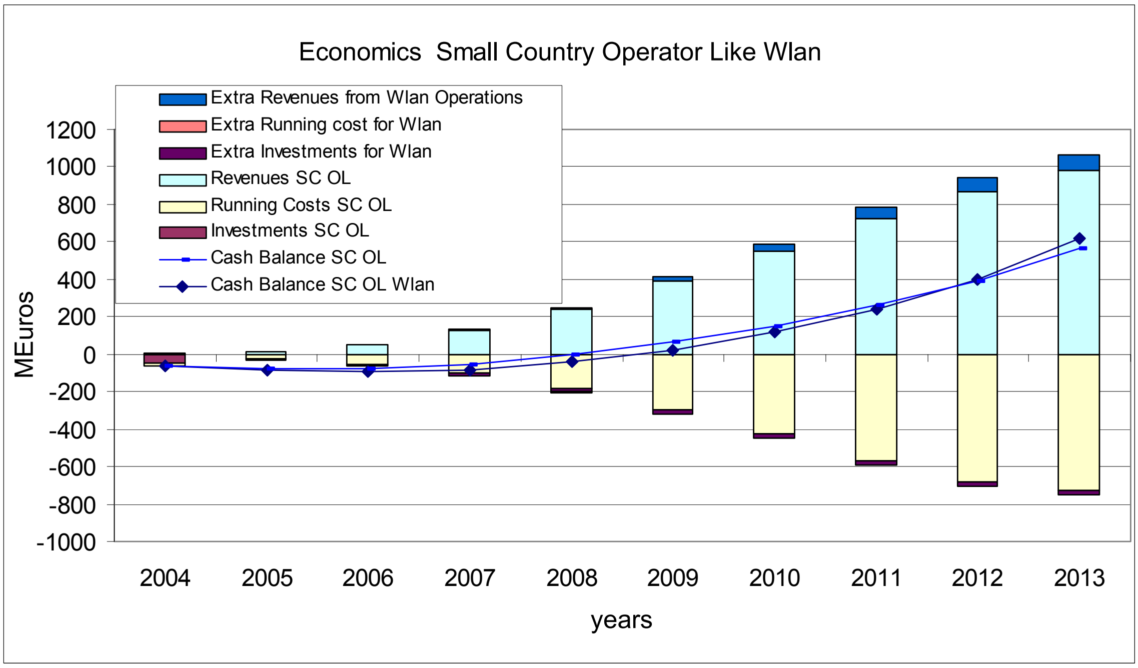



*Figure 68: Cash flow curves under nominal assumption in small country for an operator-like MVNO (SC= Small country, OL=Operator-like).*

The following plots enable a comparison of the non-discounted cash balances and cash flows for all scenarios and profiles studied as well investments and running costs. Note that there is secondary axis for the running cost (right axis) on Figure 72 and Figure 73 charts. The difference between investment cost and running cost in a large country is two orders of magnitude and in a small country is one, respectively. This is the result of the heavy license fee that the MVNO Operator must share with the MNO operator in a large country. Furthermore the additional running cost for the WLAN operation are negligible, especially in the small country.

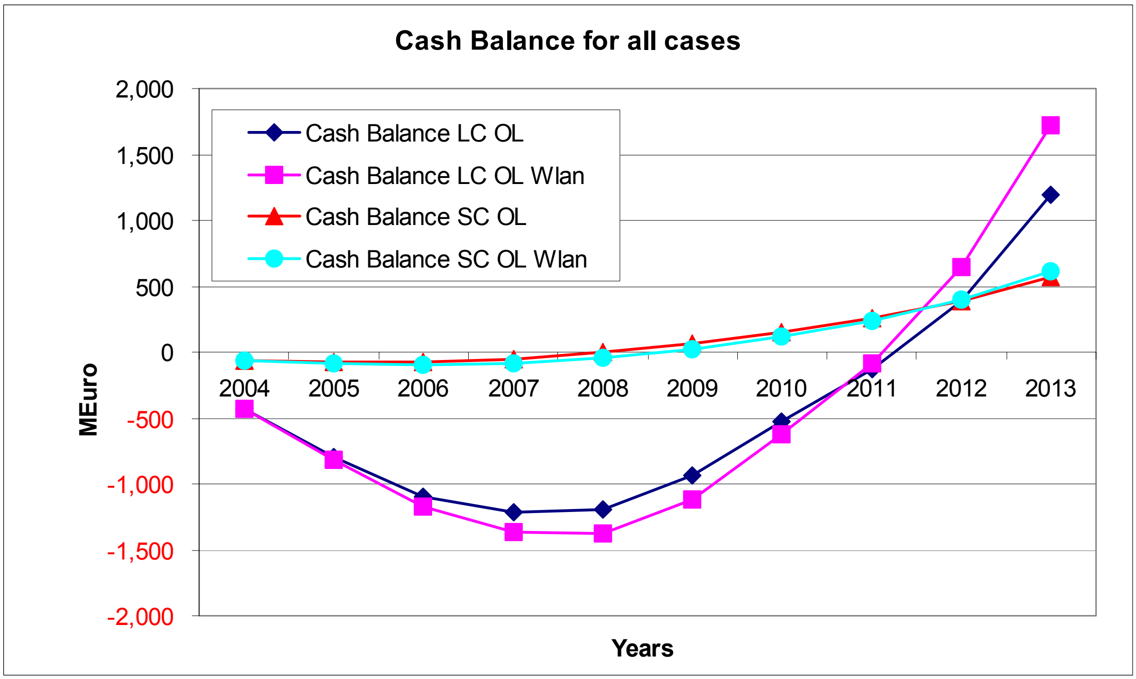



*Figure 69: Cash balance curves for all cases*

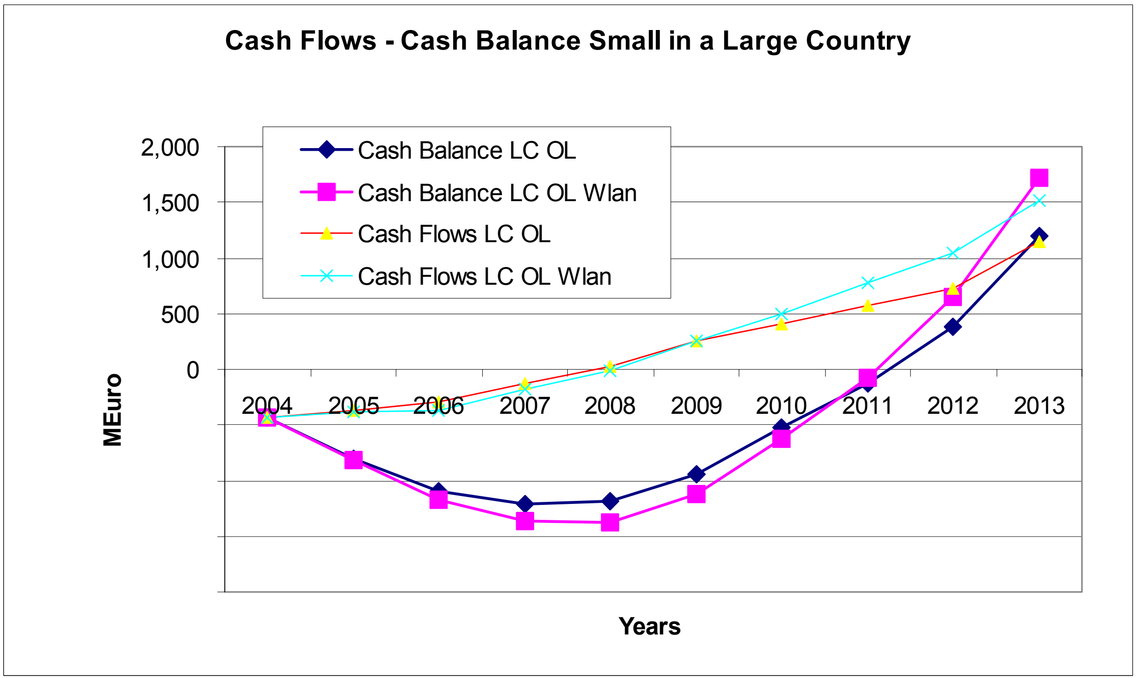



*Figure 70: Cash balance and cash flows curves in a Large Country*

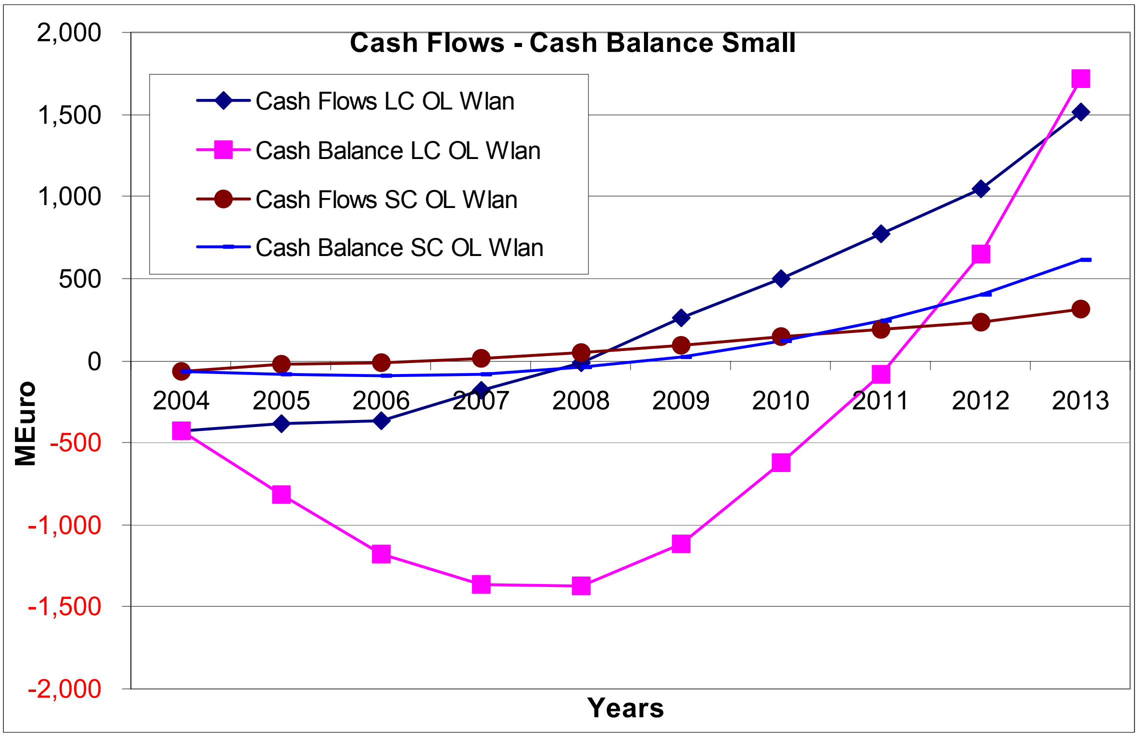



*Figure 71: Cash balance and cash flows curves in a Small Country*

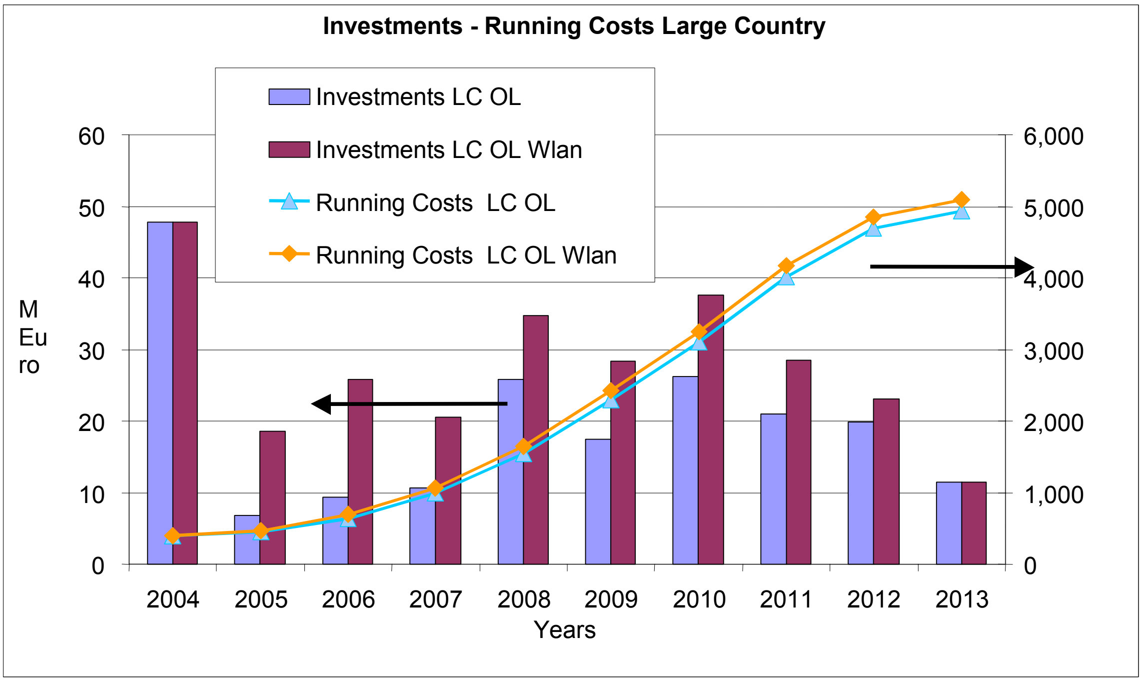



*Figure 72: Investments and running costs in a Large Country*

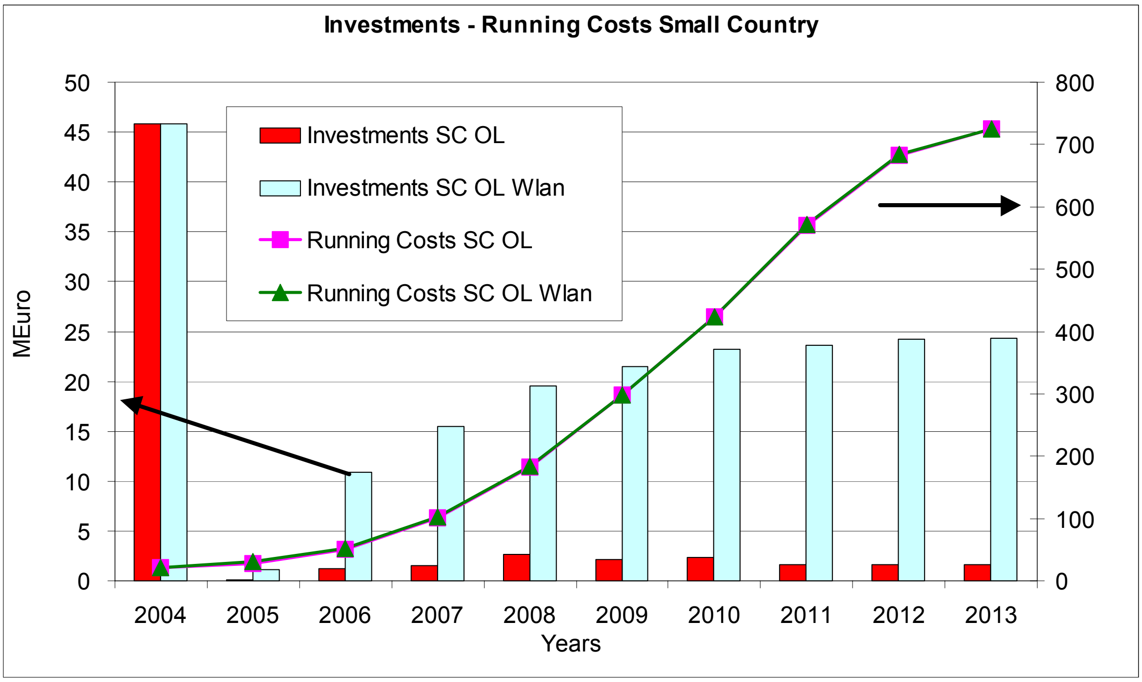



*Figure 73: Investments and running costs in a Small Country*

Looking from Figure 69 to Figure 73, it can be observed that investments are roughly proportional to population in the two country types. The population ratio is almost 14:1 (70 million versus 6 million).

It can observed that the enhancement of MVNOs service basket due to the provision of BB services can act as a significant leverage to its business. MVNO can almost double its economic figures with almost negligible investments. Taking into account the positive impact of MVNOs to MNO, the additional revenues of MVNO due to BB services can reverse the negative attitude of MNO to MVNOs.

## 11.9 Sensitivity studies

The presented results concern a set of basic scenarios with given parameter settings. In order to gain a more complete picture of how the investment project performs in regard to the modification of these settings, we perform sensitivity analyses on the UMTS scenarios in the large and small country types. We chose to modify the following parameters by +/- 50% in order to evaluate their impact on Net Present Value:

*Demand side parameters*

- Tariff level
- Tariff erosion
- Penetration of different UMTS services
- Usage of different UMTS services
- Start and end market share

*Running cost parameters*

- Operations, maintenance and administration costs (incl. terminal subsidy and marketing costs

*Investment cost parameters*

- UMTS Base Station (BTS) costs due to average cell radius length
- Total investments

*WLAN related parameters*

- WLAN tariff level
- WLAN service penetration

As the WLAN parameters have not so high impact on the total business case, they are presented separately. The results for Large country are illustrated in Figure 74 and Figure 75.It is recalled that the “low value”, marked as RED/LIGHT, represents the value obtained when the nominal parameter value is reduced by 50% and the “high value”, marked as BLUE/DARK, represents the result when the nominal parameter value is increased by 50%.

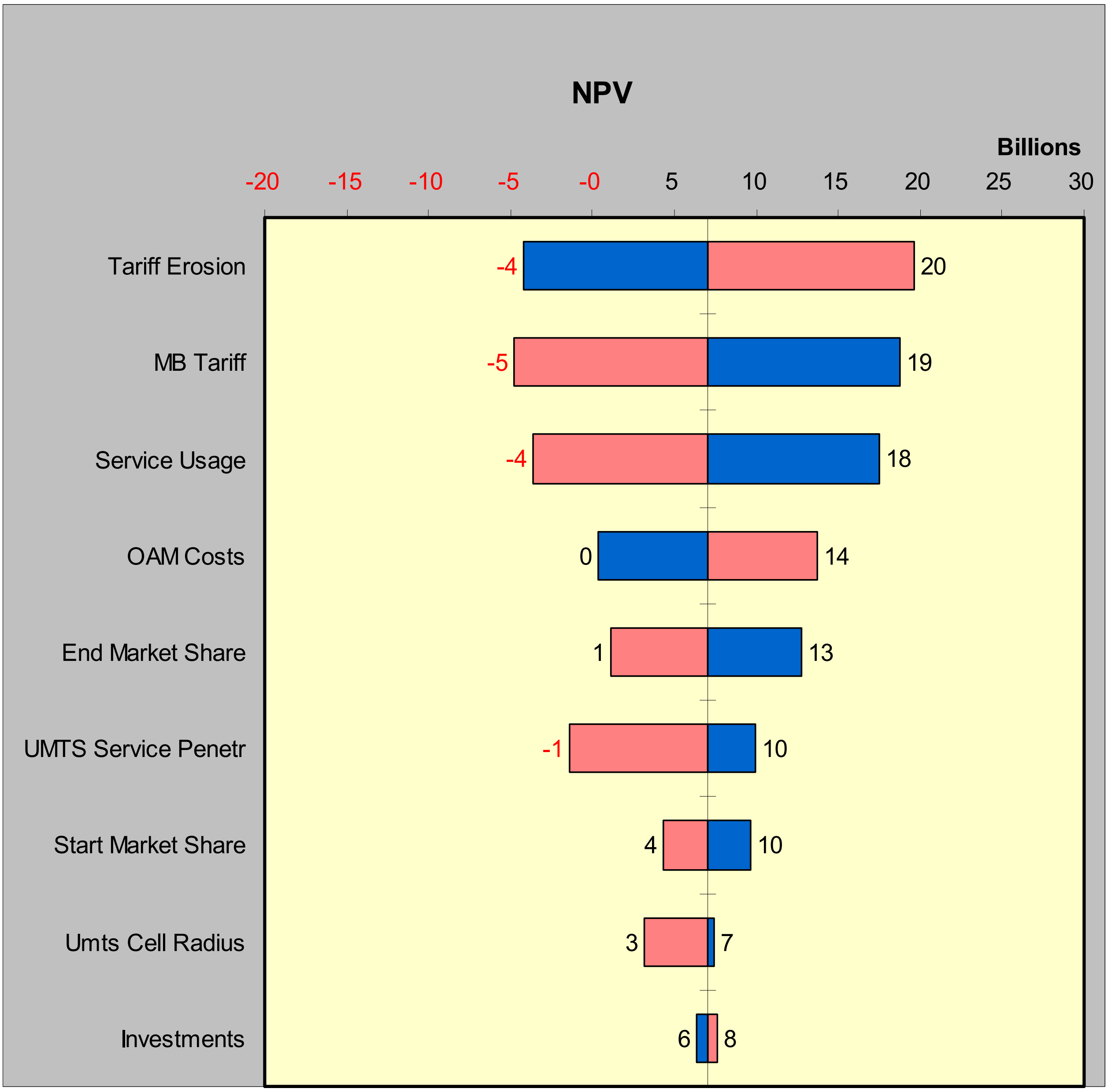



*Figure 74: Large country UMTS sensitivity parameters. Nominal parameter value is changed by ±50 %.*

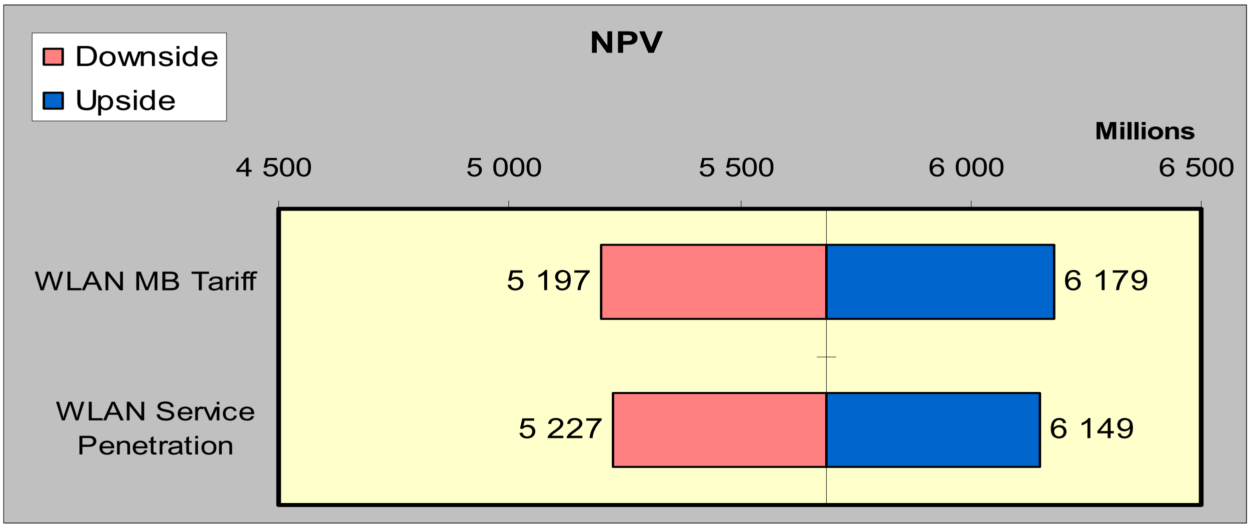



*Figure 75: Large country WLAN sensitivity parameters*

The results for Small country (with slow rollout) are illustrated in Figure 76 and Figure 77.

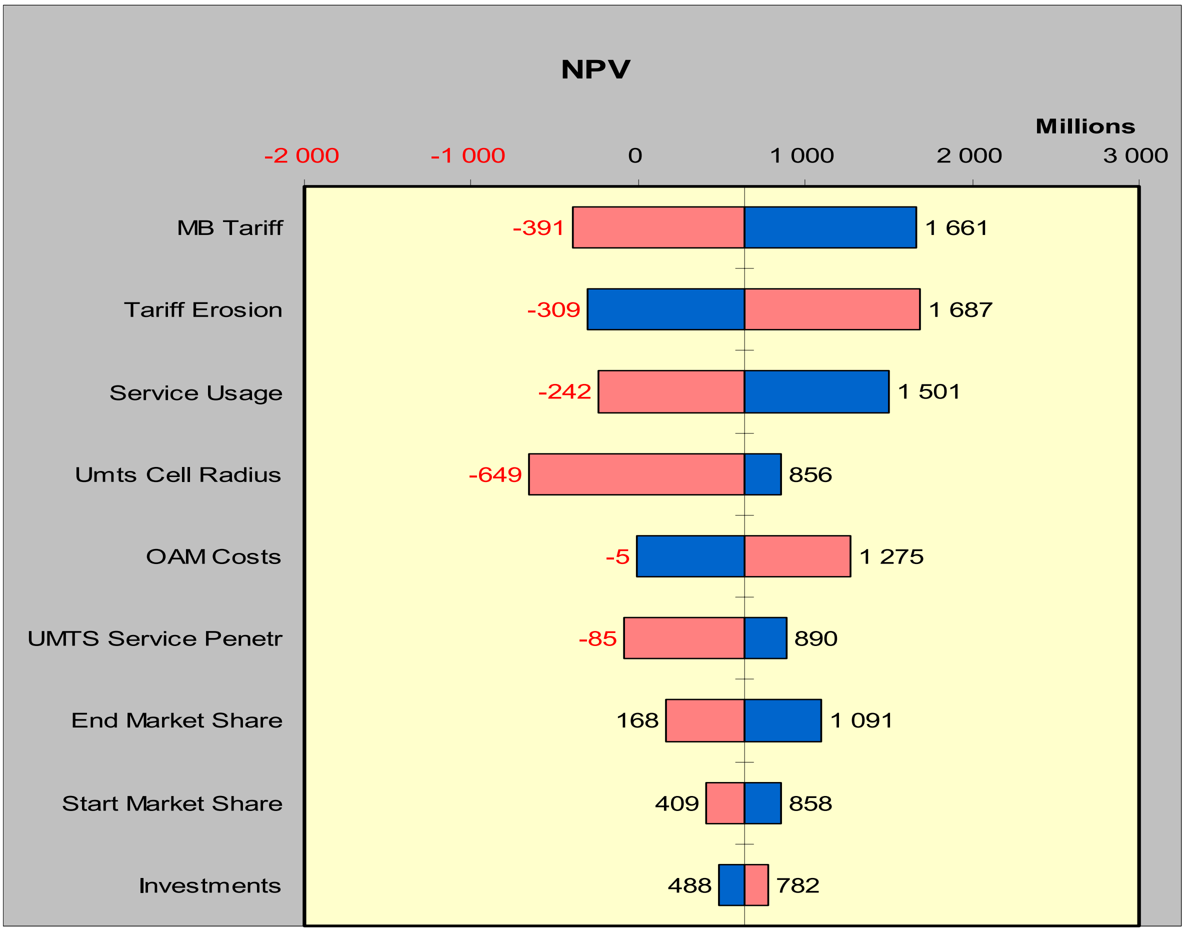



*Figure 76: Small country UMTS sensitivity parameters*

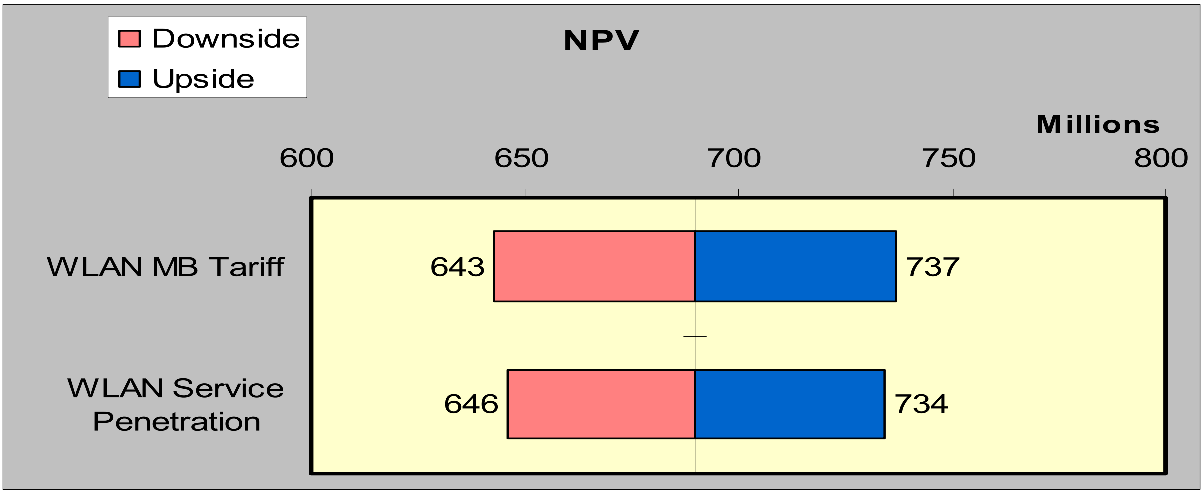



*Figure 77: Small country UMTS sensitivity parameters*

From the above figures we can see that the tariff related parameters have highest impact in both country cases. Then comes the service usage, as it brings in addition to higher revenues also some increase to the cost side, in the form of investments and maintenance. In general we can notice that the investments (CAPEX) are not so sensitive factor as the operational expenditure (OPEX); note however that the license cost was excluded from the CAPEX in this analysis as being an already fixed cost.
In the Small country case the cell radius is more influential parameter than in the Large country case, because the network build-out is very much coverage driven, as a large but sparsely populated country. In this situation, building of tighter network costs considerably more. The end and start market shares are not on the top of the list, but it should be taken into account that both cases are tracked separately and are in any case not less than 15%, as the basic assumption is 30% constant market share. We have not investigated the case, where the operator e.g. starts from scratch and has to "buy" the whole market share.
The WLAN related parameters have clearly lower impact than the UMTS parameters, reflecting the situation of WLAN being as such only a smaller ingredient in the total business case.
It is important to note that the value ranges of the parameters are not relating by any mean to the probability of their real variance, but just for illustrating their effect in a comparable way. So in the sensitivity analysis they are all varied between –50% and +50% from the base value as stated before. The real expected variances are dealt with in the following risk analysis section.

## 11.10 Risk analyses

The highest risk generally associated to 3G-business case, is the possibility of delay of the UMTS breakthrough. The other uncertain input parameters are mainly symmetric in nature, so that the case might become better or worse as the parameter varies around the estimated most probable value. This is not the case with penetration start-up point, as it is asymmetric in nature and in this phase may take actually only values describing delay and not as being earlier. This means that the mean or median of the possible case results is not that of the basic case, which is though the one we see as the most probable individual outcome.

The foreseen reasons for the delay of the UMTS brake through can be:

1) general lack of demand, lack of interesting or useful applications and services

2) lack of willingness to pay for telecom services (esp. mass market mobile data services)
3) technology immaturity
4) unavailability of equipment
5) too high price level and
6) weak economical position of the interest parties,

or combination of these, coupled with unwillingness to take the risk of initiative by the players.

Most of the factors above are touched, way or another, in the TONIC modelling and in this deliverable, but some more reasoning on this subject is still needed. There are clear indications that the take-up of the new mobile generation is very much dependent of the so called externality factors – large enough network of users are needed clearly for person-to-person communications, but it relates to other types of new behaviour (and spending) patterns too. The learning from Japan (FOMA), shows clearly the problem in situations, where the new system has not seamless roaming capabilities to the prevailing (2G) system, and where dual mode handsets are not available. Both of these shortages should be overcome in the European approach, but short delays in both handset mass-market availability and seamless roaming functionality between different vendors systems are still possible.

As the trend in service deployment has developed towards more and more independency on technology generation or platform, e.g. the OMA[10] initiative, the GPRS system is seen more as promoting the adoption of the 3G services, like MMS, than hindering the transition to UMTS. The above-mentioned externality factors work on that direction in the demand side. As also the development platforms are converging, this boosts also the application and service creation. Because of the availability of bandwidth in the new UMTS frequencies (which is not the case for GPRS in many European markets), far greater efficiency of the spectrum usage in UMTS compared to GSM voice and GPRS, and technology basis for better service quality (especially for real time data applications), it is anticipated that the usage goes reasonably fast to the UMTS – provided that the UMTS price level is competitive and the terminal availability and features (like battery life) are good enough. These are much the same risks we mentioned in the paragraph above.

The availability of useful and/or widely interesting services is no doubt a key thing to pave the UMTS boom. MMS looks a good candidate to be the first one to raise the interest, but also other mobile multimedia applications and services are needed. As mentioned above, the development in successive mobile generations have synergy here. The breakthrough is possibly near, but it has not taken place yet, presenting clearly some level of a risk factor.

The corporate applications sector introduces a similar challenge, as the faster and higher quality data connection to intranet, while on the move, gives not necessarily enough added value for quick transition to UMTS. On the other hand, the business segment is, against the history of mobile communications, keen to migrate to the best possible system and not tending to strictly monitor the telecom expenses, as effective communication and availability of personnel is seen highly valuable. Anyhow, we see room for some risk of delay also here.

Finally we see firm decisions by part of the UMTS license holding operators in Europe to start the launch in original schedule. In most cases, if the initial market position and financial situation are in acceptable level, the UMTS case is not seen vulnerable, even in case of heavy licenses, as the license period gives enough room to make profitable business. This however imposes some possibility of delays at least by some players.

[10] Open Mobile Alliance http://www.openmobilealliance.org/

We will first present the sensitivity graphs of the payback time and the NPV against the delay for the Large and the Small country (without WLAN business here). They illustrate the effect on results, when the investments are done according to the original plan, but the demand (penetration) curve moves ahead in time. The cashing period of the UMTS is considered to be extended with the same shift. The payback period starts from the first UMTS investments in the year 2002. In the risk analysis section, the large country case is with the high license fee and the Small country results are according to the slow rollout option.

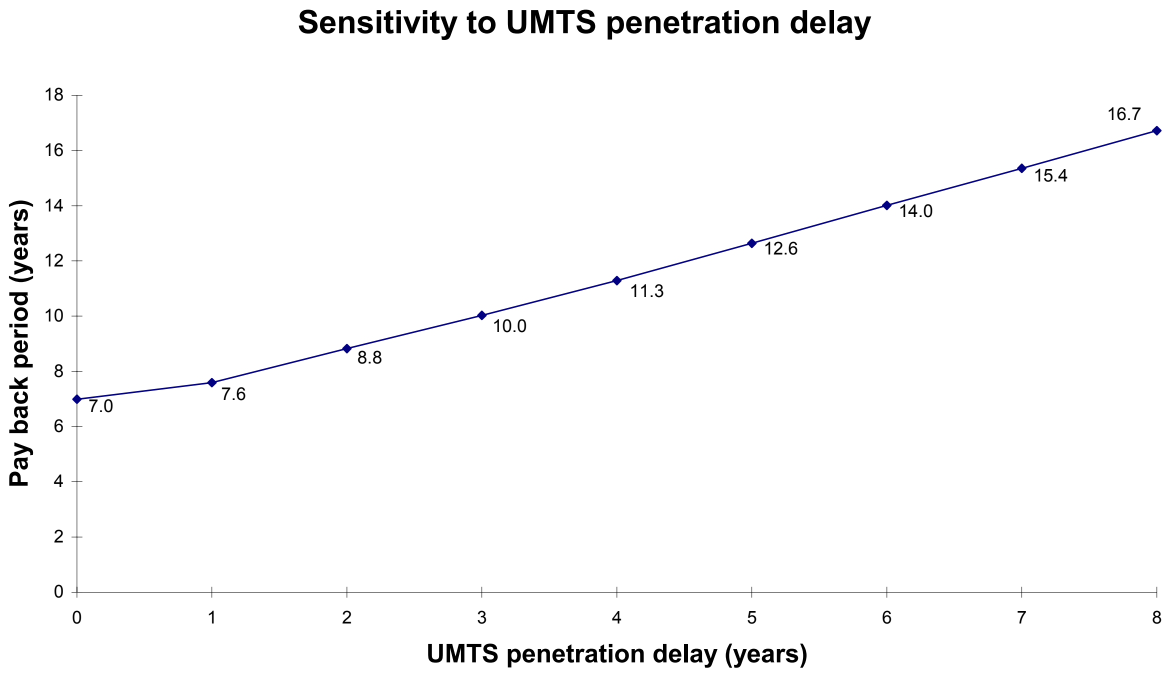



*Figure 78: Large country Payback time as a function of delay*

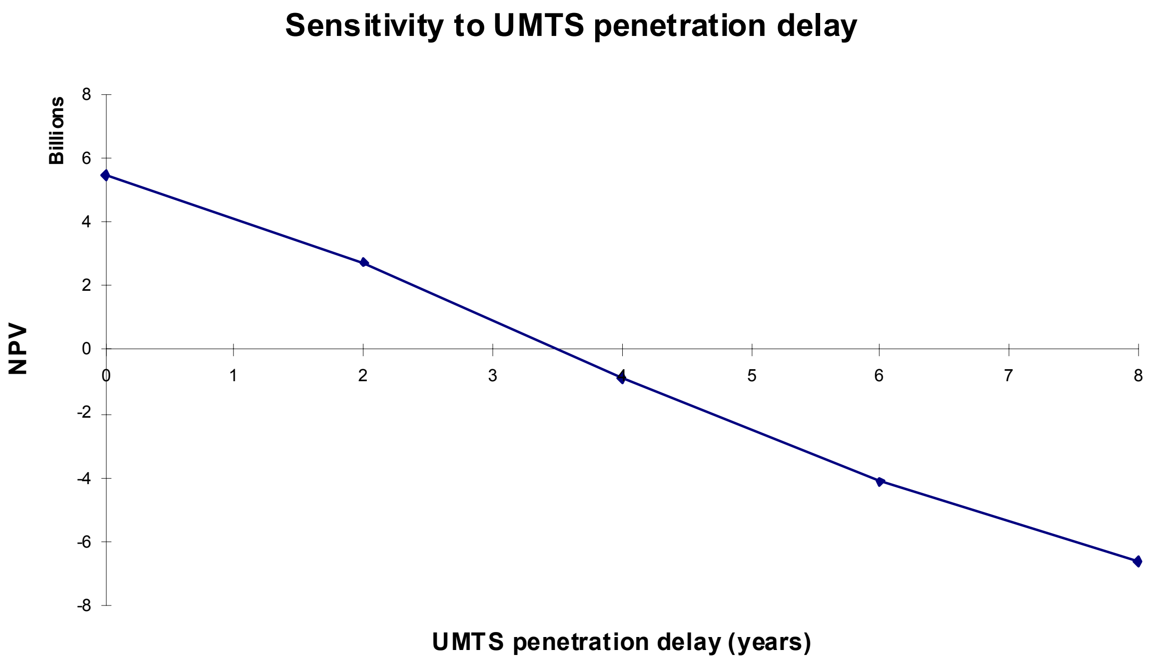



*Figure 79: Large country NPV as a function of delay*

We can notice that the point, where the Large country net result gets negative, is somewhere near 3.5 years of delay on Figure 79.

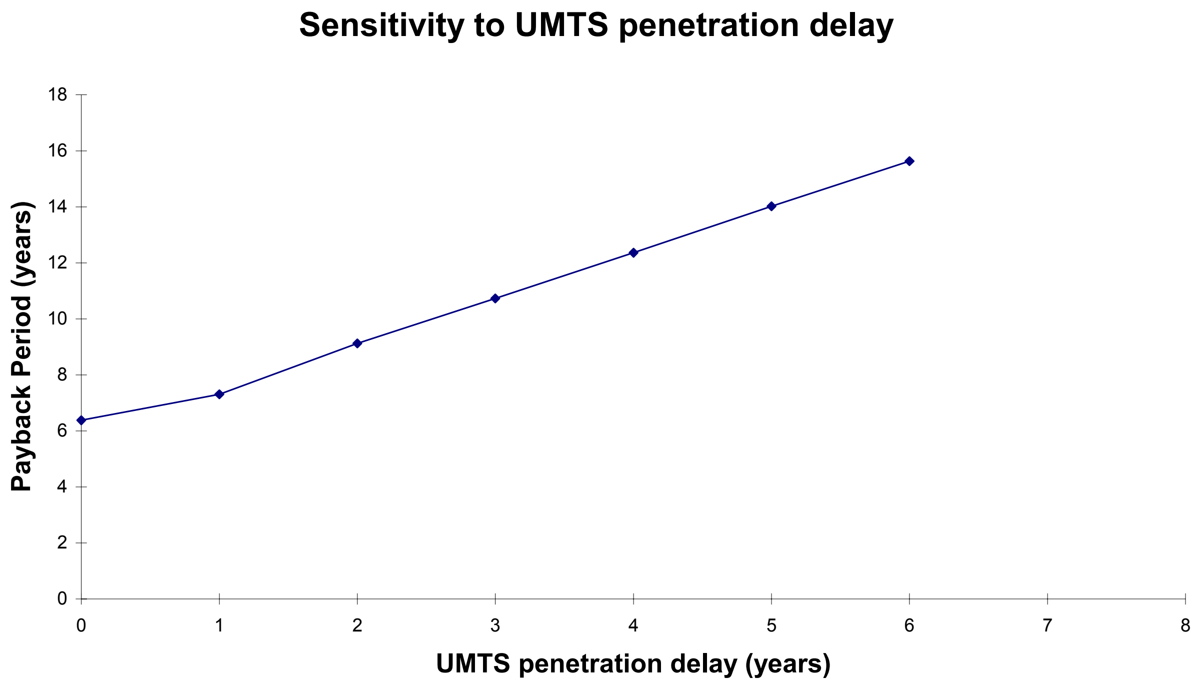



*Figure 80: Small country Payback time as a function of delay*

In the above graph (Figure 81), after year 6, the business case do not pay back at all, but the cumulative cash flow keeps minus signed until the forecasted end of the case.

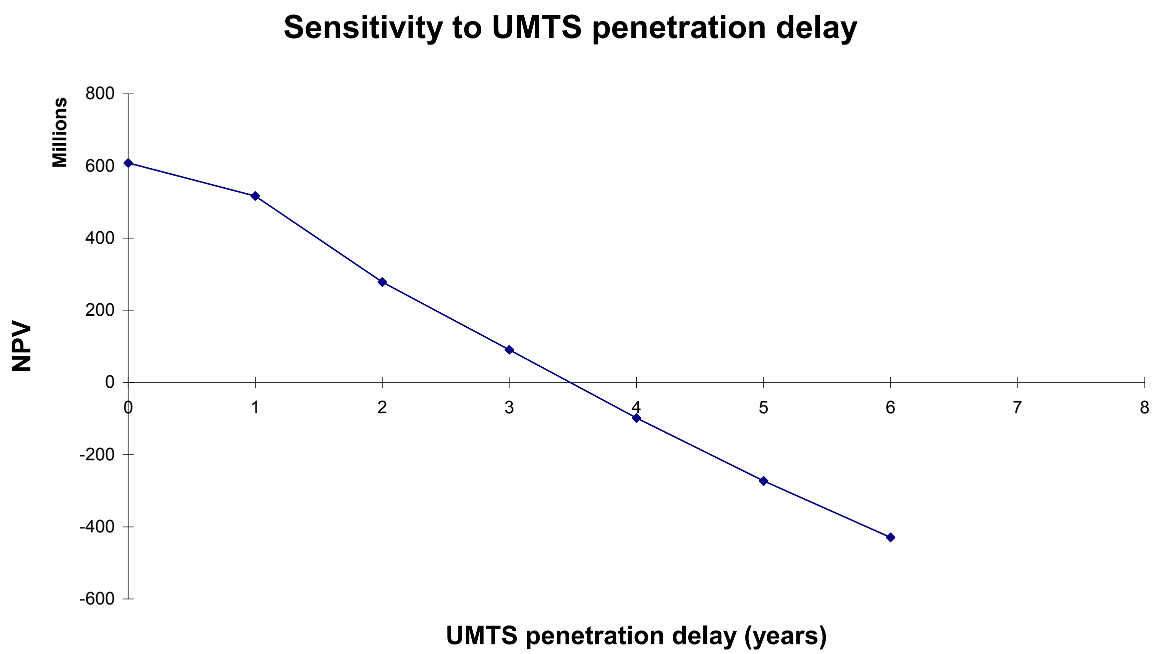



*Figure 81: Small country NPV as a function of delay*

From the above graph we see that the point where the Small country net result gets negative, is near 3.5 years of delay, much like in the Large country case.

We are just on the verge of the first European UMTS launches, but no realisation yet, so at this point we have to attach certain risk on the schedule of the UMTS penetration. In TONIC, we have assigned an exponential probability distribution to the starting point of the UMTS demand. We see that the highest probability is that the original modelled demand curve will realise, but following the probability distribution presented below, the penetration curve of the UMTS might slide a little forward in time.

In general, we see **low** probability for a long delay of UMTS in the TONIC country types on the following grounds:

- production version UMTS infrastructure has been readily available and under delivery for some time and the rollout and upgrades have started by many European operators already last year; some interoperability challenges may appear but nothing to hinder the deployment
- availability of the dual mode UMTS/GSM handsets in the year 2003 will be good in relation to the TONIC penetration estimates; as the UMTS in Europe is widely introduced, several models are launched in different functional and price categories
- by far most of the European UMTS licensed operators have pronounced their decision to launch UMTS commercially during the year 2003; it is also in the interests of those operators invested on UMTS licenses to capitalize upon the stake as soon as possible
- migration to UMTS is in the interest of both operators and advanced mobile users:
    - the trend in service specification and creation is towards platform independency, giving 3G services a smooth migration path and synergy with 2/2.5G service development; critical mass for many new mass market services is reachable in near future
    - UMTS provides better quality and richer possibilities for services compared to GSM/GPRS
    - UMTS frequency band has a great amount of free capacity and better efficiency than the former generations
    - Seamless roaming between 2G and 3G networks, introduced by European UMTS, is an essential factor for the smooth migration to 3G
    - to make this happen the operators should apply competitive and lucrative pricing for the UMTS services

The estimated probability distribution of the possible delay of the UMTS demand is described in Figure 82, the delay being presented in years.

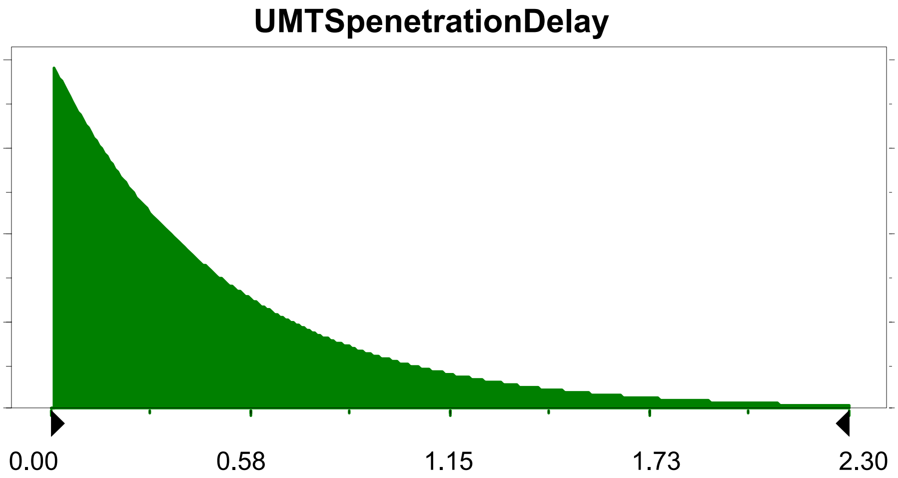



*Figure 82: Estimated probability distribution for UMTS penetration delay.*

For the actual risk analysis, we take in addition to the UMTS penetration delay the parameter of Tariff erosion, which was the one with highest impact in the preceding sensitivity analysis. It is also a parameter difficult to estimate, as developing in long time duration and having different effect depending on the delays in penetration. Many of the most sensitive parameters are tightly interrelated with each other and thus their effects should not be assumed to take place simultaneously. E.g. tariff level and service take-up decreases and increases are more probably overridden by each other, as the lower price level tend to increase usage and higher take-up to lower prices through increased competition. For these reasons we pick up the Tariff erosion parameter and describe the uncertainty of future development of the business case with it. As the probability distribution for Tariff erosion, we chose Normal distribution with standard deviation of 0.10, as presented in the Figure 83 next page.

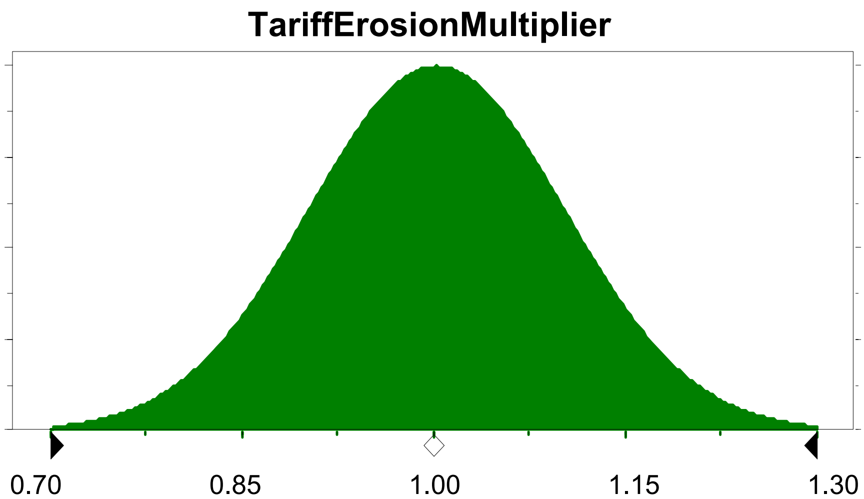



*Figure 83: UMTS tariff erosion multiplier distribution*

In the risk analysis we investigate the combined effect UMTS penetration delay distribution parameter and Tariff erosion parameter. We will first present the Large country risk analysis results and then the Small country results. The graphs give the distribution of the NPV and IRR, resulting from Monte Carlo simulation with the TONIC model. In the simulation run, the Penetration delay and Tariff erosion parameters are varied according to the presented distributions and the TONIC model results are calculated with those input values. We will also show the mean NPV and IRR values.

We can conclude that the foreseen mean end results from risk analyses are a little lower than the basic results, mostly due to the fact that the delay is an asymmetric parameter, which can have at this point of time only values with negative impact (being ahead of scheduled start and take up is of low probability).

Although we see some low probability cases with negative end results, the positive UMTS business cases are seen much more probable.

### 11.10.1 Large country risk analysis results

In Figure 84 and Figure 85 we can see the probability distribution of the Large country NPV and IRR, as the Penetration delay and Tariff erosion vary according to their distribution.

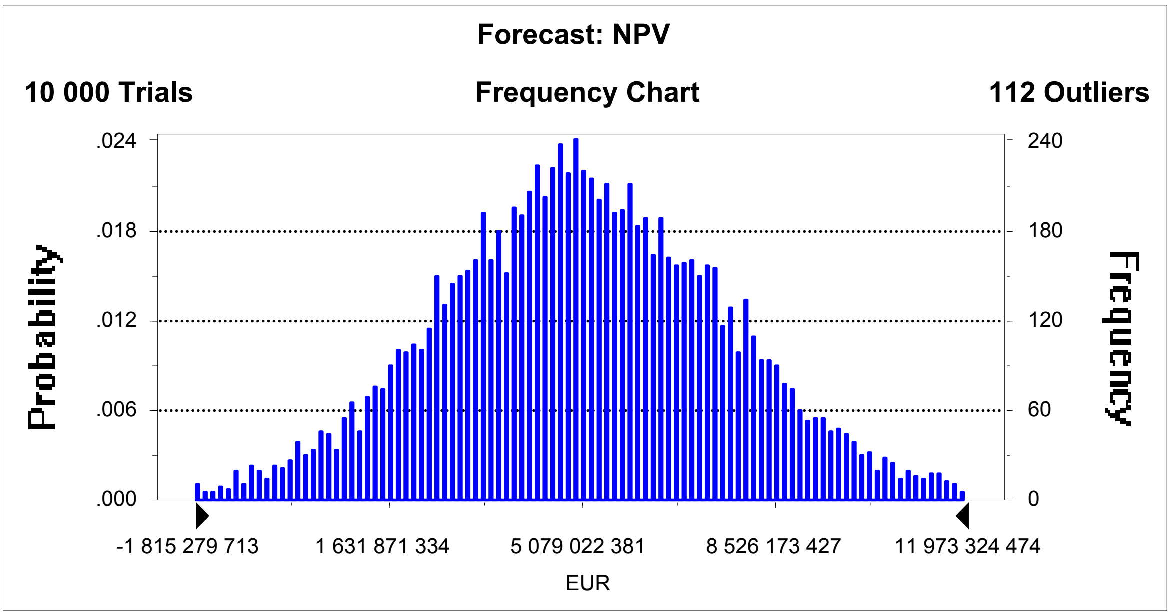



*Figure 84: Large country NPV distribution*

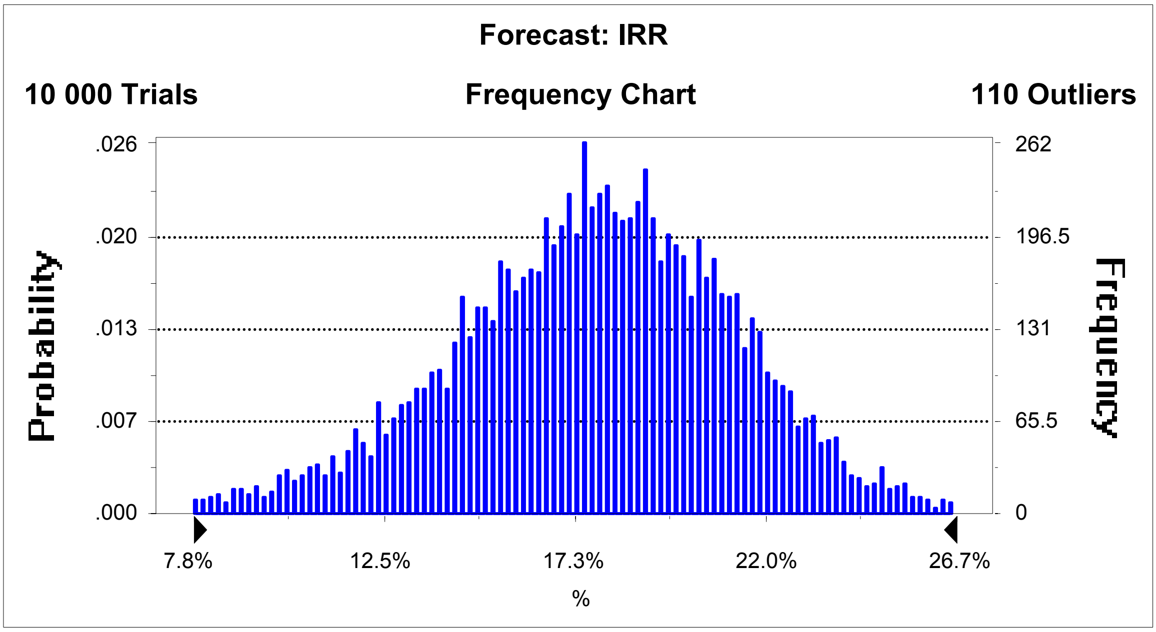



*Figure 85: Large country IRR distribution*

Taking the risk analysis into account, we get the values for mean expected Large country NPV and IRR values (without WLAN business):

- mean NPV = 5.1 B€
- median NPV = 5.1 B€
- mean IRR = 17.7 %
- median IRR = 17.9 %

11.10.2Small country risk analysis results

In both Figure 86 and Figure 87 we can see how the probability distribution of the Small country NPV and IRR, as the Penetration delay and Tariff erosion take different values.

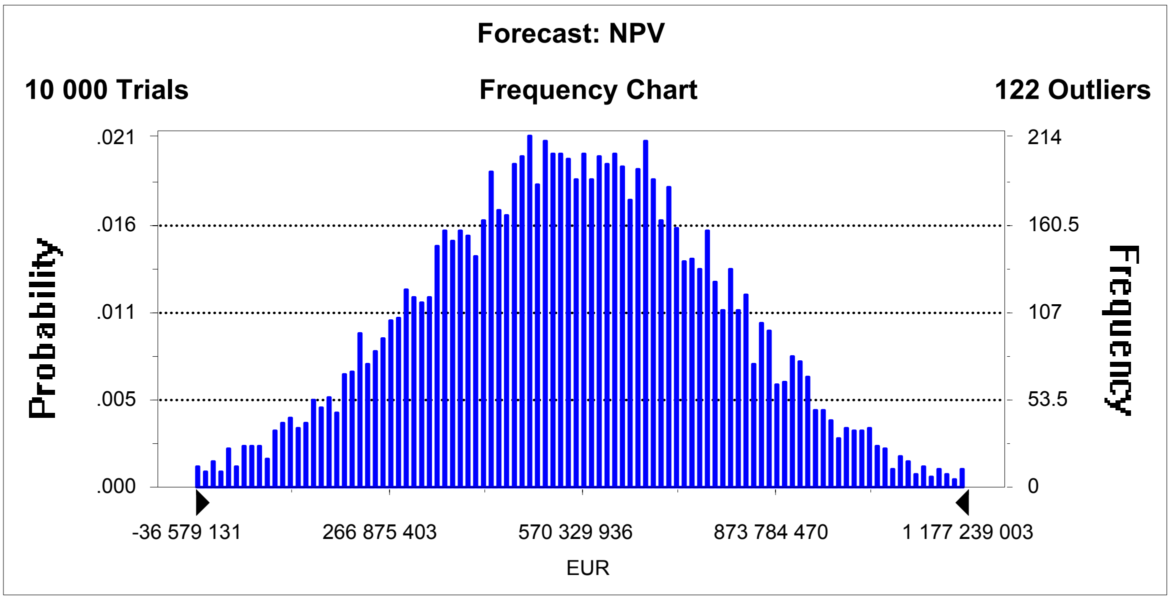



*Figure 86: Small country NPV distribution*

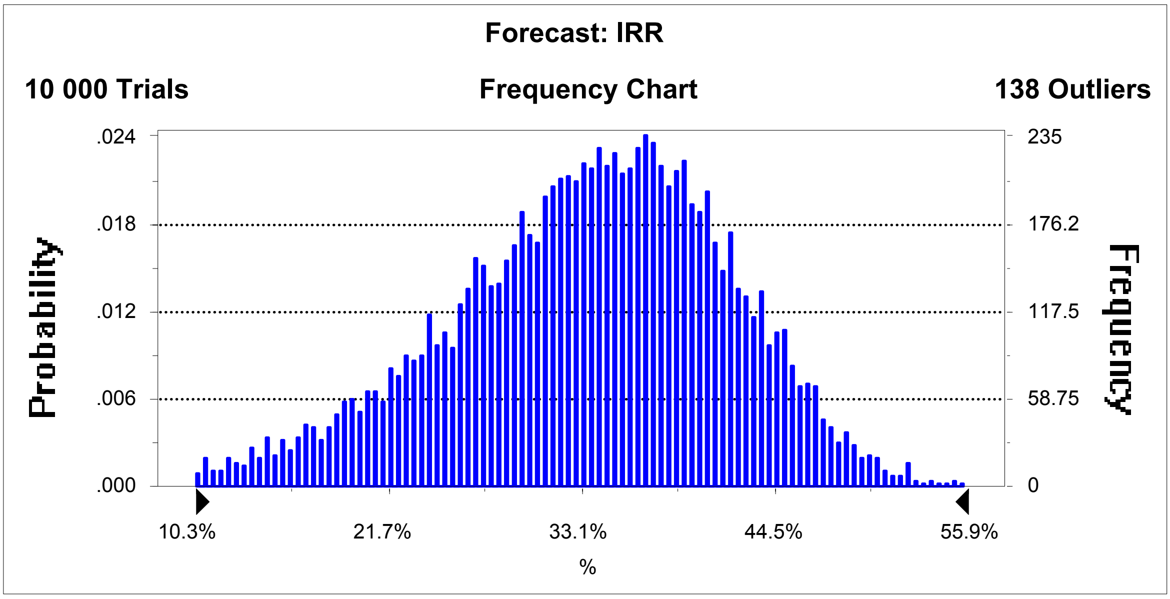



*Figure 87: Small country* IRR *distribution*

Taking the risk analysis into account, we get the mean values for Small country NPV and IRR (without WLAN business):

- mean NPV = 550 M€
- median NPV = 560 M€
- mean IRR = 33 %
- median IRR = 34 %

# 12. CONCLUSIONS

The TONIC Business Case 1, "Seamless mobile IP service provision economics" gives, after thorough modelling of the selected cases, a positive prospect on the economics of European UMTS operator in all basic cases. The penetration and ARPU figures differ somewhat from many recent forecasts, with the grounds discussed in the related chapters. The license and investment costs are not, even in the heavy license fee case, seen too high for making profitable business in the long run, as the license period is in most cases as long as 20 years. Yet the technology generations emerging afterwards have to be taken into account. The pay back periods are generally near 7 years, which is not to be considered too long against the magnitude of the project. The risk of delayed UMTS deployment and take-up, which can ruin the business case economically, should be fought back in all frontiers including operators, vendors, investors, application, content and service development/provisioning business, as well as regulatory and standardisation bodies.

This deliverable concludes that the common growing concern about the rise of public WLAN to the detriment of 3G is not justified. Instead, it indicates the economic profitability of WLAN notably as a complementary, rather than competing, solution for 3G operators towards broadband mobile service provision. Thus, WLAN is expected to boost UMTS multimedia take up and usage by 8%, and to generate some 6% of the combined UMTS-WLAN revenue stream in large countries, with additional overall investments and operating costs of just 1% and 4% in excess respectively. For small countries, the additional investment and operational costs are of 2% and 5% respectively, resulting in a similar UMTS-WLAN revenue composition. In related terms, a 3G operator in a large country with high license fees is expected to see the net present value of its investment up by 18% thanks to WLAN service provision. In a small country with a slow network roll out the net present value premium for WLAN usage is estimated at 9%. This stems from the fact that small countries are prone to higher investment levels per inhabitant in newly established networks.

Future MVNO should also benefit from WLAN if they complement their offer with WLAN services.

Sensitivity conclusion is that a delay of 3,5 years in terms of usage penetration could turn the business case negative both for large and small country case.

Nevertheless, TONIC estimates that UMTS business case will have little risk to face such long delays because next coming availability of dual mode terminals combined with seamless roaming between 2G and 3G network are key success factors.

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# 14. APPENDIX A: TRANSPORT COST MODELLING

## 14.1 Dimensioning and Optimisation

The optimisation of core network aims to determine the type and the number of leased lines between routing/switching nodes that minimise the total leased line costs, assuring that all the expected traffic is supported by that solution. Furthermore, it will be done a comparative analysis between optimised and non-optimised leased line costs (network with direct path connections between nodes), in order to calculate investments needed in each year under study, and the average annual saves achieved.

It is assumed these nodes include 3G MSC, 3G SGSN, and gateways (in the following pictures those nodes are named Core Network Sites – CN Sites), and each of them serves approximately the same number of costumers.

In the network under study the traffic is modelled according to two distinct criteria: - internal traffic (between all pairs of nodes), and – external traffic (between a node and other networks). External traffic is routed through gateways, which establish connections to external networks. It is assumed that gateways exist only in a sub-set of nodes, since equipment costs are significant and it is not cost effective the existence of gateways in all nodes. Internal traffic is defined as a capacity between each pair of nodes and external traffic is defined as a capacity between each node and a node with gateway. For the obvious reasons, external traffic of nodes with gateways are routed through their gateway and, therefore, do not occupy resources on leased lines.

For dimensioning purposes, we assume that 2/3 of total traffic is internal to the operator network, and the remaining 1/3 of the total traffic is external traffic (in general, operators stimulate communications between users inside their own networks, with cheaper tariffs);

According to TONIC methodology, two scenarios of analysis will be considered: small country and large country, with a fixed number of CN Sites for each scenario (4 in small country, 15 in large country), homogeneously distributed over its area, and each CN Site has got approximately the same number of customers. To simplify calculations of distances between CN Sites each country is represented by a suitable geometric shape (square for small country, rectangle for large one) with its own coverage area (and not its total area).

To connect core network nodes, we consider the following types of leased lines: E1 (2 Mbps), E3 (34 Mbps), STM1 (155 Mbps), STM4 (622 Mbps) and STM16 (2.5 Gbps). It is assumed that STM4 circuits will be available only after 2005, and STM16 after 2008. The leased line prices were provided by an European incumbent operator, having an annual depreciation of 5% until the end of the project.

### 14.1.1 Small Country

TONIC assumes that the total covered area of a small country is 268000 $km^2$, and the distances are: a= 517.69 km, b=258.84 km, d=366.06 km.

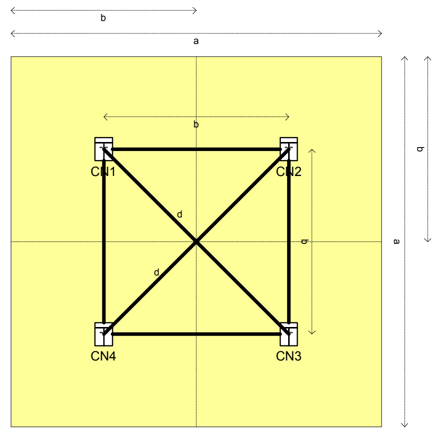



*Figure 88: Geometric model for a Small Country*

#### 14.1.1.1 Traffic Considerations

In small country there are 2 access points with gateways with connection to external networks, and traffic is considered equally probable towards all destinations. Internal traffic is dived by 4 to obtain the traffic generated in each node, 1/3 of this traffic is internal to the node CN Site, and the remaining 2/3 are delivered equally to the remaining 3 nodes, corresponding to deliver 2/9 of traffic to each one of them.

It is considered that 50% of external traffic does not waste core network resources, since it is supposed the network operators install servers in places where there are more target customers using a given service. The remaining external traffic is distributed according to an equiprobable criterion to other 3 nodes.

In most of cases, with optimisation, the final network is not constituted by all direct connections between nodes (full mesh network). The figure below illustrates this, and shows network solutions generated by PT Plan MPLS, which depend on the traffic and on the leased lines prices.

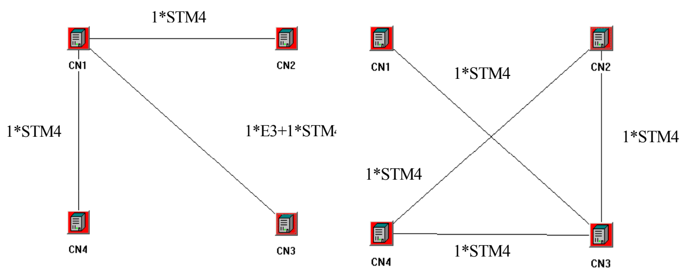
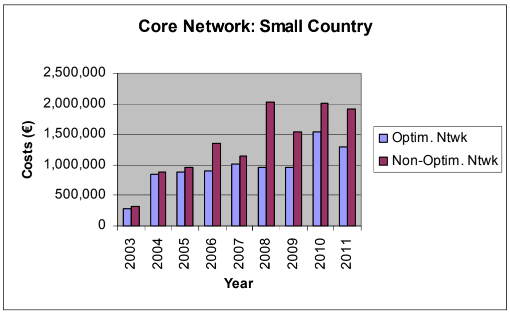



*Figure 89: Examples of optimised scenarios in small country (years 2007 and 2011, respectively)*

Table 32 show the results obtained for small country (including installation costs), and the differences between optimised and non-optimised (direct path) networks.

*Table 32: Core Network Investments and comparative analysis between optimised and direct path network with respective saves achieved (small country).*

| Core Network: Small Country Costs (€) | | | | |
|---|---|---|---|---|
| Year | Optimised Network | Direct Path Network | Amount saved (€) | % saved |
| 2003 | 272,836 | 310,311 | 37,475 | 12.1 % |
| 2004 | 848,940 | 884,679 | 35,739 | 4.0 % |
| 2005 | 876,888 | 954,246 | 77,358 | 8.1 % |
| 2006 | 905,708 | 1,359,957 | 454,249 | 33.4 % |
| 2007 | 1,018,560 | 1,145,046 | 126,486 | 11.0 % |
| 2008 | 958,713 | 2,032,542 | 1,073,829 | 52.8 % |
| 2009 | 956,463 | 1,532,361 | 575,898 | 37.6 % |
| 2010 | 1,544,055 | 2,006,109 | 462,054 | 23.0 % |
| 2011 | 1,301,820 | 1,919,676 | 617,856 | 32.2 % |




In general, leased lines costs are growing as the years are passing, except for the transition between 2008 and 2009, since in 2008 the investments in network infrastructures to support the increase of traffic are very significant. However, in 2009 the same infrastructure of the previous year supports yet the increase of traffic expected for that year. So, with a depreciation applied to the leased lines prices, and without installation costs, it is possible to justify this decrease of network costs.

The operator can save in average during the study period about 380 k€ with optimisation policies, corresponding to an average annual gain of 23.81%.

### 14.1.1.2 Large Country

In Large Country the total (covered) area is 344000 $km^2$, and the basic distance d is 151.44 km, all other distances are calculated using multiples of d, or the Pitagoras' Theorem.

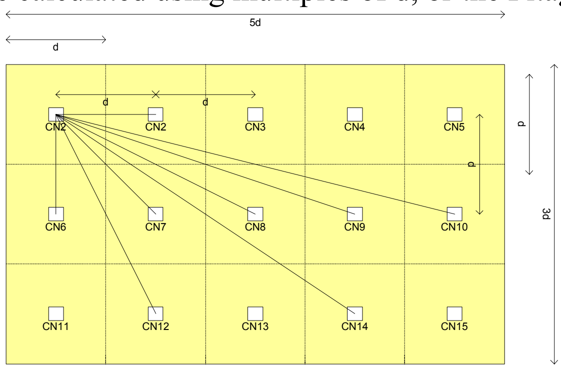



*Figure 3 - Geometric model for Large Country.*

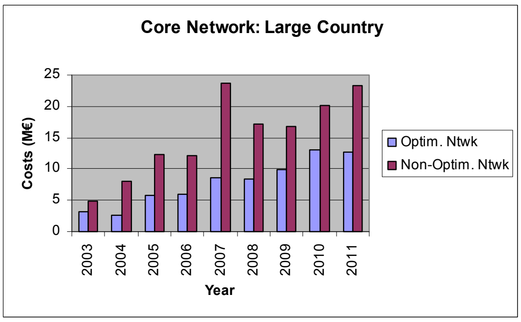
For this study, there are 3 access points (CN Sites with gateway: CN1, CN8, CN15) establishing connection to external networks.

It is assumed that all traffic is equally probable to all destinations (all core network sites). In this case, there are 15 CN sites, so the total internal traffic is divided by 15, in order to obtain the traffic generated in each node. Then, 1/10 of that traffic is internal to the node, and the remaining 9/10 are equally distributed to the others (14 nodes), corresponding to deliver 9/140 of that traffic to each one of those nodes. For the external traffic, it is considered that one half of that traffic is internally processed in each node, does not occupying core network resources; the remaining is equally delivered to the others 14 nodes.

In large country the optimisation gains are more significant and under these circumstances the operator can save in average 7.63 M€ per year, corresponding to an average annual gain of 49.46%.

*Table 33: Core Network Investments and comparative analysis between optimised and direct path network with respective saves achieved (large country).*

| Core Network: Large Country Costs (€) | | | | |
|---|---|---|---|---|
| Year | Optimised Network | Direct Path Network | Amount saved (€) | % saved |
| 2003 | 3.159.490 | 4.870.914 | 1.711.424 | 35,1 % |
| 2004 | 2.554.388 | 7.968.541 | 5.414.153 | 67,9 % |
| 2005 | 5.743.908 | 12.378.507 | 6.634.599 | 53,6 % |
| 2006 | 5.965.575 | 12.173.757 | 6.208.182 | 51,0 % |
| 2007 | 8.543.214 | 23.718.029 | 15.174.815 | 64,0 % |
| 2008 | 8.384.770 | 17.079.777 | 8.695.007 | 50,9 % |
| 2009 | 9.907.759 | 16.875.027 | 6.967.268 | 41,3 % |
| 2010 | 13.002.959 | 20.148.085 | 7.145.126 | 35,5 % |
| 2011 | 12.609.870 | 23.288.141 | 10.678.271 | 45,9 % |



# 15. APPENDIX B: ACCESS NETWORK DIMENSIONING

It is our conviction that in the access network dedicated connections E1 (2Mbps) between a NodeB and its respective RNC are not enough to support all expected generated traffic. However, if these connections were merely updated to the next level of hierarchy (E3 – 34 Mbps) this solution would be clearly expensive, since the capacity is much larger than the expected traffic per NodeB, wasting significant bandwidth resources. As a first analysis we assume that operators are unwilling to make considerable investments installing this type of leased lines, unless this extra bandwidth is used to re-route other traffic flows. In this case, it is desirable to allow a greater level of freedom to re-route traffic - which was originally flowing directly from each NodeB to the RNC - migrating to other solutions that allow to re-route the traffic through another neighbour NodeB, originating tree topologies aiming to improve the occupation rate of each connection.

The objective of this section is to determine the suitable topology for the NodeB – NodeB and NodeB – RNC connections that minimize the access network costs.

So, in this work it is assumed that NodeB's have the ability to multiplex traffic from neighbour NodeB's over its connection towards the RNC. The determination of the most suitable type of connections between NodeB and RNC under this scenario is an optimisation problem, which can be also solved using a heuristic based on Lagrangean Relaxation with Sub-Gradient Optimisation.

## 15.1 Network Topology for PTPlan MPLS

Once again, PTPlan MPLS will perform the optimisation of the access network resources according to the heuristic referred above, so it is necessary to create a specific topology based on TONIC model parameters, in order to feed the tool.

The topology considers four distinct regions (Dense, Urban, Suburban and Rural). Each one has similar traffic characteristics but different average NodeB - RNC distances.

To decrease the computational footprint, the option was to analyse topologies with only one RNC, with its assigned Node-B's located around it. Those NodeB's are randomly distributed over the area, in accordance with the Node-B – RNC average distances for each region defined in TONIC tool. The number of NodeB's in each zone is proportional to its total number in the country. For example, if, in a given year, a country has 10 RNC's and 1000 NodeB's (200 Node-B's in Dense area, 300 in Urban, 100 in Suburban and 400 in Rural), the implemented topology in PTPlan will have only 1 RNC and 50 NodeB's (20 NodeB's in Dense zone, 30 in Urban, 20 in Suburban and 40 in Rural). Tables 1 and 2 illustrate the evolution of the number of NodeB's during the study period, for both Countries (Small and Large).

The following calculations are based on a circular geometric model, which is a good approach to the mobile 3G access network topology.

*Table 34: Evolution of the number of NodeB's in Small & Large Countries during the study period.*

| Small Country | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|
| NrOfUmtsBsInDense | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 |
| NrOfUmtsBsInUrban | 84 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 |
| NrOfUmtsBsInSuburban | 0 | 124 | 248 | 371 | 371 | 371 | 371 | 371 | 371 |
| NrOfUmtsBsInRural | 0 | 0 | 467 | 933 | 1.399 | 1.865 | 2.331 | 2.798 | 3.264 |
| **Total without Additional Bs** | 110 | 317 | 908 | 1.497 | 1.963 | 2.429 | 2.895 | 3.362 | 3.828 |
| NrOfAdditionalUmtsBsDense | 0 | 0 | 3 | 13 | 33 | 55 | 80 | 100 | 98 |
| NrOfAdditionalUmtsBsUrban | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NrOfAdditionalUmtsBsSuburban | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 133 | 123 |
| NrOfAdditionalUmtsBsRural | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TOTAL** | 110 | 317 | 911 | 1.510 | 1.996 | 2.484 | 3.025 | 3.595 | 4.049 |

| Large Country | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|
| NrOfUmtsBsInDense | 285 | 285 | 285 | 285 | 285 | 285 | 285 | 285 | 285 |
| NrOfUmtsBsInUrban | 935 | 1.869 | 1.869 | 1.869 | 1.869 | 1.869 | 1.869 | 1.869 | 1.869 |
| NrOfUmtsBsInSuburban | 0 | 1.386 | 2.771 | 4.156 | 4.156 | 4.156 | 4.156 | 4.156 | 4.156 |
| NrOfUmtsBsInRural | 0 | 0 | 536 | 1.072 | 1.608 | 2.144 | 2.679 | 3.215 | 3.751 |
| **Total without Additional Bs** | 1.220 | 3.540 | 5.461 | 7.382 | 7.918 | 8.454 | 8.989 | 9.525 | 10.061 |
| NrOfAdditionalUmtsBsDense | 0 | 0 | 26 | 139 | 355 | 590 | 855 | 1.077 | 1.043 |
| NrOfAdditionalUmtsBsUrban | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NrOfAdditionalUmtsBsSuburban | 0 | 0 | 0 | 0 | 0 | 0 | 403 | 1.290 | 1.156 |
| NrOfAdditionalUmtsBsRural | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TOTAL** | 1.220 | 3.540 | 5.487 | 7.521 | 8.273 | 9.044 | 10.247 | 11.892 | 12.260 |

Assuming that each RNC can physically support a maximum of 100 NodeB's, and being the traffic generated by all of them higher than the amount an RNC can stand, the capacity will impose the number of NodeB's connected to the RNC. The number of RNC's is thus given goal here is to optimise the connections in the access network, letting the generated traffic by a NodeB to be directed to another NodeB, instead of being directly delivered to the RNC. The number of RNC's needed per year can be observed in Table 35.
by:

$$NrOfRNCs = \max(roundup\left(\frac{NrOfUmtsBs}{Umts\_Bs\_per\_RNC}\right); roundup\left(\frac{UmtsBhTotalMbps}{Umts\_RNC\_Capa}\right))$$

*Table 35: Evolution of the number of RNC's in both types of countries during the study years for optimisation purposal.*

| | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|
| NrOfRNC (Large Country) | 13 | 36 | 55 | 76 | 83 | 114 | 152 | 186 | 186 |
| NrOfRNC (Small Country) | 2 | 4 | 10 | 16 | 20 | 25 | 31 | 36 | 41 |

At this point, the task is to calculate the number of NodeB's on each area (Dense, Urban, …), for all the scenarios.

*Table 36: Evolution of the number of NodeB's for each area per RNC, for Small & Large Countries during the study years.*

| Small Country | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|
| %NodeB_Dense | 23,64% | 8,20% | 3,18% | 2,58% | 2,96% | 3,26% | 3,50% | 3,50% | 3,06% |
| %NodeB_Urban | 76,36% | 52,68% | 18,33% | 11,06% | 8,37% | 6,72% | 5,52% | 4,65% | 4,12% |
| %NodeB_Suburban | 0,00% | 39,12% | 27,22% | 24,57% | 18,59% | 14,94% | 13,92% | 14,02% | 12,20% |
| %NodeB_Rural | 0,00% | 0,00% | 51,26% | 61,79% | 70,09% | 75,08% | 77,06% | 77,83% | 80,61% |
| **TOTAL** | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% |
| NrNodeB_Dense/RNC | 13 | 7 | 3 | 2 | 3 | 3 | 3 | 4 | 3 |
| NrNodeB_Urban/RNC | 42 | 42 | 17 | 11 | 8 | 7 | 5 | 4 | 4 |
| NrNodeB_Suburban/RNC | 0 | 31 | 25 | 23 | 19 | 15 | 14 | 14 | 12 |
| NrNodeB_Rural/RNC | 0 | 0 | 47 | 59 | 70 | 75 | 76 | 78 | 80 |
| **NodeBs/RNC** | 55 | 80 | 92 | 95 | 100 | 100 | 98 | 100 | 99 |

| Large Country | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|
| %NodeB_Dense | 23,36% | 8,05% | 5,67% | 5,64% | 7,74% | 9,67% | 11,13% | 11,45% | 10,83% |
| %NodeB_Urban | 76,64% | 52,80% | 34,06% | 24,85% | 22,59% | 20,67% | 18,24% | 15,72% | 15,24% |
| %NodeB_Suburban | 0,00% | 39,15% | 50,50% | 55,26% | 50,24% | 45,95% | 44,49% | 45,80% | 43,33% |
| %NodeB_Rural | 0,00% | 0,00% | 9,77% | 14,25% | 19,44% | 23,71% | 26,14% | 27,03% | 30,60% |
| **TOTAL** | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% |
| NrNodeB_Dense/RNC | 22 | 8 | 6 | 6 | 8 | 8 | 8 | 7 | 7 |
| NrNodeB_Urban/RNC | 72 | 52 | 34 | 25 | 23 | 17 | 12 | 10 | 10 |
| NrNodeB_Suburban/RNC | 0 | 39 | 50 | 54 | 50 | 36 | 30 | 30 | 29 |
| NrNodeB_Rural/RNC | 0 | 0 | 10 | 14 | 19 | 19 | 18 | 17 | 20 |
| **NodeBs/RNC** | 94 | 99 | 100 | 99 | 100 | 80 | 68 | 64 | 66 |

The next problem to solve is to find the distance between each NodeB and the RNC, assuring that all NodeB's are random distributed in the final topology in accordance with the average distances given by TONIC Tool.

*Table 37: Average distances between NodeB's from each area and central RNC (TONIC values).*

| | Dense | Urban | Suburban | Rural |
|---|---|---|---|---|
| NodeB - RNC average distance (km) | 2 | 10 | 14 | 30 |

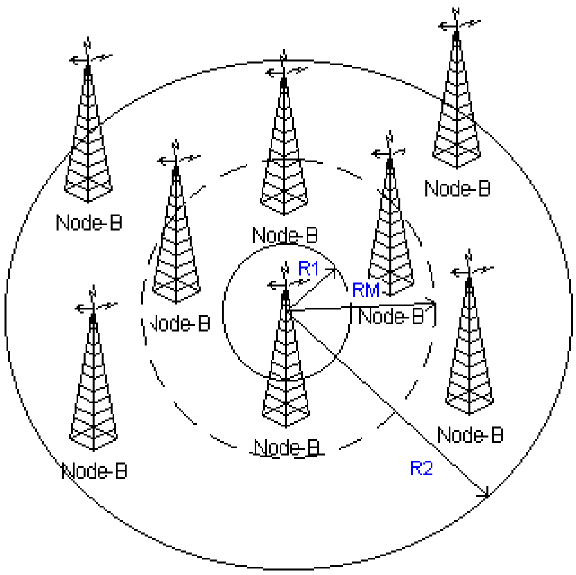



*Figure 90: Division of an area in two rings.*

In the circular model defined, R1 represents the interior edge of each region (for the inner dense region, R1 = 0), R2 is the exterior edge, and RM is the average distance shown above in Table 6. Note that R2 of one region is equal to R1 of the next region (for example, R2 of urban region is equal to R1 of suburban region). In our model, it was considered that R2 is the mean value between two consecutive RMs. For example, R2 of urban area is mean between the RM of urban area, 10 Km, and the RM of suburban area (14 Km) which equal 12 Kms. Given these considerations, we have to take into account an appropriate random NodeB's distribution:

Given the number of NodeB's (i = 1, …, N) for each region type, their locations are randomly generated based on polar coordinates (the RNC location is assumed the center of the coordinates) with the following criteria: select a random initial angle $0 \leq \alpha \leq \pi/2$ and assign the angle $\alpha + i \cdot 2\pi/N$ for each NodeB; assign a random distance value with the density function defined to the region type.

It was also considered R2 equals to 46 km on Rural area.

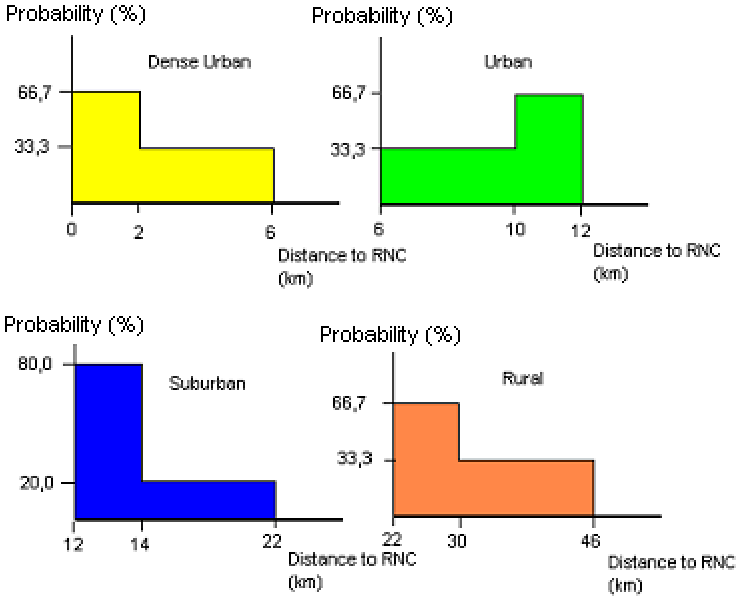



*Figure 91: Density function for assigning a random distance, for each region.*

## 15.2 Traffic Considerations

In PTPlan point of view, the most important issue to dimension a connection in terms of capacity is the traffic in bits that it can support. This way, it is not necessary to consider separately packet and voice traffic.
For this study it is assumed that each NodeB generates the same traffic.

*Table 38: Traffic per NodeB in Both Types of Countries.*

| Traffic per NB (kbps) | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|
| Small Country | 209 | 302 | 293 | 428 | 567 | 705 | 809 | 906 | 982 |
| Large Country | 210 | 299 | 537 | 948 | 1513 | 2151 | 2666 | 3075 | 3658 |

## 15.3 Leased Lines and Prices

The considered types of leased lines for this study are only E1 (2 Mbps) and E3 (34 Mbps). For the dimensioning it is assumed the payload instead of the absolute bandwidth.

The used leased lines prices were provided by TONIC Tool, and were submitted to a depreciation of 5% per year until the end of the project. Note that prices depend on the length of the link.

*Table 39: Leased Lines Prices (Source: TONIC Project).*

| Year 2003 | Link E1 | Link E3 |
|---|---|---|
| Anual cost per km (€) | 540 | 1680 |
| Anual fixed cost (€) | 6000 | 12000 |

## 15.4 Results

Figure 92 and Figure 97 are illustrative of the PTPlan MPLS network, giving an idea about the complexity of the implementation, only with 100 NodeB's in this case. Figure 92 shows a full-mesh network. Figure 93 represents the same reality, but through a network only with direct links between NodeB's and the central RNC. After the optimisation procedure the obtained topologies are illustrated in Figure 94.

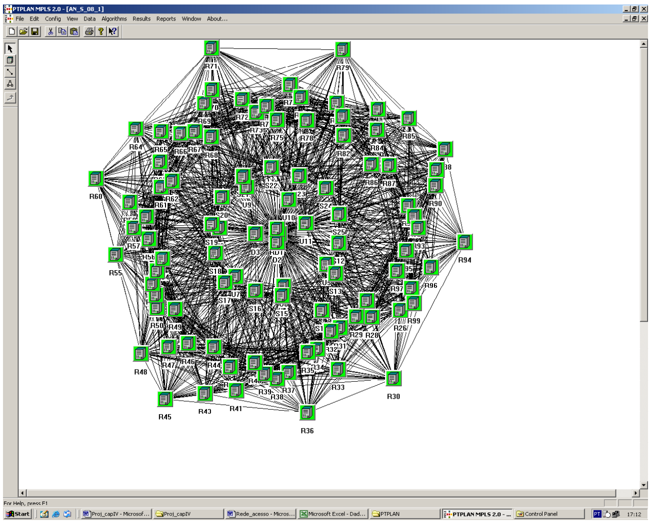


*Figure 92: Example of a PTPlan Scenario considering a full-mesh network.*

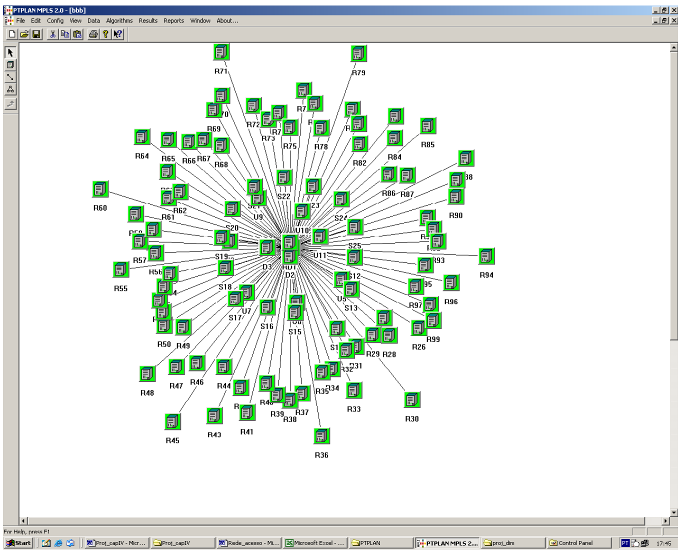


*Figure 93: Example of a PTPlan Scenario considering star topology between NodeB's and RNC.*

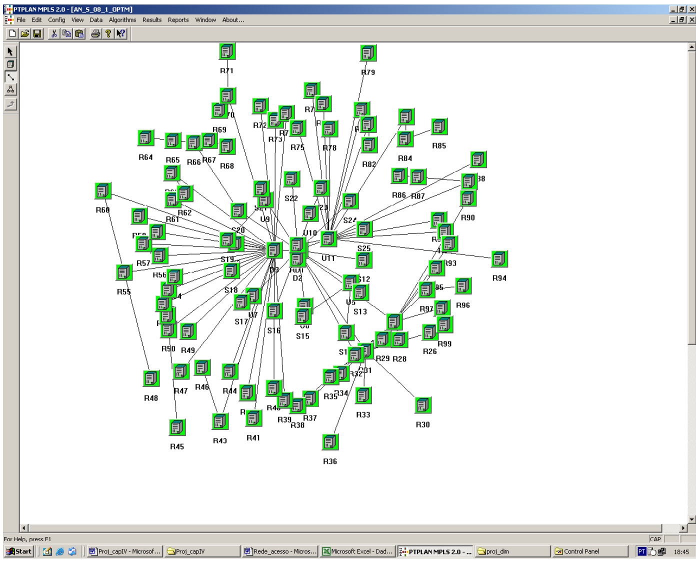


*Figure 94: Example of a PTPlan Scenario which resulted of optimisation.*

The results obtained for both countries are shown in the Figure 95 and Figure 96

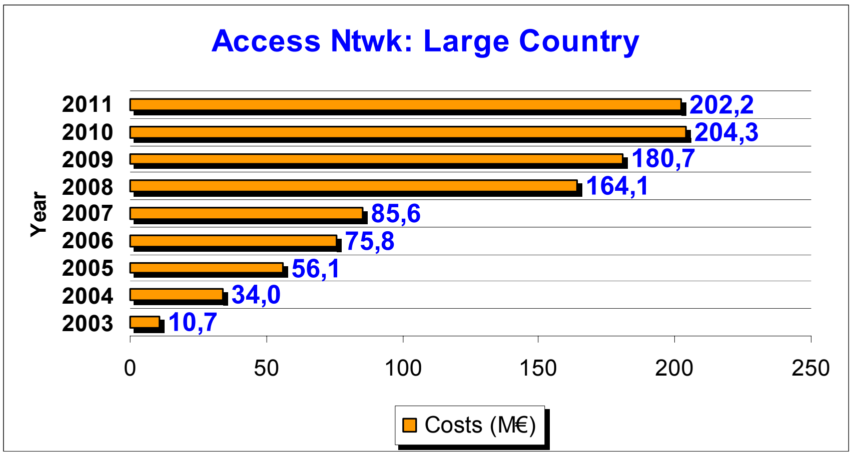



*Figure 95: Access Network Costs per Year in Large Countries.*

Due to a depreciation of 5% per year, along with the maintenance of the number of RNC's, the cost of the network in 2011 is lower than in 2010,. In the previous years, the cost of the network increases, as more RNC are needed.
Next, the results obtained for Small Countries are shown:

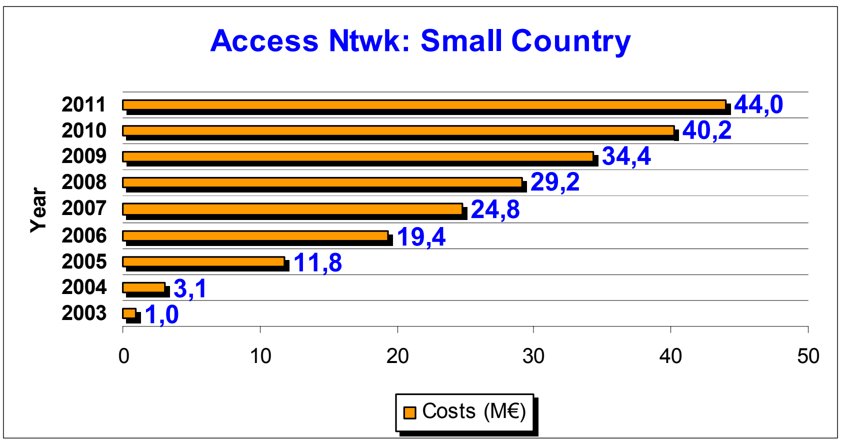



*Figure 96: Access Network Costs per Year in Small Countries.*

As in Large Countries, the cost of the network increases, as more RNC are needed.

The obtained values are based on a random distribution considered for NodeB's allocation in the scenarios. However, in average these results are considered to be a good approach for a real situation.

A more careful look at Figure *x* reveals the finding of a few loops in the final solution. This means that this solution can be improved. The reason is that the heuristic implemented on PTPlan is suitable for Core Network, but it is not fully optimised for Access Networks.

# 16. APPENDIX C: INFRASTRUCTURE SHARING LEVELS

## 16.1 Level 1: Sharing of sites and passive elements

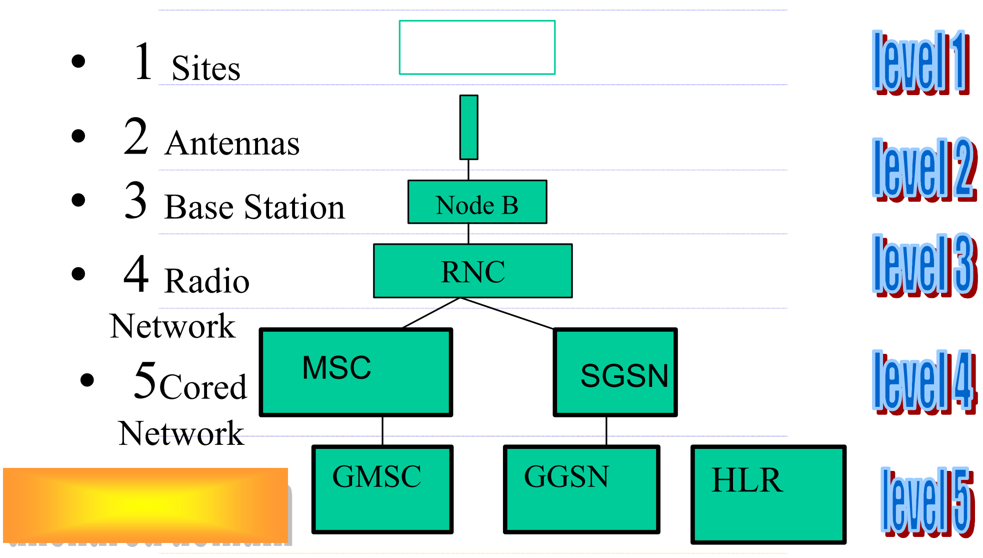



*Figure 97: The five levels of infrastructure sharing*

The use in common by several operators of all or part of the passive elements of the infrastructure, i.e.

- Costs of negotiations, leasing, acquisition of fixture and fitting elements
- Civil engineering
- Technical locations and charges
- Pylons
- Electricity supplies
- Air-conditioning
- Access protection
- etc.

The common availability of transmission elements which do not relate to the UMTS architecture: The sets of data specific to each operator are separated at the intake point of the site, by way of demultiplexers.

The Spectrum Compatibility Consultative Commission drew up a certain number of general principles relating to the sharing of any radio-electric site, whatever the service concerned, on 10 September 2001. All of these principles feature in the report entitled "EC Study of the Engineering of Radio-electric Sites". These general principles must naturally be respected and applied in the case of infrastructure sharing between 3G operators.

## 16.2 Level 2: Sharing of antennas

This level is defined by the joint utilisation, complementing one another, of the passive elements of the radio-electric site, the antenna, and the whole of the associated connection elements (coupler, feeder cable, etc.).

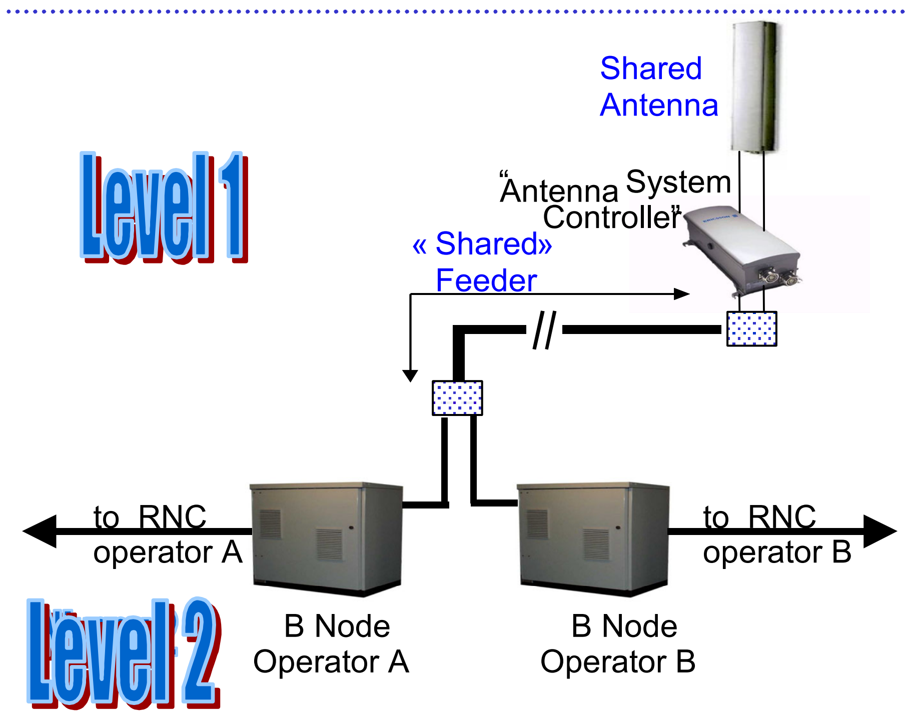



*Figure 98: Diagram of the principle behind a shared antenna*

## 16.3 Level 3: Sharing the base station (B node)

This level is defined by the "physical" sharing of B node, compatible with a "software" separation of the use of the frequencies. Each operator accordingly retains control of their B node "software" with regard to data traffic, and use exclusively their own frequencies and their own network codes (MNV[11]) to route their traffic.

This solution makes use of interfaces standardised by 3GPP.

From the practical point of view, this arrangement is manifested by the existence of hardware elements which are specific to each operator (TRX) within the context of the shared base.

In addition to this, the diagram is applicable B node by B node. Operators are accordingly also able to establish shared usage of some Nodes B and not others. In other words, sharing agreements between operators can be effected in certain geographical areas where they appear to be of interest, while in others the operators can retain complete autonomy. It is therefore possible to envisage tripartite agreements, such as one operator A sharing infrastructures with an operator B in a given geographical area, and with an operator C in another geographical area.

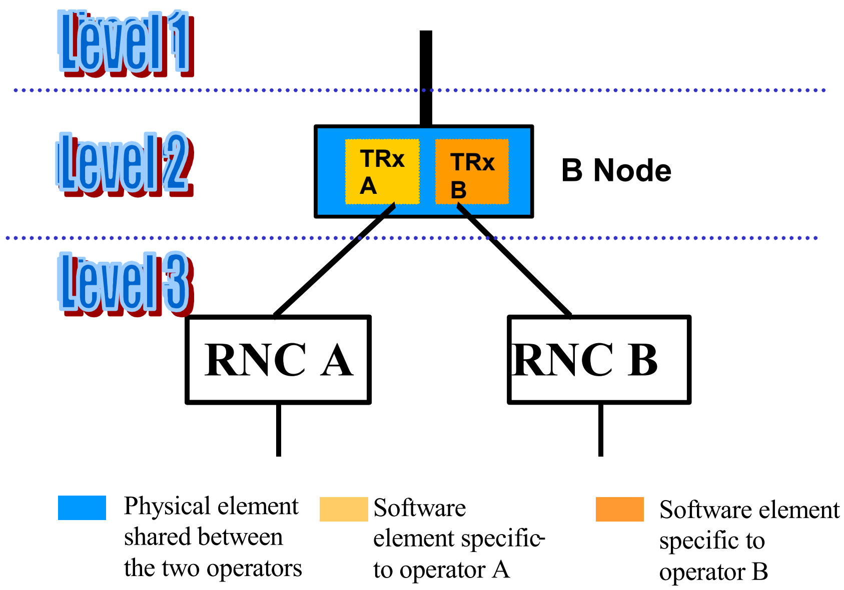



*Figure 99: Diagram showing the principle of B node sharing*

## 16.4 Level 4: Sharing base station controller (RNC)

This level corresponds to a "physical" sharing of the RNC and B node. The radio network is therefore shared, although each operator retains control of their UTRAN "software" with regard to data traffic, and use exclusively their own frequencies and their own network code (MNC) to route their traffic.

This solution makes use of interfaces recently standardised by 3GPP.

## 16.5 Level 5: Sharing network core elements

This level is defined by the sharing, in addition to radio equipment, of network core servers. The "home" networks remain separated, which allows for the differentiation of services, but the frequencies and network code (MNC) are common to the shared network.

This solution also makes use of interfaces recently standardised by 3GPP.

In this solution, the operators are in a "full" MVNO situation on the shared network

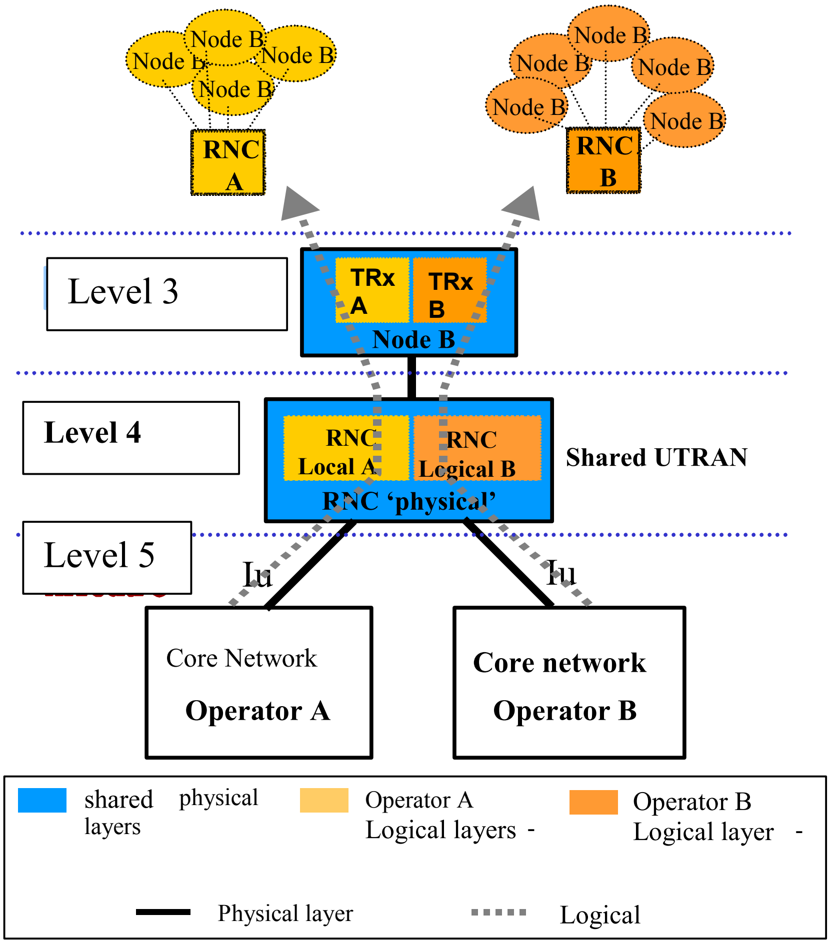



*Figure 100: Diagram showing the principle of RNC sharing*

# 17. APPENDIX D: LIST OF FIGURES

# 18. APPENDIX E: LIST OF TABLES