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Techno-economic analysis of beyond 3G mobile technology alternatives

Jarmo Harno

Abstract
Purpose – The purpose of this paper is to show how the bulk of the mobile telecom traffic is starting to migrate towards internet and IP based services, and the choice of alternative paths is widening as new technologies from different backgrounds are emerging. This paper aims to compare some possible approaches to find out suggestions for the most feasible technology selections.

Design/methodology/approach – The case study focuses on big Western European operators being in the position to choose the 3G and beyond technology track – whether continuing to the UMTS path or taking a more radical shift towards a full IP based WiMAX technology. The work includes full quantitative modeling of both cost and revenue sides, separating the network provisioning business from the service provisioning for more detailed economical analysis of the technology choices. For the revenue estimation, specific user benefit modeling has been performed against the technology related parameters. Special emphasis in this paper is on the risk and sensitivity analyses, which reveal more of the case dynamics than bare economic key figures.

Findings – The UMTS/HSPA path was found to be the most beneficial and robust continuum for the European incumbent mobile operator. Basing the new data services on WiMAX technology was identified to include more risks, although for an operator not having a license for UMTS network it provides a possibility to serve the high end advanced users profitably. The challenge lies especially in the narrower terminal and user base. In the worst development scenarios, especially the network provider of WiMAX is vulnerable, as making big investments on the network.

Research limitations/implications – Not all possible business cases were analyzed, so that no conclusion can be made, based on this study, on operators without wide GSM background, or WiMAX approaches of a limited scope.

Practical implications – The study gives support for the operators in deciding on strategic deployment plans.

Originality/value – The study provides unique information through comprehensive data gathering, analysis and forecasts, with feasible accuracy level for this kind of case study, combining both technical and business aspects of the still widely uncharted and fast developing mobile data arena.

Keywords Telecommunications, Mobile communication systems, Management strategy

Paper type Case study

I. Introduction

This study focuses on business cases of an incumbent mobile telecom player, i.e. one who has an existing 2G network with large customer base and wants to deploy its own 3G network to survive in the new 3G and beyond service competition. The study is based on the work within the EUREKA CELTIC initiative project ECOSYS, started in the beginning of the year 2004.

The scope here is a typified “Large” Western European country with population of 65 million, as defined in Table I. This study setting includes, and compares, two alternatives: a UMTS deployment, and a new competing 3G technology deployment in the supply of the new broadband mobile services. We are here concentrating on incumbent players, having
usually a clear connection between the service operator and the network operator sides of
the business. Therefore, in this scenario we have only one service operator and one network
operator linked together. Even as such, this separation gives interesting insight to the
economical dynamics in and between these entities.

The licensed UMTS operator builds on UMTS plus HSPA technologies, continuing to 3GPP
LTE in the long run. The LTE, however, is not modeled in this study, due to the time scope,
which does not allow for the full revenue potential related to the investments. The competing
3G technology selected here is mobile WiMAX (IEEE 802.16e) deployed in the licensed
3.5 GHz spectrum. The width of the used frequency band is supposed to be 10 MHz. The
characteristics of WiMAX include full IP compatibility throughout the network, and an
effective OFDM radio frequency utilization. Within both basic alternatives full GPRS
coverage is already built, and EDGE technology is utilized for a fast initial upgrade for new
services. Especially in the WiMAX case the EDGE technology is crucial, as the WiMAX
technology is available later than UMTS, and due to the shorter range of the cells, it is not
feasible to cover the suburban and rural areas with mobile WiMAX. This is much due to the
relatively high 3.5 GHz frequency band utilized.

As all the investigated technologies from GSM to UMTS or WiMAX differ in parameters that
affect the user experience and thus the service take-up and usage, the modeling of these
characteristics is very important. To analyze this effect, we have utilized a separate End-user
model.

This study aims to find answers to the following types of questions: Is it possible, in the
Western European context, to utilize alternative technologies to compete with UMTS, if no
license for UMTS frequencies is possessed? Is an intermediate EDGE deployment feasible
or necessary? How will the business situation differ for the service operator compared to the
network operator? What are the differences, in respect to new services and their revenue
potential, between the available radio technologies? What impact on economical end results
would the differing cost structures of the studied approaches generate? What are the
economical opportunities, potential risks and vulnerabilities in each case?

In this study, three technology cases are compared: “UMTS with HSPA”, “UMTS without
HSPA”, and “WiMAX deployment”. All the cases are including initial EDGE deployment that
complements the more advanced technologies that are deployed later. It is clear from the
earlier results that the EDGE deployment is vital for the profitability, especially for the mobile
WiMAX Network Operator (Harno et al., 2005).

II. Assumptions

A study period of eight years and a discount factor of 15 percent are used in the analysis.
The defined values of the parameters are based on data provided by the partners of the
ECOSYS consortium from their field data, forecasts, tests and simulations.
Country characteristics

One generic country type has been modeled: Large Western European country, like France, Germany, Italy, or UK.

Markets and services

Customer segments. Customer segmentation is one of the key assumptions made for estimating the market demand and service usage in our model. The subscribers are divided into four exclusive customer segments, and the percentage split between those is assumed to be as follows:

- Business subscriptions: 20 percent.
- Youth subscriptions: 20 percent
- Advanced user subscriptions: 20 percent
- Basic subscriptions: 40 percent

Service characteristics and pricing. Assumptions regarding service classification and pricing are presented in Table II. The service prices are assumed to be, on average, same for all segments.

Network architecture

Figure 1 shows the generic network architecture used in the modeling, and the mapping of different network elements to certain sites in the architecture.

In our modeling, we consider four different kinds of equipment sites to exist. The BTS sites are housing the radio base station equipment, radio transceivers (TRx), and related mast, cabling, and antenna equipment. The BSC/RNC sites house the base station controllers, whereas the MSC sites are housing the switching equipment. Centralized OMC sites are housing all the support systems and servers.

Network elements. Table III shows assumptions regarding the cost and capacity characteristics of some of the key radio network elements. Only radio network elements are presented here as they comprise about two-thirds of the total network investments. For control, core, operation and support, and service related elements and prices, refer to the ECOSYS deliverables (ECOSYS, 2005). For many elements, like base stations, the anticipated annual price reduction is about 15 percent in the beginning of the study period (price curve with several parameters applied (Olsen et al., 1996)).

Network dimensioning. Network dimensioning aims at calculating the optimal number of network elements (including nodes and links) that fulfill the capacity, coverage, and quality of service demands of the service area at minimal total costs (OPEX + CAPEX).

<table>
<thead>
<tr>
<th>Table II</th>
<th>Service classification and pricing</th>
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<tbody>
<tr>
<td>Subscription</td>
<td>SIM card</td>
</tr>
<tr>
<td>Voice</td>
<td>Make and receive calls</td>
</tr>
<tr>
<td>Video call</td>
<td>Make and receive calls</td>
</tr>
<tr>
<td>Push-to-talk over cellular</td>
<td>Make and receive calls</td>
</tr>
<tr>
<td>SMS</td>
<td>Send and receive messages</td>
</tr>
<tr>
<td>MMS</td>
<td>Send and receive messages</td>
</tr>
<tr>
<td>E-mail</td>
<td>Retrieve and send e-mails</td>
</tr>
<tr>
<td>Transactions</td>
<td>Ringtones, images, payments, etc.</td>
</tr>
<tr>
<td>Downloads</td>
<td>E.g. music files and games</td>
</tr>
<tr>
<td>Browsing</td>
<td>Browse to web sites and content</td>
</tr>
<tr>
<td>Streaming</td>
<td>Audio streaming</td>
</tr>
<tr>
<td>Other data</td>
<td>Business data etc.</td>
</tr>
</tbody>
</table>
The network dimensioning in the business cases is modeled according to the following logic:

- Traffic demands in different area types are calculated based on the service usage forecasts.
- The amounts of radio base station sites and transceivers are calculated for each area type based on the cell range and capacity assumptions.
- The amounts of core network elements like BSC/RNCs and MSCs, SGSNs, GGSNs are calculated from the base station amount, generated traffic load and subscriber/user amount based on the network element capacities.
- The amounts of backhaul and core transmission links (BTS-BSC, BSC-MSC, MSC-MSC) are calculated based on network architecture, generated traffic, and available link capacities. Transmission network is not built by the operator themselves, but leased, and the costs are thus included in the operational expenses.
- The amounts of OMC-related and value-added service elements are calculated based on capacity figures relating to number of transactions, service requests, messages, and users. In some cases, just one element is needed per operator.

For radio network dimensioning, the required assumptions include both coverage and capacity related parameters, as shown in Table III.

**Operational expenditures**

The following generic breakdown is used to distribute the relative OPEX costs according to the available information:
Group A: network related elements.
Group B: marketing and sales related elements.
Group C: customer service related elements.
Group D: IT, support and service development elements.
Group E: interconnection and roaming costs.

Our estimation for monthly OPEX costs is 13€-39€ per subscriber and can be further divided according to the grouping presented above, based on the knowledge and history data we have on the GSM operators. Here again we perceive much variance between different kinds of operators. Diverse competition strategies are available that affect immediately one or more of the OPEX groups: high or low network quality, big or small marketing investments, good or moderate customer service, etc.

For reference, the estimated W-European division of total network and service operator OPEX in the case studies is as follows:

- Network related elements – 20 percent.
- Marketing and sales related elements – 26 percent.
- Customer service related elements – 8 percent.
- IT, support and service development – 11 percent.
- Interconnection and roaming costs – 35 percent.

**Leased line rental.** Costs relating to the base station backhaul and transport network connecting the BSC sites and core sites are modeled as leased lines and thus included into the operational expenditures. The required number of base station sites, BSC/RNC sites, and core network elements in each area type are calculated according to the principles described in the Network dimensioning section. The assumed number of MSC sites and their interconnection links is 15 nodes and 23 links (providing redundant paths).

The number of leased lines between base station sites and RNC/BSC sites, as well as between RNC/BSC sites and MSC sites are calculated based on the traffic amounts. The required leased line lengths are calculated based on the assumptions shown in Table IV.

When the exact number of transmission links and their lengths (node distances) are known for each year, the related leased line costs (OPEX) are calculated according to Table V.

It should be noted that the leased line prices in different countries may vary substantially.

<table>
<thead>
<tr>
<th>Table IV</th>
<th>Geographical distances between key network components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distances (km)</td>
<td>Dense urban</td>
</tr>
<tr>
<td>BS/BTS – RNC/BSC</td>
<td>2</td>
</tr>
<tr>
<td>RNC/BSC – MSC</td>
<td>10</td>
</tr>
<tr>
<td>MSC – MSC</td>
<td>$2 \sqrt{\frac{\text{CountryArea (km}^2)}{\pi \times \text{NumberOfMSCs}}} = 177\text{km}$</td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>Table V</th>
<th>Leased line tariff assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>Basic price per line/year (2005) (€)</td>
</tr>
<tr>
<td>2Mbit/s (BS/BTS – RNC/BSC)</td>
<td>5,400</td>
</tr>
<tr>
<td>155 Mbit/s (RNC/BSC – MSC)</td>
<td>16,913</td>
</tr>
<tr>
<td>Up to 10Gbit/s</td>
<td>–</td>
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</table>
III. Modeling

The analysis was carried out using a techno-economic tool and modeling principles developed in the ECOSYS project (ECOSYS, 2005). The tool is an implementation of the techno-economic modeling methodology developed by a series of EU co-operation projects in the field. For publications relating to mobile networks, see Katsianis et al., 2001, Varoutas et al., 2003 and Varoutas et al., 2006. Same methodology and tool has been applied also to fixed networks (Ims, 1998 and Monath et al., 2003).

Network operator modeling

Technology alternatives. UMTS technology is modeled as an evolution path for GSM, GPRS and EDGE technologies. WiMAX technology has been modeled to represent an alternative technology approach for an operator with GSM, GPRS and EDGE networks, but not having a UMTS license.

In this case study UMTS is deployed with HSPA capability from the beginning (year 2006) and the network is ready for use starting from the most dense areas in the year 2007. WiMAX network is deployed one year later, and launched commercially in the beginning of 2008. Worse availability of WiMAX handsets is reflected in the lower service take-up figures in the beginning. Also the HSPA capable handset penetration is assumed to grow gradually starting from 2006, so that the HSPA extra capacity is utilized only according to this user penetration.

Revenues. The generated traffic amounts are calculated in the service operator model, which is in close co-operation with the network operator as described earlier. The wholesale prices that the service operator pays to the network operator in the year 2006 are as follows, with 15 percent yearly price reduction applied thereafter:

- Narrowband conversational (voice): 0.011 €/min (inbound and outbound).
- Wideband conversational (video telephony): 0.043 €/min (inbound and outbound).
- Data: 0.15 €/MB (both directions).

The annual price reduction is quite substantial compared to the average tariff erosion in the recent years, but is in accordance with the high increase of traffic foreseen. At this phase the data traffic pricing is not differentiated between, e.g. streaming, interactive, or background traffic classes.

Investments. The study period starts in the year 2006 (first calculated investments) and continues until the year 2013. In the beginning, the network operator has the GSM capacity built up to support the traffic level of the year 2006. The initial, quite low data traffic is also supported by the deployed GPRS and EDGE coverage and capacity. After that point, the additional GSM/GPRS and EDGE capacity required is rolled out and calculated in the model.

The UMTS deployment starts at the same time in all area types, except in Rural area, where it starts one year later. It is assumed to take one year to cover the dense urban areas, two years for the urban, three years for the suburban, and six years to cover the whole rural area. Figure 2 shows also the percentage of HSPA packet data traffic out of total traffic in the UMTS/HSPA case, taking into account that HSPA utilization requires special terminal support.

WiMAX rollout starts one year later and the Suburban and Rural areas are not covered with WiMAX at all, as the calculations show them to be economically unfeasible. The development of population coverage for different technologies is presented in the Figure 2, where also the WiMAX share of the traffic has been indicated. VoIP has been assumed to be utilized over the WiMAX network.

The usage amounts of EDGE and UMTS or WiMAX are dependent on the network rollout, as the usage is calculated only if the user is in the coverage area of the networks. The lack of high capacity technology leads to lower usage patterns, as indicated in the following sub-chapter “Services and revenues”. 
In the network operator case, the major part of the investments are for the radio network (in all cases over 85 percent, when BSC/RNC part included). It should be noted that service related elements reside mostly in the service operator side, and the transport network costs are modeled here as leased line costs and included in the operational expenses.

Operational expenditures. The termination and roaming costs as well as the related revenues are not modeled explicitly in this case study. The termination revenues and costs are assumed to largely compensate each other in near future due to increasing share of mobile telephony and regulatory control over price discrimination between access networks. Also the high profit margin in roaming charges is currently showing signals of radical changes due to EU regulation and initiatives of large operators. Anyhow, it should be noted in relation to these results that one factor of the current profit margins is not included here.

The operational expense profiles differ also between technology solutions, but not so much as is the case with investments. The differences originate from the different site amounts to be deployed. As the network operator is not selling to the end-users or supporting the end-user services, the operational costs are related mainly to site rentals, leased line costs, network operation and maintenance and support systems. When compared with the generic OPEX distribution in the Assumptions chapter, it can be seen that the network operator share of the total OPEX - if the big share of interconnect and roaming is left away – is roughly at the level of 25 percent, the rest being allocated to the service operator.

A high-level operational costs breakdown as a pie chart of average values and the yearly development figures of the HSPA and WiMAX operators are presented in Figures 3–5. Comparison of total OPEX between the cases is presented within the final results.

Service operator modeling

Services and revenues. Demand modeling is based on penetration estimates for different technology subscribers in selected segments and their forecasted usage patterns. End-user model gives the usage amounts for active users of each service, per each segment and each technology. For End-user modeling, please refer to Pohjola and Kilikki, 2004 and the Appendix A in the Deliverable 9 (ECOSYS, 2005).

The end-user modeling gives the usage figures relating to the specific technology parameters given for each investigated technology. On these figures we have applied the market size and market share of the operator, technology penetrations, and rollout schedules, to get the user amounts. As the end-user model gives the usage volumes for active users of each service in each segment and technology, we have in addition estimated
the penetrations of active users of each service type in each segment and technology. These figures are discussed below, after the technology penetrations.

**Technology penetrations.** Estimated percentages of different technology subscribers are based on terminal/handset penetrations. When the population coverage is incomplete, the potential usage and traffic amounts realize only partially, i.e., according to the available coverage. The figures are dependent on the particular network operator and service operator provisioning. The population coverage development by the network operator was presented in Figure 2. It should be noted that, e.g., EDGE penetration is tracked here as for operator who provides EDGE network, not as general EDGE penetration. If no 3G technology, apart from EDGE, is provided, the EDGE penetration partly substitutes this. The penetrations for users of different technologies are presented in the Figure 6. Those data users not having any of the presented technologies are supposed to use GPRS.

Subscribers utilizing more advanced technologies are supposed to have also the less advanced technologies in use. WiMAX penetration is estimated to be clearly lower than UMTS, due to the terminal availability, plus form and price factors. Potential laptop users, for example, are considered to be much less than pocket size handset users.

**Penetrations of active users.** The customer base is supposed to be 16.5 million in the year 2007, comprising a 30 percent market share of mobile users from the total population of 65 million. The penetrations of active users are out of this user base. Voice and SMS services are supposed to have 100 percent penetrations in all segments. Each technology induces slightly different penetrations for data services, so that higher capacity technology imposes more users, but this increase is not as significant as the usage amount difference calculated in the end-user model.

**Revenues.** The service operator’s revenues are calculated by combining the technology related user behavior from end-user model (usage amounts for the selected price level), with segment sizes and related actual active service users. The earlier the enhanced technology is deployed, the more traffic is generated, but only in the limits of general demand development and terminal availability. The generated average revenues per user (ARPU) for each technology case are discussed below in the Results chapter. On the other hand, also the costs are higher for early capacity provisioning.

The termination and roaming revenues are not modeled explicitly in this case study, neither the related costs. The termination fees are largely compensating the respective costs and also the high profit margin in roaming is currently showing signals of radical changes due to EU regulation and initiatives by large operators. Anyhow, it should be noted in relation to these results that one factor of the current profit margins is not included here.

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**Figure 6** Potential users of different technologies

![Figure 6](image-url)
Service operator OPEX

Service operator’s most important OPEX cost item is the wholesale charges paid to the network operator. The wholesale tariffs used between the network operator and service operator were presented within network operator modeling.

The tariffs are assumed to be technology independent for both wholesale and retail services, but as discussed above, the technology has an effect on the traffic amounts and thus on total revenues and to a smaller amount on the total costs.

The second most important operational cost items for the service operator are related to services, end-user support, sales and marketing. OPEX development over the study range for HSPA and WiMAX cases are presented in the Figures 7 and 8.

As the wholesale charges are between network operator and service operator, i.e. internal transfers in this case, and as also interconnection and roaming costs are compensated by respective incomes and not counted in here, the service operator share of the residual generic OPEX is roughly at the level of 75 percent. Total OPEX comparison between the technology cases is presented below in the Results chapter.

IV. ARPU examination

The operator results are based on pricing and traffic amounts related with each technology alternative. The end-user prices were presented in the Assumptions chapter. The traffic amounts are technology dependent, and based on end-user model.
The voice and data traffic development depends on the technology. The voice does not have much difference; only slight quality of service (QoS) benefit is assumed for UMTS users. On the data traffic, the QoS is estimated to make a clear differentiation for the advantage of the higher bit rate and lower latency technologies. Network operator revenues are directly based on traffic amounts and wholesale tariffs (voice/data), but service operator revenues relate to end-users of different segments and technologies, and their service related ARPU figures.

The ARPU development is derived from the service usage and end-user pricing data, as the subscriber amounts and active service users in each segment are taken into account. The ARPU development, if plain GPRS is provided is clearly declining, but the average ARPU throughout by segments for those users who have the UMTS service is staying stable. It should be noted that as not all subscribers have the UMTS service, this ARPU is above the total ARPU of the operator. The year 2006 ARPU figures are given for reference to the current situation, although the business cases have been calculated as service and revenues starting from year 2007.

As mentioned before, termination and roaming revenues (or the related costs) are not modeled explicitly in this case study. The termination fees are largely compensating the respective costs and also the high profit margin in roaming is currently showing signals of radical changes due to EU regulation and initiatives by large operators. Anyhow, it should be noted in relation to these results that one substantial factor of the current profit margins is not included in the ARPU.

In the current situation the roaming revenues (mainly relating to roamers from abroad that visit the network) could have produced well over 10 percent of the operator revenues, though varying operator by operator – and as the costs are not in relation to the roaming charges, the impact on profit could have been even more than that. Own subscribers roaming abroad are charged by the operator, but most of this revenue is paid furthermore to the visited operator. All in all, the roaming revenues are very much dependent on the customer base and roaming agreements with operators in other countries, and alliances. The roaming and termination fees have related mainly to circuit switched traffic, especially voice service, and the revenue migration to data services and even to Voice over IP (VoIP), will change the situation. This change depends also on the future IP network interconnection solutions.

In the end of the study period, the ARPU difference between the higher and lower level technologies have reached a substantial level. The results indicate that the lowering revenue trend can only be fought back with the advanced technologies. For earlier forecasts and suggestions for 3G competition in Europe, see, e.g. Harno, 2002; 2005.

V. Results with risk and sensitivity analysis

The most important parameters and modeling aspects were presented in the previous chapters. Here we present the model outcomes with these base case assumptions together with the sensitivity analyses, taking into account the uncertainties within the assumptions. Statistical simulations give also light to the risks involved in the business cases. Further on we proceed to the conclusions that we can draw from the modeling results.

The parameter values, relating to new service take-up, user behavior (=> service usage), data traffic volumes, tariff levels, revenues (ARPU), market shares and technical radio network parameters are only estimates, best available expert guesses, and we should consider the impact of deviation related to each factor. Because of the long time horizon, the new technologies and especially the services that we do not have any experience yet, we cannot provide exact economical figures for specific business cases. To serve the strategic decision making, it is seen to be more important to have some means to compare the alternative scenarios by estimating the opportunity and risk profiles of these alternatives, rather than just provide one set of key figures.

In the sensitivity analysis, the selected parameter set has been varied using the normal distribution. The model results are then run with parameter values drawn randomly from
these distributions (Monte Carlo simulation). As a result, the parameters are listed in the order of significance, according to their impact on the results.

In the risk analysis the result distributions are presented, supplemented with Value at Risk (VaR) measurements, commonly used for financial portfolios (ECOSYS Deliverable 11, 2005). VaR reflects here the riskiness of the business case, and presents the upper limit for the lowest 5 percent of the stochastically calculated possible results. Hence, it represents the minimum result that can be reached with high (95 percent) certainty. The total variance, as the sum effect of all parameter variations together, is presented too, reflecting in a way the ‘volatility’ of the particular business case.

For the sensitivity and risk analyses, Monte Carlo simulations were run using the Crystal Ball™ software. Parameters were varied stochastically by using multiplier varying according to Normal distribution with the following settings: Mean = 1.00, Std. Dev. = 0.10, Trials = 1,000. In addition, as mobile WiMAX launch schedule is not yet secured, we have used a delay parameter and made an assumption that the WiMAX penetration delay follows the exponential distribution. The WiMAX penetration delay varies from 0 to 1 year. The Rate parameter used in the exponential distribution is 3.00. The factors varied for the cases are:

- Penetration of 3G services (relates to penetrations of the individual services, i.e. percentage of the active users).
- Data service traffic (relates to usage amounts of the data services by the active users, but the revenue is kept constant; data service revenue, contrary to voice service, is not tightly connected to the traffic volume).
- Data service ARPU.
- Voice ARPU.
- Start market share.
- End market share.
- Wholesale tariff per minute.
- Wholesale tariff per MB.
- UMTS/WiMAX cell radius (affecting only network operator case).
- Equipment investments (significant only in network operator case).
- WiMAX penetration delay.

Results of the risk and sensitivity analyses

The following figures present the base results with risk and sensitivity analyses for the UMTS/HSPA and mobile WiMAX cases.

Service operator with UMTS + HSPA.

- Discounted cash balance in base case – 5.16 B€
- Mean/median discounted cash balance – 5.13 B€/5.05 B€
- St. deviation of discounted cash balance – 1.30 B€/25%
- Value at risk, VaR (q = 95 percent) – 3.06 B€

From these results we can see that the UMTS/HSPA Service Operator case is quite robust – not a big variance and clearly positive value at risk. The Start market share is the most important single parameter in this case reflecting the good profitability of the voice service still in the beginning and discounting that relates to the uncertainty of the future revenues. ARPU levels of both voice and data services are very important for the service operator results in the UMTS/HSPA case; more important than the penetration development of the services, as some of the services will reach the ceiling of 100 percent penetration during the study period with no room for growth, and on the other hand the usage also increases the traffic and thus costs for the service operator. The cost side, meaning wholesale tariffs and data volumes, are not as important for the service operator, and as data services (measured
in MB) dominate only in the later period, their total impact is lower than that of the voice services (measured in minutes) (see Figures 9 and 10).

Network operator with UMTS + HSPA.
- Discounted cash balance in base case – 1.23 B€
- Mean/median discounted cash balance – 1.21B€/1.19 B€
- St. deviation of discounted cash balance – 0.86 B€/71 percent
- Value at risk, VaR (q = 95 percent) – −0.15 B€

Figure 9 Risk analysis: service operator with UMTS + HSPA

Figure 10 Sensitivity analysis: service operator with UMTS + HSPA
From these results we can see that the UMTS/HSPA network operator case is not as robust as the service operator case, but has a substantially higher variance (volatility) against the input parameters. The value at risk is slightly negative. The income side of the network operator, especially the wholesale tariff of the voice minutes is clearly the most important factor for this case. The data tariff is less important, but its impact is increasing towards the end of the study period. Start market share of the service operator counterpart is also highly important. The next five factors are quite near each other in impact. For the network operator it is the better the more data intensive the services are as generating more wholesale revenue. The cost related technology parameters cell range and Investment price level have reasonable significance. Cell radius is slightly more significant, as most of the investments go to the radio network, and cell radius increases the radio network costs more than linearly. End market share impact shows up as rather modest over the study range analyzed, as also investments are reduced with lower market share, but surely it has an essential effect on the position after the study period (see Figures 11 and 12).

Service operator with WiMAX.

- Discounted cash balance in base case – 4.39 B€
- Mean/median discounted cash balance – 4.48 B€/4.42 B€
- St. deviation of discounted cash balance – 1.09 B€/24 percent
- Value at risk, VaR (q = 95 percent) – 2.37 B€

Again for the service operator, as in the HSPA case, the case is quite robust, reasonable variance (volatility) and clearly positive value at risk. The Start market share is again the most important single parameter reflecting especially the good profitability of the voice service still in the beginning. Voice ARPU is very important for the WiMAX service operator results, but the data service ARPU not so much – due to the limited data user penetration in this case. For the same reason the significance of the Wholesale tariff per MB is low compared to other parameters. End market share has higher relative importance for the WiMAX service operator than for the UMTS/HSDPA operator, higher than the Penetration of the 3G services or Data service ARPU. WiMAX penetration delay has minor significance, because its penetration is anyhow assumed to grow only towards the end of the study period; in the early days the EDGE technology compensates well the lack of WiMAX provisioning (see Figures 13 and 14).
Network operator with WiMAX.
- Discounted cash balance in base case – 0.20 B€.
- Mean/median discounted cash balance – 0.12 B€/0.13 B€.
- St. deviation of discounted cash balance – 0.67 B€/580 percent.
- Value at risk, VaR (q = 95 percent) – – 1.04 B€.

The WiMAX network operator case is clearly unstable having a very high variance (volatility). The value at risk is deeply negative in comparison to the low mean result. For the WiMAX network operator case, the start market share and wholesale tariff per minute (voice) are...
dominating. This reflects the situation where the operator is very much relying on the strong position of the mobile voice in the beginning. As seen from the sensitivity graph, the technical parameters are important, but not comparable to the first two. End market share is significant in the HSPA cases and WiMAX service operator case, as it relates to the revenues and profits in the later period. However, in the WiMAX network operator case the increased traffic and revenue is almost totally cancelled out by the needed auxiliary investments. WiMAX penetration delay again has minor significance also for the network operator (see Figures 15 and 16).

With the assumed penetration of WiMAX among its large customer base the WiMAX service or network operator cannot make the 3G data services very significant part of its business, although they are important in keeping the high end subscribers. A different kind of business
case, however, would give different view on WiMAX based approach: e.g. a start-up business building a new customer base relying in all provided services on WiMAX terminals and network. It might be geographically or service-wise focused to some customer groups.

From the risk analyses we can conclude, in the first place, that the service operator cases are more robust than the network operator business cases. The mobile WiMAX network operator case is particularly vulnerable, as being not very strongly positive in the first place, and having a very high volatility, leading to clearly negative value at risk (VaR). Both network operator cases have high volatility (standard deviation) in the results compared to the service operator cases. This is at least partly because of their investments compared to revenue are clearly higher than in the service operator cases; this increases the possibility of higher losses and thus the level of risk.

To improve the analysis especially of the network operator cases, Real Options methodology could be applied. As including the possibility to introduce flexibility in investment decisions, it would potentially increase the accuracy of the modeling, in allowing deferring or completely abandoning investments in case of low demand. This would decrease the losses in the down side of the potential outcomes, thus possibly increasing the value at risk.

VI. Conclusions

In this business case modeling we have studied European operator with high market share, continuing into 3G services from the basis of GSM, GPRS and EDGE. The UMTS path is seen to lead to first HSDPA, then to full HSPA, and eventually possibly to the 3GPP LTE type of radio network. However, due to the study time frame (2006-2013), the full LTE technology introduction has not been included into this study. The mobile WiMAX case is also first relying on the EDGE technology, but the high data traffic users are later served with WiMAX radio in addition to GSM/EDGE.

The presented results give light to the dynamics of the beyond 3G operator cases with different technology paths. When interpreting the results, it should be paid attention to the presented parameters that restrict the applicability to certain types of operator cases. Moreover, it should not be looked to only one figure to rank the cases, but to look at the sensitivity relating to different parameters and the volatilities in the results. Analyzing the network operator part and service operator part separately gives more informative results.
than doing the analysis as combined case, even though both functions may be part of one operator business.

The results of this comprehensive modeling indicate that both the UMTS path and the approach to build on mobile WiMAX technology can provide for feasible business within the selected framework. However, in the big mobile operator framework the UMTS path is indicated to be more profitable, leading to more secure position in the end of the study period, and to be more robust as analyzed against the identified uncertainties.

Especially the WiMAX network operator business case proves to be risky, but if combined with WiMAX service operator business case, the total case gives good results and has also a positive value at risk (VaR) indicator. Although in the UMTS/HSPA case the operational profit rate is near the same level for both service operator and network operator, the risk analysis results suggest that the network operator should be given bigger part of the revenues, which indicates that the wholesale price level should be higher. The higher share of irreversible investments should be compensated by higher expected returns.

When looking beyond the year 2013, high-speed IP data traffic will continue to grow in importance. Thus introduction of high capacity technology through UMTS path or WiMAX will be essential in the competition. In the Western European context, this study suggests that the UMTS/HSPA approach would give the most lucrative path for the high market share incumbent operator, due to the potential for high take-up of new services, provided cost effectively for the high-speed data users during the studied time period. The recent market development gives confirmation to the presented results and reasoning as almost all of the Western European incumbents have chosen to deploy the UMTS/HSPA network, and hardly any mobile WiMAX approaches have been seen yet.

References


About the author

Jarmo Harno received his MSc degree in Mathematical Analysis from the University of Helsinki in 1983. After working in SW industry he joined Nokia in 1987, and has worked as systems analyst and manager in R&D, Quality Assurance and Product Management. He started as a senior research scientist on techno-economics with Nokia Research Center in 2001. As doing research on the future telecom technologies and service concepts, he has also participated in the EU IST framework co-operation project TONIC (2001-2002) and EUREKA's CELTIC co-operation project ECOSYS (2004-2006), as the work package leader for mobile technologies. Mr Harno is an author of several journal articles and conference presentations relating to techno-economics, and an inventor of some patents relating to telecom technology and services. Jarmo Harno can be contacted at: jarmo.harno@gmail.com