TECHNOECONOMIC EVALUATION OF MULTISERVICE
BROADBAND ACCESS NETWORK ALTERNATIVES

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Summary

Techno-economic implications of broadband upgrade strategies for the access network are addressed in this paper. An aggressive ATM-PON upgrade solution is compared to a more conservative upgrade solution with enhanced copper technology combined with point to point fibre connections for the highest bandwidth demand. In addition the effect of competition on the overall budget is studied. The methodology developed within the RACE 2087/TITAN project is applied. The comparison of various access network architectures for broadband presented in this paper, show that the cost difference between very modest access network upgrading strategies and considerably more aggressive solutions can be marginal compared to the overall investments associated with any upgrading alternative. Since the cost of bandwidth is high for all technical solutions future-proof technologies should be favoured.

1. Introduction

The telecommunications network operators of today are faced by the challenge of how to develop the existing narrowband copper based network infrastructure to a broadband access network. Cost effective, future-proof broadband access networks accommodating a wide range of demographic diversity for a set of bearer services with different bandwidth requirement will be required. Strategies for developing the traditional access network, along a cost effective path, flexible enough to serve a complex set of customer demands are crucial for the operators. In this paper a techno-economic comparison of architectures enabling a cost-effective migration of the existing narrowband network towards a broadband access network is carried out. The emphasis is on the technological possibilities and their economic implications.

In the highly competitive environment expected at the end of the century, some specific market segments are assumed to be more sensitive to competition. In the present paper, the effect of competition is analysed. The competition is modelled by an independent linear reduction during the study period in the service penetrations of the business and residential market segments respectively.

2. Techno-economic methodology

The methodology for the analysis of access networks for a mixed residential and business marked is developed within the RACE 2087/TITAN [1] project. The TITAN Tool is intended to assess any kind of access network architectures like star-, bus-

and ring-structures, or combinations of these. A variety of services with any estimated penetration within the study period are considered. The length of the study period is flexible. Hence, scenarios may be derived, in which network and service evolutions are taken into account.

The economic viability may be estimated for a range of service penetration sets and different kind of access networks. The techno-economic evaluation is performed in several stages: calculation of the installed first cost, running costs, life-cycle costs, revenues, annual cash flows and the cash balance of the investment project. Thus, various access network architectures - optical or hybrid - may be compared through a global system assessment.

Initially, appropriate architectures which can provide a selected group of services are chosen. The parameters relevant to the engineering of the network, such as subscriber density and type of civil works must be defined. Civil works encompass digging, ducting and surface reinstatement. The cost per unit length depends on the area type, the distance from the exchange and the technology used. Conventional techniques consist of ducting and subducting for subsequent pulling of the cables through the conduits. These parameters are the inputs to one selected geometrical model which calculates the overall cable length of the various sections of the network. The geometrical model used here is depicted in Figure 1.

Duct availability which indicates the degree of usability of existing ducts, is an important input to the TITAN tool. Duct availability depends on the existence of empty duct space or ducts likely to be freed through obsolete network replacement. This modelling parameter enables a sensitivity analysis with respect to the civil works configuration. Compared to copper, optical fibre cables need significantly less duct space. This is accounted for, by differentiating the duct availability factor.

2.1 Component cost evolution during time

The costs of the network components are calculated using an integrated cost database developed within the TITAN project. The database contains data gathered from many European sources. The costs of the database elements are typical European averages. The database includes costs at a given reference year for components, installation, civil works and parameters defining Operations and Maintenance (OAM). Learning curve data together with demand estimates classified in relevant groups, are included in the database.

By combining a standard demand logistic curve for the growth over time of the accumulated component volume with a learning curve, every component can be classified by four parameters [2]. These are the component price in a given year, the learning curve coefficient, the time it takes for the accumulated volume curve to go from 10% to 90% of the saturation value and the value of the accumulated volume today. The final expression contains all the four parameters involved in the component price versus time and is used as basis for the studies.

2.2 The operation and maintenance costing approach

OAM costs are calculated using inputs from the cost database in order to produce life-cycle costs [3]. The conventional analytical method to calculate OAM costs is accurate only for very specific network in a very specific and well defined environment. The application of these results to other network architectures is not very precise.

Due to this fact TITAN adopted a simpler solution, the «proportional» approach, in which the OAM costs are related to the total capital investment. This is justified simply by the fact that capital costs usually can be related in some way to complexity, functionality, size, power and construction of hardware.

OAM costs include preventive and corrective maintenance, network management and use of installed plant and repair of defective equipment. Total OAM costs have been divided in two parts:

- Administration and Provision, representing 60% of the total OAM costs.
- Maintenance and Fault, accounting for 40% of the total OAM costs.

New architectures with a centralised computer based administration will affect the first part, while new technology, powering strategies etc. may affect the last part.

The revenues determined from given tariffs and demand estimates together with the life-cycle costs, lead to the overall financial budget of the system considered.

The impact of key parameters such as subscriber density, civil works costs, key component costs, service penetrations, tariffs and market loss can be highlighted through various sensitivity analyses.

3. Demographic areas studied

Two different mixed demographic areas have been studied, one downtown business area and one suburban residential area. The two main differences between the areas are the housing structure and the distribution of the customer groups.

Area 1, Downtown:

This is a business dominated area, with 90% business customers and 10% residential customers. The customers are located in large buildings, either business blocks or apartment blocks. The area represents a typical central part of a city.

Area 2, Suburban:

This is a residential customers dominated area, with 90% residential customers and 10% business customers. Both the business and the residential customers are located in individual houses. The area represents a typical suburban area.

In both areas one fourth of the business customers are assumed to be medium to large businesses. The spread of customer categories is shown in Figure 2 and Figure 3.
The assessment is based on several general assumptions:

The calculations include both greenfield and non-greenfield situations. In non-greenfield each of the areas has a modern copper based infrastructure in the distribution part. Considered here is only the portion of the network between the Local Exchange (LEX) and the customer premises.

Optical fibre is already installed in the feeder section connecting several Service Access Points (SAPs) in a ring structure. The SAP, as used in this study, refers to the network localisation of the concentrator, as used in Norway and some other European countries with modern access network infrastructures. The SAP has a capacity of 1024 users.

All cables in the upper level of the distribution network are installed at the start of the project period. However, new drop-cables (coax/fibre) and service specific equipment like modems, are installed during the study period at the time of connection of new service subscribers. There is a slight overdimensioning of the optical cables for future upgrade; the extra cost for this is negligible small.

A duct availability of 50% for copper and 90% for fibre is assumed.

4. Bearer services provided

This study only addresses bearer services, and as such relies on a transformation of higher level services into bandwidth requirements and respective bearer services. POTS, N-ISDN, 64 kb/s and 2 Mb/s bearer services are already offered over the PNO’s existing, modern copper based network. These services are expected to remain as a basic set of services for the foreseeable future. In addition, advanced asymmetric switched 2 Mb/s services (e.g. Service on Demand, SoD or Video On Demand, VoD) will be required by residential customers. Symmetric 2 Mb/s or 8 Mb/s bearer services will also be demanded by some residential and small-business customers and medium- to large-business customers.

4.1 Demand forecasts for bearer services in the residential and small-business market

The penetrations of the set of bearer services for residential and business customers over a study period from 1995 to 2005 are considered. The residential and small business market service set has been chosen based on a comprehensive international Delphi survey [4]. According to the survey, the relevant services are: N-ISDN, wideband, e.g. SoD and broadband (8 Mb/s). POTS are provided to all customer types. The penetration of the services as a percentage of the residential and small business market is shown in Figure 4.

4.2 Demand forecasts for bearer services in the business market

For the medium to large business market, representative figures for the ranges of demand are selected from available statistic material. Three alternative bearer services are provided: n-64 kb/s, 2 Mb/s and 8 Mb/s, with POTS/ISDN included for the two last services.

Penetration of the services for the study period, as a percentage of the total number of medium to large business customers, are given in Figure 5.
5. Bearer service tariffs

The residential market tariffs are based on the Delphi survey and represents what is considered to be an European average. The 1995 tariffs used in the calculations are: POTS: 160 ECU, ISDN: 530 ECU, 2 Mb/s: 2346 ECU, and 8 Mb/s: 2718 ECU. For the medium- to large-business market, representative figures for the tariffs are selected from available statistic material. The 1995 tariffs used in the calculations are: POTS: 160 ECU, 64 kb/s: 1136 ECU, 2 Mb/s: 3833 ECU and 8 Mb/s: 7667 ECU.

The tariff structure implemented includes an evolution of the tariffs during the study period. For the residential and small business market, the tariffs as a function of demand estimated from the Delphi survey for wide- and broadband connections have been derived (described in the next section). For the medium to large business market, an annual decrease in tariffs by 10% for n-64 kb/s, 2 Mb/s and 8 Mb/s is assumed.

6. Bearer services tariffs as a function of demand for residential and small-business market

Figure 6 shows the estimated demand curves for wide- and broadband connections as a function of tariff. The observations in the figure are the medians for each cost alternative in the Delphi survey. The difference between the demand curves is very small and indicates that the residential users are not willing to pay much more for a high capacity despite better quality.

The fitting of the demand curve is based on an exponential distribution with two parameters:

\[ y = \alpha e^{\beta p} \]  

where \( \alpha \) and \( \beta \) are parameters, \( y \) is the demand in percentage of the residential and small-business market and \( p \) the tariff in ECU.

7. Modelling the effect of competition

The competition is modelled by an independent linear reduction during the study period of the service penetrations of the business and residential market segments [5]. The loss of subscribers is given by the percentage lost for the two market segments at the end of the study period.

8. Architectures considered

Two different architectures based on existing technology and technology expected to become available in the near future are considered. Their main characteristics of the two options are:

**Architecture 1, Conservative option:**
As much as possible of the current infrastructure is kept during the study period, representing what is expected to be a minimum investment strategy. POTS/N-ISDN and asymmetric switched broadband are offered over the existing copper network. ADSL modems are installed for provision of 2 Mb/s Asymmetric Switched services, and HDSL is used for providing the 2 Mb/s symmetric services. Dedicated fibre connections are offered to provide the 8 Mb/s symmetric services. Hence, only provision of 8 Mb/s requires installation/changes in the outdoor cable plant.

The main difference between the application of the conservative option in the downtown area and the suburban area is the much higher civil works costs incurred by the individual housing structure of the suburban area.

**Architecture 2, Aggressive option:**

The network is extensively upgraded to an integrated fibre based network offering all services except POTS and N-ISDN, which are kept on the copper network. Customers demanding broadband services are served via an ATM-PON as shown in figure 3. The ATM-PON has an optical split of 1:16, with a 155 Mb/s upstream capacity and a 622 downstream capacity. Optical fibre is installed in the distribution part in either Fibre To The Building
(FTTB) configurations (downtown) or Fibre To The Curb (FTTC) configurations (suburban). The Optical Network Units (ONUs) are shared between customers.

The main differences between the application of the aggressive option in the downtown area and the suburban area is the outdoor installation of ONUs and the much higher civil works costs enforced by customers being located in individual houses in the suburban area.

![Diagram of Downtown area, aggressive architecture: existing copper network for POTS/ISDN, ATM-PON for broadband services.](image1)

**Figure 7.** Downtown area, aggressive architecture: existing copper network for POTS/ISDN, ATM-PON for broadband services.

![Diagram of Suburban area, aggressive architecture: existing copper network for POTS/ISDN, ATM-PON for broadband services.](image2)

**Figure 8.** Suburban area, aggressive architecture: existing copper network for POTS/ISDN, ATM-PON for broadband services.

9. Results

Calculations performed include the discounted installed first costs (IFC), life-cycle costs, revenues, annual cash flows and cash balances of the projects. The effect of network upgrade and degree of competition on the overall financial budget have been investigated.

**The economics of network upgrade**

Figure 9 shows the global discounted investment (IFC) and the global discounted revenue for the access network with and without upgrade. Both the downtown (left) and the suburban area are (right) shown. In the downtown business dominated area the proportion between revenue and investment is in the same range for the upgrade and the existing network, independent of technology choice. In contrast, for the residential suburban area the investment in aggressive technology is relatively more expensive than conservative technology. With the ATM-PON solution in this area the difference between revenue and investment is negligible, making the payback period of the project very long.

![Graph showing IFC and revenue with and without upgrade for both downtown and suburban areas.](image3)

**Figure 9.** Global discounted investment (IFC) and global discounted revenue with and without network upgrade.

Figure 10 and Figure 11 depict the cash flow and the cash balance of the aggressive ATM-PON solution, with the upgrade part and the existing network (before the upgrade) separated.

In the residential dominated area (Figure 10) the cash flow of the upgrade project is small. During the study period the upgrade cash flow remains smaller than for the existing project, resulting in the payback period exceeding ten years.

![Graph showing cash flow and cash balance for suburban, aggressive option.](image4)

**Figure 10.** Cash flow and cash balance, suburban, aggressive option.

In contrast, the downtown area (Figure 11) has a pay-back period for the upgrade project in the range of five years. At the end of the study period the cash flow for the upgrade part is greater than for the existing project.
10. Conclusions

The comparisons of the two technical solutions for broadband services in the business dominated area presented in this paper indicate that the cost difference between very modest access network upgrading strategies and considerably more aggressive solutions can be marginal compared to the overall investments associated with any upgrading alternatives. In the residential area, the long pay-back period and the low net present value of any upgrade project necessitates strategic incitements different from pure economical considerations. This will favour a conservative approach in such areas.

The effects of the linear market losses during the study period on the project is not evident, neither in the pay-back period nor in the cash balance. This is due to the fact that the pay-back period can be short compared to the effect of revenue losses and that the cash balance depicts the accumulated effect of a good project before the dramatic consequences of revenue losses are recognised. The effect of competition does not necessarily have a severe impact on the overall economic results of the project but dramatically affects future revenues.

References:


