Techno-economic evaluation of broadband access technologies:

The BREAD approach

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***Abstract*— Broadband for all is an essential element in the EU policy concerning the future ICT-based society. The overall purpose of this paper is to present a model for evaluation of different broadband access technologies and to present some preliminary results based on the model that has been carried out within the BREAD project[1].**

Key words: *Broadband ,BREAD ,access technologies, techno-economics ,introduction strategies*

1. Introduction

The aim of this paper is to present a model for techno-economic evaluation of different broadband access technologies in different geographical settings. The paper is based on work within the BREAD project. Part of the BREAD project is concerned with this techno-economic evaluation. To do this it is decided to compare the techno-economics of broadband deployment using four access technologies: DSL, Cable, FTTH and FWA and model this in four different geographic scenarios: Dense urban, Urban, Suburban and Rural.

The model is built as a simulation model calculating capital expenditure (CAPEX) and operation expenditure (OPEX) values for a predefined service selection in an increasing customer base for the four access technologies in the four geographic scenarios. The model and methodology is based on concepts from IST-2000-25172 TONIC and EURESCOM P1117-FAN.

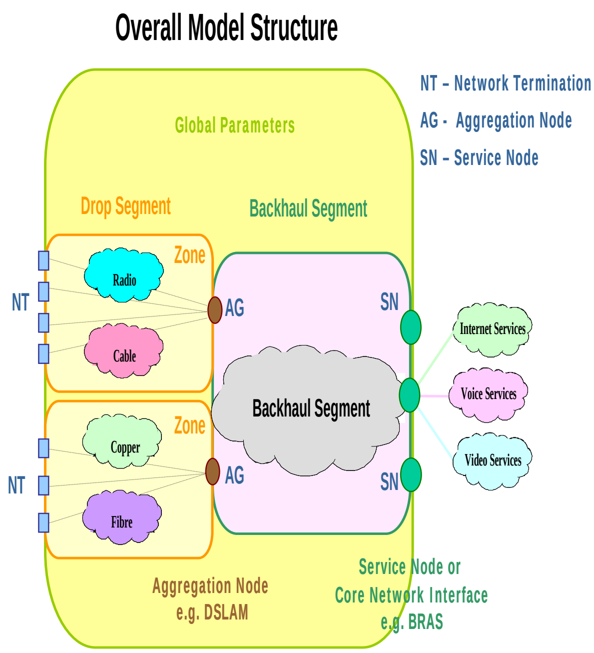

Figure 1, Layered Geographic Model Structure

The overall model structure is based on dividing the network into two segments: Drop Segment and Backhaul Segment. The Drop Segment covers the so called “first mile” from user premises to an aggregation node in the respective zone. This part is characterized by a diversity of transmission media (copper, fibre, cable, radio), technologies (TDM, ATM, IP) and topologies (star, tree). The Backhaul Segment is an aggregation network connecting all Aggregation Nodes to Service Nodes. This part is

[1] The BREAD (BRoadband in Europe for All: a multi-Disciplinary approach) IST-project is a co-ordination action that aims at performing a multi-technological analysis of the current and evolving situation and identify the impact of EU regulatory framework on the successful implementation of new broadband communication services.

characterized by one transmission media, optical fibre connections but a diversity of technologies (TDM, ATM, IP) and topologies (star, tree, ring).

The model defines configuration settings for the four access technologies: DSL, Cable, FTTH and FWA and calculates and compares the deployment cost for each of them for four geographic deployment scenarios: Dense urban, Urban, Suburban and Rural. Configuration parameters for the model can be classified into Scenario Parameters (Geographic, Existing Infrastructure, Available Service) and Technology Parameters (DSL, Cable, FTTH, FWA). As a conclusion the model displays CAPEX and OPEX values for each technology in each scenario as a function of a control variable (e.g. number of customers). Together, demographic and geographic information determine to a large extent the operational and investment cost of access networks. The most relevant parameters are number of customers and the distance to them.
The model can either take note of already existing infrastructure or assume "Greenfield" deployment. In either case the model is based on a layered structure that allows estimation of deployment cost for each level. Different technologies can calculate cost for applicable layers and disregard others.
All scenarios and technologies have to meet a set of defined available services. The available services in the models presented are as default "triple-play" voice, video and data services

In this paper preliminary results related to calculations and evaluations of a DSL-solution are presented.

2. General Description of the DSL solution

A Digital Subscriber Line (DSL) network can be described by the following figure:

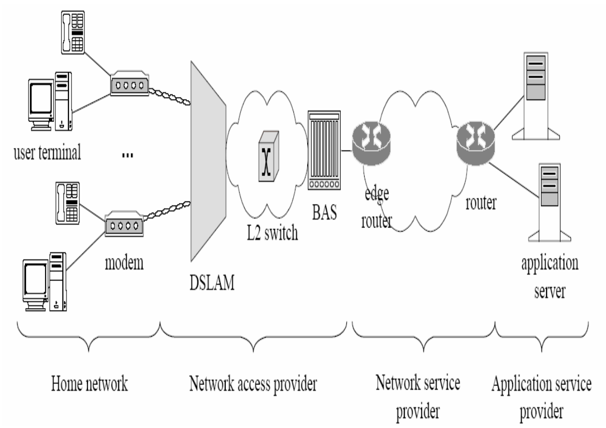

Figure 2, DSL network overview, (elements outside this cost study are shaded grey) [1]

As described in [1], DSL technology reuses the copper twisted pair infrastructure to offer data transmission services. The main strength of DSL in a techno-economic sense is the considerably lower initial investment compared to technologies that require a new physical infrastructure. Additionally, due to the star based topology of the physical infrastructure on which DSL networks are built, each customer gets a dedicated connection to the aggregation node in the DSLAM, compared to a shared connection in tree based topologies such as Hybrid Fibre Coaxial (HFC) networks used in cable access.

The deployment of ADSL and ADSL2+ is considered in an existing PSTN infrastructure. The location of DSLAM equipment is defined as Aggregation Nodes, that are assumed to be evenly distributed in the existing PSTN structures (e.g. Local Exchanges (LE) and Street Cabinets (SC)), serving households within access segment zones. The size of the Access Segment Zone is determined by the maximum copper cable distances. At Aggregation Nodes, traffic is multiplexed and transmitted over fibre based backbone network to a Service Node (See figure 2)

3. Main Cost Components

Establishing a DSL network the main cost elements are:

- Customer Premises Equipment (modem in Figure 2)
- Local Loop (access/operational fee for the copper twisted pair)
- Digital Subscriber Line Access Multiplexer (DSLAM in Figure 2)
- Aggregation Network (L2 switch in Figure 2)
- Broadband Remote Access Server (BAS in Figure 2)
- The Management System

4. Configuration Parameters

The model is configured using parameters developed within BREAD (can be obtained from the authors). For this simulation we consider two deployment technologies, ADSL and ADSL2+, where we configure ADSL has max. cable length of 3,0 Km and ADSL2+ to have maximum cable length of 1,5 Km (the Max. cable length for each DSL technology can also be calculated based on the bandwidth/services offered)

The geographic scenarios are based on average figures from a Danish Statistical Database [3]. Due to the character of the data the geographic scenarios are limited to three: urban, suburban and rural, omitting the 'dense urban' foreseen in the general model set-up. It is assumed that in each scenario, part of the population lives within city/town limits and part outside city/town limits, each with separate population densities. As an example this simulation is run for 100.000 households in each of the tree geographical scenarios and will simulate penetration rates of 25% for 2005 and 50% for 2007 for both ADSL and ADSL2+. (Configuration parameters can be obtained from the authors).

5. Service Description

Two scenarios for service profiles are considered:

- SP1 - Data Services: up to 8 Mbps downstream and up to 1 Mbps upstream using ADSL.
- SP2 - Triple-play Services: up to 20 Mbps downstream and up to 2 Mbps upstream using ADSL2+ (specification can be obtained from the authors)

The simulations show that there is not a direct cost reduction in the access network if lower bandwidths are offered within each service profile, although operators might use different bandwidth offers for price differentiation. The importance of the service profiles stems from their influence on the maximum allowable cable length in addition to controlling the backbone requirements.

6. Equipment Requirements

The maximum allowable cable length determines the zone size (area) that each Aggregation Node (AN) can serve. From zone size and total area size, we can calculate the number AN both within and outside city/town limits. Calculating the number of customers pr. AN (given a specific uptake rate), we can deduce the number of DSLAM units, given the capacity of each DSLAM. It is assumed that there are two capacity levels, DSLAMs used within city/town and detached DSLAMS (low capacity) outside of city/town (specification from the authors).

To estimate the required fibre/duct distance for connecting all Aggregation Nodes to the Service Node we assume that all Aggregation Nodes connect to a Service Node located in the geographical centre of the area. Given rectangular zones we can with some calculus calculate the total Fibre distance (i.e. we do not assume sharing of ducts or fibre between Aggregation Nodes) from all Aggregation Nodes according to [2] to be equal to:

$$L_{total} = \frac{(\sqrt{Zone_{No}})^3}{2} * \sqrt{Zone_{Area}}$$

where $Zone_{No}$ is number of zones and $Zone_{Area}$ is the Km^2 Area of each Zone (i.e. zone length).
Backbone Network

Due to the star topology of DSL network, customers get dedicated bandwidth to an Aggregation Node. At each Aggregation Node, bandwidth of all customers is aggregated and multiplexed (given bandwidth requirements and multiplex factor defined in the Service Profile). The total required bandwidth pr. Aggregation Node determines the backbone connection required for that Aggregation Node to the Service Node.

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The calculations show that the difference in Total aggregated bandwidth is not great between the service scenario SP1 and the service scenario SP2 because the size of Access Segment Zones (and therefore number of customers per Aggregation Node) is less in SP2 than in SP1 due to shorter maximum cable length.
Based on the calculations of required bandwidth pr. Aggregation Node and the backbone connection required the Total Capital Expenditure (CAPEX) and Total Operational Expenditure (OPEX) are simulated. In these simulations fully unbundled local loop is assumed where yearly access fees for the local loop are calculate as operational cost.

8. Cost simulation results

The results from the simulation are summarised below where the Capital Expenditure (CAPEX) and Operational Expenditure (OPEX) per subscriber in Euros (€) are compared in Table 3 and 4. The complete financial results of these simulations are not presented here due to space limitations (they may be obtained from the authors).

		Y2005 - 25% uptake			Y2007 - 50% uptake		
		Urban	Suburban	Rural	Urban	Suburban	Rural
ADSL	CAPEX	113	293	2.496	96	189	1.278
ADSL2+	CAPEX	151	1.008	10.290	125	555	5.170

Table 1, Total Capital Expenditure (CAPEX) pr. Subscriber for ADSL (SP1) and ADSL2+ (SP2) in €

		Y2005 - 25% uptake			Y2007 - 50% uptake		
		Urban	Suburban	Rural	Urban	Suburban	Rural
ADSL	OPEX	162	173	301	161	167	227
ADSL2+	OPEX	169	220	772	167	193	461

Table 2, Total Operational Expenditure (OPEX) pr. subscriber for ADSL (SP1) and ADSL2+ (SP2) in €

Table 1 and 2 illustrate expected tendencies: costs are higher for lightly populated areas and they are reduced with higher uptake. To illustrate the relative increase a comparison is made with the values relative to Urban ADSL. This is show in Tables 3 and 4.

		Y2005 - 25% uptake			Y2007 - 50% uptake		
		Urban	Suburban	Rural	Urban	Suburban	Rural
ADSL	CAPEX	1,0	2,6	22,1	0,8	1,7	11,3
ADSL2+	CAPEX	1,3	8,9	91,1	1,1	4,9	45,8

Table 3, Relative Total Capital Expenditure (CAPEX) pr. Subscriber for ADSL (SP1) and ADSL2+ (SP2)

		Y2005 - 25% uptake			Y2007 - 50% uptake		
		Urban	Suburban	Rural	Urban	Suburban	Rural
ADSL	OPEX	1,0	1,1	1,9	1,0	1,0	1,4
ADSL2+	OPEX	1,0	1,4	4,8	1,0	1,2	2,8

Table 4, Relative Total Operational Expenditure (OPEX) pr. subscriber for ADSL (SP1) and ADSL2+ (SP2).

Even if the general tendencies are as expected, some interesting results follow from the four tables related to the comparison of ADSL and ADSL2+ and to the difference in deployment cost for differently populated areas. An example is the very high CAPEX of ADSL2+ in rural areas. By looking at the specifics of the detailed data (not included in this paper due to space and format limitations) it is evident that the high rural CAPEX is mainly caused by the costs of laying fibre from Aggregation Nodes. Another interesting feature is the limited increase in CAPEX induced by a switch over to ADSL2+ in Urban areas. This suggest – ceteris paribus - a strategy where operators will be quite quick to migrate to ADSL2+ in urban and possibly suburban areas, but will be very reluctant to offer high bandwidth and triple play services in rural areas. It seems evident that unless they have other reasons/ inducements or access to fibre backbones in the rural areas these will not get the same future service offers.

A further result that follows from table 1-4 is that from purely commercial considerations it is not viable to offer even basic broadband access using the same technology (ADSL) at the same prices in all geographical areas. How the situation is, when different technologies may be deployed in different areas will be illustrated during further work in BREAD.

9. Conclusion

The simulations presented here illustrate some interesting DSL specific conclusions related to the comparison of ADSL and ADSL2+ and to the difference in deployment cost for differently populated areas. An example is the very high CAPEX of ADSL2+ in rural areas. Another model conclusion is that it seems not to be economically viable to offer basic broadband access using the same technology (ADSL) at the same prices in all geographical areas. This could be a policy challenging result as the operators in many countries in, e.g., the EU so far have followed this 'same price' strategy without including the broadband access in the Universal Service Obligation.

More robust conclusions demand that comparisons can be made with other access technologies deployed in the same scenarios. Such simulations will be provided during the further work in BREAD.

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