Comparative Study and Techno-Economic Analysis of Broadband Backbone Upgrading: a Case Study

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In this paper we compare and evaluate suitable methods for delivering broadband services at the metro and backbone level. In particular, the paper presents a techno-economic analysis of two key broadband technologies for metropolitan and backbone networks: The studies are based on a modelling methodology for network value analysis that involves CAPEX and OPEX calculations, while the overall technology deployment financial assessment is based on techno-economic evaluation measures such as net present value (NPV) and internal rate of return (IRR). The studied case is the Telekom Slovenia network which is the incumbent operator in Slovenia. The study is based on the operator data and plans. It deals with the upgrading the current network backbone and takes in account future development and trends of broadband services in the country.

Povzetek: Narejena je primerjalna študija in tehnično-ekonomska analiza primera nadgradnje širokopasovnega hrbteničnega omrežja.

1 Introduction

Definitions of broadband have continued to evolve and are changing with time and place. Initially a simple notion was anything perceptibly better than a basic ISDN line. This implies a rate around or exceeding 144 kbps, although customers did accept less if this was the best available to them. A common current understanding is "a service that is always on, and can scale up to at least 2 Mbps". Other definitions do not specify transmission capacity because of the continued evolution of bandwidth. A 2004 Commission Communication (COM(2004) 369: "Connecting Europe at High Speed: National Broadband Strategies") referred to "a wide range of technologies that have been developed to support the delivery of innovative interactive services, equipped with an always-on functionality, providing broad bandwidth capacity that evolves over time and allowing the simultaneous use of both voice and data services". One of the basic components of the broadband development is the convergence of the backbone, metro and the access networks. The convergence is expected to contribute to the integration of all electronic services. The convergence is based on digitalisation which is a major parameter of this process; however it is still only one amongst several parameters that influence the convergence at the infrastructure level. It is also important to emphasise that the success or failure of convergence is not directly connected to the capability of one infrastructure to integrate all services. None of the infrastructures available can integrate all the services in their current state. While integration of the back-bone parts of the networks have higher possibility to evolve due to common ownership and technology convergence, the integration of the last mile which cover the access network has been shown to be dependent on many different parameters. Common trends appear in the development of the access technologies like decentralised architectures and common optical transport, new physical and MAC layers, common IP architectures (including QoS, charging, device provisioning and security) as well as in the approaches taken in the fixed and mobile networks. The progressive introduction of the new IP protocol, IPv6 in the access, then in the backbone is also developed. "Backbone and Metro" networks have similar trends with different constraints and roadmaps; the clear recent tendency is an evolution towards lower CAPEX & OPEX architectures with "multiple services centric" compared to the old "voice centric services". A clear trend is a progressive evolution of SDH technology which remains clearly dominant in that field. Trends present at the scene are dynamic networking, more efficient robust modulation and transport format, reduction of protocol stacks, multiprotocol support with GMPLS, and the progressive apparition of Ethernet in the Metro. In this paper we compare and evaluate suitable methods for delivering broadband services at the metro and backbone level. In particular, the paper presents a techno-economic analysis of two key broadband technologies for metropolitan or backbone networks: Our studies are based on a modelling methodology for network value analysis that involves CAPEX and OPEX calculations, while the overall technology deployment financial assessment is based on techno-economic evaluation measures such as net present value (NPV) and internal rate of return (IRR). The studied case is the Telekom Slovenia network which is the incumbent operator in Slovenia. The study address the upgrading of the current Telekom Slovenia network backbone and takes in account future development of broadband services in the country.

2 Network and technology development consideration

"All-Optical" is the vision for future wired networks, where fibre is used for all wires in the WAN, MAN and Access. Nowadays, optical fibres are ubiquitous in the backbone network, and an extension to access networks is the logical next step. An optical fibre based access network offers of all available technologies by far the highest speed and can support an unlimited set of services. The backbone, national or wide area network may extend over distances of thousands of kilometres and provides an interconnection fabric for regional and metropolitan networks. In recent years considerable capacity has been installed in this network layer, so major investment is not expected in the near future. Current investment is focused on developing revenue streams or reducing operational expenditure. There is a trend towards reducing the number of major network nodes and building a very high capacity backbone, essentially a fabric of very high capacity pipes, with much of the processing and routing devolved to the regional and metro layers. The deployment of Wavelength Division Multiplexing (WDM) techniques and equipment in the field has provided backbone networks with high capacity and long reach capabilities. In this part of the network, in order to maximise the use of the available fibre bandwidth, the trend has been to develop systems with more WDM channels together with higher bit rates. Currently deployed systems could transmit 160 channels each at 10Gbit/s. In reality, as yet, few links use more than a handful (~20) of these channels however. Although practical 40Gbit/s systems have been developed, the economic downturn in telecoms has delayed their take up. The optical links are point to point and are terminated in electronic SDH/SONET switches. The SDH/SONET layer provides network management and switching of the links. The functions it provides include:

- Connection set-up
- Connection and link performance monitoring
- Management data communications
- Protection and restoration

The network providers have a large investment in SDH/SONET equipment. The downturn in the telecommunications sector from 2000 onwards has restricted investment and limited expectations to more realistic horizons than those professed in the late 1990s. The implication of this is that near term investments are likely to be based mainly on SDH/SONET technology variants. Another consequence is that any new technology deployed in an existing network will necessarily have to work alongside SDH/SONET. As voice and data networks converge there is a force for upgrading SDH/SONET. Next Generation SDH/SONET is being employed to provide an evolutionary upgrade to the legacy infrastructure by introducing new SDH switches. The Slovenian national operator Slovenia Telecom is facing the same dilemma regarding the upgrading the current national backbone network. In the sections that follow the selection of the appropriate technology is presented based on the information and data provided by the operator and by assessment of the future demands in the country. The technology is evaluated in view of the current state of the network and the future demands of the Slovenian customers. The study starts by identifying the network loops and the required upgrade to cover the next 5 years. The technical assessment is followed by economical evaluation of the OPEX and CAPEX index. Net Present Value and Internal Rate of Return are used as well as indicators that have contributed to the final selection of the technical variants.

3 The case study network and the future prospects

In Slovenia, households are using one of the following types of broadband access:

- ADSL that is being followed now by ADSL +2, offered by Telecom Slovenia
- Coaxial networks with cable modems, offered mainly by the cable operators and
- HFC Network (Hybrid Fibre Coax) which is combination of optical and coaxial networks, also offered by the cable operators.

In the business sector, SME's are mostly using ADSL and cable modems, while middle and large enterprises are using leased lines with ATM switches or Frame Relay (block mediation). Some of the business customers are still using narrowband dial-up modems due to the limitation of their business capacity. There are also residential users that are using wireless access and business customers using Ethernet access over optical lines. In order to optimize the resources the incumbent operator owning the largest part of access networks is using the DSLAM (Digital Subscriber Line Multiplexer) equipment located in urban areas where the concentration of users is highest. The estimated population coverage in towns/cities with this technology by the end of 2005 was around 95%. The growth of BB access is a result of the higher usage of different e-services such as TV, e-banking, e-learning, movie and music download and real time gaming. In order to provide an extension and upgrading of the current Telecom network the following parameters must be considered:

- DSLAMs are connected to edge routers that are or will be positioned on urban locations within cities with

larger population. In case of customers that are located on distance smaller than 50 km, the DSLAMs equipment is directly connected to the customer equipment using fibber. In that context, we can allocate the geographical points where the upgrading of the connectivity to the backbone network will take place These location are the following:
Koper, Postojna, Nova Gorica, Idrija, Kranj, Bled, Novo Mesto, Krško, Celje, Velenje, Ravne, Maribor, Ptuj and Murska Sobota,
•Traffic evaluation anticipates connection of DSLAM units with GbE interfaces, so the edge routers will have nxGbE or 10GbE interfaces, which requires in the transmission systems of the backbone network channels with 10G/bit bandwidth.
•The transmission systems will be built in ring topology.

In addition to that the Telecom network will still offer connectivity with use of Dial-up and Ethernet. Dial-up access (analogue and ISDN) is carried out over the existing SDH network, and no essential growth of the existing traffic is foreseen. Regarding the use of Ethernet connectivity over optical connections, Telekom Slovenia is expecting similarly to the other operators growth of the demand. Ethernet connectivity over optical fibre is offered on the network side, using a specific switch or router. It is also anticipated that there will be an increased demand for the provision of virtual private networks (VPNs), which may have an impact on the decision to enlarge the network topology and consequently on additional network-access locations around the country. Telekom Slovenia's backbone network is also used to run the operator service and for the leased-line market. This leased-line market is well developed and leased lines are used by many enterprises, such as banks, mobile operators, (e.g., Western Wireless International, Simobil/Vodafone, and Mobitel), dedicated networks under state ownership and management (e.g., ARNES, the academic network) and HKOM, the network services provided to the Slovenian government and administration. Leased lines are also used by new entrants to the telecommunications market, e.g., internet service providers like T2, Voljatel and Medinet. These users are mostly using 2M and 34 M PDH or STM-1 interfaces, providing 155Mbit/s bandwidth capacity.

The network topology is presented on Fig.1. The optical part of the network consists of single-mode optical fibres. They are spread over the whole country, providing a transmission capacity of more than 10 GB/s. The redundancy of the lines is due to operational requirements, as Telekom Slovenie provides basic telephone, data transmission and other (TDM) services with a QoS (quality of service) provision.

Figure 1: Telecom Slovenia backbone network.

Increase of data communication traffic is expected in the international connections of the network, in the mobile network with the UMTS technology implemented by the operator daughter company – Mobitel. Other demands are expected regarding bandwidth for the DRC (Disaster Recovery Centre), which are becoming important customers. Inquiries for such centres come from Slovenian State administration, various Ministries and banks. These users in majority of cases need SAN (Storage Area Network) interfaces. Last larger group of customers that influence the demand for bandwidth are systems or enterprises which are asking for VPNs and own private Ethernet networks.

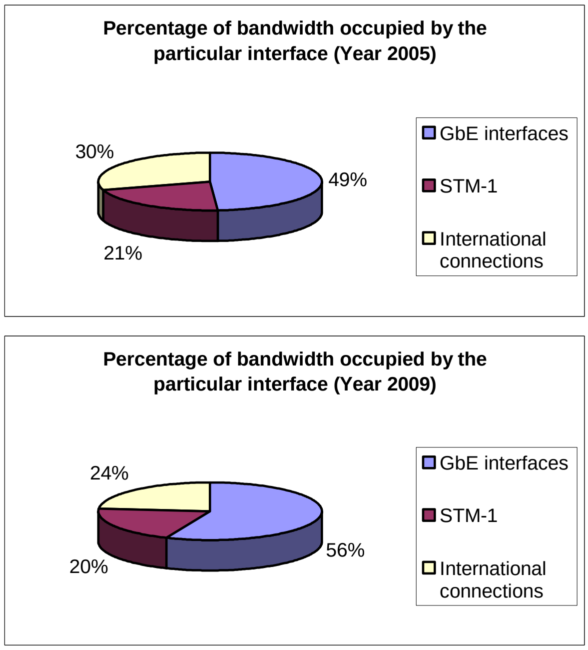

Figure 2: Comparison of bandwidth occupied by particular interfaces in year 2005 and 2009.

They are interested in FE (Fast Ethernet) or GbE bandwidth on the backbone level. The expected changes in interface occupancy regarding bandwidth in 5 years time span is presented on Figure 2.

The fast growing needs for additional bandwidth, required by the new services, are important, additional challenge is the merge of different kind of traffic on one backbone platform. The decision for a transmission technology is simple as optical cable with single-mode fibres is the only acceptable solution in economical and physical aspects. The media for upgrading and extension of the backbone network is known, the question that needs an answer is the appropriate technology. We have identified two technologies to be available for the backbone upgrading and extension of the Telecom network, wavelength multiplexing (WDM) and SDH systems of transmission. The selection depends on different factors and criteria. The next section provides more information about the approach and the upgrading proposal.

4 Technical and cost evaluation of the upgrading

Telekom network customers are familiar with the SDH interfaces as the current network is built up with SDH technology. They are cheaper than WDM (for the present needs); however they still have weakness in comparison to WDM. With enlargement of the network and the upgrading of the bandwidth capacities parallel systems will be required as the current can not answer to the increased demand. This can become expensive and time wasting. Technical solution for upgrading the existing network with WDM technology requires 16 channel DWDM transmission systems. The number of channels is specified according to the number of network elements in the loops and the estimated traffic. In case of SDH based equipment an SDH STM-64 transmission system is required capable to provide capacity of 10Gbit/s. In both cases the bandwidth per channel is same, and as a consequence the locations of the network elements are same. The upgrading with SDH technology requires for the Telecom network upgrading the following SDH equipment: network elements on all specified relations shown at the network topology (Fig.1), SDH STM-64 modules and compensation fibres. The WDM technology upgrading variant requires network elements on all locations with appropriate number of channels (DWDM systems are 16 channelled), multiplexing equipment (for locations, with highest traffic), compensating fibres, since in the 10Gbit/s transmission, the dispersion needs to be compensated.

In order to evaluate the optimal solution for the network upgrading in financial aspect CAPEX (capital expenditure) index and OPEX (operational expenditure) index were calculated for period of 5 year time span (later, new technologies are expected). In the CAPEX index price of equipment, software, installation, takeover test, setting and wiring are considered. (Caballero, 2005, page 190). In addition to that the operational cost that was also calculated includes depreciation of the equipment, maintenance of the connections, monitoring the functioning of the system and corrections, creation of new connections, system support: - maintenance contract and costs of used transmission media. The accounting regulations of Telekom Slovenie, allow appreciation of 14, 3% for the equipment and 5% for the media per year.

5 Findings and results

The calculation provided numerical values for both indexes: CAPEX for SDH and for DWDM. They are compared and presented on Figure 3.

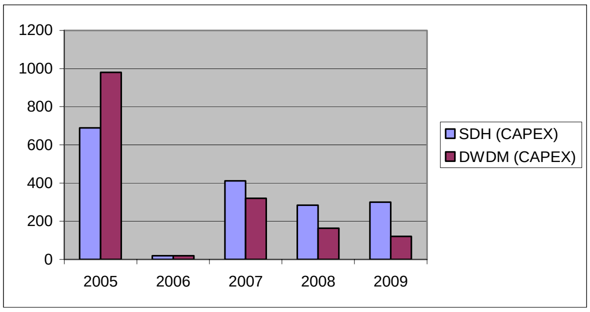

Figure 3: Comparison of CAPEX values in millions of euros for SDH and DWDM.

The data on Figure 3 shows clearly that the investments cost in fixed assets for the DWDM variant is significantly higher in the first year of investment compared to the cost for SDH equipment. In the second year both indexes come close together. In the last three years of the 5 year time span the DWDM cost of investment is much lower compared to the cost required for the SDH. The higher cost in the first year for DWDM is due the purchase of expensive amplifiers and compensating fibres, later only line cards are necessary to be purchased. In the case of SDH variant each expansion of the line capacity, requires a purchase of additional amplifiers, compensation fibres and expensive line cards. In long term the investment in SDH demands more spending and this is especially obvious if the considered time period is longer e.g. 6 or 7 years. Feeding interfaces are same in both variants since the same access traffic is expected in both cases.

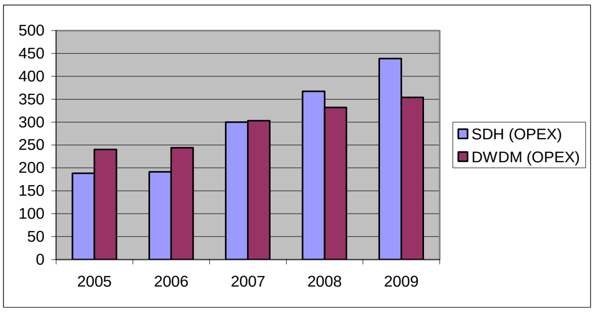

Figure 4: Comparison of OPEX value in millions of EUR between SDH and DWDM solutions.

The graph in Figure 4 shows the differences between the two OPEX indexes and they are results of two factors. The first is due to the large investments required in the DWDM case variant in the first year. In line with this the depreciation cost and maintenance contract are also somehow higher than for the SDH variant. Cost of personnel for maintenance of the equipment or systems is the same for both variants, so this does not contribute to the difference between both OPEX indexes. The increase of a bandwidth requires upgrading of the line capacity. Sufficient line capacity in DWDM variant system is provided in the first year and the system continuously works over two fibres, upgrading, or additional fibres are not required. In contrast to that in the case of SDH equipment usage each increase of line speed demands additional two fibres. This is why the media item appears as a constant in the DWDM variant, while in the SDH variant this item is much higher. In case of unexpected additional needs for bandwidth, this variant becomes much more disadvantageous. This is the second factor that influence on the difference of the two OPEX indexes. The next Figure 5 presents the comparison of both variants with aggregation of both indexes. The lines represent cumulative values of the aggregated indexes.

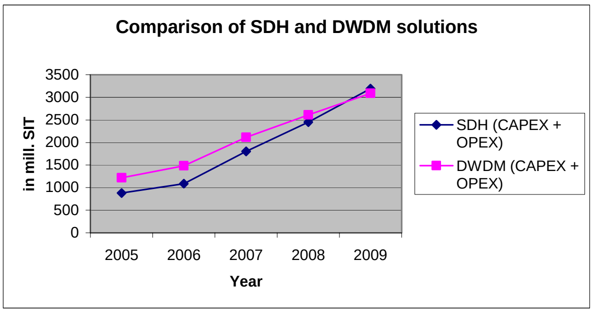

Figure 5: Comparison of SDH and DWDM variants with aggregated indexes (CAPEX + OPEX).

The findings from the two variant comparison of particular index as presented on Table 1 and Table 2 are reflected as well in the graphs presented on Figure 5. The smaller cost of investment in SDH equipment is followed with the higher costs of maintenance for upgrading, in absolute value comes close to the cost of the DWDM variant. The line for the SDH variants in the second year is rising with bigger slope then the line for the DWDM variant. In case of prolonged time period e.g. for two more years (all together 7 years were considered according to the accounting regulation of Telekom Slovenia) the lifecycle of such equipment, and the slope of the line will become even bigger and the indexes will show bigger difference in favour of the DWDM variant.

By taking into account all previously stated findings it can be concluded that for the upgrading of the Telekom Slovenia network much more attractive variant is the selection of DWDM technology. However, in this type of analysis the time component, Network Present Value and Internal Rate of Return are necessary to be considered as well. In this type of calculation the network present value that is taken in account contributes to positive and negative cash flows. Positive cash flows are the inflows from bandwidth lease, negative cash flows are the costs associated with the investment (equipment, reserve units and services), salaries, cost of the maintenance contract. In addition to that as negative cash flow are considered also the use of fibres. NPV (Net Present Value) is calculated according to the dynamic investment evaluation method that considers the life cycle of the investment (I), the positive cash flow in particular year, the interest rate and the initial investment.

$$NPV = \left(\sum_{t=1}^{n} \frac{D_t}{(1+r)^t} \right) - \left(\sum_{t=0}^{n} \frac{I_t}{(1+r)^t} \right)$$

Here r is the interest rate and I am the investment and D is the positive cash flow in particular year. The calculation method clearly shows the dependence of the NPV from the value of the capital used for the investment in course of the time (1 to t) and the interest rate associated with it. The other parameter calculated is the Internal Rate of Return (IRR). In our case the Modified IRR was used as this parameter enables re-investing of the cash flow with lower interest rate. The formula as suggested by Brigham (Brigham, 1977, p.411) was applied:

$$I_0 = \frac{\sum_{t=1}^{n} D_t (1+r)^{n-1}}{(1+MISD)^n},$$ where MISD is the modified IRR.

Both variants were compared also with the value of the Internal Rate of Return (IRR), which is calculated three times with different value for the interest rate. In the expression for NPV, r is the interest rate, I am the investment and D is the positive cash flow in a particular year. The other measure calculated is IRR. In our case, the modified IRR (MIRR, [14]) was used, as this parameter allows for the re-investment of the cash flow with a lower interest rate. In Fig 6 the NPV profiles for both variants (SDH and DWDM) are shown.

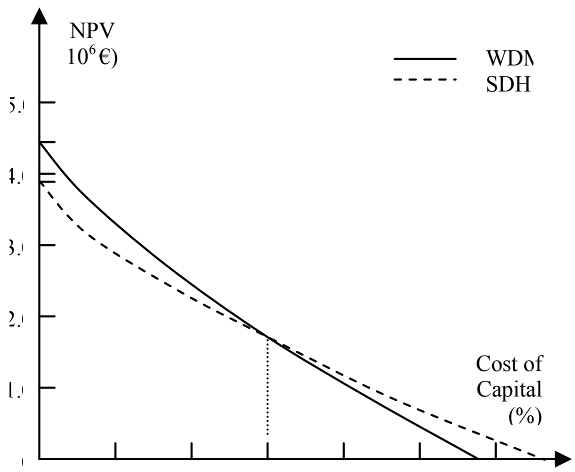

Figure 6: Net present value profiles for SDH and DWDM solutions.

We can see that the IRR method favours the SDH technology (IRR = 33%) over DWDM (IRR = 28%), but the NPV is the same for both variants at 15% ("the crossover rate"), and higher for DWDM below that point. Since both options are mutually exclusive, we can say that if the capital costs are lower than 15% (as they are in our case) the DWDM option is preferable, since we can expect a greater NPV from it.

From the technological point of view the upgrade of Telekom Slovenia backbone can be carried out with either the SDH or DWDM technology. However, a comparison of the costs of the concerned technologies shows that the DWDM variant is a better as a long-term choice, especially with current costs of capital below 15%, which enables greater NPV value. The DWDM variant is better in longer time period e.g. 5-7 years and could be said that is optimal. This solution offers as well better price performance ratio. The same applies in the case of capital investment and return.

6 Conclusion

Over the years there has been an evolution in the backbone networks from analogue to digital transmission, from Plesiochronous Digital Hierarchy (PDH) to Synchronous Digital Hierarchy (SDH) and recently from SDH to SDH upon Wavelength Division Multiplexing (WDM). Initially digital transmission was introduced with a capacity of 2 Mbit/s (the primary multiplexers) and a granularity of 64 kbit. A next step was to improve the transmission efficiency by allowing higher bitrates and introducing cross-connection, so that currently, with SDH, the granularity is 155 Mbit/s and a line capacity of 10 Gbit/s is possible. Advances in electronic processing could not follow the traffic growth so the next step is obviously the introduction of WDM. Here currently deployed systems are capable of capacity of 1600 Gbit/s (160 wavelengths) or even more, with a granularity of 10 Gbit/s. While the capability to use 160 wavelengths allows growth capacity, few systems currently deploy the full capability. Recent technology evolution gives the possibility of the WDM transport layer migrating from simple transmission links into an elaborate network providing switching, with higher manageability, lower complexity and cost. In such network scenarios, optical routes form connections between discrete point network locations through optical add/drop and cross connect nodes and provide traffic allocation, routing and management of the optical bandwidth. They also facilitate network expansion, traffic growth, churn and network resilience. Optical cross-connects are located at nodes cross-connecting a number of fibre pairs and also support add and drop of local traffic providing the interface with the service layer. Our study results show also that WDM technology in the case of the Telecom Slovenia network appears to present a better economic solution (based on the NPV and IRR indicators) compared to a SDH network upgrading. Thus, an investment in WDM presents improved prospects for answering to the increased demand of bandwidth and services. The results were based on exactly the same market demand and revenue assumptions for both technologies considered in the study, a particular concrete market with differentiation only in technology chains and related cost assumptions.

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