Traffic Forecasting Models for the Incumbent Based on New Drivers in the Market

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1 Introduction

The circuit switched voice traffic has traditionally been a significant part of the traffic in the transport network. However, during recent years Leased lines ordered by different operators and also the Leased lines ordered from the business market have expanded the transport network capacity. A new capacity wave has also started: the data traffic moving from narrowband to broadband. The data traffic is increasing exponentially and will for some years be the dominating traffic in the transport network. Important traffic drivers are broadband applications carried by HFC, ADSL, VDSL, LMDS, UMTS and WLAN.

This paper analyses the traffic and capacity evolution of the transport network of an incumbent operator having the possibility to integrate different type of traffic into the network. A traffic volume indicator is developed for traffic increase in the transport network. The access forecast modelling has been developed based on parts of the results from the projects ACT 384 TERA and IST-2000-25172 project TONIC [1–16].

2 Market Segments

Services

Traffic from the services is transported on different network platforms or on leased lines. Important services for the transport network are: PSTN/ISDN, Internet, Leased lines, PSDN (packet switched data network), Frame relay, ATM, IP Virtual private network (VPN), ADSL/SDSL, VDSL/LMDS, Fast Ethernet, Gigabit Ethernet, Lamda wavelength, Dynamic bandwidth allocation.

Market Segments

An incumbent operator leases transport capacity to other operators. In addition the incumbent offers transport capacity to the residential and the business market. The incumbent operator offers transport capacity either via own service provider or as wholesale. A segmentation of the market will be:

Residential market: PSTN, ISDN, Internet, ADSL, VDSL, LMDS, HFC.

Business market: PSTN, ISDN, IP VPN, Internet, PSDN, Frame Relay, ATM, ADSL, SDSL, VDSL, LMDS, Leased lines, Fast Ethernet, Gigabit Ethernet, Lamda wavelength, Dynamic bandwidth allocation.

Operators: ADSL, SDSL, VDSL, LMDS, Leased lines, Fast Ethernet, Gigabit Ethernet IP-VPN, Lamda wavelength, Dynamic bandwidth allocation. (mobile operators, ISPs, other operators).

Network Platforms

Relevant network platforms are: PSTN/ISDN, PSDN, Frame Relay/ATM, Digital Cross Connect, Various IP Networks including IP networks for mobile operators, Leased lines. PSTN/ISDN is a circuit switched network. Leased lines have no concentration effect at all, while the other network platforms also have packet switched concentration.

3 Traffic From the Residential Market

The residential market generates different types of traffic: Voice traffic, Dialled Internet traffic, ADSL traffic, VDSL/LMDS traffic.

The *voice traffic* has nearly reached saturation. During the next years, the circuit switched voice traffic will be rather stable before parts of the circuit switched voice traffic are substituted by IP voice. The *dialled Internet traffic* will reach maximum within a few years. Then the dialled Internet traffic will continuously be substituted by broadband traffic. A battle has already started between broadband operators to capture parts of the broadband market.

Broadband access forecasts have been developed in the IST-2000-25172 project TONIC. Figure 1 shows the market share evolution of ADSL, VDSL, FWA (Fixed wireless broadband access) and HFC/cable modem for West European countries.

Figure 2 shows total broadband penetration. The total broadband penetration forecasts are adjusted compared to the forecasts developed in the TONIC projects. A combination of the figures gives the broadband penetration for each technology.

Now, the question is which traffic is carried in the incumbent's transport network. Usually the cable TV/HFC traffic is carried outside the transport network, while a part (market share) of the

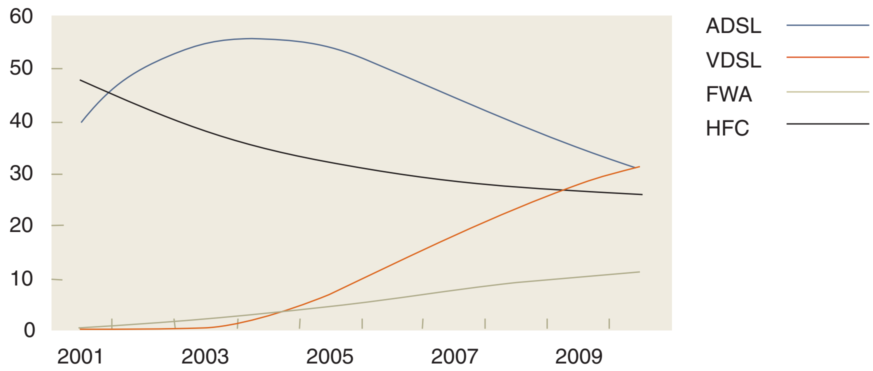


Figure 1 Market share distribution and prediction of ADSL, VDSL, FWA and HFC (cable modem) for West European countries

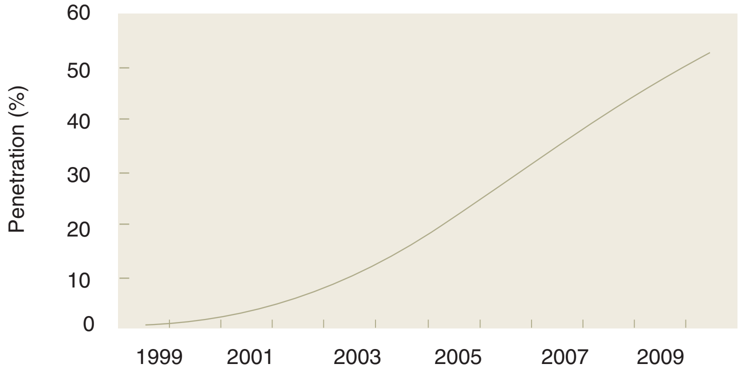


Figure 2 Broadband penetration forecasts for the European residential market

penetration of each of the other technologies will be carried in the incumbent's transport network.

A traffic volume forecast indicator, $V_R(t)$, for the residential busy hour traffic into the transport network is given by:

$$V_R(t) = N_t \Sigma_{i=1,2,3,4,5}\, b_{it}\, u_{it}\, A_{it}\, C_{it}\, M_{it}\, p_{it} \qquad (1)$$

where

$i = 1$ denotes voice traffic
$i = 2$ denotes Dialled Internet
$i = 3$ denotes ADSL
$i = 4$ denotes VDSL
$i = 5$ denotes FWA
N_t is the number of households in year t
b_{it} is busy hour concentration factor for technology i in year t
u_{it} is packet switching concentration factor for technology i in year t
A_{it} is the access capacity utilisation for technology i in year t
C_{it} is mean downstream access capacity for technology i in year t
M_{it} is incumbent's access market share for technology i in year t
p_{it} is the access penetration forecasts (%) for technology i in year t

Market Share and Access Penetration

The factor $N_t\, M_{it}\, p_{it}$ represents a forecast of number of households connected to the incumbent's transport network in year t using technology i. Suppose the incumbent operator has 40 % of the ADSL market share and expects to be in the same position the next years, then $M_{3t} = 0.40$ for t = 2001, 2002, ...

Mean Downstream Access Capacity and the Technology Evolution

The downstream access capacity, C_{1t}, for voice traffic is 64 kbs and will be the same the next years. However, the downstream access capacity C_{3t} for ADSL changes. Figure 3 shows how the mean downstream access capacity increases. Now, the operators offer a set of different access capacities. There will be an evolution from low access capacities to higher access capacities especially because of new and enhanced applications. In addition, new functionality such as bandwidth on demand will be introduced by the operators.

So far, ADSL based on reasonable low downstream capacity is introduced. The next step will be to enhance the ADSL capacity in the range 6 – 8 Mbs. However, the capacity size offered will be dependent on the twisted copper pair length. The capacity offered will decrease with the copper pair length.

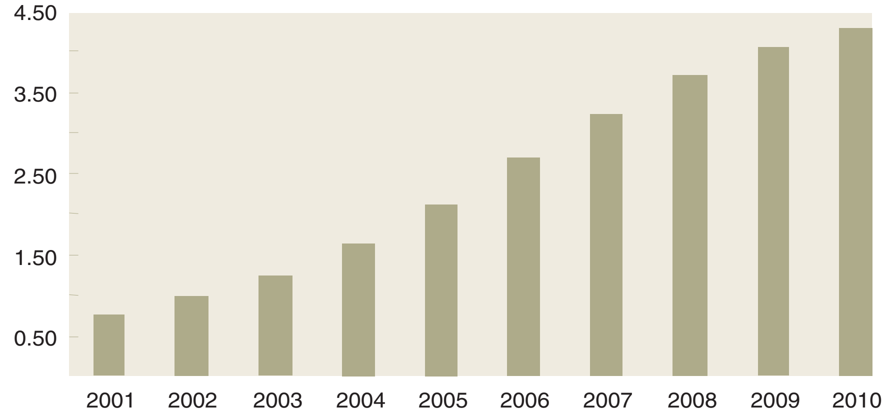


Figure 3 Evolution of predicted average downstream capacity in Mbs (Tonic 2002)

An extension to the VDSL platform will increase the offered capacity further. New services like VoD and peer-to-peer applications based on downloading and exchange of films will increase the capacity demand. The access capacity for VDSL will be in the range 15 – 24 Mbs depending on the copper pair length.

ADSL2+ is a supplement to VDSL and ADSL. While VDSL covers subscribers up to 1.5 km from the exchange or the last fibre drop, ADSL2+ has the possibility to offer 10 Mbs up to 2.0 km and probably within a few years 2.5 km distance from the exchange/last fibre drop.

ADSL2+ and VDSL have enough capacity to offer Internet and digital TV while also offering the possibility to use interactive TV. The number of independent TV streams will be dependent on the selected solutions. It will also be possible to transfer traditional TV programs on the copper pairs like the ones seen in cable TV networks. However, only part of this capacity will be individual, while the capacity for dedicated TV channels will be a common resource for all households in the transport network.

Dynamic Spectrum Management (DSM) will enhance the copper line capacity further. The methodology is based on dynamic regulation of the frequencies on the copper line to reduce the noise and cross talk.

The market share evolution for different ADSL access capacities is described in the IST-2000-25172 project TONIC. Mean access capacity is calculated according to the distribution of different access capacities for each year. The results are shown in Figure 3.

The capacity predictions are based on the assumption of flat rate principle for the first years. However, there may be a delay in the demand for capacity if and when traffic charges are introduced by the operators.

Access Capacity Utilisation

A broadband customer is not utilising the maximum capacity all the time. The access capacity utilisation factor indicates average capacity use taking into account the proportion of time during the conversation for downloading and the proportion of time for uploading. The factor also reflects the degree of using the specified bandwidth.

Busy Hour Concentration

The busy hour concentration effect is well known. Usually about 10 % ($b_{1t} = 0.1$) of the customers make phone calls in the busy hour. Traditionally Erlang's blocking formula (assuming exponential interarrival time and holding time) is used for dimensioning. The busy hour concentration factor is increasing because of the Internet. For broadband connections the busy hour concentration factor is significantly higher because of heavy users, longer holding times, flat rate and evolution of new applications.

The busy hour for residential narrowband and broadband traffic is in the evening.

Packet Switching Concentration

The circuit switched services PSTN and ISDN have no packet switching concentration ($u_{1t} = 1$). The other services have significant concentrations. Internet use consists of sessions based downloading, thinking and uploading. Traffic will be packet according to use. Traditional Internet use gives low packet switching concentration. Applications like music on demand and video on demand generate high packet switching concentration. The evolution of the packet switching concentration factor is complex.

Uncertainty in the Concentration Factors

Figure 4 shows possible evolutions of combinations between busy hour concentrations and packet switching concentrations. There are significant uncertainties in the evolution. The basis for the predictions in Figure 4 is 0.15 (15 %) busy hour concentration and 0.20 packet switching concentration in 2001. *Four alternatives* are defined having a linear yearly increase:

Busy hour concentration: 0.15 in 2001 to respectively 0.195 – 0.24 – 0.285 – 0.33 in 2010.

Packet switching concentration: 0.20 in 2001 to respectively 0.335 – 0.47 – 0.605 – 0.74 in 2010.

Figures 2–4 show a nearly exponential evolution of broadband penetration, capacity increase and traffic concentration in the coming years. The most probable prediction will be between alternative 2 and 3. The traffic volume indicator described in equation (1) has a much stronger exponential evolution because of a multiplicative effect of the same factors.

4 Traffic from the Business Market

The business market generates the following types of traffic/capacity: Voice traffic, Dialled Internet traffic, PSDN, ATM, Frame Relay, DSL traffic, IP Virtual Private Networks (IP VPN) traffic, Leased lines, Fast and Gigabit Ethernet.

There are significant substitution effects between DSL, IP VPN, Leased lines, Fast and Gigabit Ethernet, which have to be taken into account in the forecasting process. Leased lines are used to establish fixed connections between sites often based on head office and branch offices or between different enterprises. The established network forms a local network with high service quality. There are no busy hour concentration or packet switching concentration. Leased lines constitute a significant part of the transport network capacity. Some parts of the leased lines capacity will be transferred to IP VPN or DSL because of cheaper tariffs and in spite of reduced service quality/SLA.

A traffic volume forecast indicator $V_B(t)$ for the business market busy hour traffic is given by:

$$V_B(t) = N_t \, \Sigma_i \, b_{it} \, u_{it} \, A_{it} \, C_{it} \, M_{it} \, p_{it} \quad (2)$$

where the different traffic/capacity types i are defined in the first paragraph of the chapter.

5 Traffic Generated by Other Operators

Different operators like mobile operators, ISPs and other fixed network operators lease necessary capacity in the transport network. The capacity demand depends on type of services offered and the market share to the operators and of course the probability to use the transport network of the incumbent.

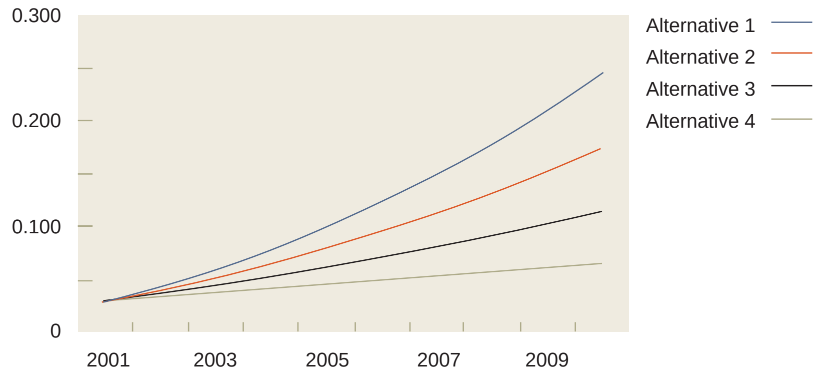


Figure 4 Description of possible evolutions of concentrations of ADSL traffic as a function of busy hour and packet switching concentration

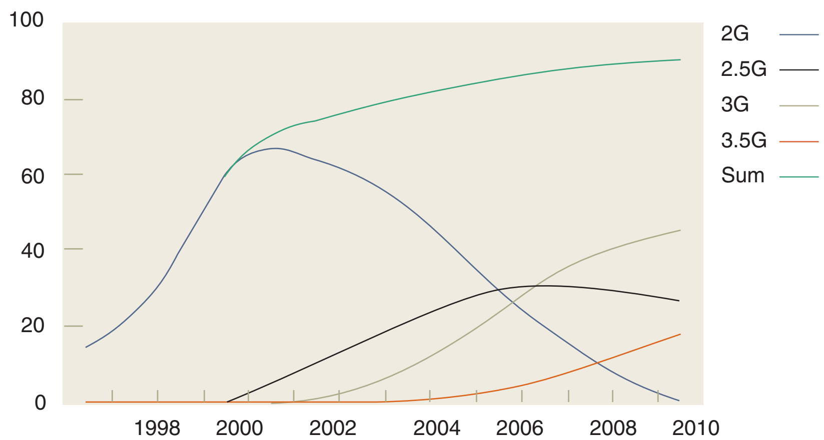
The mobile operators are important transport network customers using leased lines in the transport network. In the coming years these operators will generate the following traffic:

- 2G traffic (Digital mobile systems such as GSM)
- 2.5G traffic (HSCSD, GPRS, EDGE)
- 3G traffic (UMTS)
- 3.5G traffic (Ubiquitous roaming among 3G and WLAN systems)

The access forecasts for the different systems have been developed in the IST-2000-25172 project Tonic.

Subscription forecasts for the mobile systems, allowing the subscribers to have more than one subscription have also been developed. The traffic capacity for data applications per user increases from 40 kbs to 1.92 Mbs from 2G to 3G, while WLAN offers up to 54 Mbs. The traffic forecast model for mobile traffic is similar to the traffic in the fixed network. The busy hour concentration factor and the packet switching concentration factor are extremely important for the dimensioning. The services/applications are defined in different service classes: conversation, streaming, best effort, and the capacity is reserved according to service level agreements.

Figure 5 Subscriber penetration forecasts for different mobile systems



The traffic forecasting model $V_M(t)$ for mobile operators is given by:

$$V_M(t) = N_t \Sigma_i b_{it} u_{it} A_{it} C_{it} M_{it} p_{it} \quad (3)$$

Here N_t is number of persons, not number of households. M_{it} denotes the market share to the operator and $i = 1, 2, 3, 4$ the system generations 2G, 2.5G, 3G and 3.5G. The penetration forecasts p_{it} are shown in Figure 5. The capacity C_{it} is a mean capacity. A 3.5G subscriber has the possibility to use a data rate up to 144 kbs using UMTS but a significantly higher capacity in WLAN hot spot. The number of hot spots available and the proportion of time the subscriber uses WLAN compared with UMTS give the mean capacity C_{4t}. The factor A_{it} indicates the real utilisation of the capacity.

Let $V_O(t)$ be the busy hour traffic forecasts for the other operators, then the total of busy hour traffic forecasts $V(t)$ is given by:

$$V(t) = V_R(t) + V_B(t) + V_M(t) + V_O(t) \quad (4)$$

There are definitely possibilities to reduce $V(t)$ since the business traffic has busy hour before/after lunch, while the residential traffic has busy hour in the evening. Since the operators use leased lines, day and night capacity is equal. Let $V_{BL}(t)$ be the leased line capacity and $V_{BP}(t)$ be the packet switched traffic in the business market. Then $V_B(t) = V_{BL}(t) + V_{BP}(t)$. The residential broadband traffic is larger than the packet switched business traffic in the busy hour. Suppose that $\Delta = 0.2$ (20 %) of the packet switched business busy hour traffic is transferred during the residential busy hour the adjusted busy hour traffic forecast $V^*(t)$ is:

$$V^*(t) = V_R(t) + \Delta V_{BP}(t) + V_{BL}(t) + V_M(t) + V_O(t) \quad (5)$$

6 Capacity Forecasts

Models for making traffic forecasts during busy hour have been described. However, the capacity needed to carry the traffic is higher. Additional capacity has to be dimensioned taking into account stochastic variations around the mean traffic in the busy hour. Usually Erlang's blocking formula is applied for voice traffic, while Lindberger's approximation is useful for dimensioning the data traffic capacity [12]. The traffic will probably be transported on SDH systems where packet overhead is added. In addition the system's load average factor is less than the maximum capacity, and finally there will in general be some extra dimensioning since the expansion of the network is planned and deployed stepwise. The estimation of additional capacity depends on the planning process and the technical systems and will vary from one incumbent to another.

7 Conclusions

A traffic volume indicator has been developed to estimate busy hour traffic increase in the transport network. The indicator estimates the traffic entering the transport network. The traffic volume indicator does not include redundancy and protection capacity in the core network. Telenor uses the traffic volume indicator forecasts as input to the transport network planning process – evaluation of new network structures, expansion of the network and introduction of new core network technology.

The indicator depends on the application evolution and also the tariff regime for broadband services. So far, most countries use a flat rate for broadband traffic. However, specific applications will overload the transport network heavily if no actions are performed. There exist no incitements to control the size of the traffic in the transport network. A probable solution will be to introduce a tariff on high capacity traffic and on bandwidth on demand and specific applications. The traffic forecasts used assume that a new tariff regime for broadband services will be implemented within the next two years.

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