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# Benefits of Network Planning and Design and Advantages of Voice Telephony over ATM in a Public Network

***This paper describes the need for a business-driven network planning process and the network vision of Lucent Technologies in a fast-changing, almost exploding, world of telecommunications. At the moment operators cannot predict what the cost and profitability of new service investments will be. An integrated method has to be used to link business objectives and network investments in a continuing way. An example of the network planning process in an application of voice telephony over ATM (VToA) in the infrastructure of an incumbent operator is given.***

## Business Driven Network Planning Process

Investment decision-making in the dynamic revolutionised telecommunication industry environment must take into consideration the strategic value and implications of the three fundamental external forces that drive telecommunications change, namely *technology, user demands,* and *industry structure.* The selection of basic technology options is expanding and for each option there is a growing array of products from an increasing number of suppliers. Technology advances are producing continuing price/performance improvements in microelectronics, increase performance in computing and software technology and have lead to a dramatic emergence of photonics and lightwave communications.

The considerable decrease in technology cost and the associated increase in bandwidth/capacity present opportunities for the creation and delivery of high-value-added services and applications, along with opportunities for substantial increase in business volume. The growth in the on-line and Internet-based services is one (important) example of this effect. The result is a major shift of the telecommunications industry focus, from provisioning of the basic resource (that is, bandwidth) to competing in delivering high value-added services to users.

Network planning and design are key activities that have to be done before a network can be implemented. Results of the network planning and design process determine the technology and type of equipment to be used. This in turn determines the cost of the network itself and the cost of its implementation and operation.

The benefits of a well-planned network are paramount in the daily operations of a telecommunications service provider. An effective design maximises the revenue potential from the telecommunications company's network, and allows it to satisfy the demand of all its customers while minimising the required capital and operational investment.

The network planning process enables the following:

- identification of the network implications of business directions, and other driving forces such as competitive pressures and environmental effects;
- identification, analysis and justification of investment decisions in the emerging dynamic telecommunications environment, using a variety of engineering economic methods and tools to evaluate alternatives;
- identification and analysis of the implications of technology advances and timelines in terms of time of introduction, maturity, acceptability, and standards, on business processes, functions, applications, and services; and
- development of network architectures that take advantage of technology capabilities to efficiently support business application requirements.

Winning in the competitive environment of today requires an integrated network planning business model that focuses (in a continuing way) on giving feedback on the performance of the network compared with the requirements (see Figure 1). At the moment operators quite often do not know what the cost of their operations are and cannot predict what the cost and profitability of new service investments will be. Therefore an integrated method

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has to be used to link business objectives and network investments in a continuing way.

Some aspects of this model are:

- scenario planning,
- economic valuation techniques, and
- risk analysis.

## Scenario planning

The above mentioned modelling methodology is based on a frequently repeated study of scenarios narrowing down from a wide view in the early phases of a project (or network operation for say new entrants) towards minor differences in later phases of a project (or in a mature network of an incumbent operator).

It is essential to consider a number of possibilities and study all of them in some detail, and compare the scenarios with respect to strengths, weaknesses, opportunities and threats. A situation analysis has to be done for: business mission, markets attractiveness, existing competencies and challenges, service opportunities, competition situation and regulation.

To give an example for a new entrant the following considerations can be the starting point for scenario planning.

In such a case there could be great uncertainty (for example, about customers or services); solutions are chosen which are easy to change (like the use of leased lines from the incumbent)—these solutions tend to be costly for starters, but flexible.

One important aspect is coverage and hit rate, which could force starters to invest heavily without much return in the first phases; in these situations (fixed) wireless solutions can be an excellent and flexible vehicle.

When, after a while, the situation stabilises, then more cost-effective solutions can also be chosen, like the use of own fibre or exchanges.

Of importance for the scenarios is that data transmission in the early phases is the most costly part (estimated 50–70%) of the network, much more than switching. This is different from the situation in incumbent networks. Less costly (estimated 20–30%) are the interconnection bills from the incumbent for the termination of calls. Even less costly are the equipment costs (estimated 10–15%).

A main theme in all scenarios should be to find the right *balance* between (un)certainty and costs.

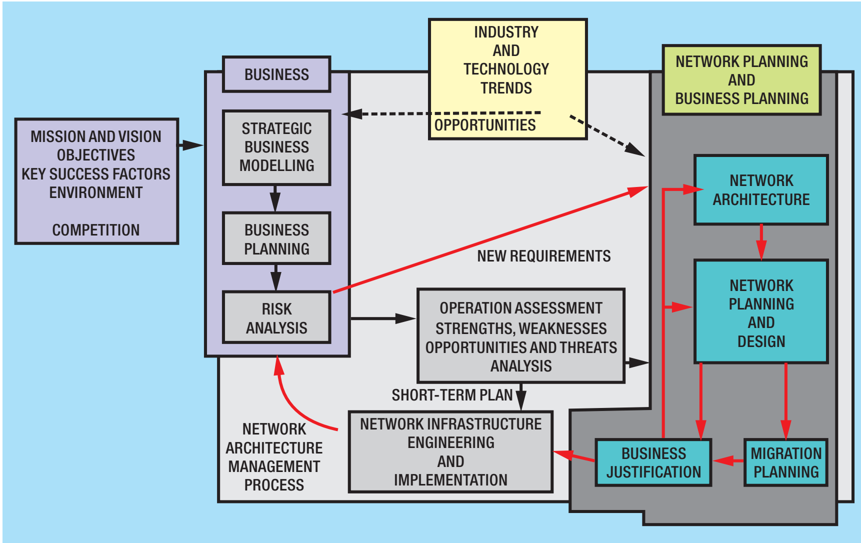



*Figure 1—Integrated approach to network and business planning*

## Economic valuation

An economic valuation technique always used in this respect is the net present value technique and cumulative discounted cash flows. As a simple example, in Figure 2 investments of $100 M are made in year one and returns are valued as high in year 2–5. The free cash flows can be higher, but the net present value is less then $100 M taking into account depreciation, capital expenditures etc. In the example, the investment becomes profitable after about 1·5 years.

## Risk analysis

The Tornado diagram (Figure 3) is a means to see very quickly what are the most important factors influencing revenues in a particular scenario. Dependant on the likeliness of change choices can be made for one scenario above the other. Tornado diagrams take into account several parameters and calculate for extreme

*Figure 2—Example of cumulative discounted cash flows*

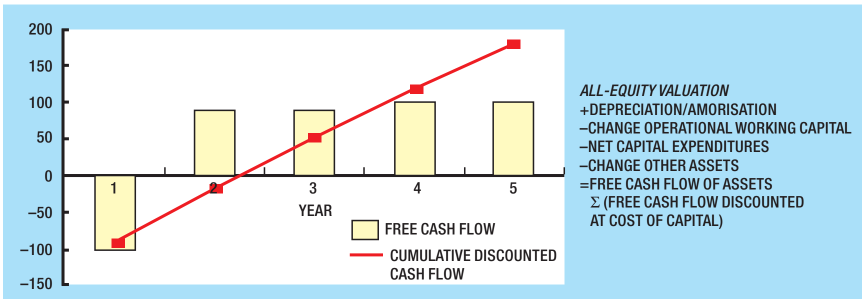
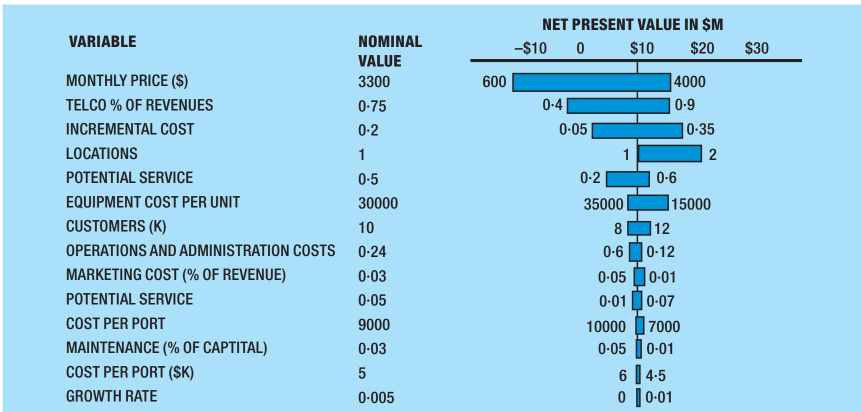



*Figure 3—Typical Tornado diagram*



values of these parameters the result on the net present value of the operation. Furthermore, the results are ranked according to size. Most important is to do studies like this in a continuing and **systematic** way. Following these guidelines (only a few of which are described here) will give an important strategic advantage and will link network technology to business objectives.

## Network Vision of Lucent Technologies

Three basic technologies—microelectronics, photonics, and wireless—are disrupting the communications marketplace.

- *Microelectronics*—or chips—are continuing to follow the famous Moore's curve and are doubling in capacity roughly every 18 months.
- *Optical transmission capacity* is doubling every 12 months—by increasing the capacity of a single wavelength of light and by putting multiple wavelengths of light on a single fibre. Presently a 1 Terabit/s system running 400 km—the typical long distance span—is possible. 1 Terabit/s is enough capacity for all the voice calls that take place around the world at any point in time.
- *Wireless capacity*—the number of calls in a given volume of air—is doubling every 9 months as smart antennas and ever cleverer signal processing algorithms are introduced.

These technology changes, along with the introduction of packet networks—either Internet protocol (IP) or asynchronous transfer mode (ATM)—are driving the march to next-generation networks.

Two areas, technology and regulation are shaping the equipment supply environment. *Regulation* has maintained a modestly pro-competitive stance but on the whole has not caused the level or rate of industry change that was expected. Regulation made it easier for new entrants but is not the dominant force in shaping the industry.

On the other hand, the rate of *technology change* has surprised everyone with the result that relatively stable public network architectures are now subject to rapid innovation at all levels. The combination of these effects has been to create a significantly more complex supply environment. The rate of innovation is dramatically increased enabling many new applications to be deployed (good news), but at the same time increasing the rate of obsolescence.

There are two reasons why the explosion of data is happening now; business demand and the supply of innovative technology. This demand-and-supply spiral has created the Internet phenomena.

First, businesses have discovered the potential to unlock dramatic value in their core operations by using data communications. An example is the overnight emergence of intranets as a knowledge-sharing tool.

Second, on the supply side, it is now possible to build applications (intranets) using modular standardised technology popularised by the Internet.

An important implication for service providers is that the business of serving this demand will operate under new competitive rules. It will lead to a new industry structure offering aggressive prices, new network architectures, and finally an unprecedented drive to offer services across national and service provider boundaries.

Three major technological developments can be recognised, looking at the history of telecommunications since the introduction of automatic telephony:

- *digitisation,* first of transmission, later of switching systems;
- *computerisation* of switching control functions; and
- *packet technology*—in the telecommunication world, first in the signalling systems and now as the alternative to circuit switching, while the Internet was designed for packet switching from the very beginning.

The three technological developments (digitisation, computerisation, and packet switching) have had major impact on the architecture of telecommunication networks. While the electromechanical switching technology led to hierarchical network structures (the tree structure of the numbering plan is reflected in the switching hierarchy of the network), modern telecommunication networks seem to 'flatten', to develop as an organic entity. However, in our vision a more functional structuring can be recognised in modern network architectures.

First we will take a closer look at how the three technological developments have changed, and are changing, the structure of networks.

- Digital transmission technology brought high-bandwidth transmission. The transmission price per circuit is falling and the bottom price will not be reached within the coming years owing to the progress that is being made with optical transmission.
- The introduction of software program control (SPC) created the possibility for address translation. While the classical telephone network encompasses a number of functions inside the network in a distributed way (routing, charging, user identification, etc.), with SPC call control functions were split off and separated. The new network consists of a number of separated functions realised by separate units in a flexible way (call control; transport, access, signalling). A strong example of this phenomenon is the functioning of the Internet. A user can be reached on a domain name address. The domain name system (DNS) translates the given domain name into an IP number, that is used by the network for routing purposes. Thus, the computer (the DNS server) facilitates unbundled network functions by translating the user addresses (domain name) into a technical number (the IP number). In fact, this possibility can be recognised too in the concept of intelligent networks.
- Packet technology was initially applied to achieve reliable non-real-time transport over a network, where data integrity was far more important than the speed of conveyance. Efficiency, since transmission capacity is only used when needed, played an important role as well. There was a clear trade-off between reliability and speed of network transport: packet switching stands for reliable but slow (store and forward); circuit switching is fast but prone to bit faults. All this has changed dramatically. With the developments in optical technology and with ATM and the new developments in IP, the technology of real-time transport with packet (cell) switching is mastered, thus

combining the advantages of both techniques: real-time transport, efficiency in voice and data networking and flexibility for wider bandwidth applications. So the principle of packet switching may become superior to circuit switching when it comes to combining speed and reliability.

It is without any doubt that the technological innovations described above have greatly influenced the architecture, planning and design of modern telecommunication networks.

Below, the vision of Lucent Technologies on the structure of the near future structure of networks will be explained.

Rather than a hierarchical switching structure, a functional architecture will be seen. In the Lucent Technologies view on networks, a grouping in three functional levels will occur (see Figure 4):

- the *user services network and service management* level,
- the *core network* level, and
- the *access network(s)* level.

The influence of the technology drivers can be clearly pointed out in this vision.

Servers provide for address translation functions and network management (upper network level). On this level services applications are handled: voice traffic, data traffic, intelligent network (IN), IP routers etc. These servers use the underlying transport layer and the access layer for connection with the end users.

The availability of very high bandwidths based on synchronous digital hierarchy (SDH) and optical transmission technology (dense wave-division multiplexing (DWDM)), combined with the notion of packet switching being superior to circuit switching, points to the occurrence of wideband, data switched transport networks: the core network. This network has become a unified transport for different services: voice, data, video and leased lines. The question whether the concept of a unified core network will ever enclose broadcast services (for example, television), remains unanswered for the moment.

Another question is what is the nature of the future access technology. Ongoing is the process of 'fibre closer to the user': with optical access rings, fibre-to-the-business and passive optical networks (PONs). Without doubt user mobility will be of paramount importance. If, as a result, wireline access will become less important over time is to be seen. With technologies like asynchronous digital subscriber loop (ADSL), commercial exploitation of copper wireline may be promising for the future.

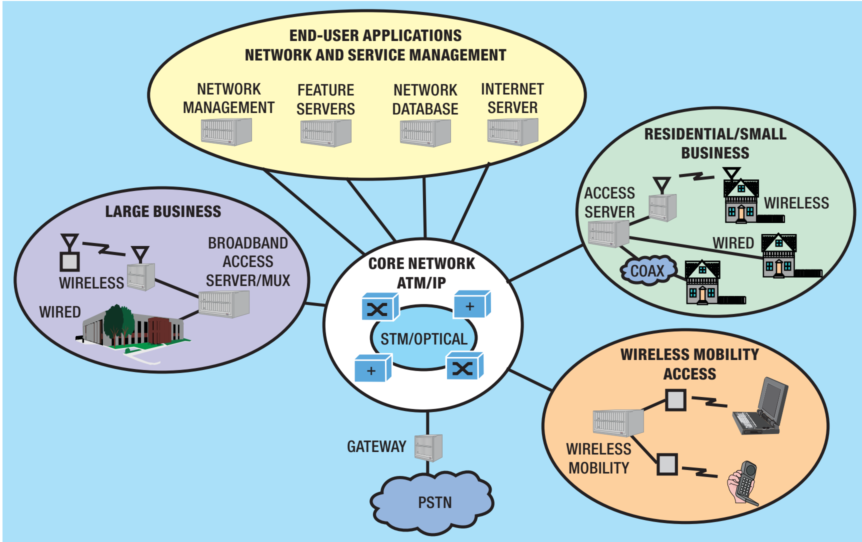



*Figure 4—Network vision*

## Example of the Network Planning Process in an Application of VtoA

Changing traffic mix is driving new networks. Today, data traffic is generally carried over circuit networks that were designed for voice traffic. In the future, as the data traffic exceeds the voice traffic, voice traffic will be converted to packets and carried over packet or cell networks. This will take place because packet networks will be more cost effective and because the packet networks can more effectively carry—and combine—a variety of different multimedia services.

Data and voice traffic have different characteristics. Data traffic has different holding times, bit rate per call and revenue to the service provider per bit transmitted, which is another force driving new networks designed for the traffic specifics.

Different types of operators will have different network strategies as a function of whether they are starting from a 'voice' network or a 'data' network and as a function of the market segments they wish to serve.

At some point in the future, however, these differing networks will converge around the packet-optical core. The real trick will be transitioning today's networks around that core in a way that rich services—both existing and new—can be provided to customers.

As a consequence of the above, many incumbent operators face the question of how to extend the capacity of the circuit switched network. Increase in traffic demand caused by Internet traffic, IN services and interfacing with other licenced operator (OLO) networks leads to capacity constraints in the current circuit switched network.

One step towards a fully packetised network can be to consider planning for a *packet core backbone* network. Some of the advantages of such a plan will be highlighted in the following. Voice-over-packet technology offers new network architecture capabilities. This holds both for IP- and ATM-based networks. Currently, ATM offers better quality of service guarantees than IP. Therefore, in this context of the future evolution of voice networks, we focus the discussion on VToA.

Current circuit switched toll networks usually consist of a full mesh of toll switches (see Figure 5), typically in the order of 40–70. This leads to a number of logical routes of the order of 1000. In the voice-over-packet architecture, devices consisting of three components will provide the toll switch functionality:

- *voice gateway*, for circuit/packet termination, packetising digit collection;
- *signalling gateway*, for signalling interworking; and

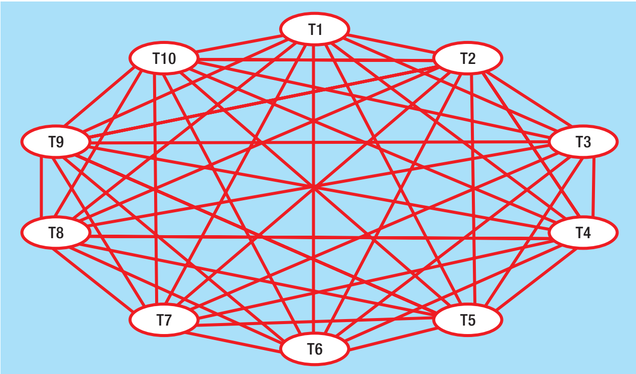



*Figure 5—Fully meshed circuit switched network*

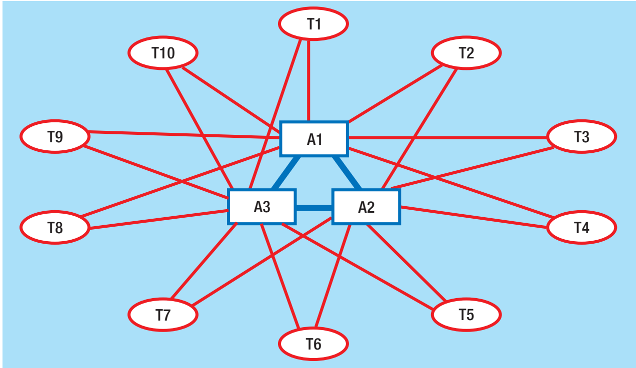



*Figure 6—Voice-over-packet architecture*

- *feature server*, for call processing in cooperation with network databases.

The switching function between the voice gateways is done by a limited number of ATM backbone switches (see Figure 6). The number of ATM backbone switches is considerably less than the number of gateways. The reason is that the core switches are designed for large traffic streams, optimised for STM-4 interfaces. Having one ATM switch per voice gateway location, connected in a full mesh, would result in a poor link efficiency, and thus in high cost, both of the ATM switches and of the transport network.

Therefore, the number of ATM switches should be minimal, taking into account their maximal capacity, and sufficient network and routing redundancy in case of a failure of one of the ATM switches. Typically, there will be 5–10 ATM switches.

The architectural differences lead to a difference in cost of the time-division multiplex (TDM) and voice-over-packet network, both from a one-time investment and from a yearly operational point of view. The main characteristics are as follows:

- *Cost per port of the equipment* In the TDM network, a call going through a switch requires two trunk terminations. In the voice-over-packet case, the voice gateway interfaces to the circuit-based side of the network via a traditional trunk termination. At the other side, the voice gateway has an ATM or IP interface. This interface has lower cost per circuit-equivalent than a TDM interface. This even compensates for the extra, but relatively very small, costs of the core ATM switches.
- *Trunk efficiency* The TDM network consists of a full mesh between the circuit switches. Therefore, there are many, relatively small entries in the traffic matrix, leading to a low trunk efficiency on these direct logical trunk groups. In the ATM case, there are a limited number of trunk groups between the voice gateways and the ATM backbone switches. Each has a quite high traffic load, thus leading to a high efficiency. The trunks mentioned so far, are E0s. Rounding these up to E1s, again gives difference in efficiency between the two architectures, for similar reasons. The difference may even grow further if higher granularity (E3 or STM-1) exists in the transmission network. The difference in capacity is reflected in the cost of transmission. Its relative impact on the total price depends on the cost structure, in particular whether or not leased lines are used.
- *Silence suppression and voice compression* ATM and IP allow application of silence suppression and voice compression techniques. These will result in further reduction of the required bandwidth, and thus in savings in the transmission network. However, this has to be applied with caution. In particular, these techniques are not suited to fax and modem traffic, and may even lead to extra capacity requirements because of the additional overhead.
- *Operational savings* As mentioned before, the TDM architecture has a much larger number of trunk groups than the voice-over-packet architecture. From an operational perspective, there is a close relation between the provisioning costs and the number of trunk groups. First of all, the size of the trunk groups has to be determined, based on traffic figures obtained from measurements and forecasts. Secondly, the actual provisioning requires operations on each trunk group. This means that the costs of the provisioning will be substantially lower in a voice-over-packet network than in a TDM network.

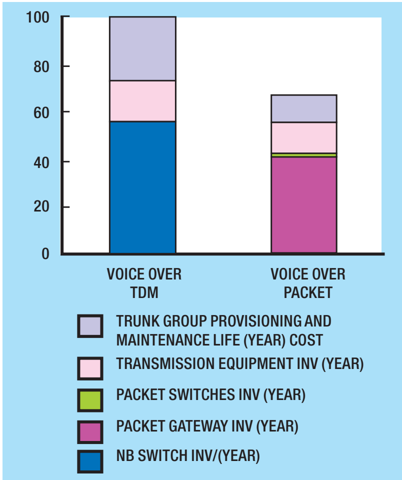



*Figure 7—Life cycle cost comparison of voice over TDM and voice over packet*

## Cost results

As an illustration of the effects mentioned above, an example life cycle cost (10 year) comparison is shown in Figure 7. It is based on a network with 50 nodes. The traffic offered to this network is 375 000 Erlang. No silence suppression or voice compression is applied.

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## *Biographies*

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Johan Kardol is regional Director Network Planning and Design with Lucent Technologies and is responsible for the design of public voice and data network infrastructures for customers of Lucent Technologies in the European region. Customers are incumbents and new entrants. Since 1970 he has worked at Philips Telecommunication Industry, AT&T and Lucent Technologies. He has experience in telecommunications in a number of assignments: responsibility for development of telecommunications equipment, project management of telecommunication projects, operational responsibility for business networks and consultant. Johan received a master's degree in electrical engineering at the TU Delft.

**Paul Kallenberg**
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Paul Kallenberg received his master's degree in mathematics in 1975 at the University of Leiden, the Netherlands. In 1979 he received his Ph.D. in mathematics, also at the University of Leaden. From 1979 to 1980, he was member of the department of Statistics of the Centre of Mathematics and Computer Science in Amsterdam. Since 1980, he has worked at Philips Telecommunication Industry, AT&T and Lucent Technologies. He was involved there in teletraffic engineering, in particular on overload control, network dimensioning, congestion control and queuing problems. Since 1990, he has worked on network planning. He has experience in modernisation plans for switching and transmission networks in many countries in Europe and the Middle East, cost comparison studies for TDM and voice-over-packet (ATM/IP) networks, in access network planning projects and planning of SDH and ATM networks.