White Paper

Mobile Network Transmission

Nokia's vision of evolution of the transmission capacities, medias and technologies in mobile networks

GSM, EDGE, WCDMA

NOKIA
CONNECTING PEOPLE

Contents

Introduction

Evolution of mobile networks

Mobile networks are leading the evolution of the information and communications society towards the MIS (Mobile Information Society). This means that subscriber numbers are continuing to increase as mobile penetration reaches new heights (see figure 1). Also, multimedia communications and other packet-based traffic will gradually increase their role and finally predominate in mobile networks.

This development has already started with modest data volumes over current mobile networks, and rapid increases in data applications and traffic is expected soon. New technologies and technical solutions enable higher data volumes right now in existing networks; in GSM networks, HSCSD (High Speed Circuit Switched Data) and GPRS (General Packet Radio Service) greatly expand these networks' capabilities to handle data traffic and enable new and more user friendly applications thanks to the higher bit rates available. This development will continue with still higher bit rates over the air interface in the new 3G EDGE (Enhanced Data Rates for Global Evolution) and 3G WCDMA (Wideband Code-Division Multiple Access) based networks.

These increasing data traffic volumes mean that the share of the packet based traffic in the total

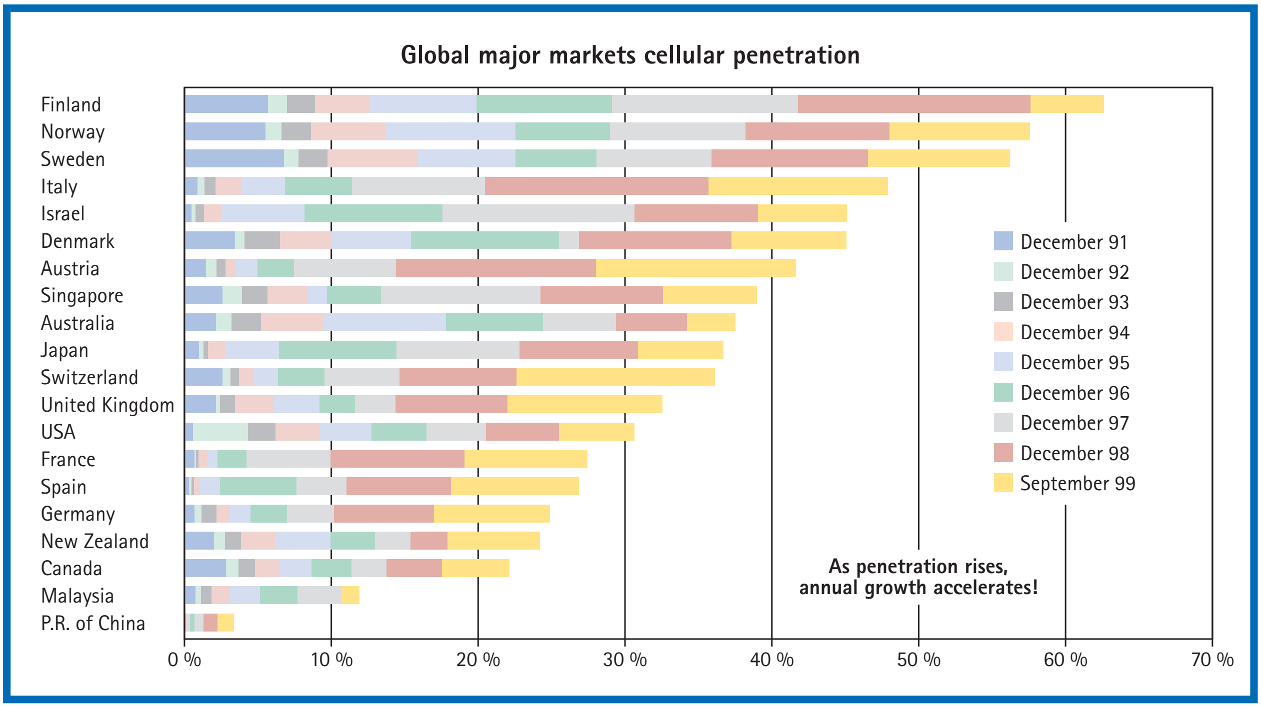

Figure 1. The growth in mobile phone penetration (Sources: Financial Times, Nokia)

traffic mix in the mobile network is increasing, at the same time as total traffic volumes are also rising rapidly. Data will make up 50 % of cellular networks' traffic in 5–7 years time, as presented in figure 2. These developments are obviously gradual. Evolution of the wholly circuit switched networks into packet based networks will take some time, and should be done in well planned and managed steps, so that the efficiency of the mobile network is preserved during the changeover phase.

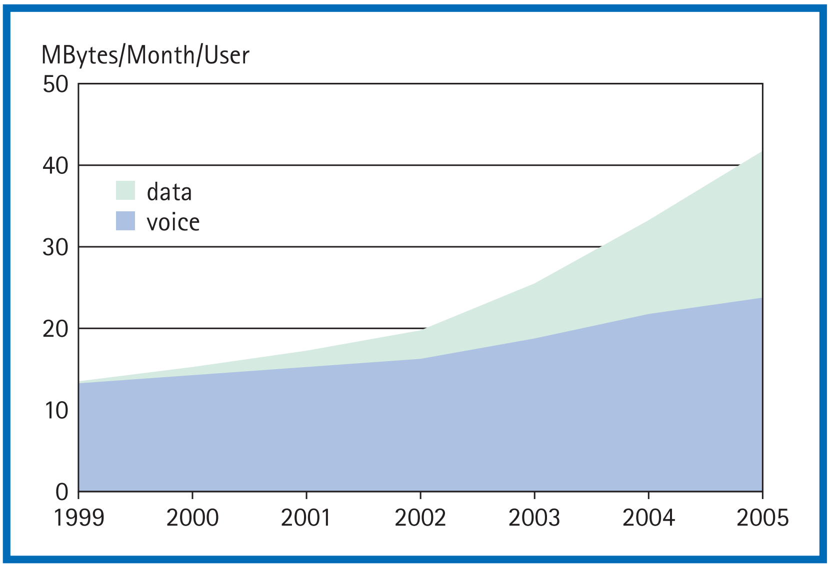

Figure 2. One estimate of wireless data evolution as a share of the total mobile traffic

In many cases, basic mobile voice services are also growing quickly due to growth in the number of subscribers, which also contributes to the overall traffic increase and continues to require economic solutions for this type of traffic. Therefore, the well-planned steps are vital to manage mobile operators' cash flows and to make full use of existing investments. It is in the interest of a mobile network operator to angle his future transmission network strategy towards this expected increase in the penetration of advanced data services.

Challenges in Mobile Network Transmission

Transmission is an important element in any mobile network, affecting both the services and service quality offered, as well as the costs of the mobile operator. Optimisation of transmission solutions is thus certainly worthwhile from the operator's business point of view.

In current mobile networks, transmission has been optimised for the narrow-band circuit switched traffic. This type of traffic will continue to dominate for some years: trying to optimise a network without taking it into consideration is totally out of question.

However, as stated above, packet based information over the mobile network will show rapid growth and any reasonable network development plans have to take this into account and plan for a smooth and economic transition and evolution path for the transmission network.

So, in broad terms, the transmission network must continue to provide well engineered and economically optimised solutions for the growing volumes of circuit based traffic, while at the same time develop the readiness to cope with the even faster growing data traffic of the future. This type of transmission solution is needed in all parts of the mobile network, both in access networks with many points and low-capacity links, as well as in core networks with high traffic volumes.

This means for example that in a GSM network, a transmission solution is needed which provides for efficient transport of large number of 16 kbit/s channels and which can evolve to also carry packet based traffic, either ATM (Asynchronous Transfer Mode) or IP (Internet Protocol) or both. The solutions might be similar or different in different parts of the network: even the role and share of the different traffic types (TDM, ATM, IP) might be different, but the transmission network must support them all in a planned and managed way.

Current Mobile Network Transmission

Transmission network parts

In any mobile network, there are different transmission needs, typically divided into two main application areas with their own characteristics:

- *Access network*, which connects the base stations to the closest network control or network hub point, and called here "Base Station Access Network", and
- *Core network*, which connects the control (or hub) points to the mobile network switching centres, and called here "Core Transmission Network".

In GSM networks, the control point mentioned above is the BSC (Base Station Controller) site: in WCDMA networks it is known as the RNC (Radio Network Controller) site. In a network structure with centralised BSC/RNC elements, the distinction between access and core in the transmission sense may be more naturally defined as certain hubsites where traffic for large numbers of base stations is consolidated into common transmission pipes.

Key characteristics for Base Station Access Network transmission are that there are a lot of base stations, in different types of location, new capacity is added constantly in the form of new transceivers and sites and the transmission capacity needed for one base station is relatively low.

In the switching and BSC/RNC environment, there are far fewer sites and distances between them are often significantly long compared to distances from one base station to another;
the transmission capacity at these connections is high as a result of traffic accumulated from a large service area; and as these connections carry a lot of traffic, they must be highly reliable.

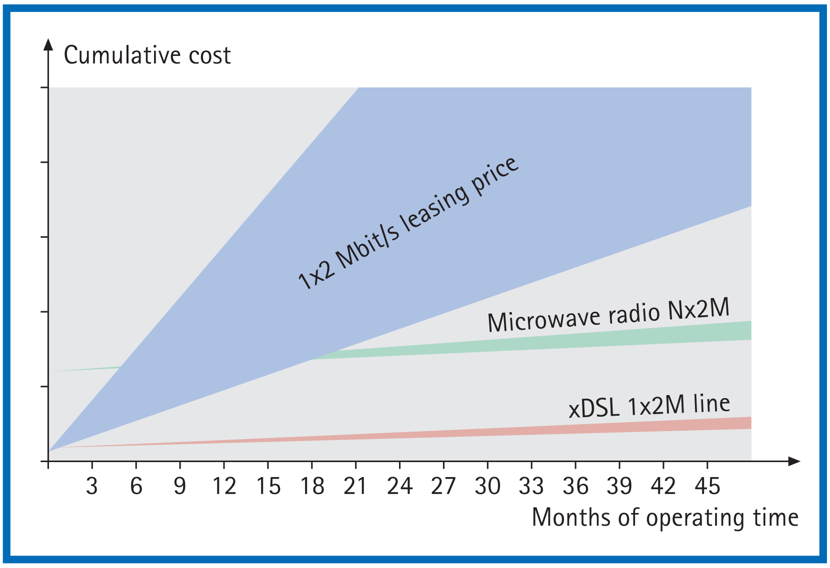

Figure 3. Cumulative-cost comparison of own vs. leased access transmission

Base Station Access Network

The Base Station Access Networks are most often both owned and operated by the mobile network operator as a strategic asset.
The main reasons for this are profitability, together with the control it gives over roll-out and services in terms of quality and the timely availability of new connections.

Microwave access dominates in base station access network implementations, as it is often the fastest means for network roll-out and capacity-expansion.
Using microwave transmission, an operator saves on operational expenses compared to laying his own cables or leasing connections.
At least two-thirds of all base station connections are based on microwave.

A good alternative in base station access is copper-based transmission, when copper lines are widely available at an attractive price.
This is particularly attractive if the operator owns copper lines.
The access technology for the “cold copper” case has been HDSL (High bit rate Digital Subscriber Line). However, copper-based connections may not always provide the same flexibility and controllability in roll-out as wireless alternatives. Copper has redeemed its place particularly in offices, where base stations need to be connected to the existing network infrastructure.

Optical fibre is constantly gaining a greater foothold. Fibre-optics have a clear role in future network implementations, providing transmission capacity to regional hubsites, from where the capacity is further distributed by using wireless or copper media up to individual base stations.

Mobile network operators who also operate an optical fibre network may use this asset today to provide access even up to the base station sites.

Hubsites are needed in Base Station Access Network transmission for grooming traffic and managing protection, especially when distances between the BSC and base station increase. Support for various topologies and media alternatives with varying interface capacities satisfy future growth path needs. Having the required solution integrated with the BTS (Base Transceiver Station) and manageable by a single Network Management System provides smooth, timely, cost efficient and reliable implementation, as well as ease of operation.

Core Transmission Network

The connections between switches, extending also to base station controller connections, are of higher capacity than the base station access connections, and the distances to cover are longer. Not every mobile network operator has so far had the resources to build their own transmission for these long legs, so these may be rented from a country-wide transmission services provider as protected 2 Mbit/s connections.

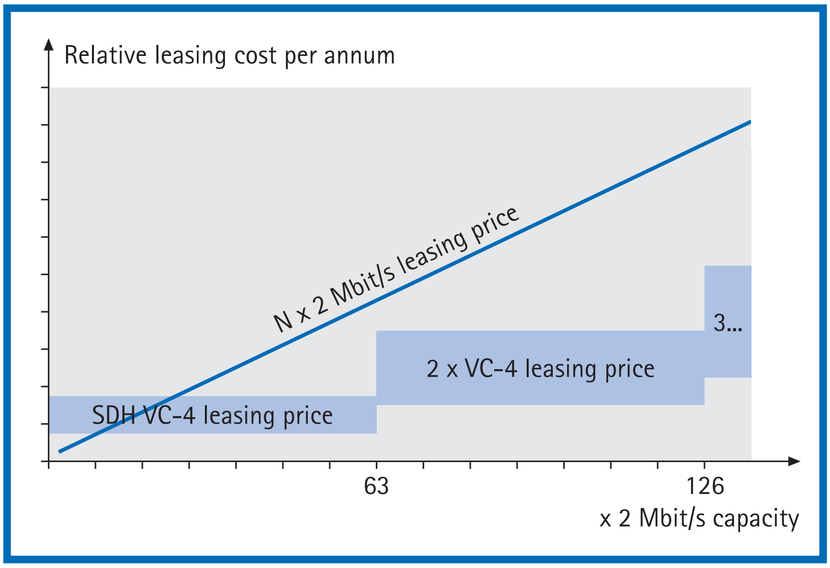

Figure 4. Cost-comparison between leased bundle of 2 Mbit/s connections vs. a VC-4 connection

Fibre-optic networks have extended in many areas. This trend has been driven primarily by the global data services boom generating the need for higher transport capacities. Fibre-optics is often the most feasible implementation of core transmission infrastructure in areas where basic telecommunications services have been scarce. BSC-to-switch and inter-switch traffic is already carried mostly over optical fibre, even if this may be invisible to a customer subscribing to a protected N x 2 Mbit/s leased line service.

The existence of fibre-optic networks, and synchronous digital hierarchy (SDH) technology in particular, compared to N x 2 Mbit/s leased line service prices, has led many operators to reconsider their core transmission sourcing policies.

Firstly, much of the existing N x 2 Mbit/s leased transmission has been converted into SDH VC-4 leased transmission, providing 63 x 2 Mbit/s capacity. The main reasons for this change are the savings achieved in operational expenses and the fast upgrades in capacity. The only changes involved for mobile network operators have been the purchase of an SDH multiplexer, located at their central transmission sites, to provide 2 Mbit/s electrical interfaces with the leased SDH stream.

If the leasing alternative is chosen for backbone services, for greatest cost-efficiency, leasing should take place at the STM-1 (VC-4) level, not the N x 2 Mbit/s level. With current leasing prices, the SDH alternative may bring the annual operating cost of leased connections down by around 70–80 % for full SDH lines, easily justifying the modest investment needed in SDH terminal multiplexers. With partially-empty lines, the savings are naturally less than this.

The second step, already directly taken by a number of mobile network operators, has been to acquire their own SDH terminal equipment and lease dark fibre to carry the signal. In areas where leased dark fibre is a scarcity, the growth-path from this has been a roll-out of own or partially owned fibre-optic cable infrastructure between key locations in the network – including the central switching sites and a number of other strategically important hubsites, for further capacity distribution to meet the needs of the base station access system.

Capacity evolution – GSM, EDGE, WCDMA

Capacity requirement at an individual site

Globally, many GSM operators possess about 5 MHz of bandwidth for their use and under this condition each macrocell can be allocated up to 3–4 TRX (Transceivers). As three-sector base station sites are very common, each base station site then has up to 9–12 TRX, requiring 1.5...2 Mbit/s of transmission capacity per site. In rural areas the number of transceivers per cell can clearly be less, and the transmission capacity requirement is accordingly lower.

When the operator has been allocated more carrier channels, either on the same band or as a dual-band solution, and these additional carriers are allocated to the sites described above, the maximum transmission capacity per site naturally increases in proportion to the number of carriers.

The limited number of mobile network radio channels available limits capacity achievable with the macrocellular solution. After the macrocellular capacity ceiling has been reached, mobile network capacity expansion takes place through a transition to micro and pico cells. These, in addition to loading the transmission connections higher up in the network hierarchy in the same way as macrocell transceivers, require low-capacity transmission connections to be available at new base station sites. The transmission network constantly expands, radially from the core network. This creates a need to use different capacity options, providing the same transmission products in various parts of the network.

If a significant number of channels are allocated to a microcell layer complementing the capacity of the macrocell network, the transmission capacity requirement accumulated from within the service area of a macrocell may increase radically (e. g. by 5–10 Mbit/s). This is because frequency re-use in the microcell layer can be considerably tighter than in the macrocell layer and the microcell layer can thus accommodate many more transceivers per square kilometre than the macrocell network can ever do.

Both scenarios thus lead to an increased transmission capacity requirement in the parts of the network where transmission lines from various base stations start accumulating into wider streams. The evolution in this respect is first to expand the Core Transmission Network. The next step is to expand Base Station Access Network with new hubsites at central locations close to major base station clusters and distribute capacity for base station access from these points.

In a combined macrocell plus high-capacity-microcell implementation, transmission to microcells can be provided either through the macrocell acting as a hub point, or by-passing the macrocell, fed directly from the base station transmission backbone. Transmission for the traffic originating from indoor office picocells can be provided in the same way.

New high capacity EDGE and WCDMA air interfaces enable a totally new service portfolio for mobile end users. This introduces great opportunities for mobile network operators to create profitable growth from increasing mobile usage. EDGE, by increasing the GSM air-interface bit-transfer capacity three-fold, also increases the capacity required at the BTS-BSC connection for the EDGE-TRX.

It may be that a GSM operator adopts EDGE for wide use fairly rapidly in urban areas, whereas in rural areas most of the transceivers may remain traditional GSM transceivers for a long time and EDGE is implemented as a thin macrocell data communication services layer. In dense urban areas, the transmission capacity requirement per site of such a network may quickly quadruple, having strong implications not only for the Base Station Access Network, but also for the core network. In the areas where EDGE is rolled out only as a thin layer, the overall increase in net capacity need may remain very modest.

WCDMA technology is an alternative way to implement high-speed data services. The transmission capacity generated by one base station is very dependent on the network configuration and traffic profile. However, as a general rule it can be said that the transmission capacity need per site is clearly higher than with GSM, and somewhat higher than with EDGE base stations.

If a GSM operator implements a WCDMA network, WCDMA base stations are likely to be co-sited with GSM macrocells. In this case, the transmission from the WCDMA base station adds to that of the GSM base station.

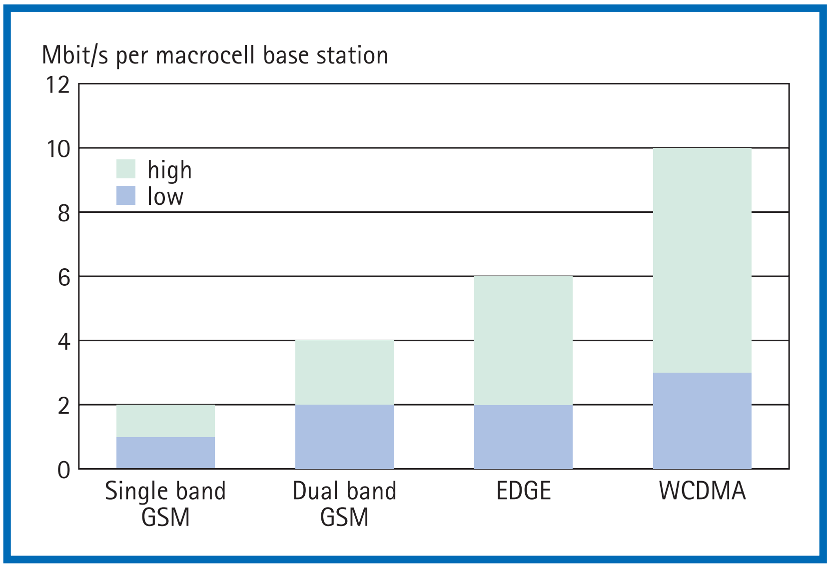

Figure 5. Indicative transmission need per macrocell base station

Transmission system capacities in Base Station Access Network

An examination on a single-site basis helps determine the capacity of the final access transmission, but does not yet give a picture of the accumulated transmission capacity need. To get an understanding of this, the service areas of each base station need to be introduced. This is performed by assigning traffic in Erlangs and seeing what kind of network is needed to support it.

Dense urban area

When the traffic generated on a square kilometre area reaches 800–1500 Erlang, one can already speak about dense urban area. In this environment, macrocellular implementation is rarely the only solution, but needs to be complemented by a high-capacity microcellular layer.

Assuming that the network is built e. g. with four transceiver-GSM macro and micro cells, the respective required connection capacity versus service area in km^2 is presented in Figure 6. About 20 % spare capacity to be used for future upgrades has been taken into account in the calculations.

This suggests clearly that the first challenge in future-proof base station access transmission implementation is the density and cost of access connections. The second challenge is collecting the accumulated base station access at city blocks and transporting them to the base station controller. The solution for these challenges is to use macrocellular sites as transmission hubsites. Capacity scaleable fibre optics with SDH technology provide a future proof growth path for macrocellular sites. The last hop access connection from the macrocell site to microcell sites and indoor sites is implemented with a dense wireless access solution.

Where fibre-optics cannot be used for the high-capacity base station backbone network, SDH STM-1 microwave systems provide a good approach, within the possible limits of available radio spectrum.

Urban area

In urban areas, where generated traffic is in the range of 300–600 Erlang/km^2, a three-sectorised three-transceivers per cell GSM system generates 10–20 Mbit/s of transmission need per square kilometre because the maximum cell range is clearly limited by capacity, not cell coverage.

Figure 7 presents respective connection capacities versus service areas. The required solution is comparable to a dense urban area but capacity grows later.

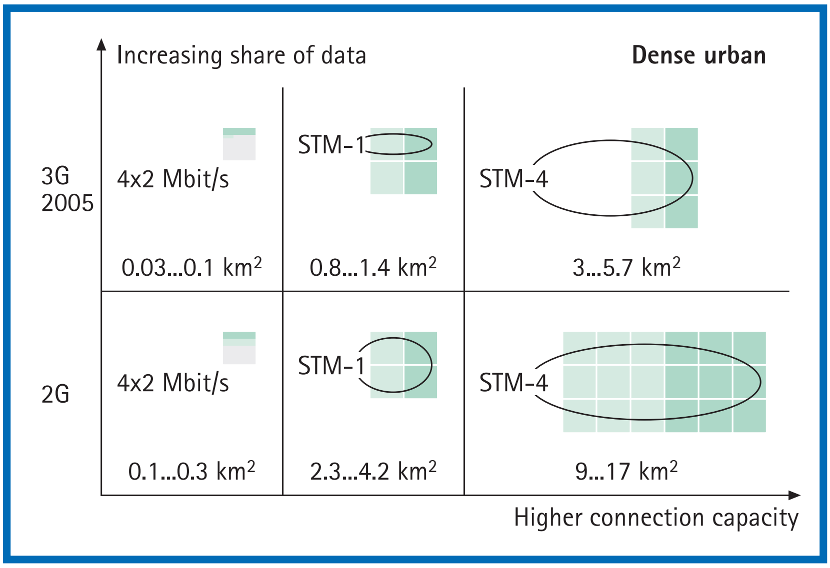

Figure 6. Connection capacities vs. service areas in dense-urban area and estimate of the evolution to year 2005

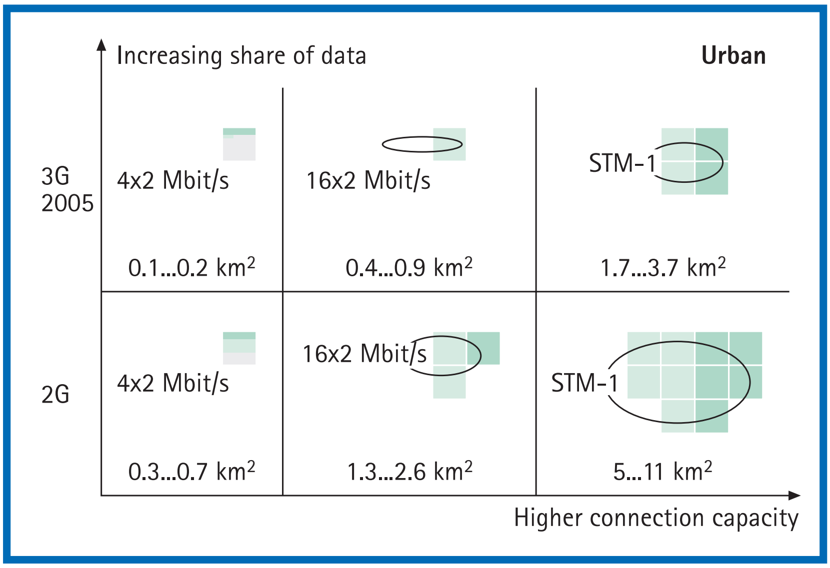

Figure 7. Connection capacities vs. service areas in urban area and estimate of the evolution to year 2005

Rural area

In rural areas, assuming up to 2 TRX per cell in a GSM system, transmission capacity is typically not a limiting factor in base station access: the main consideration is often the length, reliability and cost of connections. Even if GSM was upgraded to thin EDGE coverage, or thin WCDMA coverage, medium and short haul radio links would provide enough capacity.

Core Transmission Network

The Core Transmission Network connects the mobile network controller sites to the switching nodes of the network; in the GSM/EDGE network the BSC sites and in the WCDMA network the RNC sites, to the Mobile Switching Centre/Serving GPRS Support Node (MSC/SGSN) sites. Controllers may alternatively be co-located with the MSC/SGSN. *)

The core transmission network may be, and often is, shared by other service networks, so that a general-purpose transport network is built. Here, however, only the part of the network serving the mobile traffic is considered.

An example of a Core Transmission Network is shown in Figure 8. In this example controller sites with BSC or RNC only are shown, as well as a site with both BSC and RNC. The main differences from the transmission network point of view are different capacity and signal granularities in the interface and the different physical interfaces.

The capacity required in the Core Transmission Network increases as the access network capacity grows. The BSC and RNC concentrate traffic and the transmission capacity requirements above them are smaller – the factor depends on the type of traffic, but it is typically of the order of 3...4 for GSM networks and of the order of 2 for a WCDMA network. Thus using these factors, access network capacity data and the core network topology, a rough idea of the transmission capacity needed in the core network may be gained. Alternatively, a fixed number of 2 Mbit/s lines per BSC and a STM-1 (155 Mbit/s) line per RNC may be used for a very rough capacity estimation. For more accurate network evaluation, use of a transport network planning tool is highly recommended.

Due to the required transmission capacity, almost all new Core Transmission Networks are today built using SDH technology. In practical implementation, layered SDH provides the necessary capacity, protection, synchronisation and flexibility for routing of the traffic. It also provides seamless connectivity and easy interoperability between network elements. The fibre network capacity can be upgraded through DWDM (Dense Wavelength-Division Multiplexing) for future demands or other services.

SDH also provides a good platform for transporting different types of traffic, as it can easily support both TDM (Time-Division Multiplexing-2 Mbit/s lines), ATM and direct IP (packet over SDH) connections. The required SDH links between the sites can then be implemented using leased connections from another operator, by building own transport network, or by a combination of these. STM-1 leased lines are used where building ones own network is too expensive or otherwise difficult, e.g. due to regulatory reasons.

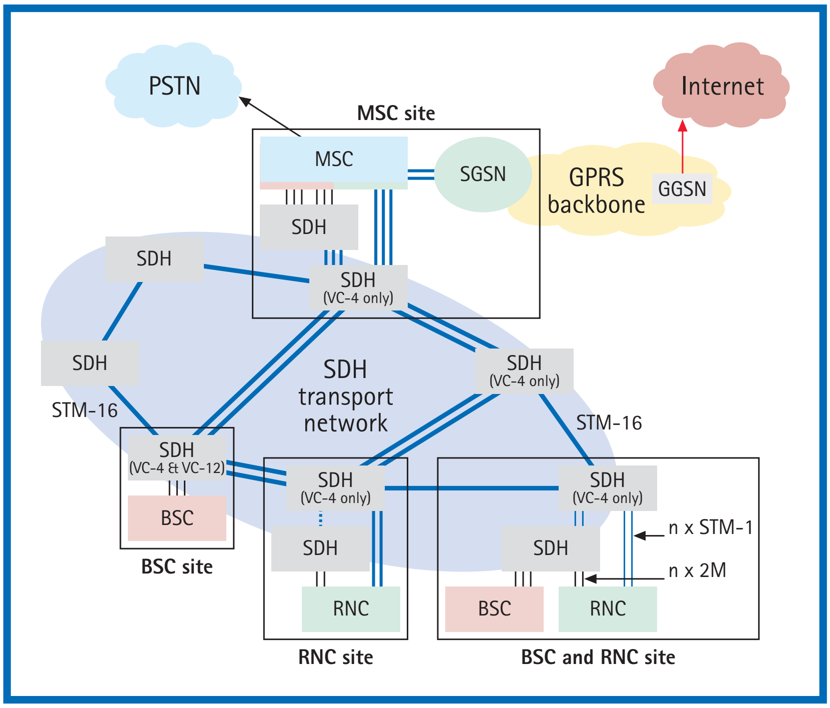

Figure 8. An example of core transmission network for combined GSM/WCDMA mobile network (in the example several different types of controller sites are shown).

In a larger capacity mobile network, especially one combining GSM, EDGE and WCDMA, the total capacity needed and the growth expected are often so high that the transport network is built using only higher capacity SDH equipment (STM-4 and STM-16, with line rates of 620 Mbit/s and 2.5 Gbit/s). In the example shown the whole core network consists entirely of STM-16 systems, which is justifiable if only a limited number of fibres is available and a reasonable spare capacity is desired for growth.

*) Controllers (BSCs and RNCs) may also be co-located with MSC/SGSN, either partly or wholly. In that case, the Core Transmission Network as defined above vanishes into local in-site connections for those controllers. However, a quite similar transmission network is also needed in this centralised controller case, for connecting major base station hubs, which collect traffic from a large number of base stations, to the controllers. This network requires, in fact, higher transmission capacity (by a factor 2...4) than the controller-MSC/SGSN network, as there are no traffic concentration points: the hubs only consolidate the connections in the transmission network layer, but do not use the actual traffic information. Therefore, building the 'upper part' of the Base Station Access Network in the centralised controller case is very similar to the Core Transmission Network described above, with somewhat higher capacity needs.

Media evolution – the increasing role of fibre

If the operator has not yet installed sufficient base station access transmission capacity, with the aid of a high capacity base station transmission backbone network, this is now worth considering as a future goal.

An important strategic consideration for a mobile network operator is the question of access to the optical fibre resources needed to implement a high capacity network. The alternatives seem to be: laying his own optical fibre network, renting dark fibre, or leasing an SDH transmission service.

Using a fibre-based SDH solution for all the backbone connections in a mobile network seems very feasible when compared to the foreseeable evolution of mobile networks, i. e. within a five-year time-period. At the same time, the number of wireless low-capacity access links grows constantly to cater for the transmission needs in the base station access system. Grooming of traffic when connecting base stations is needed in order to use the available connection capacities effectively.

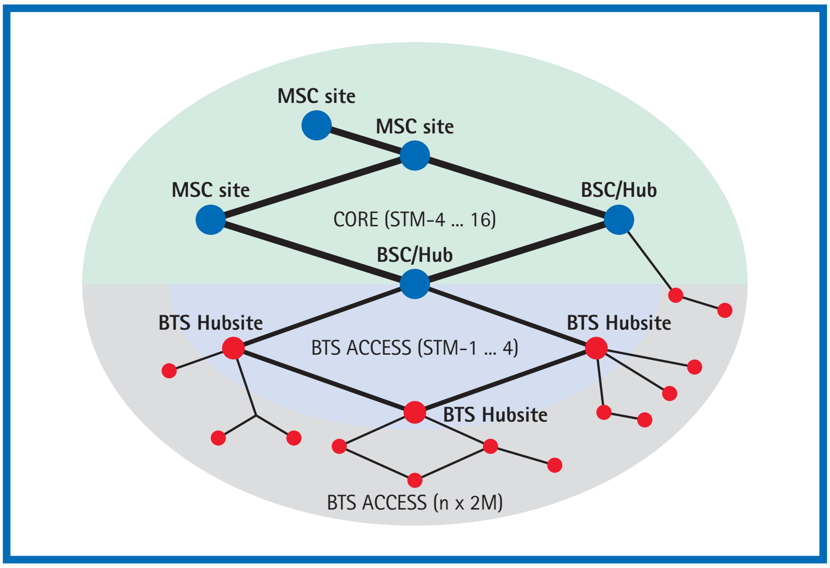

Figure 9. Evolving access-backbone approach in the transmission system of a mobile network

Evolution of transmission technologies

Packet based traffic as a share of the total traffic in mobile networks is increasing. The dominant applications create bursty data traffic best served with packet switched connections. Thus, in order to provide cost effective transmission solutions for data traffic, packet switching solutions that introduce dynamics to traffic handling must also be provided in the network.

As the network evolves to 3G, ATM and IP technologies will be used in Base Station Access Network to provide efficient and flexible connectivity and transmission solutions. Base Station Access Networks set special requirements to transmission solutions. GSM and WCDMA base station networks must meet strict delay requirements set by the radio access, presently solved using circuit switching in GSM and with ATM in WCDMA. The IP, supporting effective QoS (Quality of Service) for delay sensitive traffic, provides a way for IP Base Station Access Networks to meet the required delay. Use of IP as a transport solution for mobile traffic is efficient for Internet access applications and header compression can ensure better efficiency for voice connections.

2G and 3G base stations are required to be synchronised. Synchronisation is normally distributed to base stations via layer 1 transmission connections. Thus, synchronisation distribution and provision functionality must be supported by both ATM and IP packet switching/routing elements that are to be used in Base Station Access Networks. As the Base Station Access Network complexity grows, the amount of commissioning work increases. In order to reduce the commissioning work load, autoconfiguration of transmission elements is needed. Standard Internet Protocols provide powerful tools for configuring and managing new network elements from a centralised database.

The optimal development of the network is seen to be an evolution from circuit switched towards packet switched, building on the existing PDH and SDH transport layer and thus protecting the investment made in PDH and SDH elements. The transmission pipes implemented with fibre optic connections or microwave radio links can stay untouched while implementing packet switching capabilities in the network.
The principle of this is illustrated in Figure 10, which presents the starting point and end point of the evolution of packet switching functionality in the network.

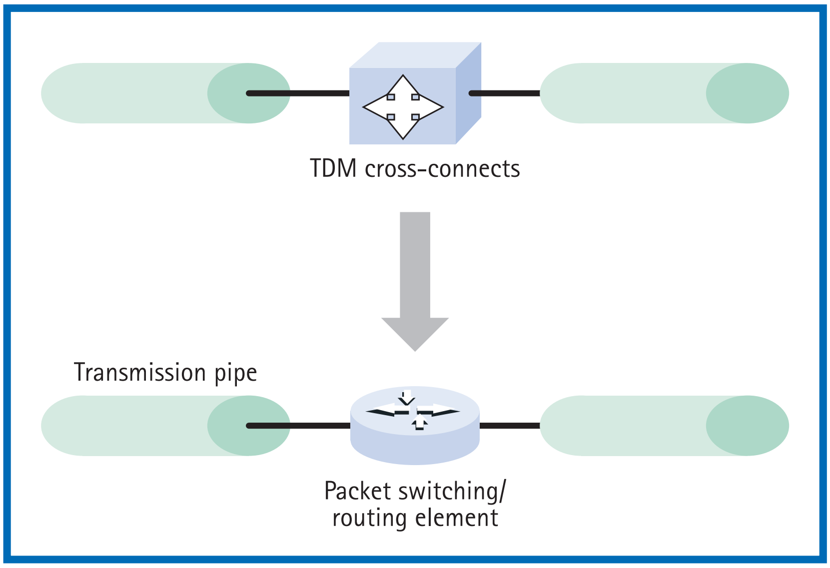

Figure 10. Upgrade of TDM network to packet switching

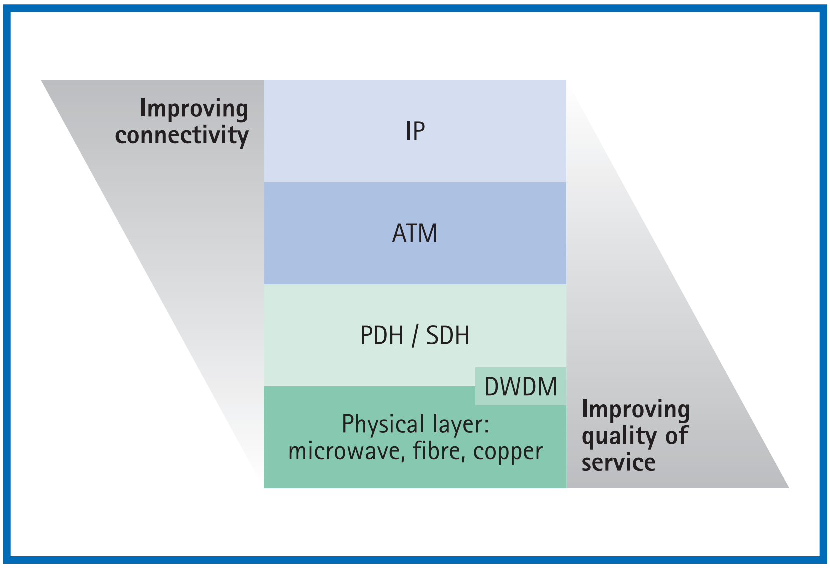

Figure 11. The hierarchical layer architecture in present data transmission

The most popular theme in modern data transmission discussions is naturally the Internet Protocol, which practically positions itself as a layer on top of, for example, ATM. IP can also be layered on top of SDH, DWDM or fibre conduit: likewise ATM can be run on top of DWDM. Circuit switched connections can be emulated through the ATM layer or IP layer.
The longer term goal is to reduce the number of traffic handling layers needed in order to reduce cost, complexity and overhead.
IP on top of fibre is seen as the ultimate goal of technology evolution in this context.

IP technology when used to build a connectivity layer seems to open new opportunities in network implementation and operation.
IP is not currently an off-the-shelf solution for Base Station Access Network transmission, due to the issues described here but is first used in the Core Transmission Network.

GPRS/EDGE transmission technology evolution

GPRS (General Packet Radio Services) in GSM and EDGE networks introduces new network elements: SGSN and GGSN, which are IP elements. GPRS traffic from a mobile subscriber is carried over the existing circuit-switched base station subsystem transmission network to a base station controller just as voice-traffic and circuit-based data are. GPRS traffic is separated and directed to the SGSN from the BSC. It is carried via 64 Kbit/s FR (Frame Relay) connections. Transmission between SGSN and GGSN is handled on an IP layer.

The IP connections between SGSN and GGSN and from GGSN outwards are typically carried over an available data network, or over switched circuits dedicated to IP traffic. The GPRS IP elements can therefore be either connected direct to an IP network, or carried to an IP access point through the circuit-based mobile network transmission system.

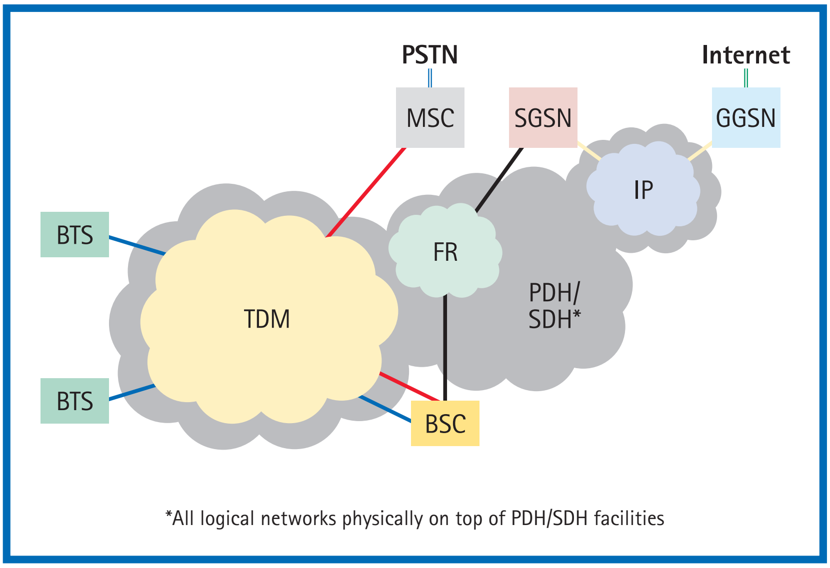

Figure 12. Logical connections in GSM network upgraded with GPRS

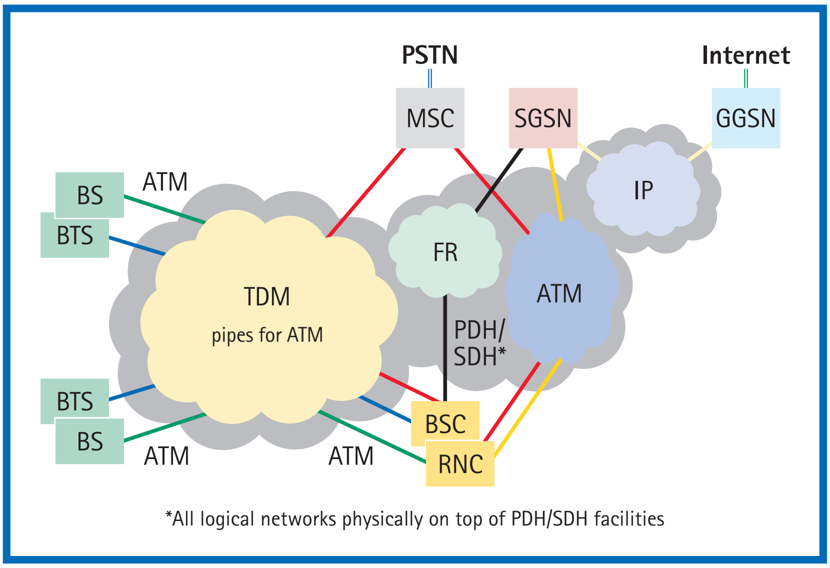

Figure 13. Synergistic view to co-existing GSM & WCDMA technologies on one transmission platform

WCDMA transmission technology evolution

The ATM functionality is embedded into WCDMA network elements, the BS and the RNC. Its main function is to offer an efficient and specified quality of service transport for the radio network layer protocols. This transport service is characterised by ATM parameters offering the necessary bandwidth and delay guarantees.

For physical transport, ATM cells from WCDMA are mapped into PDH/SDH layer timeslots, frames and virtual containers, making WCDMA appear as a capacity increase in the present PDH/SDH based transmission network. This means that the existing GSM transmission network can be shared with WCDMA.

The effect of ATM in WCDMA on the transmission network remains somewhat limited: ATM is embedded into the WCDMA elements, and the transmission between the elements may well be provided with conventional circuit-based technologies without additional investments. In this sense the circuit-switched PDH and SDH layers see WCDMA only as a capacity increase, and WCDMA sees PDH and SDH as a physical medium, providing the important functions of synchronisation and protection.

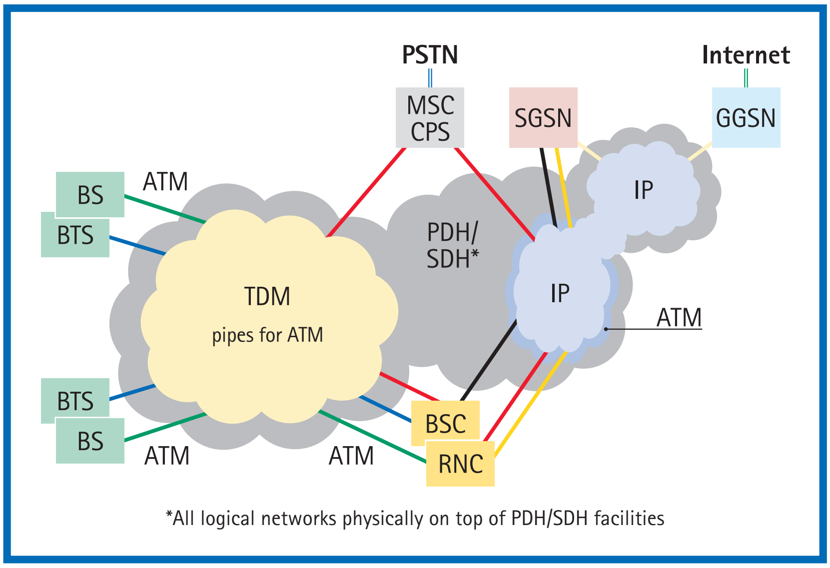

Figure 14. IP transmission between RAN and GPRS core

IP-RAN transmission technology evolution

In mobile networks, IP deployment started from the 2G GPRS core. Currently, IP is taking on the role of transmission technology between the core and RAN (Radio Access Network) and eventually it will move towards the network edges in the RAN. This trend is heading towards a single and simplified transmission technology, all the way from base stations to the Internet gateway in the GGSN. Choosing IP for transmission also means that the fast development of general Internet technologies will also be immediately available for cellular transmission.

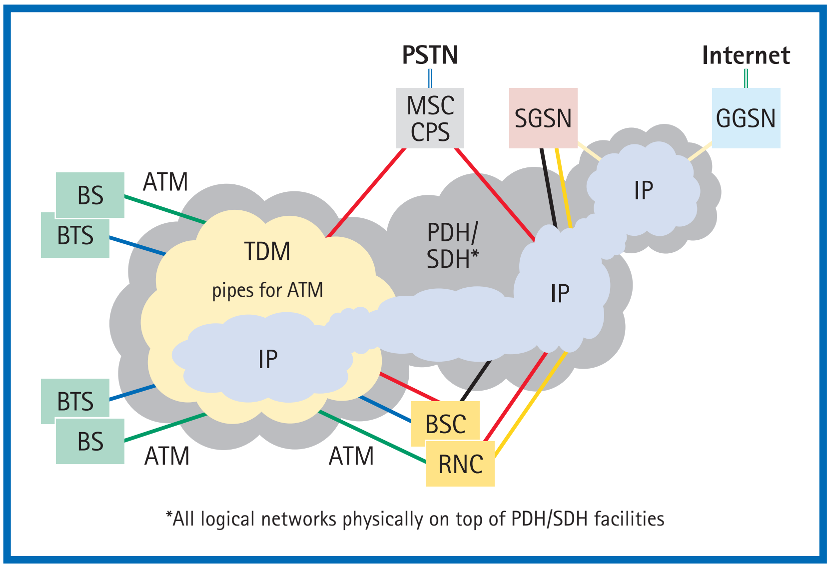

Figure 15. Shared GERAN/UTRAN transmission

In the first phase, the IP 'cloud' expands from the GPRS core to the RAN interface, i.e. between SGSN and BSC/RNC network elements. IP is a natural choice as the transmission technology for the mobile user's data traffic. Typically, the current Frame Relay and ATM pipes in the interface are capable of carrying high data volumes. IP uses the available bandwidth efficiently and results in savings due to statistical multiplexing gain.

Later, the IP cloud expands inside the radio access network down to individual base stations. The necessary solution will enable a gradual migration from TDM, to ATM, to an all IP based solution.

Certain requirements of the radio access network set a challenge to IP deployment. A traditional packet network cannot carry synchronisation signals and special means must be provided to the base stations. Current strict delay requirements and low bandwidth transmission links between the BTS and BSC need careful network planning to enable smooth evolution towards IP. Current off-the-shelf IP routers use best-effort packet forwarding, giving an unacceptable QoS variation for RAN use. Once these challenges have been met, all the network convergence and futureproof IP advantages mentioned earlier will be available in RAN as well as in the GPRS core.

From the mobile service's perspective, voice and multimedia over a packet network opens a wide variety of new possibilities. Portals and browser based access to both voice and data services changes the applications dramatically. IPv6 in the mobile and RAN will provide enhanced mobility and QoS support.
It also enables push services to the mobile by providing static IP addresses to all mobile hosts.

Conclusion

Increasing subscriber numbers and share of data traffic creates significant growth in the transmission capacity needed for long term network evolution.
The implication of this is the incresing role of fibre in future network implementation.
Microwave radio based transmission is used for last mile access to greater extent.

There will be more and more data traffic and applications which create bursty traffic. Thus, in order to provide cost effective transmission solutions for data traffic, packet switching solutions introducing dynamics to traffic handling must be provided.
It is possible to achieve a smooth evolution in the implementation of this.

Investments made in fibre and microwave radio based transmission links are protected as new evolution phases can be built on top of existing infrastructure.

Nokia Networks
P.O. Box 300
FIN-00045 NOKIA GROUP, Finland
Phone: +358 9 51121
Fax: +358 9 5113 8200
www.nokia.com

Connecting People

Nokia code: 0582_EN_0400_1.0