Microwave transmission in mobile networks

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Microwave links became an enormous success with the roll-out of second-generation mobile networks. With close to 500,000 units delivered to date, the Ericsson family of MINI-LINK microwave products has an important role in mobile operator networks. Now, the advent of third-generation mobile networks is starting a new wave of deployment characterized by cost-effective and flexible roll-out, and short site-to-site distance. Moreover, we are seeing a shift in focus from plain point-to-point bit transport to a network view with optimized site solutions.

The authors address the launch of Ericsson's microwave solution for transmission in current second-generation and imminent third-generation mobile networks, showing how combined use of the point-to-multipoint and point-to-point technologies provides the most cost-effective and spectrum-efficient solution.

The inherent reliability and cost-effectiveness of microwave technology have been given a dominant role in connecting mobile radio base stations (RBS). The roll-out of packet-data and third-generation mobile networks fundamentally changes the traffic demands on transmission systems. Consequently, new microwave transmission techniques and solutions are required.

With the continuous growth of mobile subscribers and mobile data communication, operators need enhanced microwave transmission systems. In particular, enhanced features are needed to handle changing traffic patterns efficiently, to offer increased capacity, and to make optimum use of radio spectrum.

To achieve profitability, operators must have flexibility and be able to respond quickly to dynamic market conditions. These requirements make microwave, with its ease of implementation, ideal for access transmission.

Today, 60% of all second-generation RBSs are connected via microwave technology. As voice and data traffic increases in mobile networks, PDH-based point-to-point microwave solutions can be complemented with ATM-based point-to-multipoint solutions and SDH equipment to create a unified, fully integrated and cost-effective transmission solution that gives operators the best network control and most profitable operation.

MINI-LINK portfolio

The MINI-LINK portfolio includes solutions for point-to-point as well as for point-to-multipoint operation. Terminals and smart nodes (Figure 1) are used for implementing the building blocks in a network.

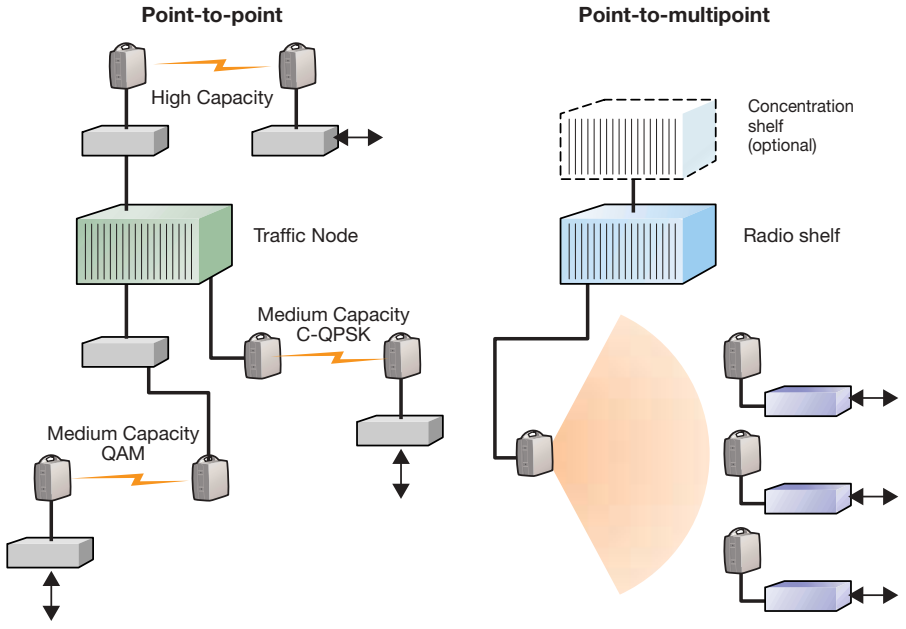


Figure 1
The MINI-LINK portfolio.

MINI-LINK point-to-point

Ericsson's microwave point-to-point portfolio consists of MINI-LINK Medium Capacity and High Capacity terminals, and the MINI-LINK Traffic Node (Figures 2-3). Depending on the range and capacity to be implemented, the MINI-LINK portfolio offers frequencies ranging from 7 to 38 GHz, for hop lengths of several tens of kilometers to just a few kilometers, and transmission capacities of up to 155 Mbit/s. Constant envelop offset – quadrature phase-shift keying (C-QPSK) and quadrature amplitude modulation (QAM) schemes are available for the terminal configurations. The MINI-LINK Traffic Node, which is a smart node for point-to-point operation, has been optimized for the aggregation nodes in the network, thus providing the ideal capacity and functionality to solve transmission needs. It complements the terminals with the additional features needed to provide a complete and efficient site and network solution.

Figure 2
MINI-LINK Traffic Node.

BOX A, TERMS AND ABBREVIATIONS

AAL2	ATM adaptation layer type 2
ATM	Asynchronous transfer mode
CPP	Connectivity packet platform
C-QPSK	Constant envelop offset – quadrature phase-shift keying
E1/E2/E3	ETSI digital multiplexing stage
IP	Internet protocol
LAN	Local area network
MIB	Management information base
OC-3	ANSI digital multiplexing stage
PDH	Plesiochronous digital hierarchy
QAM	Quadrature amplitude modulation
RAN	Radio access network
RBS	Radio base station
SDH	Synchronous digital hierarchy
SNMP	Simple network management protocol
STM-1	Synchronous transport module level 1
T1/T2	ANSI digital multiplexing stages
VC	Virtual container
xDSL	Digital subscriber line

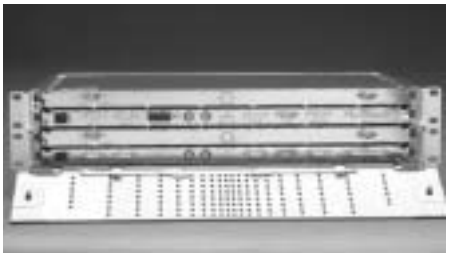


Figure 3
MINI-LINK Medium Capacity terminal (left) and MINI-LINK High Capacity terminal (right).

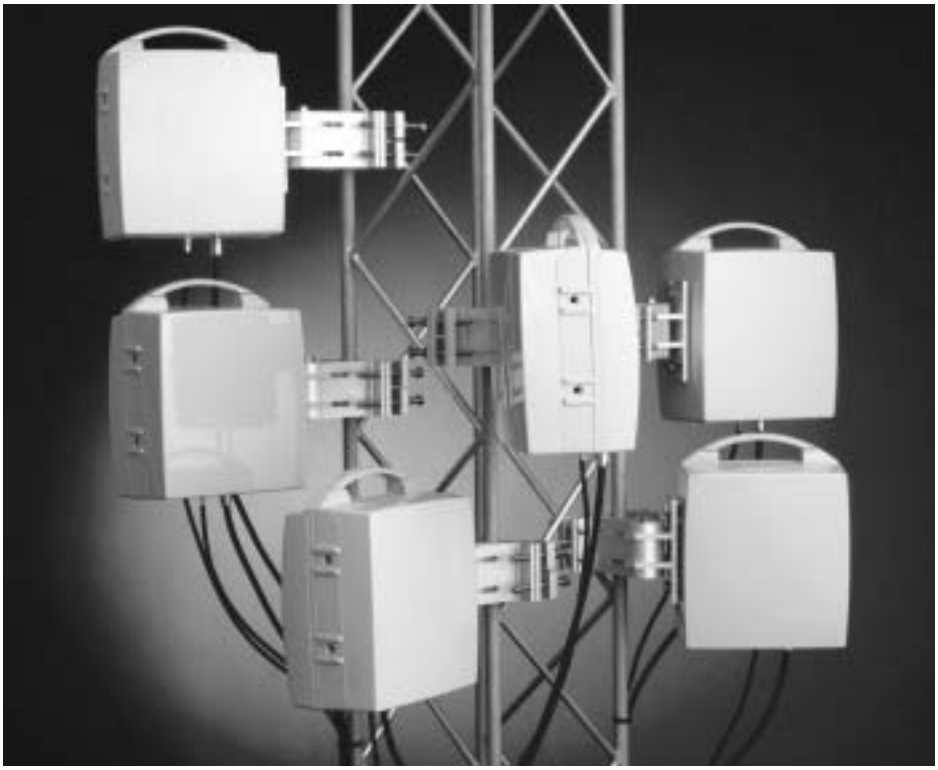


Figure 4
MINI-LINK outdoor radios.

MINI-LINK point-to-multipoint

The MINI-LINK point-to-multipoint system (Figure 5) provides 37.5 Mbit/s data transfer per sector. Each sector can be 90° in the standard solution or 180°/360° in the "launch" solution, in accordance with the required capacity and RBS density ratio. The capacity within a sector can be fixed or dynamically allocated to each terminal, allowing, in the latter case, reallocation of capacity within a few milliseconds. The system is thus very suitable for data traffic, both for business access and backhaul in mobile systems. It uses ATM to guarantee different classes of service. E1, ATM (over E1/T1, E3/T3 or STM-1/OC-3) and Ethernet interfaces are available. The system operates on frequencies from 24 to 31 GHz and uses the C-QPSK modulation scheme.

Figure 5
MINI-LINK BAS radio shelf.

Management system

The third building block in the portfolio is the MINI-LINK Manager (Figure 6), which enables operators to manage a complete MINI-LINK microwave transmission network from a single screen. Network element management provides functionality for managing faults, performance, configurations and security. Together with local craft terminals (LCT) and the element-management functionality embedded in the network elements, the MINI-LINK Manager gives operators the tools they need for efficient and cost-effective operation of a MINI-LINK network.

MINI-LINK Manager has several export interfaces for easy integration into other network-management systems. It can be incorporated into a total management solu-

tion for mobile systems, either as part of a complete solution provided by Ericsson or as an integration with an existing management system.

MINI-LINK features

Bandwidth aggregation

The point-to-point and point-to-multipoint smart nodes are hub solutions developed to support a large number of sites and future increases in capacity. Being scalable, the smart node enables the aggregation of traffic bandwidth that originates from a large number of end-nodes. At Medium Capacity aggregation nodes, the bandwidth is aggregated into a medium-capacity interface (maximum 34 Mbit/s) Similarly, at High Capacity aggregation nodes, the bandwidth is aggregated into a high-capacity interface (STM-1 or greater). Traffic from the aggregation nodes can be further transmitted either on microwave or optical links.

In a point-to-multipoint system, the air interface is shared among multiple access terminals. The shared media enables multiplexing gains over the air, provided a packet-based infrastructure is employed. MINI-LINK point-to-multipoint is based on ATM end-to-end, which enables multiplexing gains and efficient usage of the bandwidth when second- and third-generation traffic is handled in the aggregation nodes.

Use of spectrum

Spectrum is a sparse resource. Besides the continuous development of radios in newly allocated frequency bands, some important new features have been introduced in the MINI-LINK portfolio to deal with future shortages of spectrum. To allow the operator to increase transmission capacity within an existing frequency spectrum, higher-order modulation methods (based on 16 and 128 QAM) have been introduced in the MINI-LINK point-to-point portfolio. These new features give the operator additional flexibility in balancing spectrum and power efficiency in the network.

Point-to-multipoint systems (Figure 7) make efficient use of spectrum by

- allocating capacity per ATM cell (ATM granularity gain) instead of on a 2 Mbit/s-basis;
- ATM multiplexing in conjunction with fast dynamic capacity allocation. The network can be "oversubscribed" in terms of number of registered users while still maintaining QoS; and
- delivering unused access capacity to other services, such as wireless LAN access points or business access users, based on the diversity gain of the daily traffic profile (daily profile gain), since the busy hours for residential users generally differ from those of business users.

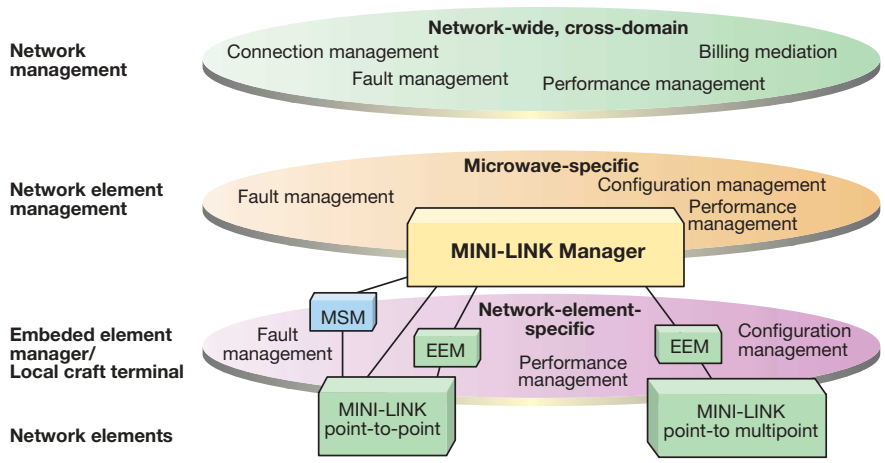


Figure 6
MINI-LINK Manager—its role in network management.

Figure 7
Aggregation gain. The diagram shows the aggregated link capacity required by multiple base stations per base station. The red line indicates aggregating link capacities. The yellow line represents peak load capacities, and the blue line, average traffic loads. The aggregation gain increases as the number of base stations connected in the same sector increases.

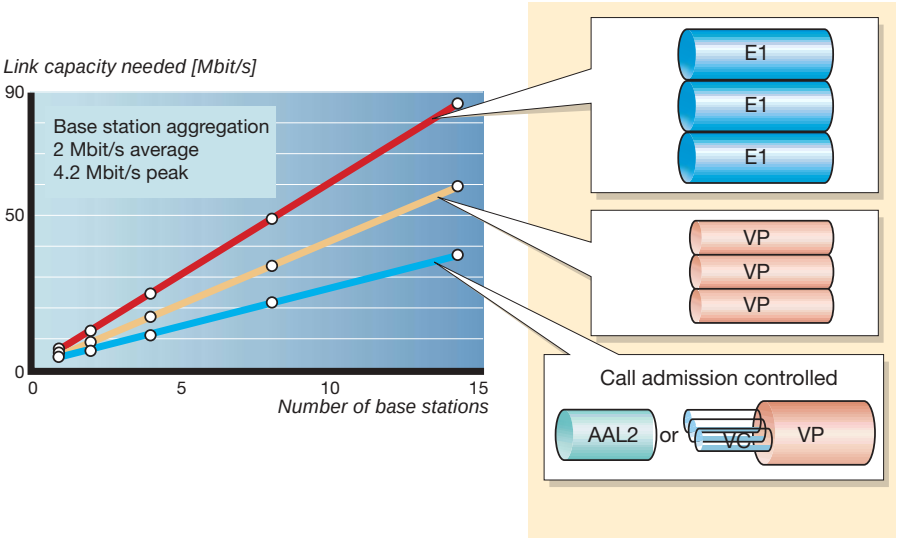


Figure 8
Installing MINI-LINK.

BOX B, PLANNING MICROWAVE TRANSMISSION, AVAILABILITY AND QUALITY

Traditionally, operators have deployed mobile backhaul networks using a combination of point-to-point microwave and leased lines. A determinant when choosing between microwave and leased lines is the individual operator's needs in terms of network control and transmission quality.

Typical leased-line contracts have often guaranteed availability figures around 98.7%, which corresponds to a potential of four or five days downtime per year. Microwave networks (which are often used to relink the entire connection between the end-RBSs and the switch site) are dimensioned for 99.95% availability or better, which corresponds to four hours or less of downtime per year.

In conclusion, the availability of a microwave network is very much a planning issue. By selecting high-quality products in combination with proper network planning, availability is normally the same as or better than that of fiber or copper networks.

Protection

The operator's most important asset is end-user traffic. If service delivery is not reliable, end-users will change service providers. High-quality equipment that is complemented with additional protection mechanisms gives operators a means of delivering high-quality services.

The MINI-LINK products are protected against equipment failure and radio propagation anomalies. All hardware is duplicated to support the configurations on one or both sides of the radio connection. The transmitting equipment can be configured to operate in hot standby or working standby transmission mode.

The MINI-LINK Traffic Node adds yet another level of protection—network or ring protection. This functionality enables the operator to build reliable ring structures based on any microwave capacity up to 155 Mbit/s. These protection mechanisms work at the E1/T1 level, protecting every or pin-pointed E1/T1s within the total payload.

The Traffic Node solution also includes line-protection mechanisms without the duplication of hardware. Instead, the E1/T1s to be protected are routed into two separate ports on the same interface board.

Ease of installation and visual impact

Speed of installation is always a business consideration, especially during the roll-out of third-generation networks in Europe. Microwave is less costly and time-consuming to deploy than copper leased lines. The MINI-LINK portfolio has been optimized for simple installation with a compact, easy-to-carry outdoor unit (Figure 8). The single-cable interface between the indoor and outdoor unit, and the single-bolt alignment fixture are well known. The point-to-multipoint system is even less complex and therefore faster to install, since only one end of the link has to be installed. In addition, new base stations or interfaces can be added to the backhaul network configuration, literally in a matter of minutes, minimizing maintenance and upgrade costs.

The point-to-multipoint hub needs only one antenna (and a single cable between outdoor and indoor equipment) per sector, regardless of the number of connected RBSs. This strongly minimizes the visual impact, especially in cities and towns where antenna pollution is an important issue. Moreover, fewer antennas means fewer sites (simpler site acquisition) and reduced installation time and cost.

Data communication networks

The Ericsson network solution for transporting operation and maintenance (O&M) information from equipment to the management center is based on IP communication over Ethernet, with a distributed management information base (MIB) architecture.

MINI-LINK provides efficient in-band data communication between end-nodes and aggregation nodes. The MIB is physically located in each network element. Using the simple network management protocol (SNMP), operators can access O&M information in the MIB remotely from a network management system. They can also access the information locally, on site, by means of the local craft terminal. The terminal software can be upgraded remotely from a central location, or locally using a laptop connected to the terminal.

Each MINI-LINK Traffic Node and High Capacity terminal holds its own IP router for extending the data communication network throughout the transmission network, and transporting O&M information on other equipment via external service channels.

Combined solutions for the mobile transport RAN

In dense areas, point-to-multipoint has clear advantages over point-to-point transmission. As a simple rule of thumb, point-to-multipoint becomes an interesting option when four or five RBSs can be seen from one location. However, the two technologies are, and will be, used in combination. Point-to-point microwave, which is typically deployed in areas with fewer RBSs, can be combined with point-to-multipoint to overcome distances or interference.

The combination of Ericsson's point-to-point and point-to-multipoint product families results in the most cost-optimized and spectrum-efficient solution for second- and third-generation networks (Figure 9).

E1/T1 aggregation via point-to-point links is typically suitable in small hubs where the number of directions (or connected RBSs) is limited and spectrum is not an issue (the required bandwidth is very likely to be a portion of that required to deploy the large hub).

ATM aggregation, typically via point-to-multipoint, is more suitable in large hubs where the number of directions (or connected RBSs) is great and spectrum efficiency is a must (since it determines the size of the frequency blocks required).

The hubs are connected to each other, to the switch site, or both, via point-to-point systems in accordance with the required range, capacity and available spectrum.

E1/T1 multiplexing nodes

The E1/T1 multiplexing node is the current solution for present-day second-generation networks. In all likelihood, it will also be the most efficient solution for operators who plan to add third-generation services in environments where second-generation traffic will continue to dominate. This is also the typical solution for operators who want to reuse as much of the existing network as possible (by exploiting spare capacity on the microwave links or on STM-1/OC-3 rings). This aggregation strategy might also be justified by the price structure for leased lines. The benefits of a network based on E1/T1 multiplexing nodes are low initial investments and secure upgrade with minimum disturbance to existing traffic.

Figure 9 exemplifies how a combination of point-to-multipoint and point-to-point links can efficiently serve the Medium Capacity and High Capacity aggregation nodes.

The Low Capacity and Medium Capacity aggregation nodes typically handle from two to four radio base stations—that is, from two to four directions. These nodes are generally deployed where RBS density is low and the RBS-to-RBS distance is great.

In the southbound direction (Figure 9), the Medium Capacity aggregation nodes interconnect the end RBSs through MINI-LINK point-to-point; in the northbound direction, the connection can be made via MINI-LINK point-to-multipoint (Low Capacity ATM aggregation nodes) or point-to-point terminals (Medium Capacity E1/T1 aggregation nodes), depending on capacity, protection and range requirements.

Ordinarily, the High Capacity aggregation nodes are located in suburban or urban areas where RBS density is high. During operation, error-free transport over microwave links is guaranteed by large fading margins and forward error correction mechanisms, which make microwave links highly suitable for ATM and IP transport. In these sites point-to-multipoint is likely to connect the end RBSs. Those RBSs that are outside the point-to-multipoint coverage range are connected through point-to-point links.

When E1/T1 traffic is aggregated, the MINI-LINK point-to-multipoint system for second-generation traffic connects to the MINI-LINK Traffic Node through *n*xE1, which, in turn, provides a single STM-1 VC12 interface to the switch site.

The main drawbacks of the E1/T1 multiplexing solution can be limited expansion and greater long-term cost of operating the network.

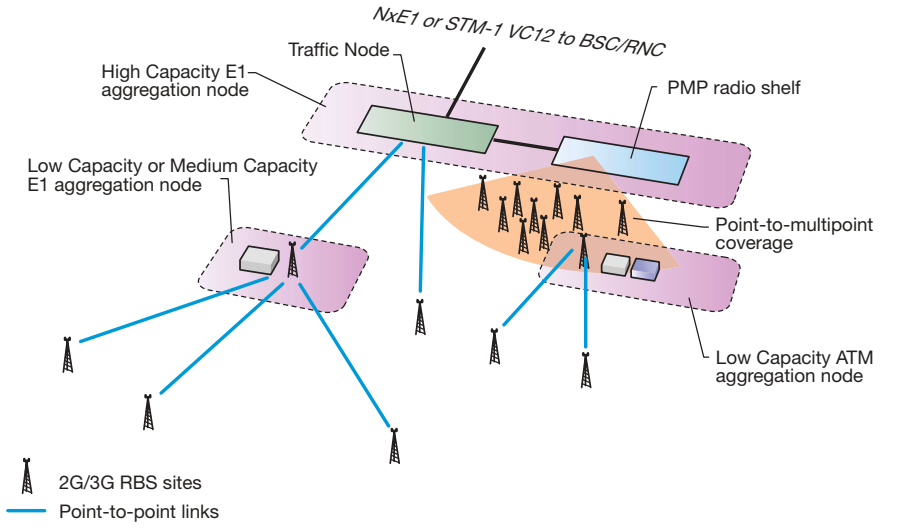


Figure 9
Example of site solutions based on E1 multiplexing and the combining of point-to-multipoint and point-to-point.

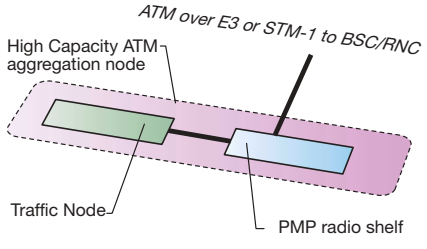
ATM aggregating nodes

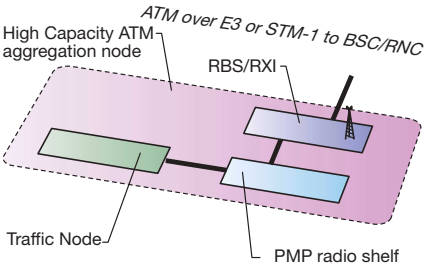
When third-generation traffic dominates over second-generation traffic, ATM aggregating nodes can be used to provide the most cost-effective network solution. Networks based on ATM aggregating nodes are likely to be typical for greenfield operators and for incumbent operators who want to overlay the existing network or to replace existing leased-line connections.

The MINI-LINK point-to-multipoint hub provides port aggregation, aggregating traffic from point-to-multipoint and point-to-point terminals. It also provides a very efficient and cost-effective solution for cellular backhaul applications. It can also aggregate traffic from leased lines and xDSL lines. In the northbound direction, a single ATM-over-STM-1 VC4 interface provides a very clean and cost-effective solution that optimizes backbone capacity, switch site complexity and cost.

This solution can also be used in combination with Ericsson's RBS and RXI products, providing a complete Ericsson mobile and transport network (Figure 10). In

Figure 10
Top: Example of High Capacity aggregation node handling ATM.
Bottom: Example of combined CPP and MINI-LINK point-to-multipoint (PMP) radio shelf.





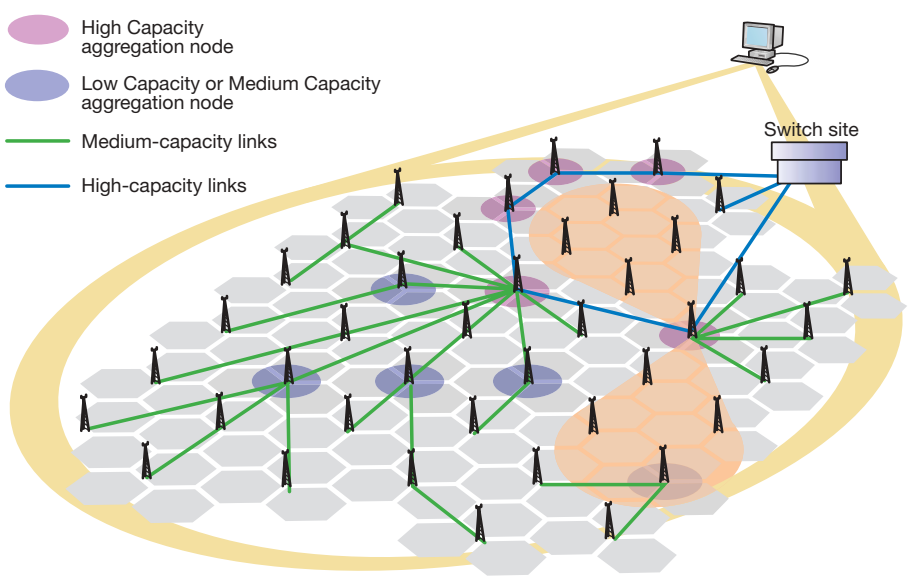


Figure 11
Network architecture.

addition to the benefits of ATM aggregation, the solution brings optimized statistical multiplexing gain, thanks to the AAL2 switching functionality of the connectivity packet platform (CPP, formerly called Cello packet platform). Because ATM virtual-path multiplexing and port aggregation are performed in the MINI-LINK point-to-multipoint radio shelf, the AAL2 functionality is achieved while optimizing costs (no increase in number of boards).

BOX C, NETWORK ARCHITECTURE

The use of short-haul microwave radio has evolved from scattered cable replacements to the forming of complete microwave-based transmission networks. The requirements put on the products have shifted from optimization of the terminal or hop level to optimization of the network level. In a microwave network, one can define logical nodes (or physical sites) with distinct characteristics. The logical building blocks are the end-node and aggregation node. Any microwave network can be implemented as a combination of end-nodes and aggregation nodes (Figure 11).

To address the network aspects, Ericsson's products are optimized for the different types of network node. Therefore, the MINI-LINK portfolio comprises compact, cost-effective access terminals and smart nodes that feature advanced traffic routing and multiplexing. The MINI-LINK portfolio includes access terminals and smart nodes for point-to-point and point-to-multipoint operation.

Typical building blocks of a microwave network

End-node
The end-node is the smallest building block. By definition, it supports transmission in only one direction. In most cases, the capacity of the end-node ranges from 2x2 up to 34 Mbit/s. Ordinarily no redundancy is required at end-node sites and therefore the normal microwave configuration is 1+0. Point-to-point and point-to-multipoint end-nodes are foreseen. The end-node should support traffic interfaces ranging from multiple E1/T1s to Ethernet. Ideally, in a point-to-multipoint system, the end-node will provide an ATM interface for third-generation backhaul, to take better advantage of the shared air interface.

Low Capacity and Medium Capacity aggregation nodes
The Low Capacity and Medium Capacity aggregation nodes have a northbound microwave link that carries traffic up to 34 Mbit/s. In the southbound direction these nodes have a limited number of subtended end-nodes.

Ericsson's solution to the Medium Capacity aggregation node has been to design smart, cost-effective Traffic Nodes that can aggregate all traffic from the southbound links into another microwave link in the northbound direction. The solution supports protected and non-protected configurations of the Medium Capacity aggregation node. The solution also supports dropping and insertion of local traffic.

High Capacity aggregation node
The High Capacity aggregation node has a northbound transmission link with a traffic capacity of 155 Mbit/s or greater. The northbound media can be either optical or microwave. The topology in the northbound direction can be ring or point-to-point. Since the High Capacity aggregation node supports a considerable amount of traffic, it is assumed that most of the sites will aggregate a substantial number of southbound links. Some end-nodes are directly connected to the High Capacity aggregation node and some are connected through a Medium Capacity aggregation node. Point-to-point, point-to-multipoint and E1/T1 and ATM aggregating sites are supported. The Ericsson solution to the High Capacity aggregation node can be designed to be very compact and cost-effective, as part of an all-microwave solution that supports 155 Mbit/s traffic capacity.

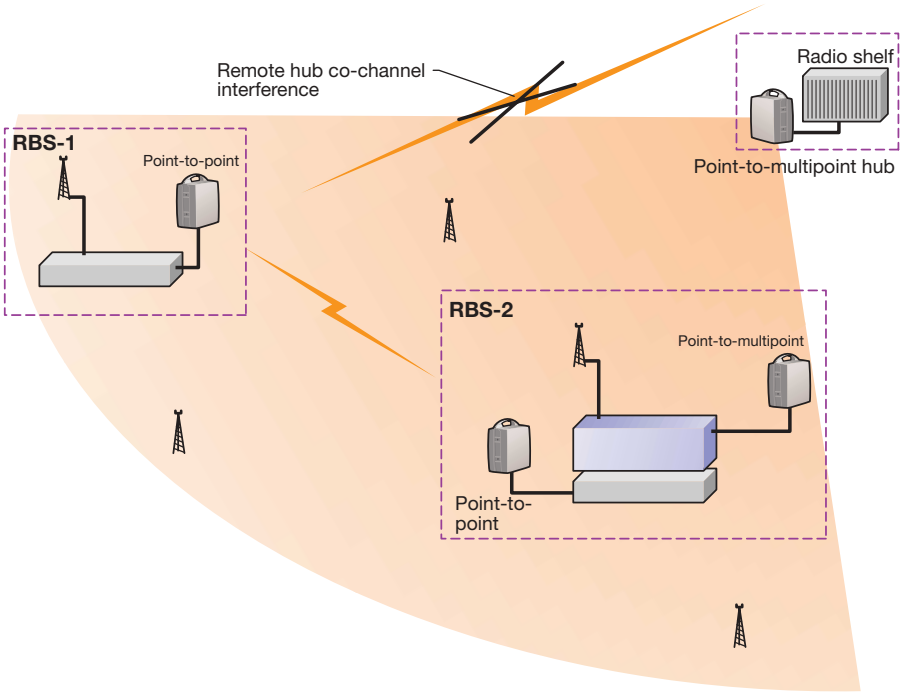


Figure 12
Operators can reuse frequencies by combining point-to-multipoint and point-to-point systems.

Conclusion

The key issues for efficient support of the mobile network infrastructure are:

- A complete portfolio of point-to-point solutions (any frequency, any capacity, PDH/SDH), explicitly designed for a smart network-oriented approach.
- An ATM-based point-to-multipoint solution that provides a suitable combination of high coverage and high capacity.
- A combination of these technologies to provide the most cost-effective and spectrum-efficient microwave solution.
- An integrated management system for the entire portfolio.
- Proven reliability and large production capability for secure roll-out.

Uniquely, the Ericsson MINI-LINK portfolio can meet all of these requirements.

BOX D, IMPROVING SPECTRUM EFFICIENCY BY COMBINING POINT-TO-MULTIPOINT AND POINT-TO-POINT SYSTEMS

One fundamental issue in microwave network planning is the efficient use of the frequency spectrum. National authorities and international committees regulate the availability of spectrum. Point-to-point links typically require a license per link, whereas licenses for point-to-multipoint systems are issued as regional or national block allowances. In many cases, operators prefer block licenses since they allow faster planning and deployment of the links.

In point-to-multipoint cellular deployments, a few locations inside the multipoint sector can experience interference from neighboring hubs. However, this effect can be minimized by avoiding reuse of frequencies in neighboring sectors or by combining point-to-multipoint with point-to-point technologies.

In Figure 12, the RBS-1 location is assumed to be affected by co-channel interference from a remote point-to-multipoint hub if connected to the local hub through a point-to-multipoint terminal. If the RBS-1 is instead connected to the RBS-2 location by means of a point-to-point link, the antenna angular discrimination improves the carrier-to-interference ratio and guarantees error-free operation. It is worth noting that the point-to-point link can reuse part of the same point-to-multipoint spectrum, allowing for a very spectrum-efficient solution. Thanks to the combined MINI-LINK point-to-point and point-to-multipoint solution, only a single 28 MHz link is required for the complete network deployment (excluding the spectrum for the northbound connections).