Fixed wireless access for broadband services

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Wireless broadband access (WBA) technology is rapidly taking root in a fertile global marketplace. It can easily provide an effective platform from which to expand existing infrastructure, or serve to provide infrastructure in hitherto under-served areas. In the world market, the potential of WBA technology is enormous, in particular, because it allows cable-like multimedia services without the cable.

The author describes Ericsson's Beewip solution, which uses fixed wireless access to bring broadband services to small office/home office and small enterprise customers.

Introduction

In the world of telecommunications, the two fastest growing areas are fixed and mobile IP services. The main reasons for this are deregulation, increased competition, market demand for broadband services, and the introduction of new technology.

New fixed wireless broadband technologies give operators an opportunity to address the issue of bandwidth in present-day access networks. The growing demand for bandwidth in the access network is mainly due to a surge in Internet and intranet traffic, LAN-to-LAN interconnect, and a mounting interest in voice over IP (VoIP). In other words, the market is demanding an access network solution that can carry different kinds of broadband multimedia service. Numerous activities are underway to extend fiber networks and to introduce digital subscriber line technologies (xDSL) into existing copper networks. However, by comparison, a radio-access alternative offers several significant benefits:

- Time to market—the rapid deployment of new broadband services will be crucial to the success of new operators. By deploying an efficient new radio-access system, operators can reduce time-to-market for new services.
- Ownership of the infrastructure also implies "ownership" of the end-user, as well as independence from other operators and from the unbundling process of the local loop.
- Low cost—fiber is expensive to deploy and copper is expensive to maintain. The main cost of radio access is the equipment. Furthermore, this cost is falling in pace with the development of new technology.
- Flexibility, pay as you grow—the infrastructure can easily be redeployed as needed.
- Efficient use of the radio spectrum—Ericsson's broadband radio technologies employ statistical multiplexing over the air interface, which allows operators to sell data services that require high peak data rates.

BOX A, ABBREVIATIONS

ATM	Asynchronous transfer mode
BAE	Base station antenna element
BOU	Base station outdoor unit
BRC	Base station radio controller
BS	Base station
BSW	Base station switch
BWLL	Broadband wireless local loop
CATV	Cable TV
CDMA	Code-division multiple access
C/I	Carrier-to-interference ratio
DSL	Digital subscriber line
E1	ETSI 2 Mbit/s interface
E3	ETSI 34 Mbit/s interface
FDMA	Frequency-division multiple access
FH-CDMA	Frequency hopping CDMA
GFSK	Gaussian frequency shift key
GK	Gatekeeper
GW	Gateway
H.323	ITU recommendation for multimedia applications
IF	Intermediate frequency
IP	Internet protocol
ISDN	Integrated services digital network
LAN	Local area network
LMDS	Local multipoint distribution system
LOS	Line of sight
MAC	Media access control
OAM	Operation, administration and maintenance
OLOS	Obstructed line of sight
PoP	Point of presence
POTS	Plain old telephone service
PSTN	Public switched telephone network
SIU	Subscriber indoor unit
SNMP	Simple network management protocol
SOHO	Small office/home office
SOU	Subscriber outside unit
SU	Subscriber unit
TDMA	Time-division multiple access
TOS	Type of service
VoIP	Voice over IP
WAN	Wide area network
WBA	Wireless broadband access
xDSL	Collective term for the family of DSL technology

- Radio technology permits selective access; investments do not rely on multiconnections. Furthermore, radio can reach where other technologies cannot, for instance, beyond CATV coverage, where fiber is too expensive to deploy and where xDSL is unsuitable.

In 1999, several important developments overlapped and intertwined to create the fiber of a new marketplace:

- licenses in the 3.5 GHz frequency band for fixed wireless access were auctioned in Europe and Latin America;
- end-users began demanding low-cost, "always-on" broadband access;
- the dominance of circuit-switched traffic was eroding in developed countries as were per-minute and by-distance charging schemes;
- deregulation enabled new operators to target high-margin customers and build growth from there;
- technological advances enabled the production of mass-market radio at 3.5 GHz; and
- previous venture-capital investments in wireless local loop and wireless LAN had created interesting packet-radio platforms on which to build complete radio systems.

To meet the market requirements quickly, Ericsson chose to use off-the-shelf technology and products in all relevant subsystems. Our focus would be on system integration and radio network performance. Open-standard interfaces and protocols provided a basis for flexibility, scalability, and system migration. The intent was to build a packet-data system that can provide real-time voice services (not the other way around). IP was the obvious choice of core traffic protocol—to provide connectivity and a multiservice system.

Beewip

Beewip provides a transparent access medium for different types of IP service. Wireless Ethernet, based on IEEE 802.11, carries IP traffic over the air interface. With its advanced system architecture, Beewip supports dynamic bandwidth allocation and provides continuous (always-on) connection at data rates of up to 3 Mbit/s per subscriber. The system makes efficient use of the radio spectrum and offers high quality of service.

Beewip is based on the Internet protocol and open standards, which facilitates evolution in terms of services, capacity, and functionality (Table 1).

System overview

The system contains three main groups of subsystems or nodes (Figure 1):

- The subscriber unit (SU), which consists of a subscriber outdoor unit (SOU) and a subscriber indoor unit (SIU), is located on the end-user premises.
- The base station (BS) includes a base station radio controller (BRC), a base station switch (BSW), base station outdoor unit (BOU), and base station antenna elements (BAE).
- Operation, administration and maintenance (OAM) system hardware and software.

The subscriber unit is connected to the base station over the air interface. At the base station, the base station switch concentrates traffic and routes it to the point of presence (PoP). However, before traffic is routed, it is converted from the 10BaseT Ethernet format to the appropriate transmission media protocol. Figure 1 shows how the Beewip system is implemented into existing networks. The PoP concentrates data and voice traffic and controls traffic flows. It also filters traffic at the firewall and shapes traffic.

TABLE 1, RADIO CHARACTERISTICS

Frequency band:	3400 - 3600 MHz
Duplex spacing:	100 MHz
Modulation:	Gaussian frequency shift keying (GFSK) (1, 2 or 3 bits/symbol)
Bit rates:	1, 2 and 3 Mbit/s
Sub-channel spacing:	2 MHz

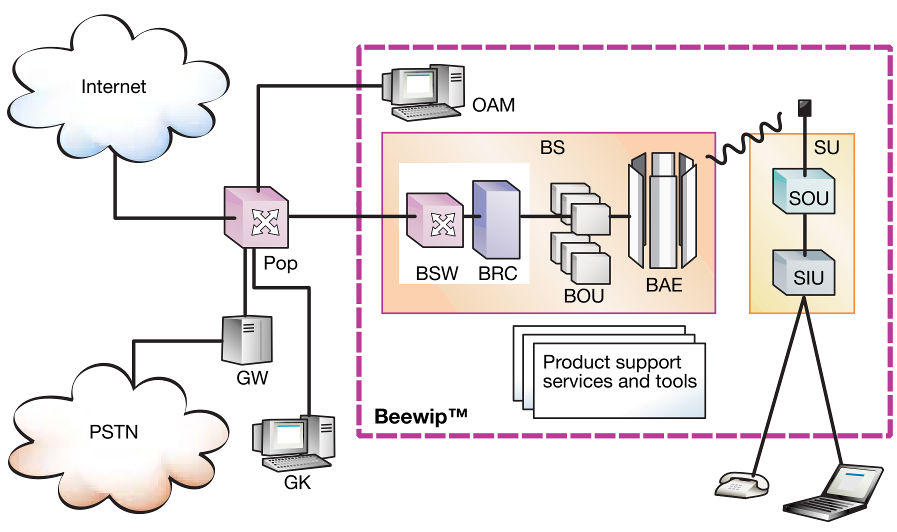


Figure 1
Beewip system components (shown inside the dotted line).

Figure 2
The subscriber indoor unit.

Telephony-related data packets are forwarded to the appropriate media gateway (GW); similarly, signaling data is forwarded to the appropriate gatekeeper (GK).

The subscriber unit

Subscribers gain access to services via the subscriber unit located on their premises. Various types of subscriber units are available offering combinations of data and voice connections. The number of data connections is determined by the maximum number of (MAC) addresses that can be connected to the subscriber unit.

The subscriber unit consists of an outdoor and an indoor unit. The subscriber outdoor unit includes a directional antenna with 17 dBi antenna gain, which provides a horizontal and vertical opening angle of 20°. The antenna must be installed properly and aligned with the base station. The radio front-end, which provides 27.5 dBm output power (0.5 W), is attached to the antenna to minimize feeder cable attenuation. The subscriber indoor unit is connected to the outdoor unit by intermediate frequency (IF) at 440 MHz over cable. The indoor part includes the IF stage and radio baseband modem, a 10BaseT interface, and a telephony interface to customer equipment. It also includes a power supply. The radio and interface platforms, based on the wireless Ethernet standard (IEEE 802.11), are taken from wireless LAN.

The subscriber unit was designed to have low installation and network maintenance costs. The use of standard components for the air interface (IEEE 802.11), computer interface (10BaseT), and wireless LAN product platforms ensure cost of scale and rapid time to market. An important feature of the subscriber unit is that it supports telephony via a standard (analog) plain old telephone service (POTS) interface. Analog voice is converted in an H.323 client implemented in the subscriber unit. Telephony-related signaling and traffic are sent to a media gateway over IP over the air. To control telephone sessions, the H.323 client communicates with the gateway or gatekeeper. The SU client and the gateway/gatekeeper communicate call set-up, call release, speech coding, and so on.

Voice-related services put requirements on the transmission quality all the way from the interfaces at the subscriber unit to the media gateway in the core network. Since voice and data traffic in most parts of the network—and, in particular, over the radio link—share the same access medium, the allocation of resources must be controlled. Therefore, to handle different traffic classes in the subscriber unit, the IEEE 802.11 protocol has been modified.

Base station

The base station consists of a radio controller, a switch, outdoor units, and antenna elements. The radio controller includes

- radio baseband parts;
- the synchronization of sectors—to eliminate inter-base-station interference; and
- power supply.

IEEE 802.11, which serves as the radio controller base for media access, works up to layer 2. As mentioned above, it has been modified to handle different service classes. The base station allocates capacity for voice at call set-up by means of a polling mechanism that regularly interrupts data traffic to allow subscriber units with ongoing voice sessions to send voice packets.

An interesting characteristic of the air interface is the decentralized MAC layer from Ethernet made for pure data over cable. The MAC layer has been migrated for use in wireless environments via the modified IEEE 802.11 standard. Each base station works independently. Semi-orthogonality (orthogonality reduces interference and collisions) is obtained by means of a random frequency-hopping technique called FH-CDMA.

FH-CDMA, which is a combination of time-division multiple access (TDMA), frequency-division multiple access (FDMA) and code-division multiple access (CDMA), is particularly suited to fixed radio networks. A re-transmission mechanism is also included, since the system presumes that collisions will occur. Indeed, at times, the system actually forces collisions to occur in certain subscriber units—to prevent discrimination in the system.

The base station switch is a very flexible sub-node that can be described as a layer 3 switch, router, or WAN access. The WAN access function is mainly a protocol conversion to the appropriate transmission interface. The main switch functionality, implemented at layer 2, pertains to switching and traffic control. Tagging is used to exchange packet-data-related information (for example, does the packet carry real-time traffic?) between the transmission and radio networks. The base station switch also provides a wide range of interfaces for transmission. Support for additional interfaces includes Ethernet, fiber, E1, E3, and ATM.

Ordinarily, the antenna arrangement of the base station has six sectors evenly distributed around the horizontal circle. However, because traffic is seldom evenly distributed around base station sites, two kinds of antenna can be used: one with a 60° and another with a 120° horizontal opening angle. The antennas and antenna arrangements facilitate flexible migration to support growth in the system or capacity.

The base station is housed in a single 19-inch cabinet that is small enough to be transported by air-freight. The cabinet can be installed indoors and out. An air conditioning unit can be installed in the door (the cabinet is configured at the factory). The AC door can be detached from the cabinet during transport, for instance, to allow it to be carried up stairs.

Operation, administration and maintenance

The OAM part enables the operator to remotely configure the nodes of the entire access network, to upgrade software, and on the whole, to control and monitor all traffic in terms of fault- and performance-management functions. The OAM part is based on the simple network management protocol (SNMP) and runs on the Windows NT platform.

System performance

Services

The requirements put on a system like Beewip are complex: Expectations change over time, as do services, means, and tools. Users of the Internet have learned to accept that speed and availability are not guaranteed; they have also learned to accept slow dial-up access connections. Likewise, users of mobile voice services have learned that coverage is not comprehensive and calls can be dropped. By contrast, users of fixed telephony do not accept anything less than (near) total availability and insignificant delay—they do, however, accept a slow emergence/introduction of new services.

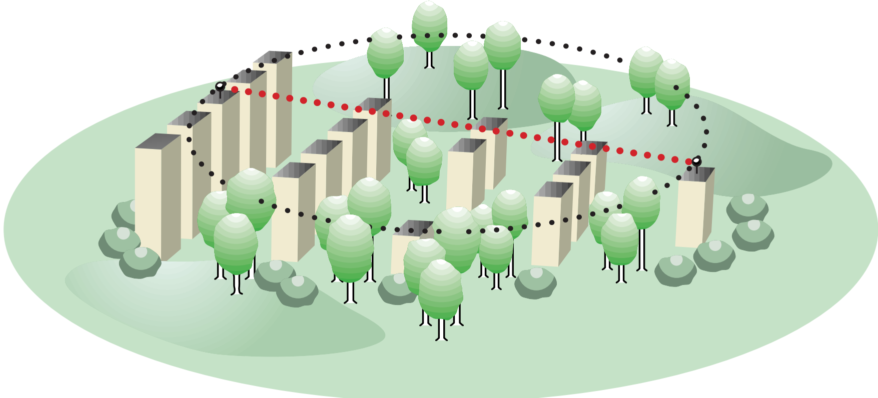
In the Beewip system, users must learn to utilize "always-on" and broadband services, which are important features. At the same time, voice services will be different from those of the traditional public switched telephone network (PSTN). But the delay, voice coding, and so on cannot be significantly different. In reality, the delay of voice in Beewip will be slightly greater in Beewip than in fixed connections, and availability will not be 99.999%. On the other hand, service evolution and price levels will be very different when IP is used to carry voice and data.

Radio network

Path loss

The building of fixed radio networks at 3.5 GHz with near line-of-sight deployment is significantly different from most other radio networks. Since the subscriber units are fixed, careful placement will create a reliable radio link. However, a car parked on the street next to the house, an open window in

Figure 3
Obstacles in first Fresnel zone—obstructed line-of-sight (OLOS) scenario. The OLOS scenario allows for easy and inexpensive installation of the base station antenna element (BAE) and subscriber outside unit (SOU).



BOX B, LOS AND OLOS

LOS	Line of sight—to use free-space (LOS) propagation, the first Fresnel zone must be free of obstacles
OLOS	Obstructed line of sight—that is, the visual path is free but obstacles (houses, trees, and so on) exist in the first Fresnel zone between the transmitting and receiving antennas.

the building across the street, or leaves appearing on trees between the base station and subscriber unit can have considerable impact on signal path loss. Fixed radio networks can thus be regarded as mobile systems whose antennas are fixed but whose environment changes. The Doppler shift is insignificant, but the fading of fixed radio systems has similar dynamics as mobile systems—although with significantly longer time constants, such as seasons.

Interference

As in any other radio network, heavy traffic in fixed radio networks creates interference. In mobile networks, mobile terminals move within the coverage area—sometimes a terminal is at the cell border with a poor connection; at other times the terminal is at the center of a cell with a perfect connection. However, in a fixed network, a terminal at the border of the cell will always remain at the border of that cell. And interference will almost always originate from the same source.

Beewip solution

By means of multi-modulation schemes with automatic fall-back, Beewip can dynamically choose the best possible modulation for each subscriber unit. Frequency-hopping techniques equitably distribute internal interference and capacity among subscribers. Since the base station is not synchronized in the network, the interference pattern is semi-random. The collisions that occur from this configuration are distributed over time and area to ensure that each subscriber unit receives the service it has been granted, even during busy hours. The frequency-hopping techniques can also be employed to eliminate external interference, for example, by shifting to a carrier frequency with less fading.

Table 2 shows the maximum transmission range at different bit rates—using the nominal radio characteristics of the system with a 60° antenna and an OLOS path-loss model.

As mentioned above, Beewip is a packet-oriented system that employs FH-CDMA radio technology. In terms of capacity, the parameter of greatest interest is the carrier-to-interference ratio (C/I). The gross bit-rate values vary in different deployment scenarios.

The results of a simulated worst-case sce-

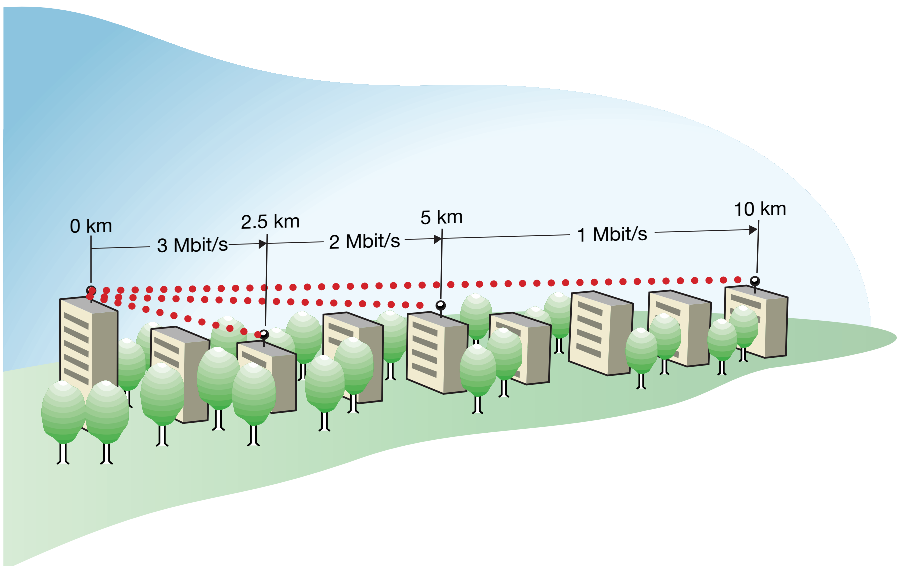


Figure 4
Line-of-sight conditions permit transmission ranges of up to 10 km.

nario, based on a large network, minimal amount of bandwidth, and heavy traffic show that the average gross bit-rate in an OLOS deployment is 2.2 Mbit/s.

Obviously, in a more typical traffic scenario, there is less interference, which means that traffic can be sent at higher bit-rates. Similarly, a network with fewer base stations and greater bandwidth can be expected to yield a gross bit-rate close to 3 Mbit/s.

Deployment

The Beewip system adheres to a cellular deployment structure in which multiple cells provide coverage to a geographical area. Each cell contains one base station and several base station antenna elements (BAE), each of which is driven by a base station outdoor unit. The base station antenna elements are sector antennas that cover either a 60° or 120° sector.

The number of subscribers that can be connected to a Beewip base station with six sectors depends on the

- manner of deployment;
- terrain;
- distance between base stations and subscribers; and
- current data traffic load—subscriber behavior, services offered, and so on.

Conclusion

To be successful in the new telecoms world, operators need to focus on new broadband services. Ericsson's Beewip product family has been optimized to carry IP traffic over a radio interface. The integration of radio and IP technology offers innovative operators very rapid and cost-effective deployment of new broadband IP services.

Beewip gives operators a competitive alternative solution for residential, small office/home office and small enterprise customers.

Its "always-on" connection (up to 3 Mbit/s per subscriber) enables end-users to exploit the benefits of a wide range of multimedia applications. Beewip, which operates in the 3.5 GHz frequency band, makes efficient use of spectrum and provides high quality of service. It is based on IP and open standards, which facilitates the evolution of services, capacity, and functionality.

TABLE 2, MAXIMUM TRANSMISSION RANGE AT DIFFERENT BIT RATES

Bit rate	Transmission range
1 Mbit/s	10 km
2 Mbit/s	5 km
3 Mbit/s	2.5 km