

Mobile Advantage Wireless Office—A digital wireless office system for TDMA/136 networks

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Ericsson's digital wireless office system was developed especially for in-building communications operating on the licensed 850 MHz cellular and 1900 MHz PCS frequency bands. Because the system is fully compliant with the TDMA/136 specification, any terminal that meets this specification can be used with the system.

The authors describe the digital wireless office system concept, its components and capabilities as well as the benefits it affords network operators, businesses and end-users.

Business customers are looking for ways to become more productive through convenient and cost-effective communication. Accordingly, the demand for in-building, wireless, voice-communication services is expected to increase significantly over the next few years. Anticipating this demand, Ericsson has developed and is marketing a digital wireless office system (DWOS) based on the TDMA/136 standard. The commercial name of this system is *Mobile Advantage Wireless Office*.

The DWOS was developed especially for wireless, in-building communication. Being fully compliant with the TDMA/136 standard, the system operates on the licensed 850 MHz cellular and 1900 MHz personal communications services (PCS) frequency bands. What is more, the indoor, wireless service provided by the DWOS is designed to minimize interference with the service of outdoor macro systems.

- The operator can choose the most appropriate and convenient frequency band.
- Frequency bands can be re-selected remotely and at any time.

Operator benefits

Operators of wireless networks make significant investments in the macro network—they purchase licensed frequencies and build up the cellular/PCS infrastructure. Since the wireless office system operates on the same frequencies as those used in the macro network, operators can employ

it to get a better return on investments in the macro system and to generate additional revenue:

- The wireless office system can be used to attract business customers—who generally use their phones more often than other subscriber categories.
- Operators can charge businesses extra for using licensed frequencies to operate the wireless office.
- Regular cellular/PCS charges apply to calls made outside the office (off the premises). Experience in the US has shown that persons with wireless office services generate significantly more calls in the macro network, which amounts to increased air-time usage in the macro system.
- US operators have also noted that user loyalty is much improved, which results in a dramatic reduction in churn.
- Operator administration and the costs of signing up new subscribers can be reduced through the signing of company-sponsored groups of subscribers. Operators can therefore bundle services for their customers; for example, long-distance service, outdoor/public wireless communications, indoor/private wireless communications, and local access.

Customer benefits

Wireless office systems increase productivity within an enterprise by making employees much more accessible in and outside of the office. As a result, fewer calls end up as voice mail (which when responded to, generate callback charges borne by the enterprise). With a wireless office system, employees can initiate calls from practically anywhere, which speeds up customer contacts and facilitates getting work done faster. Improved accessibility and greater mobility increase customer and employee satisfaction, which also contributes toward better business results. Moreover, wireless

Figure 1
Commercial name and logo of Ericsson's digital wireless office system for TDMA/136 networks.



office communication allows for more flexible office arrangements:

- No need for extensive wiring/rewiring in the building.
- Wireless office systems that use standard TDMA-compliant phones do not require businesses to provide their employees with separate phones for in-building and out-of-building communication.
- Ultimately, wired desk phones can be eliminated, since the functionality offered by the wireless office system will fully satisfy all voice-communication needs.
- Wireless office services enable employees to telecommute from their homes or from another office location.

The ability to use standard TDMA terminals also implies that wireless operators and their customers are not bound to a particular vendor of wireless office terminals. End-users can select any type of wireless device that suits their needs.

End-user benefits

Most end-users of wireless office solutions will be employees of an enterprise. The wireless-office solution gives each employee one phone and one number for all business communication, regardless of his or her location. Other significant benefits include increased accessibility and improved communication capabilities. End-users can always access office communications.

Also, as was pointed out earlier, employees who remain accessible while afoot, and who have the means of communicating when needed, are more productive and derive greater job satisfaction.

System concept

Designers of the digital wireless office system approached their task with the aim of fulfilling certain specific market requirements, namely:

- cost effectiveness—the cost per user in wireless office systems should not exceed the cost of a line in the private branch exchange (PBX). Furthermore, the market wants a system that provides local, on-site switching;
- simple installation, operation and maintenance—today, the infrastructure of most wireless communication systems is costly and difficult to install. Installation procedures for the DWOS should preclude costly and lengthy installations or the need for specially trained installers. Ongoing operation and maintenance (O&M) must be simple and easy to understand;
- self-engineering radio-network planning—several wireless-office systems should be able to operate in the same licensed spectrum as public cellular/PCS systems. Thus, frequency usage in the

BOX A, ABBREVIATIONS

AC/DC	Alternating current-to-direct current	O&M	Operation and maintenance
AFA	Adaptive frequency allocation	PBX	Private branch exchange
ANSI	American National Standards Institute	PCS	Personal communications services
API	Application program interface	PLMN	Public land mobile network
BSC	Base station controller	PRI	Primary rate interface
CRE	Cellular radio exchange	PSID	Private system identity
DCCH	Digital control channel	PSTN	Public switched telephone network
DID	Direct in-dialing (number)	QSIG	Protocol for PBX networking
DWOS	Digital wireless office system	RH	Radio head
E1	2 Mbit/s interface	SMS	Short message service
EIA	Electronics Industries Association	SNMP	Simple network management protocol
GPRS	General packet radio services	SPU	Signal-processing unit
GSM	Global system for mobile communication	SS7	Signaling system no. 7
HLR	Home location register	T1	1.5 Mbit/s interface
IN	Intelligent network	TCP/IP	Transmission control protocol/Internet protocol
ISDN	Integrated services digital network	TDMA	Time division multiple access
LAN	Local area network	TIA	Telecommunications Industry Association
MAHO	Mobile assisted handoff	TRX	Transceiver
MSC	Mobile switching center	VLR	Visitor location register



Figure 2
DWOS components.

DWOS and macro systems must be coordinated. Where possible, for the planning of cell parameters and handoff in the network, indoor radio-network planning should be automated. Capacity and coverage-related expansion must be simple and straightforward.

System overview

The DWOS equipment (Figures 2 and 3), consists of

- radio heads (RH)—which provide indoor radio coverage;
- a cellular radio exchange (CRE);
- a mobility server.

The digital wireless office system is connected to the public land mobile network (PLMN) through a network protocol interface known as ANSI-41 (Box B). Ordinarily, the ANSI-41 protocol is carried over a signaling system no. 7 (SS7) network. However, in the DWOS solution, the bearer of the ANSI-41 protocol has been replaced with the transmission control protocol/Internet protocol (TCP/IP). This solution is less complex: instead of using the DWOS as an SS7 terminating point, several hundred DWOS systems are connected to a gateway unit (the terminating SS7 point) that translates ANSI-41 messages from TCP/IP into SS7 signals.

The DWOS is connected to the enterprise office switch—a PBX—through an E1 or T1 ISDN primary rate interface (PRI). A protocol for PBX networking, called QSIG, can also be employed.

Where the PLMN is concerned, the DWOS behaves like a mobile switching center/visitor location register (MSC/VLR). In this case, however, the MSC/VLR (DWOS) only serves the radio coverage area of the business. Network signaling over ANSI-41 is used for regular digital cellular/PCS features and functions specified in the standard, such as roaming, authentication and short message service (SMS).

Similarly, where the PBX is concerned, the DWOS behaves like a networked PBX. That is, the PBX is not aware that the new networked PBX (DWOS) provides wireless coverage.

Reaching end-users

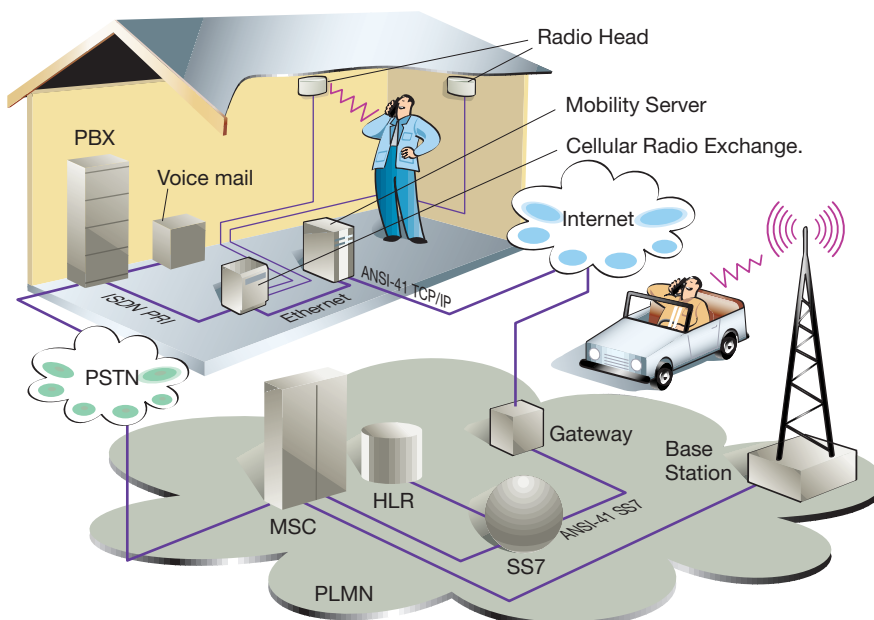
The TDMA/136 standard permits the broadcasting of private system identities (PSID). This allows TDMA terminals with an appropriate PSID to reselect and be accepted by the private system. For instance, as end-users commute to the office, their wireless terminals connect to the public TDMA network (the macro network). As they come within closer proximity of the office, their terminals automatically reselect the digital wireless office system. Once at the office, the terminals register with the DWOS, which then notifies the home location register (HLR) in the PLMN that its subscribers are “at home.”

Each DWOS user has one office phone number assigned to him or her in the PBX—a direct in-dialing (DID) number. Incoming calls to the DID line are forwarded by the PBX to the “networked PBX” (DWOS). If the called terminal is in the office, the incoming call is sent to both the wireless terminal and the PBX desk phone. The user can therefore answer the call at either terminal.

Global mobility

As we have discussed, wireless-office services enable their subscribers to be mobile around the office. Thanks to the ANSI-41 networking protocol and the TDMA/136 air-interface standard, the DWOS also offers global mobility with a regular cellular/PCS terminal. When subscribers leave the building—for example, to eat lunch, to walk to another building of the office campus, or to depart on an extended business

Figure 3
System integration into the telecommunications network.



trip—their terminals automatically reselect the PLMN:

- the macro system operated by the subscribers' cellular/PCS service provider;
- an operator with which the regular service provider has a roaming agreement.

Each terminal registers with the macro system's HLR, which notifies the DWOS system that the subscriber has left the office area and is roaming in the macro network. After having been directed to the DWOS, incoming calls to the DID line result in a query to the HLR—to find the roaming terminal. The DWOS then functions as a gateway MSC, which controls service execution. If the terminal is turned off, the DWOS executes the services set up in the user's service profile, directing calls to voice mail or executing a search profile in a personal number function. The DWOS uses the PBX voice-mailbox system as default. Thus, users need only manage one voice mailbox.

If the terminal is turned on while roaming, the HLR interrogates the MSC assigned to the area in which the terminal resides at the time of the call. The MSC returns a routing number that the HLR forwards to the DWOS. This allows the DWOS to reroute incoming calls through the PBX. The DID line is charged for the leg of the call from the DWOS to the user.

Intelligent network (IN) features allow four- and five-digit PBX numbering plans to be used even while roaming, thereby creating a global, virtual wireless office.

Radio network concept

Several tactics can be used for providing indoor radio coverage for mobile communications. Ultimately, the system equipment should offer excellent quality and be easy to administer. Likewise, upgrading capacity and coverage should be easy.

One way of providing indoor coverage is through penetration from the outside macro network. This method implies that radio signals penetrate building walls and structures. Some building materials, however, significantly reduce signal strength, which makes it difficult and costly for operators to guarantee good signal coverage in all areas inside a building.

Capacity is another important issue. To ensure good, ubiquitous, indoor coverage, the wireless office equipment should be located on the business premises. Good, efficient coverage can be provided in several ways. Two traditional alternatives are distributed antenna/coax cable networks and

- Synchronized radio heads
- Multicast DCCH
- Uplink/downlink scanner
- Macro diversity/soft handoff

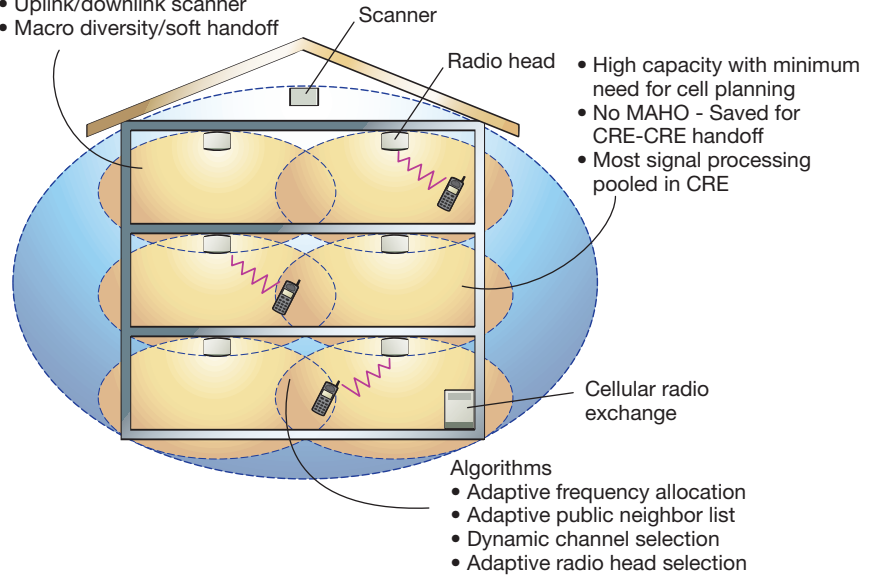


Figure 4
The virtual single cell. Radio heads are deployed inside the building to ensure that adequate coverage is provided.

picocells. A third alternative—implemented in the DWOS—makes use of a virtual, single-cell solution.

Virtual, single-cell solution

The virtual, single-cell solution involves several, small, radio base stations, called radio heads. These contain the transmitter and receiver parts of a regular radio base station. The common control and signal-processing functions are centralized in a separate, remote unit that can be pooled and shared by the entire system.

The radio heads are deployed inside a building to ensure that adequate coverage is provided (Figure 4). All radio heads in the building operate in unison. A single control channel is multicast throughout the entire building. The radio-head transceivers multicast the control channel.

Adaptive frequency allocation

Ericsson's wireless office solution uses the same licensed spectrum as the outdoor macro network without interfering with it. Indeed, operators can deploy the system without having to re-engineer the frequency plan of the macro system. Conversely, operators can re-engineer the frequencies of the macro system without affecting installed wireless office systems.

BOX B, ANSI-41

ANSI-41 is composed of a series of recommendations entitled "Cellular Radiotelecommunications Intersystem Operations" issued by the Telecommunications Industry Association/Electronics Industries Association (TIA/EIA). The recommendations describe procedures necessary to furnish cellular radio telephone subscribers with certain services requiring interaction between different cellular systems.

The frequencies of the DWOS system are automatically allocated to it through an adaptive frequency allocation (AFA) scheme. A dedicated scanner

- scans the frequencies being used by the macro system;
- detects signal interference from the macro system's base stations (uplink) and from public mobile terminals (downlink).

The frequencies least affected by interference are automatically allocated for use in the DWOS. If the scanner detects changes in the macro system, the DWOS immediately yields to it, invoking a self-engineered change of frequencies.

Adaptive public neighbor lists

Information on surrounding macrocells is conveyed to DWOS subscribers (terminals) while at the office. The terminals use this information to search for and detect the DWOS when they come into contact with nearby public macrocells; for example, when *en route* to the office. Thus, terminals automatically locate a wireless office system in the service area without burdening the public radio network for information on the system's identity and frequencies.

Adaptive radio-head selection and soft handoff

During a call, a user might move away from his or her current position. Changes of this kind are detected in the cellular radio exchange, which monitors the signal strength from all radio heads. If a stronger signal is received in an adjacent radio head, the CRE orders that radio head to begin transmitting at the frequency and in the time slot allo-

cated to the call. It also connects a speech path, so that speech information is sent to each radio head concurrently. When the target radio head indicates that it has established contact with the terminal, the "old" radio head is shut down. The terminal continues to use the same frequency and time slot as before, unaware that communication has been handed off. This procedure, called *soft handoff*, reduces the risk for dropped calls and minimizes speech muting when frequencies are retuned.

The virtual, single-cell solution and scanner combination enables operators to engineer the wireless office system with a minimum of cell planning.

System components

Mobility server

A mobility server, which functions as a local switch, is fully capable of analyzing numbers and routes, and provides common PBX services, such as call forwarding, call transfer, inquiry, call diversion, call-back, call waiting, and calling-line presentation. It also provides access to the PBX and to the public switched telephone network (PSTN). Automatic roaming to the macro network is facilitated through the mobility server's ANSI-41 connection.

The mobility server interacts with the HLR in the macro network. It also includes a TCP/IP interface for connecting to a local area network (LAN) and the Internet. DWOS administration and management is performed over the Internet/intranet via a Web browser.

In the initial release, the DWOS is connected to the PSTN through a PBX trunk connection. In subsequent releases it will be possible to connect the DWOS directly to the PSTN. Thus, the DWOS might be employed as the sole system for office communication.

Cellular radio exchange

The cellular radio exchange, whose function is similar to that of a base station controller (BSC) in a GSM system, is the central point in the radio infrastructure (Figure 5). It controls all radio heads and communicates with mobile terminals over the TDMA air interface by adapting and translating ISDN call control to TDMA call control. The CRE also includes ISDN transmission to the PBX as well as transmission to radio heads and scanners, which includes capability for power-

Figure 5
The cellular radio exchange (CRE) is the central point in the radio infrastructure.



ing -48 V over the transmission cable. The virtual, single-cell logic for managing and controlling the radio network is also implemented in the CRE.

Control and signal-processing functions (speech coding, echo cancelling, modulation, error detection and correction processing) for TDMA air-interface communication are centralized in a pool in the CRE. This configuration provides improved, cost-effective use of resources compared with distributing the functions to each radio head.

Operation and maintenance is handled using the simple network management protocol (SNMP) over an Ethernet connection to the mobility server. Performance-monitoring data and event recordings are stored temporarily in the CRE before they are transferred to the mobility server for permanent storage on disk. CRE administration and management is integrated into the Web-based management system provided by the mobility server.

From the outset, the system was designed for simple operation and maintenance and easy installation. For example, the design supports the swapping of boards while the system is running (hot-swapping): when capacity is to be expanded, a board comprising control and signal-processing capabilities (the signal-processing unit, SPU) can be inserted into any of the available slots in the cabinet. Once inserted, its presence is detected and its capabilities are evaluated. The board is then assigned an identity, loaded with software, and taken into service.

Radio head

The radio head is a dual-band radio unit that can operate on any 850 MHz cellular band (A and B) or any 1900 MHz PCS band (A, B, C, D, E or F). Output power and the frequency band of operation can be configured remotely. Moreover, the output power can be set in variable steps from 0.5 mW to 25 mW.

The radio head is a small, four-liter unit designed for indoor environments (Figure 6). It contains

- five transceivers (TRX);
- one scanning receiver;
- circuits for an E1 interface to the CRE.

Given the three time slots per radio carrier in the TDMA air interface, each radio head has a capacity of 14 digital traffic channels and one digital control channel.

The radio head can be powered remotely over the twisted-pair transmission cable (Category 5) from the CRE, which elimi-



Figure 6
The dual-band radio head is a small, four-liter unit designed for mounting on walls in indoor environments.

nates the need for battery backup or a power connection at the radio head. When powered remotely, the radio head can be located up to 800 m from the CRE. Otherwise, using a regular AC/DC converter to provide local power, it can be mounted up to 1,600 m from the CRE.

Radio heads have been designed for easy installation using wall brackets and a cable connection to the CRE. As soon as the CRE detects the presence of a new radio head, it automatically configures the radio head, uploads the correct software, and takes the transceivers into service. Without further planning, the CRE can immediately begin receiving calls from, or handoff calls into, the newly added coverage area.

Scanner

The scanner scans for the adaptive frequency-allocation function, providing input for generating the adaptive public neighbor list. The scanner uses the same control-logic hardware and is based on the same mechanical platform as the radio head. The radio circuitry includes three receivers:

- An uplink receiver that scans for interference on frequencies used by public mobile terminals in the area.
- A downlink receiver that scans for interference frequencies used by neighboring public base stations.
- A downlink receiver that detects and decodes cell identities from neighboring public base stations.

Terminals

Ericsson's digital wireless office system operates with any standard TDMA wireless

Figure 7
DWOS uses a standard TDMA/136 wireless mobile terminal—any terminal can be used as long as it meets the TDMA/136 specification.



mobile terminal. That is, any terminal can be used as long as it meets the TDMA/136 specification.

Capabilities

Operation

The DWOS provides local and global mobility in a private office environment. Global mobility enables any caller to access DWOS subscribers wherever they happen to be. If they want to, however, subscribers can turn the global-mobility feature off.

The digital wireless office system is a dig-

ital system that provides wireless communication according to the TDMA/136 standard on 850 MHz cellular and 1,900 MHz PCS frequencies. It includes features for authentication; supports automatic roaming from the in-building system to the public system via the ANSI-41 connection; and is based on the principles of adaptive channel allocation, which means it yields to the outdoor macro system—whenever the system discovers that its frequency selection is in conflict with the macro system, it switches to an idle frequency.

A PBX numbering plan can be used inside an area supported by DWOS—subscribers are accessed through the PBX number or through their mobile subscriber number. The DWOS system reroutes incoming calls to reach users wherever they are, whether inside or outside of the DWOS area. Finally, DWOS operation, administration and maintenance is simple—all necessary administration can be performed via Internet connections.

Capacity and coverage

The first version of the digital wireless office system targets systems of 25 to 500+ users. For wireless-based calls, the system can carry 45 Erlang at 0.5% blocking. This allows up to 450 users, assuming the following call loads:

- 100 mE wireless call load per user
- 100 mE load on the desk phone

In the initial system release, up to 32 radio heads can be connected to the CRE. In a typical office building, this would provide coverage to approximately 500,000 square meters (5,381,958 sq. ft). Note: Actual cover-

age by in-building wireless systems varies with building structure.

System evolution

Market and customer responses to the initial product release will influence further development of the digital wireless office system. Some of the capabilities being considered for future releases include

- stand-alone operation—that is, as a PBX replacement;
- greater system capacity;
- multi-site networking;
- radio heads for outdoor use;
- packet data services—GPRS (TDMA enhancement);
- voice over IP (based on the H.323 standard);
- semi-private systems that would allow
 - handoff to an outdoor system;
 - charging of external users;
- using DWOS as an indoor extension to an outdoor public cellular/PCS system.

Conclusion

The digital wireless office system is implemented as a private network using TDMA/136 technology. It offers full MSC/VLR functionality and is fully integrated into the core PLMN through the ANSI-41 network protocol.

The DWOS embodies a highly flexible radio-network architecture based on a virtual, single-cell concept that allows independent dimensioning and expansion of capacity and coverage. The virtual, single-cell solution and the scanner are instrumental in



Figure 8

A docking station will be available for the Ericsson terminal to improve its use as an office phone. The docking station includes a microphone, a loudspeaker and a battery charger.

providing a wireless office system that

- is simple to engineer;
- requires minimum cell planning;
- is easy to install and support.

Efforts to facilitate installation and support include the implementation of plug-and-play capabilities, a Web browser-based O&M application, and remote powering via standard twisted-pair cables between the CRE and radio heads.

The DWOS offers a wide range of features and services, including open application program interfaces (API) for third-party vendor applications for interfacing with and using unified messaging systems.