REPORT ITU-R M.2014

SPECTRUM EFFICIENT DIGITAL LAND MOBILE SYSTEMS FOR DISPATCH TRAFFIC

(Question ITU-R 37/8)

(1998)

Summary

Demand in the land mobile service is on the increase due to annual growth as well as to new data-based service requirements. This has led to the development of more spectrally efficient technologies utilizing digital modulation and in many cases trunking. These technologies are being introduced in systems worldwide to accommodate this demand.

This Report provides the technical and operational characteristics for spectrum efficient digital dispatch systems and also provides details of systems being introduced throughout the world.

This Report is a compilation of descriptions of systems which implies that neither technical nor intellectual property rights evaluations were performed in its preparation.

1 General objectives

The general objectives of a spectrum efficient digital land mobile system, for dispatch in either private or public systems, are to provide:

– systems that offer a higher spectrum efficiency, thereby accommodating more users within limited spectrum resources than analogue systems;

– a higher average level of voice quality over the network and enciphered speech for privacy;

– users with a wide range of services and facilities, both voice and non-voice, that are compatible with those offered by the public fixed networks (public switched telephone network (PSTN), public data network (PDN), integrated services digital network (ISDN), etc.);

– users with a variety of applications to satisfy their requirements, ranging from handheld stations to vehicle mounted stations, with voice and data interfaces;

– mobile and infrastructure equipment which use state of the art technology to provide savings in weight, power consumption and cost.

2 Service types

The basic services offered by a digital dispatch traffic system can be divided into three types:

– teleservices,

– bearer services; and

– supplementary services.

2.1 Teleservices

Teleservices provide the user with full capability, including terminal equipment functions, to communicate with other users. These services are typified by both lower layer (open systems interconnection (OSI) layers 1 through 3) and higher layer (OSI layers 4 to 7) functionality.

Typical teleservices should include:

– a trunked and non-trunked capability to permit direct mobile-to-mobile and group speech call facilities with user options to permit selective and secure calling;

– telephony, facsimile and some extended service offerings, e.g. videotex, telex, etc.

2.2 Bearer services

Bearer services give the user the capacity needed to transmit appropriate signals between certain access points. These services are typified by lower layer functionality, typically limited to OSI layers 1 through 3.

Typical bearer services should include:

– a circuit mode data facility to permit a minimum of 7.2 kbit/s for unprotected data and a minimum of 4.8 kbit/s for protected data;

– a packet mode connection-oriented data and connectionless data facility.

2.3 Supplementary services

The range of supplementary services varies depending on the system and also the particular implementation.

3 Channel design

Digital systems for dispatch traffic may have two types of channel categories:

– traffic channels which are used for voice and data transmission; and

– control channels which are used for signalling and control purpose, e.g. access control, broadcast messages, synchronization, etc.

4 Channel access techniques

The systems described in this report use either frequency division multiple access (FDMA), time division multiple access (TDMA), code-division multiple access (CDMA), frequency hopping multiple access (FHMA), or hybrids of these. Digital cellular technology may be adaptable for dispatch use.

5 Systems being installed or planned

General details of the systems are given in Annex 1.

Appendices 1 to 7 give general descriptions of specific systems proposed to ITU-R.

ANNEX 1

Systems being installed and planned

1 Introduction

Digital land mobile radio systems for dispatch and fleet management applications are being developed worldwide. Although these systems have been developed to meet the requirements of either general purpose applications or more specific groups of users, they share some of the basic objectives and characteristics outlined in this Report.

A description of the systems is given below and more detailed descriptions can be found in Appendices 1 to 7.

1.1 Terrestrial trunked radio system (TETRA)

The development of the standards for TETRA system has been carried out in the European Telecommunications Standards Institute (ETSI), a recognized standardization organization.

The technical requirements specification aims to satisfy the needs of a wide range of professional users, ranging from emergency services to commercial and industrial organizations.

1.2 Project 25

The development of the standards for Project 25 system has been carried out by Project 25, a combined effort of US local (Association of Public-Safety Communications Officials international (APCO)), state (National Association of State Telecommunications Directors (NASTD)) and federal government users; in collaboration with the Telecommunications Industry Association (TIA), a recognized standardization organization.

The Project 25 standards aim to satisfy the needs of a wide range of users, primarily in the area of public safety and governmental operations.

1.3 Integrated dispatch radio system (IDRA)

The development of the Standards for the IDRA system has been carried out by the Association of Radio Industries and Businesses (ARIB) in Japan. ARIB is an external Ministry of Post and Telecommunication (MPT) affiliate, a recognized standardization organization.

The technical requirements of the specification aim to satisfy the needs of users over a wide range of professions, from emergency services to commercial and industrial organizations.

1.4 Digital integrated mobile radio system (DIMRS)

The DIMRS system is one of the methods being used in North America to provide integrated dispatch services and increase spectrum efficiency.

1.5 TETRAPOL system

The development of the specifications for TETRAPOL has been carried out by the TETRAPOL Forum and the TETRAPOL users' club. The TETRAPOL specifications aim to satisfy primarily the public safety sector and could be used also by other large private networks and simple private or professional mobile radiocommunications (PMR) networks.

1.6 Enhanced digital access communications system (EDACS)

EDACS is an advanced two-way trunked radio system operating on 25 kHz or 12.5 kHz channelization in VHF, UHF, 800 and 900 MHz frequency bands. The development of these standards for the EDACS system is being carried out by TIA, a recognized standardization organization. The development of specifications based on EDACS technology will provide backward compatibility and interoperability with the large existing base of EDACS equipment and systems, globally.

The EDACS specification provides features and functions intended on satisfying requirements for public safety, industry, utility and commercial users.

1.7 Frequency hopping multiple access system (FHMA)

This FHMA system has been developed in Israel, where a test bed is operating for validation of system evolution. The prime incentive for developing FHMA has been spectral efficiency. The level of spectral efficiency achieved makes it a viable solution for public access mobile radio (PAMR)/PMR services, even when the spectral assignment is extremely small (e.g. 30 frequencies of 25 kHz for unconstrained service coverage). FHMA systems are primarily focused on the PAMR market, and trying to address challenges posed by commercial users.

2 Explanation of Table 1

Table 1 presents the core parameters for these systems. In each case, complete specifications are, or will be, available from the relevant authorities as indicated in the Appendices.

TABLE 1

Core parameters

Parameter	Project 25	TETRA	IDRA	DIMRS	TETRAPOL	EDACS	FHMA
Designation of emission: – traffic channels – control channels	 8K10F1E, 5K76G1E(1) 8K10F1E, 5K76G1E(1)	 25K0D7W/25KWDW(2) 25K0D7W/25KWDW(2)	 20K0D7W/20KWDW(2) 20K0D7W/20KWDW(2)	 20K0D7W/20KWDW(2) 20K0D7W/20KWDW(2)	 4K80P1W 4K80P1W	 16K0F1E/8K50F1E 16K0F1E/8K50F1E	 25K0D7W/25KWDW 25K0D7W/25KWDW
Frequency bands (MHz)	Not yet determined but likely to be: 130-200 360-512 800-941	380-390/390-400 or 410-420/420-430 or 450-460/460-470 or 870-888/915-933	Presently used: 1 453-1 477/1 501-1 525 Future use: 905-915/850-860	806-821/851-866	70-520 746-870 870-888/915-933	136-174 380-512 806-821/851-866 896-901/935-940	806-821/851-866 896-901/935-940
Duplex separation	Varies or none (150 MHz band) 3 MHz and 5 MHz (400 MHz band) 39 MHz and 45 MHz (800 MHz band)	5-10 MHz (400 MHz band) 10-45 MHz (800/900 MHz band) dependent on system design	48 MHz (1.5 GHz band) 55 MHz (800 MHz band)	45 MHz (800 MHz band)	As necessary (80/160 MHz bands) 5 MHz or 10 MHz (400 MHz band) 45 MHz (900 MHz band)	Varies (160 MHz band) Varies (400 MHz band) 45 MHz (800 MHz and 900 MHz bands)	45 MHz (800 MHz band) 39 MHz (900 MHz band)
RF carrier spacing (kHz)	12.5 for 8K10F1E(C4FM) 6.25 for 5K76G1E(CQPSK)	25	25	25	12.5-10 6.25 evolution	25/12.5	25
Maximum base station e.r.p. (W): – peak – average	 500 500	 25 25	 Not specified Typically 40-300	 Not specified 250	 25	 200 200	Max. 10 W at antenna, with antenna gain below level required by regulation; average: 10 W(3)
Nominal mobile station transmit power (W) Peak/average: – mobile – handheld	 from 10/10 to 110/110 from 1/1 to 5/5	 10/2.5 1/0.25	 –/2 Not specified	 10.4/0.5 3.5/0.17	 10/10 2/2	 10/10-110/110 1/1-6/6	 4/1.33(4) 0.6/0.2

TABLE 1 *(continued)*

Parameter	Project 25	TETRA	IDRA	DIMRS	TETRAPOL	EDACS	FHMA
Cell radius (km):	7.6-35	3.8-17.5	Not yet determined	5-40 (design dependent)	8-28	Design dependent	Design dependent
– handheld/suburban	7.6	3.8	Not yet determined	5	8		7-13
– mobile/rural	35	17.5	20-40	40	28		>50
Area coverage technique	Cellular channel re-use Simulcast Voting receivers	Cellular channel re-use Quasi synchronous (Simulcast) Time-sharing trans-mission Diversity receivers	Cellular channel re-use Diversity receivers (base)	Cellular channel re-use Diversity receivers	Cellular channel re-use Simulcast Diversity receiver (Time-sharing trans-mission)	Cellular channel re-use Simulcast Voting receivers Diversity receivers	Cellular channel re-use and sectorization(5) Diversity receivers, time synchronous
Access method	FDMA	TDMA	TDMA	TDMA	FDMA	FDMA	FHMA (TDMA/FHMA)
Traffic channels/RF carrier:							
– initial	1	4	6	6	1	1	3
– design capability	1	8	6. 3, 12	6, 4, 3, 8, 12, etc.	1	1	Not specified
Transmission rate (kbit/s)	9.6	36	64	64	8	9.6	36.9
Modulation	QPSK-c family includes C4FM and CQPSK	π/4 DQPSK	M16QAM (M = 4)	M16QAM (M = 4)	GMSK	GFSK	π/4 SQPSK
Traffic channel structure:							
– Basic rate speech codec:							
– Bit rate (kbit/s)	4.4	4.567	Bit rate with error pro-tection is less than 7.467	4.2	6	6.5	4.4
– Error protection	2.8	2.633		3.177	2	2.7	5.596
– Coding algorithm	IMBE	ACELP	Not specified	VSELP (6:1)	RPCELP	AME	IMBE/AMBE

TABLE 1 *(continued)*

Parameter	Project 25	TETRA	IDRA	DIMRS	TETRAPOL	EDACS	FHMA
Traffic channel structure *(continued)*:							
– Alternative rate speech codec:	N/A	Rate tbd	N/A		Half rate codec tbd	N/A	
– Bit rate (kbit/s)				8.0			
– Error protection				6.7			
– Coding algorithm				VSELP (3:1)			
– Circuit mode data (kbit/s)						N/A	Defined
– Protected	6.1	Up to 19.2	Up to 4.8/slot	7.2	4.8		4.8
– Non-protected	9.6	Up to 28.8	7.467/slot	None	7.2		9.6
– Packet mode data	IP – Internet protocol	Connection-oriented, connectionless	Connection-oriented, (option) connectionless	Connection-oriented, connectionless Supports IP and other network protocols	Yes	IP – Internet protocol	Connection-oriented, connectionless oriented, standard TCP/IP
Messaging X.400		Yes			Yes		
Control channel structure (number of channel types):				– Slot information channel: 1 – Primary control channel: 3 – Temporary control channel: 1 – Dedicated control channel: 1 – Associated control channel: 1			5
– Common control channel	2	2	1		5	1	1 TDMA slot downlink control, 3 slot uplink access
– Associated control channel	3	3	2		2	1	Slow associated, 450 bit/s; fast associated cycle stealing
– Broadcast control channel	2	2	1 (Option: 5)		1	1	Provided
Delay spread equalization capability (μs)(6)	Class A – 50 Class Q – 50	Class A – no equalization Class B – 55.5 Class Q – 111.1	Class A – no equalization Class B – no equalization Class Q – N/A	Class A – 39.8 without equalizer Class B – 65.5 without equalizer Class Q – N/A	No equalization needed	Class A – 52 Class Q – 52	Class A – no equalization Class B – no equalization Class Q – no equalization

TABLE 1 *(continued)*

Parameter	Project 25	TETRA	IDRA	DIMRS	TETRAPOL	EDACS	FHMA
Channel coding	BCH code for network ID Trellis codes for data Golay & Hamming codes for voice Reed-Solomon codes for embedded signals	Convolutional codes with interleaving plus error detection	Multirate trellis coding with interleaving plus error detection and bit Prioritization/convolutional codes with interleaving plus error detection	Multirate trellis coding with interleaving plus error detection and bit prioritization	Convolutional codes with interleaving plus error detection	Control BCH/repeat Digital voice custom with repeat Data repeat	Variable rate convolutional with long interleaving, selective priority protection for encoded voice bits, partial repetition, and channel state enhanced Viterbi algorithm; error detection (Cyclic redundancy check (CRC))
Encipherment – security levels	Types 1, 2, 3 and 4	Air interface is exportable plus authentication. Plus end-to-end encryption user definable up to the highest level of security	Not specified	Allowed for	Yes	Type 1, 3, 4	Not specified, designed on a "provisions for" concept
– multi-algorithm	Yes	Yes			Yes	Yes	
– multikey	Yes	Yes			Yes	Yes	
– encipherment control	Yes	Yes			Yes	No	
– over the air rekeying	Yes	Yes			Yes	Yes	
Handover	Yes	Yes	Option	Yes	Yes	Yes	Yes
Inter-system roaming capability	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Design capability for multiple operators (systems) in same area	Yes	Yes	Yes	Yes	Yes	Yes	Allowed for

TABLE 1 *(end)*

Parameter	Project 25	TETRA	IDRA	DIMRS	TETRAPOL	EDACS	FHMA
Direct mode	Mobile-to-mobile Channel scan [7] Repeater Trunking node gateway	Mobile-to-mobile Dual watch[8] Repeater Trunking mode gateway	Not yet determined	Allowed for	Mobile-to-mobile Dual watch gateway	Portable-portable Portable-mobile Mobile-mobile Mobile-base	Not determined
Repeater mode	Yes	Yes			Yes	Yes	

ACELP: algebraic codes excited linear prediction
C4FM: constant-envelope 4-level frequency modulation (FM)
CQPSK: coherent quaternary phase shift keying
DPQSK: differential quadriphase pulse shift keying
GFSK: gaussian frequency shift keying
GMSK: gaussian-filtered minimum shift keying
IMBE: improved multiband excitation
QPSK: quadriphase shift keying
TCP/IP: transmission control protocol/Internet protocol
VSELP: vector sum excited linear prediction

(1) Denotes the emission classifications for C4FM and CQPSK modulations. Both alternatives utilize a common receiver and are thus interoperable.
(2) Denotes the emission classification for base stations/mobiles (handportables).
(3) Not accounting for the effects of power control (15 dB dynamic range).
(4) Not accounting for the effects of uplink power control (60-70 dB).
(5) Effective reuse pattern between 2 and 3, effective also to sectorization.
(6) Classes A and B refer to single transmitter operation. Class Q refers to quasi-synchronous (simulcast) operation.
(7) Scanning channels for the purpose of alternative channel communication.
(8) Allows a terminal using direct mode service to monitor the trunking control channel for any incoming signalling. It also allows a terminal in trunking mode to monitor a direct mode channel.

APPENDIX 1

TO ANNEX 1

General description of the TETRA system

1 Introduction

TETRA is a high-performance mobile radio system which has been developed primarily for professional users such as the emergency services and public transport. The TETRA suite of mobile radio specifications provide a comprehensive radio capability encompassing trunked, non-trunked and direct mobile-to-mobile communication with a range of facilities including voice, circuit mode data, short data messages and packet mode services. TETRA supports an especially wide range of supplementary services, many of which are exclusive to TETRA.

TETRA is designed to operate in the bands below 1 GHz and the 25 kHz channel structure allows it to fit easily into existing PMR frequency bands.

The specifications cover three distinct telecommunication services corresponding to:

– voice plus data;

– packet data optimized; and

– direct mode.

The packet data optimized (PDO) standard is based on the same physical radio platform as the TETRA25 voice plus data standard but implementations are not expected to interoperate at the physical layer. Full interoperability is foreseen at OSI layer 3.

Direct mode provides direct mobile-to-mobile communications when outside the coverage of the network or can be used as a secure communications channel within the network coverage area. It will interoperate with TETRA25 both at OSI layer 1 and OSI layer 3.

2 Services

2.1 Teleservices

Clear speech or enciphered speech in each of the following:

– individual call (point-to-point),

– group call (point-to-multipoint),

– acknowledged group call,

– broadcast call (point-to-multipoint one way).

2.2 Bearer services

Individual call, group call, acknowledged group call, broadcast call for each of the following:

– circuit mode unprotected data 7.2, 14.4, 21.6, 28.8 kbit/s,

– circuit mode protected data (low) 4.8, 9.6, 14.4, 19.2 kbit/s,

– circuit mode protected data (high) 2.4, 4.8, 7.2, 9.6 kbit/s,

– packet connection-oriented data,

– packet connectionless data.

2.3 Supplementary services supported

2.3.1 PMR type supplementary services

Access priority, pre-emptive priority, priority call.

Include call, transfer of control, late entry.

Calls authorized by dispatcher, ambience listening, discreet listening.

Area selection.

Short number addressing.

Talking party identification.

Dynamic group number assignment.

2.3.2 Telephone type supplementary services

List search call.

Call forwarding – unconditional/busy/no reply/not reachable.

Call barring – incoming/outgoing calls.

Call report.

Call waiting.

Call hold.

Calling/connected line identity presentation.

Calling/connected line identify restriction.

Call completion to busy subscriber/on no reply.

Advice of charge.

Call retention.

2.4 Security aspects

The TETRA system is designed to ensure high levels of security. The security objectives are listed below:

Correct charging:	primarily of interest to commercial systems.
Authenticity:	proving the true identity of the communicating parties and of the network.
Confidentiality of communication:	protection against unauthorized reading of transmitted information.
Integrity of communication:	protection against unauthorized modification of transmitted information.
Privacy:	privacy of people using or operating the network, e.g. personal information, identities, location.
Traffic flow confidentiality:	to prevent disclosure of information which can be inferred from observing traffic patterns.
Monitoring:	to permit authorized monitoring of communications, uninhibited by the security mechanisms.
Security management:	to enable administration of a secure network.

3 Overview of the system

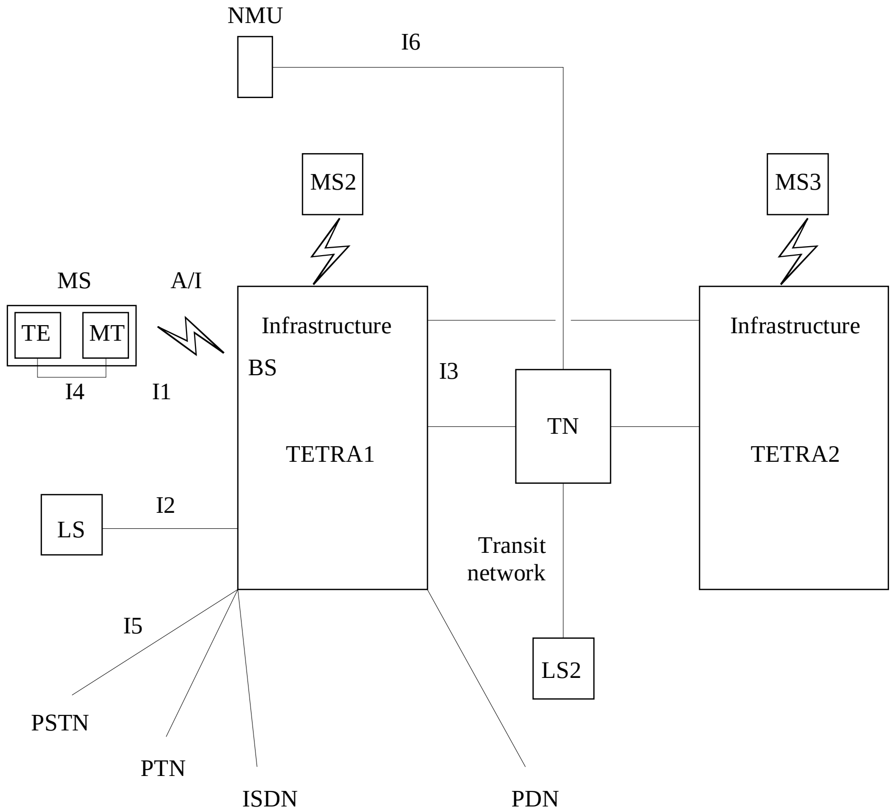
The functional architectures for voice and data, and PDO are shown in Figs. 1 and 2, including their respective standardized interfaces.

4 System specifications

Refer to Table 1.

FIGURE 1

TETRA voice plus data



BS: base station
ISDN: integrated services digital network
LS: line station
MS : mobile station
MT: mobile terminal
NMU: network management unit
PDN: public data network
PSTN: public switched telephone network
PTN: public telephone network
TE: terminal equipment

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4.1 Logical channels

The following logical channels are defined:

– common control channel (CCCH) comprising:
  – main control channel (MCCH),
  – extended control channel (ECCH).

  These channels deal with control information addressed to or received from MSs not involved in a circuit mode call;

– associated control channel (ACCH) comprising:
  – fast associated control channel (FACCH),
  – stealing channel (STCH),
  – slow associated control channel (SACCH).

  These channels deal with control information intended for or received from mobile stations involved in a circuit mode call;

– broadcast common control channel (BCCCH) comprising:

  – broadcast synchronization channel (BSCH),

  – broadcast network channel (BNCH).

  These channels carry the downlink system broadcast information;

– traffic channels (TCH) comprising:

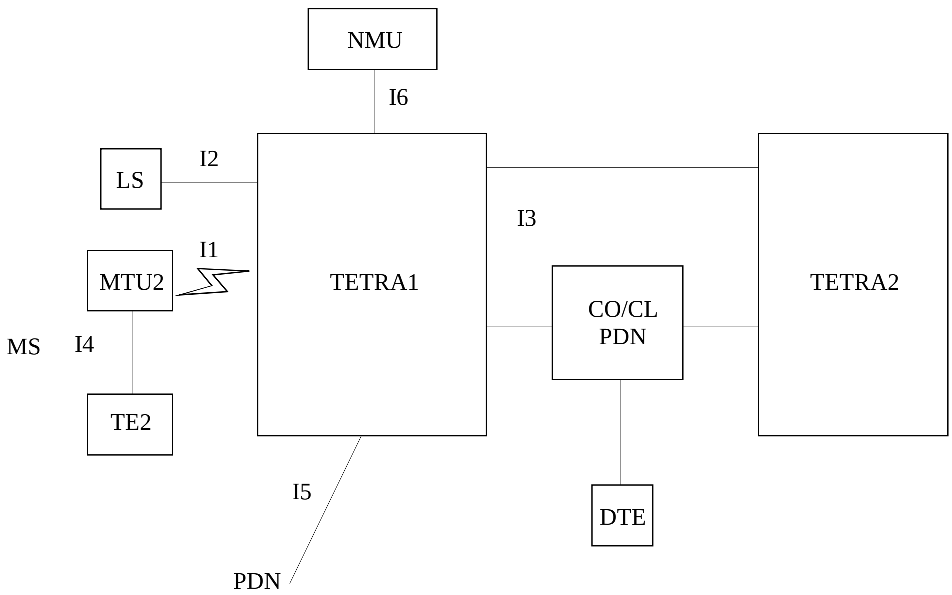
  – speech traffic channel (TCH/S),

  – speech or data traffic channels (TCH/7.2, TCH/4.8, TCH/2.4).

  These channels carry the circuit mode voice or data traffic information.

FIGURE 2

TETRA packet data optimized



CO/CL : connection/connectionless
DTE: data terminal equipment
LS: line station
MTU2: mobile terminal unit
NMU: network management unit
PDN: public data network
TE: terminal equipment

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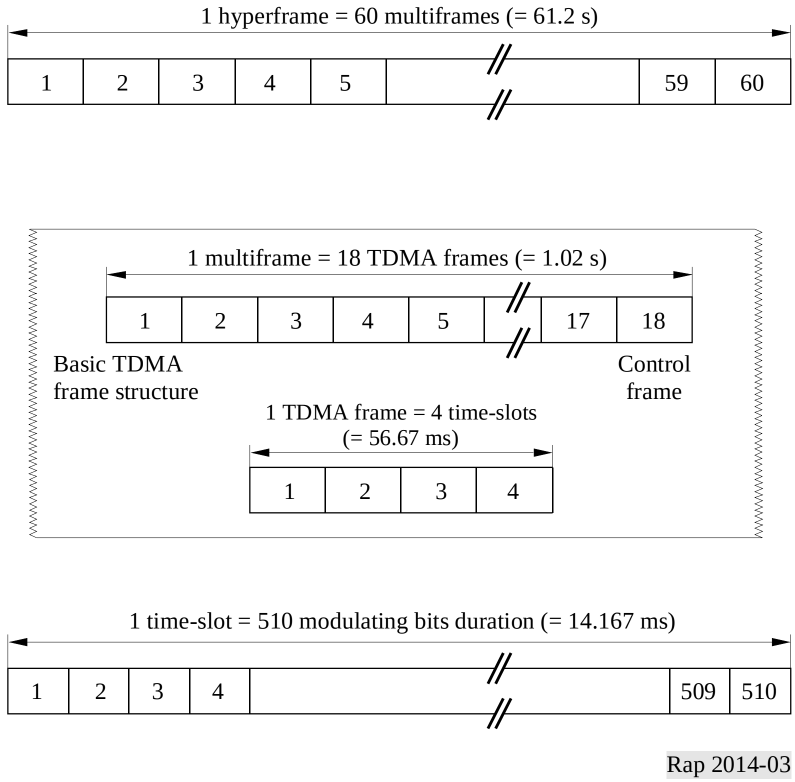
4.2 TDMA frame structure – Voice and data

The TETRA frame structure, shown in Fig. 3, has four slots per TDMA frame. This is further organized as 18 TDMA frames per multiframe of which one frame per multiframe is always used for control signalling. This eighteenth frame is called the control frame and provides the basis of the SACCH.

The circuit mode voice or data operation traffic from an 18-frame multiframe length of time is compressed and conveyed within 17 TDMA frames, thus allowing the eighteenth frame to be used to control signalling without interrupting the flow of data. Besides the basic TDMA frame structure described above, there is a hyperframe imposed above the multiframe structure. This is for long repeat frame purposes such as encipherment synchronization. Furthermore, it can be seen that each time-slot is of 510 modulation bits in duration.

FIGURE 3

TETRA TDMA frame structure



4.3 Burst structure – PDO

The PDO access schemes are statistical multiplexing for the downlink and statistical multiple access for the uplink. The carrier separation is 25 kHz.

The basic radio resources are sub bursts, transmitting information at a modulating rate of 36 kbit/s. On the uplink there are four types of sub bursts. On the downlink, there are two types of sub bursts. Figure 4 describes the PDO up and down burst format.

4.4 Traffic channels

4.4.1 Speech traffic channels

The speech codec, and the associated error correction and detection mechanisms have been defined in the TETRA standard. Speech frames of 30 ms, each comprising 137 bits provide a net bit rate of 4.567 kbit/s. The coding method, ACELP, has been designed to achieve robustness to transmission errors, and to offer a high quality in the presence of background acoustic noise while using a limited bit rate.

Error correction (consisting of a 1/3 rate punctured convolutional code) and interleaving schemes, to selectively protect the most important bits within the speech frame, have been specified. Furthermore, an error detection mechanism has been included and bad frame replacement techniques can be used, in order to minimize the impairment of the speech quality resulting from speech frames not correctly received.

4.4.2 Data traffic channels

Data services of up to 19.2 kbit/s are supported with channel coding and interleaving schemes by using up to four time-slots per TDMA frame.

Unprotected digital bearer services with a bit rate up to 28.8 kbit/s are also supported.

FIGURE 4a

PDO downlink burst structure

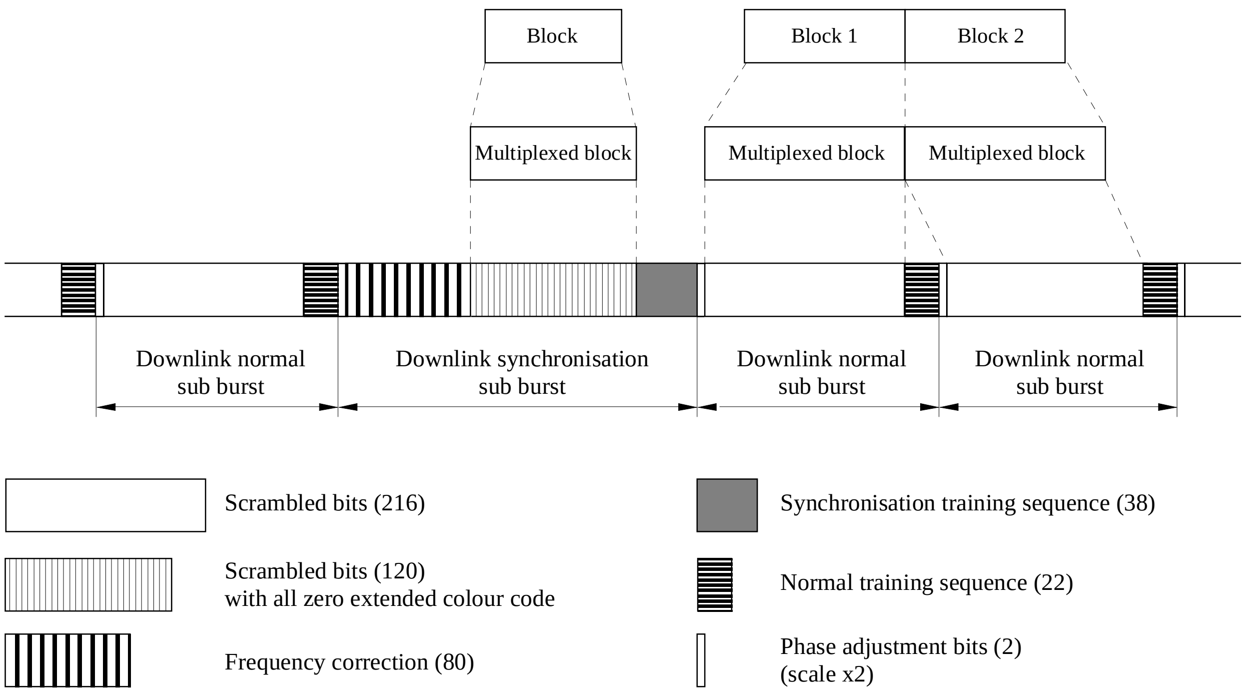


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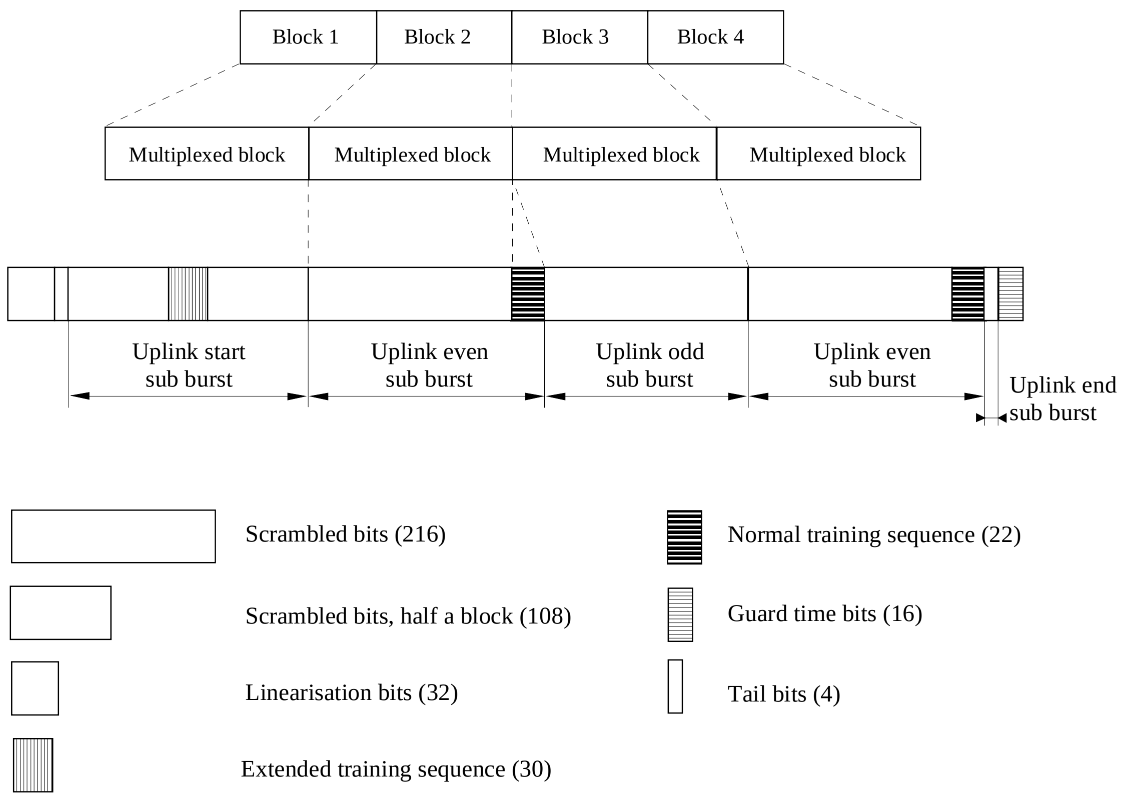
FIGURE 4b

PDO uplink burst structure



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5 Operational characteristics

5.1 Location updating and roaming

The mobile station evaluates the received signal and initiates the location updating procedure when necessary.

A location area is the area in which a mobile terminal can move freely without updating the location information maintained in the network. The paging area is the area in which a mobile is paged.

The switching and management infrastructure (SwMI) will page the mobile terminal in every location area where it is registered.

To facilitate mobility management, a mobile terminal may be temporarily registered in a number of location areas so that a mobile terminal may travel freely between the areas without the need to reregister.

Roaming is possible within a TETRA network and between TETRA networks.

5.2 Communication protocols

The communication protocols are layered according to the OSI model and are specified in the TETRA standards.

Layers 1 to 3 are subdivided as shown in Fig. 5. The C-plane corresponds to all signalling information, both control and data and also packet mode data traffic. U-Plane information corresponds to circuit mode voice or circuit mode data.

The MM, CMCE and PD are defined in Fig. 5.

The MLE (mobile/base link control entity) performs management of the mobile-to-base/base-to-mobile connection, mobility within a registration area, identity management, quality of service selection, protocol discrimination (i.e., routing to the higher layer applications).

The LLC (logical link control) layer is responsible for scheduling data transmission and retransmissions, segmentation/reassembly, logical link handling.

The MAC (medium access control) layer performs frame synchronization, interleaving/de-interleaving channel coding, random access procedures, fragmentation/reassociation and bit error rate (BER) measurements for control purposes.

5.3 Call set-up

5.3.1 Broadcast phase

The base station is continuously transmitting the following control and identification information:

– system identify (e.g. country code, operator code, area code etc.),

– system timing information (e.g. slot synchronization, frame synchronization etc.),

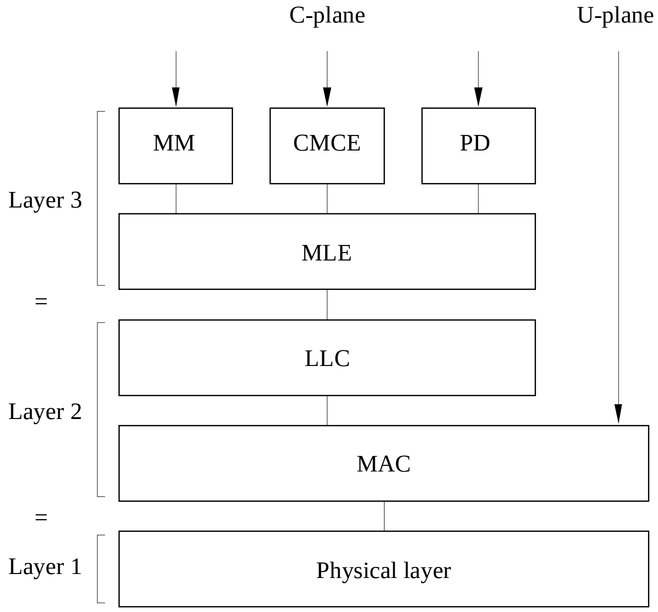
– control channel organization and loading information (e.g. announce slot structure especially for random access),

– requests for or denial of system registrations.

Information (such as paging messages addressed to a particular mobile or group of mobiles) is transmitted on a per call basis.

FIGURE 5

Mobile/base station protocol stack



C-plane traffic:

MM: mobility management - controls roaming and handover.
CMCE: circuit mode control entity - call control, supplementary services and short data service.
PD: packet data - controls connection oriented and connection-less packet data.

U-plane traffic:

Clear/encrypted speech
Circuit mode unprotected data
Circuit mode protected data (low)
Circuit mode protected data (high)

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5.3.2 Set-up

Information is exchanged between the infrastructure and mobile. Five elements of the mobile procedure are:

– wake up (if a battery economy mode),

– presence check on control channel (if required),

– transfer to the traffic channel,

– acknowledgement on traffic channel (if required),

– traffic information transfer (voice or data).

Further elements need to be taken into account, especially concerning invoking supplementary services during this phase, conveying this information to the infrastructure, checking the subscriber database to ensure these services have been subscribed to. On successful conclusion of this stage, the mobile progresses to the call in progress stage.

5.3.3 Call in progress

Terminals are now concerned primarily to communicate with each other rather than signal to the infrastructure. However, even during the traffic phase a substantial amount of control information should be supported to allow "traffic channel acknowledgement", caller authentication, notification of call waiting, call hold and transfer to waiting, priority pre-empt, include call (IC) and speaker identification during a call.

5.3.4 Call clear down

The mobile relinquishes traffic channel and returns to monitoring the control channel. If the call is on "hold" the system will retain details of the mobile and the call reference for subsequent reconnection. The system may optionally retain line resources. When the call is complete all radio and line resources should be cleared of traffic and returned to the resource pool.

5.4 Connection restoration

A number of network procedures are supported in the TETRA specifications to provide continuity of service when a mobile encounters adverse propagation effects, moves between different cells or encounters interference. Connection restoration may also be required for traffic reasons; to redistribute the load on a particular cell such as during minimum mode operation; to allow the frequency allocations at a particular cell to be reorganized, or for maintenance or equipment fault reasons.

The responsibility for initiating the connection restoration procedures can rest with the mobile station or with the base station, depending on the reason for restoration.

The mobile station is responsible for monitoring the quality of the downlink transmissions and may request an alternative channel on the same serving cell if interference is encountered or may request service on another cell if the received signal strength drops below a predefined level. The TETRA air interface protocol provides a range of restoration procedures (of different quality) which a network operator may wish to install, and to which users may choose to subscribe. These range from a totally unprepared restoration taking several seconds during which time the connection is broken, to seamless handover where the break in service is imperceptible to the user.

The base station may choose to move the mobile station to another channel on the same servicing cell if interference on the uplink is encountered. The BS may wish to hand-off the call to an adjacent cell if the loading becomes too high on a particular site (load shedding). This would be performed by altering the acquisition and relinquishing criteria defined in the broadcast (BCCCH).

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APPENDIX 2

TO ANNEX 1

General description of the Project 25 system

1 Services supported

Services will be available on Project 25 systems in accordance with system type and other specifications within this Appendix. Where a service is mandatory for a Project 25 system type, such a system must provide that service. Where a service is a standard option, and a Project 25 system provides that service, it shall be provided in compliance to the standard. Technological limitations may preclude some systems from supporting certain services.

1.1 Types of systems

Two types of systems are defined: non-trunked (conventional) and trunked. All Project 25 trunked radios shall be capable of operation in both types of systems.

1.1.1 Non-trunked (conventional)

Non-trunked (conventional) systems possess no centralized management of subscriber operation or capability. All aspects of system operation are under control of the system users. Operating modes within non-trunked systems include both direct (i.e., radio-to-radio) and repeated (i.e., through an RF repeater) operation.

1.1.2 Trunked

Trunked systems provide for management of virtually all aspects of radio system operation, including channel access and call routing. Most aspects of system operation are under automatic control, relieving system users of the need to directly control the operation of system elements.

1.2 Availability

The following table of telecommunications services (Table 2) shows service availability by system type. The services are further denoted as either mandatory or as a standard option, by system type.

2 Functional groups

2.1 Mobile end system (MES)

In the MES functional group, the term “mobile” is used as in land mobile radio (LMR), which includes all mobile radios, portable radios, and fixed remote radios. The MES functions include the voice and/or data user interface built into a radio.

2.2 Mobile data peripheral (MDP)

The MDP functional group includes all mobile, portable, and fixed remote data peripherals. The MDP functions include the data user interface of any data peripheral attached to a radio.

2.3 Mobile routing and control (MRC)

The MRC functional group includes functions of voice and/or data routing, as well as control of the mobile radio.

2.4 Mobile radio (MR)

The MR functional group includes functions of transmission and reception of all RF signals.

TABLE 2

Telecommunications services		
Bearer services	*Non-trunked*	*Trunked*
Circuit switched unreliable data	Standard option	Standard option
Circuit switched reliable data	Standard option	Standard option
Packet switched confirmed delivery data	Standard option	Standard option
Packet switched unconfirmed delivery data	Standard option	Standard option
Teleservices	*Non-trunked*	*Trunked*
Broadcast voice call	Not available	Mandatory
Unaddressed voice call	Mandatory	Not available
Group voice call	Standard option	Mandatory
Individual voice call	Standard option	Mandatory
Circuit switched data network access	Standard option	Standard option
Packet switched data network access	Standard option	Standard option
Pre-programmed data messaging	Standard option	Standard option
Supplementary services	*Non-trunked*	*Trunked*
Encipherment	Standard option	Standard option
Priority call	Not available	Standard option
Pre-emptive priority call	Not available	Standard option
Call interrupt	Standard option	Standard option
Voice telephone interconnect	Standard option	Standard option
Discreet listening	Standard option	Standard option
Radio unit monitoring	Standard option	Standard option
Talking party identification	Standard option	Standard option
Call alerting	Standard option	Standard option
Services to the subscriber	*Non-trunked*	*Trunked*
Intra-system roaming	Standard option	Standard option
Inter-system roaming	Standard option	Standard option
Call restriction	Not available	Standard option
Affiliation	Not available	Standard option
Call routing	Not available	Standard option
Encipherment update	Standard option	Standard option

2.5 Base radio (BR)

The base radio functional group includes only the functions of modulation and demodulation of the radio frequency energy. Elements within the base radio include the power amplifier, RF front-end, IF selectivity, and end-IF detection device.

2.6 Base audio (BA)

The base radio audio functional group includes the functions of frequency/level shaping and signal processing associated with transmitted signals and received signals coupled to the BR. The interface to the BR and base control are manufacturer-specific, and may be at any level or frequency.

2.7 Base control (BC)

The base radio control functional group includes the automated control functions of an individual radio.

2.8 Radio frequency control (RFC)

The RFC functional group includes all logic for translating user command signalling and control into base radio command signalling and control for one or more base radios. The RFC functions further include all logic for generating command signalling and control to a radio frequency switch (RFS) functional group, if present.

2.9 Radio frequency switch (RFS)

The RFS functional group includes all switching for establishing interconnection paths between gateways and base radios, as directed via command and control signalling from an RFC.

2.10 Console

The console functional group includes all end system functionality for dispatcher(s); including a dispatcher's man machine interface, control and audio functions.

2.11 Mobile service switching centre (MSC)

The mobile service switching centre is a switching centre for services between radio subnetworks. The MSC is the combination of the RFC and RFS functional groups.

2.12 Home location register (HLR)

The HLR is a dynamic database service which tracks the mobility of radios associated with a particular radio subnetwork, that roam to other radio subnetworks.

2.13 Visitor location register (VLR)

The VLR is a dynamic database service which tracks the mobility of roaming radios which enter a radio subnetwork, but that are associated with a different radio subnetwork.

2.14 Radio frequency gateway (RFG)

The RFG functional group functions include direct interface with any/all end systems with the exception of the console (where the end system may be an RFG into another radio subsystem), and any translation of command signalling between the end system/user and the RFC. The RFG functions further include any translation of end system/user payload between the user and the RFS. The RFG also includes interface between VLRs, HLRs, and MSCs between RF subsystems.

3 Signalling description

3.1 Data units

Information is transmitted over the air, using the common air interface (CAI), in data units. There are five types of data units defined for voice channel operation, one type of data unit for data packets, and one type of data unit for control functions.

3.1.1 Voice data units

Voice information is transferred in a sequence of logical link data units (LDUs), each convey 180 ms of voice information. There are two kinds of LDUs, denoted as LDU1 and LDU2. Each LDU conveys additional embedded information, which includes a link control word, an encipherment synchronization word, and low-speed data. LDU1 conveys the link control word. LDU2 conveys the encipherment synchronization word. Both LDU1 and LDU2 convey low-speed data.

Voice information in the LDUs is conveyed as nine frames of vocoder information, with each frame containing 20 ms of digitized voice information.

The LDUs are paired into superframes of 360 ms. Each superframe has an LDU1 and an LDU2. The last superframe of a voice transmission may terminate after LDU1, if the transmission ends before the LDU2 portion of the superframe has begun. Since LDU2 is present in each superframe (except possibly the last one), it is possible for the transmission recipient to synchronize decipherment in the middle of the transmission, and begin receiving a voice transmission on a superframe boundary.

Voice transmission begins with a header data unit, which conveys the synchronization of the encipherment algorithm. This allows voice information in LDU1 of the first superframe to be deciphered. The header data unit takes 82.5 ms to transmit.

Voice transmission terminates with one of two types of terminator data units. A simple terminator is a short word, 15 ms in duration, signifying the end of a transmission. A terminator with link control conveys a link control word for supervisory functions when terminating a transmission. A terminator with link control is 45 ms in duration.

3.1.2 Packet data unit

A packet data unit conveys general purpose data information. A packet data unit is split into blocks of information. The first block conveys addressing and service information, and is designated as a header block. Subsequent blocks are designated as data blocks. The length of the data packet is contained in the header block.

Each block is protected with either a rate 1/2 trellis code, or a rate 3/4 trellis code. The rate 1/2 trellis code encodes 12 octets of information into exactly 196 bits. The rate 3/4 trellis code encodes 18 octets of information into exactly 196 bits. A header block always uses the rate 1/2 trellis code. Data blocks use a rate 1/2 trellis code for unconfirmed delivery data packets, and a rate 3/4 trellis code for confirmed delivery data packets. The type of data packet (confirmed or unconfirmed) is indicated in the header block.

3.1.3 Control data unit

A special short data packet is defined for control functions. It consists of a single block protected with the rate 1/2 trellis code defined for the packet data unit. It requires 37.5 ms of air time to transmit.

3.2 Media access control

Data units are transmitted over the air preceded by a short burst of frame synchronization and network identity. The frame synchronization is exactly 48 bits, 5 ms in duration. The network identity is a 64-bit codeword. These allow the recipient of the transmission to determine the beginning of the message, and to distinguish traffic on the proper radio system from interference or co-channel traffic on nearby systems. The network identifier also contains a data unit identifier which identifies among the seven possible data units.

Channel access is controlled with status symbols which are periodically interleaved throughout transmissions. Each status symbol is two bits, transmitted after every 70 bits within a data unit. This spaces the status symbols exactly 7.5 ms apart. The 7.5 ms interval is designated as a microslot time interval. If a data unit happens to end before a microslot boundary, then additional null bits are inserted to pad the transmission to the next microslot boundary.

An RF subsystem indicates activity on an inbound channel by setting the status symbols on the corresponding outbound channel to a “busy” state. Radios wishing to access the inbound channel are inhibited from transmission when the status symbols indicate “busy”. When status symbols indicate “idle”, they may transmit. A third state, indicating “unknown” is used for slotting status symbols.

4 Operational characteristics

Operation over the CAI is dependent on mode, i.e., whether the message is voice or data, and whether the system is trunked or non-trunked. In general, trunked operation requires radios to request service on a control channel using a control data unit. The RF subsystem then assigns the radio to a working channel for further operations. After the operations are complete on the working channel, the call is cleared for assignment of the channel to other calls. Operation in a non-trunked system does not have the service request phase and the call clearing phase.

4.1 Voice transmit operation

Operation of a transmitter for voice messages has three main cases, with several options and variations of each case. The three main cases consist of routine group calls, emergency group calls, and individual calls.

4.1.1 Controls

A transmitter may have several controls which affect transmit operations. Controls sufficient for a radio to support all of the call types are defined below. These controls are:

PTT switch – A push-to-talk (PTT) switch is activated when an operator wishes to transmit, and released when a transmission is finished.

Channel selector – The channel selector is a switch or control that allows the operator of a radio to select a radio’s operational parameters. The operational parameters that can be selected include the following items:

– transmit frequency,

– transmit network access code,

– talk group,

– other parameters for setting the vocoder and encipherment functions. For example, the enciphering key variable may be selected.

Emergency switch – The emergency switch is asserted by a radio operator for emergency calling. Once this switch is asserted, the emergency condition remains asserted until it is cleared by a different means, e.g. turning the radio off.

Numeric keypad/display – This allows a radio operator to set numeric values. This is most useful for individual calls.

4.1.2 Call types

The different types of calls are defined as follows:

Routine group call – This is a transmission that is intended for a group of users in a radio system. Typically, it is the type of call that is made most often. These calls are typically made when the PTT switch is asserted.

Emergency group call – This is a transmission that is intended for a group of users in a radio system, during an emergency condition. The definition of an emergency condition depends on a system's operators, but it typically signifies an exceptional condition with more urgency. These calls are typically made after the emergency switch is asserted.

Individual call – This is a transmission which is addressed to a specific individual radio. The individual radio's address to which the call is directed is called the destination address. These calls are typically made after the destination address is entered into the radio.

4.1.3 Procedures

The procedures for each of these calls in the transmitter are based on the procedure for the routine group call. Consequently, that type of call is described first, and then the other types of calls are described.

Routine group call procedure

Step 1: *PTT*. The radio operator asserts the PTT switch.

Step 2: *Pre-transmit*. The radio selects the channel parameters as determined by the channel selector switch. The radio may check the status symbols, if present, to determine if the channel is busy or idle. If busy, it may optionally hold off the activation of the transmitter until the channel is idle. If the status symbols are not checked, or if the channel is idle, then the radio simply keys the transmitter on the transmit frequency. The radio also activates the voice encoder. The radio also activates the encipherment function, if present.

Step 3: *Header data unit*. The radio transmits the header data unit with the following selected-information fields:

- network access code as determined by the channel selector switch,
- manufacturer's ID,
- message indicator, algorithm ID, and key ID are determined by the encipherment function,
- talk group/individual ID is determined by the channel selector switch, as appropriate.

Step 4: *Format selection*. The following recurrent voice message parameters are set:

- network access code as determined by the channel selector switch,
- manufacturer's ID,
- emergency bit is set to indicate routine operation,
- talk group/individual ID is determined by the channel selector switch, as appropriate,
- source ID is set to the unit ID of the radio,
- message indicator, algorithm ID, and key ID are determined by the encipherment function.

Step 5: *Transmission*. The voice link data units, LDU1 and LDU2, are sent with the message parameters set above in *Step 4*. The information contents of the link control word is enciphered if specified by the encipherment function. Link control shall only be enciphered if the voice frames are also enciphered. Transmission is sustained until the PTT switch is released.

Step 6: *End of Transmission*. Transmission terminates when the PTT switch is released, or some other event forces a dekey, and the transmission has reached the end of an LDU. The radio terminates the voice encoder. Then the radio sends a terminator data unit. A radio always sends the simple terminator, consisting of frame synchronization and the network ID word. After termination, the radio notifies the encipherment function to terminate, as defined in the encipherment protocol.

Step 7: *Dekey*. The radio ceases transmission.

Emergency group call procedure

Step 1: *Emergency switch*. The radio operator asserts the emergency switch. This sets the emergency condition until it is cleared by some other action, e.g., turning the radio off.

Step 2: *Group calls*. Activation of the PTT switch now initiates calls that are very much like the routine group call described above. The only difference in procedure is that the emergency bit is asserted to indicate an emergency condition. Group calls can be made repeatedly, and each group call will indicate the emergency condition.

Step 3: *Emergency termination*. The emergency condition is cleared by turning the radio off. When the radio is turned on, the emergency condition is cleared and routine group calls are made after PTT assertion. In addition to this method, other methods of termination may also be available.

Individual call procedure

Step 1: *Select called party*. The unit ID of the individual radio to be called can be entered into the radio via a keypad or by some other means. This becomes the destination ID of the call.

Step 2: *Make the call*. The procedure for group calls is followed, with the following exceptions:

– the talk group ID in the header data unit is cleared to the null talk group (0000);

– the link control field is formatted with the individual call format, containing the source ID and destination ID of the call.

4.2 Voice receive operation

The operation of a receiver for voice messages consists of three main cases, with variations that depend on the transmitter's operation. The three main cases are called squelch conditions in this Report. They are: monitor, normal squelch and selective squelch.

As in the case of the transmitter, receiver operation will be affected by the channel selector switch. This switch can select:

– receive frequency,

– receiver network access code,

– talk group,

– other parameters for setting the vocoder and encipherment functions. The encipherment function is particularly significant to the receiver.

An additional radio control which can affect a receiver is the monitor switch. This switch allows the operator of a radio to disable any selective squelch of the receiver so that an operator can hear any sign of voice activity. This can be useful for avoiding collisions on non-trunked channels between voice users.

The types of squelch operation described are defined as follows:

Monitor – This enables the receiver to unmute on any recognizable voice signal. Selective muting based on the network access code, talk group ID, or unit address is not performed. This is analogous to monitor mode in analogue receivers. This is normally activated with a monitor switch.

Normal squelch – This enables the receiver to unmute on any voice signal which has the correct network access code. Voice messages from co-channel users which are using different network access codes will be muted.

Selective squelch – This mutes all voice traffic except that which is explicitly addressed to the radio. Messages which contain the talk group or unit address of the receiver, as well as the network access code, will be received.

FIGURE 6a

Project 25 repeater (example) reference configuration

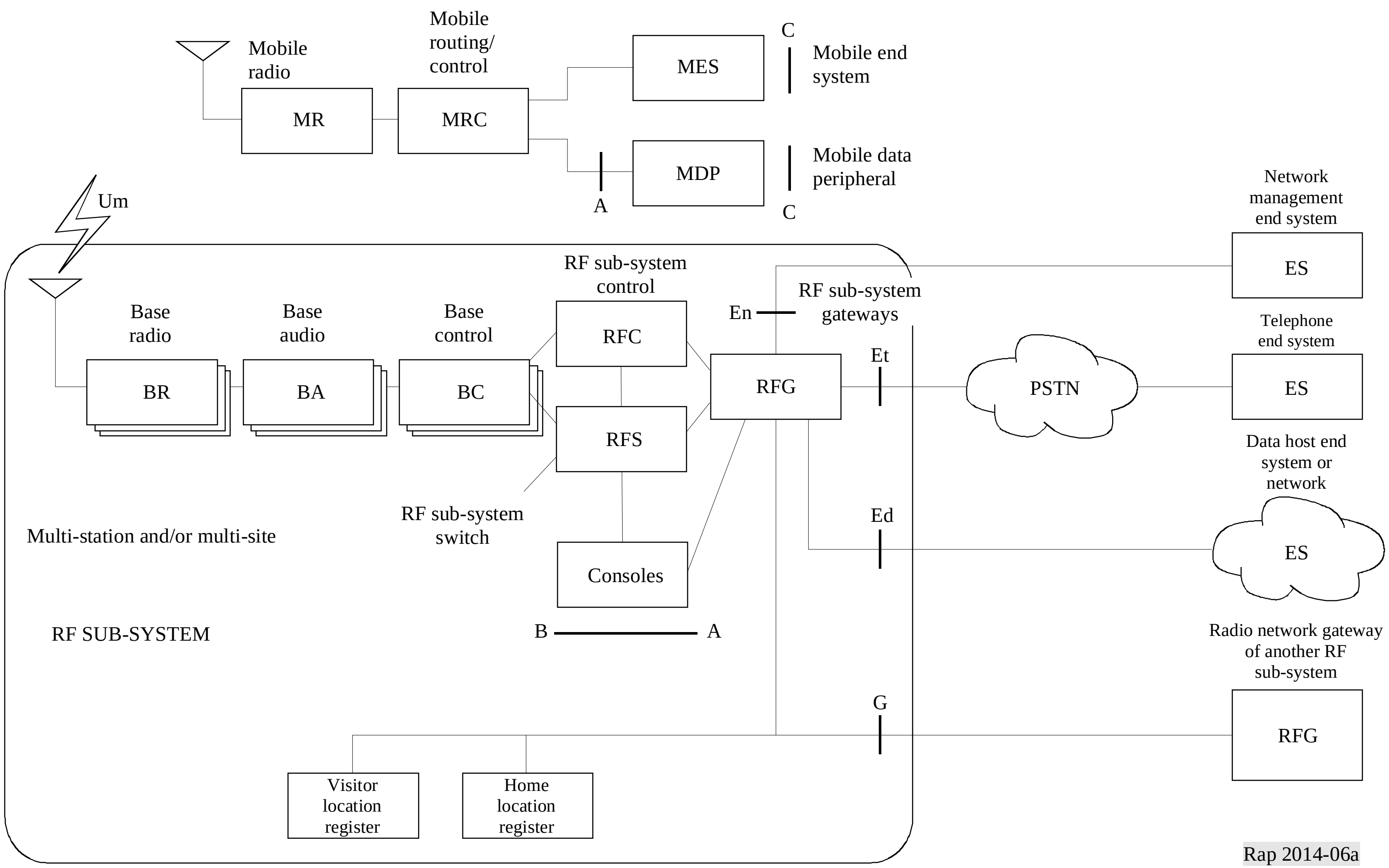

FIGURE 6b

Project 25 non-repeater reference configuration

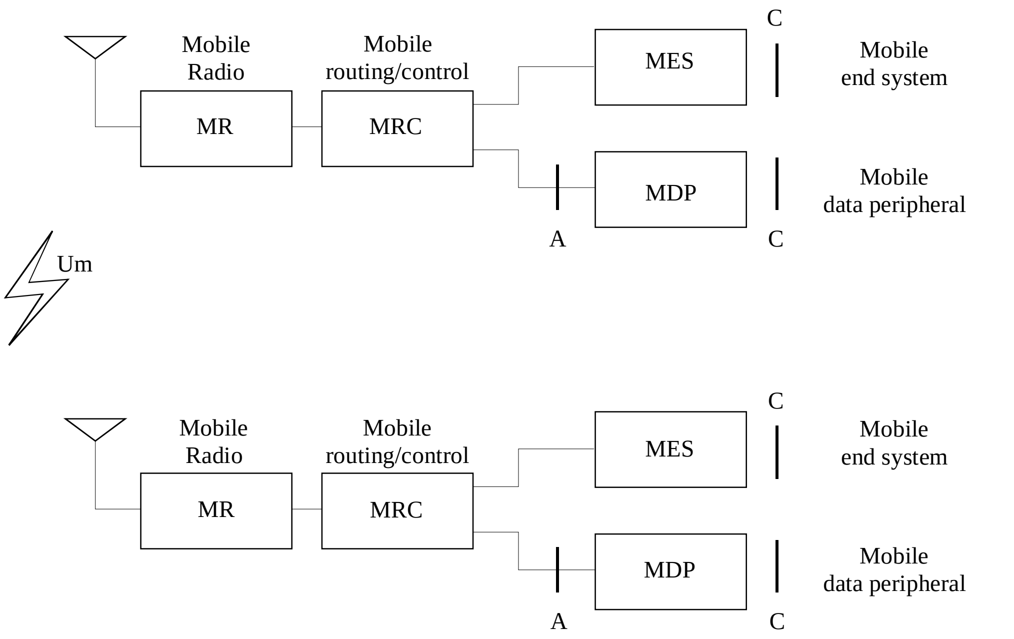

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FIGURE 7a

Project 25 voice structure

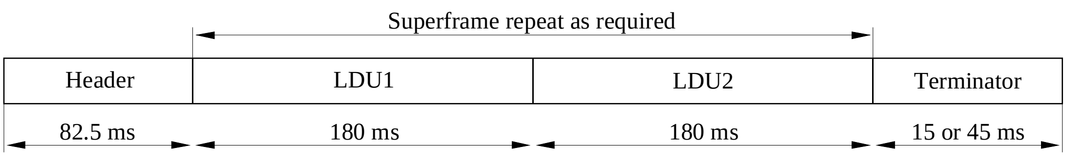

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FIGURE 7b

Project 25 voice data unit structure

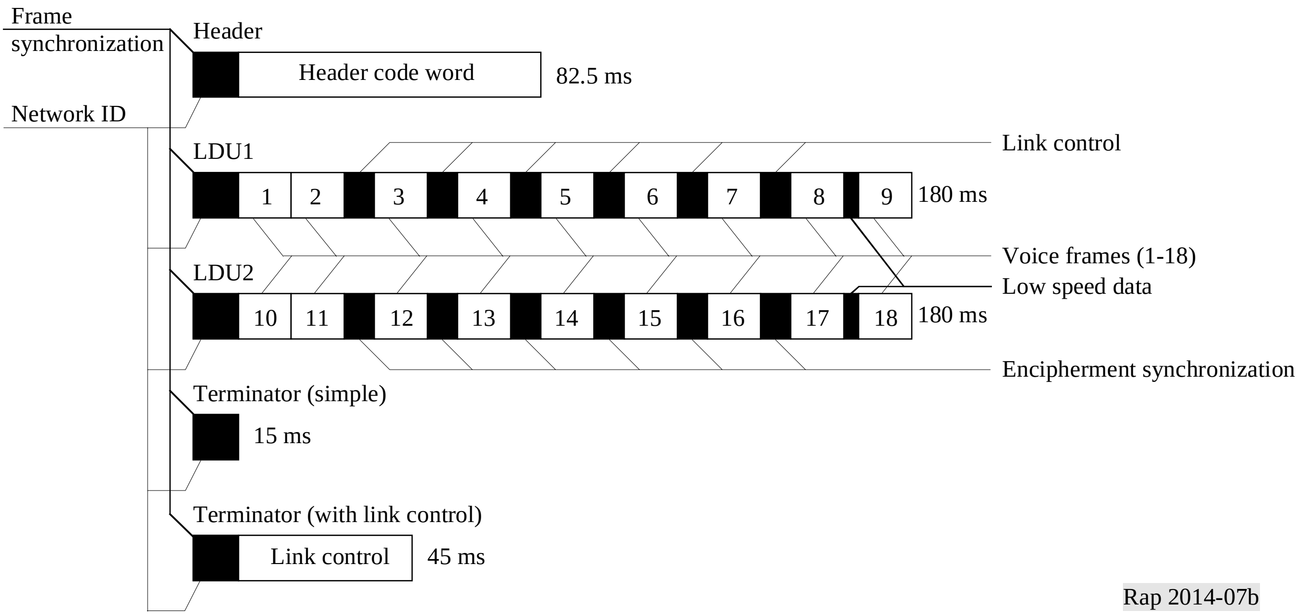

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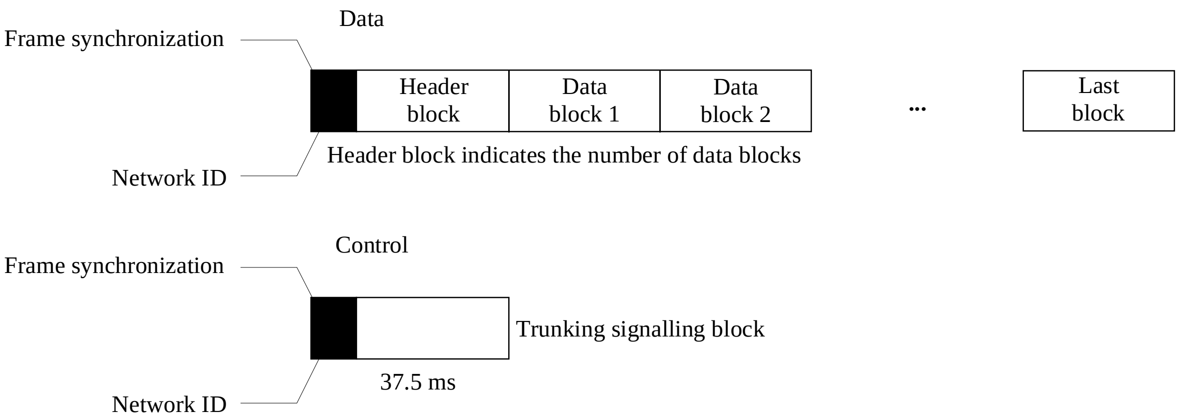
FIGURE 8

Project 25 data and control signal structure



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* These documents are referenced for completeness only. The selection of encipherment algorithm should remain a national option.

APPENDIX 3

TO ANNEX 1

General description of the IDRA system

1 Introduction

The IDRA system has been developed for use mainly in business-oriented mobile communications applications. Both voice and data communications in the IDRA system offer inter-mobile communications in a single cell and inter-mobile communications between cells, as well as communications between a PSTN user and a mobile subscriber to the IDRA. The IDRA system satisfies the following three fundamental specifications:

– voice only,

– voice and data (circuit mode data, short message mode data, and packet mode data),

– data only (circuit mode data, short message mode data, and packet mode data).

2 Services

2.1 Teleservices

Clear speech or enciphered speech in each of the following:

– individual call (point-to-point),

– group call (point-to-multipoint),

– broadcast call (point-to-multipoint, one way),

– full-duplex interconnect call,

– full-duplex dispatch call (option).

2.2 Bearer services

Individual call, group call, and broadcast call for each of the following:

– circuit mode protected data 3.044 and 4.8 kbit/slot,

– circuit mode non-protected data 7.466 kbit/slot,

– packet connectionless data,

– packet connection-oriented (option).

2.3 Supplementary services

Telephone type supplementary services:

– call completion to busy/no-reply subscriber,

– call barring incoming/outgoing call,

– calling line identity presentation,

– calling line identity restriction,

– voice operation guide (option),

– list search call (option),

– call waiting,

– advice of charge (option),

– short message service (option),

– call traffic monitor,

– call monitor with late entry,

– priority call,

– conference call (option),

– area selection,

– subgrouping call.

Network access supplementary services:

– multiple-zone access,

– PSTN/public switched data network (PSDN) access.

2.4 Security aspects

Special security aspects are not specified, but the system provides a high level of security with authentication and identification.

2.4.1 Authentication

During power up, mobile origination, mobile termination, location updating, supplementary service, and/or short message service.

2.4.2 Identification

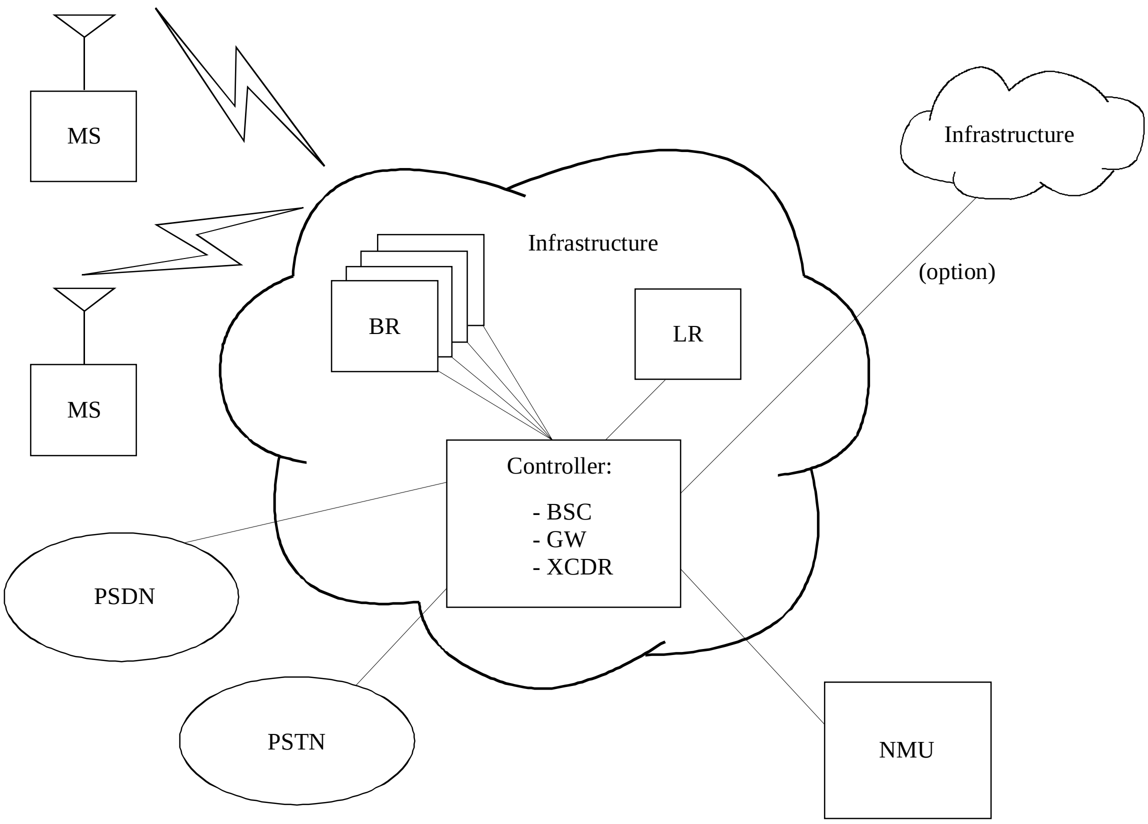
By individual identification and/or temporary identification.

3 Overview of the system

The network approach showing the major architectural components of the system is shown in Fig. 9.

FIGURE 9

IDRA network approach



BR: base radio
BSC: base site controller
LR: location register
GW: gateway
XCDR: speech transcoder
NMU: network management unit
MS: mobile station

4 System specifications

Refer to Table 1.

4.1 Logical channels

The following logical channels are defined:

– broadcast control channel (BCCH),

– common control channel (CCCH),

– associated control channel (ACCH),

– traffic channel (TCH),

– packet channel (PCH),

– slot information channel (SICH),

– random access channel (RACH),

– temporary control channel (TCCH),

– dedicated control channel (DCCH),

– radio control channel (RCCH).

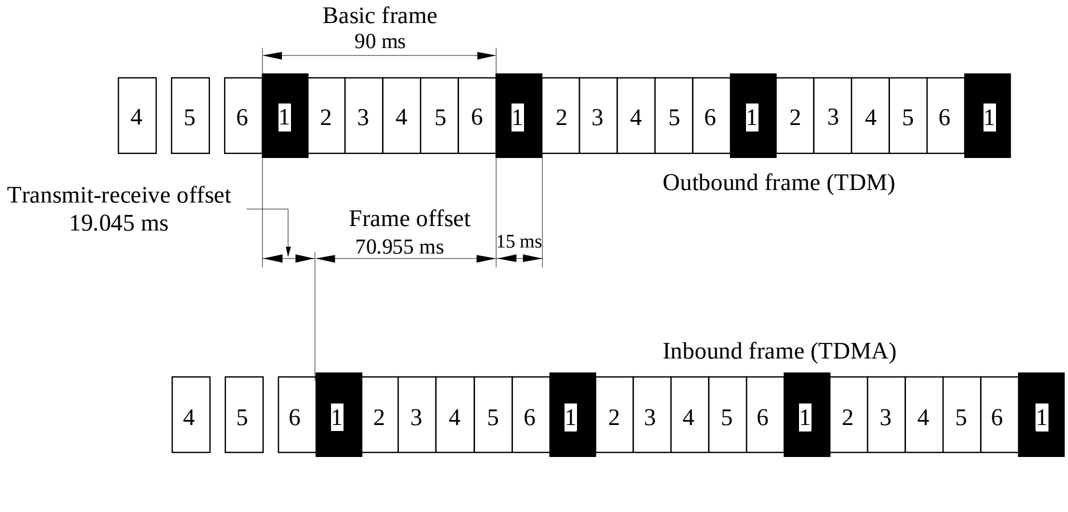
4.2 TDMA frame structure

The basic frame is prescribed at six slots. The corresponding outbound and inbound frames make a pair. The frame offset, the outbound frame delay relative to the inbound frame, is 70.955 ms.

Conversely, the inbound frame delay, relative to the outbound frame (referred to as transmit-receive offset) can be calculated by the formula, (frame length)-(frame offset). Accordingly, transmit-receive offset is 19.045 ms. Figure 10 shows the general frame structure of the IDRA System.

FIGURE 10

IDRA TDMA frame structure



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4.3 Traffic channels

4.3.1 Speech traffic channels

The speech codec for voice communication services, including error correction and error detection mechanisms, has not been defined in the Association of Radio Industries and Businesses (ARIB) standard [1995]. However, the ARIB defined the frame structure of the voice channel to have 90 ms speech frames comprised of a total of 672 bits, including the additional bits for error correction. The system operator is free to choose the codec bit rate and error control scheme up to a total of 7.467 kbit/s.

4.3.2 Data traffic channels

A circuit data protocol is available for circuit data applications. The circuit-switched data protocol offers a full-duplex packet stream.

Packet data transmission is a planned feature of the IDRA. Airtime for packet transmission is dynamically allocated to the user devices according to their instantaneous communication need. The packet data protocol is planned to allow an auto-bauding capability so that different net burst transfer rates will be available to the user.

5 Operational characteristics

5.1 Location updating and roaming

5.1.1 Roaming

Roaming, which enables automatic switching of the infrastructure when a mobile station moves into a different location area, is possible between IDRA systems.

5.1.2 Location updating (option)

The IDRA system tracks an individual mobile station location to allow the mobile station to move freely throughout the system and receive or originate calls. Location areas, which are composed of one or more sites, are used to define geographical areas in the system. The mobile terminal must report its position each time it moves between location areas.

5.1.3 Handover (option)

The IDRA supports handover between zones and between systems. Handover allows for maintaining the link quality for user connections, minimizing interference, and managing traffic distributions.

5.2 Communication protocols

The communication protocols of the IDRA are layered according to the OSI model as shown in Fig. 11. However, it does not strictly match the standard model because press-to-talk communication is the basic operation, so a protocol providing a faster response is required.

The layers are subdivided as shown below:

– Layer 1: this layer specifies the physical structure of the channel (basic slot format, subslot format, etc.);

– Layer 2: this layer specifies communication control between the mobile station and the infrastructure such as random access control, polling control and time alignment control;

– Layer 3: this layer performs as a network layer and is divided into the following three sublayers:

  – connection management

    call set-up, call management/control, call clear down, etc;

  – mobility management (option)

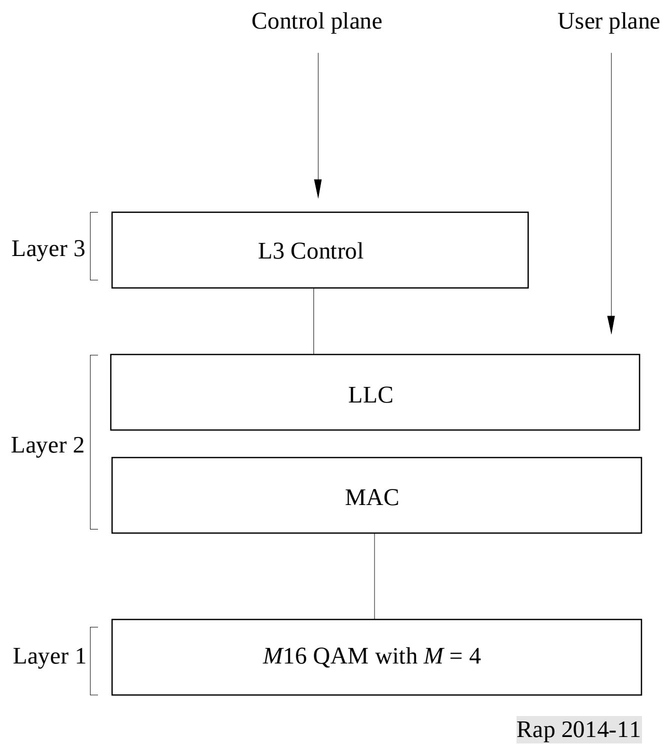
    location registration, authentication, etc;

  – radio resource management (option)

    cell selection, channel assignment, handover, etc.

FIGURE 11

Protocol stack



5.3 Call set-up

5.3.1 Broadcast phase

The base station is continuously transmitting the following control and identification information:

– control channel information (e.g. physical structures of control channel for system identification and call set-up);

– system information (e.g. types of communication services and protocols which IDRA can provide);

– restriction information (e.g. types of communication services and protocols which IDRA now restricts);

– system structure information (e.g. location area and target cell information; optional).

5.3.2 Set-up

Necessary information is exchanged between the infrastructure and mobile station. The elements of the mobile procedures are:

– wake up (if in battery saving mode);

– receive the control channel;

– exchange the necessary information for call set-up;

– receive the traffic channel;

– transfer traffic information (voice or data);

– registration and authentication (option).

5.3.3 Call clear down

The following six procedures are available for call clear down:

– the mobile station and the infrastructure clear down when the time limit for communication is reached;

– the infrastructure clears down when the time limit for no response is reached;

– the infrastructure clears down when the time limit for no communication is reached;

– the mobile station clears down on detection of poor traffic conditions;

– clear down occurs on demand of disconnection from a mobile terminal, a fixed terminal, or a telephone on the PSTN;

– disconnection from the base.

5.4 Connection restoration (option)

– The mobile station knows where to monitor from information on (BCCH).

– The mobile station continuously measures parameters during call:

  – $C/(I + N)$,

  – RSSI,

  – primary serving channel.

– When the mobile station detects trouble on primary server:

  – the mobile station sends in parameter samples,

  – base evaluates potential servers,

  – base assigns new server,

  – the mobile station switches to new server.

BIBLIOGRAPHY

ARIB [November, 1995] RCR STD-32A. Integrated Dispatch Radio System. Association of Radio Industries and Businesses. Japan.

APPENDIX 4

TO ANNEX 1

General description of the DIMRS system

1 Introduction

The DIMRS, using new digital technology, fully integrates multiple services including, radio-telephone, paging and dispatch communications into a single infrastructure. DIMRS caters both to users who require an integrated system with enhanced services as well as users who cannot justify the use of a separate pager, cellular phone, dispatch radio and data modem.

2 System services

The services provided are:

2.1 Dispatch

– Group call.
– Private call.
– Call alert.
– Push-to-talk (PTT) ID.
– Landline to individual private call.
– Selective “area” calling.

2.2 Interconnect

– Interconnect with other switched networks.
– Full-duplex operation.
– Handover.
– Custom calling features (call waiting, three party calling, dual tone multi-frequency access to services, call forwarding, busy transfer, no answer transfer, call restrictions, access to information services).

2.3 Roaming services

– Intra-system roaming.
– Inter-system roaming.
– System-to-system handover.
– Inter-system calling features.
– Registration/de-registration.

2.4 Message paging

– Paging.
– Short message service.

2.5 Data communications

– Circuit mode (protected).
– Packet mode:
  – with handshake;
  – without handshake.

3 Authentication mechanism

DIMRS provides system security control with an authentication mechanism which may be invoked prior to any chargeable service initiation.

Authentication is used to verify that a mobile station is registered in the system. It may take place during the location updating, mobile origination, mobile termination, supplementary service, and short message service procedures for an interconnect subscriber. For a dispatch only subscriber, authentication will occur during power-up or when a subscriber crosses certain system boundaries such as into another service provider's area.

Each mobile station user is assigned an individual ID, referred to as an international mobile station identity (IMSI), which is understood by both the dispatch and interconnect call processing programmes. The system will validate the user IMSI each time an interconnect call processing procedure is performed.

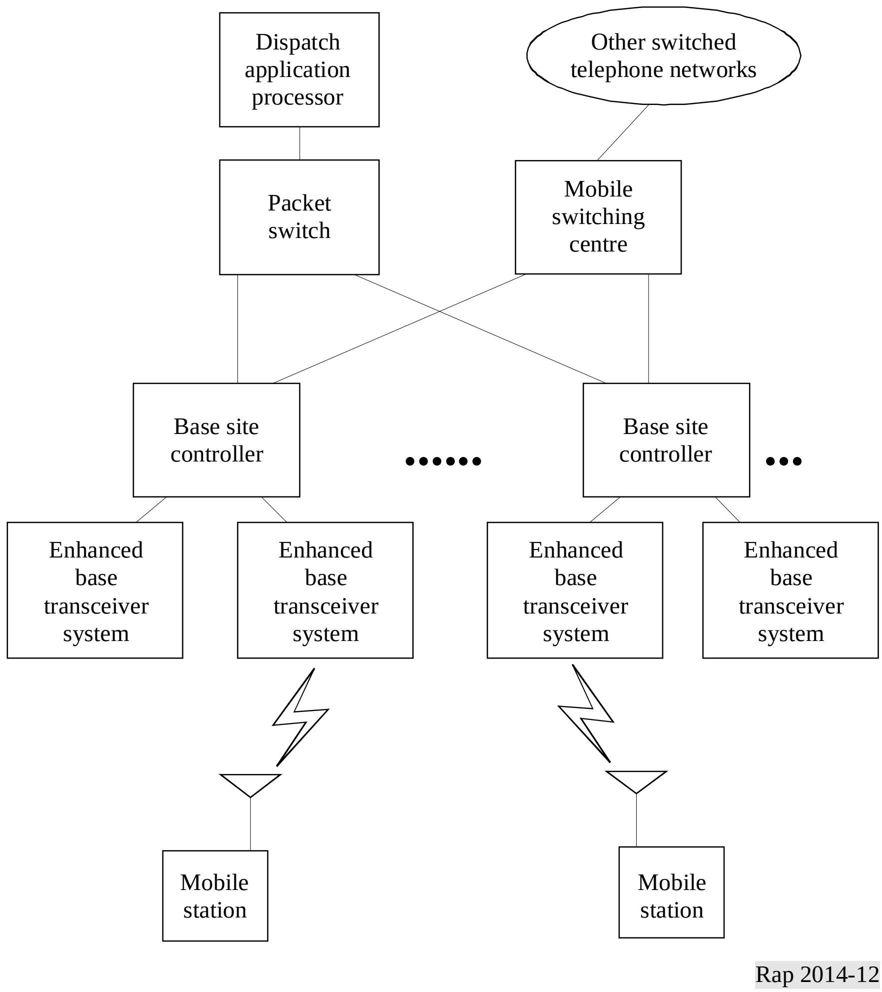
For interconnect call processing, a temporary ID, referred to as the temporary mobile station identifier (TMSI), is used to identify the mobile station to the system. This minimizes broadcasting the IMSI over the air.

4 Overview of the system

The network approach showing the major architectural components of the system is shown in Fig. 12.

FIGURE 12

DIMRS network approach



5 System specifications

Refer to Table 1.

5.1 Logical channels

The following logical channels are defined:

5.1.1 Slot information channel (SICH)

A broadcast channel used for transmission of slot control information.

5.1.2 Primary control channel (PCCH) comprising:

– broadcast control channel (BCCH).

– common control channel (CCCH).

– random access channel (RACH).

The PCCH is a multiple access channel used for layer 3 control signalling between the fixed network equipment and the mobile stations. Each cell has one PCCH.

5.1.3 Temporary control channel (TCCH)

A temporarily allocated multiple access channel used to provide a means for inbound random access on a channel which is normally reserved access.

5.1.4 Dedicated control channel

Supports more extended layer 3 control procedures which would be inefficient if conducted on the PCCH.

5.1.5 Associated control channel (ACCH)

The ACCH provides a signalling path on the traffic channel. The main application of the ACCH is to support whatever layer 3 control signalling is required for traffic channel supervision. Bandwidth for the ACCH is obtained by dynamically stealing on the TCH.

5.1.6 Traffic channel (TCH)

– Circuit-switched channels

These channels are used to transport voice or circuit-switched data traffic.

– Packet-switched channel (PCH)

These channels will support packet-switched user data communications.

5.2 TDMA frame structure

The DIMRS data stream structure, shown in Fig. 13, has six slots per TDMA cycle. A frame structure is further superimposed on this cyclical structure. Inbound and outbound frames consist of 30 240 slots, each 15 ms long. The duration of the frame is 453.6 s.

A hyperframe structure is also defined, in addition to the frame structure. A hyperframe comprises 256 frames, thus, it contains a total of 7 741 440 slots and has a duration of 116 121.6 s (32 h, 15 min, 21.6 s). The large number of slots in the hyperframe is useful for implementing encryption.

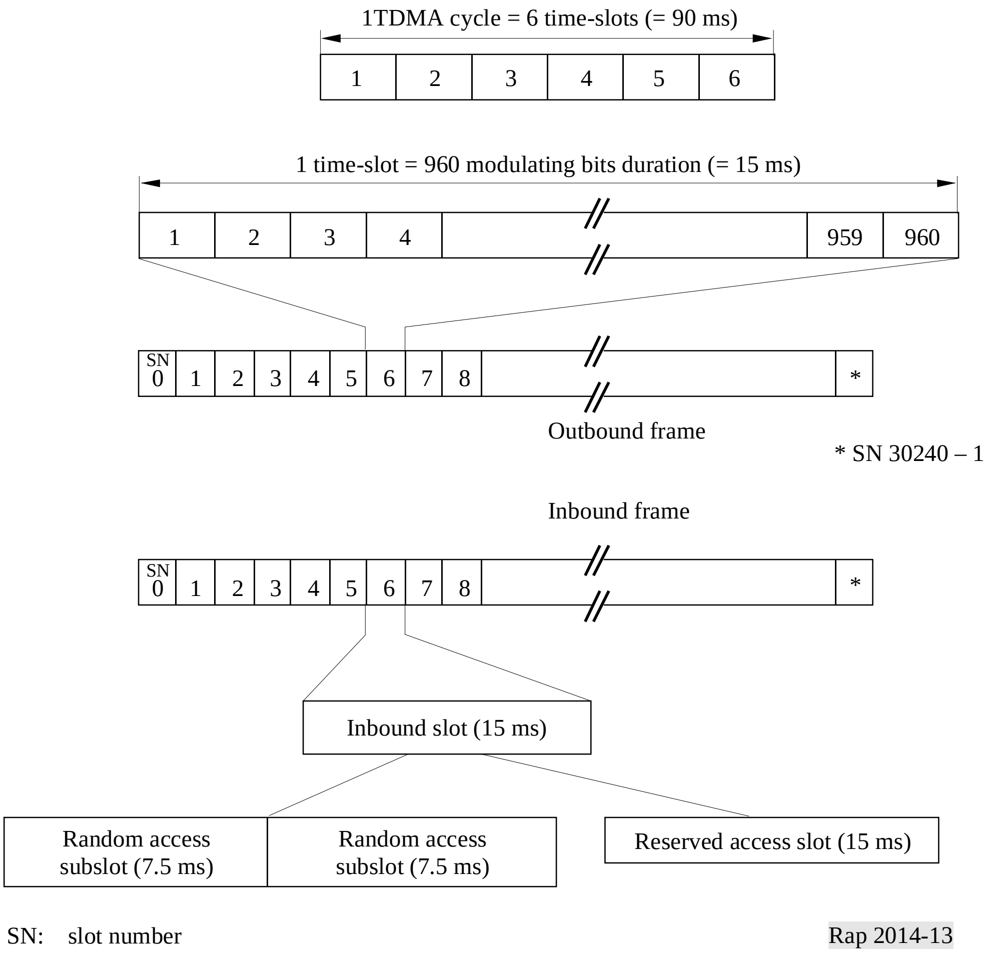
5.3 Traffic channels

5.3.1 Speech traffic channels

The speech coding technology used is VSELP. Acceptable quality is maintained at channel BER as high as 4-5% in Rayleigh fading, or 10% in static conditions. Error correction is realized through a variable rate strategy whereby the uncoded and trellis-coded 16 QAM modulations are applied selectively to speech bits in accordance with their perceptual significance.

FIGURE 13

DIMRS frame structure



5.3.2 Data traffic channels

A circuit data protocol is available for circuit data applications such as laptop or palmtop computers, fax and image processing, and file transfer applications. The circuit-switched data protocol offers a full-duplex packet stream with a single rate of 7.2 kbit/s (six users per RF carrier). This includes forward error correction coding and selective re-transmission of non-correctable blocks.

Allowance has been made for packet data in DIMRS. Bandwidth will be dynamically adjusted to accommodate demand.

6 Operational characteristics

6.1 Location updating and roaming

6.1.1 Intra-system roaming

DIMRS tracks a unit's location so that calls can be routed to it. Both the dispatch and interconnect calls require the current location of a mobile station. The DIMRS system will utilize a location area. The unique identity of a location area is conveyed via cyclic broadcast on the primary control channel. The mobile monitors the preferred primary control channel and issues a location update request when it finds its location area is no longer supported. The location update request is sent to the VLR that holds the current location of mobile station units operating in that system.

6.1.2 Inter-system roaming

The ability to travel freely throughout the single service area and originate or receive calls without regard to current location can be extended to allow mobile stations to travel from one service area to another. A single service area can consist of multiple cells covering a large geographical area (e.g. entire metropolitan area). Alternatively, it may be necessary or desirable to subdivide it into multiple service areas, because of RF coverage gaps, management, or regulatory issues.

6.1.3 System-to-system handover

DIMRS supports handover between cells, between location areas, and between systems. Handover allows for maintaining the link quality for user connections, minimizing interference, and managing traffic distributions. The inter-system handover is facilitated in the mobile station's switch.

6.1.4 Inter-system calling features

The mobile station's in the DIMRS can achieve inter-operability between any system configuration.

6.2 Communication protocols

The communication protocols are layered according to the OSI reference model.

6.3 Operation

6.3.1 Dispatch call operation

Step 1: A dispatch call is requested via PTT activation.

The call request packet is routed to the dispatch application processor (DAP).

The DAP recognizes the mobile station unit's group affiliation and tracks the group members' current location area.

Step 2: The DAP sends location requests to each group member's location area to obtain current sector/cell location.

Step 3: The mobile station units in the group respond with current sector/cell location.

Step 4: The DAP instructs the originating EBTS with packet routing information for all group members.

Step 5: Call voice packets are received by the packet duplicator, replicated, and distributed to the group's end nodes.

6.3.2 Telephone interconnect operation

6.3.2.1 Call initiation – Inbound

Step 1: Random access procedure (RAP) on primary control channel.

Step 2: Get dedicated control channel assigned.

Step 3: Authentication (optional).

Step 4: Call setup transaction.

Step 5: Get assigned to a traffic channel.

Step 6: Talk.

Step 7: Call termination request on associated control channel.

Step 8: Channel released.

6.3.2.2 Call initiation – Outbound

Page mobile station on primary control channel.

APPENDIX 5

TO ANNEX 1

General description of the TETRAPOL system

TETRAPOL is providing a spectrum efficient, digital narrow-band FDMA, voice and data system for dispatch traffic, which has been developed and validated, and which is operational since 1992. The TETRAPOL land mobile radio specification was defined by the TETRAPOL Forum to provide specifications to the most demanding PMR segment: the public safety and then extended to professional users.

The TETRAPOL applicable band is VHF and UHF, below 1 GHz, with a channel spacing of 12.5 kHz. An evolution to 6.25 kHz spacing is forecast. The access mode is FDMA, with a fully digital constant amplitude modulation GMSK.

The TETRAPOL specifications apply to three different modes:

– network mode where the mobile is under the coverage and the control of the infrastructure. trunking mode and open channel mode are included;

– direct mode where the mobile directly communicates with the other terminal;

– repeater mode where the mobile communicates with the other terminal through a repeater.

Any combination of these modes can be achieved in the TETRAPOL networks.

1 TETRAPOL model and functional groups

A TETRAPOL system is the physical implementation of interconnected elements called subsystems. Physical elements are mapped to functional groups and the interfaces are defined at the reference points (as defined by ITU).

Figures 14, 15 and 16 represent the TETRAPOL models for network, direct and repeater mode with the different network subsystems and the reference points. The subsystems corresponding to functional groups in the TETRAPOL model, which are concerned by the external open interfaces are the following:

– **Radio terminal (RT)**

The RT is the mobile termination unit (MTU) connected to the network through a radio link.

– **Line connected terminal (LCT)**

The LCT is a terminal connected by a physical connection line locally or remotely to the network.

– **User data terminal (UDT)**

The UDT is a data terminal (terminal equipment TE) connected to the RT and used for data services.

– **Switching and management infrastructure (SwMI)**

This is the TETRAPOL network itself split into two subsystems the base station (BS) and the radio switching unit (RSW).

– **Dispatch center (DC)**

This is the dispatch centre with a dispatch centre server function and a dispatch position switch function.

– **Network management centre (NMC)**

This is the management centre of different networks for operation and maintenance.

– **Message transfer agent MTA X.400**

This is the X.400 message handling switch connected to a private or public X.25 network, acting as a messaging server.

– **External data terminal (EDT)**

This is an EDT, connected through a private or public X.25 network, acting as a data communication server, data base gateway, private subscriber message base.

– **Radio terminal simulator**

This is the BS Type approval simulator including data.

– **BS simulator**

This the RT type approval simulator including the UDT, RT and SIM simulators.

– **Subscriber identity module (SIM)**

This is the removable module carrying subscriber information and security algorithms.

– **Independent digital repeater – (IDR)**

This is the equipment used in repeater mode for extending the coverage between two mobiles, irrespective of the SwMI.

– **Stand alone dispatch position (SADP)**

This is the one position terminal for dispatch.

– **Gateways**

Gateways allow connection to other systems like PMR systems (GSM, TETRA...), TCP/IP, PDN, ISDN, PSTN, private automatic branch exchange (PABX).

– **Key management centre (KMC)**

This is the centre managing the security keys.

The internal subsystems of the TETRAPOL network SwMI are:

– **Base station (BS)**

This is the infrastructure equipment with which the RT communicates through the air interface. The BS can be split into the BTS and the BSC.

Communication through a line is done via the LABS.

– **Radio switch (RSW)**

The RSW subsystem is the switching part of the TETRAPOL network.

– **Base network (BN)**

This is the elementary network within the SwMI.

2 Reference points

This section defines the connection reference points (CRPs) as shown on Figs. 14, 15 and 16. They correspond to the open interfaces in TETRAPOL.

R1 is the reference point between the UDT and the RT.

R2 is the reference point between the UDT and LCT.

R3 is the reference point corresponding to the radio air interface between the RT and the BS.

R4 is the reference point between the LCT and the network SwMI.

R5 is the reference point between the NMC and the network.

R6 is the reference point between the DC and network.

R7 is the reference point corresponding to the PABX gateway.

R8 is the reference point between the MTA X.400 and the network.

R9 is the reference point corresponding to the inter system interface (ISI) between two TETRAPOL networks.

R10 is the reference point between the EDT and the network.

R11 is the reference point corresponding to the inter working unit IWU with other PMR systems.

R12 is the reference point corresponding to the BS - RSW interface.

R13 is the reference point corresponding to the PSTN gateway.

R14 is the reference point corresponding to the ISDN gateway.

R15 is the reference point corresponding to the TCP/IP interface.

R16 is the reference point corresponding to the X.25/PDN gateway.

R17 is the reference point corresponding to the SADP interface.

R18 is the reference point corresponding to the interface between SIM and RT.

R19 is the reference point corresponding to the interface between the KMC and network.

R20 is the reference point between RT (Ud).

R30 is the reference point between the repeater and RT.

FIGURE 14

Network mode model and CRPs

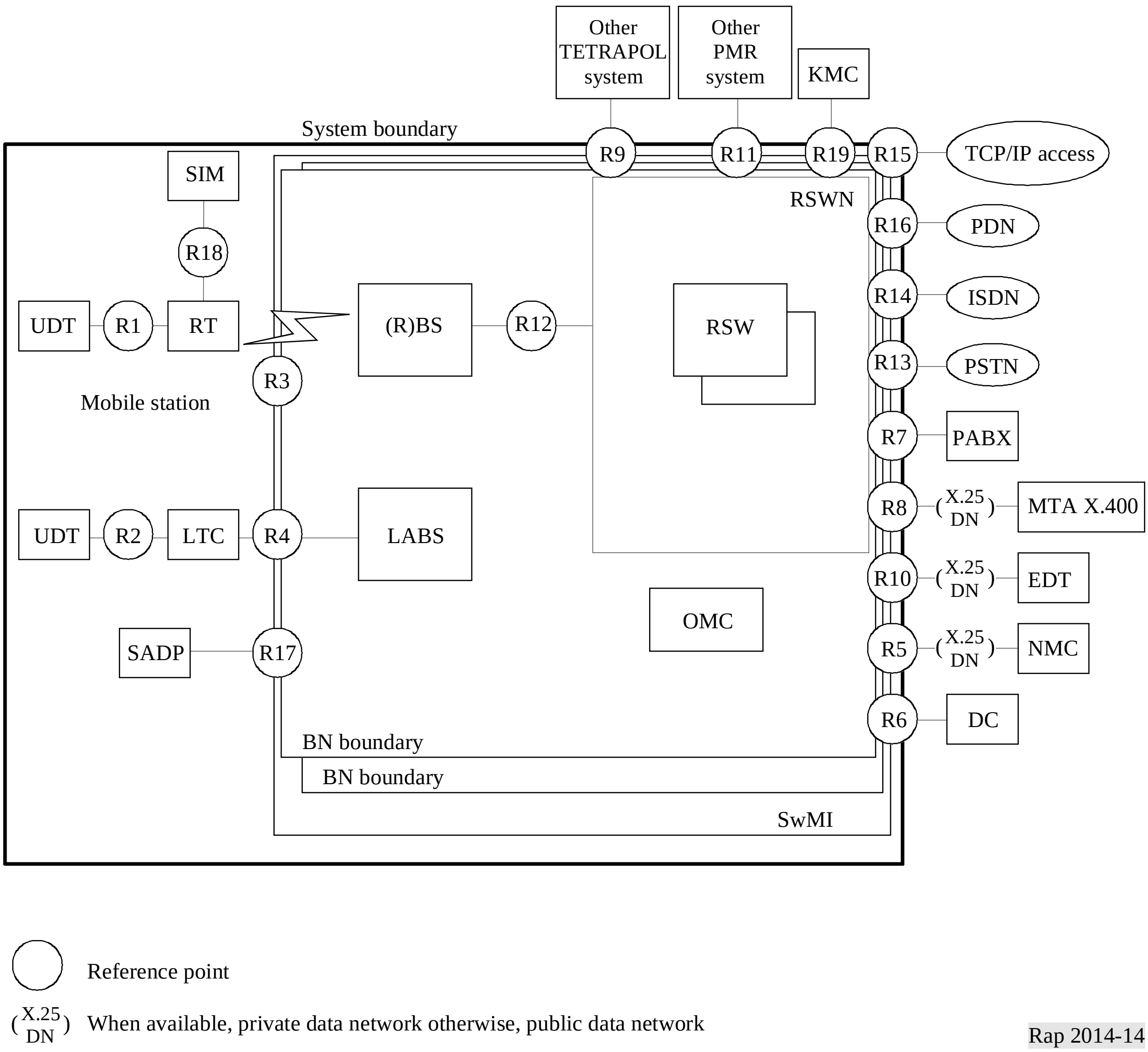


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FIGURE 15

Direct mode reference points

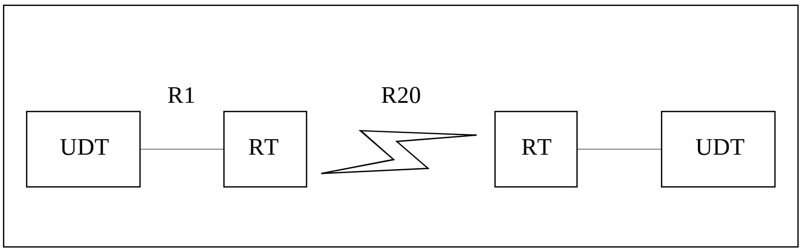

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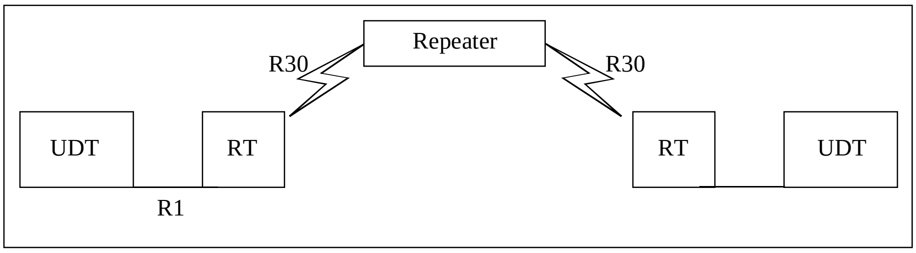
FIGURE 16

Repeater mode reference points



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3 Air interface protocol

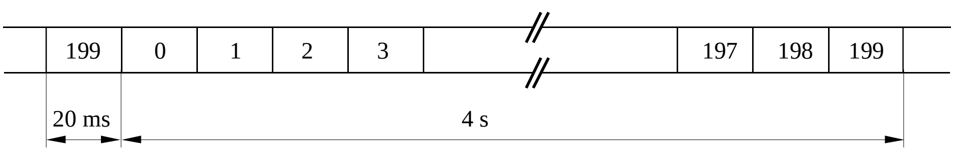
The radio transmission is based on a 160 bits frame, lasting 20 ms, with 8 kbit/s gross throughput physical channels.

A radio channel is one frequency downlink channel from BS to terminal and one frequency uplink channel from terminal to BS, the data rate is 8 kbit/s per channel.

The logical channels are organized from a superframe of 200 consecutive blocks (Fig. 17) lasting 4s. Before transmission information is coded according to a coding scheme depending of the type of burst, this adds redundancy in order to protect information.

FIGURE 17

The superframe



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There are four types of bursts: speech, data, access and interruption bursts.

The logical channels of the air interface are the following (Figs. 18 and 19):

- control channels (CCH) which are a multiplex of different logical channels allocated to the function performed: access grant, signalling and data, broadcast, paging. The logical channels are mapped on physical channels depending on the burst numbers in the superframe:
  - random access channel (RACH) used by the terminal for initial access;
  - dynamic access channel (DACH) used by the terminal for group activation, status transmission;
  - signalling and data channel (SDCH) used by the user data terminal UDT and the network;
  - broadcast control channel (BCCH);
  - response channel (RCH) used for random access acknowledgement;
  - paging channel (PCH);
  - stealing channel for signalling (SCH) and transmitter interruption SCH_TE;
- Traffic channels (TCH) used to carry speech or data are:
  - voice or data channel (TCH).

FIGURE 18

The control channels

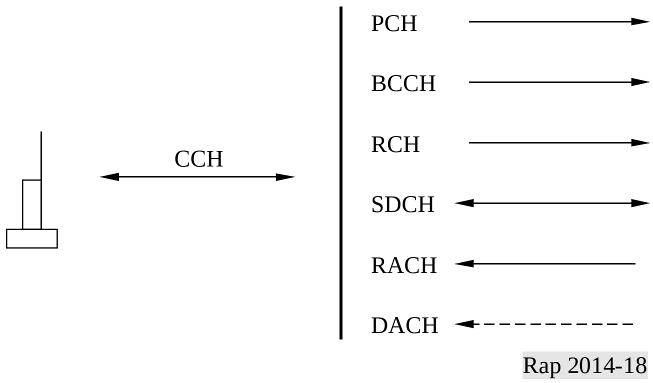
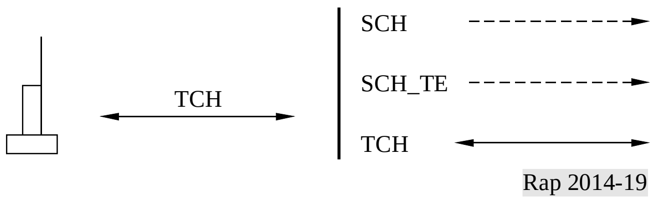


FIGURE 19

The traffic channels



4 Speech codec

Coding is done end to end and as a consequence the codec is only required in the mobile and in the gateway and is not necessary in the infrastructure. This allows, combined with self synchronized end-to-end encryption, simpler coding, faster response time and no echo. Since no transcoding is applied for mobile-to-mobile communication, speech quality is optimized.

Speech is digitized at 6 kbit/s net rate and transmitted on a 8 kbits traffic channel.

The speech frame duration of 20 ms corresponds to 120 bits. The coding technique used is RPCELP type, based on analysis by synthesis code excited approach with regular pulse codes. Channel coding is used for protection against transmission errors.

Used in half duplex mode the speech codec does not require specific acoustic processing as echo cancellation.

Speech quality measures have been performed as well as complexity calculations, as controlled by external laboratories. The codec meets the requirements of quality, complexity, delay, documentation and IPR information required.

A complete documentation is available on the speech codec algorithm including test sequences ensuring unambiguous description and bit exact validation of implementation.

In particular very good performance under specific operating conditions have been checked, like:

– noisy environment,
– double talk conditions,
– transmission of tones.

The low complexity of speech coding algorithm allows implementation on a 20 Mips DSP performing radio signal processing of the receiver.

5 Services and network procedures

5.1 Introduction

This section describes the services and the features included in the TETRAPOL system.

5.2 Services

Services mean telecom services which users can control from the terminals. They could be described in terms of bearer services, teleservices and supplementary services.

5.2.1 Speech services

Speech services are listed and described below:

– broadcast call,
– emergency call,
– duplex call – group call,
– individual call,
– multiple call,
– open channel and emergency open channel,
– PABX call,
– talk group.

5.2.2 Data Services

Data services are listed and described below:

– access to TCP/IP,
– broadcast without acknowledgement,
– circuit mode,
– connectionless packet mode,
– external application messaging,
– inter personal messaging (X.400),
– fast messaging,
– paging,
– short data message including status,
– X.25 packet mode.

5.2.3 Security services

For each mode security services have been designed to counter threats like:

– interception of control signals,
– masquerading another TETRAPOL infrastructure,
– masquerading another user,
– jamming,
– detection of control channel,
– replay,
– re-use of user identity,
– terminal theft,
– traffic analysis,
– unauthorised access,
– unauthorized interception of voice and data signals anywhere in the system.

The security services are listed as:

– prevention and detection of intrusion,
– end to end encryption,
– identity control of terminals,
– login-logout,
– mutual authentication (network-terminal),
– secured key management (over the air),
– security fall back modes,
– temporary identity,
– terminal disabling,
– total inhibition of terminal,
– access control,
– signalling protection,
– security partitioning.

5.2.4 Supplementary services

The applicable supplementary services are described and listed below:

– access priority,
– adaptative area selection,
– ambiance listening,
– area selection,
– automatic call back,
– call completion to busy subscriber,
– call barring,
– call authorized by dispatcher,
– call forwarding,
– calling line identification,
– call me back,
– call waiting,
– call transfer,
– direct call watch,

– discreet listening,
– DTMF,
– dynamic group number assignment,
– include call,
– intrusion,
– interconnect access,
– late entry,
– listening restriction,
– list search call,
– pre-emptive priority,
– priority,
– priority scanning,
– short number addressing,
– shortened numbering,
– stroke signal,
– talking party identification.

5.3 Applications

The following applications are supported in TETRAPOL:

– access to database,
– fax,
– file transfer,
– GPS,
– still video image.

5.4 Network procedures

Network procedures are features offered by the network but which the user cannot command from the terminals. They are automatically processed or they are controlled by network managers or by dispatchers.

– attach-detach,
– call duration limitation,
– call re-establishment,
– call recording,
– call retention,
– dynamic regrouping,
– group merging,
– migration,
– presence check,
– power saving mode,
– push to talk priority,
– roaming,
– terminal location (registration),
– transmitter power control,
– user profile management.

6 Abbreviations

A/I	Air interface
BS	Base station
CCH	Control channel
Codec	Voice coding decoding
CRP	Connection reference point
DB	Database
DM	Direct mode
DP	Dispatch position
DC	Dispatch position centre
EDT	External data unit
IDR	Independent digital repeater
ISI	Inter system interface
KMC	Key management centre
LCT	Line connected terminal
LS	Line station
MTA X.400	Message transfer agent X.400
MTU	Mobile termination unit
NMC	Network management centre
OMC	Operation and maintenance centre
PABX	Private automatic branch exchange
(P)DN	(Public) data network
RP	Repeater
PSTN	Public switched network
Ri	Reference point
RT	Radio terminal
RSW	Radio switch
SADP	Stand alone dispatch position
SIM	Subscriber identity module
ST	System terminal
SwMI	Switching and management infrastructure
TE	Terminal equipment
TCP/IP	Transmission control protocol/Internet protocol
UDT	Uuser data terminal

7 Document references

The TETRAPOL specification is a multipart document which consists of the following parts:

PAS001-1 General network design

This part contains the reference model, the functional specifications, the protocol architecture and the principles of the main mechanisms.

PAS001-2 Radio air interface

This part describes the radio channel coding, multiplexing, modulation.

PAS001-3 Air interface protocol

This part contains the air interface protocol description including the protocol data units PDUs.

PAS001-4 Gateway to MTA X.400

This part contains the gateway protocol to X.400 messaging.

PAS001-5 Interface to dispatch centre

This part contains the interface to the dispatch centre.

PAS001-6 Line connected terminal interface

This part describes the interface protocol between the network and the line connected terminal.

PAS001-7 Codec

This part contains the exact bit description of the codec and the relevant tests.

PAS001-8 Radio conformance tests

This part contains the mobile and base station radio conformance tests conforming to ETS 300-113 (22).

PAS001-9 Protocol conformance tests

This part describes the air interface protocol conformance tests.

PAS001-10 Inter system interface

This part describes the inter system interface protocol between two TETRAPOL systems.

PAS001-11 Gateway to external networks

This part describes the gateways to fixed networks X.25, RNIS, PSTN and to PABX.

PAS001-12 Network management centre interface

This part contains the protocol description of the network management centre (NMC) interface.

PAS001-13 User data terminal and radio terminal interface

This part contains the protocol description of the user data terminal (UDT) (terminal equipment (TE)) to the radio terminal (mobile termination unit (MTU)) interface.

PAS001-14 Mobile station and base station simulators

This part describes the simulators of radio terminal and base station (BS). These simulators include the RT simulator for the UDT and the UDT simulator for the RT. The EDT simulator is also included, with the RSW simulator for data.

PAS001-15 Gateway to external data terminal (EDT)

This part describes the gateway to EDT in messaging application.

PAS001-16 Security

This part describes the TETRAPOL security mechanisms and SIM interface but is available only under controlled disclosure procedure.

TTR1 Guide to TETRAPOL features

This part is a designer guide to give information on characteristics and choices in the system.

PAS001-18 Base station (BS) to the radio switch (RSW) interface

This part describes the protocol between the BS and the switch RSW.

PAS001-19 Stand alone dispatch position interface

APPENDIX 6

TO ANNEX 1

General Description of the EDACS system

1 Introduction

The EDACS is an advanced two-way trunked radio system operating on 25 kHz or 12.5 kHz channelization in VHF, UHF, 800 MHz and 900 MHz frequency bands. The development of specifications based on EDACS technology provide backward compatibility and interoperability with the large existing base of EDACS equipment and systems, globally.

The EDACS specification provides features and functions intended on satisfying requirements for public safety, industry, utility and commercial users.

2 Communication modes

The following communication modes are supported:

– **digital voice**: all call types, group, group emergency, individual and system all call, are supported;

– **digital data**: individual calls are supported;

– **encryption**: encrypting the already digitized voice provides very secure communications even against sophisticated eavesdroppers. The advantage provided by encryption is very high security with no loss of audio quality. Encryption via the DES algorithm is optional;

– **analogue**: analogue FM per 16K0F3E standard signalling in accordance with TIA-603 for mutual aid capability

3 System interfaces

The Fig. 20 represents the general system model for EDACS. This figure also identifies a total of 7 system interfaces that will be defined by the EDACS Standard. These are designated Um, A, Ec, En, Et, Ed and G.

3.1 Digital air interface

The digital air interface, Um, is required for every EDACS implementation. This interface defines all of the digital signalling that is required for communication between the base repeaters and the terminals (portable and mobile radios). One channel bit rate and modulation technique are used for all voice and data communications and, for single-channel operation, control, voice, and data features can be integrated into a common channel.

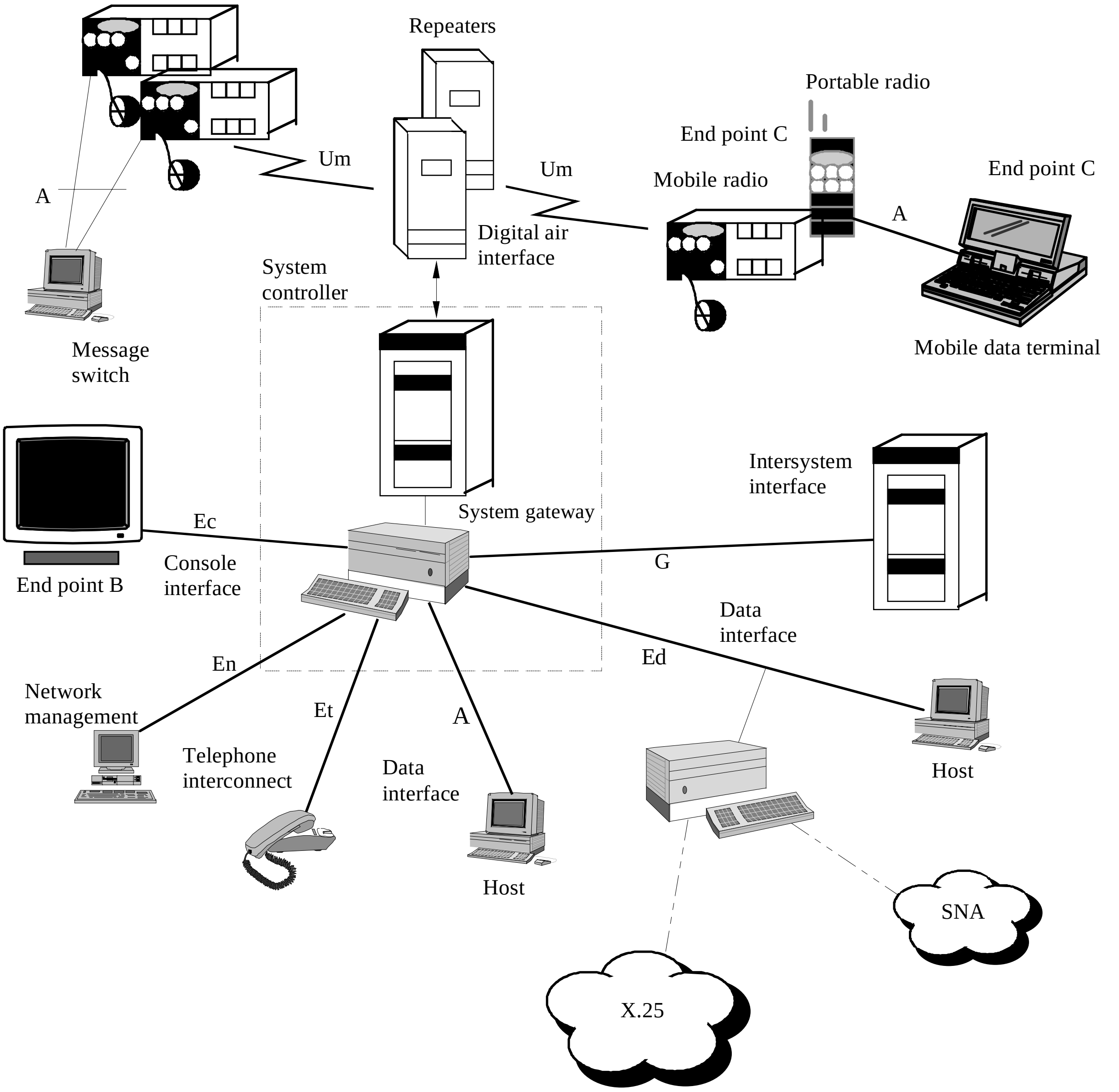
3.2 Mobile data terminal interface

EDACS terminals may support a port through which laptops, terminals or other terminal unit peripherals may be connected. This interface, A, allows communication between a terminal unit and a peripheral.

3.3 Console interface

The interface between a system controller and a console unit is the console interface, Ec. This interface provides for control of certain system functions and features via the console unit.

FIGURE 20



SNA: short number addressing

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3.4 Network management interface

The interface between a system controller and a network management device is the network management interface, En. This interface provides for control of components of the system via the standard network management protocol (SNMP).

3.5 Telephone interconnect interface

The interface between a system controller and a telephone network is the telephone interconnect interface, Et. Either analogue or ISDN telephone interfaces are supported.

3.6 Data interface

The interface between a system controller and a computer network is called the data interface, Ed. This interface supports connection of the radio system to an established computer network via Internet protocol (IP).

3.7 Intersystem interface

Individual radio systems (subsystems) can be interconnected into larger systems via the intersystem interface, G. This interface will also permit systems of different frequency bands and technologies to be interconnected together. This interface supports ISDN.

4 Standardized features and services

A fundamental attribute in meeting the communication needs of today as well as in the future is the EDACS proven migration path. EDACS products and services are designed to be compatible with past, present and future technologies. As an Extended Life Technology™, EDACS continues to evolve to accommodate new features and services that are compatible with systems sold since 1987 as well as provide a migration plan to integrate this technology with future, spectrally efficient EDACS F-TDMA prism systems.

Mandatory features/services	Optional features/services	
Fast channel access	Encryption	Telephone interconnect
Automatic call sign	Dynamic regrouping	Simulselect
Transmit prompt tone	Patch	Advanced console features
Continuous channel updating	Console pre-empt	8 Priority levels
Late entry	Conventional failsoft	Recent user priority
Random retries	Alert tone disable	Dynamic transmission/message trunking
Convert to callee	Up to 16 system/groups	Management reporting
Out of range	SCAT	Call validation
Caller ID display	Power up system/group	Activity logging
Group scan	Failsoft display	Alarm subsystem
Call queueing	Radio enable/disable	
ESN	I-Call callback	

5 System specifications

5.1 General description

The EDACS system utilizes a digital modulation technique for all communications including control channel, digital voice and data modes. This is accomplished through binary modulation of a carrier frequency with two states via a non-return to zero (NRZ) signal. A premodulation Gaussian filter is used between the digital input signal and the modulator stage to reduce the carrier occupied bandwidth. The modulation technique is a form of binary frequency shift keying (FSK) known formally as GFSK. It is a continuous phase, binary FSK modulation with a Gaussian pulse-shaping function. Continuous phase means that phase continuity is maintained during the bit switching times and the FSK scheme is also known as CPFSK (continuous phase FSK).

5.2 Mobile data

All EDACS data systems are designed to be used as transparent data networks. The intent is to provide a fast access, fully integrated digital trunked radio platform that inherently supports the transfer of data between standard computer hardware. This open approach maximizes both the number and type of hardware and software sourcing options available to the EDACS customer. Mobile data terminal options range from traditional purpose built MDTs to standard MS-DOS pentop, notebook or laptop PCs. Existing host computers and networks are easily accessed through RDI protocol interface or the more ubiquitous IP optional packet-switching standard. Other protocols such as SNA and X.25 can be supported using external gateways. Applications can be supplied by a range of MDT vendors, PC application developers, IBM business partners or generated in-house with existing expertise.

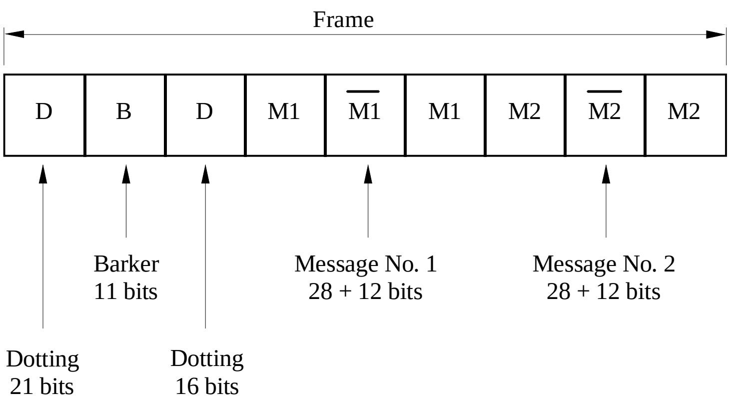
5.3 Trunking control channel

A control channel receives and transmits resource allocations, status and short data messages.

The trunking control channel structure consists of two main parts, the outbound control and inbound control.

The *outbound* control channel consists of frames of data, each beginning with 16 bits of dotting (5555H), followed by a 16-bit field containing an embedded 11-bit barker (712H). This is followed by 16 more bits of dotting, which is then followed by 2 messages. Each message is 40 bits, consisting of a 28-bit message along with an attached 12-bit BCH code. Each message is sent 3 times with the middle copy of each message inverted. Each *outbound* control channel frame constitutes a “slot” and is 30 ms long – the amount of time required to transmit 288 bits of data at 9 600 Bd rate.

FIGURE 21



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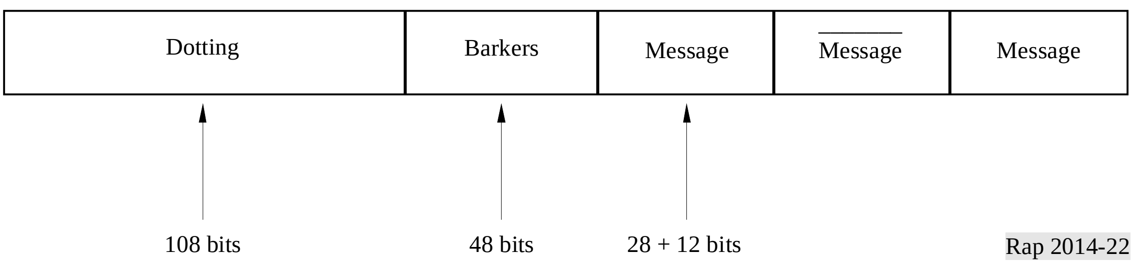
The *inbound* control channel frame, or slot information, consists of 108 bits of dotting for bit synchronization, 3 repeats of the 16-bit barker-like codeword (85B3H) for word synchronization, and then 3 repeats of the 28 bits of data and the attached 12-bit BCH codeword. As with all cases of repeated messages, the middle repeat is inverted.

FIGURE 22



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5.4 Working channel

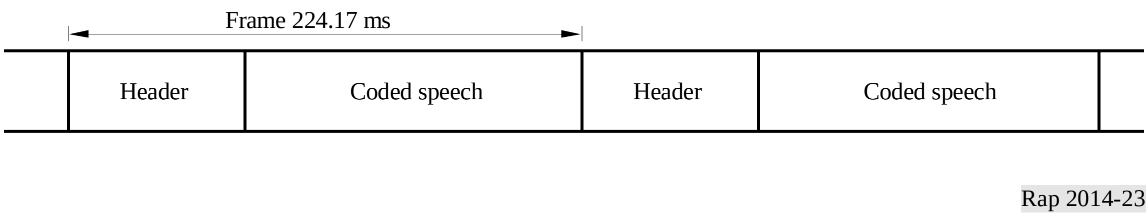
A working channel is assigned on the basis of a request from the control channel. This request is processed and a working channel is assigned. When the communication is first initiated there is high-speed handshaking on the working channel. Following the initial handshaking, the signalling mode changes. The working channel is then used for digital voice, encrypted voice, or data communications. Dispatching capabilities are also provided.

5.4.1 Operations

A variety of signalling functions must be performed on the inbound and outbound working channel. The inbound data stream consists of standard working channel information. The outbound working channel data stream contains embedded messages from the trunking controller.

After the working channel preamble is transmitted at the beginning of a communication, working channel frames are then transmitted. These data frames are about 224.17 ms long. The inbound working channel frame transmitted from the calling unit is shown in Fig. 23. Each data frame is preceded by a working channel frame header, containing information for the maintenance of cryptographic and data sync. The remainder of the frames consists of coded speech.

FIGURE 23



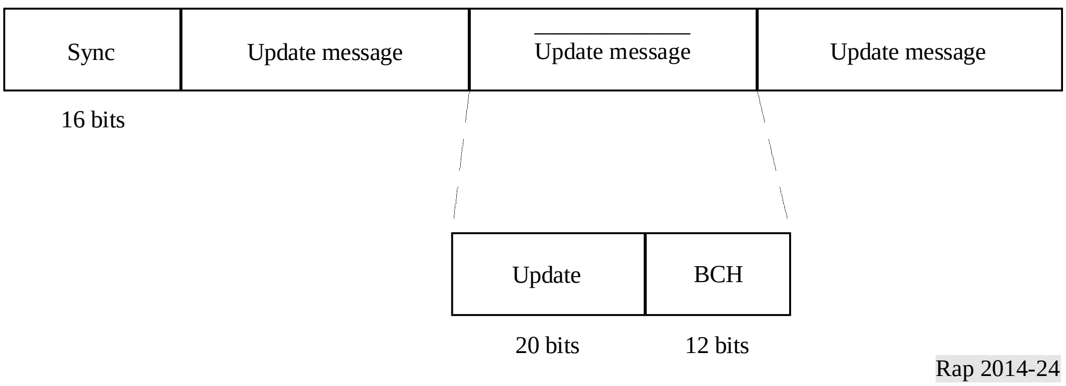
The contents of the each frame are:

Coded speech: 2 040 bits

Header: 112 bits

Outbound working channel signalling consists of working channel frames as described in Fig. 23. In addition to the working channel frames, low-speed subaudible signalling is embedded on the voice outbound working channel. The following format is used for updates during periods of silence and system hang-times.

FIGURE 24



6 References

TIA reference documents are available through Global Engineering, (Tel: +1 800 854 7179), and ECR documents are available from Ericsson Inc., (Tel: +1 804 528 7000).

Document number	Description
ECR 69	EDACS system and standards definition
ECR 69.1	EDACS system gateway specification
ECR 69.2	EDACS vocoder and encryption definition
ECR 69.3	EDACS digital signalling specification
ECR 69.3-1	EDACS call procedures
ECR 69.4	EDACS system conformance tests and procedures
TIA/EIA-603	Land mobile FM or PM communications equipment measurement and performance standards

APPENDIX 7

TO ANNEX 1

General description of an FHMA system

1 General

FHMA has been developed in Israel, where a test bed is operating for validation of system evolution. The prime incentive for developing FHMA has been spectral efficiency. The level of spectral efficiency achieved makes it a viable solution for PAMR/PMR services, even when the spectral assignment is extremely small (e.g. 30 frequencies of 25 kHz for unconstrained service coverage). FHMA systems are primarily focused on the public access mobile radio (PAMR) market, and trying to address challenges posed by commercial users. FHMA has been specified and developed to comply with the US Federal Communications Commission (FCC) regulations (e.g. Parts 90, 15, 68, 94).

2 FHMA technology

FHMA is primarily an advanced digital radio technique, which yields an optimal spectral-efficient mobile radio system. The underlying communication technique is a combination of TDMA (3:1) and of frequency hopping multiple access (a CDMA method). Powerful error protection codes, together with deep interleaving provide excellent protection against deteriorated channel conditions, either due to low received signal power or to interference.

Hopping parameters were selected for accomplishing the objective of high spectral efficiency for the mobile and to operate in mobile interfered channels. The robustness of the physical layer of the FHMA technology is utilized for capacity enhancement by implementing a cellular re-use pattern with a low frequency re-use factor. The system enables trading re-use for capacity and vice versa i.e. re-use of 1 with smaller capacity per topological unit or opt for a re-use of e.g. 3, with higher capacity for same topological unit (base station, sector). The FHMA air interface defines traffic channels and control channels (bi-directional), of which only traffic channels are hopping.

The Attachments describe the system:

Attachment 1 – FHMA services.

Attachment 2 – Procedures and interfaces.

Attachment 3 – Abbreviations and acronyms.

ATTACHMENT 1

TO APPENDIX 7

FHMA Services

The FHMA system has been developed primarily for PAMR users. The services selected are those that are required by the commercial community. Furthermore, special applications have been developed for specific users, especially data applications like embedded automatic vehicle location (AVL), and data dispatch (“Manifest”).

An effort was made in defining the services and applications such as to provide the community of the mobile fleets with all their communications and control needs by a single system. This includes voice telephony, voice dispatch (individual and group), data bearer services, and data specific applications (e.g. AVL, Manifest).

1 Offered services

1.1 Teleservices:

All means necessary to provide basic communications and applications (practically all 7 layers of the OSI standard) like:

– mobile to mobile telephony and dispatch (trunked) speech communications;

– mobile to group voice communications (trunked);

– selective access to services, including optional secure communications (primarily user-furnished algorithms);

– telephony communications between a mobile unit and PSTN;

– fax capabilities;

– data applications like data dispatch (to individuals and groups), and short messaging;

– 2-way paging;

– automatic vehicle location (GPS based).

1.2 Bearer services:

Packet mode data, connection and connection-less oriented, which provide:

– nominally 4.8 kbit/s protected data;

– 9.6 kbit/s unprotected data;

– 2.4 kbit/s (and 1.2 kbit/s) heavily protected data;

– multislot data, up to 28.8 kbit/s unprotected;

– multislot data, up to 14.4 kbit/s protected.

1.3 Supplementary services:

Services, which are extension to those presently offered, and which may be implemented for satisfying requirements typical to PMR.

2 Voice services

2.1 Telephony

Standard telephony	Full duplex operation Transcoding done only for calls involving PSTN subscribers	Comfort noise 4.4 kbit/s vocoder, optional 2.4, and 5.55 kbit/s

2.2 Group dispatch

Unacknowledged group call	Unacknowledged point to multipoint on single TCH with a single call owner at a time and a predefined broadcast group. Group call participants might roam between service areas. A special emergency group dispatch call is defined per fleet	500 ms PTT response time Short group number sent on the air
Acknowledged group call	Similar to unacknowledged group call yet the call owner may get a presence list during call initiation (and possibly later on). Session oriented with hang timer and in-band handshaking over the traffic channel	
Broadcast voice message	Unacknowledged one way point-to-multipoint call on single TCH initiated from MS or LS unit	

2.3 One to One dispatch (121)

121	Semi-duplex two way point-to-point operation. Session oriented with hang timer and in-band handshaking over the traffic channel. Switching controller (CC) solves contentions	500 ms call-setup

3 Data service

3.1 Packet mode connection-oriented data

Connection-oriented	Standard TCP/IP connection-oriented service	9.6 kbit/s unprotected 4.8 kbit/s nominal protected 2.4, 1.2 kbit/s heavy protection

3.2 Packet mode connection-less data

Connection-less	Standard UDP/IP protocol using shared channels (statistical multiplexing)	9.6 kbit/s unprotected 4.8 kbit/s nominal protected 2.4, 1.2 kbit/s heavy protection
	Direct Internet connectivity (packet handler integrated in the FHMA network)	

3.3 Circuit mode data services

Circuit data	Extended AT command set Character mode access to packet assembler/ disassembler (pad) (X.28/X.29)	9.6 kbit/s unprotected 4.8 kbit/s nominal protected 2.4, 1.2 kbit/s heavy protection
Protected FAX	Protected fax transmission using extended AT command set	4.8 to 14.4 kbit/s (3 slots)

3.4 Short message service

Short messages	Basic units of 96 bytes with practically unlimited message length (random access is paired with subsequent allocations) Point-to-point and point-to-multipoint	

3.5 High speed data

Data Up to 3 TDMA slots	Group and broadcast connections	Protected 14.4 kbit/s Unprotected 28.8 kbit/s

3.6 Network application services

FHMA provides the following network application services based on the standard TCP/IP services:

– *Special data messages (SDM)* – A store and forward messaging service provides subscribers with additional message handling services such as: individual (IDM) and group (GDM) messages, registered, special delivery messages. These services are all accessed through special communications APIs;

– *Modem-like (Hayes compatible) communication services (PCCA/AT)* that enable subscribers to use standard Modem communication commands (AT/PCCA);

– *AVL* – Fleet management based on GPS (Etak application on PC) running from subscriber unit (SU), PSTN or leased line access.

3.7 Supplementary services

CF	Call forward – unconditioned or conditioned (busy, no reply, not reachable)
CW	Call waiting – incoming call notification during connection
LE	Late entry – allow late comers to join a multipoint voice call
EC	Emergency fleet group call
FD	Fast dialing (numbers allocated per fleet)
CLI	Calling/called party identification presentation
CR	Call report – leave identity to non available called party for subsequent call back
TPI	Talking party indication – inform all party about the identity of the active party in a multipoint connection
LSC	List search call – distribute a call to the first available subscriber in a list of attendants
CAD	Call authorized by dispatcher – involve operator upon restricted access
SNA	Short number addressing – use short abbreviations
AS	Area select – establish a call to other party only if it is located inside a selected area
AP	Access priority – priority level used to allocate resources in congested networks
PC	Priority call – give preference in resource allocation
CH	Call hold – interrupt ongoing call but keep the resources engaged
CCBS	Call completion to busy subscriber – attempt to complete the call later
ToC	Transfer of control – transfer ownership of a multipoint call
PPC	Preemptive priority call – as PC but allows disconnecting ongoing calls in order to allocate resources
IC	Include call – involve a third party in an active call
BC	Barring call – incoming or outgoing call bearing
AoC	Advice of charge – charge indication to end-user
DL	Discreet listening – facility, which allows tapping into calls
AL	Ambiance listening – activating the terminal transmission without giving an indication to the end user
DGNA	Dynamic group number assignment – facility for group creation

ATTACHMENT 2

TO APPENDIX 7

Procedures and Interfaces

1 Procedures

Handover	Mobile controlled handover
Mobility management	Air interface: FHMA standard procedures Location registers: Standard MAP based (HLR/VLR)
Call management	Air interface: FHMA standard procedures MSC interworking: SS7-ISUP/TUP based with additions necessary for management of voice group calls

2 Interfaces

Intersystem signalling	SS7-MAP (IS-41C)
Service interworking	Distributed connectivity towards PSTN, ISDN and Internet
Line-station interface	Standard Internet connectivity towards integrated packet handler (DC)

ATTACHMENT 3

TO APPENDIX 7

Abbreviations and Acronyms

AIN Advanced intelligent network

AuC Authentication center

AVL Automatic vehicle location

BHCA Busy hour call attempts

BER Bit error rate

BS Base station

BSC Base station controller

BTS Base transceiver station

CCC Customer care center

CCH	Control channel
CMM	Channel mode modify
CUG	Closed users group
CRC	Cycling redundancy checking
EIR	Equipment identity register
GC	Group call (dispatch)
GCR	Group call register (GSM-R)
GOS	Grade of service
HLR	Home location register
HO	Handover
IN	Intelligent networks
IWF	Inter-working function
MM	Mobility management
MO	Mobile originated call (outgoing)
MS	Mobile station
MSC	Mobile switching center
MT	Mobile terminated call (incoming)
OMC	Operation and maintenance center
PDN	Packet data network
PDU	Packet data unit
PH	Packet handler
RR	Radio resource
SDL	Specification and description language (UIT-T) or software download
SID	Silence detection packet
SIM	Subscriber identity module
SMS	Short message service (GSM) or subscriber management system
SS	Supplementary services
SU	Subscriber unit
TBD	To be defined
VAD	Voice activity detection
VLR	Visitors location register.