Radio in the Local Loop Systems - Technology Trends

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Summary: This document presents in a concise way the relevant information on Radio in the Local Loop (RLL) systems addressing besides others transmission technology, system architecture and access protocols, frequency bands, system capacity, state of development of forthcoming RLL-systems and applications to be served. Emphasis of the paper is put on the specific situation in Germany, where due to the deregulation of the telecommunications (telco) sector in the next five years one of the fastest growing markets for RLL-systems worldwide is expected to come into existence. Due to the fact that all major telco systems equipment manufacturers and many newcomers have recognized this opportunity, this document cannot claim to be complete in the sense that all the relevant systems under development are addressed or taken into account. Nevertheless, the main streams of development and the typical characteristics of the forthcoming systems are completely covered.

Contents

1 Introduction

There are at least five groups of telco networks operators looking for radio based equipment to provide or improve the local loop connectivity:

1. Conventional countrywide operators (incumbents) seek to connect subscribers to their networks in areas where
   - the existent cabling has reached its capacity limits
   - rural subscribers have to be connected
2. Conventional countrywide operators seek to offer their subscribers cordless access combined with some limited mobility around the fixed network termination in order to remain competetive to the establishing cellular radio operators

3. New regional or countrywide operators (competitors to the incumbent) who do not own cabling in the vicinity of the subscriber
4. Cellular radio operators looking for alternative (low cost) equipment to connect fixed subscribers and to offer cordless mobility at home (possibly using dual-mode handsets)
5. Communities operating their own local or regional telecommunication network to connect
    - subscribers of a closed user group (fire brigade, city administration, police, airport authorities, etc.)
    - subscribers not related to the community to increase the subscriber basis and thereby reduce cost of network operation

All of those have to consider the needs of the following types of users which differ in their communication capacity and services needs:

1. Business users operating a local PABX[1] requiring at least a T1 or E1[2] interface to the telco network or multiples of these, e.g. according to ETSI interface V5.2 (n x E1). Business users in many cases in addition to telephony operate a LAN[3] or local data termination equipment. In this case they need connectivity to data networks supporting e.g. X.21 (stream data), or packet data services like X.25 or Frame Relay.
2. Small business users operating a small PABX and having demand for sporadic data connectivity amounting in total to a link capacity of n*64 kbit/s resulting in a range of 144 to about 576 kbit/s, typically below 2 Mbit/s.
3. Individual users typically served either by one analogue a/b or an ISDN[4] interface to the telco network with a maximum capacity requirement of 64 kbit/s when communicating data.

It is clear from the capacity definitions of these three types of users that business users (seen from today's technological constraints) need be connected either via

- unshielded twisted pair wires (using high speed transmission techniques like HDSL[5] or ADSL[6]) or coax cabling or via
- line-of-sight (LOS) radio links.

Business users are of very high importance to the telco network operator due to their substantial contribution to load his network. Therefore these users will not be multiplexed to other subscribers on a radio medium in the access network. In Germany it is known that about 5% of the subscribers to DTAG[7] pay more than 5.000 DM per month usage fees. This group of subscribers apparently is quite small and worth to especially be taken care of (in fact, DTAG recently has developed specific tariffs for that user group).

Small business users are estimated to amount between 20% and 35% of the subscribers to DTAG and (by definition) pay less than 5.000 DM but possibly at minimum about 500 DM per month usage fees. Although this group of subscribers apparently is much more contributing to the load of the telco network than the business users, the operator will still take any possible measure to reduce the cost to connect to these subscribers to maximize his revenue. Instead of exclusive direct high-speed wires or line-of-sight radio links, a tree-shaped wired network to make use of the trunking gain or point-to-multipoint (PMP) radio links appears best suited for them, since the capacity of a T1 or E1 link than can be shared among them. Since a small business user requires some percentage only of the capacity needed for a business user, and the

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[1] Private Automatic Branch Exchange
[2] ITU-T G.703 defines primary rate trunks for PCM voice: T1 = 1.536 kbit/s; E1 = 2.048 kbit/s
[3] Local Area Network
[4] Integrated Services Digital Network
[5] High Speed Digital (subsriber) Link
[6] Asymmetric Digital Subscriber Link
[7] Deutsche Telekom AG

distinction between both is not easy to define, it could be wise to apply different versions of the same technology for both, i.e. the same classes of wired lines and related modems and the same radio based techniques to serve them. (As described later, the frequency bands allocated to the LOS and PMP services by the national regulation authority might be different, requiring appropriate up-/downconversion techniques to cover a sufficient range of the frequency bands aimed at).

The **individual users**, apparently, must share a common medium to the maximum possible extent using multiplexing of their messages to cost efficiently connect them to the local exchange of the telco network. Multi-level tree shaped wired networks in the local loop using sequential trunks of increasing capacity or radio channels shared under the control of multiple-access protocols are the appropriate measures to reduce the investment per subscriber to an acceptably low amount. Since the link capacity per connection is quite small (e.g. 12.5 or 25 kHz for analogue voice transmission, with digital transmission and voice compression 6.5 to 13.0 kbit/s, again resulting in a bandwidth consumption of 12.5 to 25 kHz[8]), it appears natural to use radio based systems, applying e.g.

- FDMA[9]-protocols to access a trunk of radio frequency channels
- TDMA[10]-protocols to access a trunk of TDM[11]-channels defined in a given number of FDM[12]-channels
- CDMA[13]-protocols to access a trunk of code channels in, typically, one radio frequency (FDM)channel
- hybrid of the above.

It appears natural that RLL-systems aimed at only serving individual users rely on similar technology as applied to mobile telephony, but with reduced system complexity due to the fixed location of the subscriber terminal.

It can be concluded that it is not easy to define a radio based system architecture to serve both, small business and individual users, efficiently, since their needs much more differ than those of business and small business users. The usual choice is for individual and small business users to rely on CDMA-technology as the basis of the radio system and to apply TDMA/FH[14] or DS[15]-CDMA-protocols.

ETSI RES in 1995 has established a study group on PMP and CDMA systems for RLL applications. The group will at least take 2 years to produce a draft standard. Meanwhile, operators are asking for equipment to be tested in the field in mid 1996 to be ready in January 1998 to open the telephony services.

2 Technologies to be applied for RLL-systems and related frequency bands

Fixed Radio Access to offer telephony and data services of the PSTN[16] (using analogue transmission) or of the ISDN to fixed subscribers is offered from equipment manufacturers in a number of different ways described in the following.

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[8] For this calculation the modulation and channel coding techniques of the GSM [2] has been assumed
[9] Frequency Division Multiple Access
[10] Time Division Multiple Access
[11] Time Division Multiplexing
[12] Frequency Division Multiplexing
[13] Code Division Multiple Access
[14] Frequency hopping
[15] Direct Sequence
[16] Public Switched Telephone Network

2.1 Analogue Cellular Radio Networks to provide RLL services

The poorest (in performance) and quite expensive solution[17] is to use cellular radio system technology to serve fixed subscribers (individual users). Cellular based RLL systems are estimated to cost approx. $1000 per line [10]. Two kinds of cellular radio systems have to be distinguished: analogue and digital systems. Analogue systems enable to extend the services of the PSTN, namely 3.1 kHz voice and modem based fax and data, e.g. 4.8 kbit/s at maximum to the wireless subscriber terminal. These systems are in use to either operate as a RLL-system to substitute the wireline in the local loop, i.e. to cover only the access network by means of a radio based access line to the fixed network exchange, or to operate as a Fixed Cellular Radio System, a complete network solution, comprising everything from switching systems to subscriber terminals.

Ericsson RAS 1000 system is an example of both. It is able to support PSTN services and distinguishes between RLL technology and Fixed Cellular technology both based on the RAS 1000 system [1]. The system is based on the Ericsson NMT (Nordic Mobile Telephony) technology using analogue base stations, able to use either 2x5 MHz in the range 380-500 MHz or up to 2x25 MHz in the range 800-1000 MHz. One large installation results from a turnkey RLL contract of 1989 by Deutsche Telekom A.G. (DTAG) to quickly provide telephone services to new subscribers in the former East Germany. This system connects 13.000 subscribers to the DTAG network. Another German RLL system was contracted 1993 to connect subscribers in the city of Potsdam, near Berlin.

2.2 Digital Cellular Mobile Radio Networks to provide RLL services

2.2.1 Proprietary Systems

Interdigital Communications Corporation (IDC), a US based company, owns the key patents on a system design very close to US TIA[18] interim standard IS54 (digital ADC[19]) [6]. The company's own RLL-system called UltraPhone has been deployed successfully many times worldwide. This local radio system is based on digital transmission technologies and typically connects many small subscribers served by one base station connecting them to a local exchange or PABX. IDC owns also many key patents on wide-band CDMA-techniques, originally owned by Donald Schilling, currently one of its vice presidents. Siemens bougth a license and started a co-operated development with IDC of wide band CDMA RLL-systems in 1995.

2.2.2 GSM/DCS1800 based systems according to ETSI standard

Systems based on the ETSI GSM/DCS1800 standards [2] are another example of digital cellular radio. Since they are designed to extend the ISDN to mobile users, these systems are able to support digital transmission of voice (compressed to 13.0 or 6.5 kbit/s) and data at 9.6 kbit/s. Eplus, the operator of the so called E1 cellular radio network in Germany, using network elements mainly provided by Nokia (and some from Ericsson), established picocells in highly populated areas with cell radii down to 250 m, to completely penetrate the buidlings from outside and thereby provide a radio based access technology able to bypass the DTAG's local loop. The GSM operates in the ranges 890-915 MHz (uplink) with an extension band at 880-890 MHz, and 935-960 MHz (downlink) with 10 MHz extension band at 925-935 MHz with a duplexing distance of 45 MHz, whilst DCS1800 operates in the ranges 1710-1785 MHz (uplink) and 1805-1880 MHz (downlink) with 95 MHz duplexing distance.

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[17] A basestation of a picocell in the E1 network amounts to approx. DM100.000,00

[18] Telecommunication Industries Association

[19] American Digital Cellular system (a system able to coexist with the American Mobile Phone System, AMPS)

The systems use 200 kHz FDM channels providing a 270 kbit/s modulation data rate, which carry 8 TDM traffic channels each providing a gross bit rate of 22.8 kbit/s. Forward error correction is used resulting in a code rate of about 0.5.

All three cellular operators in Germany (DeTeMobil, Mannesmann Mobilfunk, and Eplus) have been assigned 15 MHz bandwidth so far. GSM/DCS1800 based digital cellular radio systems appear not to be competitive in cost when used as a fixed subscriber access technology for telephony to bypass the DTAGs local loop. Due to the throughput limitation for data transmission to 9.6 kbit/s, these systems are not attractive as an alternative to a wireline for users needing ISDN-like channel rates. ETSI is currently preparing a standard to interface GSM/DCS1800 to X.25 terminals enabling to multiplex the virtual connections of many terminals via one or even some parallel traffic channels; a standard to make use of the full capacity of a 200 kHz FDM channel to carry a true 2B+D ISDN-channel (144 kbit/s) is under discussion.

2.2.3 DS-CDMA based systems according to US TIA standard

DS-CDMA based cellular radio systems e.g. according to TIA IS 95 (Qualcomm system) are designed to serve compressed voice and are severely limited in the data troughput per traffic channel to 4.8 kbit/s. Voice and data are transmitted as data packets on a code channel established between the mobile (or fixed) terminal and the base station. The whole frequency band occupied by the system amounts to e.g. 3.5 MHz and this bandwidth is claimed sufficient to serve the same number of subscribers as the GSM with a comparable quality of service but with much higher spectral efficiency. All basestations transmit/receive in the same frequency band, using different code channels. The basestation controls all active mobiles through a sophisticated power control mechanism to come in within a 1 dB tolerance of the receive level. Since the data rate offered per code channel is not sufficient to meet the expected subscriber needs (i.e. 64 kbit/s), derivatives of the system are in discussion offering multiples of the basic data rate by using many code channels in parallel. However, this would use up the capacity of the system quite rapidly, if many data users are active concurrently.

2.3 Digital Cordless Radio Networks to provide RLL services

2.3.1 The DECT System

The Digital European Cordless Telecommunications (DECT) standard [8] has been recently supplemented for local loop applications [3] and appears to be superior to cellular based system designs in terms of performance and cost[20]. Following [10], first generation RLL systems designed from scratch, using currently available technology are available for about $400 per line (without user terminal). Second generation RLL systems with digital transmission, using high volume integrated components (e.g. DCS1800/DECT) will reach $300 per line. From a study performed by the author for the BMPT[21] [4] to define the capacity and technical limitations of DECT to be taken into account for licensing DECT for public operation, it is known that the DECT system is a very attractive technical solution to bypass the local loop. It has the capability and capacity to economically connect fixed subscribers by substituting the wired access by base stations with below 1 km cell radius using 60° sectorized antennas „over the roofs“ with small gain receive antennas at the subscriber site. It can provide the capacity needed (about 2.000 Erl./km^2 for a Personal Communications System (PCS) with picocells of about 170 m radius „below the roofs“ to provide the radio coverage needed to offer full subscriber mobility indoors and outdoors without antenna gain at the mobile terminal; fixed terminals of cause can

[20] A radio fixed part (basestation) costs about 15.000,00 DM

[21] German Bundesminister für Post und Telekommunikation

then be served also. Both types of systems are expected to be applied, possibly a mixture of both approaches will prove to be the winning design. In December 1995, in Germany, licences to test the suitability of the DECT system as an RLL-system in large field trials have been granted.

The DECT system operates in the range 1880-1900 MHz and is Europe-wide licensed for use in homes and on private ground, even to provide cordless PABX-services. An extension band is in preparation in the range 1900-1930 MHz (the FPLMTS[22] band) for public operation only. 10 FDM-carriers in a distance of 1.728 MHz are defined in the 20 MHz band, each carrying a modulation data rate of 1152 kbit/s. TDM divides the capacity of each carrier into a frame of 10 ms length containing 24 time slots, of which the first 12 slots are paired to the other 12 to define in a time division duplexing (TDD) mode 12 TDMA duplex channels per carrier. Each TDMA channel has a gross capacity of 32 kbit/s unprotected data plus 6.4 kbit/s for signaling data. A 32 kbit/s channel is used to transmit ADPCM coded voice, or data at 25.6 kbit/s (protected). Like the ISDN the DECT system allows to establish connections using multiples of one TDMA channel, up to the capacity of one carrier. E.g. one DECT channel has been standardized to carry one ISDN voice grade channel and three DECT channels to carry one 64 kbit/s ISDN data channel [5]. Since the transmit power is limited to 250 mW in the DECT standard, the system is limited to high capacity local systems for populated areas and (mainly) individual users. Different from cellular radio, DECT is completely decentrally organized allowing any base station to operate any frequency/time-channel pair if possible according to the current interference situation, based on a dynamic channel selection algorithm controlled by the terminal.

The DECT standard also defines a wireless base station (WRS) able to communicate with an upstream basestation like a mobile terminal, operating multiple connections in parallel, and behaving downstreams like a wired basestation to serve many mobile terminals. The WRS is useful to extend the coverage of the wired basestation to areas with small traffic contributions and to reduce cabling costs to connect basestations. It is expected that the DECT system will reach some share of the market of fixed access network technology esp. in highly populated areas where support of local user mobility is expected to be a selling argument.

In Europe, most of the major telco systems providers offer DECT equipment designed for the local loop application, e.g. Bosch, Siemens („DECTLink"), Alcatel (A4220 with up to 128 subscribers and 36 fixed network interfaces/A4400 with up to 8000 subscribers and 48 fixed network interfaces, see Fig. 1), Philips, Ericsson, Nokia, Hagenuk, DeTeWe, etc.

2.3.2 Other Standardized Cordless Systems

Systems standardized in Japan (Personal Handyphone System, PHS) and in the US (Personal Access Communication System, PACS) have similar technical performance parameters like the DECT system, since they can be considered as further developments or modifications of the DECT standard. The PACS system has been developed by Bellcore (like the DECT system by Ericsson) for outdoor RLL applications and is called Wireless Access Communications System, WACS.

2.4 Digital Point to Multipoint (PMP) systems to provide RLL services

PMP systems are used in the RLL to connect small business and business users to the local telco network exchange.

[22] Future Public Land Mobile Telecommunications System, an initiative of ITU-R

According to a BAPT[23] publication [13], the frequency bands in Table 1 are reserved for RLL applications. Besides TDMA/FH- also DS-CDMA-based systems are existent or under development. The advantage of DS-CDMA-systems in RLL-applications is that multipath interference can be suppressed dramatically (when using a suitable spreading of about 100 to 150) without having to live with the known drawbacks of mobile cellular radio networks like the need for a real-time based power control and a complex handover process (requiring operation of two channels to two basestations to support one connection in a substantial percentage of the service area).

Table 1: Frequency bands allocated for RLL applications

Frequency range	Bandwidth	Remark		
PP[24]-LOS radio	27.5-29.5	2 GHz	not used currently	
PMP-LOS radio	3.4-3.58 GHz	180 MHz	~~up to now used by DTAG~~	o. K.
	2.5-2.67 GHz	170 MHz	~~up to now used by DTAG~~	o. K.
	24.5-26.5[25] GHz	2 GHz	~~up to now used by DTAG~~	o. K.

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According to a BMPT publication [8], for PP-LOS systems frequency ranges at 7, 23, 26, 28 and 38 GHz and the optical range (300GHz to 500 THz) have been assigned. The frequencies to be used are assigned by the BAPT, dependent (besides others) on the length of a link. For short links and for PMP links to be used in RLL applications, frequencies in the 26 GHz band-will be assigned (see Table 1).
PMP-systems basically rely on PP LOS technology which has proven in telco networks to be reliable and offer the same quality of service (e.g. in bit error ratio) as cables or fiberoptic trunks. Using Reed-Solomon channel coding to protect the transmit data against bursty bit errors, the bit error ratio can even be reduced to a lower value than available from cable of fiber systems [11]. In the following, some important characteristics from system description documents of RLL manufacturers are reported. More details are available for some of the systems from the author.

The ALCATEL A9800 PMP, Fig. 2, is one example for systems using TDMA channels. A wireless (DECT) system can be combined with the PMP-system to enable cordless access to the subscribers, Fig. 3. As indicated in the Figures 2 and 3, frequency bands in the ranges 1.517-1.525 GHz (a band reserved for RLL) and 2.4-2.5 GHz (an ISM[26]-band) are used there to connect the central radio station (RSC) PMP to radio station nodes (RSN), radio station terminals (RST) or wireless radio station terminals (WRST). The frequencies F2/F2' shown are not specified in the figure. Possibly, ISM bands at higher frequencies e.g. 5.725-5.875 GHz or 24,00-24,25 GHz [7] are used. The frequency f shown in Fig. 3 is the DECT band.

AT&T Network Systems at the Telecom '95 at Geneva has announced its Airloop digital wireless local loop system aimed to connect fixed subscribers (individual and small business users. The system), which will be available in April 1996, claims to cover POTS[27] to ISDN

23 Bundesamt für Post und Telekommunikation (German frequency coordination authority on behalf of BMPT)
24 Point-to-Point
25 According to [12]
26 Industrial, Scientific and Medical band
27 Plain Old Telephone Service

services, making Airloop completely feature transparent. The system applies DS-CDMA access technology and comes with integrated operations, administration, and maintenance systems to help the service provider monitor and control the fixed wireless network.

Philips IRT 2000 PMP TDMA radio system operates in the ranges 1.4-1.5, 2.3-2.5, and 2.5-2.6 GHz bands (2 MHz spacing) to connect a central station to many repeater stations up to 30 km in distance, providing E1 trunks, which in turn serve DECT terminal stations in a distance up to 5 km. The IRT 4000 system extends to multiple primary rate) n*2 Mbit/s, E1 to E2[28]) operation using 4 MHz spacing at various frequency bands, allowing to connect up to 1920 subscribers (up to 480 subscribers per remote station), i.e. 100 Erl. at 1% blocking. The focus is on individual and small business users. Transmission quality is monitored according to ITU-T rec. G.821.

Siemens, besides the joint development of a broadband CDMA-system mentioned above is developing a PMP access radio network to serve fixed subscribers (including some limited mobility) based on DS-CDMA („CDMALink") applied to 7 MHz bands as the basic unit in the range of 2.52-2.67 GHz [9]. At the air interface, voice services at 8, 16, 32, and 64 kbit/s, ISDN services, 384 kbit/s video and data services up to 2 Mbit/s are supported by transport of Air Interface Packets (AIP), closely related to ATM cells. The focus is on individual and small business users. A physical channel is a CDMA-channel with a bandwidth of 7 MHz, carrying one or more logical channels multiplexed by a TDM-scheme. Multiple physical channels might be used in parallel and six sector antennas are used, together with a 12-15 dB gain at the fixed terminal, equipped with a RAKE receiver.
Bosch (ANT Telekom) introduced its MULTILINK Access Radio based on FDMA/TDM transmission in April 1995. The central station contains multiple Tx/Rx sets each supporting channel rates from 64 kbit/s to 8.448 Mbit/s (E2). An user terminal (type 1) is able to support channel rates in the range of 64 kbit/s, n*64 kbit/s ($n \leq 30$), 2 Mbit/s, n*2 Mbit/s ($n \leq 4$), and 2-8 Mbit/s. An user terminal (type 2) supports 4.8 to 64 kbit/s. The frequency ranges, channel bandwidths, modulation and access techniques used are described in Fig. 4. The necessary bandwidth to transmit 2.048 Mbit/s is 1.23 MHz using trellis coded modulation and 8-PSK with code rate 2/3. The user interfaces are G.703, RS 422/449, V35 and CMOS TTL, the network management interfaces RS 232, RS 485, QD2, and Q3 are supported. Interworking scenarios of MULTILINK and DECT are also covered. A 50 Mbit/s version is under development.

DSC Airspan 60 fixed subscriber access PMP network is an available DS-CDMA based product. At the moment it does not have a BZT[29] type approval in Germany. However, the system will participate in field trials planned for 1996 in Germany. Cell radii between 300 m and 20 km can be covered, dependent on the propagation conditions. The capacity is up to 60 non-blocking subscriber terminals per central terminal. Channel plans are available for 2.0-2.3 GHz (according to ITU-R and CEPT plans) and for 1.5-2.7 GHz. Frequency re-use is based on 1 to 3 cells, depending on the cell structure (antenna sectorization). Interfaces at the central terminal are 2 wire VF (2*64 kbit/s for two PCM telephony channels, non-ISDN!) or 2 Mbit/s G.703 with various signalling systems (CAS, DASS2). The subscriber terminal (V2) provides 2-wire analogue telephony interfaces, which can be used to support two separate subscribers or provide a subscriber with two lines, offering telephony, Group 3

[28] ITU-T defines E2 = 4 times 2 Mbit/s

[29] Bundesamt für Zulassung in der Telekommunikation (type approval authority in Germany)

Fax and in-band data services (V.22, V22bis, V.32, V32bis, V.FC, V.34, i.e. 2.4 to 28.8 kbit/s{with data compression}) with a transmission delay less than 1 ms, and DTMF or loop disconnect dialling, fully compatible to the public PSTN. The Airspan 600 system is aimed to offer larger capacity and will support 280 simultaneous 64 kbit/s or 560 32 kbit/s channels. The system characteristics are otherwise the same as with Airspan 60.

In the US also the PPS2000 system by Motorola has to be mentioned. In the UK, IONICA (manufactured by Northern Telecom) intended to open a fixed radio access RLL system (one half year delayed) in autumn 1995 and Millicom based on proprietary AT&T technology introduced a system for broadband access (up to 384 kbit/s for POTS and video).

2.5 Wireless LANS to provide RLL data services

Wireless LANs using the above described technology are available from many manufacturers but are in use mainly for indoors applications. This is due to the fact that private use for data transmission on private ground is generally permitted in ISM-bands in Europe. To mention just the best known wireless LAN systems, in the sequel a short listing is given.

CYLINK offers the AirLink™, a DS-CDMA based radio LAN operating in the ranges 2.4-2.4835 GHz and type specific providing data rates from 1.2 up to 512.448 kbit/s and 902-928 MHz providing rates from 1.2 to 256 kbit/s. Both system types offer asynchronous and synchronous data interfaces.

AT&T WaveLAN is a DS-CDMA based system at 2.4 GHz offering a gross bitrate of 2 Mbit/s which requires a PCMCIA[30] interface at the terminal..

IBM, Xircom (NetWave) and Telemation (BreezeNet) offer TDMA/FH based systems with a gross bitrate of about 2 Mbit/s, all operating in the 2.4 GHz ISM band, all requiring a PCMCIA interface card at the terminals.

Acknowledgement: Thomas Walke has contributed to the paper by providing informations on details of the frequency regulations situation.

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4 Figures

The following figures are taken from vendor presentations as indicated in the figures.

ALCATEL SEL

General Architecture DECT in Public Access

RANGE:	
Indoors mobile	50m
Outdoors mobile	300 m
Fixed NLOS	250-500 m
Fixed LOS	up to 5 km

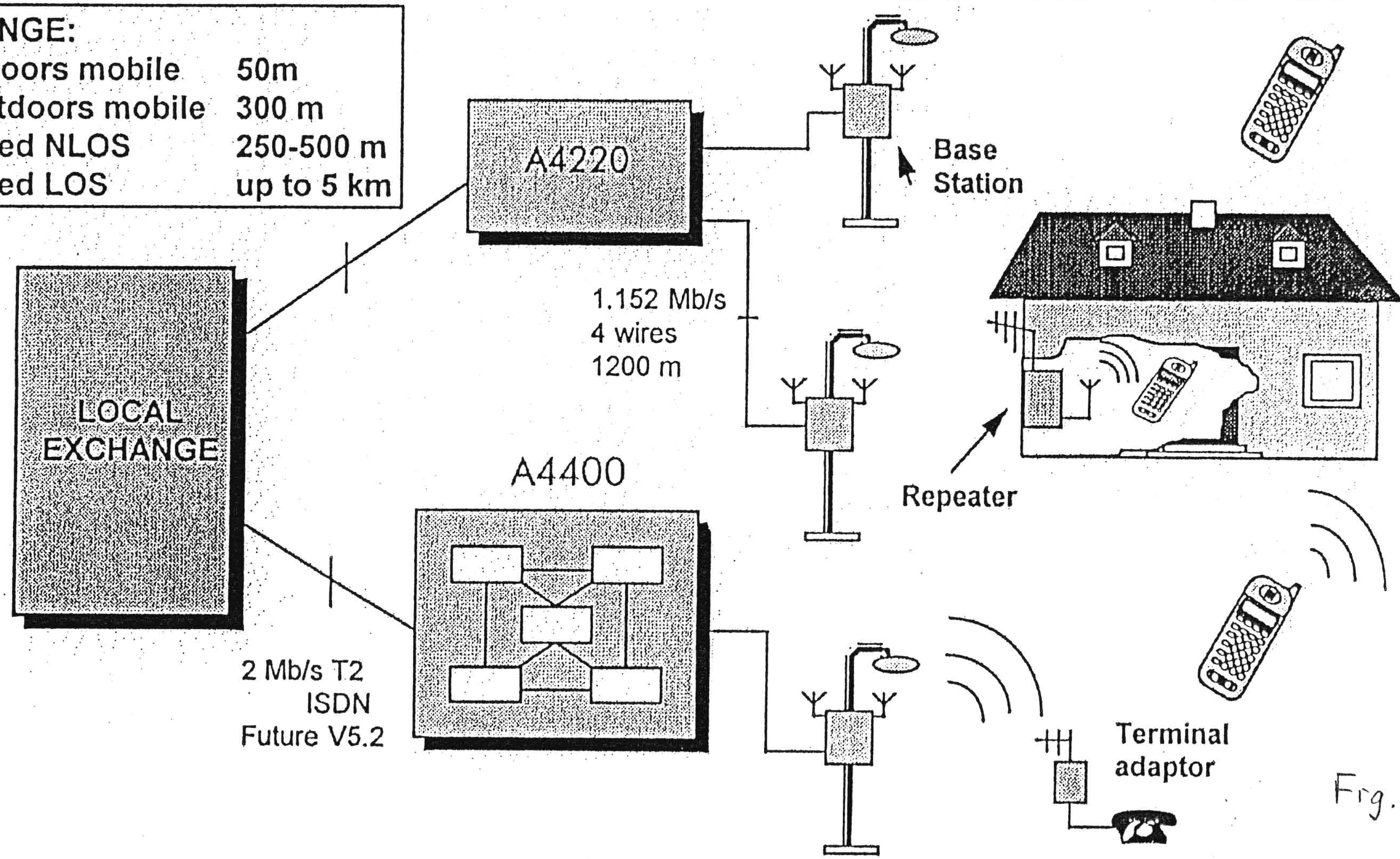
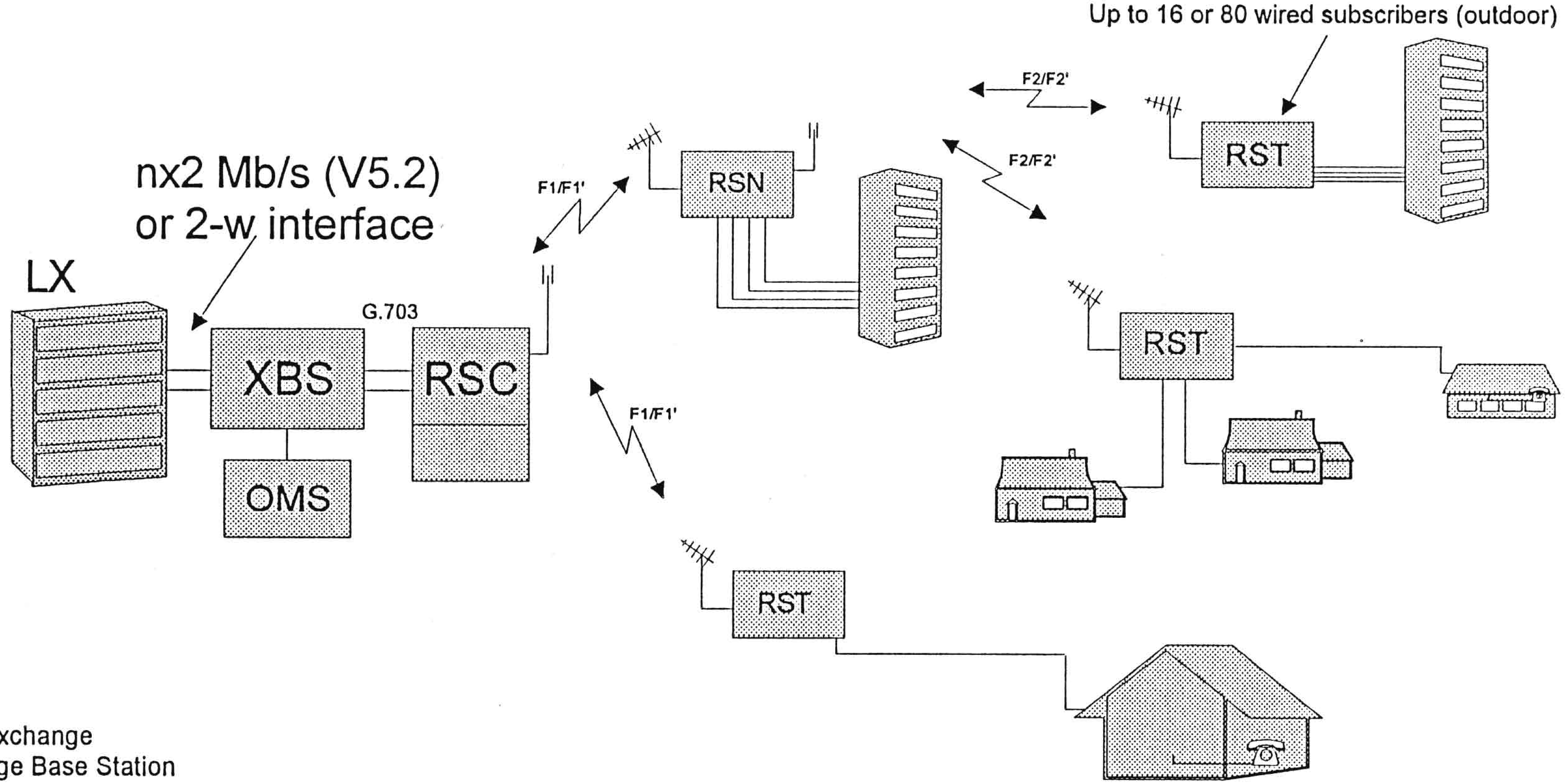


Fig. 1

ALCATEL SEL

Alcatel A9800 PMP Network Example

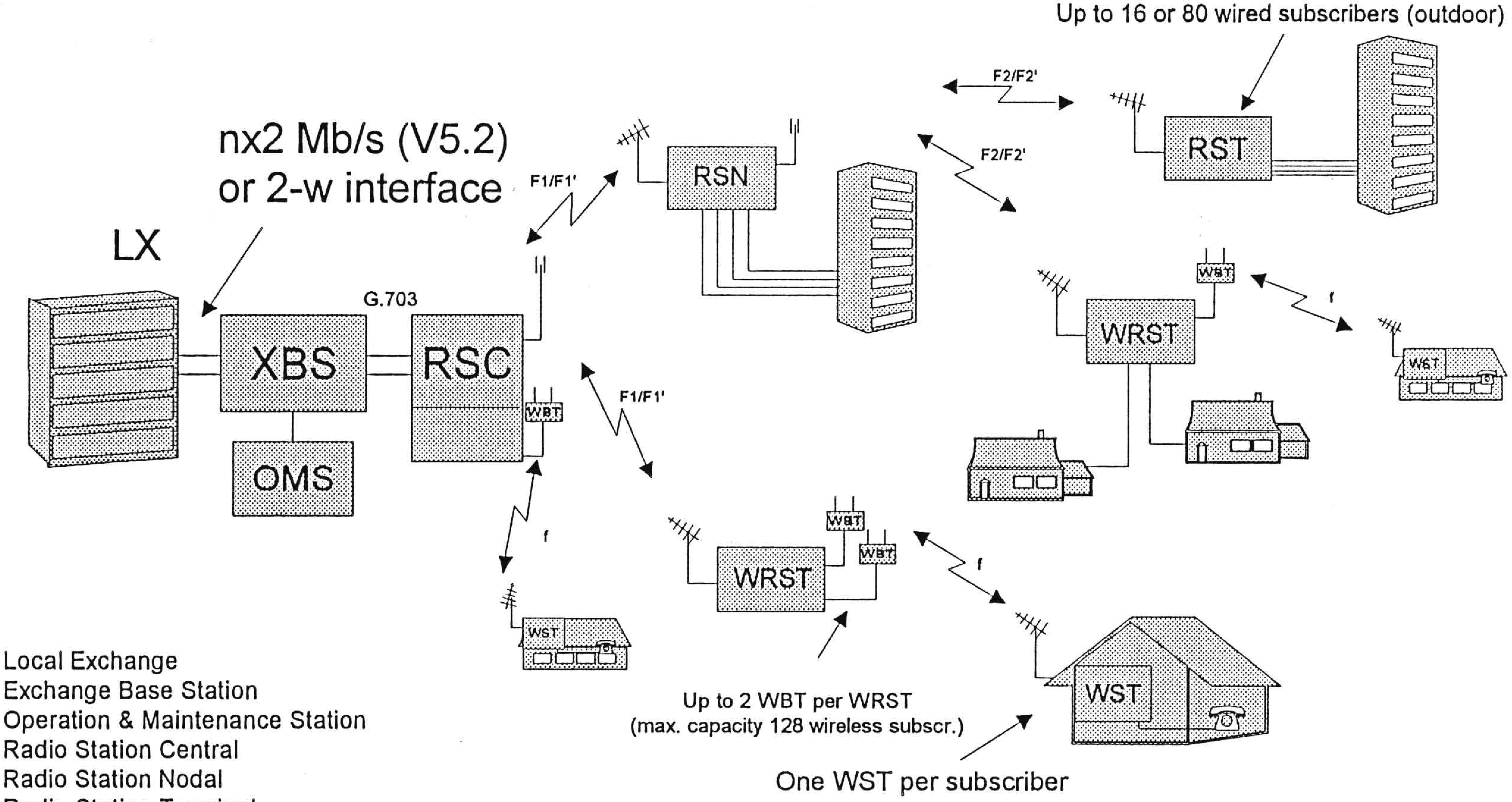


LX : Local Exchange
XBS : Exchange Base Station
OMS : Operation & Maintenance Station
RSC : Radio Station Central
RSN : Radio Station Nodal
RST : Radio Station Terminal
F1/F1': 2 or 4 Mbit/s per hop in 1,5 or 2,4 GHz Band

Fig. 2

ALCATEL SEL

Alcatel A9800 PMP Network Example incl. Wireless Subsystem



LX : Local Exchange
XBS : Exchange Base Station
OMS : Operation & Maintenance Station
RSC : Radio Station Central
RSN : Radio Station Nodal
RST : Radio Station Terminal
WBT : Wireless Base Station Transceiver
WST : Wireless Station Terminal
WRST: Wireless Radio Station Terminal
F1/F1': 2 or 4 Mbit/s per hop in 1,5 or 2,4 GHz Band

Fig. 3

VDE_02.DRW

MULTILINK Access-Radio
PRELIMINARY SPECIFICATIONS (I)

■ Frequency Ranges:	1	17.70 - 19.70 GHz	ITU-R Rec. 595-3
	2	22.00 - 23.60 GHz	CEPT Rec. T/R 13-02
	3	24.50 - 29.50 GHz	CEPT Rec. T/R 13-02
	4	27.50 - 29.50 GHz	CEPT Rec. T/R 13-02
	5	37.00 - 39.50 GHz	CEPT Rec. T/R 13-02
	6	(other, acc. to national regulations)	
■ Channel Bandwidth:	1	55 MHz	
	2	n*3.5 MHz (max. 112 MHz)	
	3	n*3.5 MHz (max. 112 MHz)	
	4	n*3.5 MHz (max. 112 MHz)	
	5	n*3.5 MHz (max. 56 and 140 MHz)	
■ Modulation:	QPSK, TCM 8/16-PSK		
■ Demodulation:	Coherent, Viterbi decoder		
■ Multiple Access Technique:	FDMA and DAMA		

Fig. 4

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ANT TELECOM