

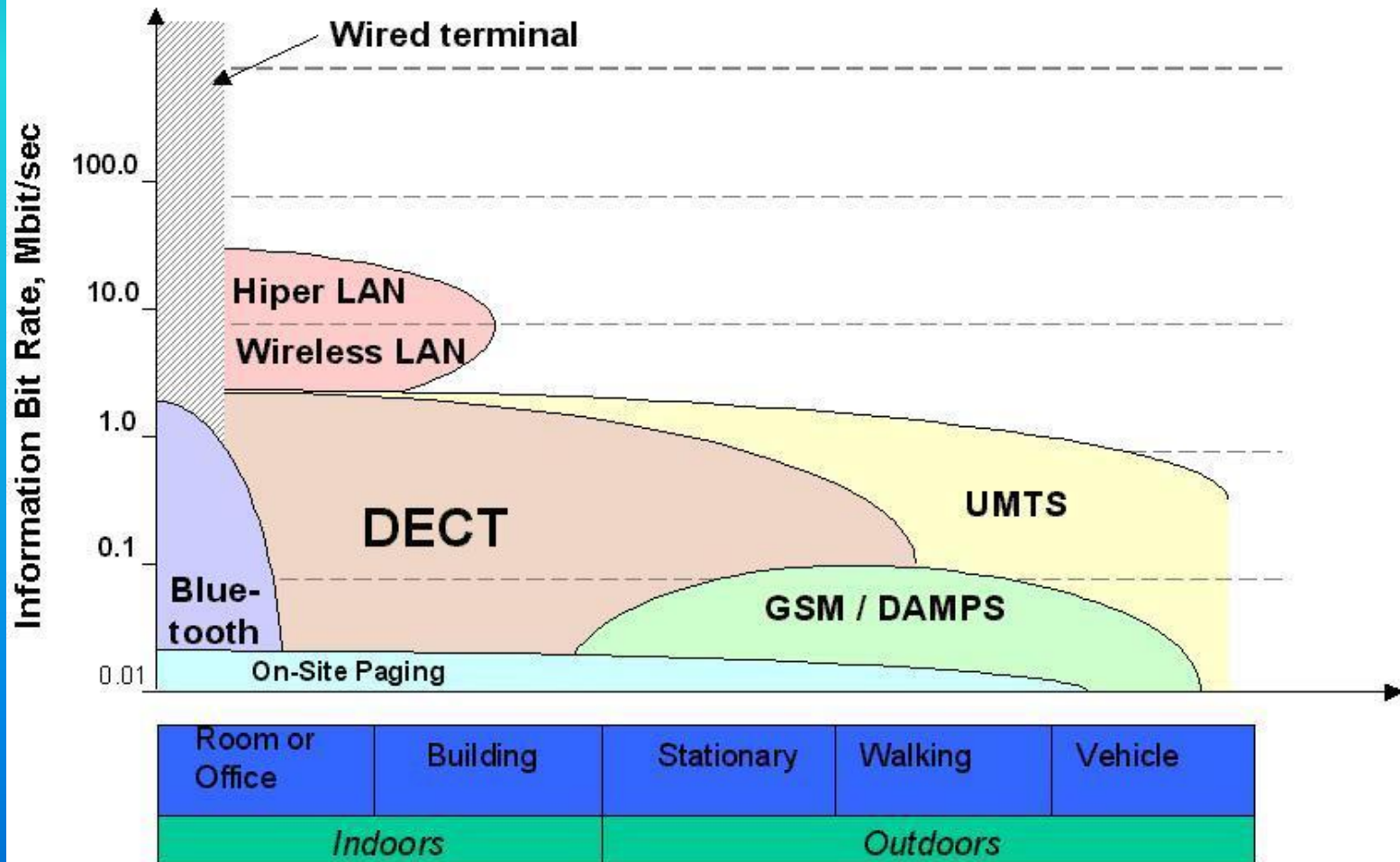
2. IP DECT Wireless Network

What is DECT?

Introduction:

- The Digital Enhanced Cordless Telecommunications (DECT) standard provides a general radio access technology for wireless telecommunications, operating in the preferred 1880 to 1900 MHz band using GFSK (BT = 0.5) modulation.
- DECT has been designed to provide access to any type of telecommunication network thus supporting numerous different applications and services. The range of DECT applications includes residential, PSTN and ISDN access, wireless PABX, GSM access, Wire-less Local Loop, Cordless Terminal Mobility CTM, Local Area Network access supporting voice telephony, fax, modem, E-mail, Inter-net, X.25 and many other services in a cost efficient manner.

Wireless Technologies



DECT Radio Spectrum

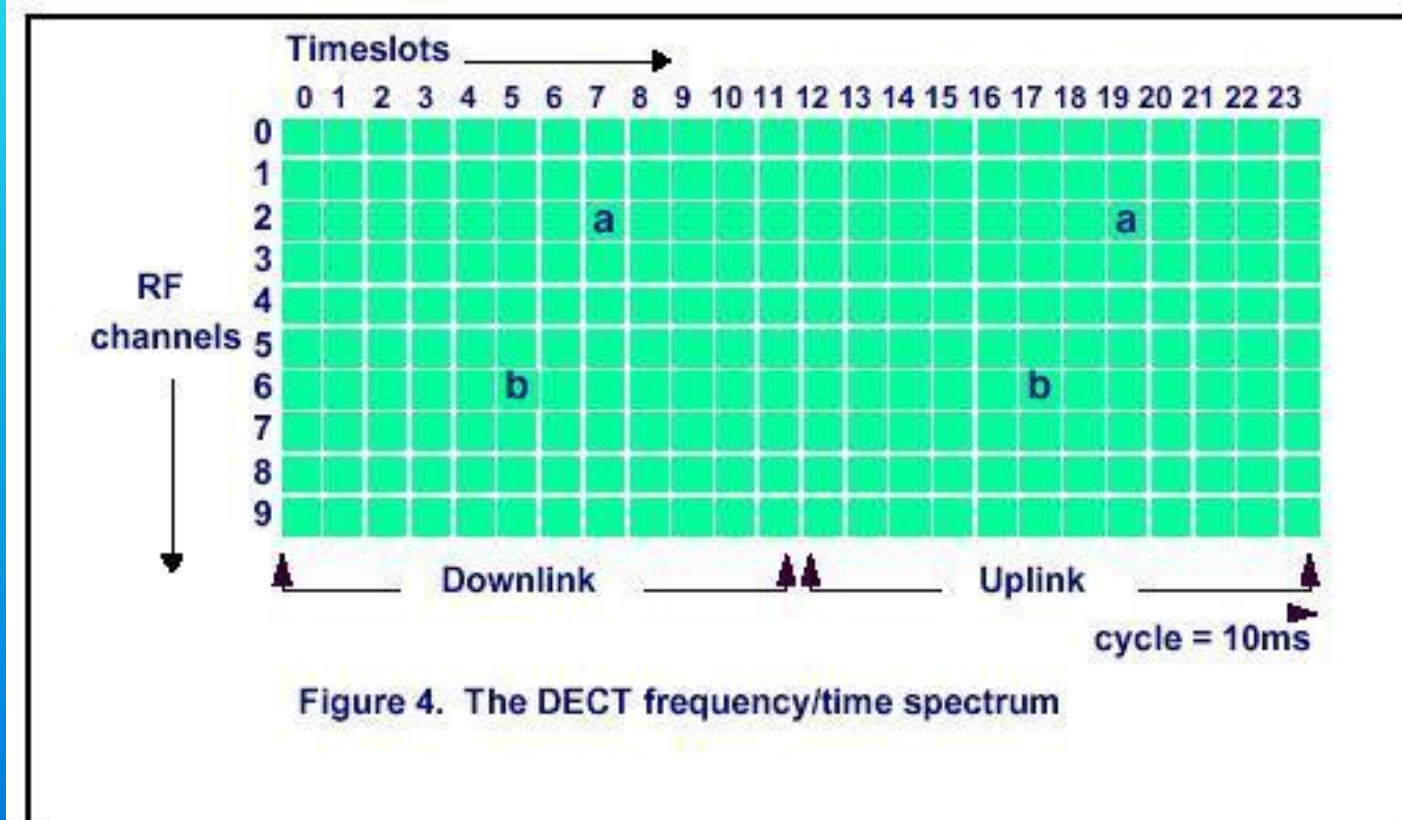


Figure 4. The DECT frequency/time spectrum

DECT System Specifications

1880 – 1900 MHz

10 Carriers, 24 Time Slots (2 x 12 Duplex)

Carrier Space: 1728 KHz

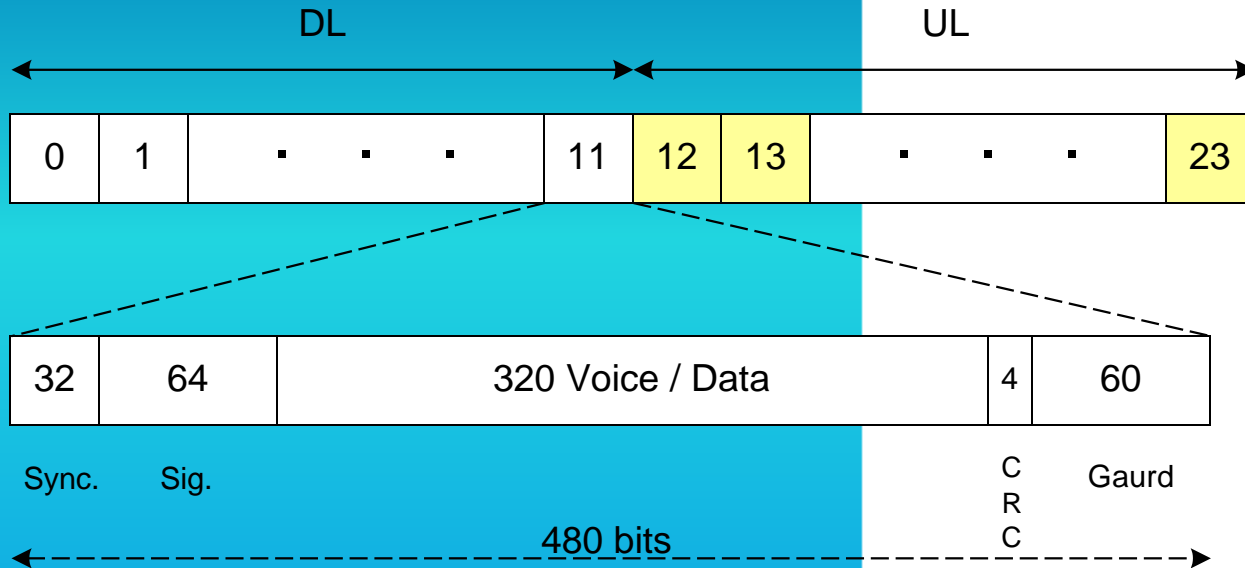
Frame of 24 TS Repeating every 10 ms

Carrier 0: 1881.792 MHz

Carrier 1: 1883.520 MHz

-
-
-

Carrier 9: 1897.344 MHz



G711: 64 kb/s

G723.1: 6.4 kb/s

G723.1: 5 - 3 kb/s

G726: 32 kb/s

G726: 24 kb/s

iBLC: 15 kb/s

GSM: 13 kb/s

(480 x 24)

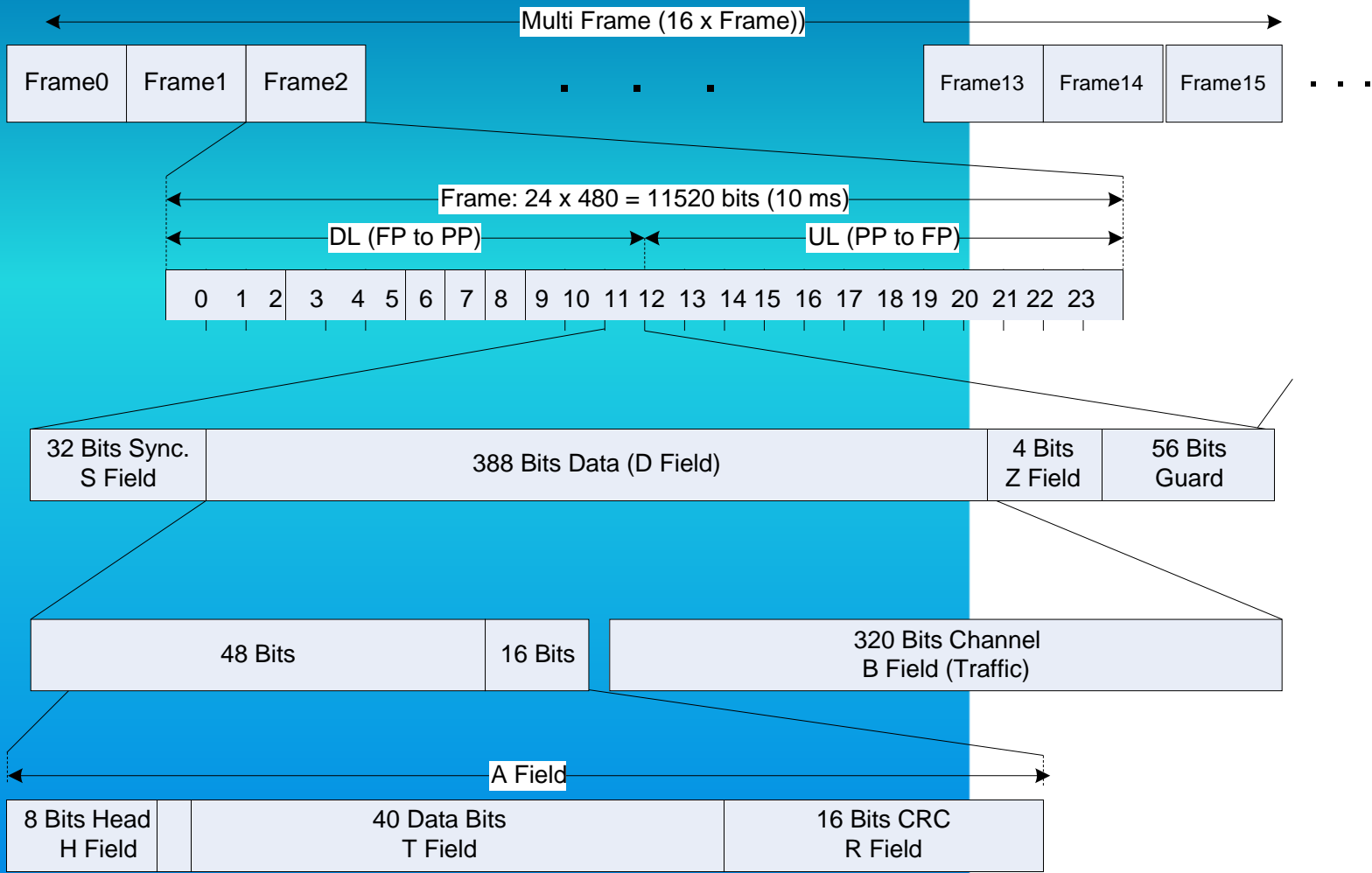
10 ms

Voice: 32 Kb/Sec.

Data: 24 Kb/Sec. (Because of CRC)

DECT System Specifications ...

- DECT (Digital Enhanced Cordless Telecommunication)
- Frequency Band: 1880 to 1900 MHz for 10 Carriers
- Number of Carriers: 10
- Carrier Spacing: 1728 MHz
- Maximum Peak Transmit Power: 250 mW (24 dBm)
- Carrier multiplex: TDMA, 12 Double Slots/ 24 Full Slots/ 48 Half Slots per Frame
- Frame length: 10 ms
- Basic Duplexing: TDD using 2 slots on same RF carrier
- Gross bit rate: 1152 kb/s, 2304 kb/s or 3456 kb/s for 2, 4, 8 level modulation respectively
- Net channel rate: 6, 4 kb/s A-field (Control/ Signaling per slot)
- $F_c = F_0 - C \times 1,728 \text{ MHz}$ where $F_0 = 1897,344 \text{ MHz}$ and $C = 0,1,2,\dots, 9$



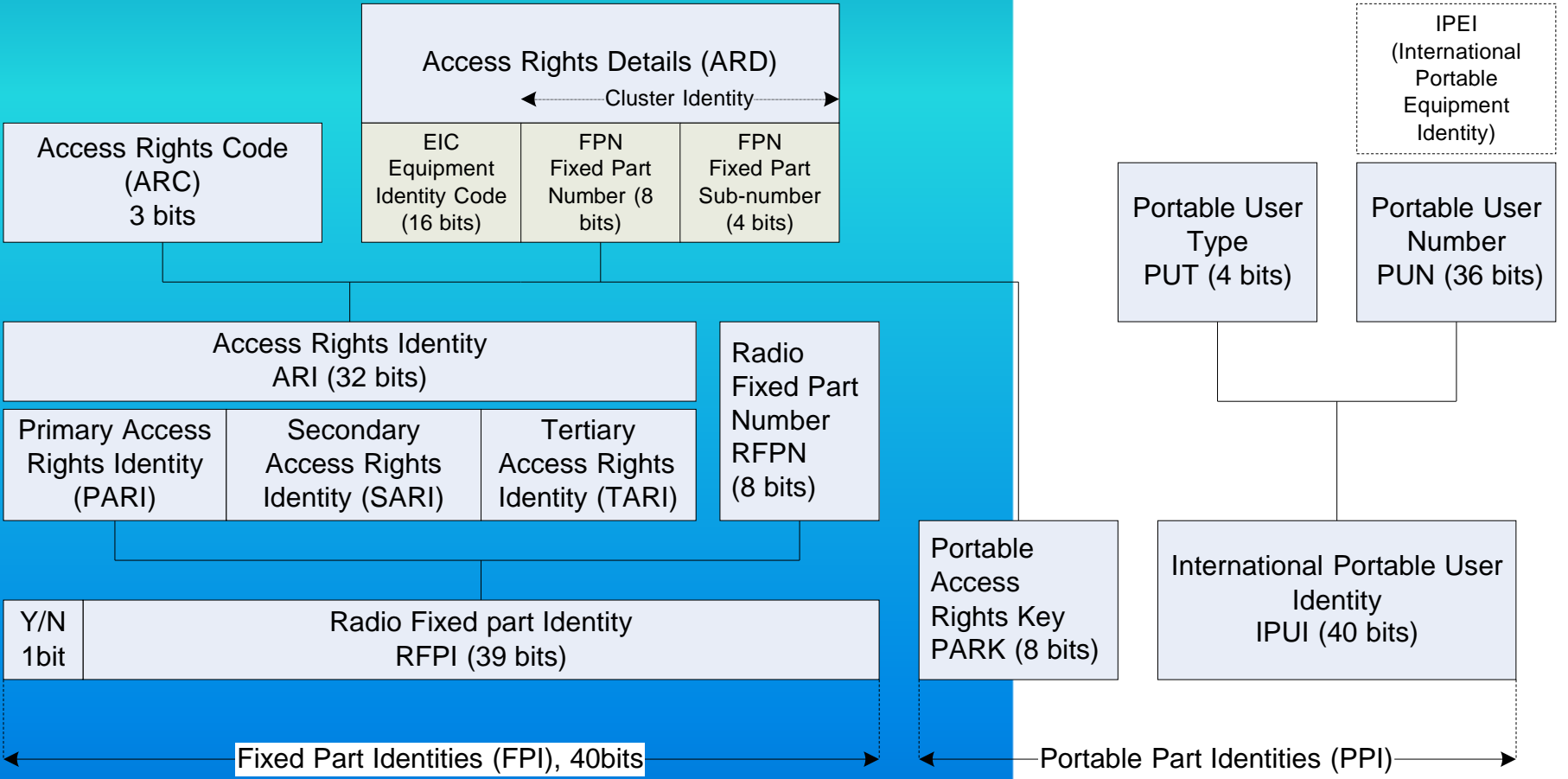
S Field: RFP sends 1010 1010 1010 1010 1110 1001 1000 1010 and PP sends 0101 0101 0101 0101 1110 1001 1000 1010

A Field: Signaling (In NT Channel, it is RFPI, 40 Bits)

B Field: User Data

X Field: Parity Check

Z Field: Optional (Copy of X Field)



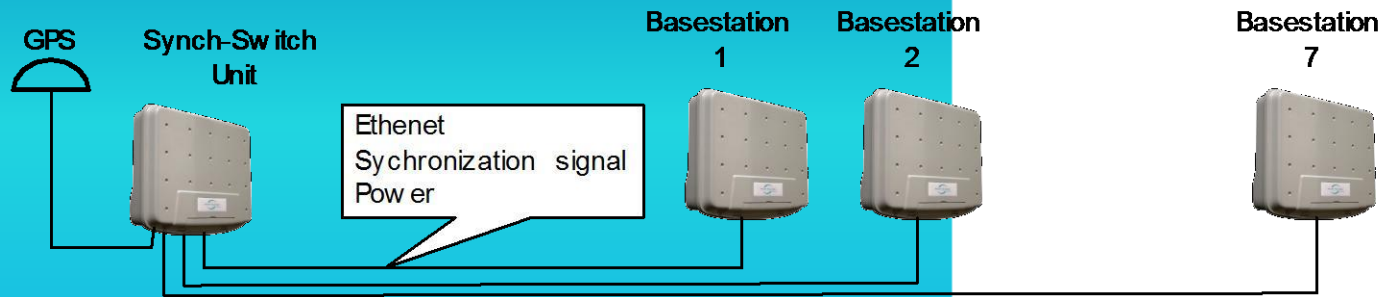
System overview

IP Wireless Network Concept

To offer End-users the possibility of:

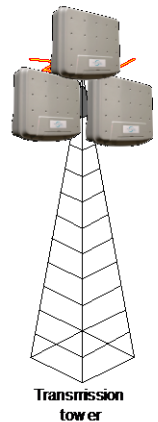
- Making and Receiving Calls and other related services such as SMS
- Data communication (MODEM, Fax and Internet Access)
- Being Mobile within a city (or Region) via a DECT/WLAN network and Over an IP Infrastructure

IP Wireless Rural Cluster

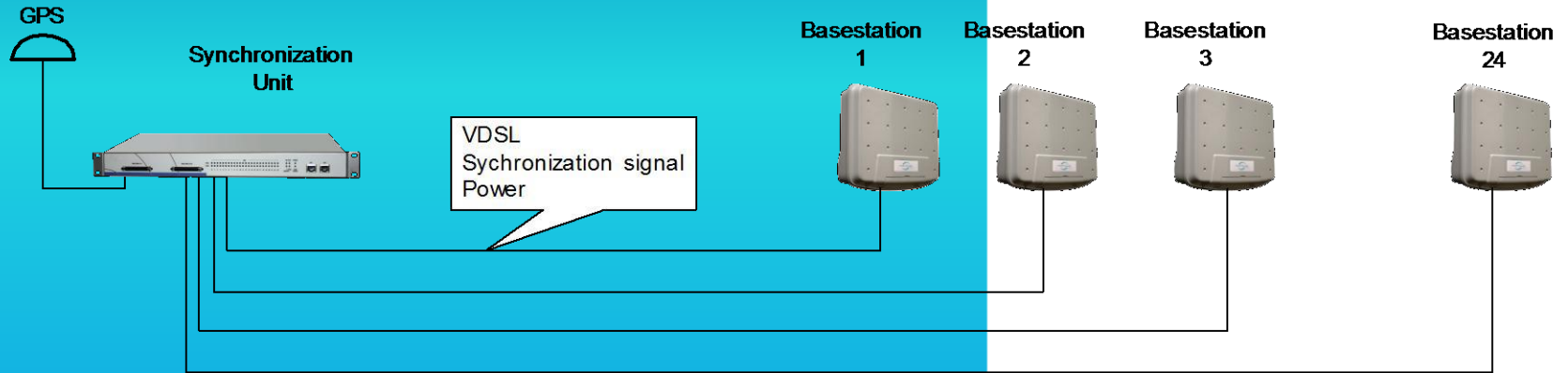


Typical cluster configuration for rural areas:

- Basestations can be feed up 100meter on standard CAT-5 cable
- Basestations are typically installed in a tower covering 60 degree sectors each (6 basestations)
- A Sync-Switch unit is suitable for outdoor installation

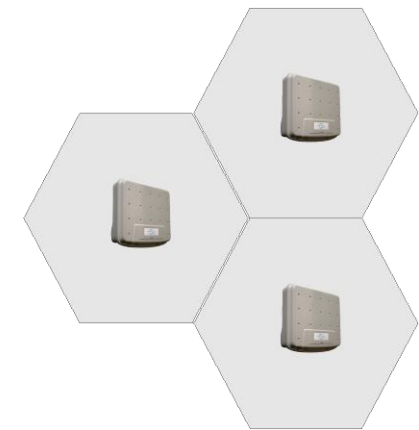


IP Wireless Urban Cluster

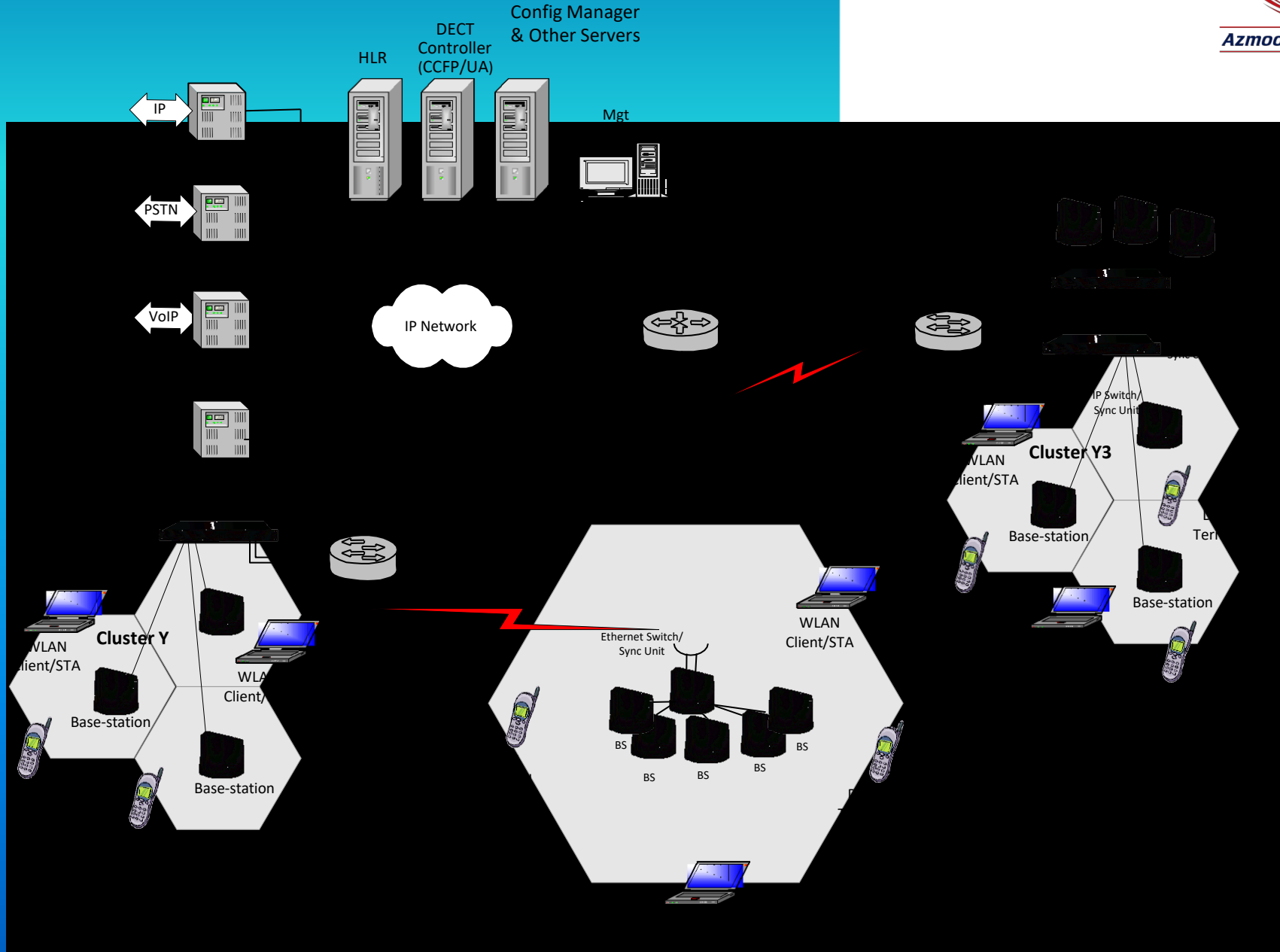


Typical cluster configuration for urban areas:

- Basestations can be installed up 1.5km from Synchronization Unit
- A Synchronization unit is connected to a VDSL switch
- Up to 10 Synchronization Units are stackable in one cluster



System overview . . .



Network Architecture

Network Architecture - Overview

- The IP DECT Network consist of a few servers placed central in the system, typical together with the Soft Switch
- The higher layers of the SW is executed on the servers, CCFP and UA
- UA, User Agent, handling the users, SIP protocol (VoIP protocol), DECT SIP IWU, HLR interfaced and controlling a set of CCFP
- CCFP, Cluster Control Fixed Part, handling the higher layer of the DECT protocol stack
- One Cluster can be up to 256 Cell, a Cell is a base station or a repeater
- On one server, there will be only one 1 UA, a group of CCFP now limited to 250
- One server can handle 18000 simultaneously calls (assumption: call duration 3 min)
- The system can then be scaled by adding new servers for a new UA. The numbers of servers will be unlimited
- Network planning shall be optimized to keep signaling load on a minimum, between Cells and the central placed servers

Handover

Three different types

- In DECT systems there are 3 levels of handovers
 - ✓ Bearer handovers are handled locally by the Base Station, no signaling load between Base Stations and CCFP servers
 - ✓ Connections handovers are handover between Base Stations in the same Cluster, controlled by the central CCFP server.
 - ✓ External handovers are handover between Base Stations in different clusters, controlled by the UA
- Bearer handover is the most efficient way to make handover, require no network traffic
- Connection handover involve only the CCFP in the network, loading the network
- External handover involve UA, old CCFP and new CCFP, loading network and central servers

– Bearer Handover

- Bearer handovers are handled locally by the Base Station, not involving any network signaling
- Used for intra cell handover if there are interferences from other terminals
- Also used for inter cell handover between Base Station and Repeaters
- Bearer handover area is defined for each Base Station
- Such bearer handover areas are formed by a Base Station or a Base Station and the attached repeaters
- The size of the bearer handover area is broadcasted by the Base Station and relayed by the attached repeaters (bearer handover bit mask)
- The number of RPN's in a bearer handover area may be 1, 2, 4, 8, 16, 32, 64, 128 or 256.

– Connections Handover

- Connections handovers are handover between Base Stations in the same Cluster, controlled by the central CCFP server.
- Used for handover when terminals are moving from one cell to another

- External Handover

- External handovers are handover between Base Stations in different clusters
- External handover involves UA, old CCFP and new CCFP, loading network and central servers
- Network shall be planned in a way that reduce external handover, e.g. plan clusters so they are geographical logical

Cell - Bearer Handover Area

- Bearer handover area size = 1 (bearer handover bit mask = 11111111)
- Each RPN value forms its own bearer handover area.
No repeaters to be attached.
- Bearer handover area size = 2 (bearer handover bit mask = 11111110)
- Bearer handover areas: (0,1) (2,3) (4,5) ... (254,255) For each Base Station is only attached one repeater. Ex.: Basestation RPN=0 and repeater RPN=1.
- Bearer handover area size = 4 (bearer handover bit mask = 11111100)
- Bearer handover areas: (0,1,2,3) (4,5,6,7) (8,9,10,11) ... (252,253,254,255)
For each Base Station can be attached up to 3 repeaters.
- The IP DECT configuration tool has functions to facilitate the allocation of RPN values and setup the bearer handover bit mask.

System Features

System Features – DECT (1)

- Compliant with ETSI standard EN 300 175 part 1-8
- Generic Access Profile (GAP)
- Option for synchronization to GPS, increase capacity and reduce interference, recommended in all outdoor installations
- CLIP
- Network information is provided in the terminals
- System Time/Date is provided in the terminals
- Enhanced location registration, configurable
- Emergency call, option to add prefix / replace emergency number, so emergency call can be located on cluster level

System Features – DECT (2)

- Flash dialing, PBX functionality
- Booth pre dialing (GSM alike) and post dialing (PSTN alike)
- Audio encoding: ADPCM or PCM
 - ✓ PCM transmission over the DECT interface (modem, fax...) – V34, V90
 - ✓ Dial up to ISP with 40 kbit/s
- Over air terminal maintenance, including over-the-air (OTA) firmware load
- Supported timeslots: full, double
- MAC connection types: basic, advanced
- Encryption: DSC
- Authentication: DSAA

System Features – DECT (3)

- Support of seamless mobility
 - ✓ mobility within a single DECT cluster
 - ✓ mobility within a group of DECT cells (city-wide roaming)
 - ✓ mobility within all DECT Clusters in the network (nation wide roaming)
- Mobility can be limited/defined per user account
- Timing Advance, increase coverage up to 8 km
- Advanced self check build in the system
 - ✓ Detection of errors in HW components
 - ✓ Detection of Link loss to the Base Stations
 - ✓ Detection of Base Station switching down

System Features – WiFi (1)

- IEEE802.11g compliant
- Multiple SSID up to 4 (released end October), each SSID has it's own configuration, VLAN ID and priority for
- Multiple concurrent clients, configurable up to 64 per base station
- Dynamic and static frequency selection
 - ✓ Dynamic frequency used when physical distance between each access point is relative large (20 m)
 - ✓ Static frequency selection used when more access points are mounted at the same location (tower)
- Antenna diversity
- Access Control - MAC addresses of hosts the WiFi client is allowed to communicate with on the WiFi VLAN, up to 10 MAC addresses per SSID.

System Features – WiFi (2)

Access and authentication

- Open access, no authentication, everybody can connect to the wireless network. No encryption of data supported.
- WEP, Clients can connect using WEP authentication and AP uses WEP encryption for data transfer.
- WPA; Clients can connect using WPA authentication. AP uses TKIP or AES encryption for data transfer. All clients supporting WPA can connect, no key required.
- WPA-PSK, WPA authentication and the pre-shared key. AP uses TKIP or AES encryption for data transfer.
- IEEE 802.1X authentication, data transfer is encrypted using TKIP or AES. IEEE 802.1X is based on RADIUS. RADIUS server and client application handles extensions to 802.1X, independent of the AP implementation.

System Features – WiFi (3)

Encryption

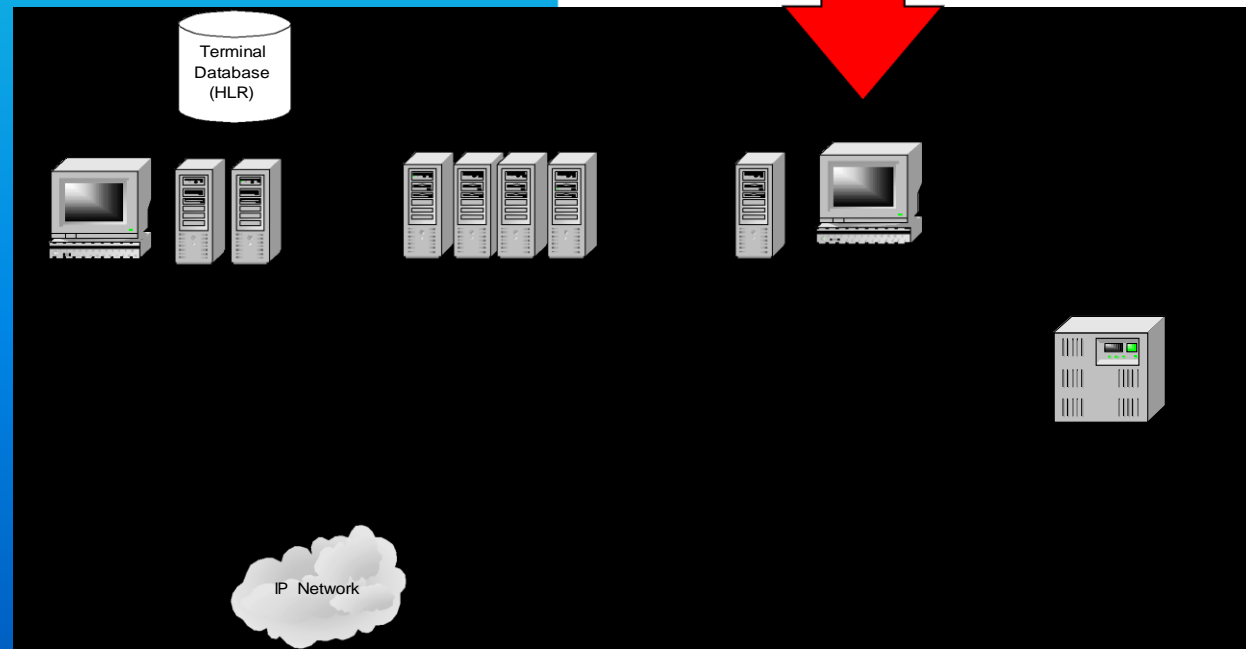
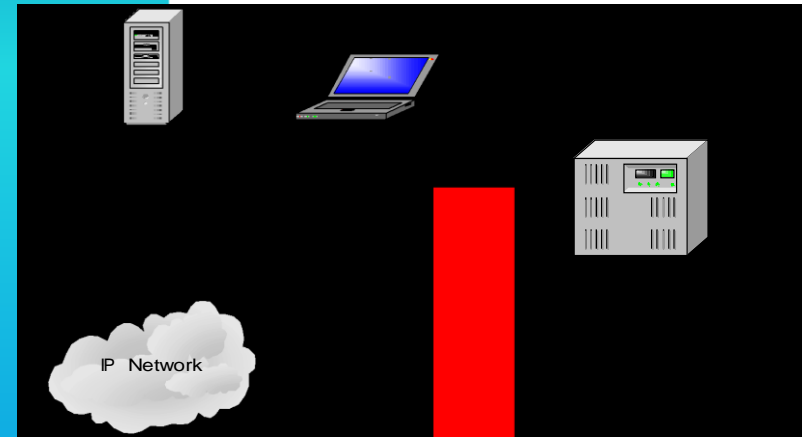
- WEP - Standard 64-bit WEP uses a 40 bit key, which is concatenated to a 24-bit initialization vector (IV) to form the RC4 traffic key. At the time that the original WEP standard was being drafted, U.S. Government export restrictions on cryptographic technology limited the key size.
- TKIP, provides per-packet key mixing, a message integrity check and a rekeying mechanism. TKIP ensures that every data packet is sent with its own unique encryption key.
- AES - the strongest WiFi encryption yet, now considered to be 100% safe. AES has a fixed block size of 128 bits and a key size of 128, 192 or 256 bits. Due to the fixed block size of 128 bits, AES operates on a 4×4 array of bytes, termed the state.

System Features - Managements

- **IP Wireless Configuration Manager.**
 - ✓ Configuration of all network components
 - ✓ Firmware upgrade of all network components
 - ✓ Multi operators with differentiated access rights
- **SNMP manager (3rd party).**
 - ✓ Inspection of detailed SNMP parameters in all network and server elements.
 - ✓ Collections of SNMP traps (alarms)
- **IP Wireless Terminal Manager.**
 - ✓ Monitoring and management of all wireless terminals, including over-air firmware load.
 - ✓ Collections of traffic statistics and logging of traffic events.
 - ✓ Multi operators with differentiated access rights

System Features – scalability

- Scalability from few subscribers to millions of subscribers
- Simple servers setup from no redundancy to full geographical redundancy



Network Structure

DECT Network - overview

- The network is divided into Cluster groups and Clusters
- Cluster group will be typically a city
- The Cluster name shall be unique (32 character), recommended to use city name and area e.g. Goodwood_A1; Goodwood_A2;
- One Cluster can be up to 256 Cell, a Cell is a base station or a repeater
- On one server, there will be only one 1 UA, a group of CCFP now limited to 250
- One server can handle 18000 simultaneous calls (assumption: call duration 3 min)
- The system can then be scaled by adding new servers for a new UA. The numbers of servers will be unlimited
- Network planning shall be optimized to keep signaling load on a minimum, between Cells and the central placed servers

DECT Cluster - Characteristic

- The network is divided into a number of clusters.
- A cluster is a group of DECT cells, which forms an internal handover region.
- A cell is formed by either a Base Station or a repeater.
- When a terminal is inactive (idle locked), it can be moved around between all the cells in a cluster without network communication.
- Paging for incoming calls are sent on all cells in a cluster.
- During established connections, terminals have to do connections handover or bearer handover to move a connection from one cell to another cell.
- When terminals are moved from one cluster to another cluster, they have to perform location registration to inform the network where paging for incoming calls should be sent.
- During an active call, a terminal has to perform external handover to move a call from one cluster to another.

DECT Network Rights

- Each cell is identified by its RFPI (Radio Fixed Part Identity), which consists of PARI (Primary Access Rights Identity) and RPN (Radio Part Number). The PARI again consists of EIC (Equipment Installer Code) and FPN (Fixed Part Number) + FPS (Fixed Part Sub-number).
- The FPN+FPS is effectively the identity of a cluster and has the length of 12 bits
- During DECT access rights procedure all terminals are assigned DECT rights to all clusters in the network (= all PARI's).
- The PARI can be reused, only requirement is that the PARI shall be geographically unique (eg. PARI used in one city can be reused in another)

DECT Network Roaming

- The Roaming limitations are controlled on network application level defined by this information from the HLR. This means roaming rights can be modified in the network (HLR) without requiring any changed configuration inside the terminals.
- The HLR database stores handset related subscription information. The HLR field used to control handset roaming rights, is the **Capabilities** field. Among more features, this field can be used to control in which clusters a terminal has roaming rights, see separate document
- Minimum Roaming area is inside one cluster

WLAN Network

- The WLAN network is more flat architecture
 - ✓ WLAN Access point +
 - ✓ Nomadix / Radius server
- WLAN network is a separate VLAN (DECT and maintenance is untagged and has highest priority)
- WLAN access point control
 - ✓ Access and authentication
- Nomadix / Radius
 - ✓ Bandwidth control for each subscriber
 - ✓ customer acquisition
 - ✓ Provisioning, security and revenue

HW Components

IP DECT Wireless Network Components

➤ **Hardware/Software Based Products:**

- ✓ IP Wireless Base Stations
- ✓ IP Wireless Ethernet Sync/Switch
- ✓ IP Wireless VDSL Sync/Switch
- ✓ Repeaters (outdoor and indoor)
- ✓ WTLU (Wireless Phone Jack)
- ✓ DECT Telephones (portable and desk-top versions)

➤ **Software Based Products:**

- ✓ Configuration and Management Server
- ✓ Terminal Manager Server
- ✓ Home Location Register Server
- ✓ IP Wireless Controller Server

IP DECT Wireless Network Components

Third Party Components:

- Softswitch; 3rd party
- Media Gateway; 3rd party component to interface to other telephone networks (V5.2, ISDN, SS7 Networks)
- SNMP Manager ; 3rd party component to survey the IP network and components
- 48 V Power Supply
- P2P Link SKYWAY 7000

Hardware Components

- IP Wireless Ethernet Sync/Switch
- IP Wireless VDSL Sync/Switch
- IP Wireless Base Station
- 48 V power supply
- P2P Link
- WTLU (Wallset Terminal Line Unit)
- Repeater (indoor and outdoor)
- DECT Desk-top phone
- DECT Handset



IP Wireless VDSL Sync/Switch



IP Wireless Ethernet Sync/Switch



IP Wireless Base Station



DECT Handset(s)



DECT Desk-top phone



WTLU



Repeaters

Ethernet Sync/Switch

Functionality:

- Makes it possible to synchronize a number of base stations to each other (using GPS timing) and provides a common synchronization signal for timing reference
- Includes a 7 port 10/100 Ethernet switch to distribute Ethernet to the Base Stations
- Power distribution to 7 Base Stations (only 6 for outdoor use)
- Remote monitoring of supply current and voltages, ON/OFF control, cluster positions, and cable parameters
- If the GPS receiver is not functional, e.g. when the antenna is blocked from receiving the GPS signals, an internal timing reference will be used to keep the reference timing



Ethernet Sync/Switch

Technical details:

- Voltage: Nom. 48V (42-62V)
- Protection against ESD and short circuits, over-current protection, separate for each line
- The IP Wireless Ethernet Sync/Switch is in a housing similar to the base station and outdoor repeater housing
- GPS Antenna Connector: SMA
- Base Station Interface: 7 x RJ45, Ethernet to system: RJ45
- Mechanical Box is approved according to IP55

VDSL Sync Unit (1)

Functionality:

- A GPS synchronization module provides synchronization signals to DECT base stations to obtain slot, frame, and multi-frame synchronization. This is required to provide DECT inter-cell handover and to maximize DECT system capacity
- Is used as the timing reference in the IP Wireless system
- If a number of VDSL Sync/Switch's are deployed in the same outdoor cabinet they can be linked together through sync. ports, i.e. only one of the VDSL Sync/Switch's needs to get a GPS signal
- If the GPS antennas are blocked from receiving the GPS signals, an internal timing reference will be used to keep all VDSL Sync Units at a common timing reference. The loss of GPS signals can be monitored remotely

VDSL Sync Unit (2)

Functionality:

- VDSL Sync/Switch's with GPS information can be replaced without changes in configuration database
- The VDSL Sync/Switch has 24 sync. ports for control of up to 24 Base Stations. The Sync ports have 3 functions:
 - ✓ To provide a common synchronization signal for timing reference,
 - ✓ Automatic cable delay measurement, allowing adjustment of the timing according to the cable length used, and
 - ✓ Power feed to the base stations, incl. ON/OFF control and remote monitoring of supply current and voltages

VDSL Sync Unit

Technical details:

- Input voltage: min. 42V, max. 62V
- Input power: max. 70W + 12W per Base Station
- The VDSL Sync/Switch will internally convert the input voltage to an output voltage of approx. 72V (Max. 1.5km cable length)
- Individual control of ON/OFF through remote commands
- Protection against ESD, short circuits, and over-current protection, separate for each line
- The VDSL Sync Unit is housed in a 19" rack mount box, height 1U
- GPS Antenna connector: SMA on the rear. Power input: 42V - 62V on rear. Sync. ports: 1 x DB68.
- VDSL in: 1 x DB68. VDSL out: 1 x DB68. Ethernet on the front: RJ45 Sync ports on rear: 2 x RJ45



Base Station

Functionality:

- Provides DECT coverage in one DECT cell
- Can terminate media streams encoded as G.711, G.726 or G.729 AB
- The IP network interface is VDSL or Ethernet based
- Can be supplied with power either locally or remotely over twisted pair interface/ Ethernet interface
- Also referred to as Radio Fixed Part (RFP)
- Handles connections to the PSTN network (Through Media Gateway) or handsets in other areas
- Handles data connections (DECT voice will have priority over data)
- 11 active DECT connections per base station (one spare for handover)
- Mini-PCI slot for WiFi card

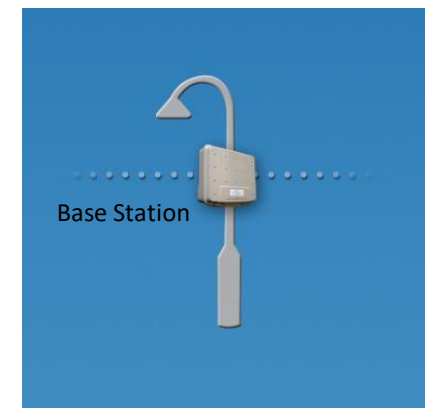




Base Station

Technical Details:

- Power: max. 7.8 W with WiFi + loss in cables (VDSL mode)
- Power: max. 5.2 W with WiFi (Ethernet mode)
- Voltage: nom. 72V feeding voltage (VDSL), nom. 48V feeding voltage (Ethernet)
- Housing is IP55 approved
- Internal antennas, including Directional Antenna (10dB gain)
- Antenna connectors for external antennas via external antenna module
- Ethernet: RJ45 with power feed via connections not used for Ethernet
- VDSL: 4 pin male connector, 5 mm pitch



WTLU

Functionality:

- WTLU: Wireless Telephone Line Extension Unit
- Wireless telephone line replacement
- Supports both voice and modem/fax
- Firmware update over the air

Technical details:

- High-speed analogue modem V.34 and V.90
- PSTN line interface (line current for telephone/fax/modem)
- Connector: RJ11 plug
- Dimension: 95 x 60 x 75 mm
- Power: 110 and 230 V versions are available
- (plugs directly into power outlet)



DECT Repeaters

Functionality:

- The Repeater is used to extend the range of DECT (in all directions)
- Seamless handover between Repeaters included
- Two products are offered Indoor Repeater and Outdoor Repeater
- Indoor Repeater:
 - ✓ 6 slot design, 2 active simultaneous connections
 - ✓ 2 internal diversity antennas + 1 internal directional antenna (6 dB gain)
- Outdoor Repeater:
 - ✓ 12 slot design, allowing 5 active simultaneous connections
 - ✓ 2 internal diversity antennas + 1 internal directional antenna (10dB gain)
- Firmware update over the air



Technical details:

- ✓ Range: Up to 1 km (indoor repeater) and 8 km (outdoor repeater with Timing Advance)
- ✓ Back-up battery (outdoor repeater)

Internal Repeater

Technical details:

- Range: Up to 1 km (indoor repeater) with Timing Advance
- Back-up battery (outdoor repeater)
- Low power consumption
- Frequency band: 1880MHz - 1900MHz
- Transmit power: 240mW (+24dBm). Receiver Sensitivity:
<-92 dBm at 10⁻³ BER
- Up to 6 repeaters per base station.
- 2 internal antennas
- SMA connector for an external directional antenna
- Designed in accordance with the (DECT) standard.
- The DECT Repeater is compliant with:
TBR6, TBR22 (Generic Access Profile, GAP), ETS 300 700 - ETSI Wireless Relay Station Specification



Software Components

Software Components:

- IP Wireless Controller Server
- IP Wireless HLR Server
- Maintenance Software
 - ✓ IP Wireless Configuration & Management Server
 - ✓ SNMP tool
 - ✓ Terminal Manager Server

IP Wireless Controller

Functionality:

- A dedicated PC with an IP interface (Ethernet) to control a group of Base Stations.
- The DECT Controller consists of one User Agent and up to 250 CCFPs
- One DECT Controller per up to 3,600 Base stations/40,000 users

Technical Details:

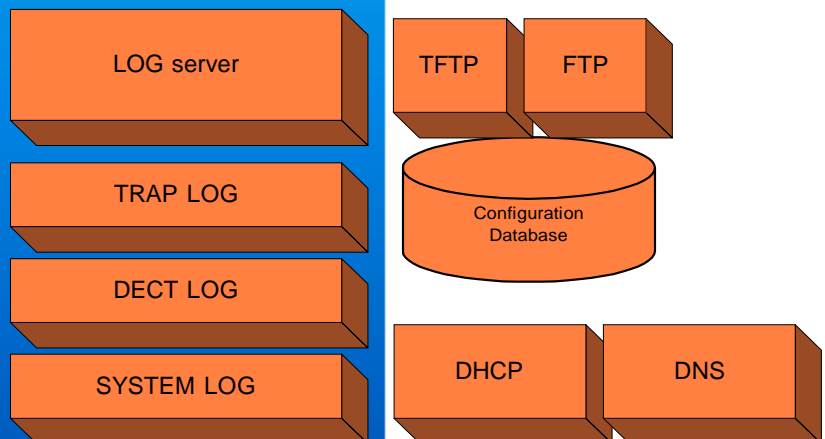
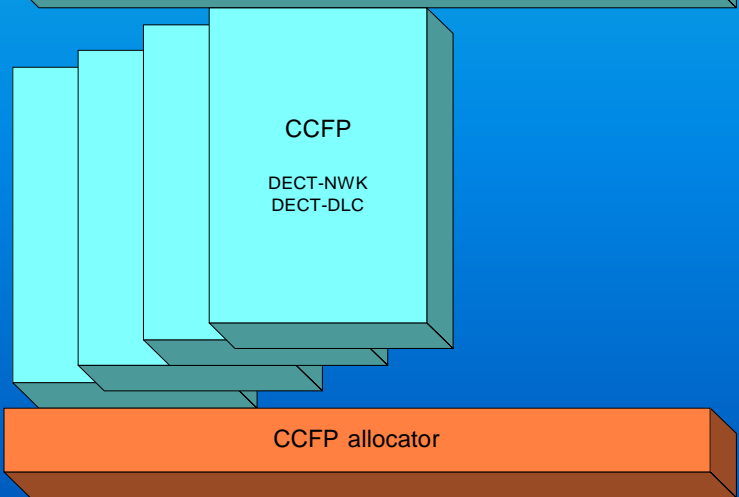
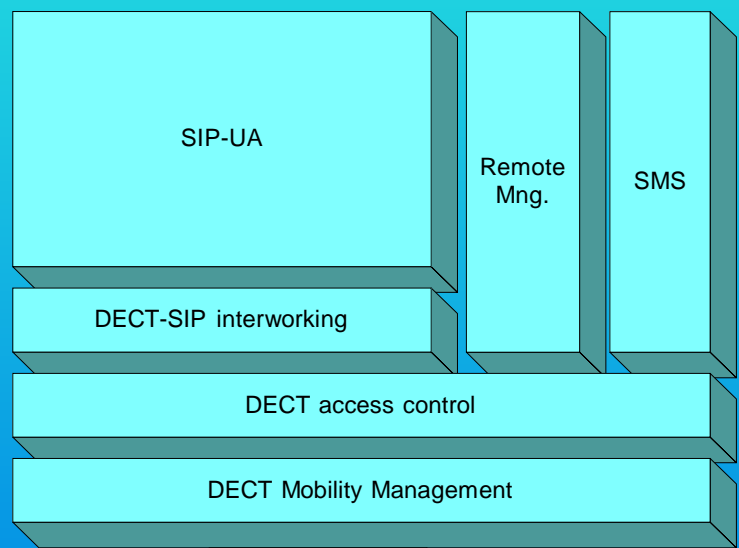
- Controls the Call Processing:
 - Call set-up and Call release,
 - Digits analysis
 - Handover procedure
- Registration, Authentication, Detach, Identity, Encryption activated, and Access Right Termination
- SIP based interface towards the softswitch
- Proprietary IP based interface towards the base stations

IP Wireless Controller

Functionality:

- IP address assignment (DHCP) to Synchronization Units and BSs
- Configuration of network elements (Synchronization Units, BSs and Servers) via configuration files stored on TFTP database
- SIP User Agent functionality
- DECT DLC/NWK protocol layers
- SIP / DECT call control interworking
- SMS receive/transmit
- Mobility, media stream management
- Network event logging
- Traffic event logging and performance monitoring
- Terminal equipment information and status
- Network and terminal surveillance
- Terminal maintenance, over-air firmware updates

Server components

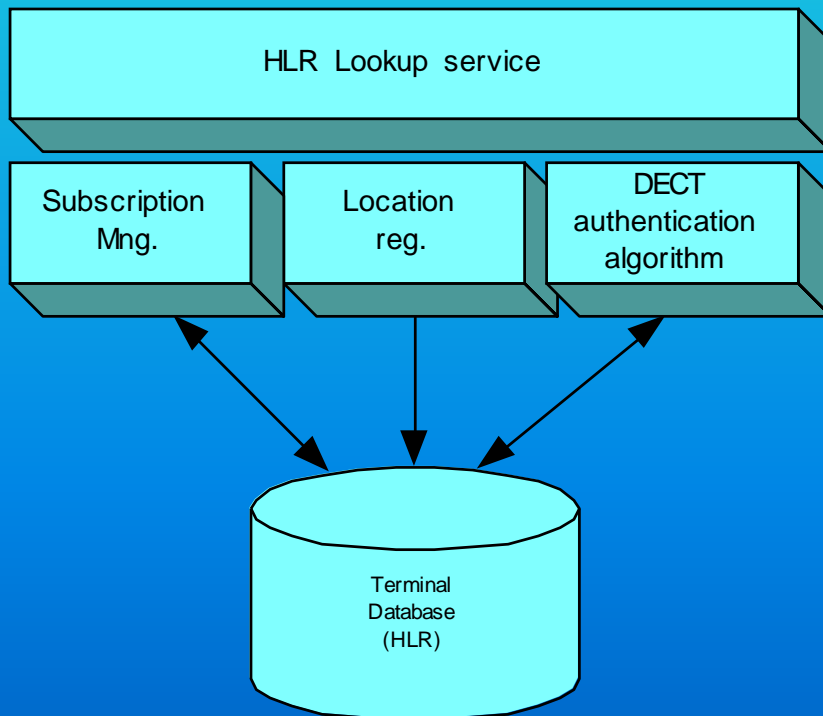


HLR server

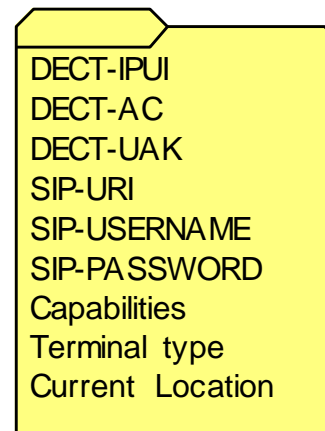
Functionality

- Subscription database
- Terminal authentication
- Binding DECT identities and SIP identities
- Controlling subscription capabilities

Server components



Terminal subscription record



Radio Planning Overview

Tower Setup Specification



Item	Capacity	Subscriber	No. of E		
BS	5.8 Elang @ 2% GoS	116 @ 50mE			
Outdoor Repeater	5 Simultaneous Calls	-			
Indoor Repeater	2 Simultaneous Calls	-			

BS to Terminal (HS) Coverage

LOS (Line Of Sight)				
300 – 400 meter				

BS to Repeater Coverage with different to

Repeater Tower (Meter)	BS (Base Station)				
	12	22			
2	0.8 Km	1.6 Km			
4	1.6 Km	3.2 Km			
6	2.4 Km	4.8 Km			
8	3.2 Km	6.4 Km			

Tower coverage / Subscriber profile

DECT		Total
No. of Subscribers	500	
Coverage area (cell size radius 1km)	3.14 km ²	
Traffic per subscriber	0.05 Erlang	25 Erlang
Numbers of subscribers per tower	2*100 Kbit/s	
WiFi		
Ratio of WiFi subscribers	0.7	350 sub.
On time ratio	0.2	
Total numbers of subscribers online	500*0.7*0.2	70 sub.
Bandwidth pr subscriber (UL +DL)	0.5 Mbit/sec	
Overselling factor	4	

IP DECT Radio Planning

DECT Traffic Capacity

DECT		Total
Numbers of subscribers per tower	500	
Coverage area (cell size radius 1km)	3.14 km ²	
Traffic per subscriber	0.05 Erlang (500*0.05)	25 Erlang
Required BW per Voice channel (UL+DL) (G711)	2*100 Kbit/s	

DECT Capacity – Tower Base Station

- Each tower has 6 DECT base stations with 11 channels, total 55 channels, total 55,3 Erlang / 1106 subscribers.
 - ✓ It is not the case in Real Installations
- One base Station has 11 channels, 5.8 Erlang. Total of $6 \times 5.8 = 34.8$ Erlang or 696 subscribers.
 - ✓ It is better in Real Installations as Subscribers should see more than one Base Station
- The fact that the subscribers are mobile will increase the capacity requirements, more subscribers can be in the same area of the cell and therefore higher traffic capacity can be required in a sector of the cell
- Based on the assumptions the maximum traffic capacity is estimated to be 34.8 erlang / 696 subscribers per tower

DECT Capacity – Tower Repeater

- Each outdoor repeater has a capacity of 4 simultaneously channels, 1.1 Erlang (assumption the subscriber can only see one repeater)
- If all subscribers should use repeaters – worst case – it will require:
 - $500 \times 0.05 = 25$ Erlang or $25/1.1 = 23$ repeaters
- One repeater capacity is – 1.1 erlang: $1.1 / 0.05 = 22$ subscribers
- Repeaters will not run in capacity limitation, the required repeaters is determined of the coverage requirements, not capacity

DECT Coverage Strategy

- Direct coverage from the base stations in the tower in the inner coverage zone (400 meters from base station)
- Outside the inner coverage zone, outdoor repeaters shall be mounted to secure coverage
- In special cases with large buildings indoor repeaters can be added at the subscribers Premises

DECT Link Budget



DECT link budget	Indoor terminal	Indoor		
TX power	24 dBm			
Base Station antenna	10 dBi			
RX antenna	0 dBi			
Receiver sensitivity	-90 dBm			
Fade margin	-10 dB			
Indoor	-20 dB			
Link Budget	94 dB			
Range	630 m			

DECT Radio Propagation

udget

	6 slot Repeater		
Output Power	24 dBm		
Antenna gain, Base Station	+ 10 dB		
Antenna gain, Repeater	+ 6 dB		
Receiver sensitivity	- (- 90) dBm		
Margin (weather condition, etc.)	- 10 dB		
Interference margin	- 0 dB (10 dB)		
Link Budget Total	120 dB (110 dB)		

- The DECT link level budget is 120 dB for 6 slot repeater and 124 dB for 12 slot repeater – using the Build-in Patch Antennas

Free Space Loss

- Free Space Loss, Loss of power over distance assuming nothing in the way. LOS (Line Of Sight) condition
- This a very idealized calculation and in practice everything interferes with the signal but it will give a reasonable approximation of the actual loss over distance.
- The theoretical free space loss as a function of distance is shown in the table below

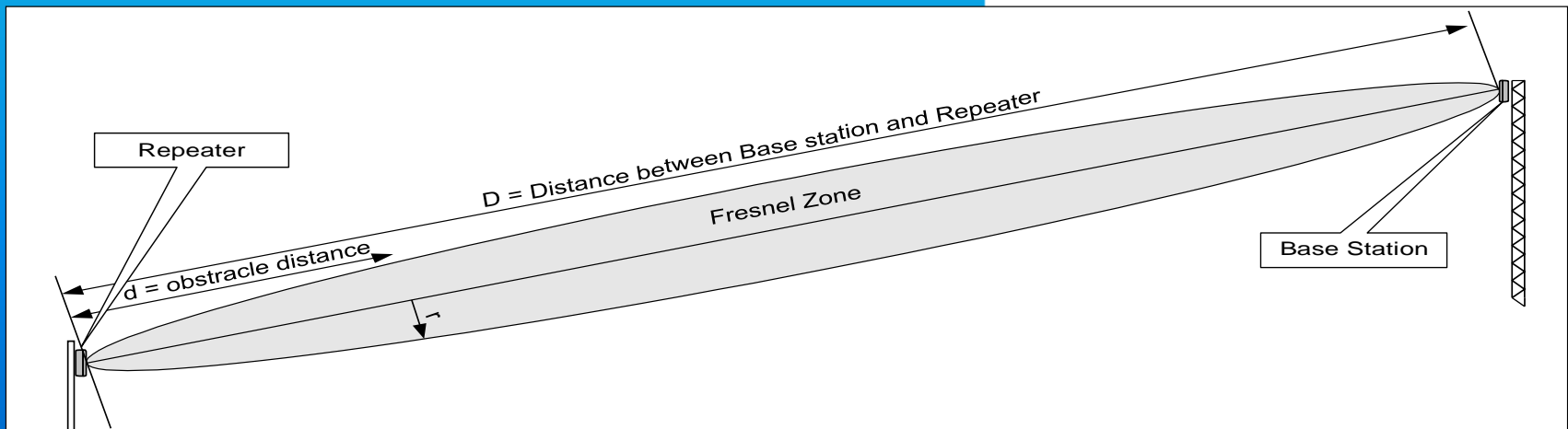
Distance	0,5 km	1 km	2 km			
Theoretical Free Space Loss	92 dB	98 dB	104 dB			

RF LoS (Line Of Sight)

Installation for Repeaters

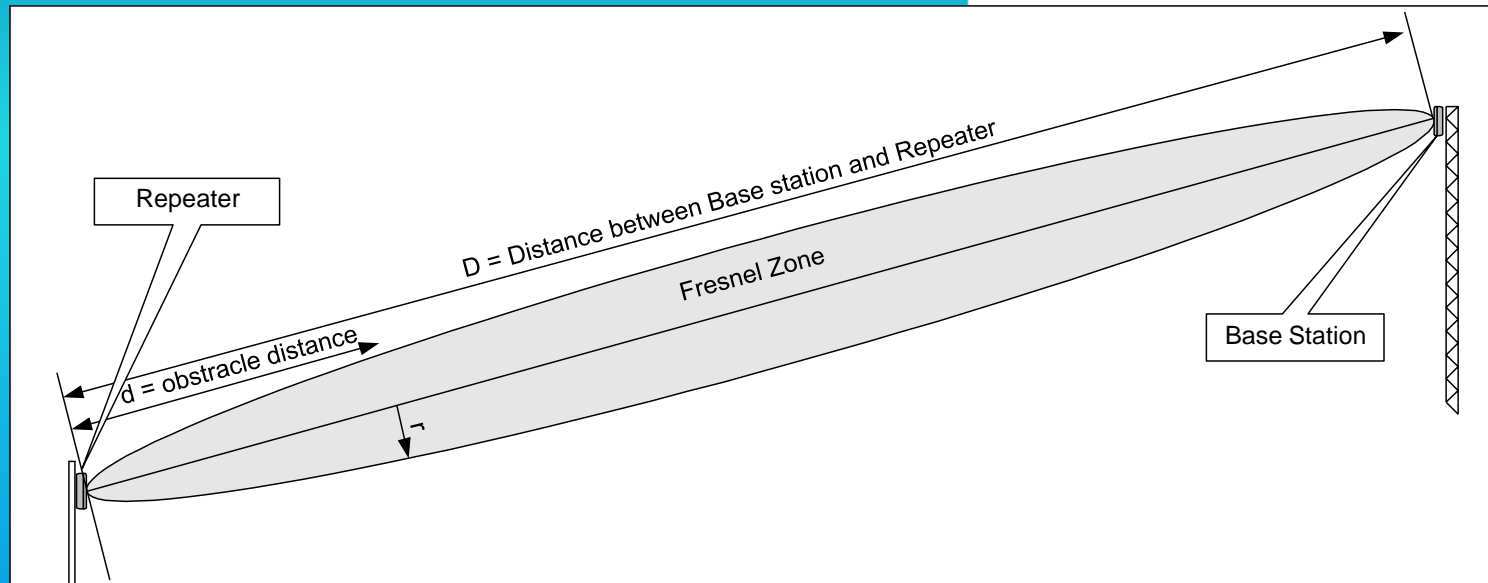
Line-of-Sight (LoS) Conditions

- A radio modem system must be installed such that true RF Line-of-Sight (LOS) conditions exist between the transmitting and receiving antennas.
- RF LOS requires not only a visual sight line between the antennas but it also requires that a football shaped area between the two antennas be free of obstructions.
- This football shaped area is called the Fresnel Zone



Line-of-Sight (LoS) Conditions

- The Fresnel zone is an area that is larger in diameter at the center and smaller in diameter at either end. Also, the greater the distance between the antennas, the larger the diameter of the Fresnel zone in the center.
- Any obstructions that enter into the Fresnel zone will reduce the communication range; including buildings, vegetation, the ground, etc.



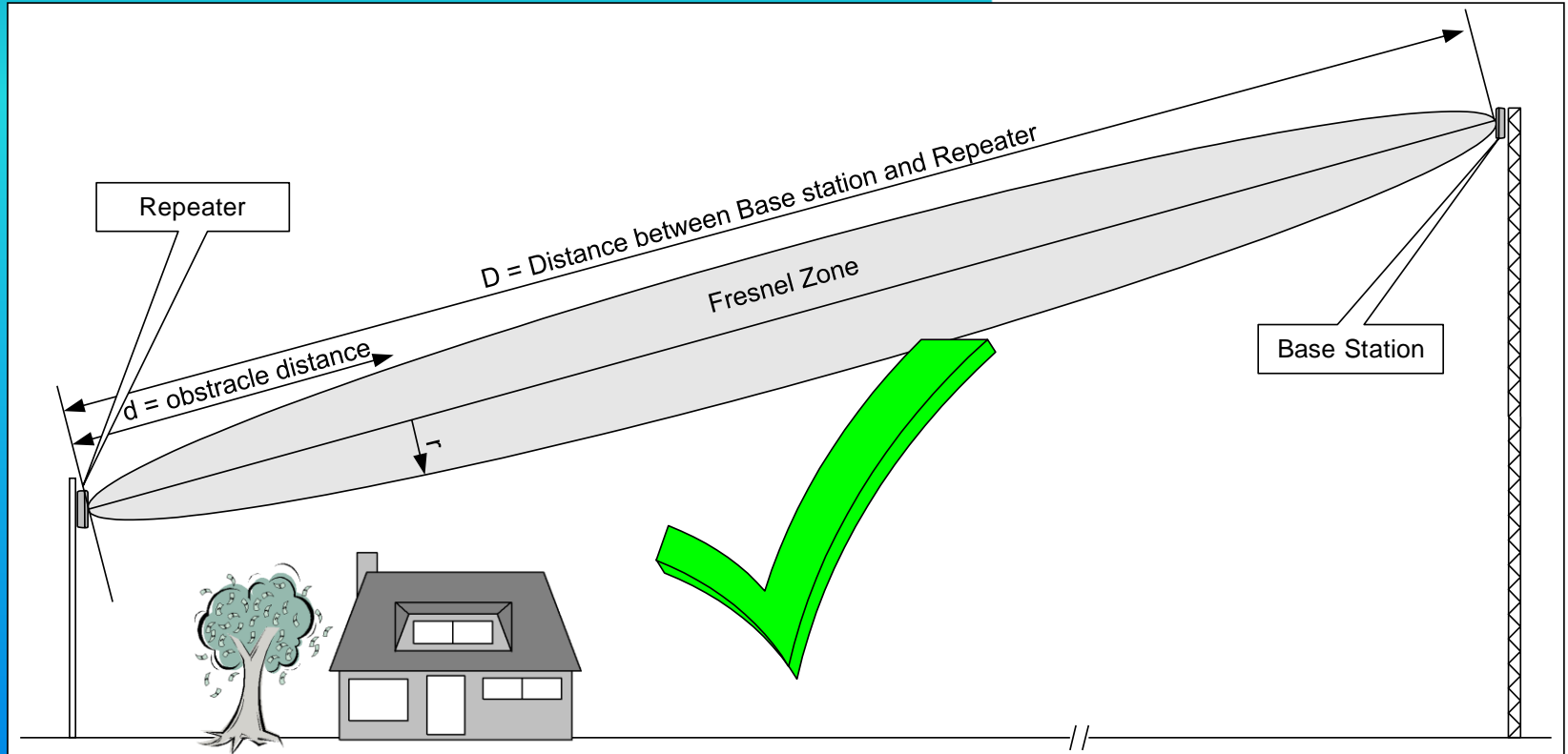
D	8 km	8 km	8 km	8 km	8 km	8 km	8 km	8 km	8 km	8 km
d	0,01 km	0,05 km	0,1 km	0,2 km	0,5 km	1, km	2, km	3, km	4, km	
r	1,3 m	2,8 m	3,9 m	5,5 m	8,6 m	11,7 m	15,4 m	17,2 m	17,7 m	
r 0,8	1, m	2,2 m	3,2 m	4,4 m	6,9 m	9,4 m	12,3 m	13,7 m	14,2 m	
r 0,6	0,8 m	1,7 m	2,4 m	3,3 m	5,2 m	7, m	9,2 m	10,3 m	10,6 m	

- The first zone (r in the table) must be kept largely free from obstructions to avoid interfering with the radio reception.
- Some obstruction of the Fresnel zones can often be tolerated, as a rule of thumb the maximum obstruction allowable is 40% (r 0,6), but the recommended obstruction is 20% (r 0,8) or less.

- The diameter of the Fresnel zone is a function of the frequency and the distance between the antennas, below table for DECT frequency band and different distances, 4, 8 and 10 km

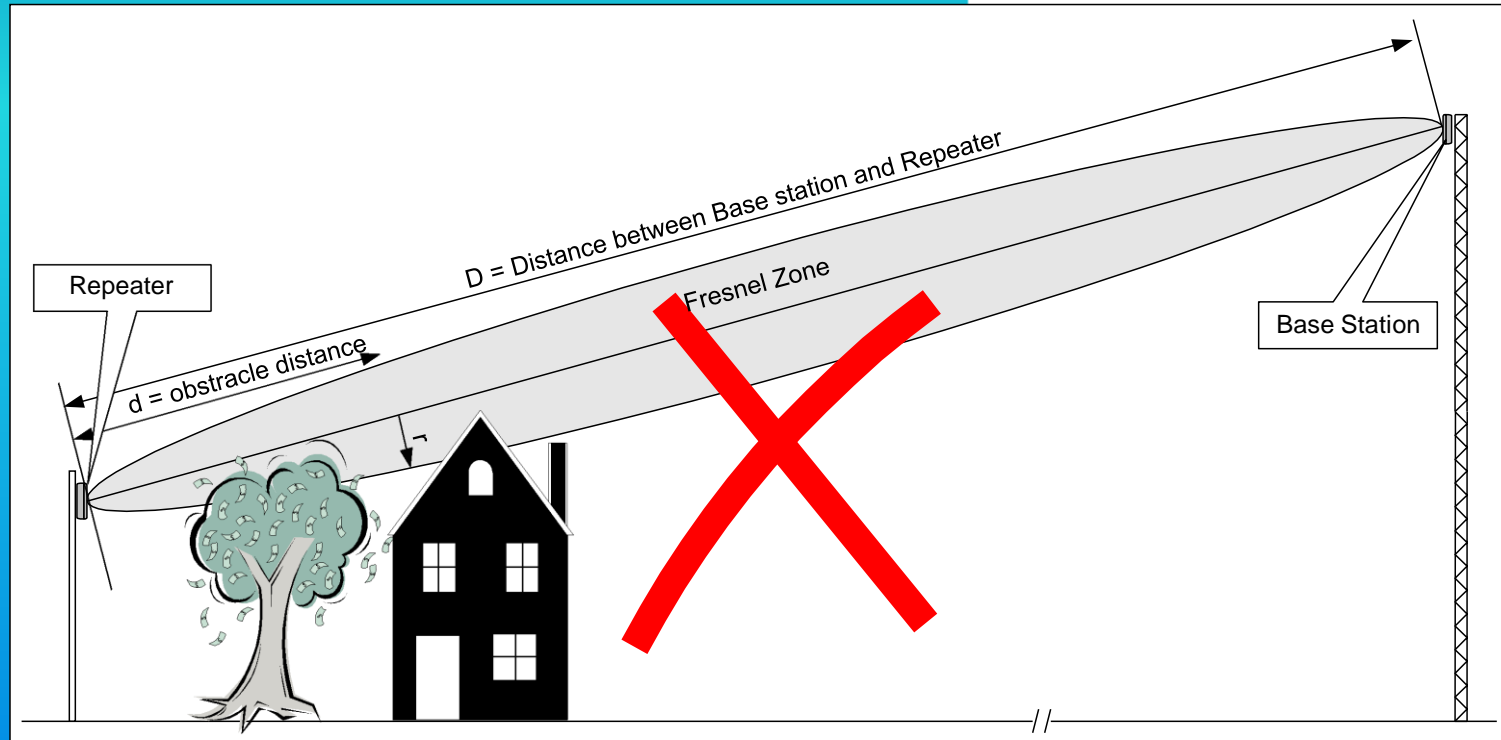
D	10 km	10 km	10 km	10 km	10 km	10 km	10 km	10 km	10 km	10 km
d	0,01 km	0,05 km	0,1 km	0,2 km	0,5 km	1, km	2, km	3, km	4, km	5, km
r	1,3 m	2,8 m	3,9 m	5,6 m	8,7 m	11,9 m	15,9 m	18,2 m	19,4 m	19,8 m
r 0,8	1, m	2,2 m	3,2 m	4,4 m	6,9 m	9,5 m	12,7 m	14,6 m	15,6 m	15,9 m
r 0,6	0,8 m	1,7 m	2,4 m	3,3 m	5,2 m	7,1 m	9,5 m	10,9 m	11,7 m	11,9 m
D	8 km	8 km	8 km	8 km	8 km	8 km	8 km	8 km	8 km	8 km
d	0,01 km	0,05 km	0,1 km	0,2 km	0,5 km	1, km	2, km	3, km	4, km	
r	1,3 m	2,8 m	3,9 m	5,5 m	8,6 m	11,7 m	15,4 m	17,2 m	17,7 m	
r 0,8	1, m	2,2 m	3,2 m	4,4 m	6,9 m	9,4 m	12,3 m	13,7 m	14,2 m	
r 0,6	0,8 m	1,7 m	2,4 m	3,3 m	5,2 m	7, m	9,2 m	10,3 m	10,6 m	
D	4 km	4 km	4 km	4 km	4 km	4 km	4 km	4 km		
d	0,01 km	0,05 km	0,1 km	0,2 km	0,5 km	1, km	2, km			
r	1,3 m	2,8 m	3,9 m	5,5 m	8,3 m	10,9 m	12,6 m			
r 0,8	1, m	2,2 m	3,1 m	4,4 m	6,6 m	8,7 m	10, m			
r 0,6	0,8 m	1,7 m	2,4 m	3,3 m	5, m	6,5 m	7,5 m			

Fresnel Zone – OK installation



- ✓ All buildings, trees ect is clear of the Fresnel zone

Fresnel Zone – Bad installation



- Building and trees in the fresnel zone
- Half of the Fresnel zone shadowed with obstruction will reduce the power with 10-20 dB (reduce coverage from 10 km to between 1 to 3 km)

WLAN Radio Planning

WLAN – Traffic load



DECT				
	Number of subscribers	500		
WiFi				
	Ratio of WiFi subscribers	0.7	Total	
	On time ratio	0.2		
	Total numbers of subscribers online	70		
	Bandwidth pr subscriber (UL +DL)	0.5		
	Bandwith requirement with out overselling factor	70*		
	Bandwith requirement with overselling factor 4	35/4		
Total bandwidth requirement (UL+DL) / Acces				

WLAN Traffic

Settings:

- Access point set to maximum 32 clients (can be increased up to 64 clients)

WLAN link Budget

WLAN Link Budget	Senao USB dongle		Senao USB W			
Band-Width	54Mbit	12 Mbit	54Mbit			
TX power (Atheros)	19 dBm	22 dBm	19 dBm			
Loss filters+ cables	-5 dB	-5 dB	-5 dB			
TX antenna gain	17 dBi	17 dBi	17 dBi			
RX antenna gain	0 dBi	0 dBi	0 dBi			
Receiver sensitivity	-74 dBm	-88 dBm	-74 dBm			
Fade Margin	-10 dB	-10 dB	-10 dB			
Indoor	-20 dB	-20 dB	-10 dB			
Link Budget	75 dB	92 dB	85 dB			
Range	55 m	388 m	173 m			

WLAN coverage strategy

- For client near the access point:
 - ✓ Use WLAN in Laptop
 - ✓ Or used Senao dongle

- If not possible
 - ✓ Use Senao dongle at the window

- If not possible
 - ✓ Use outdoor unit or connect outdoor directional antenna to Senao dongle

- Directional antenna on the client side will reduce the interference in the system

WLAN – Interference

- Careful radio planning is required for the WLAN
- WLAN is asymmetric and not synchronized so one P2P link transmit, when another receive => require high isolation between the links:
 - ✓ Physical separation – 20 meters is required if channel filters is not used
 - ✓ Frequency separation
 - ✓ Use directional antennas with low gain backwards
 - ✓ Add filters in the tower to reduce interference for neighbor channels