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Foreword

This ETSI Technical Report (ETR) has been produced by the Radio Equipment and Systems (RES) Technical Committee of the European Telecommunications Standards Institute (ETSI).

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1 Scope

This ETR describes applications of the Digital European Cordless Telecommunications (DECT) Wireless Relay Stations (WRS). A WRS has the function of an Radio Fixed Part (RFP) that needs no wired connection to the Fixed radio Termination (FT). It is suitable for the provision of cost effective infrastructures for low traffic density applications.

This ETR presents application examples, and discusses related cost, quality, traffic capacity and spectrum efficiency aspects.

2 References

This ETR incorporates by dated and undated reference, provisions from other publications. These references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this ETR only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

[1] ETS 300 175-1: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT); Common Interface (CI); Part 1: Overview".

[2] ETS 300 175-2: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT); Common Interface (CI); Part 2: Physical Layer (PHL)".

[3] ETS 300 175-3: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT); Common Interface (CI); Part 3: Medium Access Control (MAC) layer".

[4] ETS 300 175-4: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT); Common Interface (CI); Part 4: Data Link Control (DLC) layer".

[5] ETS 300 175-5: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT); Common Interface (CI); Part 5: Network (NWK) layer".

[6] ETS 300 175-6: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT); Common Interface (CI); Part 6: Identities and addressing".

[7] ETS 300 175-7: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT); Common Interface (CI); Part 7: Security features".

[8] ETS 300 175-8: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT); Common Interface (CI); Part 8: Speech coding and transmission".

[9] I-ETS 300 176: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT); Approval test specification".

[10] TBR 6: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT); General terminal attachment requirements".

[11] TBR 10: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT); General terminal attachment requirements: telephony applications".

[12] ETR 015: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT); Reference document".

[13] ETR 043: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT) Common interface Services and Facilities requirements specification".

[14] ETR 056: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT) System description document".

[15] ETS 300 444: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT); Generic Access Profile (GAP)".

[16] ETS 300 700: "Radio Equipment and Systems (RES); Digital European Cordless Telecommunications (DECT): Wireless Relay Station (WRS)".

3 Definitions, and abbreviations

3.1 Definitions

For the purposes of this ETR, the following definitions apply:

Cordless Radio Fixed Part (CRFP): A Wireless relay station (WRS) that provides independent bearer control to a PT and FT for relayed connections.

Fixed Part (DECT Fixed Part) (FP): A physical grouping that contains all of the elements in the DECT network between the local network and the DECT air interface.

NOTE 1: A DECT FP contains the logical elements of at least one FT, plus additional implementation specific elements.

Fixed radio Termination (FT): A logical group of functions that contains all of the DECT processes and procedures on the fixed side of the DECT air interface.

NOTE 2: A FT only includes elements that are defined in the DECT CI standard. This includes radio transmission elements together with a selection of layer 2 and layer 3 elements.

Portable Part (DECT Portable Part) (PP): A physical grouping that contains all elements between the user and the DECT air interface. PP is a generic term that may describe one or several physical pieces.

NOTE 3: A DECT PP is logically divided into one PT plus one or more PAs.

Portable radio Termination (PT): A logical group of functions that contains all of the DECT processes and procedures on the portable side of the DECT air interface.

NOTE 4: A PT only includes elements that are defined in the DECT CI standard. This includes radio transmission elements (layer 1) together with a selection of layer 2 and layer 3 elements.

Radio Fixed Part (RFP): One physical sub-group of a FP that contains all the radio end points (one or more) that are connected to a single system of antennas.

REpeater Part (REP): A WRS which relay the information within the half frame time interval.

Wireless Relay Station (WRS): A physical grouping that combines elements of both PTs and FTs to relay information on a physical channel from one DECT termination to a physical channel for another DECT termination.

NOTE 5: The DECT termination can be a PT or an FT or another WRS.

3.2 Abbreviations

For the purposes of this ETR, the following abbreviations apply:

ADPCM	ADaptive Pulse Code Modulation
CRFP	Cordless Radio Fixed Part
DECT	Digital European Cordless Telecommunications
FP	Fixed Part
FT	Fixed radio Termination
PP	Portable Part
PT	Portable radio Termination
REP	REpeater Part
RFP	Radio Fixed Part
WRS	Wireless Relay Station

4 Introduction

4.1 General

This ETR describes applications of the DECT WRS as defined in ETS 300 700 [16]. WRSs are an additional building block for the DECT fixed network. A WRS has the function of an RFP that needs no wired connection to the FT. It is suitable to provide cost effective infrastructures for low traffic density applications.

The WRS is a physical grouping that contains both FT and PT elements, and that transfers information between an RFP and a PP. The FT element acts towards a PP exactly as an ordinary RFP. The PT element acts like a PP towards the RFP, and is locked to the closest RFP. The WRS contains interworking between its FT and its PT, including transparent transfer of the higher layer DECT services. WRS links may be cascaded.

Compared to an RFP, a WRS may introduce capacity restrictions to the services offered. The restrictions may increase with the number of cascaded WRS links. Single WRS link applications can be generally applied.

Special precautions are however needed when applying cascaded WRS links. The capacity may be too low or there may be a need to adjust the echo control requirements. The maximum number of cascaded links is automatically controlled by setting the maximum number of hops in a broadcast message from the FT. The number of hops should be no more than one. Use of more than one hop may be subject to agreement with national radio authorities.

A WRS has to comply with the general FT identities requirements for RFPs. Installing or adding a WRS to a DECT infrastructure is not possible outside the control of the system operator and/or system installer and/or system owner, who provides the required system identities, access rights and authentication/encryption keys.

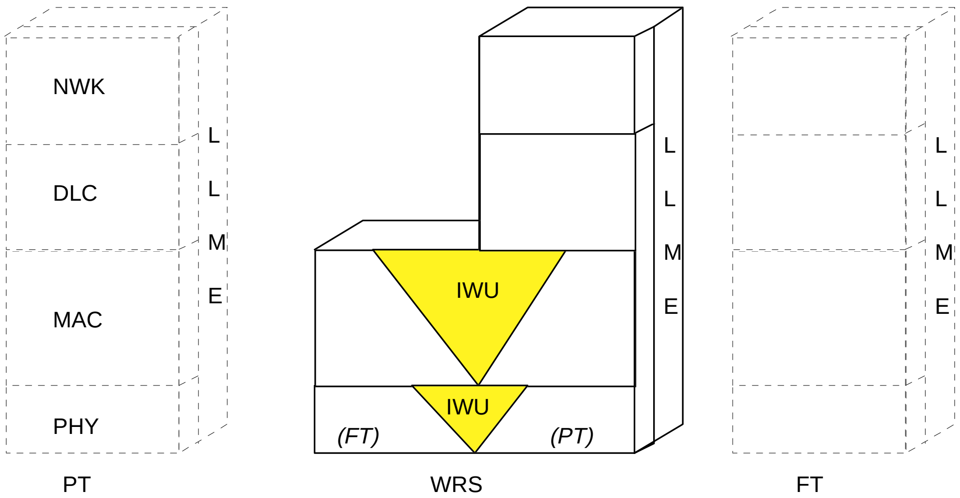

Figure 1: WRS reference model

Figure 1 shows the interworking of the WRS with the PT and FT as defined in ETS 300 175, Parts 1 to 8 [1] to [8]. The FT needs to implement optional provisions for interworking with a WRS. The PT needs no special provisions.

The WRS may be used in applications as defined in ETR 43 [13]. Typical WRS applications are presented in clause 5.

The WRS provides a relay service for MAC layer connection oriented, broadcast and connectionless services as defined in ETS 300 175-3 [3], subclauses 5.6 and 5.7.

4.2 WRS implementation concepts

Two different WRS concepts are defined in ETS 300 700 [16], the CRFP and the REP.

4.2.1 Cordless Radio Fixed Part (CRFP)

The CRFP uses independent bearer control and standard channel selection procedures towards both the PT and FT. For ciphered connections, each link uses different cipher keys and the PT cipher key is transferred to the WRS.

Figure 2 shows the typical Frame multiplexing structure for a CRFP that supports full slots with In_minimum_delay.

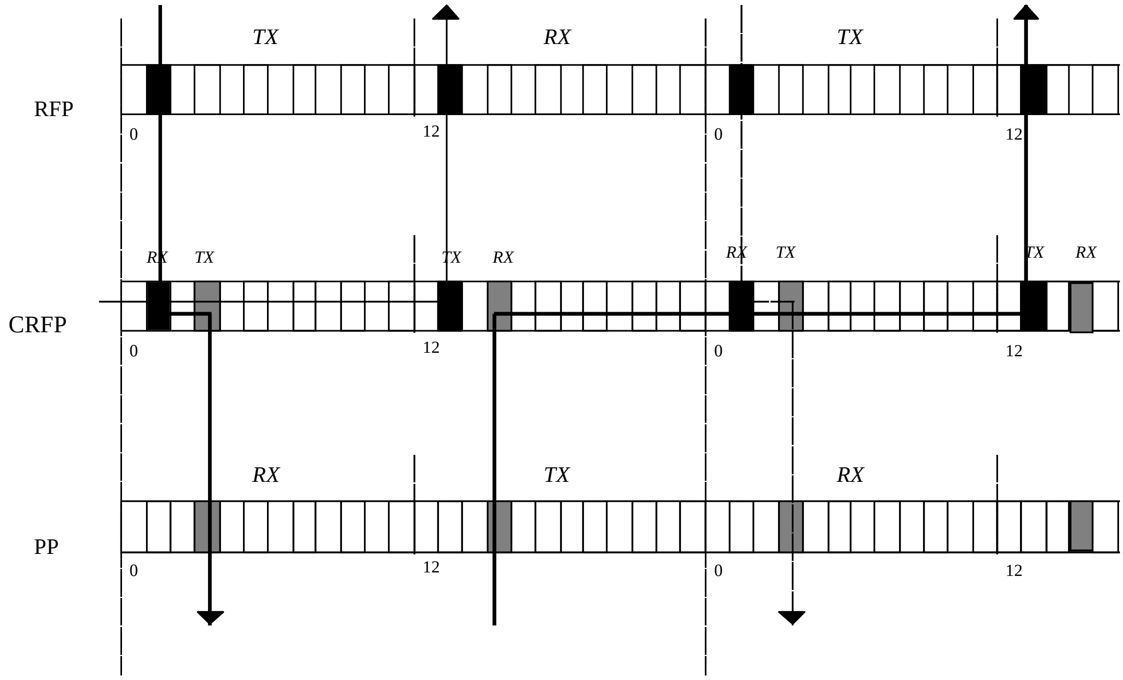

Figure 2: Typical frame multiplexing structure of the CRFP

The frame multiplexing structure supports a combination of both links with PTs and FTs. In this dual frame multiplexing structure the CRFP may transmit or receive during any slot of a frame. A duplex bearer to either the PT or FT is still supported by a combination of an CRFP RX and TX slot separated by one half frame.

4.2.2 REpeater Part (REP)

The REP uses two duplex bearers between the FT and REP for one link to a PT. Special channel selection rules and bearer control for the links between FT and REP are applied. Each relay of the information between the two radio terminations is completed within a half frame time interval.

Figure 3 describes the frame structure and slots allocation within REP, RFP and PT for a single duplex bearer relayed connection and for one hop.

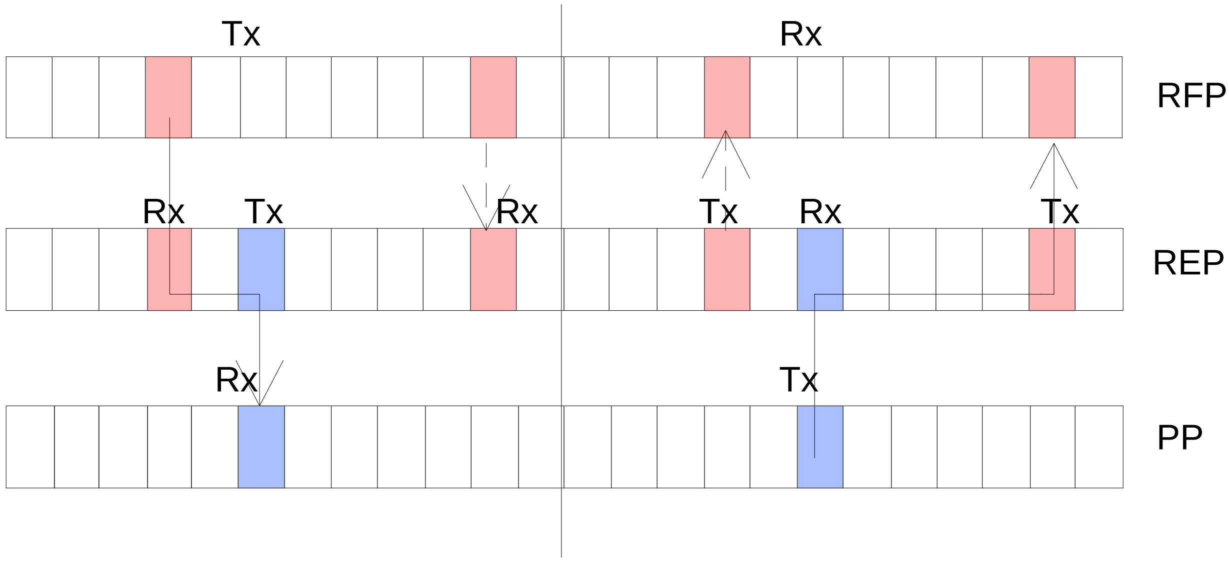

Figure 3: Frame structure and slots allocation for a single duplex bearer connection (1 hop)

5 Application scenarios

5.1 General

This clause describes a number of scenarios for DECT infrastructures with WRSs. Advantages and limitations are discussed.

It is important, both from operator's and regulators point of view that the application of WRSs do not violate reasonable requirements on spectrum efficiency and on the quality of the transferred service, specifically speech.

5.2 The relationship between infra structure cost and spectrum efficiency

Efficient use of the spectrum can not be determined by such a simple term as e.g. "traffic channels per MHz". For a technology like DECT, spectrum efficiency for speech has been defined as Erlang per km^2 per floor at comparable (speech) quality and infrastructure cost, (see ETR 042, clause 2).

The relation to the cost comes from the fact that the traffic capacity (Erlang/km^2) for DECT will be proportional to the number of base station density (RFPs/km^2), (see note). Thus the capacity is very dependent of the infrastructure cost.

Cost efficient implementations at required capacity and service quality is known as a prime goal for all standardisation and is beneficial to the general public.

Thus efficient use of a spectrum has both a cost, a quality and a spectrum efficiency (spectrum/connection) component.

With this wider definition, the WRS concept supports efficient use of the DECT spectrum by making the infrastructure deployments become more cost efficient for applications where maximum capacity is not a prime requirement.

NOTE: DECT can maintain the radio link quality at decreasing cell sizes due to the C/I limited dynamic channel selection and quick seamless inter-cell handover procedures.

5.2.1 General use of WRS

At higher density applications the WRS is not efficient, because installing RFPs will generally be much more cost efficient at high densities. Table 1 shows how many more WRSs are needed to provide the same traffic as one RFP at 0,5 % blocking.

Table 1: Number of WRSs required to provide the same capacity as one RFP

Type	Single link WRS	2 WRS links cascaded
CRFP	3,3	7,6
REP	6,2	30,3

As seen from the comparison in table 1, WRSs are generally attractive only for low-density applications. The figures are calculated from information in table 4 and from the fact that one RFP provides 5,3 E average traffic. Corresponding figures for the specific scenarios in figures 8, 9 and 10 are easily derived by comparing the traffic densities with the traffic density of figure 7. These figures will be similar or larger than the figures of table 1.

It is however also true that WRSs use more channels (spectrum) per connection than an RFP, even if there often is a natural isolation between the two sides of the WRS link. For low density cases the number of channels are shown in table 2.

Table 2: Number channels required to provide one connection through a WRS chain

Type	Single link WRS	2 WRS links cascaded	3 WRS links cascaded
CRFP	2	3	4
REP	3	5	7

This increased number of channels per connection is not a limitation for the operator as long as the total number of calls is limited, as in low-density applications. The increased number of channels will however, in environments with C/I limited capacity, increase the blocking probability compared to RFP–PP links. This increase could typically be proportional to the number of channels in table 2. See subclause 5.3.1.

5.2.2 The maximum possible interference from a total chain of WRSs

In order to estimate the maximum number of channels that are occupied by a chain of WRS links, the upper limit of the total average number of occupied channels have been calculated for an RFP and for different chains of WRS links. The figures in table 3 have been calculated from the average capacity figures in table 4 which have been multiplied by the number of channels in table 2.

Table 3: Total average number of occupied (interfering) duplex full-slot channels from an RFP cell and chains of WRS links at 0,5 % blocking probability

Cell type	RFP	Single link WRS		2 WRS links cascaded	
		CRFP	REP	CRFP	REP
Lowest traffic (dummy bearer only)	1	1	1	2	2
Highest average traffic (0,5 % blocking)	5,3	3,2	2,6	4,2	1,8

It is interesting to find that interference from WRS chains never will exceed maximum possible interference from one RFP to neighbour installations, because any chain of WRS links always provides a lower upper limit of the total average number of occupied (interfering) channels than an RFP cell will provide.

5.2.3 Summary

WRSs help to provide cost efficient installations for low-density applications, without violating maximum spectrum utilisation at high capacity installations. General spectrum inefficient use of WRSs in high traffic applications is prevented by a very high capacity loss and cost penalty. Total average interference from a chain of WRS links is always less than the interference from the highest allowed average traffic of one RFP. Furthermore at equal cost (number of WRSs) the CRFP concept carries two to four times more traffic than the REP concept (see table 1).

5.3 Quality of the transferred service

5.3.1 Bit Error Ratio (BER)

Typically the BER for a connection over a WRS link will be as many times larger, compared to an RFP-PP link, as the number of channels required for a connection indicated in table 2. A factor of two to five is not critical for low density applications where the channel selection is not interference limited. But, with the larger factors large care is required in interference limited environment.

5.3.2 Incremental delay

Another quality issue is the influence of the added delay. The incremental average 1-way delay for B-field user data is 5 ms per cascaded CRFP and maximum 2,5 ms for any chain of cascaded REP links.

5.3.2.1 Influence of incremental delay on data services

These short delays cause in practice no relevant throughput or other limitation to data services, because each CRFP has relevant data buffers and terminates the Medium Access Control (MAC) layer separately for each part of the link, and the REP has only one end to end MAC control.

5.3.2.2 Influence of incremental delay on speech services

For speech services the incremental delay causes no fundamental limitation. Analysis shows that one CRFP link and any REP chain can be generally allowed without the need to add anything to the standard DECT echo control functionality. Depending on the characteristics of the specific network, the FT network echo control requirements may need to be modified in agreement with the national authorities when 2 or 3 CRFP links are cascaded (see ETS 300 175-8 [8], subclause 8.4 for information on the echo control requirements when 2 or 3 CRFP links are cascaded).

5.3.3 Summary

No relevant quality degradation is introduced by WRSs as long as necessary adjustments are made in the FT echo control functionality when 2 or more CRFP links are cascaded. These adjustments are specified in ETS 300 175-8 [8], subclause 8.4.

5.4 Examples of scenarios for WRS implementations

5.4.1 Fill in where the coverage is marginal

One of the most important applications for WRS is the possibility to easily and quickly improve the service quality in an area with marginal coverage. This fill in without the need to support a wired connection is very useful as such. This property can also be utilised when making the installation plan for the RFP infrastructure. Instead of applying very high power margins to ensure coverage everywhere, the planning can be made with lower margins. Afterwards, when testing the RFP installation, WRSs are installed in local areas where the coverage is found to be marginal.

5.4.2 Where it is difficult to install a wired connection to an RFP

Some times it can be very difficult to install a wire to part of the infrastructure.

Examples are:

- a separate parking house;
- a small annex on the other side of a public street;
- subway cars.

5.4.3 Behind obstruction

Especially for public and Radio in the Local Loop (RLL) applications, the WRS is useful to provide coverage behind larger obstructions like a hill, or to cover a perpendicular street or a patio or a park behind a tall compact city block.

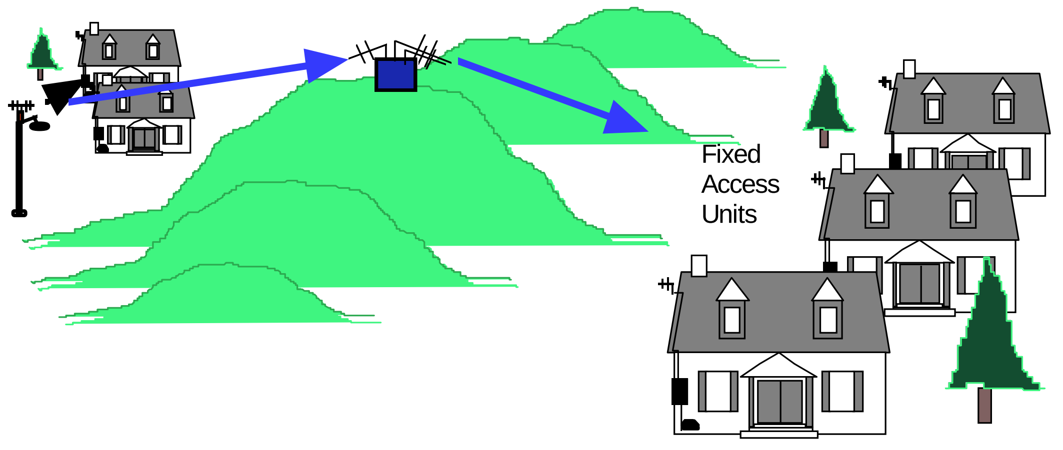

Figure 4: Typical WRS application

5.4.4 Residential RLL and wireless centrex with local (private) DECT PP

A very attractive application is to apply the WRS functionality to the fixed subscriber units of an RLL system. This can be made with or without maintaining a tethered connection possibility to the subscriber unit, e.g. for fax or data services.

The WRS functionality provides mobility in and around the residence. The alternative way is to connect a second DECT system to the tethered connection of the fixed subscriber unit. This both costs more, a second DECT FP, and introduces higher quantization distortion since two analogue to ADPCM conversions are required instead of one. The WRS also provides multiple public calls (see figure 5).

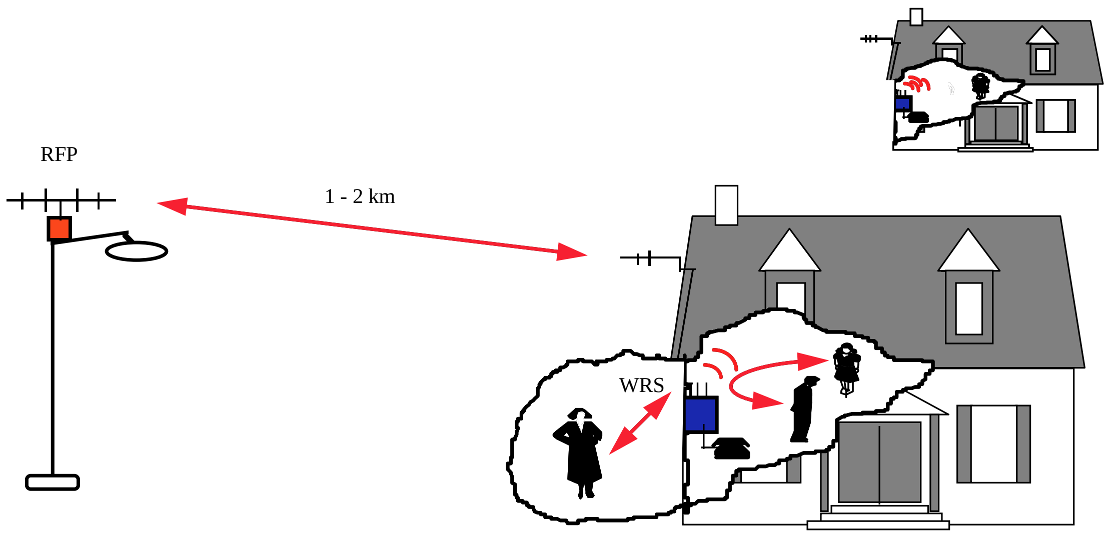

Figure 5: Residential WRS application

Examples of options that may be added to the subscriber unit with WRS functionality are:

- local private access rights identities;
- local intercom service;
- ISDN B+D or 2B+D services.

The same principle may be extended for wireless centrex, which provides both local mobility with intercom, and a wireless link to a central RFP.

The mobility access options are:

- own local fixed access unit/WRS;
- own RFP (to which the WRS is locked);
- a number of local fixed access units/WRSs;
- all local fixed access units/WRSs;
- a number of the RFPs;
- all RFPs;
- any combination of these options;
- the local links may use other access rights identities than the external links.

Another installation possibility is to mount the fixed access units/WRSs outdoors (e.g. on lamp posts), each covering a number of residences.

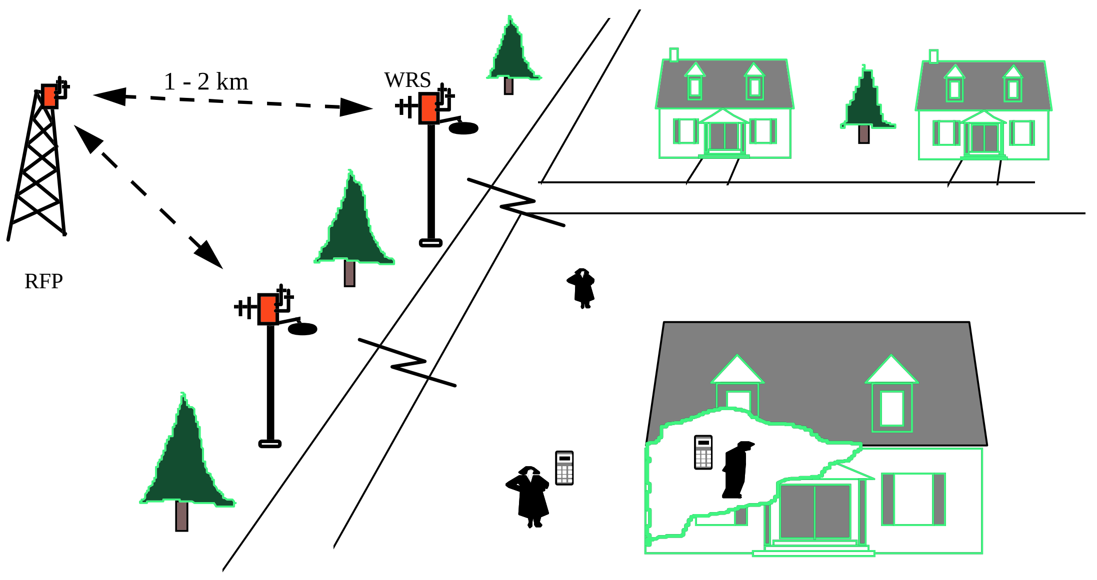

Figure 6: Residential WRS application

5.4.5 General low-density applications

Below are a number of low density applications of RFP-WRS cell combinations.

The derived traffic density figures are based on the assumption that each cell covers an area corresponding to a 400 m x 400 m square. The capacity expressed in Erlang (E) relates to full-slot duplex bearers and 0,5 % total blocking probability for a PP connection in a cell. The full availability Erlang B equation has been used to calculate the trunk limited capacities.

Experience from full scale simulations of multi-cell DECT systems with single radio standard RFPs, shows that the trunk limited base station capacity for many scenarios is a good first estimate of the real capacity. A standard RFP provides 12 (duplex) trunks which corresponds to 5,3 E at 0,5 % blocking probability. From figure 7 is seen that the reference average traffic density using only RFPs is (3 x 5,3)/ 0,48 E/km^2 = 33 E/km^2. Traffic figures below regard the average traffic.

a) 3 RFP cell cluster

- Capacity/cell:
  - RFP: 5,3 E.
- Traffic density:
  - RFP: 33 E/km^2.

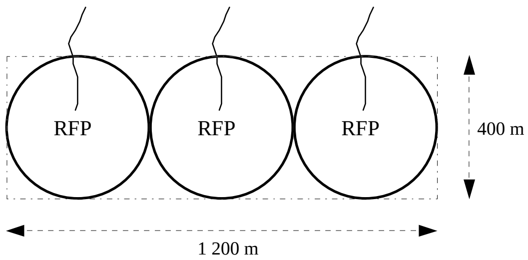

Figure 7

The capacity for the mixed RFP-WRS scenarios is based on a combination of analytic estimates and simulations. A bases for the estimates are the capacities below for 1 - 3 cascaded WRS links. These figures relate to 0,5 blocking.

Table 4

Type of WRS	CRFP	REP
1 WRS link	1,6 E	0,85 E
2 WRS links	1,5 E	0,35 E
3 WRS links	1,4 E	0,10 E

In table 4 it is supposed that the blocking probability in the RFP does not contribute significantly to the total blocking for a PP. Further it is assumed that all traffic is tapped from the last WRS in a chain, and that interlaced channel selection is applied for the REPs.

Another information derived from REP simulations, is that the total traffic offered from two REPs connected to the same RFP is 1 E at 0,5 % blocking, or 0,5 E per REP. This shows that the RFP blocking limits the capacity for this case.

In the examples below adjustments have been made to include the blocking contribution from the RFP. For each case, except figure 10, the tapped PP traffic capacity has been chosen to be equal in the RFP and WRS cells. Interlaced channel selection has been assumed for the REPs.

b) 1 RFP and 2 WRS cell cluster

- Capacity/cell:
  - CRFP: 1,5 E;
  - REP: 0,4 E.
- Traffic density:
  - CRFP: 9,4 E/km^2;
  - REP: 2,5 E/km^2.

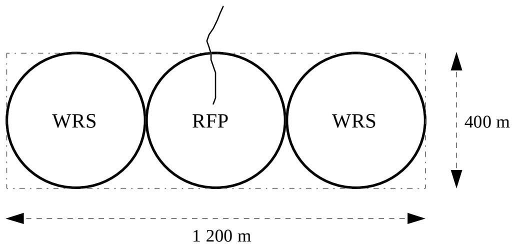

Figure 8

For the CRFP case, the total traffic through the RFP has been limited to 4,5 E, which gives 0,17 % blocking at the RFP. 1,5 E through the WRSs gives 0,35 % blocking in the WRSs. Thus the PP traffic tapped at the RFP will have 0,17 % blocking and the traffic tapped at the WRSs will have 0,52 % blocking.

For the REP case, the total RFP traffic is 1,2 E, divided on 0,4 E tapped PP traffic at the RFP and totally 0,8 E tapped over the WRSs. This has been estimated to correspond to about 0,5 % blocking of the traffic tapped at WRSs, since 0,5 % blocking is reported (see above) when no PP traffic is tapped at the RFP, but totally 1,0 E is tapped over the WRSs.

c) 1 RFP and 8 WRS cell cluster

- Capacity/cell:

  - CRFP: 0,6 E;
  - REP: 0,11 E.

- Traffic density:

  - CRFP: 3,7 E/km^2;
  - REP: 0,7 E/km^2.

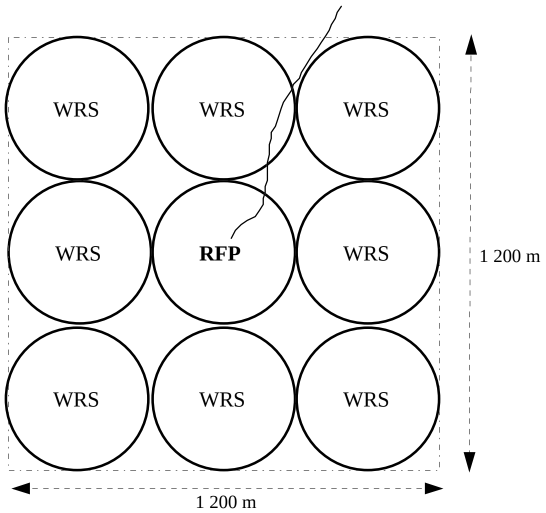

Figure 9

For the CRFP case, the total traffic through the RFP has been limited to 5,3 E, which gives 0,5 % blocking at the RFP. This gives 0,6 E tapped traffic per cell. 0,6 E traffic through the WRSs gives negligible additional blocking for the traffic tapped at the WRSs.

For the REP case, the total RFP traffic has been limited to 1,0 E since almost all traffic is tapped over the WRSs, whereby the blocking should be about 0,5 %.

d) 1 RFP and 4 WRS cell cluster

- Traffic density:

  - CRFP: 5,3 E/km^2;
  - REP: 0,6 E/km^2.

- Capacity/cell:

- CRFP:	0,7 E	0,7 E	1,4 E	0 E	1,4 E;
- REP:	0,1 E	0,1	0,15	0 E	0,15 E.

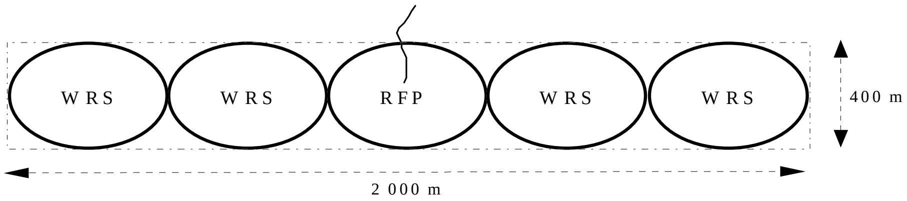

Figure 10

In this scenario one WRS has no tapped traffic at all.

For the CRFP case, the total traffic through the RFP has been limited to 4,2 E, which gives 0,10 % blocking at the RFP. This together with the maximum 1,4 E traffic through any WRS will ensure less than 0,5 % blocking of the traffic tapped at the WRSs.

For the REP case, the total load has been limited to 0,5 E traffic at the RFP, divided on 0,15 E of traffic tapped at the RFP and 0,35 E tapped over the WRSs. This is supposed to give close to 0,5 % blocking for the following reason; in the scenario b, the maximum traffic at the RFP is about 40 % larger than the maximum traffic for a single WRS link in table 4. For 2 WRS links, the corresponding figure in table 7 is 0,35 E and adding 40 % gives 0,5 E.

5.4.5.1 Transfer of multi-bearer services

The capacity for multi-bearer services will become very low compared with single bearer services. For instance, a CRFP chain can only support one 2B+D connection at a time. The REP has less capacity than the CRFP, and cascaded REP links are hardly applicable. Large care is recommended when applying WRSs for multi-bearer connections. Only very low-density applications are possible to implement.

6 On approval and conformance testing

A WRS is required to meet the channel selection rules and other radio requirements as defined in TBR 6 [10]. It has to meet the FT requirements when operating as an RFP and the PT requirements when operating as a PT. For the duration of the actual TBR 6 [10] test the Lower Tester (LT) has a stationary (fixed channel) dummy bearer established for the WRS to lock on.

DECT FTs approved according to TBR 10 [11] are allowed to implement single link WRS in its infrastructure. Application with 2 or 3 hops may be subject to agreement with national authorities.

Installing or adding a WRS to a DECT infrastructure is not possible outside the control of the system operator/installer/owner.

The WRS applications are not limited to a specific inter-operability profile. When the WRS is implemented for a specific profile, it can be tested for conformance to that profile. To ensure inter-operability with any PP approved for that profile, the combination FT-WRS should fulfil the requirements for FT conformance.

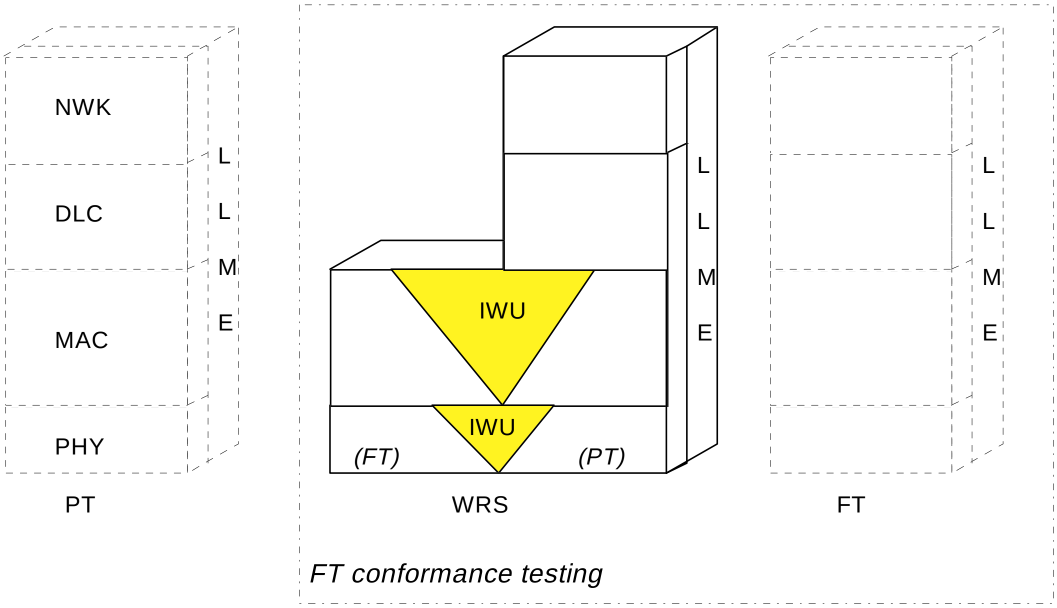

Figure 11: Conformance testing of WRS

History

Document history	
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