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Specification of the Dynamic Channel Selection (DCS) in DECT

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Specification of the Dynamic Channel Selection(DCS) in DECT

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Abstract

Switching the physical channel while maintaining the communication link is a feature of both cordless and mobile systems. In this paper we consider the Dynamic Channel Selection (DSC) algorithm of the Digital European Cordless Telecommunications (DECT) system. This algorithm is used in the radio interface between the portable parts and the fixed part. The main feature of this algorithm is that the Portable Parts select the radio channels and time slots for the call. In GSM, another mobile radio system, the base stations control the allocation of these resources although assisted by the mobiles. We specify the DECT algorithm as a refinement of the GSM system.

1 Introduction

Marconi demonstrated in December 1901 that it was possible to send messages across the Atlantic. Since then the use of radio is regulated by Governments and international treaties. Operators are granted licences to use parts of the spectrum. Initially, telecommunication companies set up systems almost independently or in small groups, e.g. Nordic Mobile Telephone. Telecommunication is a lucrative business and often different systems were designed to protect the local industry. However, in 1982 it was decided to develop a pan European system and a European wide body the European Telecommunications Standardisation and the Information Society (ETSI) was set up to coordinate the design and specification of the system. ETSI is now the regulatory body for any future system that will be expected to operate right across Europe. Negotiations are taking place to design global systems.

Mobile and Cordless telephone systems are types of radio based telecommunication systems. Cordless systems use the radio link over very short distances (tens of meters at most) while in mobile radio the link can be as long as a few miles. In urban areas, the distance of the mobile from the base station may be quite small and of the order of hundreds of meters. As the number of radio channels is limited, there is a high probability that the same frequency is being used simultaneously to provide other links. Despite this interference, communication is still possible as long as locally, the wanted signal is dominant. Therefore, the transmitting power is closely regulated. Other frequencies are monitored and the system may switch radio frequencies to provide a better link. If the interference on a particular frequency exceeds prescribed limits, that frequency may not be used to provide a link. Thus modern radio telecommunication systems need to be able to switch accurately to specified frequencies, control their transmitting power, and receive satisfactorily despite interference up to the specified limits.

These days, telecommunication systems are built from components supplied by different manufacturers. Specifications in Europe are drawn up by ETSI so that the various components built by different manufacturers can operate together. The specifications control the aspects necessary for interoperability, such as modulation schemes, frequency accuracy, radio emissions, protocols and behaviour algorithms. Aspects of the man machine interface, size, and weight are regarded as features and are loosely specified.

Switching the physical channel while maintaining the communication link is a feature of both cordless and mobile systems. In this paper we consider the Dynamic Channel Selection (DSC) algorithm of the Digital European Cordless Telecommunications (DECT) system. The main feature of this algorithm is that the Portable Parts select the radio channels and time slots for the call. In GSM, another mobile radio system, the base stations control the allocation of the resources although assisted by the mobiles. We specify the DECT algorithm as a refinement of the GSM system.

There are several time division multiple access systems (TDMA), where a channel is identified by the radio frequency and the time slot used. One of the systems (Global System for Mobile Communications or GSM) is already in widespread use. It transmits speech at 13.1KBits per s using interleaving and error correcting procedures for channel coding and an adaptive equaliser to provide reliable binary signal detection. The hand portables, in the GSM system require considerable computation resources to implement the coding and decoding algorithms for

receiving and transmitting speech. The base stations in GSM control the handportable's transmission frequencies and time slots. This system is designed to communicate with mobiles moving up to 200Kilometres per hour. The GSM system has been in operation since 1992.

Another system is the DECT cordless system. DECT systems are designed for use in offices and homes, and the speeds of the portable parts are of the order of 5 to 10 Kilometres per hour. The links between Radio Fixed Parts (RFP) and the Portable Parts (PP) are not noisy. The RFPs are expected to be meters away from the PP. There is, therefore, no channel coding or equalisation. The speech rate is 32kbits per second. The computational requirements for coding and decoding the speech are minimal. On the other hand the size of the RFP is meant to be small, the devices being located inside the homes and offices. The basestations in GSM are large structures located in stand alone buildings or outside large buildings. However, many RFP are expected to be sited in the same vicinity. as DECT supports a multi-system environment with uncoordinated installations co-existing on a common resource of spectrum.

In view of the different loading and environment of the PP in DECT, the PP controls the use of the spectral resources.

2 Specification

2.1 Mode of Portable Part

Power efficiency and size are important concerns in the design of portable parts. When the portablepart, *pp* is making a call, it uses far more resources than when it is on standby. In order to make efficient use of energy, parts are activated as and when required. Therefore, the mode when the portable part is making a call, is distinguished from that when it is waiting for a call i.e *Active* or *Idle*. We do not consider any other modes in this specification .

We introduce a type called *Mode*

[*Mode*]

Active : *Mode*

Idle : *Mode*

Idle $\neq$ *Active*

$\forall (x : Mode) \bullet (x = Ideal) \vee (x = Active)$

2.2 Resources of the two Systems

2.2.1 GSM

The GSM system has three main elements – mobile stations, base stations and mobile switching centres. There are two primary interfaces in the GSM system the mobile station – base station interface (the radio interface) and base station – mobile switching centre interface. The GSM recommendations give the necessary and sufficient specifications so that items procured from independent manufacturers will interwork with each other.

The GSM system is required to operate over the band 890 – 915 MHz for the mobile to transmit and 935 – 960 MHz for the mobile to receive. The radio frequency(RF) channel separation is 200 KHz, and the RF part of the system signals at 270.833K Bits/s. Each RF channel is divided into time slots of duration of 577 μs . These slots are grouped as sets of 8 into one TDMA frame. The fundamental speech rate is 13.1 k Bits/S, but the encoding, encryption, and noise protection and associated signalling result in an effective raw bit rate of 33.8 kHz for each speech channel. Thus each RF channel can support 8 speech channels.

RF power control can be used in the mobile and base station to reduce the transmit power to the minimum required to ensure adequate speech quality, and hence reduce the level of interference caused to other users and providing

the possibility of the reuse of the RF channel in another cell nearby. The data protection enables the system to operate with mobiles moving upto 200 KMeters/s.

2.2.2 DECT

DECT is designed to provide a cordless telephone service. The base station and mobile are at most tens of meters away from each other. There is very rudimentary protection for the data. The DECT system is designed to signal at 1.152M bits/sec and speech is transmitted 32kbits /sec. One base station can support several conversations. There are 12 separate time slots on each frequency and 12 frequency carriers with a channel spacing of 1.7MHz. The system can support faxes and ISDN links. This is achieved by using multiple links with the same RFP and PP. DECT systems are designed to operate in the frequency band 1880 – 1900 MHz.

Throughout this specification, we will use the terminology used in the DECT specification.

PP : Portable Part
 RFP :Radio Fixed Part
 FC :Frequency Channel
 S :Slot (time)

In this specification, we are not interested in the particulars of the frequencies and time slots. We regard them as given types.

[*PP*, *RFP*, *FC*, *S*]

In GSM specifications, the terms Mobile and Basestations are used instead of PP and RFP.

2.3 GSM Basestation System

At any particular instant, a link in the system can be characterised by the identities of the PP, RFP and the FC and time slot being used. The state of the system is just the collection of the links. The resource allocation algorithm in GSM needs knowledge of the set of *RFP*'s visible to each *pp* and the state of the *pp*. These are communicated to it by the individual *pps*.

GSM_System_Links

System : $P(PP \times RFP \times S \times FC)$

ParticularsPP : $PP \rightarrow Mode \times P(RFP)$

$\forall (pp_1, pp_2 : PP, rfp_1, rfp_2 : RFP, s_1, s_2 : S, fc_1, fc_2 : FC) \bullet$

$(((pp_1, rfp_1, s_1, fc_1), (pp_2, rfp_2, s_2, fc_2) \in System) \wedge pp_1 = pp_2) \Rightarrow$

$rfp_1 = rfp_2 \wedge (s_1 = s_2 \Rightarrow fc_1 = fc_2)$

Each *pp* can link with only one base station at a time. There cannot be two links in the System with different RFPs and the same *pp*. We do not consider the temporary case during hand overs where one *pp* may be in contact with more than one *rfp*.

2.4 GSM Portable Parts

GSM_PP_State records the state of a particular *pp* in the system. This is characterised by its *mode* and if active, (i.e. making a call), by the *link* which is of the form(*rfp*, *slot*, *FrequencyCarrier*) is defined by specifying the base station, slot and frequency. Finally, it needs to report to the *rfp*, those *basestations* the *pp* can make radio contact with. In fact it makes a list of likely candidates of *rfps* that can be used and reports this list. The final decision of which *rfp* to use is taken by the GSM system and not the *pp*. We stress that this schema describes the system from the point of view of a particular *pp*.

GSM_PP_State

$pp : PP$
 $basestations : P(RFP)$
 $link : RFP \times S \times FC$
 $mode : Mode$

The complete state space consists of the state space of the basestations and the statespace of the individual users of the GSM system and this is described in the **GSM_Global_State**.

Every time a link is created in the system, the mode of some pp changes from *Idle* to *Active*. $link$ in **GSM_PP_State** is a record of the rfp , Clearly, the slot and frequency utilised in creating the link. $link$ does not contain valid information when the portable is in *Idle* mode. Also note, that as defined, the system does not cope with ISDN i.e. occupying multiple links to transmit higher bit rates. We would need to specify $link$ as a power set, making the rest of the specification more complex. It is best to treat it as a separate mode. We do not do so in this specification.

GSM_Global_State

GSM_System_Links

$users : P(PP)$

$\forall pp : users \bullet [GSM_PP_State \mid$
 $ParticularsPP (pp) = (mode, basestations) ;$
 $mode = Active \Rightarrow$
 $\exists_1 (rfp : RFP, s : S, fc : FC) \bullet$
 $(pp, rfp, s, fc) \in System ;$
 $mode = Idle \Rightarrow$
 $\forall (rfp : RFP, s : S, fc : FC) \bullet$
 $(pp, rfp, s, fc) \notin System]$

The set $users$ consists of all the pps that are either in *Active* or *Idle* mode and registered in the system. There is a **GSM_PP_State** schema for each pp in the set $users$. **GSM_Global_State** ensures that all the pps and their states are correctly monitored by the system. We insist that $ParticularsPP$ is built up from $mode$ and $basestations$. Since these particulars have been supplied by the pp , they should contain the same information. When the pp is in *Idle* mode, there should be no link in *System*. When a pp is in *Active* mode, there should be a unique link in the system.

We use the delta notation to define the states before and after a change of state.

$$\Delta GSM_System_Links \equiv GSM_System_Links \wedge GSM_System_Links'$$

$$\Delta GSM_PP_State \equiv GSM_PP_State \wedge GSM_PP_State'$$

$$\Delta GSM_Global_State \equiv GSM_Global_State \wedge GSM_Global_State'$$

3 Operations On State

In this section we identify the operations by their names in DECT rather than by GSM, as they have different names for the same operations. The state of the system changes when

- calls are setup or received
- calls are lost
- the mobile part moves requiring a handover from one link to another.

3.1 Call Set Up

When a portable makes a call or receives a call, a new link is created from a time slot and frequency carrier. The resource allocation algorithm in the GSM system selects a basestation to be used by the *pp*. We do not specify this algorithm here. The handset mode is changed from *Idle* to *Active*. The new link is recorded both in *System* and in *link* defined in **GSM_PP_State**. Note we do not consider all the intermediate stages that the system makes. We describe this operation in terms of two schemas. The change of state in the *pp* is recorded first. A valid *link* is possible only if the selected *rfp* is in the set *basestations* visible to the *pp*.

GSM_Call_Set_Up_PP

$$\Delta \text{GSM_PP_State}$$

$$rfp : RFP$$

$$s : S$$

$$fc : FC$$

$$mode = Idle \wedge (rfp \in basestations)$$

$$basestations' = basestations$$

$$link' = (rfp, s, fc)$$

$$mode' = Active$$

Next we describe what is done by the basestation system. In order to set up a call the *pp*, *rfp* the time slot *s*, the frequency channel *fc* must be available. The new link is added into *System* and the function *ParticularsPP* needs to be updated. This has to be done every time any of the users makes a call.

GSM_Call_Set_Up_Base

$$\Delta \text{GSM_System_Links}$$

$$pp : PP$$

$$rfp : RFP$$

$$s : S$$

$$fc : FC$$

$$basestations : P(RFP)$$

$$System' = System \cup \{ (pp, rfp, s, fc) \}$$

$$Particulars(pp) = (Idle, basestations)$$

$$ParticularsPP' = ParticularsPP \oplus (pp, (Active, basestations))$$

Finally, to set up a call, we combine the two schemas.

$$GSM_Call_Set_Up \equiv GSM_Call_Set_Up_Base \wedge GSM_Call_Set_Up_PP$$

The two operations together ensure that all actice calls are recorded by the system. We can express this in the form of a theorem

$$GSM_Call_Set_Up \vdash \Delta GSM_Global_State$$

Strictly speaking we need to prove that this is a theorem of the specification but we do not do so here.

3.2 Call Hang Up

As this is a mobile radio link, the mobile can loose contact with the *rfp* for one of several reasons. The mobile may have moved out of range or completed the call or there is some radio interference, and we are unable to hand-over. The link is then broken *GSM_Call_Hang_Up* is the process where the system is required to deal with this loss of the link. As in the previous case we split the operation into two parts from the point of view of the *pp* and basestation system. There is some indeterminacy in the specification because we do not choose to distinguish between the call ending naturally and the link failing, resulting in a particular *rfp* being out of range of the *pp*

GSM_Call_Hang_Up_PP	
ΔGSM_PP_State	
$rfp : RFP$	
$mode = Active$	
$mode' = Idle$	
$link = (rfp, s, fc)$	
$(basestations' = basestations) \vee (basestations' = basestations \setminus \{rfp\})$	

We ensure that *mode'* is changed and *ParticularsPP* is updated. *basestations* is updated differently depending on the reason for the hang-up. If we hang up because the call finishes, then basestations remains unchanged, else we remove the rfp that was used to support the link from the set of basestations.

GSM_Call_Hang_Up_Base	
ΔGSM_System_Links	
$pp : PP$	
$rfp : RFP$	
$s : S$	
$fc : FC$	
$basestations : P(RFP)$	
$System' = System \setminus \{(pp, rfp, s, fc)\}$	
$ParticularsPP(pp) = (Active, basestations)$	
$(ParticularsPP' = ParticularsPP \oplus (pp, (Idle, basestations))) \vee$	
$ParticularsPP' = ParticularsPP \oplus (pp, (Idle, basestations \setminus \{rfp\}))$	

Because of the indeterminacy, need to insist that **GSM_Global_State** is included in the definition of the operation of a call hang up.

$$GSM_Call_Hang_Up \cong GSM_Call_Hang_Up_Base \wedge GSM_Call_Hang_Up_PP \wedge$$

$$\Delta GSM_Global_State$$

3.3 Inter Cell Handover

If there is a significantly better link available, we change links. We can change slots and frequency and the *rfp*. The schema ***GSM_Inter_Cell_Handover*** describes the state changes which take place when the *pp* is handed over to another *rfp*. The original *rfp*₁ may have to be removed from the set of basestations if it gets out of range hence necessitating the handover. These changes are similar to the changes made in the previous schemas.

GSM_Inter_Cell_Handover_PP

$$\Delta GSM_PP_State$$

$$rfp, rfp_1 : RFP$$

$$s, s_1 : S$$

$$fc, fc_1 : FC$$

$$mode = Active$$

$$mode' = Active$$

$$link' = (rfp, s, fc) \wedge rfp \in basestations'$$

$$(rfp_1, s_1, fc_1) = link$$

$$(basestations' = basestations) \vee$$

$$(basestations' = basestations \setminus \{rfp_1\})$$

GSM_Inter_Cell_Handover_Base

$$\Delta GSM_System_Links$$

$$pp : PP$$

$$rfp, rfp_1 : RFP$$

$$s, s_1 : S$$

$$fc, fc_1 : FC$$

$$basestations : P(RFP)$$

$$System' = (System \setminus \{(pp, rfp_1, s_1, fc_1)\}) \cup \{(pp, rfp, s, fc)\}$$

$$(ParticularsPP' = ParticularsPP \oplus (pp, (Active, basestations'))) \vee$$

$$ParticularsPP' = ParticularsPP \oplus (pp, (Active, basestations \setminus \{rfp_1\}))$$

$$GSM_Inter_Cell_Handover \cong GSM_Inter_Cell_Handover_Base \wedge GSM_Inter_Cell_Handover_PP \wedge$$

$$\Delta GSM_Global_State$$

The mode remains active, the new *link* must use a *rfp* that is visible to the *pp*. The cause of the handover has a bearing on how the set *basestations* is updated. System is updated as expected and so are the *ParticularsPP*

3.4 Intra Cell Handover

If the system is changed so that just the time slot and frequency are changed, we use **GSM_Intra_Cell_Handover**. This completes the operations that generate a change of state.

GSM_Intra_Cell_Handover_PP
ΔGSM_PP_State $rfp, rfp_1 : RFP$ $s, s_1 : S$ $fc, fc_1 : FC$
$mode = Active$ $mode' = Active$ $link' = (rfp, s, fc) \wedge rfp \in basestations'$ $(rfp, s_1, fc_1) = link$ $basestations' = basestations$

GSM_Intra_Cell_Handover_Base
ΔGSM_System_Links $pp : PP$ $rfp : RFP$ $s, s_1 : S$ $fc, fc_1 : FC$ $basestations : P(RFP)$
$System' = (System \setminus \{(pp, rfp, s_1, fc_1)\}) \cup \{(pp, rfp, s, fc)\}$ $ParticularsPP' = ParticularsPP \oplus (pp, (Active, basestations'))$

As there is no indeterminacy inside the operations, the schema **GSM_Global_State** is satisfied before and after the operation.

$$GSM_Intra_Cell_Handover \cong GSM_Intra_Cell_Handover_Base \wedge GSM_Intra_Cell_Handover_PP$$

We therefore get the following theorem which again we should prove.

$$GSM_Intra_Cell_Handover \vdash \Delta GSM_Global_State$$

4 Refinement of Specification

We now regard the DECT system as a refinement of the GSM system. We remind the reader, that the onus of selecting the link has shifted to the *pp* and so the function *ParticularsPP* of the GSM system is unnecessary in this system. In any case, the GSM system assumed that all the resources were under its control. The DECT system is designed so that more than one network can co exist in the same vicinity.

4.1 State in a DECT system

The schema is based on the corresponding schema **GSM_System_Links** except the function *ParticularsPP* is hidden. In the DECT system the *pp* select the *link* to be used, thus the set of basestations visible to the *pp* need not be explicitly monitored. We insist that if a RFP is supporting more than one *pp*, each *pp* uses a different time slot and a different carrier frequency.

<i>Dect_System_Links</i>
<i>GSM_System_Links</i> / (<i>ParticularsPP</i>)
$\forall (pp : PP, rfp : RFP, s_1, s_2 : S, fc_1, fc_2 : FC) \bullet$ $(((pp_1, rfp, s_1, fc_1), (pp_2, rfp, s_2, fc_2)) \in System \wedge$ $pp_1 \neq pp_2 \Rightarrow s_1 \neq s_2 \wedge fc_1 \neq fc_2)$

In the first place, one may wonder why this requirement is placed on the system. This surely does not utilise the spectral resource efficiently. Consider two *pps* and two *rfp* close to each other. The *rfps* belong to different DECT systems. The *pps* also belong to different DECT systems. These two DECT systems are not synchronised. Their slots may overlap. Thus, the frequency may be occupied by the first *pp* when it is time for the second *pp* to transmit. The solution is for the second *pp* to either skip a whole slot (thus guaranteeing the end of the first activity) or to select a frequency where there is no activity. It is better to find another frequency than wait for another time slot. This critical requirement that makes a distributed control possible.

4.2 State Space of Portable Parts

We intend to specify the state space of a particular *pp*

Each portable is responsible for selecting the links. i.e. selecting the time slots and frequency channels that give the best performance. In order to select the best links, the portables monitor and record the slots at all frequencies that are currently active or noisy.

As there are several base stations, many frequencies are occupied at the same time. Some of the activity may originate from adjacent DECT systems operating in the same locality.

Each portable part records the activity in its vicinity and is aware of the radio fixed parts nearby.

We quote directly from the specification next : "DECT uses a simple but efficient and robust Dynamic Channel Selection, DCS, procedure that is decentralised to each portable part, PP, and its closest base station radio fixed part, RFP."

Again quoting from the specification : "DECT provides, without special physical control channels, frequent system information and basestation access rights identification that allows any portable, by receiving only, to identify any system or base station within reach , and , if wanted, to lock to it".

In this specification, each *pp* knows the set of *rfps*, *basestations*, it currently is capable of establishing a radio link with. There may be *rfps* outside its immediate vicinity that belong to the same DECT system. Also, much of the interference may be due to activity from other DECT stations operating in the same radio space.

Schema **DECT_PP_State** is a refinement of **GSM_PP_State**. We introduce the set *map* which is a record of the activity in the slots and frequency

DECT_PP_State

$$GSM_PP_State$$

$$map : P (S \times FC)$$

$$\{ (s, fc) \mid \exists (pp_1 : PP, rfp : RFP, s : S, fc : FC) \bullet \\ (pp_1, rfp, s, fc) \in System \wedge rfp \in basestations \} \subset map$$

$$\forall (rfp : RFP \ s : S, fc : FC) \bullet \\ ((rfp, s, fc) = link \wedge mode = Active) \Rightarrow \\ (s, fc) \in map$$

map records the occupied links in the vicinity of the portable. We insist that if a *pp* is capable of being in radio contact with an *rfp*, and that *rfp* is linked to another pp, then, the slot and frequency used by *pp* and *rfp* are busy and cannot be used for transmission by this pp. Next if the *pp* is active, then the slot and frequency used by the link is in *map*. Finally, we insist that different pps on the same rfps use different slots and frequency.

DECT_Global_State

$$DECT_System_Links$$

$$users : P(PP)$$

$$\forall pp : users \bullet [DECT_PP_State \mid \\ mode = Active \Rightarrow \\ \exists_1 (rfp : RFP, s : S, fc : FC) \bullet \\ (pp, rfp, s, fc) \in System ; \\ mode = Idle \Rightarrow \\ \forall (rfp : RFP, s : S, fc : FC) \bullet \\ (pp, rfp, s, fc) \notin System]$$

For change of state operations we need states before and after.

$$\Delta DECT_System_Links \equiv DECT_System_Links \wedge DECT_System_Links'$$

$$\Delta DECT_PP_State \equiv DECT_PP_State \wedge DECT_PP_State'$$

$$\Delta DECT_Global_State \equiv DECT_Global_State \wedge DECT_Global_State'$$

5 Operations On State

5.1 Call Set Up

The portable part when switched on after initialisation goes into *Idle* mode awaiting either to receive a call or make a call. *Call_Set_Up* describes the state changes of making a call. We must find a clear timeslot and frequency to be able to set up a link.

DECT_Call_Set_Up_PP
$\Delta DECT_PP_State$
$GSM_Call_Set_Up_PP$
$(s?, fc?) \notin map$
$map' = map \cup \{(s?, fc?)\}$

The load on the basestation has been eased. All actions pertaining to *ParticulatsPP* and *basestations* need not be performed.

$$DECT_Call_Set_Up_Base \cong GSM_Call_Set_up_Base \setminus (basestations, ParticularsPP)$$

$$DECT_Call_Set_Up \cong DECT_Call_Set_Up_Base \wedge DECT_Call_Set_Up_PP \wedge \Delta DECT_Global_State$$

5.2 Call Hang Up

Call_Hang_Up is the process where the system is required to record the end of the link. This may be because the call has terminated or the link was lost *map'* changes accordingly.

DECT_Call_Hang_Up_PP
$\Delta DECT_PP_State$
$GSM_Call_Hang_Up_PP$
$\begin{aligned} \exists (rfp_1 : RFP, s_1 : S, fc_1 : FC) \bullet \\ (rfp_1, s_1, fc_1) = link \wedge \\ ((map' = map \setminus \{(s_1, fc_1)\}) \vee \\ (map' = map)) \end{aligned}$

$$DECT_Call_Hang_Up_Base \cong GSM_Call_Hang_up_Base \setminus (basestations, ParticularsPP)$$

$$DECT_Call_Hang_Up \cong DECT_Call_Hang_Up_Base \wedge DECT_Call_Hang_Up_PP \wedge \Delta DECT_Global_State$$

5.3 Inter Cell Handover

If there is a significantly better link available, we change links. We can change the radio fixed part or stay with the base station but change slots and frequency. The state changes in moving base stations is described by the schema *DECT_Inter_Cell_Handover*

The DECT system is designed to be used in offices and homes. The PP must be able to receive a call, change base stations like the GSM pp and in addition update its map. In view of the fact that the system is meant to be cheap,

the requirements on the oscillators in the system, used for timing purposes, are not very stringent and it is possible for the adjacent slots to overlap. This is termed a sliding collision. The other reason for wanting to change links is that a better link is available while the call is still in progress. The system must be able to maintain the call but change links during the call.

$$DECT_Inter_Cell_Handover_Base \equiv GSM_Inter_Cell_Handover_Base \setminus (basestations, ParticularsPP)$$

$$DECT_Inter_Cell_Handover \equiv DECT_Inter_Cell_Handover_Base \wedge DECT_Inter_Cell_Handover_PP \wedge \Delta DECT_Global_State$$

5.4 Intra Cell Handover

Similarly for *Intra_Cell_Handover*

$$DECT_Intra_Cell_Handover_Base \equiv GSM_Intra_Cell_Handover_Base \setminus (basestations, ParticularsPP)$$

$$DECT_Intra_Cell_Handover \equiv DECT_Intra_Cell_Handover_Base \wedge DECT_Intra_Cell_Handover_PP \wedge \Delta DECT_Global_State$$

5.5 Update Base Station Map

This is the operation that keeps the link and mode unchanged. As a result of the dynamic behaviour of other portable parts, we need to update *map* and *basestations* constantly.

Map_BaseStation_Update

 $\Delta DECT_PP_State$

$$\{ (s, fc) \mid \exists (pp_1 : PP, rfp : RFP, s : S, fc : fc) \bullet \\ (pp_1, rfp, s, fc) \in System \wedge rfp \in basestations \} \subset map'$$

$$pp = pp'$$

$$link' = link$$

$$mode' = mode$$

6 Conclusions

In this paper we have attempted to give, in Z, the specification of the state space of a DECT system, We specified the state space of a GSM like system and refined it to obtain the specification of the DECT system. We have highlighted the changes in the operations of state as we go from the GSM to the DECT system. In this specification we can see the changes to be made in the implementations to convert a GSM implementation to a DECT implementation. We need an extra relation *map* in the state space of **DECT_PP_State** and the operations on state also modify *map*. Finally, there is one more operation **Map_BaseStation_Update**

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8 References

1. Spivey J. M. The Z Notation A Reference Manual
2. Hodges M. R. L. The GSM radio interface Br. Telecom Technol J Vol 8 No 1 January 1990
3. European Telecommunications Standardisation and the Information Society – The State of the Art 1995, Published by Atalink Ltd, 40 Bowling Green Lane ,London EC1R 0NE
4. Radio Equipment and Systems 03(92)021, ETSI
5. Macario R. C. V. Cellular Radio, Principles and Design, Macmillan New Electronics