American Journal of Applied Sciences 2 (4): 746-750, 2005
ISSN 1546-9239

Scheme for ISDN/DECT Wireless Internetworking and Verification

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Abstract: A novel scheme to access the basic rate service of the Integrated Service Digital Network (ISDN) using the Digital Enhanced Cordless Telephone (DECT) radio interface standard is presented. The S-interface in the ISDN reference configuration has been used for the ISDN interface and the unprotected class 0 transmissions are used for the DECT interface. The design of a state of the art interworking unit is described which endeavors to make the use of DECT transparent to the ISDN equipment. The complete design has been simulated and the results presented quantify the overall quality of the link for varying qualities of the radio channel. The simulation results show that DECT radio link can actually replace the fixed S-bus hence locating and relocating of terminal equipment is achieved and this can form the stepping stone for user locating in the 3G (third generation) Universal Mobile Telecommunications System (UMTS). Furthermore, the study also shows that this technique saves on the spectrum usage as it gives 20% spectrum efficiency improvement.

Key words: Integrated Service Digital Network, Digital Enhanced Cordless Telephone, Universal Mobile Telecommunications System

INTRODUCTION

The urgent need to provide quality communications services to rural and remote regions and the associated difficulties are well recognized[1,2] This problem is investigated in[3] and since then, there is no realistic solution to this problem and even, the work addressing it is sparse. This study puts forward a scheme for interlinking ISDN/DECT to wireless utilizing the basic rate ISDN services. The advancement and flexibility of digital technology and the emergence of DECT[4] has stimulated the concept of using DECT interface technology standard in various applications. The internet working of DECT and ISDN solves the problem of serving the increasing demand on digital (multimedia) communications in the neglected rural areas or remote habitable locations. This would indeed reflect positively on these remote locations economic growth and its relation to increase in: productivity, efficiency and enhancement of the quality of life for such societies. The developing and developed countries alike will benefit from this new technology.

The Basic Rate Service (BRS) of the ISDN network provides two independent 64kbps duplex channels, (B channels) for carrying user data and one duplex 16kbps channel (D channel) for signaling. In Europe, the BRS is terminated at the user's premises by a unit called the Network Termination (NT). This, in turn provides a four-wire interface (called the S-interface or S-bus) which is used for connecting user Terminal Equipment (TE) to the NT[5, 6]. Up to eight TE can be connected to the S-interface if required and the general scheme is shown in Fig. 1.

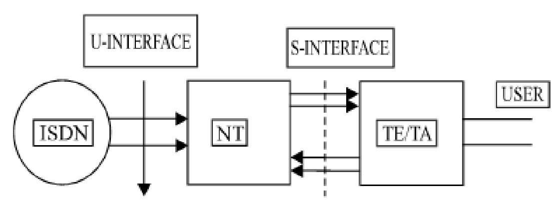

Fig. 1: ISDN Basic Rate Service Architecture

Therefore, the impetus of this research is the hypothesis to investigate the feasibility of replacing the fixed-wire S-bus with a radio link, so that the terminal equipment can be more easily located or relocated and communicated with. The radio link is novelliy implemented using the DECT radio interface technology standard.

Interworking Requirements: The design for the interworking scheme between DECT and ISDN equipment is shown in Fig. 2. It is shown that, the link between the ISDN NT and the TE is provided by the DECT Radio Fixed Part (RFP) and Wireless Portable Part (WPP). The S-bus associated with the NT and TE are terminated using standard chipsets and the bit streams associated with them are then linked by the DECT radio channel through a pair of Interworking Units (IWU). The latter performs the necessary merging function between the two dissimilar systems in a novel way; that the use of radio is transparent to the ISDN equipment.

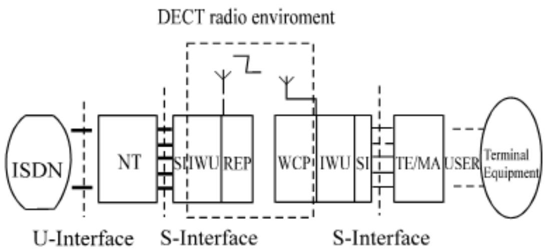

Fig. 2: Transparent ISDN/DECT Internetworking

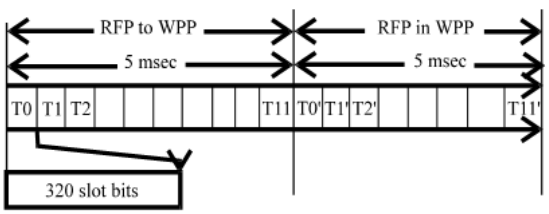

Fig. 3: DECT Transmission Scheme

DECT uses a Time Division Multiple Access/Time Division Duplex (TDMA/TDD) scheme to achieve duplex communications[7]. A TDMA frame lasts for 10ms and is divided into 24 time-slots, with 12 time-slots in the uplink direction and 12 times-slots in the downlink direction as depicted in Fig. 3. The RFP transmits in the first half-frame; while the WPP transmits in the second half time. In this research DECT supports ISDN by providing basic rate adaptation (LU5 and LU6) and a multi-channel set; hence make efficient use of the scarce radio resources available for meeting the large demand discussed earlier. It also specifies a number of transmission schemes at the DLC layer to meet different user requirement[5], in terms of the extra services needed by the society. Of these, class 3 transmission is suitable for ISDN as it provides a constant bit rate throughput with a selective repeat strategy,[8] for error control. Error protection is thus provided by the IWU instead of DLC and MAC layer of DECT. It must also be stressed here that the adoption of class 0 transmissions, has the advantage that the transmission protocol in the IWU can be readily adapted to suit a particular application or situation not directly supported by DECT. Thus, the ISDN can reach where DECT is reaching. The role of the IWU can best be described by first considering the S-bus and DECT time-slot architecture.

ISDN S-Interface: The frame structure of the S-bus bit stream is of the following architectural arrangement: there are two independent bit streams, one in each direction of transmission with a 2-bit delay between each stream. Each frame comprises of 48 bits in 250μs and contains 16 bits for each of the B-channels, 4 bits for the D-channel and a range of control bits. The latter has a number of functions such as frame alignment and DC balancing. Prior to transmission over the DECT radio channel, therefore, the control bits are removed and just the 2B+D bits are transmitted. This scheme conserves bandwidth and the resulting bit rate is reduced before passing over the S-interface, giving rise to an increase in the frame efficiency and overall system capacity.

DECT Transmission Scheme: A study of the DECT radio frame architecture[9], shows that, each time slot contains 320 bits of user data in each direction every 10ms. This provides a basic rate per time-slot of 32kbps duplex, which is the rate used for ADPCM transmission. It can be concluded from this, therefore, that multiple time slots must be used to obtain a bit rate of 144kbps. This is another factor which actually, increase the overall system capacity required to meet the high demand, which is one of the main aims of this study. Also, additional slots are required for retransmission purposes, to ensure reliable communications.

Interworking Approach: It can be seen from the above analysis that both ISDN and DECT interfaces are incompatible. In this section therefore, a novel technique is presented to interlink them so that the ISDN can utilize the existing DECT interface for its wireless transmission. However, the wireless ISDN operates at a frequency range between "(1.4-2.7) GHz". This makes the frequency part of the interfacing compatible with the DECT standard as DECT also operates in 1.8GHz band, which would alleviate the burden of the interlinking process between the two technologies.

A schematic diagram Fig. 4 showing the ISDN/DECT interworking approach. Using this approach a new protocol format is suggested that merges the data bits in the three dedicated ISDN channels, giving a new frame made up of 320 bits.

Hence the IWU format, the 2B+D, whose architecture is shown in Fig. 5. As can be seen from Fig. 5, this protocol is based on the FU5 frame structure of DECT. Where, each frame contains 28 bytes (or 244 bits) of user data plus additional fields for error detection and retransmission purposes. Each of these frames is passed to the DECT DLC layer and subsequent to the MAC layer, which maps the frame onto an available DECT transmission time-slot. And this implies that the control bits are no longer needed, to give a 20% increase in the frame efficiency as indicated from the computational results obtained. This result is new and can quite uniquely distinguish this research, as it is a prime requirement to increase the system capacity. Hence; be able to meet the highly increasing consumer demand on modern communications in the developed and developing countries.

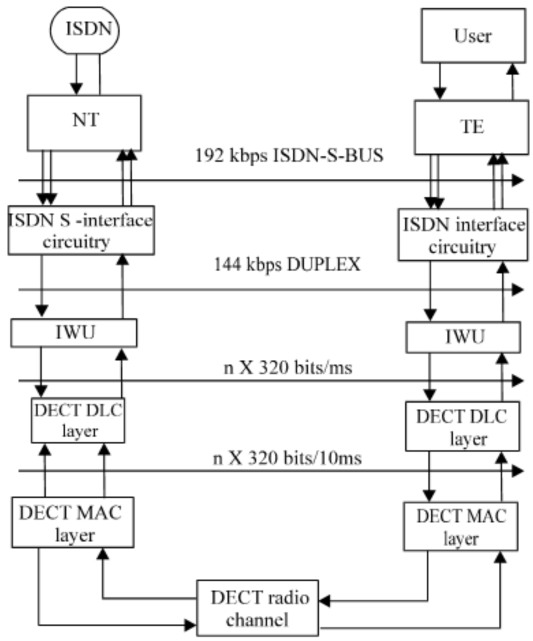

Fig. 4: Interworking Approach Schematic Diagram

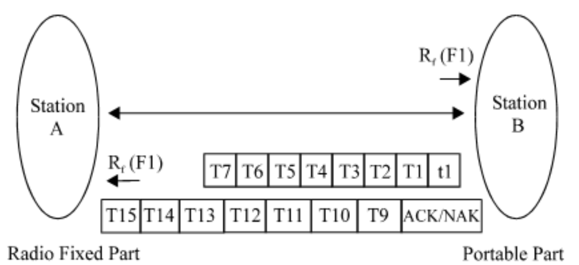

Fig. 5: Transmission Process Between RFP and PP

At the receiving side however, each received frame is passed to the IWU, which then checks the frame for errors and determines its sequential order. If for example, the frame is correct; the DECT control information in the frame is stripped away and the remaining 2B+D bits delivered to the S-interface circuitry. The latter then generates the S-bus control bits and inserts them into the appropriate positions to reconstitute a valid S-bus frame before passing it to the NT (or TE). For each frame received, either a positive or negative acknowledgment has returned to the transmitting side so that any incorrect or missing frames are retransmitted. The sending and receiving IWUs buffer all frames for a defined period, to allow for the retransmission of erroneous frames whilst still retaining a constant delivery rate. Hence a place for advancement however over this technique is to use sunblock coding methodologies such as FEC to correct any erroneous bits on the received frame rather than retransmitting it. Such method is proposed by[10,11] for the European link project for broadband (1.8GHz band) digital transmission and a similar scheme is also used in[12] and proved a success.

Since each frame contains 224 bits of user data, the user bit rate for each DECT time-slot is 22.4kbps. Hence, to provide a constant 144kbps data throughput, a minimum of 7 DECT times-slots must be used. Extra slots are then needed for retransmission of erroneous frames. The last seven time slots that have been allocated in each TDMA frame are always reserved for transmission of new frames. Hence, if 9 time slots (not necessarily in the same frequency carrier) is available, then the last seven times slots are used for transmission of new frames and the first two times slots are used for retransmission of erroneous frames transmitted in the pervious TDMA frame. Hence, there will not be any transmission in the time slots allocated for retransmission purposes if none of the frames in the previous TDMA frame is corrupted. As mentioned earlier, the receiving side generates either a positive or negative acknowledgment for each of the received frames. This acknowledgment, with a receive sequence number (Nr), is then piggybacked in the reverse direction with the outgoing information frames in the corresponding time-slots. The same procedure is followed in the reverse direction and hence duplex transmission is obtained, as required and set by the standard ISDN interface.

The number of retransmission attempts depends on the latency period permitted; for example, with a 10msec latency only a single retransmission attempt is allowed. And this is the mode of working considered in this study. The transmission and retransmission under various conditions with 9 transmission slots available, is investigated to verify the validity of this new ISDN/DECT internet working scheme[13]. Due to space limitation in this study, only three cases are explored, however, subsequent publications will consider further cases.

Case Studies:

Case 1: No transmission errors occur t1, a new block of 7 frames is submitted for transmission. In Fig. 5 stations A (e.g., the radio fixed part) transmits the 7 frames and stores them in the transmit buffer should retransmission be required. All seven frames are received without errors by station B (e.g., the portable part) and these are stored in the received buffer. For the next half frame, station B transmits 7 frames in the reverse direction and, at the same time, acknowledgment information (Nak or Ack) relating to the seven frames it has just received from station at. Station A discards positively acknowledged frames in its transmit buffer and retransmits up to two negatively acknowledged frames.

The entire letter is then discarded. At time T2, the contents in the receive buffer in station B are delivered to the IWU software forming the interface with the interface circuitry.

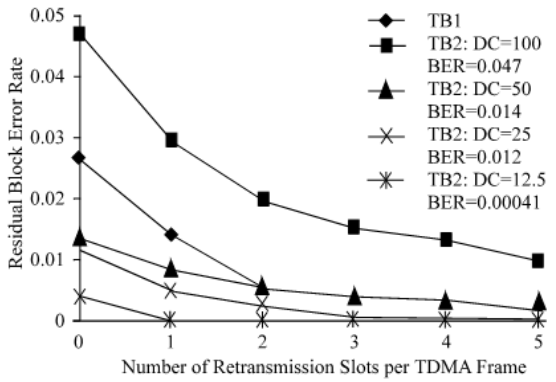

Fig. 6: Residual Block Error for Various Conditions

Case 2: Three frames (3, 5 and 6) from station A are corrupted. The negative acknowledgments relating to these frames cause station A to retransmit frames 3 and 5. After successful retransmission, station B replaces the erroneous frame in the receive buffer with the good frames. Frame 6 previously received is nonetheless delivered to the S-interface software with errors as no retransmission is possible.

Case 3: Frames 3 and 5 are corrupted and retransmitted. However, frame 5 is again corrupted during the retransmission. It therefore cannot be corrected and will be delivered to the interface (IWU) with errors.

The above analysis illustrates certain cases but there are of course other possibilities. For example, acknowledgment information can be corrupted and thus result in the retransmission of frames that are previously correctly received. The receiver must therefore, be able to detect and discard these duplicate frames as well as to detect missing frames. Such capabilities are included in this scheme.

Simulating the Transmission Technique: Once the two systems are internet worked it is worth verifying its functionality to ensure that the ISDN/DECT networking scheme presented is valid and has the capability of providing reliable communications to a wider sector of the population particularly those in remote habitable locations. The verification process is achieved by proving the above error control technique, quantify its performance and buffer requirements, the technique has been simulated using the Block Oriented Network simulator (BONeS). The residual block error rate with different numbers of retransmission slots has been obtained under different DECT channel conditions. The channel characteristic has been simulated by taking measurements from two simulated DECT test beds. Each reading considered represents the total number of erroneous bits in a frame of 420 bits; that is; user plus control fields. In the simulation, for each frame transmitted, a residual value is obtained to represent a DECT channel measurement condition for a non-zero entry means the frame is corrupted. Otherwise, the frame is received without error. In this study 4000 frames are transmitted for each simulation run; each run is programmed to specify a given number of available slots for retransmission purposes. The results of the simulation are presented in the performance and verification section.

Buffer Size Requirement and Latency: The testing procedure described in this study sets a permanent DECT connection and hence in this case the latency of the link will be just 10msec. If however, the DECT connection is to be set up dynamically at the start of each ISDN call, then buffers are required to hold the S-bus bit stream (effectively 144kbps), while the radio link is being set up. The buffer size is decided by the product (DECT call set-up time x 144kbps). A set-up time of, for example, 0.5 sec. would require 9kbytes of memory for the S-interface. In addition, in both cases, the DECT interface needs buffer storage to hold the newly transmitted frames in case retransmission is required. As each TDMA frame contains 7 new frames and each contains 320 bits, then the DECT interface buffer size required in this case is 280 bytes in the uplink and downlink directions of transmission. At the receiver, the IWU delivers the received frames to the S-interface at the same rate as the incoming frames, but it only starts delivering after the latency period. With a permanent DECT connection, the overall latency is 20msec-10msec at each interface, but with a dynamic connection the call set up time will be added to it. As shown by Fig. 6, at t=T1, the first block of frames is received by station A and at t=T2, the block is delivered to the ISDN interface at station B. During this period, up to 12 frames (allowing for the possibility of 5 retransmissions) could have been buffered. In this case up to 480 bytes of buffer is designated to be available at the portable part.

Performance and Verification: This section shows some of the main results obtained from the experimental tests carried out on the simulated tested. Figure 6 however, shows the residual block error rate for varying number of retransmission slots under different delay spread (channel quality) values. The delay spread values considered are those measured in the mobile radio environment using GSM interfacing[7]. This enables healthy air transmission to provide coverage for remote habitable locations, that would be very costly to serve otherwise, which makes the process economically unfeasible. As can be seen from Fig. 6 and as expected, the residual block error rate decreases with the number of retransmission slots used. Also, the poorer the quality of the channel, the higher the number of retransmission slots required to obtain an acceptable residual block error rate.

For TB1, the nature of the errors is such that with the retransmission scheme adopted, no or only minor improvement can be obtained beyond that with 3 retransmission slots, similar results are presented in[9]. For TB2, with a good quality channel (delay spread=12. 5nsec), all errors can be corrected with just one retransmission slot.

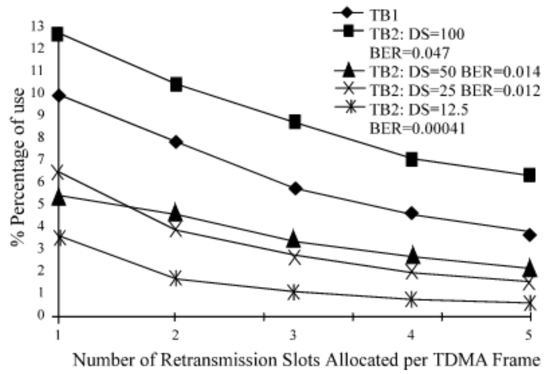

Fig. 7: Retransmission Usage for Different Condition

When the channel delay spread is 25nsec., three retransmission slots are required to correct all errors. With the maximum number of retransmission slots available, an acceptable block error rate can be obtained in all but the worst quality channel. Such results clearly, verify the adopted scheme of ISDN/DECT internet working and prove its effectiveness over other schemes and methods, that provide similar services and tasks. Figure 7 shows the usage of the retransmission slots with the proposed retransmission scheme for varying channel conditions.

Furthermore, Fig. 7 also shows, that the utilization percentage of the retransmission slots decreases with the number of retransmission slots allocated. The reason is that with more retransmission slots allocated, the chance that they are not used increases. A perfectly good channel will, of course, use no retransmission slots. And hence, as the channel quality improves, the percentage utilization of the retransmission slot drops. In addition to the overall block error rate, the uniformity of error distribution also affects the percentage utilization of the allocated retransmission slots. If the errors were random single block errors, for example, then these would be corrected with just a single retransmission slot. In practice, the errors affect bursts of blocks and hence the effectiveness of the retransmission scheme inevitably will be reduced. This can be seen by comparing the curves for DS=25nsec.

CONCLUSION

This study presented the results of a research considers DECT interface to provide a wireless link to a basic rate ISDN termination. It is shown that wireless ISDN/DECT system is a powerful tool to provide basic multimedia communications services to rural and remote locations. A prototype design has been simulated and the results show that the transmission using DECT interface provides a quality of service at a high level that can be achieved using other radio methodologies. A study of residual errors for data communications, to verify this scheme, shows that a maximum achievable packet size of data communications in this particular concept is in the region of 1kbyte. Above all an increase in the frame efficiency of 20% over a standard ISDN gives an improvement in the spectrum utilization of the overall system. Also, the results show that the high capacity digital links attained using DECT interfacing makes this solution an absolute novel technology that has to be deployed to: Solve the digital communications congestion problem, hence allowing ISDN services to reach where DECT coverage is available, particularly in remote areas where the deployment of ISDN is very costly and solve the high blocking probability rate and improve on the poor communications quality in the basic rate ISDN services.

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