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- Catching the mobile future -

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Table of Contents

Volume III

Session WT4: Wireless data communications I
Organiser: T. Ermolovich, DEC, U.S.A.; Chair: Prof. A. Laloux, UCL, Belgium

WT4.1 Design of error control schemes for wireless data networks
Sanjay Gupta, Magda El Zarki, U.S.A. ................................................................. 771
WT4.2 A comparison of CDMA, TDMA and slotted Aloha multiple access schemes in cellular mobile radio systems
Michele Zorzi, Luciano Tomba, Italy ................................................................. 776
WT4.3 Effective block recovery schemes for ARQ retransmission strategies
M. Aghadavoodi Jolfaei, U. Quernheim, Germany ........................................ 781
WT4.4 The evolution of wireless networking: conformance or conflict with the OSI reference model?
O. Spaniol, Germany (invited paper) ................................................................. 786

Session WA2: Multimedia data services
Organiser: TPC; Chair: Dr. C. L'Anson, HP Labs., U.K.

WA2.1 Multimedia broadcasting to mobile, portable and fixed receivers using the EUREKA 147 digital audio broadcasting system
J. Hallier, Th. Lauterbach, M. Unbehaun, Germany ........................................ 794
WA2.2 Mobile data communication in Germany - a survey
B.H. Walke, Germany ......................................................................................... 799
WA2.3 Secure access to electronic newspaper
Zygmunt Haas, Sanjoy Paul, U.S.A. ................................................................. 805

Session WT6: Wireless data communications II
Organiser: TPC; Chair: Prof. I.G.M.M. Niemegeers, Univ. Twente, Netherlands

WT6.1 Capture-division packetized access (CDPA) for cellular systems
Flaminio Borgonovo, Luigi Fratta, Michele Zorzi, Italy ............................... 810
WT6.2 Bit error rate estimation for low rate services in a mobile radio environment
A. Wilde, U.-C. Fiebig, Germany ................................................................. 816
WT6.3 A study on a TDM wireless LAN system using a spread spectrum control signal
Makoto Itami, Kazushige Asada, Kohji Itoh, Japan ...................................... 821

Session WT7: Wireless LANs
Organisers: Dr. J. Whitehead & Dr. R. Krishnamoorthy, AT&T/NCR, Netherlands;
Chair: Prof. R.A. Grünewald, PTT Research Lab., The Netherlands

WT7.1 Equilibrium analysis of ALOHA and CSMA in wireless networks
Ad Kamerman, James F. Whitehead, Netherlands ...................................... 825
WT7.2 Performance study of WaveLAN and ALTAIR radio-LANs
Willem Hollemans, Arie Verschoor, Netherlands .................................................. 831
WT7.3 The AT&T GIS WaveLAN air interface and protocol stack
A. Claessen, L. Monteban and H. Moelard, Netherlands ........................................ 838
WT7.4 Application of the asynchronous transfer mode in indoor radio networks
P.F.M. Smulders, C. Blondia, Netherlands ............................................................... 839

Session WA3: Future PCS
Organiser and Chair: Prof. A.H. Aghvami, King’s College, London, U.K.

WA3.1 Network architecture and functionalities for UMTS
G. Colombo, H. Hegeman, Italy (invited paper) ................................................... 844
WA3.2 Evolution towards UMTS
Jan Oudelaar, Netherlands ......................................................................................... 852
WA3.3 Considerations on network interfaces for third generation mobile telecommunication systems
Evert Buitenwerf, Netherlands ................................................................................... 857

Session WT8: HIPERLAN I
Organiser and Chair: Prof. S.K. Barton, Univ. Bradford, U.K.

WT8.1 HIPERLAN markets and applications standardisation issues
Bernard Bourin, France ............................................................................................... 863
WT8.2 The HIPERLAN MAC sub-layer architecture
Larry Taylor, France ................................................................................................... 869
WT8.3 HIPERLAN medium access control
T. Phipps, U.K. ............................................................................................................ 870
WT8.4 Collision detection in HIPERLAN
Philippe Jacquet, Paul Mühlethaler, Nicolas Rivierre .............................................. 875

Session WT9: Access control
Organiser: TPC; Chair: Dr. Z. Haas, AT&T Bell Labs., U.S.A.

WT9.1 Bridging functionality for medium access control sublayer
Tomoki Ohsawa, Gerald Q. Maguire jr., Sweden ..................................................... 880
WT9.3 Decentralized dynamic terminal access control in local area network
V.A. Korolenko, E.D. Faktorovich, V.V. Fokanov, Belarus .................................. 885
WT9.4 Performance of trunked mobile radio networks based on MPT 1343 standard for voice and data transmission
R. Hekmat, Netherlands ............................................................................................ 886
WT9.5 Open packet radio protocols for highly survivable LAN to LAN interconnectivity
N. Karavassilis, F. Eken, Netherlands ....................................................................... 893

WA4: Frequency allocation, standardisation and regulation
Organiser and Chair: Prof. G. Stette, Univ. of Trondheim, Norway

WA4.1 Economic methods for radio spectrum assignment
L. Benzoni, E. Kalman, A.M. Youssef, France ........................................................... 901
WA4.2 ETSI - the European approach to standards making
P.J.C. Hamelberg, Netherlands .................................................. 909
WA4.3 Standardization and the telecommunications innovation process: the cases of
SDH, TETRA and DECT
Tom J. Paffen, Netherlands ...................................................... 915
WA4.4 A technical discussion on the wireless internetworking technologies and protocols
T.M. Maheshwar, James T. Geier, U.S.A. ................................. 920
WA4.5 Commercial opportunities and legal constraints for mobile satellite communications
L.F.E. Mischke, Netherlands .................................................. 924

Session WT10: GSM Data Services
Organiser: TPC; Chair: Dr. L. Pouzin, France

WT10.1 Packet data service over GSM networks: proposal and performance evaluation
attempt
Giuseppe Bianchi, Flaminio Borgonovo, Antonio Capone, Luigi Musumeci, Italy .... 929
WT10.2 A packet protocol for group communication suitable for the GSM mobile radio
network
P. Decker, Germany ............................................................... 934
WT10.3 Short message service based applications in the GSM network
Sergio Collesei, Paolo di Trin, Gaetano Morena, Italy .................... 939
WT10.4 Real time simulation of fax transmission on the transparent GSM data service
Roberto Morassi, Mark Eve, U.K. ............................................ 944

Session WT11: HIPERLAN II
Organiser: Prof. S.K. Barton, Univ. Bradford, U.K.; Chair: B. Bourin, France

WT11.1 Modelling the HIPERLAN radio channel
Geoff Halls, France ............................................................... 954
WT11.2 Modulation and equalisation techniques for HIPERLAN
S.W. Wales, U.K. ................................................................. 959
WT11.3 Modulation and equalisation considerations for high performance radio LANs
(HIPERLAN)
WT11.4 Multicarrier COFDM scheme in high bitrate radio local area networks
Michael Aldinger, Germany .................................................. 969

Session WA5: Application of Wireless Networks
Organiser: TPC; Chair: E.L. Petersen, Fischer & Lorentz, Denmark

WA5.1 The Walkstation project on mobile computing
F. Reichert, Sweden (invited paper) ........................................ 974
WA5.2 Data networking using public paging systems
C. Rindorf, Denmark (invited paper) ....................................... 979
WA5.3 Use of 115 kb/s infra-red interface for mobile multi-media
David Dack, Colin I’Anson, Gracme Proudler, U.K. ..................... 980
Session WT12: Network aspects
Organiser: TPC; Chair: Dr. P. Agrawal, AT&T Bell Labs., U.S.A.

WT12.1 A conceptual framework to integrate mobility into ISDN
J.P. Ebert, B. Rathke, A. Wolisz, Germany (invited paper) ........................................ 986

WT12.2 Functional approach to a hybrid wireless network for mobile stations
Hassan Zeino, Michel Misson, France ................................................................. 994

WT12.3 The effect of user authentication on the performance of a cellular mobile communication system
Le-Pond Chin, Jin-Fu Chang, Taiwan ................................................................. 999

WT12.4 GSM subscriber management on top of a generic TMN agent
Tom Leskinen, Finland ....................................................................................... 1004

Session WT13: Random Access II
Organiser: TPC; Chair: Dr. R. Krishnamoorthy, AT&T/NCR, Netherlands

WT13.1 Spectrally efficient universal time slots using time-frequency-code slicing
Clark B. Woodworth, Mark J. Karol, Zygmunt J. Haas, Richard D. Gitlin, U.S.A. .... 1009

WT13.2 Performance of dynamic capacity allocation in future wireless communication systems
Terje Jensen, Arne Myskja, Eirik Larsen, Norway ............................................... 1014

WT13.3 An algorithm of resource allocation for multihop packet radio networks with radial data flow
Di Huo, Germany .................................................................................................. 1019

WT13.4 Performance of a hybrid CDMA/ISMA protocol with multiple return channels and buffering
H.R.R. van Roosmalen, J.A.M. Nijhof, R. Prasad, Netherlands ......................... 1024

Author Index
Multimedia Broadcasting to mobile, portable and fixed Receivers using the Eureka 147 Digital Audio Broadcasting System

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Abstract: The Digital Audio Broadcasting (DAB) system developed within the Eureka 147 project is well adapted to the requirements of broadcasting audio, programme associated data and general data including e.g. video, still images and coded traffic messages. The configuration of the DAB multiplex (i.e. data rates and error protection of the different applications) is flexibly adjustable.

Having evaluated the performance of DAB data channels in typical mobile reception situations, we conclude that the system will allow multimedia services to be reliably broadcast to mobile, portable and fixed receivers. To demonstrate this capability of DAB, we set up and operated experimental low bitrate video and still image transmissions associated to audio programmes.

I. INTRODUCTION

The Eureka 147 Digital Audio Broadcasting (DAB) system [1], [2] has been designed for broadcasting to mobiles with audio quality comparable to CD without any impairment even in severe multipath reception situations. This has been achieved by applying a wide band (1.5 MHz) transmission scheme known as Orthogonal Frequency Division Multiplexing (OFDM) [3] in conjunction with Rate Compatible Punctured Convolutional Codes (RCPC) [4] to allow for an efficient forward error correction mechanism adapted to the characteristics of the sources. To maintain high spectrum efficiency, audio sources are encoded according to the ISO 11172-3 (MPEG audio) Layer 2 standard [5]. For other than audio components, a number of transmission mechanisms including a packet mode are provided.

The maximum net data rate of the DAB system is 1.728 Mbit/s providing capacity for a multiplex of services containing e.g. several audio components, data components (e.g. coded traffic messages, text channels etc.) and even still or moving picture channels. This makes DAB highly appropriate to multimedia broadcasting in a sense that audio, video, text and other data all related to one programme can be delivered to the listener in parallel.

After a brief description of the DAB multiplex structure, this paper focuses on two issues: Firstly, measurements of the performance of the DAB audio and data channels using prototype equipment will be reported. The results show that components carried by the different DAB transport mechanisms can all be reliably received at a signal-to-noise-ratio of about 10–12 dB. Secondly, we describe multimedia broadcasting experiments which we performed to demonstrate the capability of the system to transmit still images associated to an audio programme and moving pictures in a separate data channel.

II. DAB MULTIPLEX AND SERVICE STRUCTURE

The data of audio components and other applications in a DAB multiplex are carried in what is called the Main Service Channel (MSC), which is divided into subchannels. Data carried in a subchannel are commonly convolutionally encoded and time interleaved. Fig. 1 shows the conceptual multiplexing scheme of the DAB system. The data rates available for individual subchannels are given by integer multiples of 8 kbit/s. There are two transport mechanisms: stream mode and packet mode.

Stream mode subchannels may contain audio encoded according to ISO 11172-3 Layer 2. Within each DAB

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III. EVALUATION OF THE PERFORMANCE OF DAB DATA CHANNELS

Radio reception is quite different in different reception environments. Portable and mobile reception often suffer from multipath propagation, low field strength and man made noise, whereas fixed reception using an outdoor antenna or cable distribution enjoys high field strength and good signal quality. For a multimedia service, consisting for example of a stereophonic audio programme, a still picture channel carried in a different subchannel and some other components, it is desirable that the coverage areas of the different components can be tailored to the user groups addressed (e.g. listeners in mobiles, at home etc.). To achieve this, a wide range of code rates is available for the MSC subchannels. For audio, unequal error protection (UEP) profiles have been defined taking into account the different sensitivity to bit errors of the different parts of the audio frame [7], see Fig. 2. This results in a subjectively more acceptable degradation of the system when leaving the coverage area. For each audio data rate, five UEP profiles with different average code rates (0.34, 0.43, 0.5, 0.6, 0.72) are defined. For general data, four code rates (0.25, 0.38, 0.5, 0.75) are available (equal error protection, EEP). In the measurements described below, we investigated the performance of an EEP subchannel in different fading channels to test whether the coverage expected for data transmission is comparable to that achieved for audio including PAD.

a) DAB experimental equipment and measurement set-up

For field trials and demonstrations of DAB, test equipment has been developed and produced within the Eureka 147 consortium. The multiplex used by this equipment is composed of six audio subchannels with various bit rates and UEP coding profiles and two data subchannels with EEP and data rates of 64 and 24 kbit/s. Data interfaces are available to feed the coders and to transfer data from receivers to external decoders or to a PC for on- or off-line evaluation of the data. For the field trials in Germany, a central DAB transmitter is operated jointly by German Telecom and Institut für Rundfunktechnik in Munich. The signal is frequency modulated and distributed to the terrestrial DAB transmitters via a 30/20 GHz transponder of DFS Kopernikus.

The bit error measurements and multimedia transmission experiments described below made use of feeding data into this transmission chain and receiving the signal at our laboratory via the satellite link. The experimental set-up is shown in Fig. 4. After FM demodulation, the DAB signal was mixed to 225.5 MHz. A fading channel simulator was used to provide typical mobile reception situations. The channel parameters used...
for setting up the channel simulator were some of the ones defined for GSM[8] and a specific DAB one (single frequency network, SFN). To adjust the signal-to-noise-ratio (S/N), a variable attenuator was inserted in the DAB signal path and noise was added. The S/N was measured with a spectrum analyser, the result being improved by averaging 256 traces of the DAB signal in fading channels. For the measurements, the signal was fed to a DAB receiver. After channel decoding, the bit stream was transferred to a PC where it was compared with the transmitted bit stream to detect bit errors. Due to Viterbi decoding, the errors were expected to occur in bursts. Therefore, the "error gap distribution"[9] was calculated. An error gap is defined as the string of consecutive correctly received bits between two bit errors. Its length is the number of the correctly received bits plus one. The error gap distribution \( \text{EGD}(j) \) is the probability that the gap length is greater or equal than \( j \), \( j \) being an integer. All measurements were performed in the EEP subchannel with a data rate of 24 kbit/s and a code rate of 0.38.

b) Results and discussion

The results on the bit error rates versus S/N (Fig. 5) indicate that the error probability increases with the delay spread of the channel and decreases with S/N. The plots of the error gap distributions (Fig. 6a-d) show that the errors indeed occur in bursts, even in the Gaussian channel. The gap lengths inside an error burst usually are shorter than 15 bit due to the properties of Viterbi decoding. The probability of an error gap shorter than about 15 bit to occur is higher than 80\%, so we can assume that error bursts will typically contain a number of errors separated by short gaps. Long error gaps (> \( 10^5 \) - \( 10^6 \) bit) are observed between these error bursts.

During the long error gaps, a large number of packets (several thousands) can be successfully transmitted. Consequently, a single or two consecutive packets out of several thousand packets are expected to be rejected by the CRC due to an error burst. The length of data groups is limited to 65536 bits in the DAB system. This figure is considerably smaller than the length of the long error gaps measured at S/N \( \geq -10 \) dB. Therefore, even complete data groups can successfully be transmitted during an error gap. These results clearly show that a packet mode transmission using the code rate we investigated is feasible at S/N=10 dB even under severe multipath conditions.

During audio reception using the same set-up, a subjective impairment of the sound due to transmission errors in the samples of the audio frame at average code rates of 0.5 was observed at S/N values of about 8 and 10...12 dB in the Gaussian and the fading channels, respectively. Therefore, it is expected that audio, PAD (which in its majority enjoys the same protection as the audio samples) and general data carried in a packet mode subchannel with suitable code rate all begin to fail below about the same value of S/N. Nearly identical coverage areas can hence be expected for all the components of a multimedia broadcasting service on DAB.

IV. EXAMPLES OF MULTIMEDIA BROADCASTING USING THE DAB SYSTEM

To demonstrate the potential of the DAB system for multimedia broadcasting, experiments have been performed focusing on the transmission of images associated to the audio. For still picture transmission, JPEG coding was used. A low bitrate videophone codec was used for moving picture transmission.
a) Still picture transmission in the PAD channel

During the CeBIT fair in Hannover in March '94, a slide show broadcast using a DAB audio subchannel (192 kbit/s, average code rate 0.5) was demonstrated. To achieve synchronisation of the still pictures with the audio, photographs and computer graphics coded according to the JPEG [10] format were transported in the PAD part of the audio subchannel. The PAD data rate available in the existing DAB equipment is 16 kbit/s. The JPEG compression factor was chosen such that a picture could be transmitted within a few tens of seconds while maintaining a high picture quality. A command byte was inserted in each DAB audio frame to indicate the start, continuation or end of a JPEG file and providing a "show next image" command to achieve synchronisation with the audio. A PC based JPEG hardware was used for decoding and display: the JPEG data read from the PAD interface of the DAB receiver were written to files. As soon as the "show picture" command was received, the next image file was sent to the JPEG decoder and displayed on the monitor. An example of a multimedia programme was produced explaining some technical background of DAB and presenting examples of a news message, a weather forecast, traffic messages and musical entertainment, all illustrated by suitable pictures, e.g. a weather satellite photo, a map with traffic jams indicated and the cover photo of the CD a track of which was played. Due to the high quality stereo sound, the high resolution of JPEG encoded photographs and the easy synchronisation of both, this arrangement certainly is a promising one for a later multimedia service on DAB.

b) Low Bitrate (24 kbit/s) Moving Picture Transmission in an MSC data Channel

In another experiment, a low bitrate moving picture transmission in a data subchannel of the MSC was tested and demonstrated. A video codec developed for videophone systems in our laboratory [11] was used at a data rate of 24 kbit/s. A six minute sequence of different still and moving pictures had been compiled showing a newscaster, several maps with traffic related information, some logos, and fish in an aquarium. Although only the equal error protection of DAB was applied (code rate 0.38) and although the very low bit rate video coding is extremely sensitive to bit errors due to interframe coding and the high compression ratio, the system worked in multipath channels without any perceptual transmission errors at S/N values only 3 to 5 dB higher than that required for reception of an audio signal without impairment of the sound (UEP, average code rate 0.5). Due to the limited resolution of the low bitrate video codec (176x144 pixels) it turned out that the symbols and texts on the maps were not very well legible. The slowly changing
moving pictures showing the newscaster and the fish, however, gave a very good impression of what was going on.

V. CONCLUSIONS

There clearly is an excellent potential for broadcasting multimedia services using the Eureka 147 Digital Audio Broadcasting system. It provides a number of transport mechanisms suiting a wide range of needs regarding data rates, forward error correction and synchronisation with other components of the same service. The multiplex structure being highly flexible, DAB offers the possibility to adapt the capacity assigned to the individual components to their specific requirements. In this paper, we focused on the performance of transport mechanisms provided to broadcast other applications than audio. The experimental results of bit error measurements and examples of video transmissions in DAB showed that a sufficient performance of still and moving picture transmission systems can be achieved near the minimum signal levels required for reception of audio without impairment of the sound without the need for a further source adapted outer code. The progress already made in a JESSI project (AE14) towards developing Integrated Circuits [12] towards mass production of low cost consumer receivers will result in a fast penetration of the market with DAB. This will make multimedia broadcasting services on DAB available for many listeners at home and in mobiles in the near future.

VI. ACKNOWLEDGMENTS

The authors would like to thank the members of Eureka 147 who actively contributed to the multiplex structure and data service aspects of the DAB system. They also thank German Telekom and Institut für Rundfunktechnik for making the DAB transmitter and satellite link available for the video experiments. This work was partially supported by the BMFT (German Federal Ministry of Research and Technology) and German Telekom. The authors thank A. Neutel for excellent technical assistance.

VII. REFERENCES

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