Interactive mobile streaming services

– the convergence of broadcast and mobile communication

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In this article, the authors discuss some of the challenges and opportunities resulting from the convergence of broadcast and mobile communication services. Starting with an overview of DAB, DVB and the emerging third-generation mobile communication networks – with a special focus on UMTS – the advantages that result from a combination of UMTS with data broadcast facilities, as provided by DAB and DVB, are discussed. This allows us to provide mobile users with interactive mobile IP streaming services, thereby opening the door for a lot of interesting mobile applications.

The enabling of new services is not enough, however, if we take into account the limited spectrum allocation for mobile communication systems. Hence the article discusses the possibilities for efficient and flexible spectrum utilization. Mechanisms for dynamic spectrum and service allocation are introduced, which can be seen as a prerequisite, not only for efficient spectrum utilization, but also as an enabling technology towards more flexible communication services than we have today.

1. Introduction

In the past, broadcasting just meant the distribution of radio and television programmes to the people's living rooms. Evolving digital broadcasting standards, such as DAB and DVB, can do a lot more. They can be used as a flexible digital multimedia content-broadcasting platform. They enable access not only to multiple sources of TV and radio channels, but to data programming as well [1]. Data programmes alone can consist of multimedia channels, each carrying a mixture of synchronized video, audio and text content. Beyond that, data programmes can also comprise continuous transmission sets of software modules, such as games software or other applications software.

Besides the trend towards multimedia broadcasting, interactivity and personalization are also important to the broadcasting industry. By offering interactive broadcast services, users can control the content and the way it is presented in several ways. Furthermore, interactive broadcast services enable the user to find the content he/she is really interested in, in a much quicker way than today.

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At the same time as analogue TV transmissions are being replaced by digital multimedia transmission techniques, mobile communication networks are evolving from pure telephony systems to third-generation mobile multimedia networks. The most important evolving systems in this area are GPRS and UMTS. UMTS will very likely become the first truly *global* mobile multimedia communication standard. Due to its flexible system design, UMTS is able to offer a variety of different services – ranging from speech telephony over data applications such as web-browsing, to interactive communication and entertainment services.

An appealing scenario results from the combination of multimedia broadcast systems such as DAB and DVB with mobile multimedia networks such as UMTS. The EBU is currently in the process of assessing the potential of the DAB/UMTS synergy for mobile multimedia services, and the terminal equipment manufacturers are already investigating the concept of combined DAB/UMTS user terminals. The integration of broadcast transmission techniques into UMTS can help to overcome the limited spectrum problem mentioned above. Most mobile multimedia applications have an asymmetric bandwidth demand, meaning a higher bandwidth is required for the downlink while the uplink is mainly used to transmit control information, such as user selections or commands.

However, the deployment of asymmetric communication services alone will not be enough to satisfy the demand for new mobile communication services, because it can already be foreseen that the market demands much more spectrum for UMTS services and applications than is available today [2][3]. Hence, we will discuss the possibilities for efficient and flexible spectrum utilization which shall open new frequency ranges for mobile communication services and which shall also enable the coexistence of mobile and broadcast services within the same spectrum. We will introduce mechanisms for dynamic spectrum and service allocation. The technology we propose can be seen as a prerequisite, not only for efficient spectrum utilization, but also as an enabling technology towards more flexible communication services than we have today.

2. Data broadcasting over DVB-T and DAB

The development of DVB-T started in 1993 and, in 1997, the DVB-T specification was approved by ETSI [4]. The achievable data-rates of DVB-T range from 3.7 - 23.8 Mbit/s for a 6 MHz channel and from 4.9 - 31.7 Mbit/s for an 8 MHz channel. The maximum achievable data-rate depends on the channel quality expressed as the signal-to-noise ratio observed at the receiver. This trade-off between SNR and achievable data-rate gives broadcasters a great flexibility in the system design. For instance, a broadcaster can decide between wide-area, medium data-rate, coverage or local-area, high data-rate, coverage.

The DVB data broadcasting specification [5] is designed to allow software downloads over satellite, cable or terrestrial links, to deliver Internet services over broadcast channels (using IP tunnelling), and to provide interactive TV, etc. The specification is based on a series of four profiles. Each profile corresponds to an application area. The four application areas covered by the DVB data broadcasting specification are as follows [2]:

- *Data Piping* – This is the simple, asynchronous, end-to-end delivery of data through DVB-compliant broadcasting networks.
- *Data Streaming* – This supports data broadcast services that require a streaming-oriented, end-to-end delivery of data in either an asynchronous, synchronous or synchronized way through DVB-compliant broadcast networks.

- *Multiprotocol Encapsulation* – This supports data broadcast services that require the transmission of datagrams of communication protocols via DVB-compliant broadcast networks.
- *Data Carousels* – This supports data broadcast services that require the periodic transmission of data modules through DVB-compliant broadcast networks.

The DVB standard already contains specifications for the use of different kinds of return channels (e.g. PSTN / ISDN and DECT). For mobile applications, the mobile phone standard GSM has been proposed as a return channel for DVB-T [6].

The development of DAB started back in 1987 within the framework of the European research initiative, Eureka. In 1994, a draft version of the DAB standard was presented to ETSI. The final version of the standard was approved in 1995. An improved version of the standard was finalized in 1997.

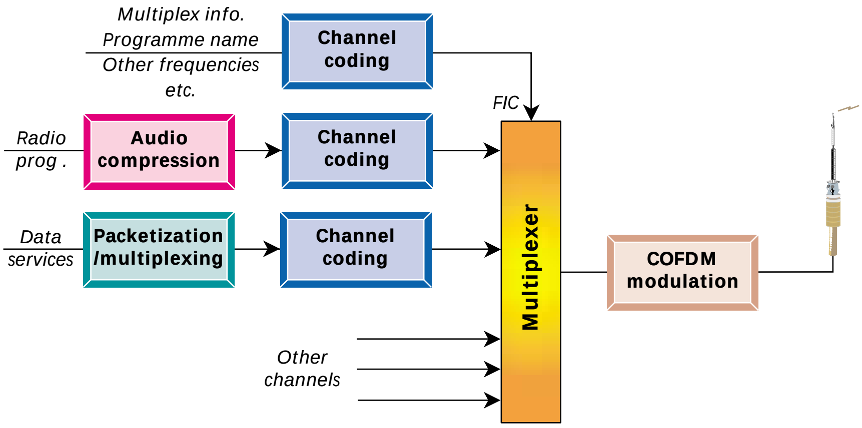

Figure 1
DAB system architecture.

The overall architecture of a DAB transmitter is depicted in *Fig. 1*. As can be seen, several sources of information such as radio programmes and data services are multiplexed into one data stream, which is then transmitted over a 1.563 MHz channel. For mobile reception, e.g. within cars, overall data-rates around 1.5 Mbit / s are achievable. The packet format used for data services is specified by the Multimedia Object Transfer (MOT) protocol [7].

3. Third-generation mobile communication networks

The success of second-generation mobile communication networks and, especially, the success of GSM has given an enormous amount of users access to mobile speech and data services. At the same time, the users expect more and better mobile services which cannot be met by circuit-switched second-generation technology. Enhancements of second-generation networks, such as the Global Packet Radio System, will soon hit the market, followed by the roll-out of third-generation mobile communication systems.

3.1. Global Packet Radio System (GPRS)

GPRS is the packet-oriented extension of GSM. This extension relies on the re-use of the radio infrastructure of GSM while introducing new network nodes in the core network to provide the required packet-switching functionality. GPRS is mainly intended to provide a better service for Internet applications, when compared with the existing circuit-switched services of GSM. Certain timeslots of the TDMA frame can be statically or dynamically allocated to GPRS, which provides efficient sharing of these radio resources, by multiplexing several users over one timeslot, as well as the possibility that one user transmits over several time-slots in parallel if the terminal equipment supports this. For a more detailed description of the GPRS concept, see [8].

3.2. Universal Mobile Telecommunications System (UMTS)

The Universal Mobile Telecommunication System (UMTS) is one of the major new third-generation mobile communications systems being developed within the IMT-2000 framework of the ITU. Third-generation mobile communication systems are characterized by offering:

- wideband multimedia services, which include both data and voice services;
- real-time as well as non real-time support;
- dynamic user bandwidth and services;
- IP connectivity from end to end.

UMTS, with its wideband CDMA radio access scheme, truly meets these requirements. It has the support of many major telecommunications operators and manufacturers, because it represents a unique opportunity to create a mass market for highly personalized and user-friendly mobile access to tomorrow's mobile "Information Society".

UMTS will deliver high-speed data, Internet services and mobile multimedia as well as audio to people who may be on the move. It will build on and extend the capability of today's mobile technologies (such as digital cellular and cordless) by providing increased-capacity data capability and a far greater range of services. UMTS will use an innovative radio access scheme and an enhanced, evolving core network which builds on the core network of GSM. It will, equally well, support circuit-switched and packet-switched services, which are currently being added to GSM under the headline of GPRS.

The standardization of UMTS phase 1 will be finalized at the end of 1999. While national regulation is still ongoing, the first licences for UMTS will be granted in Europe during 1999. The commercial launch of UMTS services in Europe will happen from the year 2002 onwards (UMTS will hit the Asian market in 2001). UMTS will see the evolution of a new "open" communications universe, with players from many sectors (including providers of information and entertainment services) coming together harmoniously to deliver new communications services, characterized by both mobility and advanced multimedia capabilities.

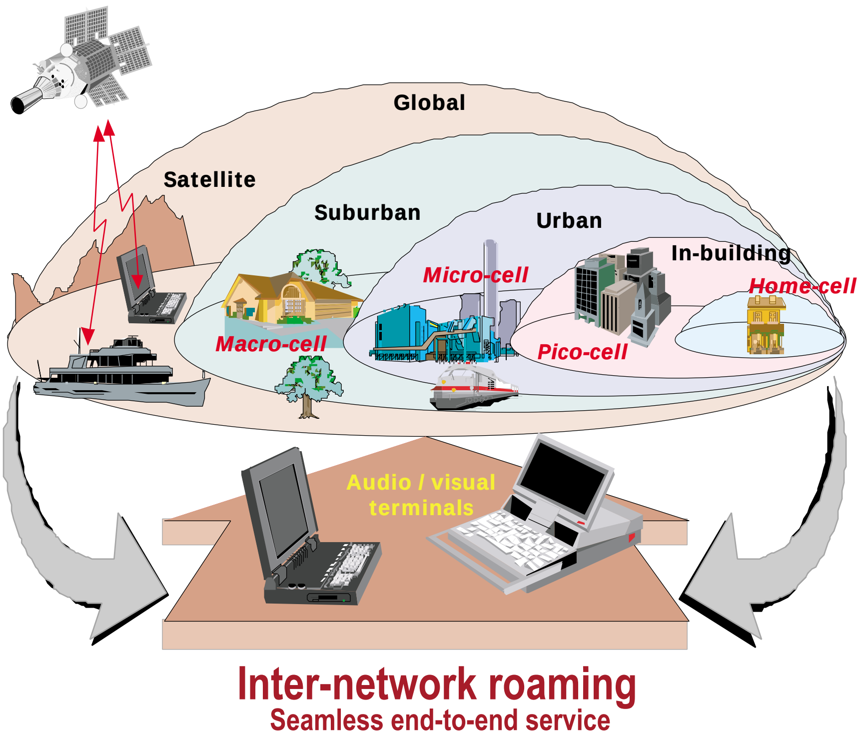

Figure 2
UMTS system architecture.

Fig. 2 depicts the system architecture of UMTS which comprises a hierarchical cellular environment consisting of pico, micro and macro cells, complemented by wide-area satellite coverage. The transmission-rate capability of terrestrial UMTS will provide at least 144 kbit/s for full mobility applications in all environments, 384 kbit/s for limited mobility applications in macro and micro cellular environments and 2.048 Mbit/s for low mobility applications particularly in micro and pico cellular environments. The 2.048 Mbit/s rate may also be available for short range or packet applications in the macro cellular environment, depending on deployment strategies, radio network planning and spectrum availability.

The target frequency bands for terrestrial UMTS services, identified by the ERC, are 1900 - 1980 MHz, 2010 - 2025 MHz and 2110 - 2170 MHz. From the year 2002, the spectrum designations will probably differ from country to country [9][3], due to national regulations.

4. Spectrum considerations

Recently, the UMTS Forum and other fora have identified that additional spectrum in a range of 150 - 342 MHz is required to satisfy the projected market needs for the year 2010 [3] (see also *Table 1*). Therefore, an investigation on possible UMTS extension bands was launched. One of the proposed candidates is the frequency range between 470 - 862 MHz. It is assumed that the replacement of analogue TV transmitters by DVB-T, together with an improved frequency re-use, will offer the possibility of considering a part of this spectrum for UMTS. However, parts of the band are also used for military services, demand for which is expected to remain even beyond 2010.

	Total	Identified for 2nd & 3rd G	Additional
UMTS Forum	582 MHz (403 MHz in 2005)	395 MHz	187 MHz
CEPT Administrations	556/543 MHz	395 MHz	161/148 MHz
US Administration	499 MHz (GSM Alliance)	190 MHz	309 MHz
Japanese Administration	440 MHz		
ITU-R (Draft)	532 MHz (Region 2)	190 MHz	342 MHz

Table 1
Spectrum requirement calculation.

As a solution to the limited spectrum problem, we propose dynamic resource management techniques as described in the next section. The idea is to dynamically assign spectrum to various communication services as required or demanded.

In the following, we discuss two different approaches to the limited spectrum problem which can easily be combined for maximum efficiency: firstly, the development of dynamic resource management techniques which can dynamically assign spectrum to various communication services as required or demanded. Secondly, the integration of data broadcast services as provided by DVB and DAB into third-generation mobile communication systems.

5. Dynamic spectrum and service allocation

Technological advances allow the operation of mobile communication systems in very different frequency ranges, and also the terminals can nowadays easily “tune” to these frequencies (see GSM900, DCS1800, PCS1900 and multiband phones). However, spectrum for public services is a scarce resource. Allocation of spectrum for new services must be co-ordinated across national borders and, if successful, can still take several years. Most of the spectrum that can, in principle, be used for mobile communication systems is allocated for systems that have at best a regional importance, if any.

Moreover, spectrum is allocated for specific systems, to avoid conflicts and to overcome the still-unsolved problem of sharing rules. If the system is no longer operational or the operational phase will not start for a few years yet, the spectrum remains unused even if other systems have an urgent need for it. In parallel, GSM and other successful mobile communication systems are in areas with a high user density; most of the time, additional spectrum for these system is not available because the spectrum is often split between several operators, in the same quantities, regardless of which operator has more customers.

While the proposed mechanism is a global approach, by following this approach the actual spectrum allocation can be made much more flexible and involves much less harmonization effort. Also, more dynamic approaches can be introduced to get more spectrum allocated for successful services. Our concept extends the already well-known concepts for frequency harmonization (see [10] for a good overview). This will help maximizing the use of spectrum.

5.1. Flexible allocation of mobile communication systems

The solution described in the following provides a flexible scheme to allocate mobile communication systems such as GSM and UMTS, but also new upcoming systems in new frequency ranges. Our solution offers a way to co-ordinate the spectrum use for mobile communication systems. Therefore we have called it *System Spectrum Co-ordination* (SSC).

A useful generic means for co-ordination between systems, as part of the system spectrum co-ordinator, could be a *Common Co-ordination Channel* (CCC). This (logical) channel could convey information to the terminals on the services provided, the spectrum supported, and traffic characteristics such as loading, data-rate capabilities, etc. A likely scenario would be that each

Abbreviations

CDMA	Code division multiple access
CEPT	European Conference of Postal and Telecommunications Administrations
DAB	Digital Audio Broadcasting
DECT	Digital enhanced cordless telecommunications
DVB	Digital Video Broadcasting
DVB-T	DVB - Terrestrial
ERC	European Radiocommunications Committee of the CEPT
ETSI	European Telecommunication Standards Institute
GPRS	Global packet radio service
GSM	Global system for mobile communications
IP	Internet protocol
ISDN	Integrated services digital network
ITU	International Telecommunication Union
MOT	Multimedia object transfer
PSTN	Public switched telephone network
SNR	Signal-to-noise ratio
TDMA	Time-division multiple access
UMTS	Universal mobile telecommunicaton system

participating system would transmit the CCC itself. The contents, however, could differ from system to system, location to location, and from day to day, describing the transmitting system in more detail than other locally-available systems. The information transmitted via CCC is maintained and co-ordinated by a system spectrum co-ordinator located in the network, which has contact with all the co-ordinated systems.

The member systems providing a downlink *and* an uplink could provide more CCC functionality, exploiting the availability of the uplink. The CCC would already support a flexible, location-dependent allocation of spectrum to different systems, e.g. the spectrum allocated in Sweden for DVB-T could be used in Germany for UMTS. A terminal could read from a CCC of a member system, where to find the different systems in the spectrum. In this respect the CCC makes it easier to use a particular system globally, since a unique spectrum allocation in the world for the system is not required anymore. This may prove important in the discussions on a new usage for spectrum, such as the frequency band between 470 MHz and 862 MHz.

Note that SSC is concerned with the dynamic spectrum allocation for mobile communication technologies. It is not in the scope of SSC to actually assign radio resources to single users or sessions. As such, the proposed SSC is an add-on to existing and new standards. SSC can be a technical mechanism to organize the co-existence of services. As a tool, it does not provide regulatory frameworks. Rather, it is foreseen that regulators will appreciate tools such as SSC in the future, for optimizing the usage of spectrum according to public demand in a more dynamic way.

5.2. Introductory phases

SSC must be introduced in phases, in order to work smoothly with existing standards such as GSM. In phase 1, SSC will only be used as a service announcer. On CCC, the spectrum availability will be posted, containing also the validity region, the technology to be used, and the operator. This will allow us to find extension bands for mobile communication systems.

In a second phase, SSC could be extended to enable an optimal use of the available spectrum, by adaptively allocating spectrum to the different systems (DVB, UMTS, GSM, ...). The dynamics of the spectrum adaptation are likely to be rather slow, following both slow and large traffic-load variations. Furthermore, the dynamics may vary according to the different kinds of operator consortia that are running the systems in a given frequency band. Network planning and adaptation will be a challenge with such dynamic systems.

5.3. Benefits of SSC

SSC will provide advantages for information providers, end users, regulators and equipment manufacturers. Information providers, such as radio and television providers, internet information providers and electronic newspaper publisher will benefit from SSC because it could make spectrum for wireless services available at locations where their customers tend to be at a certain time. End users will be enabled to perform high quality communication at any time, at any location and at any speed – and at low cost. SSC will open markets across national borders for network providers. Regulators will enjoy the accelerated introduction of new technologies on the basis of regionally available spectrum, thereby maximizing the use of existing and attractive spectrum. And last but not least, equipment manufacturers will benefit from SSC because new technologies can be introduced, based on little standardization and can quickly be deployed in limited markets and spectrum. Spectrum-sharing, which is based on a frequency allocation according to the technology used, gives much more freedom for medium access than frequency-sharing rules based on, for example, "listen before talk", which limit the service possibilities in the so-called ISM (Industrial, Scientific and Medical) bands.

6. Integration of data broadcast services into third-generation mobile communication systems

An example of a future network architecture, which integrates data broadcast services into third-generation mobile communication systems is depicted in *Fig. 3*. We assume an IP-based transport network, which interconnects all the relevant components including the mobile terminal. High bandwidth data in the downstream direction are transmitted via a DVB-T transmitter. Low bandwidth downstream data and control information from the user is transmitted by means of GPRS or UMTS.

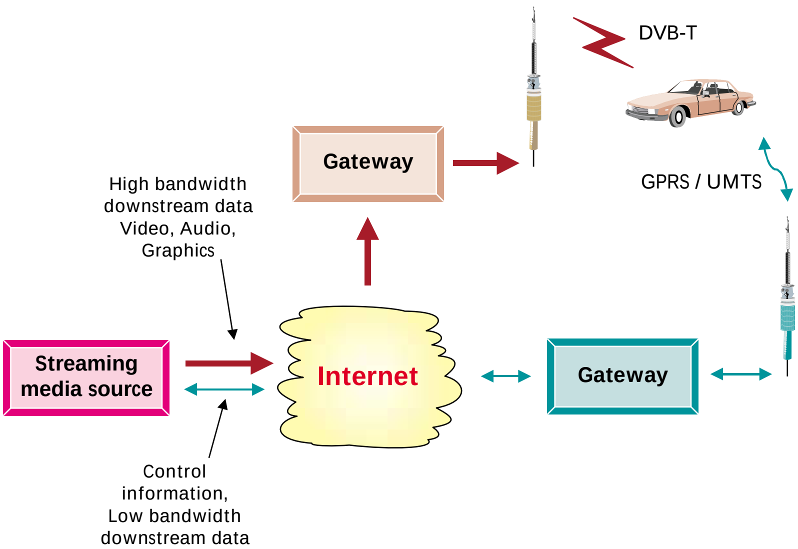

Figure 3
Interactive mobile broadcast services.

One solution to the limited bandwidth problem is the integration of data broadcast techniques, as described above, and the implementation of dynamic radio resource management systems. For instance, during the day where the demand for bi-directional communication is higher than in the evening, more spectrum could be allocated to mobile speech and multimedia services whereas in the evening and during night hours, more spectrum could be given to video and audio broadcast services such as DVB-T and DAB.

7. Conclusions

Fulfilling the increasing demand for interactive and asymmetric mobile communication services cannot be achieved by one single technology, due to the limited spectrum allocation for such services. Two demanding development lines have been described in this article, both targeting at an efficient and flexible use of the limited spectrum: firstly, the integration of broadcast and mobile communication services, offering a broadband downlink with DVB-T or DAB and an uplink with UMTS. Secondly, we have sketched the dynamic spectrum and service allocation. Each of these two development lines will optimize the spectrum utilization, but only their combination will offer the biggest advantages. However, both areas require a considerable research effort and the future will show whether the vision presented herein stays valid or will be overridden by even more demanding technologies.

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