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Broadcast/multicast service delivery via the Satellite Digital Multimedia Broadcasting system and the MoDiS demo

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I. INTRODUCTION

The concept of overlaying 3G mobile networks with broadcast & multicast capabilities is gaining increasing interest in Europe and Japan, because many mobile entertainment services, as they are today envisaged, will directly raise the challenge of handling heavy asymmetric traffic towards large audiences. There is clear evidence that low prices and high quality will be key issues to ensure the success of these services.

Indeed the one-to-many distribution mode is the most efficient way in terms of radio/network resources usage and cost to provide large audiences with appealing multimedia content. Moreover, with sufficient large storage capacity in the user equipment, unidirectional one-to-many services are able to provide on-demand and interactive applications because push and store mechanisms make the one-to-many relationship transparent to users.

The SDMB system architecture (Figure 1) combines geo-stationary satellites and terrestrial repeaters to provide mobile network operators with a cost-effective solution that increases the point-to-multipoint transfer capacity over their whole mobile network coverage. Being effectively a content delivery network oriented towards the mobile users, the system features inherent broadcast and multicast transfer capability over a wide coverage, favouring content distribution to large, spatially distributed audiences.

The expected system will operate in the IMT2000 frequency band allocated to Mobile Satellite Systems (MSS), which is directly adjacent to the IMT2000 allocated to the terrestrial mobile network. The use of dedicated radio resources enables the SDMB system to carry the most cumbersome traffic and consequently contribute to the reduction of the mobile network congestion.

Figure 1. The SDMB system architecture

The satellite radio interface makes use of the 3GPP UTRA FDD WCDMA standardised technology [1] preventing significant cost impact on the 3GPP standardised handset. The implementation of SDMB features

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[1] The EU IST project MoDiS (Mobile Digital Broadcast Satellite) started in April 2002 and will be completed in October 2004. The consortium includes, in alphabetical order, Agilent Technologies (Belgium), Alcatel Space (France), Alcatel Bell (Belgium), Daimler Chrysler (Germany), Ercom (France), Monaco Telecom (Monaco), Space Hellas (Greece), TV Files (Italy), Udcast (France), University of Surrey (United Kingdom)
in the 3G handset is basically limited to the frequency extension agility to the IMT2000 MSS band and additional application software, thus enabling the SDMB system to address the 3G mass market.

The integration of the SDMB system with the 3G mobile network goes beyond the user terminal: the system relies on the outstanding 3G mobile network point-to-point (p-t-p) service capability to manage and control the services delivered via the satellite unidirectional link. The terrestrial repeaters envisaged to cope with the heavy shadowing in urban areas are designed to be smoothly co-sited with the 3G base stations reducing the infrastructure mass and cost.

This report focuses on the transport services offered by the SDMB system and the wide range of the applications that can make use of these services. One-to-many content delivery services such as streaming and push-and-store form the main SDMB service offering, with additional capabilities for non real-time few-to-many services, called hereafter peer-to-peer services, as explained in section II.A, and emergency services.

II. SDMB SERVICES AND APPLICATIONS

3G services and related requirements have already been identified through the studies carried out mainly within working groups in standardization (3GPP) [2], [3] and market fora (e.g., UMTS Forum). Satellite systems are also expected to play a significant role in 3G services delivery to end customers. At first, it is important to select the most suitable services, which can be delivered by satellite efficiently. Multimedia services deployed for mobile terminals will be a subset of all fixed network multimedia services. This is mainly due to limitations that are intrinsic to mobile networks with respect to fixed networks (available bandwidth, quality of service, etc.). Services, which are most efficiently delivered by S-UMTS, are those where the satellite network capabilities are more suitable and advantageous compared to those of terrestrial mobile networks.

A. The SDMB push service portfolio

All services targeted by the SDMB systems share the content delivery concept, in that they deliver the same content to many users. However, the network services within MoDiS have been divided into two categories, content delivery and peer-to-peer (P2P) services, with regard to the originating point of the content: the originating point for the content delivery service is the content server and for P2P is the end terminal. P2P in SDMB, is not the same as in the Internet. The P2P term is used to indicate applications where the users are not only receivers of information, as in the content delivery service, but can also produce and send content to their peers.

In the SDMB system, all the services come under the push service category since there is no one-to-one correspondence between the single user request (via Internet) and the delivery of content. Push services deliver their contents one-way to mobile phones based on end user subscription criteria or criteria determined by an operator. Push messages can include information like headline news, mail arrival notifications, alarming, weather forecasts, stock quotes, and advertisements.

1) Content delivery services

Push-and-store service

Whereas in the traditional pull model the delivery of service initiated from a user, push type transactions are initiated by the content providers/distributors. Figure 2 depicts the push service model. This service delivery mode relies on local caching to store content for later usage. It is more appropriate for applications that do not have delay constraints and whose data are not updated frequently. The push-and-store service also allows higher flexibility with respect to the reliability of content delivery, in that applications that are not delay tolerant can be better supported, when compared to the streaming service.
The Push Service is initiated by a Push Initiator in order to transfer push data (i.e., multimedia content) from Push Initiator to Push recipient without a previous user action. The Push Service could be used as a basic capability or as component of value-added services.

**Streaming service**

Streaming means sending data (multimedia content) from a server to a client over packet based networks. A series of time-stamped packets is called a *stream*. A difference is made between real time and non-real time streaming. True streaming refers to time-based media (audio, video) where the samples have to be played in the right order and at exact time, otherwise it is called progressive transmission and rendering. In principle all media is streamable but the real advantage is seen with audio, video data, whereas still images, text, graphic, 3D data, software download etc. do not benefit significantly from the streaming delivery mode.

Streaming technology offers a significant improvement over the download-and-play approach to multimedia file distribution, because it allows the data to be delivered to the client as a continuous flow with minimal delay before playback can begin. The multimedia data arrives, is briefly buffered before being played, and is then discarded. It is never actually stored on the user’s computer.

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Figure 2: Push-and-store Service

Figure 3: Infrastructure for data streaming

The requirements for streaming of on-line encoded or pre-compressed video using p-t-m connections (e.g. multicasting or broadcasting of live or pre-recorded video) will be:

- Resilience against packet loss (fast resynchronization, error protection, error concealment), although streaming service is for applications with higher tolerance to packet loss than push-and-store applications
- Minimisation of the processing/queueing delays in the network to reduce the playout buffer size at the terminal side
- Scalable bitstream / bitstream adaptation to network QoS (bandwidth, packet loss rate)
- Provision of different video quality classes → multicast of scalable bitstreams
2) SDMB “peer-to-peer” service

The following requirements apply for the P2P connectivity. These, again are just tools for submitting and acquiring content. Nonetheless, these tools can be used for the following purposes:

1. A terminal can transmit content to a group of terminals: In this scenario, a user has content which he/she likes to share with other users, hence its terminal needs to be able to transmit this content to a group of terminals. We must first establish the nature of this delivery in terms of the “store-and-forward” and the “live delivery”.

The store and forward scenario is exactly the same normal mechanism as that of the Push & store for content delivery: the content is first negotiated with the content server for publication and then the server delivers it according to its negotiated criteria. For the live delivery, such as in the case of video briefing (or conferencing), the content may bypass the server and be directly delivered to the recipient group of terminals via a suitable multicast facility. Figure 4 below clarifies the distinction between the two scenarios.

Figure 4: Point-to-multipoint delivery in P2P

2. Transmission of content to the SDMB service centre via the mobile network

3. Forwarding towards the group of the terminals via the space component

Figure 5: Content submission and forwarding in the SDMB context
Finally, emergency service may use elements from various aforementioned services to enable the broadcast of urgent information towards the user population.

**B. SDMB applications**

1) *Push-and-store applications*

On-demand-content, such as MP3 audio, video clips, movies, mobile games and entertainment are potential applications for mobile users in particular when broadband bearers with wide coverage are available. ‘WebCasting’ may be the base application for an Internet user. The desire of a mobile user is to have the same quality and functionality for Web Browsing as on a stationary PC. Mobile devices offer usually reduced bandwidth and fewer browser functions than a powerful home-PC system. A realistic goal in mobile environment is to integrate a small web browser that is able to display HTML pages to the user and offers as much Web-typical functionality as possible.

*Entertainment-related* applications include pre-stored audio on demand (music and radio) and video on demand (movies, video clips) as well as software delivery (games, ring tones, animated images).

*Information-related* applications refer to the distribution of regional or national information of common interest to the mobile users cache. The user navigates through the applications without a return channel. The content may be filtered and pre-selected according to the users preference, the location and the situation before it is presented to the user. The information transmitted can be categorized into two information classes and they are listed below.

- “Basic” information (text): Traffic information, tourist information, finance, news, public information (security, ...), job offers, weather forecast, horoscope, classified adds,
- “Rich” information (audio, video, image & text): sport (video clip showing a goal during a football game), video document for news, Personalised information portal: based on DMB cache and filtering capabilities.

*Webcasting* is another important application. A significant number (i.e. top 1000) of Internet pages is transmitted via the broadcast satellite link to the end users’ cache. Missing pages can be delivered on request via the cellular mobile network. This combination ensures a quick Internet access also in a vehicular environment with the possibility of access to individual sites not included in the top 1000. The result is a service that offers mobile access to fixed ISP services with near-wireline transmission quality and functionality. It includes full Web access to the Internet as well as streaming video/audio capabilities. Possible variations of the application include the replication of famous sites, also in-car, shopping gallery sites, mobile professional portals.

2) *Streaming applications*

Typical examples are audio and video broadcasting/multicasting of live events (e.g., sports events etc.), access to a live web-camera, or “web-TV”, real time data update.

The data rate for the transmission of video files depends on the display size of the terminal and on the frame rate of the video system (picture size and quality).

The European PAL-Norm uses 768 times 576 pixels with 50 frames per second, which means about 25 Mbit/s to provide an optimal TV quality, which is definitely too high for mobile communication. To reduce the data rate, the video signals are compressed and encoded. MPEG-4 encoding will be preferred in this context.

3) *SDMB peer-to-peer applications*

The combination of a number of application components can create a powerful tool to fulfil most of the user requirements within the mobile environment. Session management and stream synchronization will enable a moderated and smooth collaboration environment. Examples of such applications components are listed below:

- Chat (several users form a group and exchange written messages)
• Whiteboard (a common “drawing” area is used by a group of participants, every participant sees changes caused by other users, pictures could be loaded and displayed within the whiteboard)
• File transfer
• Location-based information based on user location provided to the server via a location detection technique
• Data streaming services such as weather alerts and reports, traffic reports, stock prices, etc, to registered or all of the users and according to user location.
• Application sharing (an application executed on a server or on a client PC is controlled by one user at time, all participating users may interact with the application if they have a token, changes are visible to all participants)
• Streaming of music and/or video clips
• Streaming of live video generated at a video server or from a mobile device to a group of users

The peer-to-peer service is also a promising candidate for Public Protection and Disaster Relief (PPDR) applications, in particular when the baseline system architecture is enriched with a low-rate, satellite return link [4].

III. THE MODIS DEMO

MoDiS implements an SDMB experimental platform where a number of SDMB features and services are validated by means of tests and trials [5], [6]. Figure 6 depicts the main components of this platform.

When comparing this platform with the SDMB architecture, the differences are the following:

• The satellite and the transmission part of the hub have been replaced by an emulator. Due to the lack of an existing satellite being able to provide enough power and bandwidth in the L/S frequency bands, the SDMB satellite is replaced by an UMTS Node B located at a high altitude place. This transmitter is set to have a transmission power equivalent to a satellite. For the trials, transmission is performed in the terrestrial IMT2000 frequency band.

• The Hub network function emulator performs the same baseband functions as defined for the SDMB hub. The Hub network functions correspond to a RNC simulator featuring broadcast / multicast support and adapted to MoDiS platform constraints.
The terrestrial repeaters are transparent, namely they reproduce the same signal (same frequency, same scrambling code) as the satellite emulator. Two transparent terrestrial repeaters are used in the MoDiS testbed.

The interactive link is provided by a 3G network.

The MoDiS terminal is not an integrated handset, but merely an assembly of equipment: SDMB receiver, laptop, PDA, 3G handset, GPS receiver. Two MoDiS terminals are used in the testbed: one set up on a trolley and the other one in a car.

The MoDiS data server is a simplified replica of the SDMB data server; the connections to real content providers are simulated and the service announcement is not implemented.

In order to accelerate the adaptation of existing components (or development of new ones), but also the validation procedures, it has been decided to split the MoDiS testbed into two distinct sub-tests: a) the application testbed and b) the transmission testbed, as illustrated in Figure 7. This approach enables simultaneous implementation of the features to be validated by the project partners and facilitates the assembly of the corresponding subsystems into a single testbed later on that exhibits the full MoDiS functionality in an integrated manner. Furthermore, this approach allows for some features to be demonstrated by only using either of the two sub-tests [7]. Figure 8 shows the MoDiS testbed protocol architecture.

The application sub-testbed is related to the transport and application layers integration of the MoDiS system. These tasks are mostly independent from the transmission layers and consequently most features can be validated and partly demonstrated before the completion of the transmission layers. It is thus possible to also demonstrate SDMB applications without requiring the availability of the MoDiS transmission chain. The transmission sub-testbed, on the other hand, deals with the radio and network layer aspects of the MoDiS system [8]. In the following, we focus our attention on the application testbed. For a more detailed discussion of the overall test bed and the scope of the MoDiS trials, the interested reader may refer to [9].

![Figure 7. Functional view of the MoDiS testbed](image1)

![Figure 8. MoDiS testbed protocol architecture](image2)

### IV. APPLICATION TESTBED OVERVIEW

The application testbed on the one hand enables the integration of a number of transport, application and service level MoDiS features, and on the other hand allows for the demonstration of the SDMB concept – without the underlying access mechanisms – to users and providers in environments where the installation of the whole MoDiS experimental platform is not possible, such as meeting rooms and conferences.
Every SDMB service demonstrated in MoDiS is based on the Content Delivery layer. This is an end-to-end layer, which aims at empowering the system with an efficient link between the content providers and end users. The main mission of the Content Delivery layer is the broadcasting of multimedia content, provided by various content providers, through satellite and its automatic filtering by each receiver in order to store on the terminal only the contents likely to be of interest to the user.

This relies on a broadcast delivery scheme allowing the efficient distribution of a large amount of content. The actual delivery uses a distributed filtering mechanism based on matching between user profiles, capacity allocated to different services and characterisation of the content. The combination of content description, filtering, and cache manager are part of the Content Delivery Layer mechanisms described hereafter:

- **Content description**: this is made using XML technology, generally by the producer of the content. The resulting descriptor is known as the Content Delivery Descriptor (CDD).

- **Filtering at server side**: the server classifies the content according to the CDD, in order to provide some quality of service at the transport layer taking into account the limited resources bought by service providers from the satellite operator. QoS is provided using state of the art multiplexing technologies and multiple queues management distinguishing between emergency and video for instance.

- **Filtering at client side**: using the matching between the content identifier list placed on the receiver and the content identifier of the current transfer placed in the CDD, it is possible to filter the content and potentially drop it at reception.

- **Cache manager**: it stores the content according to priority and user profiling. The user profile is continuously updated by analysis of the user behaviour with regard to content stored on his/her terminal. The mechanism that implements this updating mechanism is called the Active Cache.

**MoDiS Data Server**

The mission of the MoDiS data server is five-fold:

- **Gathers the multimedia contents from content provider in order to be scheduled for broadcast**
- **Packages these contents in terms of adding the metadata for content delivery purpose: the cache management server part and the CDD completion**
- **Schedules the various contents to set up the MoDiS services provided to the users**
- **Hosts the routing unit: it encompasses the server part of the push engine providing the MoDiS network with a reliable transport layer and the interconnection to the MoDiS physical network**
- **Hosts the server part of the application, which provides all the MoDiS services to the MoDiS terminals**

The MoDiS Data Server encompasses the File Server, the Application server, the Scheduler and the Routing Unit modules. The MoDiS data server modules and their internal interfaces are illustrated in Fig. 1. The Scheduler and the Routing Unit functional parts are gathered in a single module because their implementation is tightly coupled and constitutes the MoDiS push engine server part. Although the Content Providers do not belong to the MoDiS Data Server, they are shown in the figure for the sake of clarity.
The File Server / Application server interface consists of three events:

- The Application server creates the CDD – thanks to the Redaction terminal – on the File Server for content that has been placed on the File Server without it. Concerning the peer-to-peer service, the CDD creation and usage is not created for each individual peer-to-peer content to be broadcast but only once at the initiation of each peer-to-peer session. Moreover, the P2P server, that is part of the application server, outputs on the File server the peer-to-peer individual contents after these have been uploaded by the user from his/her terminal and processed by the P2P server.

- The Application server – thanks to the Redaction terminal – associates a newly created CDD with its corresponding content, and checks the file names consistency between both files so as to respect the naming rules defined by the Cache Management application for uniqueness purpose. Consequently, the CDD may be copied into a particular repository, the so called “hot folder”, in order for the corresponding content to be considered as ready for broadcast by the Scheduler server.

- The Application server creates on the File server the content files of Emergency Notification type. It consists of information restricted to the minimum, e.g. a text message of 200 characters, required to inform as fast as possible the user of the MoDiS terminal with, for example, the instructions to respect to preserve her/his health.

The File Server / Scheduler and Routing Unit interface encompasses the following functionality:

- The content broadcast scheduling: the Scheduler periodically polls the “hot folder” on the File server and considers any found files as a content to be scheduled for broadcast.

- The CDD parsing to retrieve the information needed to determine the priority of broadcast of the associated content and the parameters (e.g. file size) involved in the scheduling strategy that manages the different file queues.

The Application server / Scheduler and Routing Unit interface is used only to allow the scheduling and control of the streaming sessions of audio and video contents over the MoDiS network. The Scheduler communicates with the Streaming server part of the Application server to:

- Plan the streaming session of content. The list of contents able to be streamed is managed by the streaming server due to the information given internally by the Redaction terminal at the CDD/content association time (typically, if the video content is of an encoding format compatible with the streaming server or not).
• Order the start and the end of the session to the Streaming server on the basis of the time and date defined in the scheduling phase.

**MoDiS Terminal Application Part**

The MoDiS terminal application part consists mainly of the push client, the cache manager and the user application. The details of the terminal implementation that is used for the vehicular environment are shown in Fig. 2.

**Push client**: The Push client is an application in charge of processing incoming content. Its main functions include:

- Filtering of incoming traffic. The Push client filters among all current push those that interest the terminal (receiver side filtering); all non-interesting transfers are simply dropped; all interesting transfers are passed to the cache manager for further processing using an ad hoc protocol.

- Turning off the SDMB receiver once the content has been correctly received. The Push client sends a command to the modem to turn it off when required.

- Managing the list of Content Identifiers. The Push client manages initialization and updates of the Content id list of the SDMB receiver; it ensures the filtering of incoming traffic when the SDMB receiver is turned on “ON” state; then, it removes the Content Identifier of a specific content when this latter has been correctly received.

- Deciphering incoming data according to pre-stored keys. It is able to change keys on the behalf of the Group Controller/Key Distributor (GCKS).

**Cache manager**: One key element of the Content Delivery layer is the dynamic management of the cache memory of the user terminal in association with the profiling of user interests. This feature is called Active Cache.

The Active Cache principles are two-fold:

- It has the ability to filter out the received contents, achieved by implicitly building the user interest profile, based on a classification tree where a weight is associated to each class of content; an auto-adaptive process allows to build the user profile strictly according to what the user likes to get and is generally not interested in. This process is fully implicit: it does not need any programming effort from the user, it can be used by any user, even without any PC or web experience; it even efficiently copes with any dynamic profile evolution;

- It has the ability to store contents; picture and audio compression have brought down the need for very large memory to store contents, while at the same time low cost flash memory has fairly increased in capacity.
V. TRIALS

The trials include tests for the validation of SDMB specific features as well as application and services. These trials are conducted on the application or transmission sub-testbed alone and/or on the complete MoDiS testbed. The application-layer oriented trials are described below [6].

Reliable Transport

The use of push protocols over SDMB bearers are validated. The test proves that the push is possible with potential tuning of transmission parameters such as FEC, interleaving depth, etc. Quality of transmission and performance of the algorithms are demonstrated and statistical tools are used for results’ evaluation. Alternative ways to distribute the content using terrestrial means are validated with either point-to-point or point-to-multipoint connections.

Content Delivery

The purpose of the transport layer is to efficiently deliver the content to the selected community. As explained before, three types of content are sent. Depending on their nature different delivery techniques are taken into account:

- For push & store service: multimedia content is selected by the operator using a web-based GUI for the selection of the appropriate channel. This is typically a movie or audio file. Once the file transmission is scheduled, a monitoring tool is used to check the status and change it; for instance to stop/resume.
- For streaming service: the operator schedules a transmission using the CDD, usually a Windows Media Stream. The server then activates the multicast routing and forward the stream onto the satellite. A session is announced periodically to wake up incoming terminals
- For the peer-to-peer service: once a session has started, the server periodically checks new content on a dedicated directory and send it like a standard content.

Tools are also used for monitoring the reception quality on the client side. Relevant state machines have been developed for this purpose. Statistics are also collected on each receiver for fine-grained tuning of transport layer parameterization (e.g. FEC ratio, interleaving depth).

Conditional Access

The use of IPSec protocols over SDMB bearers is validated. The test show that providing high quality, cryptographically based security for IPv4 is possible with potential large amount of contents and several receivers having different access rights.

Demonstration of applications

These trials are ultimately related to the demonstration of applications using Push & Store, Emergency notification, Streaming, Peer-to-peer services. The trials include tests for the validation of SDMB specific features such as Cache management, User profile management and Conditional content use.

The objective of the Push and store application is basically to push a large amount of multimedia contents from the data server into the cache memory of user terminals with the highest efficiency regarding the matching of topics of pushed contents with individual user expectations, as well as the optimisation of the transmission bandwidth to reach at once the widest user audience. An additional objective of this application is the great enhancement of the subjective QoS felt by the users compared with today’s equivalent services relying on the 2G/2.5G mobile network.

The objective of the tests related to the emergency notification application is to demonstrate the feasibility and interest of an emergency notification service based on the SDMB system. The emergency notification is therefore to be inserted in the data flow that is pushed towards the User Equipment (UE), with the following special features:

- Resource pre-emption is used if needed.
The power saving strategy, one of the features implemented in the transmission test bed, must have no impact on the emergency notification delivery to the MoDiS terminal in terms of delivery delay.

The emergency notification shall be displayed on the MoDiS terminal as soon as it is received whatever the configured content filtering.

Other features of the emergency notification are standard ones, e.g. FEC at application level is used. The Public Security Service Provider (PSSP), that is intended to be the originator of the emergency notifications, is replaced by a direct action on the MoDiS data server MMI. The notion of “crisis area” (i.e. the defined area over which the notification is sent) is not modelled in the MoDiS testbed.

For the streaming application, the objective is to have a streaming solution simple and able to produce valid streams at different speeds (from 64kbps up to 384kbps).

Finally, for the peer-to-peer application, the objective of the tests is to demonstrate the feasibility to support peer-to-peer services (also known as groupcast services) by SDMB. The scenario that is demonstrated assumes a predefined group of users (mobile/vehicular/fixed) that are engaged in a collaborative session. Each group member is able to use video messaging and chat, as well as a location mapping service that allows everyone to be aware of the location of his peers. The content that is received at the data server from each user is processed and then pushed to all the members of the group using the push and store delivery mechanism.

VI. CONCLUSIONS

The MoDiS project enables the demonstration and validation of broadcast and multicast services via satellite for the 3G cellular market. In this paper we described the services provided by the SDMB system, outlined the applications that can make use of these services and presented the MoDiS experimental platform, which is used to demonstrate the SDMB concept through experimentation with the main system features and demonstration of representative multicast/broadcast services.

The MoDiS experimental platform is being upgraded in the context of the project MAESTRO, the continuation of MoDiS within the 6th Framework Programme [10]. MAESTRO extends MoDiS as well as the results of other IST and ESA contracts in order to consolidate the overall feasibility of the proposed SDMB concept.
REFERENCES

[2] 3GPP TS 22.146 “Multimedia Broadcast/Multicast Service”