Satellite Digital Multimedia Broadcasting for 3G and beyond 3G systems

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ABSTRACT

This paper presents an overview of a satellite based broadcast layer to enhance the 3G and beyond 3G systems in the delivery of Multimedia Broadcast/Multicast Services (MBMS), as identified within the European IST integrated project MAESTRO. The foreseen content delivery architecture, also referred to as Satellite Digital Multimedia Broadcast (S-DMB) architecture, shall become an enabler for the success of 3G point-to-multipoint multimedia services. In fact, it takes advantage of the satellite inherent capability in providing broadcast/multicast services over global coverage, and it is best suited to distribute popular multimedia content towards 3G handsets with local cache memory. The system architecture combines high power geo-stationary satellites and a limited number of terrestrial gap-fillers, providing outdoor and in-building coverage with nation wide umbrella cells maximising the potential audience.

The use of 3GPP standardised technology as well as IMT2000 frequency band allows to accommodate S-DMB features in 3G handsets with low cost impact and no form factor modifications to optimise market entry and penetration. The system meets the MBMS requirements [1] as set in the 3GPP standards in terms of service offer as well as operational constraints. The paper also includes an introduction to information-theoretic aspects related to S-DMB delivery.

In this paper 3G system encompass 2G, 2.5G and 3G mobile systems.

I. INTRODUCTION

Introduction of multimedia services in mobile systems is of key importance for mobile operators to maintain the Average Revenue Per User (ARPU) in the coming years, since voice service revenues are expected to decrease over the next decade. Putting the market into context, a recent report [2] forecasts 2006 spending levels for mobile content at around $3.3 billion in Europe alone. However, the effective development of this market to the benefits of mobile operators will be closely related to the emergence of critical conditions.

a) Multimedia services acceptance by end-users, related to:

- Low traffic fees ideally comparable to Internet levels.
- Service continuity over nation wide coverage in line with today's coverage for mobile voice communications
- Security issues, preventing virus attacks to personal data
- Tailored content, adapted to mobile environments
- High standards of sound/image quality

b) Major operators interest and willingness to produce, aggregate appealing multimedia services, linked to:

- Cost effective content delivery and nation wide coverage to maximise audience
- Protection against unauthorised content sharing
- Acceptable sharing agreement with the mobile operators regarding services revenues
- Flexible billing system that includes subscription, bundle, pay per usage, etc.

Several market surveys have identified that mobile users' main interest lies in multimedia content related to handset personalisation, news, sports and music. Mobile multimedia services will deliver short format content, since customers typically use their mobile in short intervals. The average usage of multimedia services is expected to be less than 30 minutes per day due, to the rapid decay of interest with the relative small screen compared to TV screen. Although interactivity will enable personalisation to produce attractive multimedia services, the associated traffic is highly asymmetric since Short and Multimedia Message Services is considered already as very effective on the return link. Most content do not require stringent delivery constraints in terms of delay, apart from special occasions (e.g. Alert of population for risk management or disaster relief operations, World cup final).

Based on these findings, Multimedia Broadcast/Multicast Services (MBMS) technologies are clearly well positioned to meet some of the above challenges, since the one-to-many distribution mode is the most efficient way in terms of radio/network resources usage and cost to deliver data to a large audience. Therefore, MBMS is seen as an obvious and effective way to significantly increase the mobile system content delivery capacity. To complement other mobile MBMS solutions, the MAESTRO integrated project [3] is focusing on an architecture based on a satellite broadcast layer to enhance 3G and beyond 3G systems in the delivery of MBMS. The resulting hybrid architecture makes the most out of satellite broadcast and terrestrial point-to-point technology efficiency. Finally, to provide point-to-point low data rate service capabilities the MAESTRO architecture foresees an enhanced satellite direct return link.

MAESTRO builds on several preliminary studies carried out under European Space Agency (ESA), European Commission (EC/IST) and French Space Agency (CNES) funding. It aims at defining the business model with representative partners acting in the multimedia business chain and to validate the system performances and implementation with major players from the mobile and satellite industry.

II. MOBILE BROADCAST/MULTICAST STATE OF THE ART

Three main broadcast/multicast service implementation approaches in 3G systems have been identified and analysed.

In band MBMS [1]: in the framework of the 3GPP activities, a MBMS delivery approach which makes use of UMTS radio resources is under definition. This solution has the clear advantage of avoiding a significant cost impact on the network and the user equipment, but

- it is mainly appropriate for multicast services with a geographically limited audience;
- it reduces the availability of resources for the highly remunerative point-to-point services;
- it increase the RAN complexity because of the need to deal with mobility management, power control and random cell loading issues to provide service continuity;
- it does not provide for service continuity is in heterogeneous networks.

DVB-H [4]: this approach relies on upgraded broadcast technologies, such as DVB-T, to complement the mobile network and to provide data rates much more attractive than that of the in-band MBMS. However,

- dual mode terminals complexity is not small;
- system deployment can be hindered or delayed by the lack of a pan-European homogeneous regulatory framework and by the cost of the infrastructure

Hybrid mobile satellite broadcast system: in this approach Broadcast and multicast services are delivered through a satellite network which relies on terrestrial repeaters to extend satellite coverage in urban areas. Several hybrid mobile satellite broadcast systems, in operation or being deployed, have demonstrated the efficiency of the satellite-terrestrial hybridisation: the XM-radio system in the USA provides radio broadcasting services to vehicular terminals and has achieved 1.4 millions of subscribers in 24 months of commercial operation; the Mobile Broadcast Corporate system (MBCO)[1] is currently launching commercial operation in Japan and Korea providing multimedia services to vehicular and portable terminals. Key characteristic of these systems is the use of ad-hoc air interfaces. As detailed in the following section, the S-DMB system developed in the MAESTRO project proposes a solution able to solve most of the challenges identified in the previous section relying on the standardised UMTS air interface.

III. SYSTEM DESCRIPTION

A. *Services*

Largely inspired by personal video recorder (PVR) service implementation, the S-DMB system depicted in Figure 1 provides anytime, anywhere service consumption to the end-users. The multimedia content is conveyed to the 3G handset local cache through a direct satellite distribution link exploiting the 3GPP push service over MBMS, whereas service management and interactivity is achieved through the 3G mobile network.

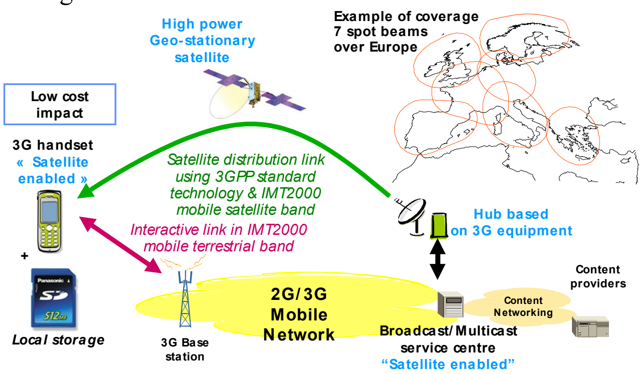

Figure 1: S-DMB concept architecture to enhance MBMS delivery on 3G and beyond 3G systems

Local storage combined with push service technology optimises the bandwidth usage over the whole day duration and maximises the satellite broadcast content delivery capacity: local storage can be filled at any time of day and regularly updated with predictive cache management techniques providing mobile operators with an increased content delivery capacity. In each handset, only those contents with a potential interest for the user are processed at physical level and stored to be available upon user's request.

Streaming services are delivered using the 3GPP MBMS streaming by pre-empting the capacity allocated to push & store services.

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[1] The MBCO system is also known as Satellite Digital Multimedia Broadcasting system. It makes use of a specific CDMA technology occupying 25 MHz spectrum. In that respect it differs from the S-DMB system presented in this paper which makes use of the 3GPP W-CDMA technology.

Service interactivity is achieved at two levels:

- the local storage enables immediate interactivity and contributes to decrease the access time resulting in an enhanced perceived Quality of Service;
- the 3G system point-to-point capability provides service interactivity with the distant service centre, when local interactivity cannot serve the user's requests.

B. *Nation wide coverage*

To allow nation wide coverage, e.g., in Europe, S-DMB system is able to offer umbrella cells with typical diameter of 700 up to 1000 km. This gives the advantage to integrate a larger scattered audience and significantly reduce the retail service fee.

The system infrastructure will typically aim at an average availability greater than 95% over the umbrella cell to address the 3G handset mass market. This requires that indoor satellite coverage must be ensured. MAESTRO aims at achieving indoor coverage through the use of a combination of several techniques operating at different layers of the air interface:

- Large radio margin, higher than 15 dB [5]. This requires at least 12 kW satellite platform to serve 2 to 3 umbrella cells with a 9 meters diameter deployable reflector with a satellite EIRP per umbrella cell of ~72 dBW.
- Specific reliable transport layer based on Forward Error Correction, interleaving and carousel techniques. These will boost the error correction performance of physical layer coding scheme to overcome limited duration impairments especially in case of multipath propagation environments.
- Terrestrial repeaters can be deployed to overcome some key shadowed areas in urban centres.
- Selective retransmission using the 3G system point-to-point capability and/or the satellite direct return link. User equipment powered-off or performing other network operations, long blockages on signal reception, content not selected for local storage are some of the many reasons that justify the need for selective retransmission in point-to-point mode via the 3G system. In these cases, the satellite role still remains since the selective retransmission is kept under 5% of the user consumed content.

C. *Low impact on 3G user equipment*

To prevent any form-factor impact and to minimise additional costs associated to S-DMB features on 3G handsets, S-DMB layer makes use of

- 3GPP UTRA FDD W-CDMA standardised technology and MBMS protocol stack (under definition).
- IMT2000 satellite downlink frequency band (2170-2200 MHz) adjacent to the frequency band allocated to IMT2000 terrestrial mobile networks which prevents the need of double tuner for S-DMB signal reception.

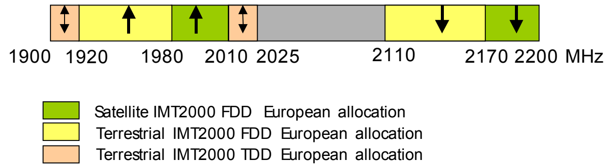

Figure 2: Satellite band adjacent to terrestrial band for IMT2000 systems

- High power geo-stationary broadcast satellites with large deployable reflectors to accommodate with the 3GPP standardised handsets G/T performances.

The S-DMB features to be implemented on the S-DMB 3G handset are

- Extension of the frequency agility to the IMT2000 satellite downlink frequency band enabling reception of the dedicated S-DMB downlink carriers.
- Specific software package to configure the UMTS/MBMS protocol stack and implement multimedia broadcast application enabling technology.

D. *Interworking with 3G system*

The S-DMB layer interworks with the 3G system architecture as depicted in the figure below.

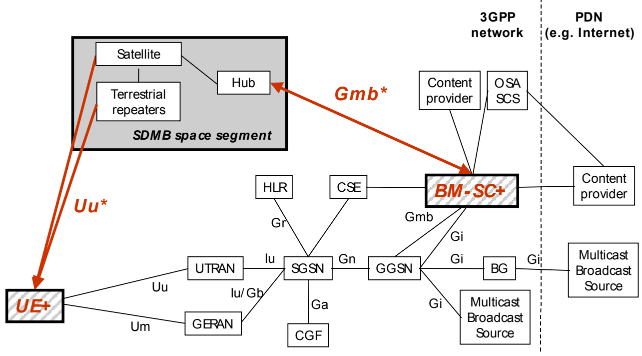

Figure **3** : Satellite MBMS/3GPP reference architecture

The 3G handset activates S-DMB features as a background task in order to allow 3G default network operations without requiring any additional WCDMA reception chain. In this mode, the ability to receive paging messages, SMS or to set-up a connection is preserved, while the discontinuous satellite signal reception results in a compound signal blockage estimated well below 10% of time.

The S-DMB layer interfaces with the 3GPP Broadcast/Multicast Service Centre (BM-SC) which needs to be upgraded to take into account the additional WCDMA downlink carriers capacity. Moreover, it implements an opportunity routing scheme that, on the basis of the targeted geographical area, delay delivery constraints, audience type, size associated to the multimedia content to be distributed, selects the best multimedia distribution link among S-DMB and terrestrial

WCDMA carriers. For example, a relative large multimedia service addressing large audience over a scattered area will be routed to the S-DMB layer, whereas a football result addressing a stadium audience will be delivered using the terrestrial carrier.

The hub includes 3G radio access network equipment and 3G core network functions. It takes as input the incoming multimedia services from the BM-SC via the Gmb interface. Further mapped on the Iub interface, this information stream is fed to a Node B modem to build the S-DMB WCDMA downlink carrier which is modulated with a specific Radio frequency sub-system onto Fixed Satellite System (FSS) frequency band 5 MHz carrier for direct satellite path.

The satellite down converts the FSS band S-DMB WCDMA to IMT2000 Mobile Satellite System (MSS) frequency band and transmit it directly to the S-DMB enabled 3G handsets in the umbrella cell.

The on channel terrestrial repeater amplifies the satellite WCDMA signal in the same IMT2000 MSS frequency band as the one generated by the satellite.

The S-DMB enabled 3G handset can then combine these identical signals possibly received from the satellite and/or different terrestrial repeaters with its rake receiver provided that the system ensures that the satellite and the terrestrial repeaters signals are received within the appropriate window.

E. *Reliability of distribution*

A reliable transport layer has been designed to boost the S-DMB physical layer correction performances. As a matter of fact, S-DMB reception is subject to periodical losses due to S-DMB/3G system interworking mode on the one hand, and propagation impairments stemming from the mobile satellite propagation channel and in particular in building environment, on the other hand.

Applied to the multimedia service information streams, this reliable transport layer relies on forward error coding algorithms over blocks of bytes resulting in redundant error correction. Moreover, it encompasses judicious long interleaving in order to take as much as possible advantage of the good reception states, thanks to the local storage in the handset. The scheme allows several multimedia services multiplexed on the same carrier to be protected differently.

With less than 10% overhead, this scheme rebuilds losses due to S-DMB/3G system interworking issue and propagation impairments, increasing overall link availability and limiting gap fillers deployment.

The distribution reliability is also extended by carousel feature, as well as by a selective retransmission scheme relying on the 3G system point-to-point capability to overcome any severe loss such as handset powered off or deep indoor environment conditions. The reliable transport can be implemented with software in a 3GPP standard handset at application level. Particular attention has been paid to limit CPU consumption and buffer size for decoding purpose in the handset.

F. *Capacity*

The S-DMB layer provides a WCDMA downlink carrier per umbrella cell able to offer a useful capacity of minimum 768 kbit/s per umbrella cell. Even 144 kbit/s capacity allows to distribute more than 450 Mbytes of data per day taking into account a carousel factor of 3. This accounts for 10 hours of 100 kbit/s video content which is sufficient to achieve a good video quality for the screen size of handsets.

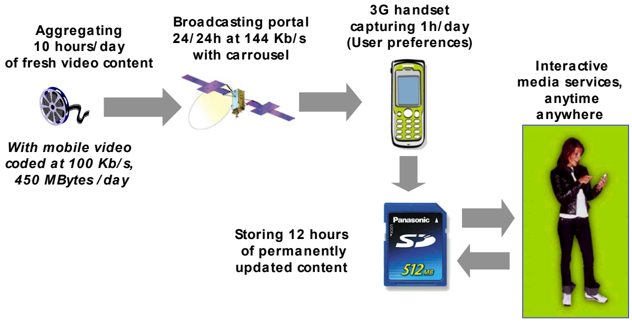

Figure **4** : Satellite MBMS bandwidth usage

As depicted in Figure **4**, assuming a user preference filtering factor of 1/10th results in more than 45 Mbytes (i.e., about 1 hour of video) of fresh multimedia service per day in the local cache. Up to 1 Mbit/s of capacity per Spot beam with one WCDMA downlink carrier can be achieved with a larger terrestrial repeater network deployment in urban and sub-urban areas, since the radio link margin required for indoor penetration can be decreased.

G. *Service personalisation*

The handset automatically selects for local storage the most pertinent multimedia services distributed by the S-DMB layer taking into account the user preference profile. The profile is automatically updated with a dynamic user profile learning scheme by observation of the multimedia service usage enabling service personalization. The profile includes a set of preference criteria and weighted content classification which are matched against the multimedia descriptor or metadata as part of the multimedia service information stream. Once the multimedia service is stockpiled in the local cache, it can be accessed locally.

This automatic scheme is also used to renew the multimedia content in the limited size local cache and maximise local interactivity in front of distant interactivity via the 3G system resources.

Even though a S-DMB umbrella cell may cover several countries, the capacity can be shared by several national mobile operators and support different language/cultural multimedia services on the same carrier.

H. *Security*

The main security function is the user authorisation which prevents content use by unauthorised users, it will be used to perform an efficient billing for a broadcast service. Two mechanisms may apply:

- the one based on a subscription mechanism, i.e. all users requesting the S-DMB service have subscribed to a given service therefore the terminal has the relevant key and is able to decipher the encrypted data.
- the one based on a digital right management (DRM) security method, i.e. every user receives the encrypted data but only the user who buys the rights will be able to have the service. In the figure below, the content objects in dotted grey are ciphered and are not usable when loaded inside the terminal, when the terminal gets the rights object via a secured unicast session, the content is plain grey coloured and is usable.

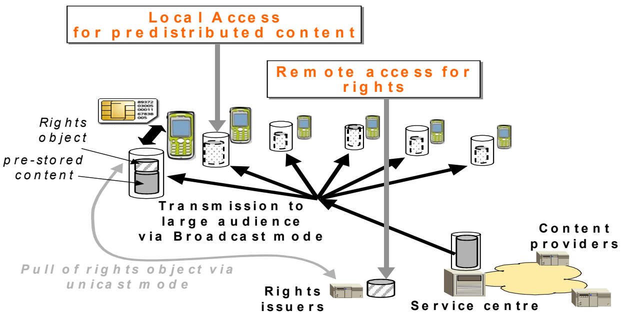

Figure **5** : Content delivery architecture based on DRM concept

I. *Power saving management*

Due to the inherent nature of broadcast services, the reception activity in the terminal should be continuous with the loss of the traditional idle mode with DRX as defined by the 3G system (GSM or UMTS mode) and finally to a drastic reduction of the battery autonomy.
A 3G handset with 200 hours typical autonomy in idle mode would see its autonomy drastically declining to 10 hours if it needs to continuously receive data over the broadcast channel.
As the main S-DMB service is the push and store service which does not allow the user to manually enable/disable the MBMS activity, a dedicated automatic procedure is necessary to solve this power saving issue.
The main criteria permitting to save power at the terminal side is to be selective at the reception: taking into account the data which are interesting for the user, the system shall allow the terminal to know which content is currently broadcast. This is achieved with the two standardised MBMS procedures: the Service Announcement and the MBMS notification.

Service announcement

In S-DMB, service announcement is the distribution to users of detailed information about the service – parameters required for service activation (e.g. IP multicast address), and detailed information about what will be sent over the service. This Content Descriptor is used by the handset to select the most relevant multimedia services. This information is distributed to the handsets via a specific MBMS channel.

MBMS notification

When a session starts, i.e. the BM-SC needs to broadcast a new multimedia service, it sends a message Start-session containing a multimedia service reference. This reference is included in an MBMS notification transmitted by the Hub to ensure the reception by all the UEs. The UE decodes the MBMS notification and checks if the reference belongs to the selected multimedia services which description was included in the previous Service Announcement. If it is the case, it starts to receive data on the MBMS traffic channel. If not, it stays in idle mode and wakes up regularly to listen to the MBMS notification channel.

IV. INFORMATION THEORETIC ASPECTS ON S-DMB

The problem of optimal information transfer from a source through the satellite to a multitude of receivers is very challenging from the point of view of information theory. This can be classified as a particular case of broadcast channel, the capacity of which is known only in a few particular cases [6]. The difficulty of the problem is exacerbated by the fact that the propagation channels are largely diversified within the user population. We have for example: static users in line-of-sight (LOS) to the satellite; users moving at various speeds in LOS; users in non-line-of-sight (NLOS) propagation conditions receiving signals from terrestrial repeaters, moving at different speeds or static; users in LOS to the satellite and to a group of IMRs at the same time; users in indoor propagation conditions. In essence, the signal-to-noise ratio (SNR), the delay spread, the Doppler spread, the direct-to-diffuse power ratio [7], and even the channel propagation statistics themselves are largely different from user to user, and it is not possible to identify easily the "worst case channel conditions" to use in the classic design approach. In all cases, the channel is affected by non-linear distortion due to the on-board High Power Amplifier (HPA). In addition, the signal to be transferred is a bundle of multimedia services, each characterized by a different set of requirements in terms of error rate and delay. Finally, it is certainly possible that users are equipped with terminals of different classes, with various display capabilities requiring diversified coding to satisfy distortion requirements. System design can exploit the following degrees of freedom: source coding, channel coding, modulation technique, multiplexing technique, medium access control scheduling, network and transport protocol, and packet coding, i.e., the error protection techniques applied at an entire packet, irrespective of any lower layer protection. Very promising solutions are currently being investigated within IST MAESTRO project to recover lost packets without retransmission. In general terms, the S-DMB problem can be formulated as: what is the optimal set of source, channel, and network coding rates to deliver S-DMB services to a diversified user population jointly satisfying the required Quality of Service? It is evident that the solution to this extremely complicated problem is far out of reach. However, it is possible to use all the instruments provided by information theory to at least guide the selection of techniques and reach a sub-optimal solution which is efficient and valuable in terms of resource exploitation. This is one of the aims of the on-going S-DMB research initiatives.

V. CONCLUSIONS

The paper provided an overview of the S-DMB layer implementing the broadcast mode of 3GPP also known as MBMS, and showed how it enhances the 3G architecture design for MBMS services. The proposed system minimises cost impacts on the 3G handset by relying on 3GPP standards, provides nation wide umbrella cells able to integrate a large scattered audience, permits a significant service fee reduction enabling subscription based multimedia services for the end-user, allows profitable business case for multimedia operators and consents a traffic increase on the 3G system due to content sharing practice. These are key enablers to address the 3G mass market with high quality multimedia services.

The proposed S-DMB concept can be applied outside Europe on the basis of other IMT2000 air interfaces, such as CDMA2000. Finally, it shows the efficient role of advanced mobile satellite systems in systems beyond 3G architecture.

VI. ACKNOWLEDGEMENT

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Last, the authors would like to dedicate this paper to their colleague Jean Bouin who actively contributed to the S-DMB concept definition before he died on the 6th of June 2003.

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