Relative positioning of the Satellite Digital Multimedia Broadcast (S-DMB) amongst candidate mobile broadcast solutions

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Abstract— **Mobile TV is becoming a hot topic, since it is expected to create significant revenue opportunities for both the media and mobile industries. Several mobile broadcast technologies are emerging around the world. Among the terrestrial-only architectures, one finds the DVB-H, the T-DMB and the 3GPP MBMS technologies. Alternatively, hybrid satellite/terrestrial architectures are also promoted, based on the success of XM radio and Sirius Satellite Radio which have started operation in 2002 and have already captured 5 millions subscribers with "pay to hear" radio broadcasting programs. The S-DMB system studied in the European IST project MAESTRO [7] is a promising hybrid architecture which aims at full-fledge integration with terrestrial 3G UMTS networks. This paper attempts to show how S-DMB can complement other technologies in terms of coverage, capacity or service capability.**

Index Terms—**Satellite communication, Mobile communication , Digital TV, Satellite broadcasting**

I. Introduction

In this context, there is a strong interst for highly efficient one-to-many distribution means, which can be seen as the missing scheme in 3G network economics to deliver these bandwidth consuming applications to handheld terminals in a cost effective manner. Consequently, the industry is developing a number of technologies among which Multimedia Broadcast & Multicast Services for 3G (MBMS), DVB-H, as well as terrestrial and satellite Digital Multimedia Broadcast (DMB). Facing this large technology selection, mobile and media operators are currently investigating which technology will best serve their strategy. Mike Brooks, chairman of the mobile application group at U.K.-based Digital TV Group, reminded that "technical, commercial and regulatory" criteria are all critical for determining the best technology for mobile broadcasting. "If any one of these elements is missing, the whole thing will fall over".

The satellite DMB (S-DMB) system investigated within the European IST MAESTRO project offers significant assets that should be taken into account in the analysis. This paper intends to show how this S-DMB system positions itself with respect to other mobile broadcast solutions in terms of service capability, technical complexity, regulatory and standardization context as well as business model.

II. Television, a future killer application for mobile network but a real challenge

Extensive market surveys in Europe have shown that kill time is the main incentive for TV services. TV services on mobile encompass from the least to the highest bandwidth consuming services:

- Video on demand services, corresponding to short videos tailored to be played on demand. It may be downloaded or watched on line. The content refers to news, movie trailers, music video, snap shot TV, etc.
- Mobile TV, a mix of already existing TV content and specific content adapted to screen size and usage conditions. Interaction is possible while watching for vote, gamble or subscription.
- Broadcastingof existing radio and TV channels. All content comes from a public TV or radio broadcast channel. Interaction is possible while watching for vote, gamble or subscription.

There is a clear interest in news, weather, sport, entertainment and gaming. Focus group carried out within MAESTRO project showed that news, weather and MTV/entertainment fit best while live sport was not adapted since it invites to share emotion behind a large screen. But the user demand in Mobile TV is highly related to several constraints:

- Coverage is important to provide the advantage of "anytime/anywhere".
- Battery life must not interfere with communication needs.
- Cost of service: the Average Revenue Per User is expected to reach between 5 to 10 €/months
- Ease of use: Just as traditional TV invites to keep on watching with smooth transitions between successive

programs, Mobile TV user interface shall be designed to circumvent any discontinuous viewing effect.
- Screen size, which requires shorter sequences (typically 3 minutes duration) of tailored content.

Interestingly media and mobile industry players consider that the potential revenue associated to TV services decrease as the required bandwidth increases. Indeed, video services are easier to charge compared to simulcast TV. The same has been observed with 2G where SMS are charged hundreds of €/Mbytes while GPRS data traffic is only charged between 2 to 5 €/Mbytes. Nevertheless like any emerging business, some key issues need to be solved such as the business relationship between mobile operators and content providers as well Digital Rights Management to prevent piracy similar to the one experienced in Internet.

III. CONSIDERATIONS ON MOBILE CONSTRAINTS

Several constraints have to be taken into account when designing the infrastructure that addresses mobile handsets.
- The choice of the frequency band affects the antenna gain as well as the propagation. Free space propagation loss experienced at 2 GHz (IMT2000 frequency band) is about 12 dB higher than at 0.5 GHz (UHF frequency band) since it is proportional to the square of the frequency. Also penetration losses in building increase with frequency. At the same time, the size of the receiving antenna is constrained by the form factor of the handset. One can achieve a $\lambda/4$ antenna size at 2GHz procuring a typical 0 dBi gain, while the antenna size will be about $\lambda/10$ at 0.5 GHz with a –10 to -8 dBi gain. Moreover, the transmission antenna shall be designed 4 times bigger at 0.5 GHz than at 2 GHz to achieve a similar transmission EIRP.
- As the transmission capacity increases, the transmission power shall also be increased following a linear law. Typically the transmission power shall be multiplied by 12 (10.8 dB) when the capacity is increased from 1 Mbit/s to 12 Mbit/s. In addition, a network made of several small transmitters outperforms a single high power transmitter to achieve the required coverage in mobile environment encountering fast and slow fading conditions.
- Since mobile handsets are battery activated devices, efficient power saving schemes are required to prevent mobile broadcast reception from draining the battery and reducing the terminal autonomy for mobile operations.

IV. MOBILE BROADCAST TECHNOLOGIES

Several industrial initiatives aim at providing one-to-many distribution channels for mobile users in Europe.

3G Cellular MBMS: Multimedia Broadcast Multicast Service [1]

The MBMS is a unidirectional point to multipoint bearer service, which is being standardized by 3GPP for Release 6. MBMS provides for data-grams transmission from a single source entity to multiple recipients in UMTS networks.

3GPP has defined two operation modes:
- The broadcast mode is a point-to-multipoint transmission of multimedia data (e.g. text, audio, picture, video) from a single source entity to all users in a broadcast service area. The broadcast mode is intended to efficiently use radio/network resources e.g. data is transmitted over a common radio channel. Data is transmitted in the broadcast service area as defined by the network (home environment).
- The multicast mode allows the point-to-multipoint transmission of multimedia data (e.g. text, audio, picture, video) from a single source point to a multicast group in a multicast service area. There is the possibility in the multicast mode for the network to selectively transmit to cells within the multicast service area which contain members of a multicast group.

MBMS provides for two different delivery schemes
- MBMS Download User Service: Transmission of files via the unidirectional MBMS Bearer Services. Download Content is stored in the local files-system of the user equipment. The download is triggered by network as users are registered to the service.
- MBMS Streaming User Service: Continuous transmission of data and the immediate play-out via the display and/or the loudspeaker (multimedia data only).

MBMS makes use of UMTS radio resources. It is ideally suited to deliver multimedia services to an audience geographically concentrated. Indeed, using MBMS to serve users in a wide area reserves a significant amount of radio resources, which mobile operators would rather spend on more profitable services with respect to the bandwidth consumed (ex: voice & SMS).

DVB-H: Digital Video Broadcast for Handheld terminals [2]

This technology has been defined by the DVB forum. The implementation guidelines for operation in the UHF band have been recently been completed. Based on the DVB-T standard, it implements specific features mainly to meet power consumption constraints, reception and mobility scenarios as well as propagation environments associated to handheld terminals.

The network infrastructure consists in several high-power transmitters (up to 43 dBW) complemented by a large number of medium and low power gap fillers (on-channel or frequency conversion ones) to achieve a suitable coverage for mobile handheld reception. The system targets at delivering Mobile TV services to dedicated receivers, smart phones as well as cellular handheld terminals.

The network is expected to operate in the UHF band (474 – 698 MHz) in Europe. Its deployment will depend on regulatory issues such as the re-planning of the UHF band

and the varying pace of analogue to digital TV switchover each country is embarked on.
This technology offers high capacity-per-carrier capabilities, ranging for a mobile environment – from 5 Mbit/s (QPSK and code rate ½) up to 12 Mbit/s (16 QAM, 2/3 code rate) on a single 8 MHz channel. The use of an additional transmission protection (¾ MPE-FEC), strongly recommended in adverse propagation environment, would limit the range of this useful capacity to respectively 4 and 9 Mbit/s.
Since it needs a multi-frequency network, the system requires the terminal to perform hand-over between transmitter stations.

T-DMB: Terrestrial Digital Multimedia Broadcasting [4]

Terrestrial Digital Multimedia Broadcasting (T-DMB) is a modified version of the Eureka 147 (T-DAB) standard. T-DMB is going to open service in Korea by mid 2005.
T-DMB system targets reception by mobile, cellular handheld terminals and fixed receivers with a non-directional antenna. It can be operated at frequencies from 30 MHz to 3 GHz. T-DMB offers a general purpose digital multiplex which can carry a number of services, including video and audio-programs and associated data and independent data services.
The T-DMB overall bandwidth is 1.536 MHz, providing a useful bit-rate capacity of approximately 1 Mbit/s in a complete "ensemble". Each service is independently error-protected with a coding overhead ranging from about 25% to 300% (25% to 200% for sound), the amount of which depends on the requirements of the broadcasters (transmitter coverage, reception quality, etc). T-DMB uses OFDM technology.

S-DMB/MAESTRO

The purpose of the Satellite Digital Multimedia Broadcast system (referred to as S-DMB in the rest of the document) is to provide a datacast capacity for various mobile operators. This capacity can be used to deliver cost effective streaming and download services directly to mobile handsets over nation-wide umbrella cells (ex: ~700 - 1000 km diameter) in both outdoor and indoor environments.
The system is designed to minimize impacts on the 3G cellular user terminal or prevent any operational constraints to the service provision. In other words, it shall be as transparent as possible to 3G handsets with respects to cost, autonomy, form factor, aesthetics to maximize market penetration. It is assumed that most 3G handsets will operate on both 2G and 3G type of networks.
The system relies on an hybrid satellite & terrestrial repeaters architecture operating in the IMT2000 core frequency band allocated to Mobile Satellite Systems. The architecture is currently being defined in ETSI.
The system makes use of the UTRA FDD WCDMA waveform in full compliance with the relevant 3GPP standard to allow a low cost impact on the 3G handset bill of material. It relies on a very high power, transparent, geo-stationary satellite and on low power, frequency-converter gap-fillers. A typical satellite configuration allows to offer coverage over 6 umbrella cells with a broadcast capacity of 1.15 Mbit/s per umbrella cell.
The system capacity can be increased up to 3.45 Mbit/s per umbrella cells by adding satellites and gap fillers. Note that the satellite and the gap fillers are designed to be transparent to new features or waveform introduced in the 3GPP standards.

Summary

Several technologies are being developed to provide mobile broadcast services to cellular handheld terminals. Clearly there is a need for an additional infrastructure providing distribution services on dedicated radio resources to preserve revenues associated to the cellular frequency bands. Several approaches consider either "pure terrestrial" or "combined satellite / terrestrial" infrastructure. The main issues which are currently being tackled are:

- definition of a business model enabling a fair share of revenues between the mobile operator and the content providers,
- deployment of this additional infrastructure,
- definition of an harmonized regulatory framework.

The table hereafter summarizes the characteristics of the different technologies:

Technologies	DVB-H	MBMS	T-DMB	S-DMB
Name	Digital Video Broadcasting for Handheld	Multimedia Broadcast Multicast Services	Terrestrial Digital Multimedia Broadcasting	Satellite Digital Multimedia Broadcasting
Waveform technology	COFDM, DVB-T	UTRA FDD WCDMA	COFDM, T-DAB	UTRA FDD WCDMA
Standardization organization	DVB forum	3GPP	World DAB forum	ETSI
Targeted frequency bands	UHF band 470-700 MHz for analog & digital TV	IMT2000 band, 1920-1980 MHz in uplink, 2110-2170 MHz in downlink Shared with T-UMTS	VHF band 174-238 MHz, L band 1452-1467 MHz	IMT2000 band allocated to mobile satellite systems adjacent to T-UMTS band
Targeted commercial opening	End of 2006 in some urban areas	2007	May 2005 in Korea with coverage limited to main urban areas	Possible service opening early 2007 in some urban areas 2009 with global coverage
Capacity	4 to 9 Mbit/s per 8 MHz	384 kbit/s per 5 MHz channel	1 Mbit/s in 1.5 MHz channel	1.15 Mbit/s per 5 MHz channel
Power saving scheme	Timeslice selection	Code selection	Time-demultiplexing & selective Fourier transformation	Code selection

In addition, one should also note that an hybrid satellite/terrestrial system also known as S-DMB system is being launched in Korea. It makes use of CDM technology and operates at 2.3 GHz. In the same time Qualcomm is

currently designing a multicast technology known as Media Forward Link Only technology which encompasses a content distribution system and would operate in the 750 MHz frequency band in the USA.
One could add WiMax to the list of candidate technologies. However, it has not been considered at this stage since mobile broadcast services have not been identified yet for this technology.

V. RELATIVE POSITIONING OF S-DMB

The table below synthesizes the differences between the mobile broadcast systems in terms of business, regulatory and technical aspects:

Technologies	**DVB-H**	**MBMS**	**T-DMB**	**S-DMB**
Service capability	Video delivery, Mobile TV, TV & Radio broadcasting	Video delivery	Video delivery, Mobile TV, TV & Radio broadcasting	Video delivery, Mobile TV
Mobile Broadcast capacity	4 or 9 Mbit/s assuming 8 MHz allocation per country	Max 128 kbit/s per cell assuming <10% of the base station transmission power consumption [5]	1 Mbit/s assuming 1.5 MHz allocation per country	3.45 Mbit/s per spot beam assuming 15 MHz allocation (Spot beam corresponds typically to a linguistic area in Europe)
Market opportunity	Subject to UHF band availability	World-wide 3G market	Subject to VHF and UHF band availability	World-wide frequency band allocation
Service commercialization	Broadcasters or mobile operators	Mobile operators	Broadcasters or mobile operators	Mobile operators
Business model trend	Free to air and pay per view services	Pay per view services	Free to air services	Pay per view services
Coverage	Urban areas dependant on analog switch over	Correlated to 3G deployment	Urban areas	Global
Impact on cellular handset	Additional reception chain (antenna, tuner and baseband chipset)	None	Additional reception chain (antenna, tuner and baseband chipset)	* Additional radio frequency reception chain * sharing of high end 3G antenna & baseband chipset
Regulatory framework	Broadcast	Telecom	Broadcast	Telecom
Environmental constraints	High density of medium power (~100 W) gap fillers with large transmission antennas	None	Medium density of High power transmitters (~50 kW)	High density in urban areas of low power gap fillers (< 20 W) co sited with 3G base stations

The S-DMB system can offer per spot beam a maximum of 27 pay per view mobile TV channels with 128 kbit/s encoding rate, adapted to the handset screen size. However, local storage technology, already reaching 1 GBytes end of 2005 in some handset, will allow the end-user to benefit from several hours of new video content per day.
Relying on 3GPP technology and taking advantage of IMT2000 satellite frequency band adjacent to IMT2000 terrestrial frequency 3G system allows to implement the S-DMB features massively in 3G handsets at a negligible cost. This technology synergy is well positioned to address 3G handsets rather than dedicated receivers. The single frequency network achieved in an umbrella cell doesn't require complex hand-over procedures to be implemented in the network.
Fully compliant with the 3GPP defined Multimedia Broadcast Multicast Service feature, the system can support an open mobile broadcast service platform for which the application enabling technologies are currently defined in the Open Mobile Alliance forum. Power saving schemes are inherited from the 3GPP defined MBMS technology.
With this concept of MBMS services on a dedicated carrier over a nation wide umbrella cell, this allows mobile operators to commercialize cost effective rich multimedia service delivery (TV, video) with a total interactivity via their terrestrial cellular network (2G or 3G).
The satellite operator invests in the development and launch of the space segment and sells the broadcast capacity to mobile operators who bear the cost of the gap fillers integration in their infrastructure. Trials carried out within the MoDiS project [6] have shown that the required density of gap fillers is lower than for UMTS base stations to achieve the same coverage in dense urban areas. This can be explain since the system takes advantage of site diversity and transmission synchronization techniques. In addition, the gap fillers can share the Node B antennas and reduce the environmental constraints. The hybrid satellite and gap-fillers architecture is the most optimized approach in terms of cost to achieve a global coverage. This global coverage enables a mobile operator to differentiate from the competition by offering the service truly anywhere and anytime.
The IMT2000 satellite frequency band are allocated world wide to mobile satellite systems. The technology can then be spread along with UMTS networks ensuring global roaming. A significant economy of scale on handsets and gap fillers technology can be achieved.
Thanks to the high reliability of the satellite, the S-DMB infrastructure may also be used to support alert and guidance services to population in case of natural or man made disasters during which terrestrial infra is suffering either congestion or damages.
In Europe, the DVB-H technology benefits from a wide support and visibility. It is now widely accepted that its

commercial opening may well start second half of 2006. While it is easy to cover metropolitan areas by partly relying on DVB-T transmitters, it will be hard to reach national coverage quickly due to the current non uniform radio frequency allocation, government regulations associated to the UHF band, and the costly network building. S-DMB is then best positioned to complement the coverage and meet the anywhere anytime service availability that mobile users are expecting. On the other side, MBMS is ideally positioned to deliver multimedia services to geographically concentrated audience. With nation wide umbrella cell and technology commonalities, S-DMB combined with MBMS can serve national or local targeted content in the most efficient way. Last, the demand for Mobile TV will likely exceed the possible capacity of a single technology/available spectrum. It is most likely that Mobile TV will require several technologies to serve the different types of markets. A market being defined by the type of service model (free to air or pay per view) and type of usage with integrated handset, dedicated receiver and vehicular terminal.

VI. Conclusions

This paper has identified different mobile broadcast technologies well-suited to offer Mobile TV services in Europe. Since the regulatory conditions and the business model scenarios may differ from country to country, it is most probable that several mobile broadcast technologies will emerge; thus they may complement each others in term of service offers or coverage for the benefit of the mobile users.

It has been shown that the Satellite Digital Multimedia Broadcast system is a cost-effective solution that can easily complement the coverage of the high-capacity DVB-H solution in Europe. S-DMB is also well adapted to be deployed overseas since it relies on a world-wide frequency allocation.

Inter-working techniques allowing a service roaming between DVB-H, S-DMB and MBMS need now to be addressed to offer service continuity for mobile end-users.

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