

Broadcasting to Handheld Devices: The Challenges

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Abstract—Digital Video Terrestrial Broadcasting (DVB-T) allows combining broadcasting, telephone and data services in one network. It has facilitated mobile TV broadcasting. Mobile TV broadcasting is dominated by fragmentation of standards in use in different continents. In Asia T-DMB and ISDB-T are used while Europe uses mainly DVB-H and in USA it is MediaFLO. Issues of royalty for developers of these different incompatible technologies, investments made and differing local conditions shall make it difficult to agree on a unified standard in a very near future. Despite this shortcoming, mobile TV has shown very good market potential. There are a number of challenges that still exist for regulators, investors and technology developers but the future looks bright. There is need for mobile telephone operators to cooperate with content providers and those operating terrestrial digital broadcasting infrastructure for mutual benefit.

Keywords— Broadcasting to handheld, broadcasting value chain, Digital broadcasting, mobile TV.

I. INTRODUCTION

THE ITU Council adopted a resolution no. 1185 in its 2001 and 2002 sessions that required its member states to develop strategies to migrate to digital terrestrial audio and video broadcasting from analogue that had been in use for several years in line with the GE89 agreement. This was followed by Geneva agreement G06 [1]. The rapid developments in telecommunications and information technology (IT) and massive IT applications and services, that lead to countless service providers and users of such services. For example, Japanese ICT industry average annual growth rate between 1995 and 2004 was 5.5% that accounted for 11.5% of its industrial output in 2004 [2] while South Korea IT exports accounted for 36% of export volume in 2005 [3]. Japanese broadband subscribers grew from 3.9 million in 2001 to 23 million in 2005 while its mobile subscribers increased from 1.5 million in 1995 to 97 million in 2006 [2]. The same trend is observed in East African Region following liberalisation of the telecommunication sector. Hence, the bandwidth requirement kept on increasing that called for a technical solution.

The traditional data communication is primarily unicast; while historically, broadcast networks have provided virtually everyone with a broadband one-way channel offered through

satellite, terrestrial broadcast systems and cable networks. However, the common internet video and audio service is currently a unicast-based delivery mechanism that enables many simultaneous connections requiring a large amount of bandwidth and server processing power to serve a large user community. The unicast operation mode kept increasing very fast bandwidth requirements hence the capacity of both the backbone and the access network inline with expanding usage. Digital broadcasting largely operational in developed countries and slowly being adopted in developing countries is principally a multicast system that increases frequency capacity utilization. The movement from analogue to digital terrestrial broadcasting presented technical challenges and business opportunities. Digital broadcasting can integrate traditional broadcasting with multimedia and telephony services in a single network and has made broadcasting to handheld possible. Broadcasting to handheld that combines telephony, multimedia and broadcasting calls for introduction of broadcast/multicast schemes over wireless and wired broadband access networks services. For integrated system, downlink requirement outweighs that of uplink at present, a trend that shall continue for sometime.

In analogue terrestrial broadcasting, the broadcaster handled and managed the studio, signal transportation, distribution, and the transmission at each area covered by the broadcaster. Each frequency channel carried one programme. In digital scenario, the broadcasters share the signal transportation and transmission facilities and each frequency channel carry several programmes. The basic terrestrial TV broadcasting (DVB-T) is an OFDM modulation multi-carrier system using 2k or 8k carriers each with 4 different guard bands using 68 OFDM symbols per OFDM frame, and 4 OFDM frames per superframe. To meet bandwidth and efficiency requirements and to provide ruggedness for a wide range of practical applications, the DVB-T system uses QPSK modulation, 16-QAM or 64-QAM signal constellations which supports simultaneous transmission of two independent MPEG transport streams, referred to as the high priority (HP) and the low priority (LP) streams [4]. Hence, several signals for transmission can be coded, multiplexed, interleaved, compressed, and carried in a single channel. The principal advantage of digital broadcasting is in sharing resources from bandwidth to infrastructure and the possibility of a return path. Therefore, broadcasters remain with content provision and at times its generation with a possibility of introducing interactive services. Aggregation, distribution and

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transmission (delivery) is a function done at a fee by another entity known as a multiplex (MUX) Operator.

Digital broadcasting enables offering interactive digital and telecommunication services including telephone and internet services, see fig. 1. For example, by May 2007 South Korea had 28 channels for mobile broadcasting services with 7 video channels, 13 audio channels and 8 traffic and other channels in Seoul [5]. Since broadcasting coverage is by far higher than that of mobile telephone in developing countries, digital broadcasting brings hope to the reduction of the urban-rural digital divide of present times. This provides another option since many suggested solutions are largely based on the infrastructure owned by those providing the services. Satellite or cable owners, telephone companies, etc will each come with a solution based on their systems.

There are a number of options for digital broadcast; however, DVB-T system is the most popular for digital terrestrial television system in the world that has been adopted in more countries than any other [4]. It uses the ETSI 300-744 standard [6] designed for digital terrestrial television services and to some extent mobile receivers [7,8]. To use the existing very high frequency (VHF) and ultra high frequency (UHF) bands effectively, the DVB-T system must operate in three nominal bandwidths at 6 MHz, 7 MHz, and 8 MHz and provide sufficient protection against high levels of co-channel interference (CCI) and adjacent channel interference (ACI) emanating from existing broadcast services. The other standards are Advanced Television Standards Committee (ATSC) of the USA and Integrated Services Digital Broadcasting-Terrestrial (ISDB-T) of Japan.



Fig. 1: Digital Terrestrial Broadcasting Outlook

The MUX operators should target dynamic communication environments where a multitude of different wireless devices and radio access technologies network can be offered hence making it feasible for telephone network operators and the MUX Operators to cooperate and compete for the benefit of both users and operators. This however needs multi-radio access architecture consisting of resource management and generic link layer to facilitate dynamic composition of network by means of effective radio access selection mechanism.

Indicators show that introduction of TV broadcasting to handheld was primarily initially driven by vendor community and broadcasters than market demand. However, consumers are taking up its growth. There were 14 commercial deployments by 2006 and it is expected that consumer spending on broadcasting to mobile will be \$ 11 billion by 2011 with over 250 million receivers operational [9,10].

However, challenges are still immense that includes technology standardization [11] and frequency availability that makes them costly thus slowing down market take up. There is a move to integrate with other media products.

II. MOBILE TV TECHNOLOGIES

A number of contending technologies developed has made the broadcasting to handheld possible [9]. These include those summarized in fig. 2:

A. 2.1 Technology comparison

Table 1 summarises the main technologies and frequency bands that could be used for mobile TV. When comparing the cost of these technologies, it is to be noted that [2,12,13,14]:

- DVB-H is based on DVB-T standard and implements specific features mainly to meet power consumption constraints, reception and mobility scenarios as well as propagation environments associated to handheld terminals. The system targets the delivery of Mobile TV services to dedicated receivers and cellular handheld

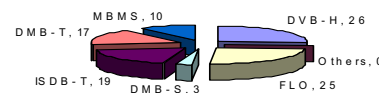


Fig. 2: Utilisation of different technologies in % by 2007[1]

terminals. It operates in the UHF band (474 – 698 MHz in Europe). It can offer 5 Mbit/s to 20 Mbit/s in 8 MHz in the UHF. It is acceptable for city coverage with numerous repeaters but uneconomical for nationwide coverage of countries with large geographical area like Tanzania. It can be introduced as an upgrade of BVB-T infrastructure or as a dedicated network. User interactivity not normally included now [15];

- DVB-SH (operates in UMTS band (S-band)) using a hybrid solution offers city coverage with repeaters, nationwide coverage from satellite, high reuse of cellular UMTS site assets due to proximity of the S-UMTS and terrestrial UMTS bands. However, the costs of terminal equipment are still prohibitive for rural communities of the African continent. Moreover, the connection charge rate is still high for such communities. It can offer 1.35 Mbit/s to 10 Mbit/s in 5 MHz bandwidth. It uses IP-based transmission and an OFDM waveform with an improved link budget by employing codes. It is a European satellite-based concept with direct-to-mobile transmission addressing coverage in rural areas and complemented with terrestrial repeaters to provide deep indoor coverage in urban areas [9,15];
- T-DMB uses the Eureka 147 standard originally allocated for DAB. It targets reception by mobile, cellular handheld terminal and fixed receivers with a non-directional antenna operating at frequencies from 30 MHz to 3 GHz.

It offers a general-purpose digital multiplex that can carry a number of services, including video, audio-programme associated data and independent data services. T-DMB uses OFDM technology that offers 1.06 Mbits/s – 2.3 Mbits/s in 1.536-1.712 MHz bandwidth. It does not allow nationwide coverage at a reasonable cost because of

TABLE I
THE MOST DEPLOYED MOBILE TV SYSTEMS

Technology	DVB-H	BMB-S	BMB-T	ISDB-T	FLO	DAB-IP	DVB-SH
Region	Europe, US, Taiwan, China, (tba), Australia, Singapore	South Korea, France, UK, Germany, China, Japan	South Korea, France, UK, Germany, China (tba)	Japan, Brazil (tbd)	U.S., Taiwan, Hongkong, Malaysia, UK		UK
Time frame (20XX)	(05) elsewhere (06) Europe	(04) Asia	(04) Asia (06) Europe	(05) – (06)	(06) U.S. (08) others	(06)	(07)
Technology	OFDM		OFDM	OFDM	OFDM		
Service	FTA + PPV	PPV	FTA + PPV	FTA + PPV	FTA + PPV	PPV	PPV
Device	Cellular & non-cellular	Cellular	Cellular & non-cellular	cellular	Cellular	cellular	cellular
Mbits/s	5.0-20.0	3.0-8.5	1.1-2.3	23.0	3.7-14.9		1.35-8.0
Bandwidth [MHz]	8.0	5.0	1.5	6.0	8.0		5.0
Band	UHF, L	L, 3G, S	VHF, UHF, L		UHF, L		S, UHF

required repeaters. Since it operates with a 1.5MHz bandwidth, several transmitters may be required on each site to provide large capacity. User interactivity not included. Can be realized as an upgrade of existing DAB infrastructure;

- MBMS over TD-CDMA requires upgrade of UMTS (commonly known as TD-CDMA) infrastructure where it exists. Makes use of the UTRA TDD technology to broadcast mobile TV streams in existing UMTS TDD licensed spectrum. It is based on the 3GPP MBMS architecture, with layer 1 enhancements to increase coverage and capacity. It is a unidirectional point to multipoint bearer service. The transmission can be selective to the intended cell level. MBMS can support download to the user local file system and streaming user services. UMTS offers a very limited number of channels. It has uplink channel. It can offer 3 Mbit/s to 8.5 Mbit/s in 5 MHz bandwidth. The other variant of MBMS could be used in multicasting multimedia streams over a GSM or IMT-2000/3G/UMTS network to multiple mobiles subscribed to the service, or to broadcast to all mobiles in the geographic area covered by the base station.
- WiMAX is primarily a complementary service. Mobile WiMAX (802.16e) permits the delivery of high broadband data and video services using SOFDMA

technology associated with smart antennas and an IP-based architecture. Mobile WiMAX could be used as a stand-alone solution for urban areas but requires additional technology for full coverage capabilities. Mobile WiMAX has the potential to offer a higher number of mobile TV channels in unicast mode and is therefore an ideal complement to provide additional capacities. It should be noted that mobile WiMAX can be provided at 2.5GHz and 3.5GHz and requires a license for spectrum [9].

- MediaFLO is based on the Forward Link Only (FLO) specification for “Terrestrial Mobile Multimedia Multicast” (standardised as TIA-1099). MediaFLO is an end-to-end system that enables broadcasting of video streams, audio-only streams, clipcast media, and datacasting to mobile devices, including handheld receivers. The system is designed to optimise coverage, capacity and power consumption as well as overall user experience for handheld receivers using the TIA-1099 air interface standard. The system can reuse existing broadcast network infrastructure such as sites, antennas, DVB-T transmitters that are upgradeable to support the FLO modulator, and other ancillary equipments, in either a Multiple Frequency Network (MFN) or Single Frequency Network (SFN). User interactivity not included. It can offer 3.7 Mbit/s to 14.9 Mbit/s in 8 MHz bandwidth.
- ISDB-T – Integrated Services Digital Broadcasting-Terrestrial: a satellite-to-tower system similar to DVB-T, used in Japan and Brazil to provide digital service to TV sets and handheld mobile units. It has a bandwidth of 5.6MHz with 13 channels embedded. It adopts MPEG-2 for signal multiplexing, enhancing its interoperability with other information media. It uses OFDM transmission with digital modulation schemes (i.e. QPSK, DQPSK, 16QAM and 64QAM) [16].

Technology adopted so far is region based. FLO is dominantly in the USA, DVB-H in Europe, satellite and T-DMB in Asia. It is said that T-DMB will remain a niche technology supported by smaller service providers struggling to gain access to capacity on the DVB-H MUX or looking to gain speed to market advantages. The future of mobile broadcasting will be dominated by technology fragmentation because of the number of competing system operational at present. Table 1 shows the systems so far deployed in various countries and it is expected that Finland, Russia, South Africa and France will launch their systems in a very near future. Handheld devices sales for free-to-air services by far outstripped those for pay TV ($\approx 4:1$).

B. Challenges

The introduction of mobile broadcasting will have impact on both broadcasters and telephone operators. The telephone operators should cooperate with broadcasters for mutual benefit and survival. Video broadcast to a handheld mobile device is now a reality in a number of countries. What is still not clear is its future because of the many contending technologies now deployed in a number of countries across

the world [12,13,14]. The amount of investment made and differing local conditions poses a great challenge in unifying standard for mobile broadcasting. The current scenario using a combination of different technologies that shall evolve over time - starting from current unicast streaming using current 3G technologies to finally arrive at mass broadcast using DVB-H, FLO or T-DMB based overlay networks may be one way forward. The regulatory authorities may have to look at the challenges and respond appropriately while observing the concept of service and technology neutrality in force in many countries. In most countries, the unavailability of UHF frequencies may prevent going beyond multi-city coverage before analogue broadcasting switchoff. For a mobile operator, the likely migration path over the next five years will see their existing 3G unicast-based mobile TV systems initially boosted, in terms of capacity, with the deployment of HSDPA capability and the switch on of additional 3G carriers. Afterwards, adding a parallel broadcast capability to broadcast channels that are more popular will allow the operator to transparently migrate most of the urban and rural unicast mobile TV load and hence enable continued 3G growth without resorting to cell splitting [17]. 3G cellular networks are currently not optimised to deliver large amounts of data to a multiplicity of receivers, from both a cost and a technical viewpoint.

The only single frequency available worldwide today that can be used for harmonization of mobile TV and offering a possibility of easier integration with 3G mobile networks is the 2.2 GHz. If this were to be adopted as the standard, then economies of scale can help in reducing rollout and terminal equipment costs. However, operation in this range will require higher investment in repeater stations and may not be a realistic option considering the investment made in different countries worldwide.

III. SPECTRUM

Suitable and sufficient spectrum availability is necessary for success of commercial mobile TV take-up. Available spectrum

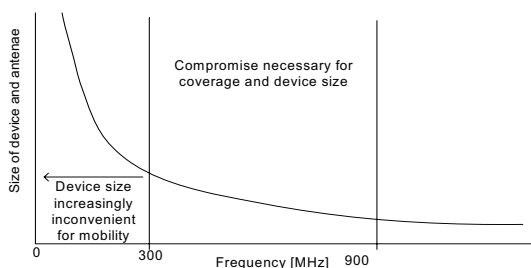


Fig. 2: Effects of operating frequency

will have impact on technology choices open to operators and a significant cost impact on handsets. Allocating many narrow and fragmented bands for mobile TV would need handsets capable of operating on all the bands – at an added complexity and cost. Also, the cost of deploying radio networks shall be affected. Lower frequency bands imply larger cells (all other things being equal) and hence lower costs of deployment

because Band III has much better propagation properties than the UHF bands. This is significant when deploying in remote and sparsely populated areas [13,18,19,20]. Furthermore, it has less possibility of interferences with existing mobile phone service frequencies. However, UHF spectrum has also good properties for mobile TV but is currently being used for analogue broadcasting in many countries.

Technical constraints to the frequency planning could arise while ensuring coexistence of broadcasting networks intended for fixed rooftop reception and those for indoor portable mobile TV. This may be minimised by harmonising a sub-band for mobile applications allowing for improved terminal performance and reduced network costs. Mobile TV can be deployed over existing broadcast bands. If mobile TV were commercially successful it is likely that a mobile operator's bands could quickly become overloaded. If this were to happen, then the L-Band could be availed for terrestrial services. However, there are cost implications associated with this option. Another option could be the use of a harmonised UHF sub-band consequent to a technical feasibility assessment. This might give rise, without any order of priority, to the following possible scenario of spectrum use; 3G, L band, UHF band and VHF.

The use of single frequency network (SFN) for mobile TV should be the choice because of simplicity in mobility and protocol handover.

IV. DIGITAL BROADCASTING VALUE CHAIN

The broadcasting value chain involves the following basic functions: content generation, the content or service provider, and signal distribution and transmission. The later involves aggregation and multiplexing of services and content for delivery to customer, distribution of contents and services to intended localities and customers and transmission that can be performed by the MUX Operator, Network Operator, and Service Operator.

A. Content Provider

Content providers are broadcasters that run mobile television or radio channels using content from content owners or produce content in-house. These are paid for their services through pay-TV fees, advertisements or in the case of the public broadcaster by grants or television license fees. In the mobile broadcast platform, the content provider produces an encoded audio-video stream, and sending it to the mobile broadcast system [14,17,21] of the MUX Operator. The encoded A/V streams can be sent as IP multicast packets over a multicast network, covering the country or area where mobile broadcast services are available. There can be several content providers on one mobile broadcast platform, limitations coming only from the total broadcast bandwidth available in the system. For example, a DVB-H systems using 16QAM modulation with a bit rate of 12 Mbp/s can have channel count of 15 to 50 depending on the audio and video quality and the amount of bandwidth used for Multi-Protocol Encapsulation – Forward Error Correction (MPE-FEC).

Therefore, the regulators have to define acceptable quality for different offering.

B. MUX Operator

The MUX Operator, sometimes referred to as datacast operator is responsible for the central management of a mobile broadcast platform i.e. generating the Electronic Service Guide (ESG), controlling and managing the IP datacast system, and provisioning form content providers and service operators. The MUX Operator multiplexes and aggregates programmes from content providers. Effectively the operator buys mobile broadcast capacity from the broadcast network operator and re-sells that capacity to content provider companies.

C. Network Operator

The network operator would own frequency licenses. The operator operates multicast network carrying the content streams from broadcasters' encoders to the transmitter sites, modulates and transmits them. The operators also own and operate the IP encapsulators [21] bridging the IP-based multicast traffic to the DVB that transforms IP packet streams to a DVB transport stream (TS).

D. Service Operator

Service operator is responsible for content pricing, selling and primary end-user support. The operator would run the Broadcast Account Manager (BAM), a platform component for selling channel bundles and pay-per-view programs to end-users and generating charging details for the purchases made [21]. The purchase requests and the delivery rights can use HTTP or any available IP return channel.

E. Operation Scenario

It is important however to consider reducing to the minimum the necessary number of key players in delivering services to consumers particularly where the volume of services is low and in the interest of minimizing conflicts. Therefore, some of the operators in 4.2-4.4 can be turned to functions of an operator. A number of systems in operation today have lumped all these functions to the MUX Operator to optimize operational costs and services. There are scenarios however where the service operator function is done by a separate operator to provide cooperation platform for different players in the broadcasting chain.

F. Mobile Network Operators Interests and Roles

Digital broadcasting can incorporate return path through the DVB-T MUX Operator, although some installed systems did not include this functionality. In such a case, the mobile network operators can provide interactivity through collaboration. The mobile operator has to ensure that the charging structure is competitive to attract cooperation. In such a scenario, the mobile operator can play the following roles:

- Interactivity associated with the return channel for content selection, transaction, broadcast selection mode, etc;
- The service portal, which may be accessed via the cellular network;
- Control of the terminal specifications and distribution for subsidisation policy, pre-configuration, functionality selection, etc;
- End-user knowledge and technical expertise in network service provisioning for single authentication and billing, customer profiles, m-payment, Digital Rights Management, decryption key delivery, location and positioning mechanisms, etc; and
- The ability to assemble an integrated offering using its own mobile network transmission capabilities along with overlay broadcast network content delivery.

V. DELIVERY OPTIONS FOR MOBILE BROADCAST

A. Broadcast Networks

The mixed unicast/broadcast delivery of mobile TV services in broadcast network should preferably work to be complementary rather than at a competitor of mobile networks. In this mode most popular channels shall operate in parallel with mobile networks while maintaining access to interactive features and wide choice of a unicast-only solution. Hence, both national and indoor coverage could be achieved easier with adequate, but not over-dimensioned, broadcast capacity. Furthermore, the integration of broadcast and unicast components could be simplified by integration at base station sites (equipment, towers, feeders, antenna, etc.) and within terminals. To ensure fair play in the cooperation, regulators have very significant role considering that the mobile operators are well established and would tend to be protective.

B. A Hybrid Satellite/Terrestrial Broadcast Network

By evolving the DVB-H and DMB standard using turbo codes, modified interleaving and S-band operation, mobile TV offering using a hybrid satellite/terrestrial transmission system is a reality. The hybrid system use a high-power geostationary satellite (for cost-effective nationwide coverage) and a network of medium and low-power repeaters that are co-located with mobile base stations, to provide urban and indoor coverage. Such deployment has been tested in US for radio only, in Japan, and S-DMB in Korea for radio and TV programs. The system maintains the key features of terrestrial DVB-H and DMB systems such as OFDM modulation, time slicing, and IP datacasting, while improving link budget through turbo-codes and deeper interleaving. However, if such a system operates at 2.2GHz, higher antenna gains and reception diversity can be realised. The Satellite used has nine channels of net capacity of 2.3Mbit/s for each carrier that can be increased to 18 using adjacent carrier repeater transmitters complementing the satellite signal. The repeaters retransmitting at the satellite carrier frequency facilitate indoor coverage [21,22].

C. Terrestrial Broadcast Systems

DVB-T was primarily designed for stationary TV reception and possibly for in-car receivers. Hence, the transmission network needs a few high-power transmitters to cover vast areas. Therefore, DVB-T had to be adapted for reception by handheld terminals by addressing power consumption issues, the processing power of mobile terminals, and poor indoor coverage. Hence, elements using IP transport technology had to be added at the physical and link layers of DVB-H and similar mobile TV technologies. The different technologies require different bandwidth, have different bit rate capabilities and number of channels at 256kbit/s depending on configuration but also the power of transmitters differ. To provide good urban indoor coverage requires a mix of around 100 high-power transmitters and up to 10,000 low-power repeaters to offer indoor coverage for a country like France. Additional high power transmitters will be required to cover all rural areas for outdoor handheld reception.

VI. CONCLUSION

Mobile video broadcasting is a reality today in many countries using both existing cellular infrastructures in unicast mode, as a complementary offering in DVB-T infrastructure for multicast mode and a cooperation mode between the two. Mobile infrastructure is not optimised to deliver the same content to many users, which inhibits mass-market deployment. For mass use of video on mobile, overlay broadcast networks, distinct from cellular networks, are necessary. The two therefore must compete but cooperate in their own interest and that of the consumers. In an effort to determine best means fit each operator's needs and prevailing local conditions, different technologies have been developed to provide complete mobile TV solutions having different capabilities and requirements. The technologies available can be through terrestrial, satellite and a combination of the two. To enable indoor coverage, ranges of low power transmitters/repeaters are required.

To make mobile TV a reality for the mass market quickly, all stakeholders (mobile operators, broadcasters, equipment vendors, contents providers, etc.) need to work together. Together they need to create the right combination: infrastructure to offer the service everywhere, affordable mobile phones, and attractive contents.

There is need to emphasize that mobile and digital Broadcasting networks should cooperate. Through cooperation they can be able to provide unicast and interactively broadcast at the same time. The large broadcasting cells offer very good broadcasting/multicasting capabilities to hi-speed mobile users while cellular systems can provide the return channel necessary for interactive broadcasting, and error correction through their dense network.

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