MOBILE TV: A TECHNICAL AND ECONOMIC COMPARISON OF BROADCAST, MULTICAST AND UNICAST ALTERNATIVES AND THE IMPLICATIONS FOR CABLE

Michael Eagles, UPC Broadband
Tim Burke, Liberty Global Inc.

Abstract

The growth of mobile user terminals suitable for multi-media consumption, combined with emerging mobile multi-media applications and the increasing capacities of wireless technology, provide a case for understanding facilities-based mobile broadcast, multicast and unicast technologies as a complement to fixed line broadcast video.

In developing a view of mobile TV as a compliment to cable broadcast video; this paper considers the drivers for future facilities-based mobile TV technology, alternative mobile TV distribution platforms, and, compares the economics for the delivery of mobile TV services.

We develop a taxonomy to compare the alternatives, and explore broadcast technologies such as DVB-H, DVH-SH and MediaFLO, multicast technologies such as out-of-band and in-band MBMS, and unicast or streaming platforms.

INTRODUCTION

Cable MSOs operate in an increasingly competitive market with incumbent Telcos and independent wireless operators. Cable's early victories in the voice market led to an aggressive response to offer video products by the Telcos.

The next area for intense Telco competition will likely be mobile television. The addition of television to their mobile voice and data products may be the logical next step ... but it may not be for cable.

We provide a toolkit for the MSO to assess the technical options and the economics of each.

Mobile TV is not a "one-size-fits-all" opportunity; the implications for cable depend on several factors including regional and regulatory variations and the competitive situation.

In this paper, we consider the drivers for mobile TV, compare the mobile TV alternatives and assess the mobile TV business model.

EVALUATING THE DRIVERS FOR MOBILE TV

Technology drivers for adoption of facilities-based mobile TV that will be considered include:

- Innovation in mobile TV user terminals - the feature evolution and growth in mobile TV user terminals, availability of chipsets and handsets, and compression algorithms,
- Availability of spectrum - the state of mobile broadcast standardization, licensing and spectral harmonization,
- Evolution of network technology – the increasing capacity of wireless bandwidth the emerging mobile return path and channel change improvements,
- Usage context and prospects – demographics, viewership, and subscriber willingness to pay.

1. Innovation In Mobile TV User Terminals

As a key driver for mobile TV, advances in user terminals enable new features and usage models that enhance the mobile TV experience. We believe this trend will result in a wide availability of handsets capable of receiving mobile TV over time.

In particular, increasing screen sizes, resolutions, and decreasing power consumption, support longer usage period and usage scenarios and enable a greater number of radio and network alternatives.

We note that mobile TV user terminals supporting mobile TV are predominantly targeting QVGA resolutions today. However, increasing mobile screen resolutions may drive a need for higher bandwidth in the future.

Table 1: User Terminal Resolutions [1]

	Example User Terminal	Width	Height	Total Pixels
VGA	Nokia N800	640	480	307,200
HVGA	Apple iPhone	480	320	153,600
QVGA	Samsung P910	320	240	76,800
QCIF	Motorola V8	176	144	25,344

How much bandwidth is required to support QVGA at 20 frames per second?

We can estimate this by considering QVGA resolution of 76,800 x 24 bit colour x 20 frames per second = 36,864,000 bits per second. Assuming a compression rate of 141[2] provides an approximate video bandwidth of 256 Kbps.

Can today's multi-media user terminals support full frame rate broadcast video?

Over time we believe all mobile TV user terminals will be able to support full frame rate video. Early mobile TV user terminals could not process QVGA resolution at 25 fps or higher[3], typical of most broadcast systems. For example, the Nokia N92 and N77 could not support this frame rate due to processing limitations. This is changing with the new Nokia N96 being capable of up to 30fps at QVGA resolution.

With mobile TV user terminal processing capability improving, it will become an operator decision regarding support for full frame rate video, as the bandwidth required is around 1.5-1.8x higher than today's 256Kbps bit rates, at around 400 Kbps.

Some common data rates for mobile TV are highlighted below. The analysis that follows in this paper will focus on the Class B/Medium data rate.

Table 2: Common Data Rates for Mobile TV [4]

	Data rate (Kbps)	Frames per second (fps)
Class A	128	10 – 12
Class B – Low	256	15 – 20
Class B – Medium	256	30
Class B – High	384	20 – 25
Class C	768	30

How do we know what users consider the minimum acceptable quality when viewing mobile TV user terminals?

Several studies have been conducted into the acceptability of mobile TV content at varying resolutions and varying bit rates.

Figure 1: Mobile TV User Terminal Acceptability of Video [5]

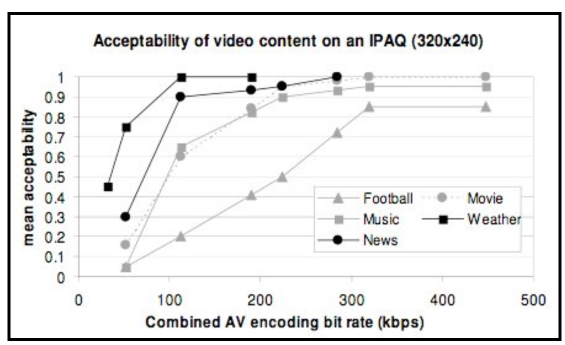


Figure 1, above, indicates that QVGA mobile video acceptability for football reached a plateau for bitrates of 332 Kbps and greater than 84%. In contrast news and weather delivered an acceptable service to 90% of people at bandwidth of just 112Kbps[6].

What compression improvements are possible with advances in mobile TV user terminals?

As full frame rate handsets become available, requiring higher bandwidth, operators will look to advances in compression technology in order to maximize use of finite mobile TV bandwidth.

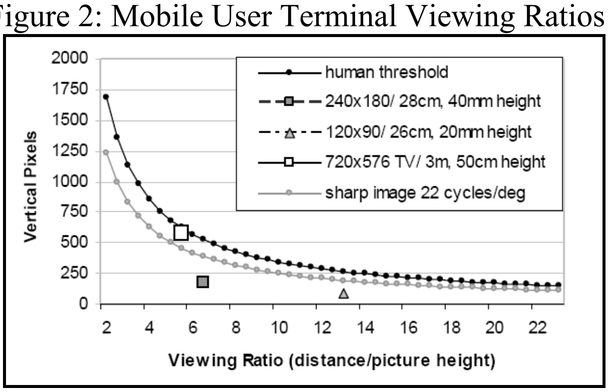
Table 3: Mobile TV Compression Improvements

	2008	2009	2010
Compression Profile	MPEG4 AVC / VC1	MPEG4 AVC / VC1 enhanced	MPEG4 AVC / VC1 improved
Percent Improvement Possible	Today	10 – 15%	10- 15%

Does a smaller screen size make mobile TV user terminals less attractive to the viewer than cable's typical fixed-line TV?

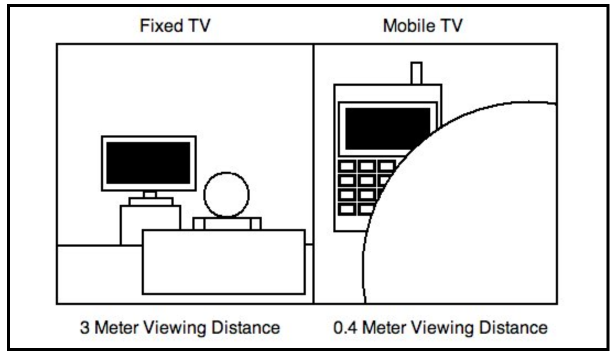
Perhaps counter-intuitively, studies indicate that standard television is much closer to the limits of human perception than mobile TV user terminals.[7]

Figure 2: Mobile User Terminal Viewing Ratios



Interestingly, if we represent this visually in a fixed and mobile scenario, we can see that a typical living-room fixed widescreen TV at 3 meters can be visually similar to a QVGA screen held 40 centimeters from the eyes, as seen in figure 3 below.

Figure 3: Visual Saturation for Fixed and Mobile TV



However, research indicates there are some key perceived issues with mobile TV user terminals for viewing TV, other than 'general detail' and 'image size'. These included 'fatigue' and 'effort', perhaps associated with correct positioning of the user terminal.

Table 4: Mobile TV User Terminal Problems across All Content [8]

Problem	% of General Comments
General Detail	20%
Insufficient Image Size	18%
Fatigue	10%
Effort	8%

What is the availability of mobile TV chipsets and user terminals ?

The availability of user terminals capable of delivering mobile TV is increasing over time. Variations in different regional approaches to standardization and service characteristics have resulted in broader user terminal availability in Asia.

For example, mobile TV user terminals in Japan have reached 20 million units shipped in just under two years since launch, noting that Japan's mobile digital TV service ISDB-T (OneSeg) offers a simulcast of Japanese terrestrial TV stations at no cost to the end user. The broadcasts are not secured, which facilitates the production of low-cost compatible devices and handset diversity[9].

Other markets appear to be challenged with respect to handset diversity due to the emergence of multiple differing distribution standards (i.e. DVB-H, MediaFLO), the need for diversity and potentially filters (i.e. TDtv), and the need for security support (i.e. OMA Bcast standard) capabilities to protect content.

We believe that as the number of mobile TV distribution standards proliferate, the emergence of handsets with the ability to support multiple technology options will emerge.

2. Availability of Spectrum

Another key driver for mobile TV includes the availability of spectrum, including the state of mobile broadcast standardization, licensing and spectral harmonization.

Considering the standards for mobile TV, we note that today there are five worldwide broadcast TV standards (DVB-H™[10], MediaFLO™[11], ISDB-T, T-DMB, S-DMB) and three more broadcast standards planned (MHP, DVB-SH and CMBB).

When the two most widely known multicast standards (TDtv & MBMS) and the entire category of unicast (in band cellular) are added to the mix it is apparent that the world of mobile TV technology is extremely fragmented[12].

Table 5: Current & Future Standards

	USA	W. Eu	Japan	Global
Current Most Popular Standard	MediaFLO	DVB-H & T-DMB	"one-seg" ISDB-T	T/S-DMB Korea
Options	MPH, DVB-H, MBMS	TDtv, MBMS, DVB-SH	MediaFLO, MBMS, DVB-H	MediaFLO, MBMS, MPH, DVB-H, CMMB (China)
Expected "Winning" Standard	MediaFLO dominates until unicast over 4G	DVB-H will dominate with TDtv, MBMS & DVB-SH emerging.	ISDB-T dominates until unicast over 4G	MediaFLO may emerge in Japan & Hong Kong with large CMBB volumes expected in China

With a view to assessing the availability of spectrum for mobile TV we survey the typical frequency bands available in the summary below and Table 6.

VHF Band: In some European and Asian countries (Korea) narrow slices of the 200 MHz VHF band has become available for terrestrial broadcasters to provide Mobile TV services. T-DMB technology was used in these allocations.

UHF (470 to 870 MHz): In relation to UHF spectrum, we believe that the long wait plus the uncertainty on how much spectrum will be made available for Mobile TV and who will get the spectrum complicates the technology selection for operators[13]. Unfortunately, in many countries this spectrum will not get released until the digital TV transition (Digital Dividend) in the 2012/2013 timeframe.

L-Band (1.452 – 1.492 GHz): Alternatively, the L Band is slated to be made available in some countries (U.K.) in the near future and could offer an alternative for broadcast mobile TV services[18].

UMTS-Bands (1.7 to 2.5 GHz): Because of the broadcast spectrum issue and lack of alternative frequency options it is highly likely that multicast options like TDtv and MBMS will get deployed in Europe in existing UMTS 3G spectrum bands to begin to relieve unicast capacity problems.

S-Band (2.17 – 2.20 GHz): One interesting alternative is the S-Band satellite spectrum planned for allocation across the entire European continent in 2008. This spectrum will be available earlier and offer a uniform frequency and technology across a large region. The DVB-SH standard is being positioned to serve this frequency range. In the USA, ICO Satellite is looking to promote a similar spectrum and technology allocation[17].

Table 6: Possible Spectrum for Mobile TV

Band	Name	Status
2500 – 2690 MHz	3G Extension Bands	Technology neutral, usable for 3G, DVB-SH, WiMAX, etc.
2170 – 2200MHz	S-band (usable with DVB-SH)	EC decision & Selection process,
1900 – 2170 MHz	UMTS TDD	Usable with MBMS. Possible interference with 3G FDD
1785 – 1805 MHz	UMTS FDD (3G streaming)	Used for mobile TV already today in unicast mode.
1452 – 1492 MHz	L-Band	Possible T-DMB, MediaLFO, DVB-SH.
470 – 860 MHz	UHF (usable DVB-H, others)	Subject to broadcast license laws, used by DTT, analog.

Considering the alternative spectrum options for mobile TV, it is clear that in-band unicast over cellular has a time-to-market advantage.

Other frequency bands are currently either subject to ongoing regulatory approval, competing with alternative technologies or services, or at risk of interference from neighboring services.

The spectrum availability issue may cause technology fragmentation in the near term. Some standards bodies are eager to prevent this outcome by promoting a single specification as the official approved standard for mobile TV. Other regulatory bodies seem to be taking a more technology neutral stance.

What other regulatory factors have an impact on the business case for mobile TV?

Power levels that are permitted in each market have a substantial impact on the number of sites required in a given frequency. For example, MediaFLO in the USA transmit at 50 kW[14], DVB-H in Europe transmit at 5 kW[15]. This can have an impact on the number of sites required and hence the economic viability of a mobile TV network.

For example, in the USA a typical cell radius of the MediaFLO network operating at 50kW transmit power from 150 to 300 meter towers is 19 Km to 27 Km while providing equivalent indoor coverage over similar terrain[16,17].

By comparison, DVB-H technology in Europe has 5 kW power limits imposed due to EMF and interference regulations severely restricts cell site radius. In a Belguim trial an average 3 Km cell radius was typical in suburban locations from 60 meter towers[18].

Additionally, the available heights of transmitter sites will increase or decrease the total broadcast mobile TV site counts and ultimately mobile TV economics[19].

3. Evolution of network technology

Another driver of mobile TV is the evolution of network technology.

Wireless network technologies continue to evolve, with increasing capacity of wireless bandwidth, support by new technologies such as OFDMA modulation and MIMO (Multiple Input Multiple Output) antenna technology, improved compression algorithms, and greater cell densities of mobile operators

Additionally, in-home devices such as femto-cells and Wi-Fi™[20] allow the wireless operator to off-load capacity from its wide area radio network, which will help reduce the need for an overlay network to support mobile TV.

4. Usage Context and Prospects

We consider the usage context for mobile TV; characterizing the demographics and viewership, willingness to subscribe to a pay mobile TV service, and elasticity to the prospects for mobile TV.

What mobile TV viewership and demographics can an operator expect?

A review of literature reveals that perceived mobile TV viewership differs significantly by region. For example, of the markets that have launched mobile TV, France is reported to have the lowest usage with 70 minutes per week, whereas Korea is reported to have the highest consumption with 160 minutes per week, or about 20 minutes per day[21].

Research is showing that consumers tend to watch mobile video in the home more than previously thought … despite the presence of big screen TV's [22]. In addition, content executives have been surprised in the performance of long-form content on mobile devices [23].

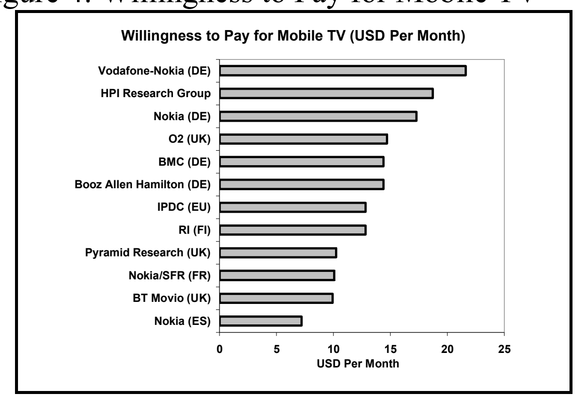
It is a common hypothesis that consumers will use mobile TV to "kill time" leading to the consumption model that mobile TV viewership is a "snacking" phenomena. Data from early research studies[24] indicate otherwise. Namely, that a high proportion of mobile TV viewing (30% to 50% in 3 out of the 4 surveys) is in the home.

Additional research and improved viewership statistics and a better understanding of mobile demographics would assist in refining the technology choices and business model for mobile TV.

What will the mobile TV subscriber be willing to pay for a subscription service?

Recent studies [25] indicate that while a majority of the people were interested in viewing mobile TV 80% of the respondents said they would not pay $15/month for it. The study also concluded that subscribers are more willing to watch mobile TV that is essentially the kind of programming they get on their TV now. Certainly this second conclusion is a positive indication for cable companies regarding the importance of mobile TV to their future business.

Figure 4: Willingness to Pay for Mobile TV [26]



Other studies in European countries assessing the propensity for consumers to pay for mobile TV content indicate a range of US$10 to US$20.

For example, in Italy 3 Italia has 800,000 DVB-H mobile TV subscribers (out of 8 million mobile subs). 3 claims, their mobile TV offering has been instrumental in raising their ARPU 60% over the last year where one-third of the increase has been driven by mobile TV and the remaining two-thirds by voice & data services. 3 Italia may have discovered one willingness to pay pricing model as they offer a popular all inclusive package (voice, data & mobile TV) for US$42 per month [27].

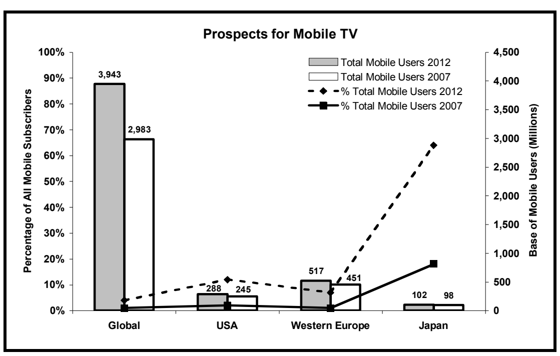
Japan and Korea also offer an interesting benchmark for a mobile TV subscriber's willingness to pay. The ISDB-T (One-Seg) amd T-DMB services, make up a majority of the current mobile TV subscribers worldwide yet are free service offerings, delivering free-to-air content.

We have provided early evidence of operator-based research into end user willingness to pay for premium mobile TV. However, it is not clear at this stage whether a free simulcast model, a pay TV model, or ad supported model will dominate Europe, the United States and Asia. The type of model that emerges could be expected to have a significant impact on mobile TV's prospects.

What does this mean in terms of the prospects for mobile TV?

Based on industry information, the projected take up of mobile TV is estimated at 150 million users or 4% of all mobile users globally by 2012 from a base of almost 4 billion mobile users, with developed economies expected to experience higher penetration rates. For example, by 2012, mobile TV is expected to have 35 million users or 7% mobile user penetration in Western Europe, 35 million users or 12% penetration in the United States and 65 million users or 64% mobile user penetration in Japan by 2012.

Figure 5: Prospects for Mobile TV [28]



We chose a conservative study summarized in Figure 5 to highlight mobile TV's prospects, focused on linear TV programming, rather than all types of video content[29].

Observing the range of industry forecasts, i.e. up to 465 million by 2010 [30] we note that (a) cable operators need to be aware of differing research definitions as to what constitutes mobile TV, (b) methodology of today's forecasts and, (c) as mobile TV is at an early stage of development, variation in forecasts can be expected.

Overall, we note that where a pay TV subscription model is the focus (i.e. USA, Europe), the penetration of mobile TV services is lower than in markets where the service is bundled as a free offering (i.e. Japan). We believe that mobile TV is therefore very price elastic, and significant penetration will most likely come from bundling and cross subsidization with other core mobile or entertainment services.

COMPARING THE MOBILE TV ALTERNATIVES

Which mobile TV technology should a cable MSO consider and what platforms pose the largest threat or present the greatest opportunity?

For the purposes of this paper we are focusing on facilities-based mobile TV technologies and setting to one side alternative non-facilities based alternatives (i.e. in-home radio technologies such as Wi-Fi or storage-based PC to user terminal file transfers).

There are several competing facilities-based platforms for mobile TV. We consider an overall taxonomy based on classifying the technical alternatives into (1) Broadcast, (2) Multicast and (3) Unicast;

Table 7: Mobile TV Delivery Alternatives [31]

	Broadcast	Multicast	Unicast
Network	Broadcast	Cellular	Cellular
Topology	One-many	Mixed	One-one
Return path	No	Yes	Yes
Bandwidth	Dedicated	Mixed	Shared
Throughput	Fixed	Mixed	Variable
Zap speed	1-3 secs	2-5 secs	5 – 8 secs [32]
Technology Example	DVB-H DVB-SH MediaFLO	TDtv MBMS	WiMAX LTE HSPA, HSPA+ 3G (UMTS/ WCDMA)
Advantages	Cost structure, performance	Re-use of existing spectrum	Variety, on-demand
Disadvantages	Variety, additional network	Price, performance	Price, performance

We take a closer look at the technology alternatives to determine what the advantages and disadvantages are, and what this means for the cable MSO.

1. Broadcast

Looking at a typical broadcast architecture for facilities-based mobile TV we note that there are quite a number of similarities to the traditional cable MSO broadcast architecture; including the need for encoders, and electronic program guide, and conditional access systems.

Exploring the broadcast alternatives in more detail we consider MediaFLO, DVB-H, DVB-SH and T/S-DMB.

(a) MediaFLO

The MediaFLO specification was developed by Qualcomm specifically for broadcast mobile TV applications. Consequently, it was optimized for high bandwidth (many simultaneous video channels), high speed mobility, single frequency networks, low power drain CPE devices, large cell radius and fast channel changing capability.[33]

OFDM (Orthogonal Frequency Division Modulation) was chosen as the most effective way to meet these design goals. Fortunately, it was able to leverage other standards such as Wi-Fi™[34], ADSL, DTV, UWB, WiMAX™ [35], LTE and DVB-H that all employ OFDM technology.

Just as TDMA separates communication channels and end user conversations with time division and CDMA segments channels with codes (orthogonal spreading codes), OFDM utilizes frequency. It differs from 1st generation analog cellular frequency division techniques by using very tightly spaced frequencies without overlapping and interfering. It does this by forcing the narrowband FDM carriers (called subchannels or tones) to appear unique or independent from each other. The mathematic concept of orthogonality is the key to maintaining separate communication channels even though the subchannels are very narrow and spaced close to each other.

Qualcomm effectively incorporated time slicing into their specification so that mobile devices used as little power as possible. This technique transmits chunks of data in bursts so that the receiver could be turned on and off during inactive time periods. The result is substantial power savings (90%) over traditional broadcast technologies using fixed high power receivers. Because MediaFLO was designed without the need for compatibility with legacy standards by a company with relevant experience in mobile devices it utilized some very effective techniques. MediaFLO uses a more frequent transmit time interval than DVB-H, which helps in having quicker channel change speeds and improved power saving[36].

The most unique design aspect of the MediaFLO implementation is the ability to have layered modulation. Basically, the data stream bursts are divided into base and enhanced layers. The base layer supports the widest coverage area using lower quality (15 fps) video that subscribers and receivers in poor signal areas (such as in-building) can decode. The enhancement layer supports high quality 30 fps video and is decoded by the receiver in high SNR (signal to noise) areas. The MediaFLO handset dynamically adapts the video quality based on the signal strength. Consequently, there is a smoother degradation of service as the signal strength varies[37].

An important design tradeoff for a broadcast mobile TV architecture is determining the optimum number of OFDM subcarriers or tones. On the one hand, a large number of subcarriers (8000 in a 5 MHz channel bandwidth) will provide for higher capacity and a larger single frequency network (avoids handover to different frequencies) but will negatively impact high speed mobile performance. Qualcomm and the DVB-H specification both settled on 4,096 subcarriers as the optimum compromise for mobility, capacity and large single frequency networks.

A final unique aspect of the MediaFLO specification is the use of a variable bit rate and statistical multiplexing allocation for the video services. This feature provides a bandwidth efficiency gain of about 30% translating into a higher number of video channels at comparable quality in a channel.

(b) DVB-H

The Digital Video Broadcast standard for handheld devices is based on the existing DVB-T standard for fixed digital TV reception.

Most changes were made to the layer 2 portion of the specification and focused on making improvements so that video transmission would be robust enough for a severe multipath mobile environment and low power mobile devices. Consequently, time slicing and forward error correction elements were added to the specification. Physical layer changes included the use of 4,096 OFDM subcarriers (DVB-T allowed for just 2K or 8K options), better flexibility in using all modulation formats (QPSK, 16 QAM, 64QAM), creating a 5 MHz channel bandwidth and expanded bit interleaving options[38].

For the most part these layer 1 and 2 specification changes put MediaFLO and DVB-H at a similar capability. Overall, MediaFLO has more beneficial performance, coverage and capacity technical characteristics. Conversely, the DVB-H standard is much better positioned as a uniform worldwide standard because of its strong backing in Europe.

(c) DVB-SH

A European wide allocation of satellite spectrum and the vision of a uniform continent wide roaming capability has prompted the creation of the DVB-SH standard. This architecture will provide direct outdoor coverage to handhelds and vehicles (with outdoor antennas) from a satellite. Indoor coverage will require a large number of repeater sites located at existing cellular sites. Utilizing an existing wireless carrier's dense cell site network will be critical for this service to be effective.

DVB-SH provides two key improvements to DVB-H: (1) 3GPP2 Turbo Codes, that improves the quality of reception in tough conditions and (2) Physical layer time interleaving that improves the quality of reception while in motion.

The net result is that, under the same conditions (frequency, channel size, data-rate) signal reception requirements (carrier to noise) are a minimum of 5 to 6 dB lower[39] and up to 6 to 8 dB lower[40] for DVB-SH relative to DVB-H.

Additionally DVB-SH is able to leverage cellular sites to down-convert S-Band Satellite mobile TV content transmissions to maximize coverage and minimize distribution/backhaul costs. All other terrestrial based broadcast technologies require backhaul transport of the mobile TV content to every site. DVB-SH requires a more economical satellite dish and regenerator equipment. On the down side, DVB-SH requires a very small cell radius to get sufficient transmit power at 2.2 GHz to penetrate buildings.

An overall comparison of the three standalone broadcast alternatives indicates performance advantages for DVB-SH.

(d) T/S-DMB

DMB technology was first developed in South Korea and was designed to operate as either a satellite (S-DMB) or terrestrial (T-DMB) mobile TV transmission system.

In some countries, DTT and DAB broadcasters were allowed to utilize narrow bandwidths (1.5 MHz) of their spectrum for mobile TV. To accommodate these opportunities in the VHF spectrum (200 MHz), the T-DMB broadcast mobile TV standard was created by making modifications to the terrestrial broadcasters DAB specification.

Besides the much smaller channel bandwidth T-DMB does not allow for higher modulation formats (16-QAM or 64 QAM) and has less robust coding schemes (lacks either MPE-FEC or turbo coding). Additionally, T-DMB lacks the device power saving advantage of a full time slicing architecture of other broadcast technologies (DVB-H & MediaFLO)[41].

The S-DMB system concept is based on a combination of satellite and terrestrial architecture for the delivery of broadcasting digital multimedia services to mobile end users. Because the satellite coverage provides outdoor only mobile TV service S-DMB is extended indoors with terrestrial repeaters.

Essentially, T-DMB and S-DMB are very similar specifications. The biggest difference is the RF planning and implementation of the network associated with S-DMB as the interference between satellite and terrestrial transmission makes it complicated to design the broadcasting network.

Overall, the success of both T and S DMB technology has been very limited because of capacity constraints (associated with narrow bandwidth allocations), limited CPE and performance/quality issues. The major take-up has occurred where the service offers free to air content to mobile devices (T-DMB).

2. Multicast

Multicast distribution of mobile TV services provides point to multipoint transmission of video and TV media from a single source to a group of users in a specific area. The key distinction between broadcast and multicast is that the end users must have joined the particular multicast group while in broadcast technology all users obtain the content. A classic illustration of multicast is the delivery of radio station content over the internet.

Figure 6: Multicast Network Architecture[42]

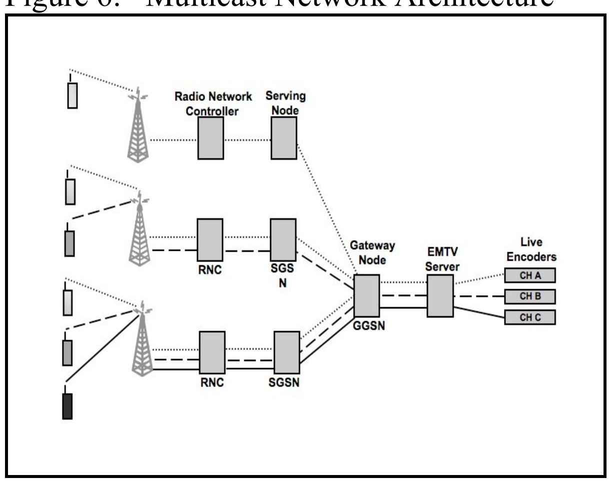


Figure 6 is a visual representation of a typical cellular multicast architecture such as TDtv or MBMS. Only mobiles in a cell site interested in viewing a particular channel (dotted line) join the multicast group in that cell. Other cells obtain additional channels (dashed & solid lines) because of the desire by the mobiles in that cell to view different content at the same time.

A multicast enabled network ensures that content is solely distributed over those links that are serving receivers which belong to the corresponding multicast group. This is a very resource efficient way of delivering services to larger user groups[21].

(a) TDtv

Many mobile operators in Europe were awarded 5 or 10 MHz of TDD unidirectional spectrum (1.9 to 2.0 GHz) as part of the 3G licenses won through auctions and "beauty contests". To date, very few operators have used this spectrum because it is unidirectional and little equipment is available.

TDtv is a multicast technology that uses the existing TDD spectrum in a 3G license. Since there are no TDD capable transmitters on base stations, these have to be added, but they can go on the same towers and use the same power supplies and antenna of the existing base station. Using two antenna in the handset means that only 30% to 50% [43] of base stations require transmitters. Two signals from any base stations in reach can combine through the antenna to give in-building penetration. At present operators have proven 15 channels in 5 MHz of TDD, but claim they can stretch to 28.

Potential interference issues exist as the spectrum sits next to existing 3G spectrum, meaning that not all of the 10 MHz may be available for use and expensive filters may be required in related handsets.

Dynamic channel broadcasting is not envisaged yet but could increase the effectively available number of channels to 90 in the future with the limitation then based on contribution capacity (i.e. E3 at 34,368 Kbps at 75% utilization or 25,776Kbps divided into 256 Kbps of video and 32Kbps of Audio or 286 Kbps).

(b) MBMS

The 3GPP Release 6 specification created the Multimedia Broadcast Multicast Service (MBMS) standard. Only minor changes were made to the existing radio and core network protocols. A new physical bearer channel that carries the media content was created along with logical scheduling and control channels.

The key for MBMS is that it can use all or a portion of an existing 5 MHz HSPA radio channel. TDtv is a multicast configuration that requires dedicated TDD spectrum, cell site equipment and chipset enhancements to the mobiles. MBMS requires none of that additional equipment. But portions of the existing HSPA network must be dedicated to MBMS services. For instance, if 256 Kbps mobile TV channels are planned for then 32 TV channels can be created in a single 5 MHz radio channel. If desired, only a portion of the 5 MHz is allocated to MBMS while the remaining amount is used for voice and data services. Additionally, 128 Kbps or 64 Kbps mobile TV channels can be set.

Overall, MBMS has a capacity advantage over unicast when several subscribers reside in the same sector of a cell and are watching the same mobile TV channel. When there are very few users in a sector then a unicast architecture may make more sense[21].

<u>3. Unicast</u>

Unicast mobile TV technologies stream video to mobile devices over various 3G wireless technologies. Streaming video to handsets in unicast has some inherent limitations that present challenges relating to performance. `

The most limiting problem for unicast mobile TV has been the overall capacity constraints and end user speeds possible over existing cellular network technologies. Many network upgrades and advancements have been made in recent years that begin to break the capacity limits of unicast mobile TV over 3G cellular technology.

Additionally, channel zap performance can be challenging in relation to unicast mobile TV. In particular, an inherent 15 to 20 seconds delay to move from one specific channel to another because the current session must be closed and a new one must be opened.

Advances have been made in this area, that enable the player to remain "alive" when switching from one channel to another; and keeping the video displayed when switching; and finally, optimization for network conditions, that allows for zap speeds between 3 to 8 seconds[44].

(a) 3G (UMTS/WCDMA, HSPA and HSPA+)

For the purposes of this paper we will focus on the use of mobile TV over the group of mobile standards to come out of the 3GPP (3rd Generation Partnership Project) standards body.

Table 8: 3GPP Specification Releases[45]

Version	Released	Description
Release 99	2000	Original UMTS/WCDMA 3G air interface
Release 4	2001	Added new features including all IP core
Release 5	2002	Added HSDPA (improved Downlink) and IMS
Release 6	2004	Added HSUPA, (improved Uplink) and MBMS … release is called HSPA
Release 7	2007	Added downlink MIMO, improved QOS and VoIP … Release is called HSPA Evolved or HSPA+

The ongoing evolution of the 3G UMTS family of technologies, which builds on the foundations of GSM, are listed in Table 8.

The original promise of UMTS/WCDMA, to provide high speed broadband connectivity, never occurred. Although speeds of 2 Mbps were hoped for, in reality 256 to 384 Kbps were more typical[9]. Recently downlink and uplink software enhancements (HSDPA and HSUPA) have been adopted by operators worldwide that provides much improved performance.

A number of technologies have been deployed to make these improvements including adaptive modulation and coding, fast packet scheduling and Hybrid Automatic Request (HARQ). Adaptive modulation software analyze each end user for signal strength and determines which modulation format (16QAM, QPSK…) and coding scheme will work the best. Fast packet scheduling allows communication between the mobile device and cell site to make the most efficient use of the bandwidth available. In CDMA systems the use of orthogonal CDMA spreading codes and time slots is critical in allowing a device to attain its maximum data rate. In the case of HSPA, devices using 5 codes allows for a maximum theoretical peak speeds of 3.6 Mbps, 10 codes correlates to 7.2 Mbps and 15 codes can theoretically attain 14.1 Mbps.

The combination of HSDPA and HSUPA (called HSPA) is reflected in the 3GPP Release 6 specification. Only 7.2 Mbps capabilities are currently available and most operators claim from 5.0 to 6.0 Mbps speeds are attainable in "real world" operation. More appropriately, the average cell throughput capacity of a sector is the critical design metric as this is the capacity to be shared among all users simultaneously accessing the network. For HSPA the average sector throughput will range from 4 to 6 Mbps.

As is expected, much depends on the cell radius design, indoor or cell edge coverage and signal strength assumptions. If it is assumed that a large % of users will get great signal strength (for example; 200 meters from site with line of site, outdoor coverage, 16QAM modulation) then the sector capacities will be higher[46].

As an illustration of the variability, a single end user in the sector (no contention with other subscribers) with outdoor coverage could get between 2 and 4 Mbps service depending how far away and if there is line of site to the cell location. A single user indoors will typically get between 800 Kbps and 2 Mbps, again depending on distance from the site, type of building material and how far inside the building the user is located. For this reason most HSPA networks (7.2 Mbps & 10 codes type devices) are designed and offer an average 1 to 3 Mbps product to subscribers. The peak rates advertised are typically marketing buzz as the peak speed is only obtainable if there is a single end user in service on the sector and is operating at the strongest possible signal strength.

Mobile broadband networks with sufficient capacity to provide for some unicast mobile TV applications are becoming more prevalent throughout the world.

For instance, there are 165 HSPA networks in place and a device ecosystem of 465 different devices from 102 suppliers currently available around the world[10]. According to industry research, UMTS/WCDMA/HPSA is the world's most popular 3G cellular technology as it represents more than 200 million customers worldwide. Almost 20 million are already subscribers to high-speed HSPA mobile broadband networks and this number is expected to double by the end of 2008[11]. Nevertheless, penetration of high bandwidth cellular connectivity is still emerging and needs to develop further. For example, only 13% of homes in the U.S. are 3G capable today. [47]

With GSM exceeding 2.6 billion mobile connections worldwide and global subscriptions to all mobile network technologies exceeding 3.3 billion, the 3GPP family of standards (GSM/UMTS/WCDMA/HSPA) represents over 80% of all cellular connections worldwide.

HSPA Evolved or HSPA+ will enhance the downlink and claims to provide a theoretical peak of 42 Mbps by utilizing 64QAM modulation and the uplink to 11.5 Mbps through 16QAM. A further enhancement to help in achieving the increase data rates is the addition of MIMO antennas, usually deployed to enhance the system performance. MIMO increases downlink sector capacity by implementing a technique that transmits multiple desired signals via separate antennas. This has the effect of multiplying the amount of data that is able to be transmitted over a single radio channel.

Other features include reducing latency by keeping the devices in a different state when inactive. Although the lab simulations of MIMO technology are positive, this advancement still needs to be proven out in the challenging RF environment of mobile devices in a live network.

While HSPA+, with its MIMO capability, can provide a capacity improvement over 3G and HSDPA, the upgrade is not cost free to the mobile operator. In order to support MIMO additional capital costs associated with antenna and installation, radio planning; in addition to additional operational expenditure for the site rental associated with the additional antenna. Additionally the upgrade from 3G to higher network bandwidths requires the buildout of larger capacity backhaul.

(b) 4G (LTE and WiMAX)

Long Term Evolution or LTE (3GPP Release 8) and Mobile WiMAX (802.16e) are emerging as 4th generation standards being specified to offer very large average sector throughputs (20 to 40 Mbps) and as such could be impactful to the application of Unicast Mobile TV applications over broadband cellular technologies. Both technologies utilize OFDMA technology, incorporate MIMO antenna and transmission gains and wide channel bandwidths (10 and 20 MHz) that contribute to large capacity improvements.

Some research forecasts that LTE should be going commercial by 2010 and represent around 24 million subscribers globally by 2012[15].

The research also predicts that HSPA will dominate mobile broadband network deployments by 2012, consistently accounting for about 70% of the total mobile broadband subscriber base. LTE and Mobile WiMAX are expected to achieve only a small proportion of the 1.2 billion total mobile broadband subscriber base[48].

4. Technology comparison across coverage, capacity, and mobility variables

As is typical with wireless technologies, understanding the tradeoffs among coverage, capacity and mobility characteristics is critical when assessing mobile TV technologies. The key to comparing these characteristics is having knowledge of the key assumptions that drive coverage, capacity and mobility performance results.

For instance, the coverage claims of broadcast technologies such as MediaFLO and DVB-H vary widely as a number of assumptions are changed. In our Flanders DVB-H field trial many scenarios were tested. The results of one scenario are illustrated in Table 9 below.

Table 9:DVBH Coverage in Flanders Trial[54]

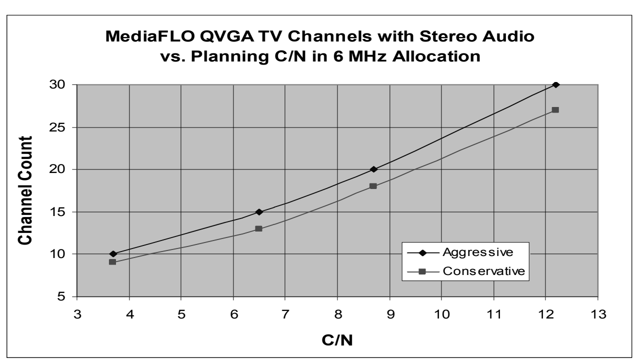
Suburban terrain, 5kW transmit power & 60m antenna heights	Location, CPE Type & Mobility/Portability		
	Outdoor, Handheld, 3Km/hr	Indoor, Handheld, 3 Km/hr	In-car, Handheld, 70 Km/hr
Cell Radius (Km)	9.25	3.35	1.45

The measurement of the cell radius calculations assumed a common modulation scheme being received (16QAM ½) by the device, a fixed maximum quantity of mobile TV channels and an overall probability (90%) of obtaining a minimum signal level. The conclusion from the trial is that coverage can vary widely (from 1.45 Km to 9.25 Km) as different types of mobile devices, their location and speeds are changed. To illustrate further the complexity of the wireless tradeoff's typically encountered we changed the transmit power and antenna height for the Flanders test. Reducing the transmit power to 2 kW and the antenna height to 30 meters for an indoor handheld moving at 3 Km/hr caused a severe reduction in cell radius from 3.35 Km to 1.65 Km[54].

How is the capacity of a mobile TV technology determined?

The ability of the mobile TV device to receive a strong enough signal in the presence of interference is a critical determinant of capacity. Qualcomm has conducted numerous tests illustrating the relationship of sufficient signal strength received by the mobile TV device and overall system capacities for their MediaFLO technology. Figure 7 below shows the relationship between the maximum numbers of 256 Kb/s H.264 mobile TV channels possible for a given received signal at the mobile handheld. The signal strength is represented as a Carrier to Noise ratio (C/N) in decibels.

Figure 7: Capacity vs. Signal Strength[49]



Extensive testing has revealed that a 10 dB C/N ratio is an attainable signal strength under a number of typical mobile TV conditions. As can be seen from the graph a 10 dB C/N results in a capacity of 22 Mobile TV channels. Consequently, the MediaFLO network is designed for a capacity of 22 mobile channels operating at 256 Kb/s per channel. To meet this capacity figure the key design criteria used to determine transmitter locations for the mobile broadcast network will be to meet the 10 dB signal strength level in a majority (90%) of the locations the network serves.

A common question asked of mobile TV services and technologies is what do we really mean by mobility?

Mobile TV terminals are expected to be usable in stationary, pedestrian walking speeds, and high speed in-vehicle applications that encompass both outdoor and indoor environments. Delivering a consistent high speed video signal to a low power, low gain handheld device in motion is a difficult technical challenge[58].

One of the key issues with fast moving mobile devices is the concept of multipath propagation. In effect, the radio signal from the cell site transmitter takes multiple paths to reach the mobile device which results in “echoes” that make it difficult for the mobile to recover the video transmission. These echoes cause the digital video information (or symbols) to “blur” across each other creating severe problems called inter-symbol interference.

Unfortunately, handheld devices in high speed motion amplify the inter-symbol interference reception issue. This effect is called the Doppler shift. Simply put, the faster a mobile is moving the more of a Doppler shift occurs which translates into a greater interference effect on the mobile device receiver. The Doppler shift interference effect is more noticeable at mobile systems operating at higher frequencies (e.g.- > 400 MHz). Mobile TV standards such as MediaFLO and DVB-H attempt to minimize this problem by using various advanced error correction coding, modulation formats and OFDM sub carrier schemes.

A considerable amount of high speed mobility testing has been conducted at 850 MHz for DVB-H mobile TV networks and is illustrated in one design scenario in Figure 8. Figure 8 illustrates the relationship of mobile speeds along the x-axis (represented as Doppler shift frequencies in Hz) and mobile receive signal strength (C/N ratios) along the y-axis for the DVB-H mobile TV specification.

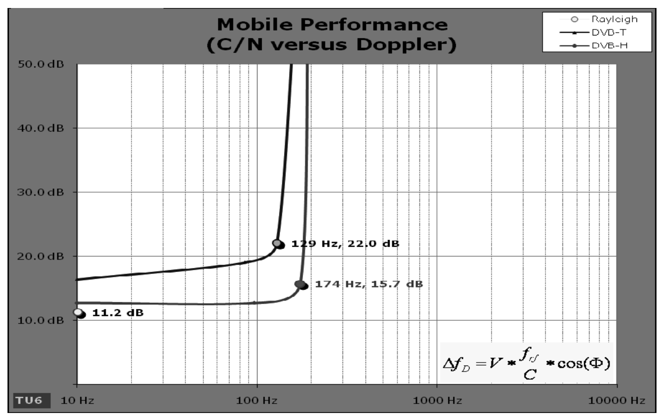


Figure 8: Mobile speeds vs. signal strength[57]

The graph shows that as long as a minimum signal strength can be maintained (11.2 dB) then mobile devices speeds from 3 Km/hr (at 10 Hz on the y-axis) to 126 Km/hr (corresponds to the 100 Hz point on the y-axis) will support mobile TV services. It is interesting to note that at the Doppler frequency of 174 Hz (equivalent to ~200 Km/hr) a sharp increase in C/N signal strength is required. This means that at speeds greater than 200 Km/hr a nearly impossible signal strength would be required to be received by the fast moving mobile.

The major mobile broadcast technologies (DVB-H, MediaFLO and DVB-SH) are designed to operate in a high speed mobile environments (< 200 Km/hr). Likewise, multicast and unicast technologies, being required to serve traditional mobile voice and data applications, are capable of operating at high speed vehicle and train speeds as well.

THE MOBILE TV BUSINESS MODEL: A COMPLIMENT TO FIXED LINE BROADCAST

What is the cost of extending fixed-line broadcast to mobile broadcast? Are the costs different for a mobile operator? We explore the economics across multiple mobile TV platforms.

Developing the network "Pain Threshold"

Using revenue and operating assumptions from earlier sections of this paper and reference literature we can determine the network "pain threshold" for Mobile TV network economics.

We assume that the average revenue from mobile TV is $20 per month per subscriber[50]. Of this $20 per month we assume that 45%[51], or $9 per month, goes to mobile TV content costs and $8 is required for sales and marketing, billing and G&A per subscriber per month, about half of the amount for mobile data [52]. This leaves $3 per month per subscriber to cover all network related costs.

1. Unicast economics

Initially considering the economics of unicast mobile TV we find that the economics quickly pass the pain threshold of $3! Unicast economics appear suited to low quality, short-clip, long tail content that have low bit-rates and short view times rather than high quality premium content with longer average view times.

Table 10:Unicast Mobile TV Cost/Sub/Month [53]

	HSPA+	HSPA	UMTS/ WCDMA
256 Kbps @ 20m	$7.66	$24.42	$30.21
128 Kbps @ 6m	$1.28	$4.07	$5.04
128 Kbps @ 2m	$0.38	$1.22	$1.55

We assumed quality and viewership parity when comparing unicast mobile TV to multicast or broadcast mobile TV, with all platforms delivering 256Kbps encoded video and 32Kbps encoded audio with average viewing times of 20 minutes to match the viewership studies referenced earlier.

Under differing quality and viewership conditions unicast mobile TV results in varying degrees of network congestion depending on the network evolution technology deployed. We assumed an average sector throughput of 2.5 Mbps for UMTS/WDMA, 6.0 Mbps for HSPA (7.2) and 9.5 Mbps for HSPA+ technologies. Additionally, an urban market density of 1,500 Pop's per Km^2, 0.57 Km cell radius and 3 sector cell sites assumptions were used.

Clearly an early 3G network using UMTS/WCDMA would be unable to support mobile TV services at 256Kbps and 20 minute average view times! Although the evolution of 3G to HSPA, HSPA+ and ultimately LTE reduce the probability of congestion, we need to take into consideration that other services are also operating on the same network. Consumption of 3G and HSPA networks for high speed data is increasing. In the United Kingdom, Vodafone is reporting 50% to 60% of its available 3G capacity is being used for data in dense urban areas[54]. Therefore in this analysis we assume 50% of the sector capacity is allocated to data services.

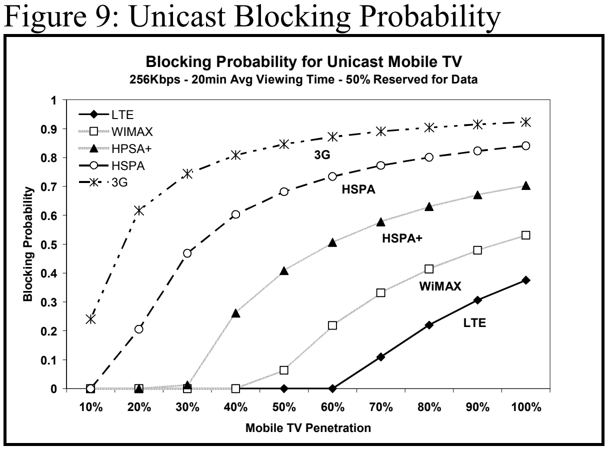
Table 11: Unicast Mobile TV Blocking Probability @ 15% Penetration

	HSPA +	HSPA	UMTS/ WCDMA
384 Kbps @ 20m	0.00	0.26	0.65
256 Kbps @ 20m	0.00	0.00	0.49
128 Kbps @ 6m	0.00	0.00	0.00
128 Kbps @ 2m	0.00	0.00	0.00

We can see from this analysis that low bit-rate, short clips have less impact on unicast mobile network congestion that high bit –rate, long form content, indicating that the mobile network can support short clips such as you-tube like rich-data content.

Because the traffic is unicast as the penetration increases to 30% the blocking probability increases to the point where our 256k, 20 minute scenario has blocking probability of 0.47 for HSPA and 0.74 for 3G … put another way 74% of 3G mobile TV subs could not get the service, in addition to there being no room for growth in data services!

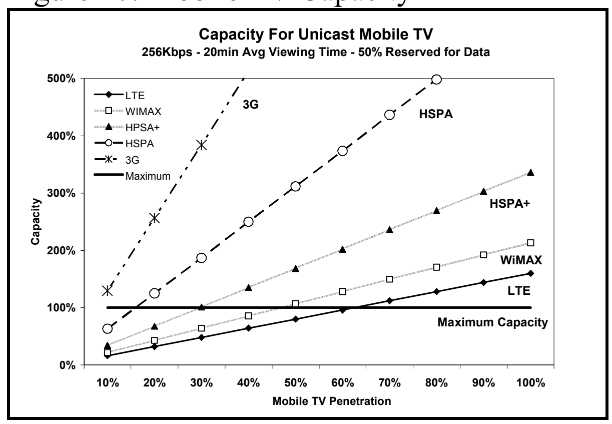
Figure 9: Unicast Blocking Probability



As seen in figure 9, as wireless technologies evolve, reasonable penetration levels of mobile TV could be expected if 15 Mb/s (WiMAX) and 20 Mb/s (LTE) sector capacities are obtainable. Our analysis indicates future WiMAX and LTE technology could provide non-blocking mobile TV service at 40-60% penetration.

Our analysis of blocking probabilities also provide insights in relation to capacity advances for mobile TV. We can see in Figure 10 below that new wireless technologies can enable Telcos and independent wireless providers to deliver mobile TV at greater penetration rates.

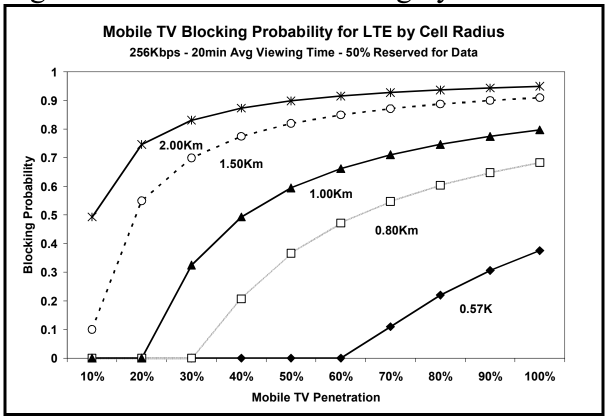
Figure 10: Mobile TV Capacity



It is also important to point out that if a mobile operator has sufficient spectrum to add another 10 MHz channel to their network and reasons that there is sufficient return to allocate it to video services then these capacities can be increased further and therefore provide for improved mobile TV capacities.

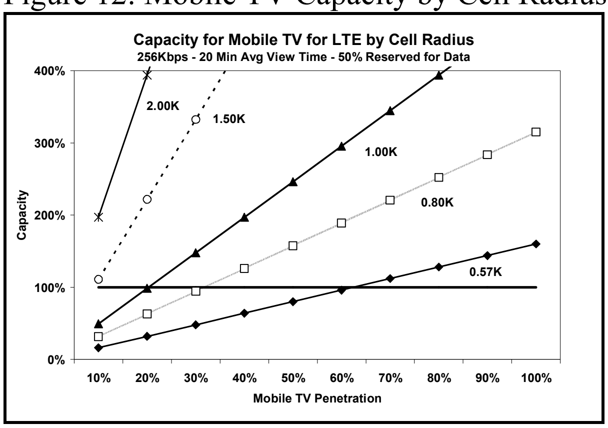
The importance of a dense cellular network for delivering unicast mobile TV is illustrated in figure 11 below. Using LTE as a base we illustrated the impact of larger cell sizes, noting that an increase in cell radius from 0.57 to 0.80 kilometers results in a halving of non-blocking mobile TV penetration potential!

Figure 11: Mobile TV Blocking by Cell Radius



We can also show this in capacity potential, where a cell size of 0.57Km exhausts capacity for mobile TV at 60%, a cell size of 0.80Km exhausts capacity for mobile TV at just 30% penetration (assuming a constant market density).

Figure 12: Mobile TV Capacity by Cell Radius



2. In-band multicast economics

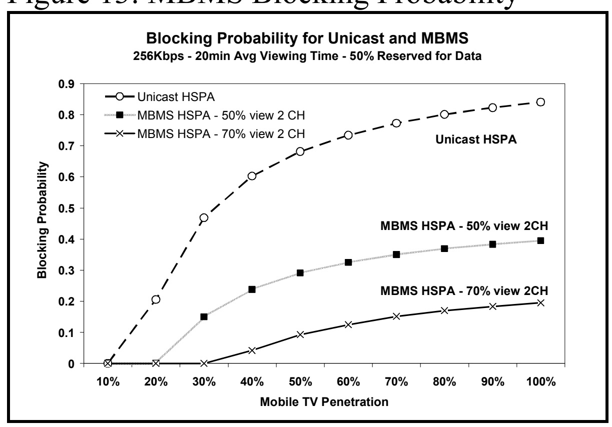
Considering In-band MBMS, or Multicast assumptions to the cellular models without extending available spectrum, we assumed that 50% of the users viewing time was for 2 channels, and accounted for up to 80% of the viewing time for those channels.

We also assume that for in-band multicast over 3G/HSPA/LTE networks that a mobile broadcast bearer requires more radio capacity. We assume that about 13% of the Node-B (Base Station) power is required for Multicast, assuming that soft combining is not enabled (possible reduction to 6%)[55].

Table 12: Multicast Mobile TV Blocking Probability (256Kbps, 20 minutes view time, 30% penetration)

	HSPA+	HSPA	UMTS/ WCDMA
Unicast	0.01	0.47	0.74
50% view 2 Channels	0.0	0.0	0.31
60% view 2 Channels	0.0	0.0	0.21
70% view 2 Channels	0.0	0.0	0.11

Figure 13: MBMS Blocking Probability



As seen in Figure 13 above, unicast HSPA mobile TV begins to suffer from blocking when penetration exceeds 15%, where as adding MBMS can enable support higher penetration rates.

However, because enabling MBMS increases power usage, and the reduction in blocking probability is mitigated by the existence of other services (i.e. mobile data, with its speed and subscriber growth) it appears to be inefficient to deploy in-band with other IP services until LTE becomes available.

Based on our analysis of network congestion, we assume that mobile operators would not consider enabling MBMS as an in-band capability for some time, but would rather focus on deploying MBMS capabilities in separate dedicated unicast spectrum (i.e. TDtv).

3: Broadcast overlay network economics

We used a specific propagation model based on a trial in Gent, Belgium [56] [57] to determine the site radius for typical European DVB-H deployments, and validated this information with other reference deployments in Europe.

Our MediaFLO analysis was based on a reference architecture for Chile. Results were reduced to a cost per kilometer square basis to determine the comparable cost of coverage to Europe.

4. Hybrid network economics

With emerging hybrid mobile TV architectures we used information based on a reference UK model for DVB-SH and assumed a 6dB to 8dB gain over DVB-H providing approximately a factor x2 improvement in coverage area.

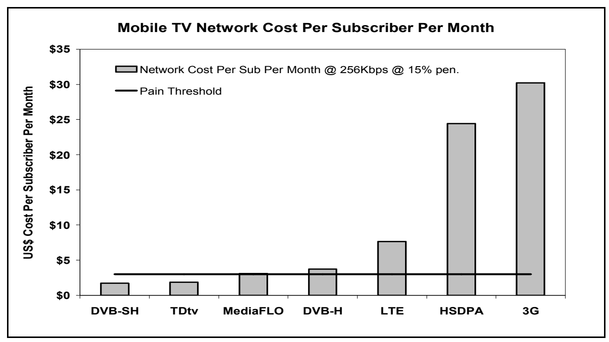
Out TDtv analysis was based on industry information including the assumption that 40% of cell sites require the TDtv transmitter, and used industry literature to determine the capital cost of the network extension.

Comparing the alternatives, what technologies are below out pain threshold of $3 per subscriber per month?

Table 13: Network Cost of Mobile TV

	Network Cost Per Sub Per Month @ 256Kbps @ 15% pen.	Channels Supported @ 256Kbps
MediaFLO	$3.10	22
DVB-H	$3.72	18 [58]
DVB-SH	$1.70	18t & 9ts[59]
TDtv	$1.87	15 – 28, Uni.
HSPA+	$7.66	Unlimited
HSPA	$24.42	Unlimited
3G	$30.21	Unlimited

Figure 14: Mobile TV "Pain Threshold" and Network
Costs



CONCLUSION

Based on our analysis we believe that the market for and penetration of mobile TV is relatively elastic to price, with pay markets seeing 10% to 20% penetration and free markets seeing about 60% penetration.

If Mobile Network Operators (MNO) or Multiple Service Operators (MSO) gave away mobile TV as a bundled offering the experience in Japan tells us we would require capacity for 60% penetration and require broadcast overlay solutions such as DVB-H and DVB-SH, or need to wait for high capacity mobile pipes (i.e. LTE) and/or multicast technologies.

On the other hand, cable MSOs or Telcos/MNO considering charging for mobile TV as a pay offering, could expect penetration between 10% and 20% by 2012. This type of penetration rate is more suited to in-band HSPA, HSPA+, MBMS and ultimately LTE alternatives for mobile TV. Subsequently, today's Telcos with mobile operations, are in a better position to deliver a mobile TV pay service as this alternative does not require a separate overlay network.

We can present the alternatives for the cable MSO as follows:

Table 14: Cable MSOs Mobile TV Choices

	Mobile TV Free Bundle	Mobile TV Pay Service
Penetration	~ 60%	~10 – 20%
Technology Options Eliminated	S/T-DMB **(Limited Capacity)**	UMTS, HSPA **(Limited Capacity)**
Technology Options Today	MediaFLO, DVB-H/SH **(Spectrum)**	HPSA+ TDtv, MBMS **(MNO/Telco)**
Technology Options Emerging	WiMAX, LTE, **(MNO/Telco)**	WiMAX, LTE, **(MNO/Telco)**

In view of Table 14 it is less clear how the many mobile TV distribution choices are suited to a cable operator that does not own suitable spectrum or a wireless network asset, in view of challenging economics and fragmentation of spectrum options.

A summary of the economics of the different facilities-based mobile TV alternatives determined that the economic margin for error is low, flexibility for an sustainable deployment is limited and that the selection of an economically viable distribution technology for the delivery of mobile TV is critical.

Given the inherent low margin aspects of the mobile TV business, the tight linkages to unicast video (and data) consumption over existing cellular data networks and the device centric nature of mobile TV, Mobile Network Operators have a large advantage over MSO's and TV broadcasters.

It is highly unlikely that mobile TV content and viewership will steal subscribers from the in-home TV viewing revenues of cable operators but TV viewing time could be impacted. Any opportunity of competitors to gain a foothold on video and TV viewing time and habits, content aggregation and user interfaces could be deemed a viable mid to long term threat. One area to monitor closely in this area may be the technology advancements such as pico-projectors being built into mobile phones.

Therefore, given the tough barriers to entry in the mobile TV space, combined with advances in mobile technology, it is the opinion of the authors that mobile TV is more of a threat than opportunity for cable operators. In particular, MNOs that serve the low end cable TV base with free to air mobile TV and are able to complement this with premium content delivered using either broadcast or higher capacity in-band wireless could be threatening.

On the other hand, MNO's may need considerable assistance on the technical and economic aspects of content acquisition, management, aggregation, rendering & distribution. An MSO's ability to leverage this strategic advantage into an effective partnership with MNO's is the most viable option for cable operators. This may be particularly attractive to the MNO where the significant cost for mobile TV content can be reduced through partnering with the MSO.

Should MNO partnerships prove challenging, cable operators that strongly desire a mobile TV strategy need to consider the possibility of acquiring or building out a multi-service cellular wireless network to facilitate sustainable mobile TV economics. The build or buy path appears overly aggressive if mobile TV is the only economic driver.

An MSO going it alone in the broadcast area (MediaFLO & DVB-H) appears risky as well. At the end of the day mobile TV using broadcast technology requires devices. Therefore broadcast technologies need a mobile operator's network and mobiles. An MNO operator is a formidable competitor in the mobile TV market, with many distribution options in the toolkit, including established multicast and unicast delivery options that may not be perfect, but allow the MNO to evaluate what content works for mobile TV as the market emerges.

REFERENCES

1. Yoram Soloman, "The Economics of Mobile TV", 2007, p.1
2. Yoram Soloman, "The Economics of Mobile TV", 2007, p.2
3. The "frame rate" of interlaced systems is usually defined as the number of complete frames (pairs of fields) transmitted each second (25 or 30 in most broadcast systems). For example 25p is a video format which runs twenty-five progressive (hence the "P") frames per second. This frame rate is derived from the PAL television standard of 50i (or 25 interlaced frames per second).
4. Yoram Soloman, "The Economics of Mobile TV", 2007, p.2
5. Hendrick Knoche & John D. McCarthy, "Design Requirements for Mobile TV", 2005, p.75
6. Hendrick Knoche & John D. McCarthy, "Design Requirements for Mobile TV", 2005, pp.74-75
7. Hendrick Knocke, John D. McCarthy, M. Angela Sasse, "Can Small Be Beautiful? Assessing Image Resolution Requirements for Mobile TV", MM05, Nov 6-11 2005, p.837
8. Hendrik Knoche, John D. McCarthy & M. Angela Sasse, "Can Small Be Beautiful? Assessing Image
9. Resolution Requirements for Mobile TV", 2005, p.836
10. The Online Reported, 23-29 Feb 2008, Issues 577-I, p.14.
11. DVB-H is a registered trademark of the DVB-H Project
12. MediaFLO USA, and FLO are trademarks of Qualcomm Incorporated
13. Crawford, "Spectrum for Multimedia Services" 2006, page 4
14. Rethink Research, Faultline: European CellCo's act rather than wait for DVB-H spectrum", March 2008
15. Lombardi,Qualcomm, "Presentation to U.S. Subcommittee on Telecom & Internet", May 10, 2007, Pages 6 & 7
16. Joseph, Plets, Martens "DVB-H Broadcast Network Design for indoor reception of DVB-H in Flanders" 2007, page 3
17. Walker, Qualcomm, Presentation to ATSC, "Technical and Business Challenges of Mobile TV" May 17, 2007, Page 3
18. Lombardi,Qualcomm, "Presentation to U.S. Subcommittee on Telecom & Internet", May 10, 2007, Pages 6 & 7
19. Joseph, Plets, Martens "DVB-H Broadcast Network Design for indoor reception of DVB-H in Flanders" 2007, page 3
20. Erkki Aaltonen, Nokia, "DVB-H Radio Network Aspects", July 2005, page 24
21. Wi-Fi® is a registered trademark of the Wi-Fi Alliance
22. Perceived usage rather than measured usage. Ericsson paper, "Changing The Way We Look at Television", p.22
23. Mitch Feinman, Fox Mobile Entertainment, "NATPE 2008 Conference Sessions", "Mobile Content: What's Hot, What's New? What's next?"
24. Salil Delvi, NBC Universal, "NATPE 2008 Conference Sessions", "Mobile Content: What's Hot, What's New? What's next?"

25. Crawford, "Spectrum for Multimedia Services" 2006, page 4
26. Kaufhold , "US Consumers Attitudes About Mobile Communications & Entertainment" , In-Stat, September, 2007
27. All values originally in Euro, converted to USD assuming 1.44 USD/EURO. Urban, "Mobile Television: Is it just Hype or a real Consumer Need" Observatorio Journal,3 (2007) 045-058, Page 53
28. DVB-H Web Site, "3 Italia – Italy Services", May 2007, http://www.dvb-h.org/Services/services-Italy-3Italia.htm. Euro 29 per month at 1.44 EUR to USD
29. David Sidebottom, Understanding & Solutions, Mobile TV Forecast Update based on 3GSM 2008 Review, Feb 22, 2008.
30. Understanding & Solutions define mobile TV in two ways, dedicated mobile TV whereby a dedicated broadcast technology chip is required in the handset to receive programming and includes DVB-H, Mediaflo, ISDB-T and S/T-DMB standards (plus others). The second method is cellular mobile TV delivery, which is linear TV programming delivered direct to the mobile handset via the operators cellular networks. The data and analysis was complied via a mixture of primary and secondary research. Company financials and reports and trade press sources are supplemented with dedicated face to face and telephone research with the key players in these sectors. Total market estimates are derived from a "bottom-up" approach, with individual services totaled to create a total market estimate.
31. A late 2007 ABI research study projects 462 million mobile TV subscribers by 2012. This number assumes a combination of Unicast and Broadcast technologies. Interestingly Asia Pacific has the most growth and represents 56% (260 million) of the 2012 number. The Cable & Satellite Broadcast Association (CSBAA) provides better granularity to these numbers as they track broadcast only mobile TV numbers. Their studies project 76 million broadcast subscribers by 2012. From these two projections one can conclude that a vast majority of Asia Pacific (and probably worldwide) Mobile TV usage will be over unicast technology.
32. Adapted from Yoram Soloman, "The Economics of Mobile TV", 2007, p.10, figure 8.
33. Herbert Mittermayer, "Fast Channel Switching Description", Alcatel-Lucent, p.1
34. Gallouzi "Deal with OFDM, a new old technology" July, 2007, Page 2
35. Wi-Fi is a registered trademark of the Wi-Fi Alliance
36. WiMAX is a trademark of the WiMAX Forum.
37. Gallouzi "Deal with OFDM, a new old technology" July, 2007, Page 2
38. Gallouzi, Brew 2005 Conference,"MediaFLO 101: FLO Technology" June 2005, Pages 23 -25
39. Faria, Henriksson, Stare, Talmola "DVB-H: Digital Broadcast Services to Handheld Devices" 2006, Page 2 & 3
40. Herbert Mittermayer, "Unlimited Mobile TV, DVB-SH A Natural Evolution of DVB-H", Alcatel-Lucent, Jan 2008, p.14
41. Discussion with Juan-Pablo Torres, Alcatel-Lucent, Feb 2008
42. Digital Video Broadcasting Project, "System Comparison of T-DMB vs. DVB-H, 2006, Pages 3-5
43. Bakhuizen, Horn "Mobile broadcast/multicast in mobile networks", 2005
44. Rethink Research "Wireless Watch: In-depth Analysis of WLan, Cellular and Broadband Wireless Markets", Vol. 5, issue 46., Feb 15th 2008, p.19

45. Herbert Mittermayer, “Fast Channel Switching Description”, Alcatel-Lucent, Feb 2008
46. Ericson Technology Paper, “Technical Overview and Performance of HSPA”, June 2007, Page 6
47. Ericsson Presentation, “Mobile Features to increase HSPA performance”, July 2007, Page 1
48. Louis Gump, The Weather Channel Interactive, “NATPE 2008 Conference Sessions”, “Mobile Content: What’s Hot, What’s New? What’s next?”
49. Juniper Research, “Mobile Broadband Markets WIMAX, EV-DO, HSPA & Beyond 2007 -2012” November 28, 2007, Page 7
50. Walker, Qualcomm, Presentation to ATSC.
51. Ericsson paper, “Changing The Way We Look at Television”, p.23
52. Michel Grech, Alcatel-Lucent Mobile TV Business Case (DVB-SH) UK Model” Jan 2008, p.14
53. Qualcomm paper “The Economics of Wireless Data” p.16
54. Economics are based on a snapshot and do not take into account potential declines over time or volume discounts.
55. Iain Morris, “Telecommunication Magazine”, Jan 29, 2008
56. Frank Hartung, Uwe Horn, Jorg Huschke, Markus Kampmann, Thorsten Lomhar, Magnus Lundevall, “Delivery of Broadcast Services in 3G Networks”, IEEE Transactions on Broadcasting, Vol 53, No. 1, Mar 2007, p.194
57. D. Plets, W. Joseph, L. Martens, E. Deventer, and H. Gauderis, “Evaluation and Validation of the Performance of a DVB-H Network”, 2007 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting, Orlando, Florida, USA, March 28 – 29, 2007.
58. D. Plets, W. Joseph, E. Tanghe, L. Verloock, L. Martens, “Analysis of propagation of actual DVB-H signal in a suburban environment”, IEEE International Symposium on Antennas and Propagation, Honolulu, Hawaii, USA, Paper No. 1386, 10 – 15 June 2007.
59. DVB-H channel based on 16QAM, 18 channels in 8MHz of UHF spectrum.
60. Configuration based on (a) MUX of 5MHz both via satellite and terrestrial, using QPSK = 9channels, nationwide; and either (b) MUX of 5MHz via terrestrial, using QPSK = 18 channels (9channels each MUX), terretrial indoor 3G-like coverage; or (c) MUX of 5MHz via terrestrial, using 16QAM = 36 channels (18channels each MUX), terretrial indoor 3G-like coverage. We assume QPSK in our example to create a comparison to DVH-H. Same number of channels with DVB-SH using half of the repeaters.
61. TeamCast and DiBcom, Mobile Performance Calculator, 2005, http://www.teamcast.com/en/maj-e/c2a2i12445/support/dvb-h-calculator/dvb-h-calculator.htm
62. IBC Show, TeamCast, “DVB-H: Digital TV in the Hands”, Sept. 2005, page 2