ECONOMIC IMPACTS OF VIDEO FOR THE BROADBAND WIRELESS OPERATOR

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Abstract

The ability to offer compelling wireless video services over a wide area has been a long awaited goal for consumers and operators alike. Finally, 4G wireless technologies such as WiMAX and Long Term Evolution (LTE) offer adequate performance characteristics to support IP based video services to a large number of consumers simultaneously with a quality that most will find attractive. However, there are a number of economic and technical factors that the operator will need to consider when it comes to actually implementing video services in a wireless network.

In this paper we begin by summarizing the history of broadband wireless technologies and their shortcomings relative to the desired consumer experience and operator economics. Next we review the key attributes and performance implications of 4G broadband wireless technologies and relate those to the capabilities necessary for a service provider to deliver a viable mobile video service offering.

The paper then describes an overall network architecture and essential elements to deliver an end-to-end video solution. The mobile wireless environment enables the operator to tailor the offered content, services, and advertising, dependent on user location and context. Operators that offer both wireless and wireline access networks have the opportunity to integrate them under a common IPTV video headend which provides not only consistent consumer experience and content access, but also the ability to provide mobility between these networks. Video streams in progress can be moved among wired and wireless devices, and content can be made available to any device, anywhere. We conclude with a brief look at some anticipated future trends and applications of mobile video.

INTRODUCTION

Our world is increasingly mobile, and this is driving the demand for easier access to content and services from any location at any time. Existing *wireline* networks have made universal access to the Internet possible, but only for those that have a physical cable or short-range WiFi connection to the network.

The underlying demand is for untethered wide-area mobility, i.e. accessing content and services without wires. To partially satisfy this demand, a vast market has grown in support of a "cache and carry" model. Since digital technology has enabled the efficient storage of vast amounts of content in small portable devices, content can now be downloaded from a multitude of public and personal sources and stored (or "cached") in a portable device that is carried wherever a person goes.

However, "cache and carry" requires the step of pre-loading, which doesn't solve the problem of access from any location whenever the need arises. Nor does it support streaming real-time content or social interaction services like real-time communications. Fortunately, *wireless* mobile data networks, coupled with a converged content and delivery network, are a solution to these mobility aspects. However, only recently have wireless technologies become fast enough to support delivery of bandwidth heavy content, in particular the type of content that is the focus of this paper: video.

EARLY WIRELESS DATA TECHNOLOGIES

Since they were first deployed, there have been attempts to use wide-area wireless mobile data networks to provide some level of video service. Early examples of wireless mobile data networks were in the military and public safety realms [1]. Early public mobile data networks, such as Cellular Digital Packet Data (CDPD), Mobitex, and DataTac offered data rates of 19.2 Kbps or less, and suffered from relatively low subscriber interest. The first public wireless data networks to gain significant subscriber uptake were extensions to the 2G cellular telephony networks, primarily GSM (3GPP) and CDMA IS95A (3GPP2). Early technology demonstrations of video services on these networks centered on video telephony and the exchange of video clips via the multimedia message service (MMS).

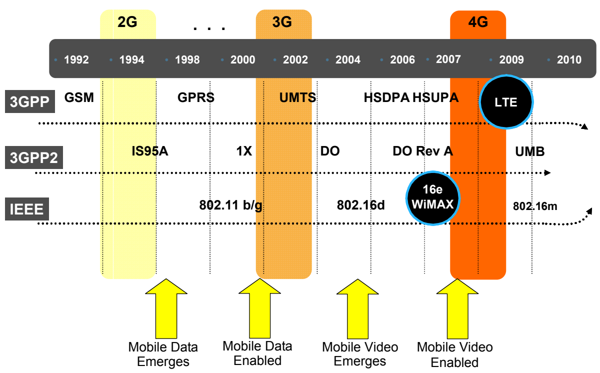

Figure 1. Timeline for the Introduction of Mobile Data Functionality

Figure 1 summarizes the evolution of the commercial wireless broadband standards [2]. With the advent of 2.5G technologies – such as GSM GPRS and CDMA 1xRTT, basic data services such as email and web browsing were offered commercially and were somewhat successful. There was much discussion of extending the cellular data offerings to include some form of video service, with attention focused on video telephony and multimedia messaging. Technical feasibility was demonstrated for these services but commercial versions of the services never materialized. While there were undoubtedly multiple reasons for these commercial failures, the three most significant were high cost of data delivery, low bit rate performance, and limited mobile device functionality.

The device limitations in particular, such as very little memory, slow processors, and small low resolution displays, were the pivotal factors that drove the data services offered for 2/2.5G cellular phones to be primarily limited to browsing of cellular-aware web sites and specialized email programs; and even these were painfully slow. There have been some 2/2.5G data commercial successes in controlled system environments. A notable example was the i-Mode service offered by NTT DoCoMo in Japan [5]. Success was achieved through creation of unique applications and experiences that were optimized for low bit rates, by a large development community.

A wider range of services could be offered using PCs with 2/2.5G access cards. In theory, subscribers could even attempt video downloads using these cards, assuming they had enough time and money. The predominant business model employed by operators was to charge for usage (bytes transferred). Download of even a small 5MB highly compressed video file at low resolution with a typical data rate 50 Kbps or less would have taken over 13 minutes; and given the tariffs of the time (often as much as $1 per 100 KB for GPRS), cost as much as $50.

The introduction of 3G and 3G+ technologies – UMTS, HSDPA and EV-DO – during the middle of the current decade provided a marked increase in wireless data capabilities, with typical data rates on the order of 0.5 to 1 Mbps achievable for HSDPA and EV-DO. These new technologies also provided a dramatic decrease in the cost of delivering data services, as is shown in Table 1.

	Peak Speed	Realistic Speed	Cost to Deliver MB ($)	Cost to Deliver 5GB/Month ($)
HSDPA	14 Mbps	900 Kbps	0.021	$105
1xEV-DOr0	2.5 Mbps	300-500 Kbps	0.022	$110
UMTS	2.0 Mbps	150-200 Kbps	0.069	$345
1xRTT	625 Kbps	60 Kbps	0.059	$295
EDGE	384 Kbps	30 Kbps	0.138	$690
GPRS	120 Kbps	12 Kbps	0.415	$2075

Source: CSFB, HSDPA Networks Group

Table 1. Data Delivery Costs for 2G/3G Wireless Technologies

"Unlimited" data services (where unlimited is defined as a few GB per month) were now being offered by several operators at less than $100 per month. During this same time period, dramatic advances were made in the quality and cost of the cameras and displays that can be incorporated into a mobile phone. With the combination of the new functionality and reduced cost, non-text services finally began seeing substantial growth. Multimedia messaging incorporating both still and moving images is now in wide use; and, as is demonstrated almost daily on the evening news, the uploading of embarrassing film clips from mobile phones to YouTube has become a world-wide hobby.

BROADBAND WIRELESS TECHNOLOGIES BECOMING AVAILABLE NOW

4G wireless broadband in the form of WiMAX and 3GPP's Long Term Evolution (LTE)[1] (see [7], [8], [10]) provide a further significant step forward in consumer experience and network capacity, as well as network price performance.

Before diving into the specifics of 4G wireless performance for video, it's useful to compare to wireline performance since that's the more traditional reference for carrying video. Figure 2 compares fixed/wireline and wireless broadband technologies in terms of throughput capability over time [3]. In general, we see that wireline bandwidths fairly consistently exceed those of the contemporary wireless technologies by approximately two orders of magnitude. The dotted line approximates our view of expectations for "good enough" mobile wireless performance. We see that it's not until 4G that wireless throughput reaches a level that is satisfactory.

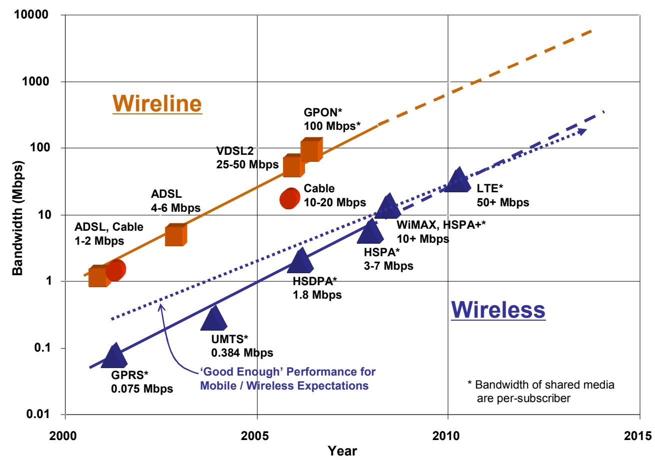

Figure 2. Technology Bandwidth Comparison

Mobile Video Needs

Table 2 illustrates typical bandwidth demands for video services using the current generation of mobile terminals and video displays. It is reasonable to assume that these values are the minimum acceptable; going forward, higher resolutions and faster frame rates will become the norm since consumers will expect the better picture quality that they experience at home to be duplicated in the mobile environment.

[1] 3GPP2 is also defining a 4G air-interface standard called Ultra-Mobile Broadband (UMB), which is technically very similar to LTE.

Resolution Name	Picture size (& frame rate)	H.264 (MPEG-4 part 10) Bit Rate
QCIF	176 x 144 (10 to 15 fps)	64 to 80 kbps
CIF	352 x 288 (7.5 fps)	192 to 240 kbps
QVGA	320 x 240 (10 fps)	192 to 240 kbps

Table 2. Example Data Rates for Mobile Video

4G Air Interface Advantages

Table 2 shows that QVGA resolution video (currently used by YouTube) at 10 frames per second can be supported with a data throughput of 240 Kbps (max). Using the performance projections in Table 3 and assuming a 10 MHz carrier deployment, we estimate that WiMAX can deliver a sustained downlink streaming video session with a throughput of 240 kbps to about 60 randomly scattered video users simultaneously in an area of roughly 3 km^2. This results in the capability of supporting 20 video sessions per square kilometer with a good (i.e. QVGA) user experience. LTE, using the same spectrum allocation and cell size, can support slightly more than 1.5 times as many video sessions. Furthermore, in the near future, LTE and WiMAX, may exploit increased bandwidth allocations up to 40 MHz. Support of 100 or more simultaneous streaming video users per square kilometer will then be within reach.

The uplink is typically the weaker link, supporting 20% to 50% of the data throughput of the downlink. For uplink streaming applications such as See-What-I-See that require about 120 kbps we can expect today's WiMAX to support about 10 such sessions per square km and LTE and future WiMAX to support up to 50.

Parameter	HSPA 5+5 MHz FDD	WiMAX 10 MHz TDD	LTE 10+10 MHz FDD
DL Peak Rate (Mbps)	14	32	60
DL Peak SE (bps/Hz/Sector)	2.8	6.3	6
DL Sector Throughput (Mbps)	3.3	7.9	16.7
DL 5%ile User Throughput (Kbps)	120	210	450
DL SE (bps/Hz/Sector)	0.66	1.30	1.67
UL Peak Rate (Mbps)	5.8	5.0	20.0
UL Peak SE (bps/Hz/Sector)	1.15	1.0	2.0
UL Sector Throughput (Mbps)	1.5	1.4	7.6
UL 5% User Throughput (Kbps)	43	52	192
UL SE (bps/Hz/Sector)	0.31	0.37	0.76

Table 3. Wireless Broadband Performance Comparison

The estimates in Table 3 are based on technology simulations performed by Motorola and other major suppliers of wireless broadband access points and network equipment [11], [12]. An important metric used in these comparisons is Spectral Efficiency (SE). SE is calculated by taking a ratio of the throughput as measured in bits per second (bps) and the amount of radio spectrum allocated (Hz). So the units are typically given in bps/Hz (or equivalently, Mbps/MHz). Higher spectral efficiency translates to lower cost per subscriber for the operator. 4G wireless technologies are able to achieve higher spectral efficiency through the use of advanced transmitter and receiver designs, multi-antenna arrays, adaptive coding and modulation techniques, and smart packet scheduling methods, all of which take advantage of the changes in the radio environment during a data session. While earlier technologies possessed some of these methods they were not able to utilize them all in concert over a wider spectrum allocation to achieve the high data rates of WiMAX and LTE. In addition, the improvement in uplink spectral efficiency possible with LTE is primarily enabled by the use of an advanced coherent detection scheme [13].

As the relative total cost of ownership curves presented Figure 3 show, LTE and WiMAX, which are based on OFDMA (Orthogonal Frequency Division Multiple Access) radio technology, provide a substantial improvement in network price performance (Total Cost of Ownership, or TCO), especially as the amount of data consumption increases per device. Based on the above QVGA estimation, a heavy mobile video user (say one who averages an hour of viewing per day) would consume on the order of 7 GBytes per month of data service. Examination of Figure 3 indicates that it would cost 2 to 4 times as much to operate an HSDPA or EVDO network when providing this level of per user capacity, as it would to operate an equivalent LTE or WiMAX network.

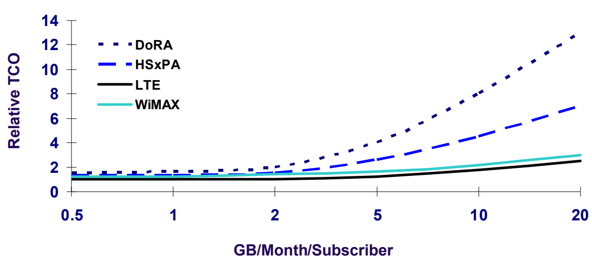

Figure 3. Relative Total Cost of Ownership for Broadband Data Delivery[2]

4G Network Technologies & Topologies

Prior to 4G, macro-area wireless networks were first and foremost cellular voice systems optimized for carrying narrow circuit voice style traffic. These systems had packet data facilities "glued" on almost as an afterthought. WiMAX and LTE are pure, broadband data systems that have no specific circuit voice provisions (other than as a constant bit rate QoS class) – they are IP packet based access technologies. This results in simpler and more decentralized network architectures relative to earlier networks and eliminates the need for complex protocol interworking between the wireless network and the operator's IP backbone.

The architectures of the 4G WiMAX and LTE networks are contrasted with that of the 3G UMTS network in Figure 4.

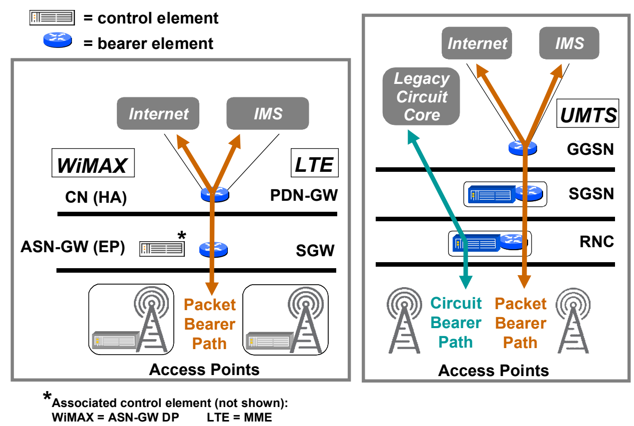

Figure 4. Flatter, Data-Only Architecture for LTE and WiMAX

The WiMAX and LTE network architectures were specifically created to support packet data services and are optimized for those services. Voice services for WiMAX and LTE are based on VoIP technology and are treated just like other data applications. Both WiMAX and LTE make extensive use of Internet concepts and protocols. This allows them to limit the amount of domain-specific equipment that must be used and leverage the volume production of components designed for Internet use. In contrast, the 3G UMTS network has both a data architecture and a legacy circuit architecture. Since legacy circuit and packet data are dramatically different concepts, this combination architecture gives rise to complex, domain-specific components that limit network performance and drive up infrastructure costs.

The WiMAX and LTE architectures are flatter (i.e. more distributed, with fewer layers of system elements) than the UMTS data architecture. In WiMAX and LTE there are two levels of components in the bearer path between the BTS / AP and the application core network,

[2] For this illustration: a population density of 1000/km^2 is assumed with a 15% subscriber penetration rate. The spectrum usage is normalized across the technologies.

while in UMTS there are three. In networks designed to support legacy voice services this additional level was useful for a variety of reasons including aggregation of low speed circuit traffic, scheduling of timeslots on circuit transport facilities, and setup/teardown of transport bearer circuits. In a high speed data network however, these circuit-related functions are not needed, and this additional layer accomplishes nothing other than driving up cost and slowing performance. The flatter architecture of LTE and WiMAX also aids in simplifying network operations, as there are fewer different types of components to be managed.

One final characteristic of the high-level architectures of WiMAX and LTE that contributes to their cost advantage over 3G networks is better separation of wireless control functions from data plane functions. By definition, wireless control functions are unique to the wireless domain. Separating the unique wireless control functions from the data plane functions makes it possible to leverage some network elements that can be produced in higher volumes with lower costs. This separation also simplifies network sizing and expansion. For example, wireless control functions are influenced by the frequency with which subscribers enter and leave the network and the speed with which they move around in the network. And, the data plane processing load is determined by the number and size of data packets that are sent between terminal devices and applications servers. The ability to scale wireless control network elements and data plane elements separately in LTE and WiMAX enables operators to size their networks to their exact needs and to focus capacity increases on those functions that are under stress.

WiMAX and LTE will also include specific provisions in support of video broadcast. For example, 3GPP is in the process of defining the Multicast Broadcast Multimedia Service (MBMS) for LTE. In principle, MBMS provides facilities in the network that define sets of base stations over which a given service or media stream should be broadcast. There are provisions to control when a particular service is broadcast including facilities to dynamically enable broadcast based upon user demand in a particular location. IP Multicast will be the network level distribution method to direct content from the content source via a gateway function (MBMS-GW) to specific base stations as required.

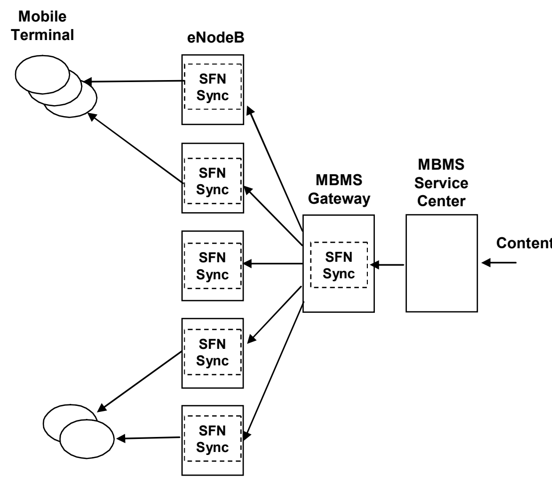

Figure 5. LTE Multicast Broadcast Multimedia Service (MBMS) Operation

MBSFN (Multicast Broadcast Single Frequency Network) further optimizes broadcast operations of the network by synchronizing the delivery of specific content across multiple base stations so that the media can be transmitted simultaneously by each station, as shown in Figure 5. This provides a much improved RF environment and corresponding signal/noise ratio by allowing the mobile terminal to combine reinforcing signals from multiple adjacent base stations.

Mobile Device Advances

Device technologies will continue to improve with the same technology advances that drive the desktop computing environment. Moore's law coupled with substantial improvements in power management and memory density advanced the functionality available on the handheld computing platforms. Just as the laptop computer became a staple among business professionals and college students, now the handheld mobile device is as well.

The potential for new and expanded video services is also being impacted dramatically by technological advances in the mobile device domain. Advances in materials and Micro Electro-Mechanical Systems (MEMS) technology are spawning a new generation of miniature advanced antennas systems that enable devices to fully exploit the capabilities of LTE and WiMAX. MEMS is also a key to new designs that leverage the DLP™ technology developed for HDTV to provide high-quality, reflective-light displays that are well suited for mobile applications. These new displays promise to provide much improved visibility is high ambient light environments and extremely low power consumption, ameliorating two of the most serious challenges to supporting video applications in a truly mobile environment. 12 GB flash memory cards will be available for mobile devices this year. One card has enough storage to hold 1500 songs, 3600 photos and over 24 hours of video at the same time[3]. One manufacturer has even announced a 120 fpm video capability in one of its mobiles to support slow motion video functionality comparable to today's in-home DVD players. By early 2009, wireless devices are expected to have built-in projectors. These devices have the potential to eliminate the most frequent cited inhibitor to video on mobile devices – their small screen. Finally, advances in lens, flash lighting, memory cards, and other technologies are making certain that the explosion in bandwidth utilization for video will not be a one way street.

[3] Approximation based on 4 minute songs using 128 kbps MP3, pictures taken with 2Mpixel camera and MPEG-4 video at 384 kbps. Pictures and video assume typical compression and resolution.

A FULL SERVICE SOLUTION IS NEEDED

A high-performance wireless access network is important, and generates revenue on its own. But access networks are really just an enabler for providing content and services to consumers. The Internet model has taught consumers to expect universal access to hundreds, if not thousands of valuable applications and content sources. For a network operator to maximize revenue and profitability, it's desirable to participate in every way possible in the business of delivery of content and applications. Two key ways to do this include supporting an open environment in client devices, and establishing unique value added applications.

Open Client Environment

The open client environment is the first tier in the application value chain. This allows 3rd party application providers to create and deploy applications quickly, constrained only by competitive capitalism. Even if these applications are hosted outside of the operator's network, the open client environment benefits the network operator by increasing 'stickiness' since consumers know (and expect) that they can enhance what their device can do, freely and at their own discretion – said another way, they don't need to move to a competitor's network to gain access to new services.

Operator Provided Applications

The 2nd tier up the application value chain is when the network operator provides some applications themselves. Again, these are supported within the same open client environment, and may be developed by 3rd parties or by the operator, but they are hosted within the operator's own network. Now the operator gains revenue not only from the use of the access networks, but also by charging for the services themselves. Of course the goal for an operator is to identify as many compelling applications as possible and bring them into an integrated environment in their network, rather than passively watching as others gain revenue for those applications.

Over time, consumers have come expect to access applications and content from the Internet as well as from the operator. However, there are still many ways that operator hosted applications can differentiate and more easily provide capabilities that Internet hosted applications can't. Here are some examples:

- Integrating multiple applications by linking data between them
- Sharing user preferences
- Sharing user identity information
- Improving performance through application linkage to QoS enforcement in the access network
- Tailoring content and functionality based on client geographic location *(note that Internet hosted applications can do this too – if the client knows its location.)*

Video (streaming, VOD, and linear) will be a major component of the future service offerings for the mobile and converged service provider. Table 4 shows the results of a survey done by *M:Metrics* showing the percent of users of a given device type who performed a number of popular data activities in the month of January 2008 [6]. There is a clear trend towards significantly increased video usage by consumers who have an easier to use device (and typically a flat-rate data service plan).

Activity	iPhone	Smart-phone*	Market
Any news or info via browser	**84.80%**	**58.20%**	**13.10%**
Accessed web search	**58.60%**	**37.00%**	**6.10%**
Watched mobile TV and/or video	**30.90%**	**14.20%**	**4.60%**
Watched on-demand video or TV programming	**20.90%**	**7.00%**	**1.40%**
Accessed Social Networking Site or Blog	**49.70%**	**19.40%**	**4.20%**
Listened to music on mobile phone	**74.10%**	**27.90%**	**6.70%**

Table 4. Mobile Content Consumption: iPhone, Smartphone and Total Market, January 2008

Video content and applications are most cost effectively delivered by a comprehensive end-to-end network architecture. This architecture should leverage the all-IP nature of video and voice services to provide a converged set of functionality which can support service delivery across both wireline and wireless networks.

CONVERGED VIDEO DELIVERY ARCHITECTURE

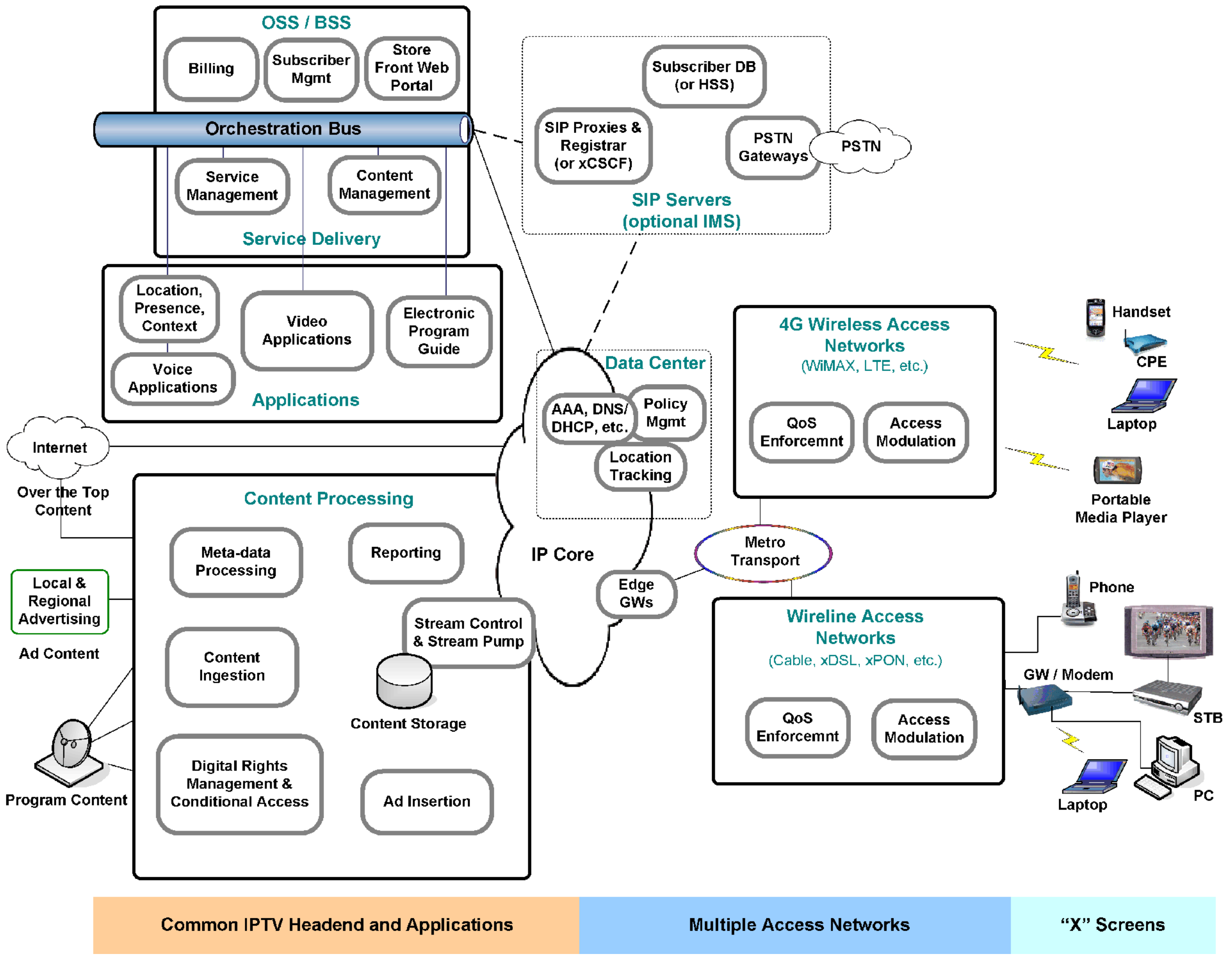

Figure 6. Functional Blocks of the Converged Video Architecture

The primary functional blocks of the converged video architecture are shown in Figure 6.

Content Processing – Includes direct video manipulation such as content ingestion, storage, and stream playout, ad insertion, logo insertion, linear (real time) and off-line encoding / transcoding, and off-line production tools.

Most video content has associated informational data files that are delivered to the system either coincident with or at some time before the content is available. This supporting information is referred to as meta-data. Some examples of information contained in the meta-data include program title and synopsis, length, encoding, points where ads can be inserted, etc.

Linear (real-time) content is ingested, processed, and streamed out immediately. Video on Demand content processing includes delivery of the VOD program (asset) to the system, ingestion of the asset meta-data into the VOD catalog, and storage of the content itself into the VOD stream pump.

Digital Rights Management (DRM/IPRM) and Conditional Access functions include linear and non real-time (offline) encryption, and Key / Certificate Management.

Middleware (not shown) – Middleware typically describes a software layer in the client and network that enables and supports video applications. The open client environment described earlier is embodied as part of the middleware of the solution. Middleware typically supports many or all of the following functions:

- Retrieval of the meta-data information described above from the Electronic Program Guide or store front portal server, and formatting that for display. This includes a list of what video programs are available for viewing, what's being played now, what can be purchased on demand, and what has been stored locally.
- Actions related to viewing, including Picture in Picture, control of video display (play, pause, rewind, fast forward)
- DVR functions such as recording video for later viewing, or starting playback of content already recorded.
- Emergency Alerts and display of desired informational streams
- Content Advisory / Parental Control

Motorola's preferred implementation for middleware is to use a 'thin-client' strategy, such that the centrally managed servers deliver "display ready" user interfaces to the clients, from which the viewer makes a selection. This allows having the same user experience across multiple devices, which will be described in more detail in the next section entitled *Media Mobility.*

Applications – Includes the multitude of application servers that provide operator managed video related services to client devices (as well as voice services, if offered). Some examples of these will be given shortly. Supporting applications, such as Presence, Location/Mapping, and user context services are also ideally integrated here with the other application servers in an orchestration environment. This approach allows for sharing of data and linking of multiple applications together to create more feature rich offerings.

SIP Servers – The converged architecture takes advantage of the capabilities defined within a SIP environment to provide a consistent mechanism for managing control of applications that are naturally session based such as Video on Demand or Voice over IP. Operator implementations will likely rely on SIP for providing converged session control of voice, multi-media, and video streaming services. This convergence allows for rapid deployment of compelling combined services, such as concurrent voice and video (talk to your friend while you both watch the same content, integration of presence for dynamic personalization of content, and so on. Many carrier class operators are expected to use variations of 3GPP's IP Multimedia Subsystem (IMS) architecture, which is SIP based [9], to enable this convergence.

Service Delivery – Includes Content Management functions such as VOD asset management, and the Electronic Program Guide / store front portal servers, as well as Service Management functions such as service bundling and merchandising, access rule management, and mediation functions.

Policy Management & Quality of Service - Includes Quality of Service (QoS) mechanisms which coordinate the assignment of capacity to individual clients based on session needs. The converged architecture proposed here uses information within the Session Description Protocol (SDP) structures of SIP messaging to determine the session needs, thus the SDP contains information on flow rate and the end points which are used to establish a connection from video source to client. The underlying system is then expected to enforce the requested connection during the session, or to work with the Policy Management and Application servers to adapt the video stream to match revised system capabilities.

Access Networks – In previous sections, this paper has focused on wireless broadband access networks such as LTE or WiMAX. However, the real power of this converged architecture is the applicability of the same video application and content delivery environment to devices in any broadband IP access network, whether wireline or wireless.

Media Mobility™

An important class of applications that this converged architecture enables is what Motorola calls Media Mobility™.

Media Mobility applications enable a commonality of service between all of the content access and display devices used by consumers. These devices include PCs, televisions (and set-top boxes), and mobiles, including phones and PDAs. Drawing on the lessons that content providers have learned through the growth of the web, Media Mobility promises to provide consumers with entirely new forms of video entertainment that combine traditional program styles with emerging social network-driven entertainment modes across a wide range of consumer devices.

Benefits to the Consumer

The converged SIP-based solution offers consumers access to advanced applications that provide a personal video experience. For example, the ability to pause a video stream on one device and pick it up on another allows consumers to seamlessly carry their video with them wherever they choose to view it. As discussed earlier, the simple cache and carry approach limits video mobility to content that has been previously stored, whereas the Motorola Media Mobility solution applies to live broadcast (linear) content as well as personal video sharing among consumers.

The flexibility of the converged applications architecture means that the underlying mechanisms that have been developed to allow video transfer among devices can be readily applied to other applications as well. Presence notifications, news feeds, home caller-id, and many others are all examples of information that could easily have their target context changed from one device to another, as a user wishes.

Benefits to the Operator

A comprehensive network architecture which allows an operator to ubiquitously deliver video and multimedia content to their subscribers offers significant business advantages, such as:

Network efficiencies from a common video headend and converged session control - Operators with fixed and wireless networks can especially benefit from a converged architecture. It is a single video headend delivering content independent of access technology. Significant savings in CAPEX and OPEX are realized by this approach, as opposed to deploying individual independent video delivery solutions for each.

The SIP mechanisms used to move the content from one device to another also enable the network to be aware of what is being viewed, by whom, and on what device. The Motorola solution that supports the gathering of these kinds of information, including service brokering and service orchestration, is being designed as a modular architecture that allows for easy integration into existing IMS environments.

Ubiquitous access and meeting increased expectations - By having 'always on' access regardless of location, there are more opportunities created for pay-per content access, or advertising 'eyeballs' reached. Additional ARPU should be possible simply by providing consistent service across multiple environments. For example, consumers clearly find YouTube to be an interesting way of consuming video at their PC and this is already becoming desirable in a mobile environment (it is reported that in 2007, YouTube video generated more Internet traffic in the United States than all of the Internet traffic combined, worldwide, in the year 2000). As consumer expectations grow, it becomes a competitive imperative for a carrier to meet the common denominator.

Taking advantage of location – Targeted advertising is possible based upon an individual's past behaviors as well as the content that is currently available (e.g., when a particular piece of media is about to be distributed by a MBMS broadcast, the user can be alerted). With feedback of current subscriber location information back into the video headend, it is possible to customize individual streams (VOD for example) based upon a particular user's location. This enables location based advertising with a fine degree of granularity (e.g., for individual shopping malls, restaurants, events, etc.).

Additional public services – Enhanced emergency communications services are also possible such as broadcast alerts and/or updates on surrounding context (e.g., traffic, etc.) based upon location. Minimally, this becomes a crucial part of a user's bundle and dependency on the mobile media environment. Many of these information services can be subscription based. It is also possible that public carriers may be able to "wholesale" selected broadband capabilities to public safety agencies.[4]

[4] Note that the FCC's recent attempt to formalize this with the D-block spectrum auction failed in that no carrier was willing to accept the business terms associated with operating in this spectrum.

Stickiness – Providing consistent access, management of preferences, as well as look and feel (e.g., EPG, storefront) to the user in a mobile environment as well as the home/fixed locations increases the stickiness of the subscriber to the carrier.

THE FUTURE – EMERGING SERVICE TRENDS

Many services and capabilities that appear in wireline networks (i.e. the Internet) tend to make their way to wireless, gated by the ability of the wireless access technologies to support them. 4G wireless technologies are clearly able to support most activities people do with the Internet. Also, in the past there tended to be a slower pace of client development for wireless. However, given the inevitable trend toward web based applications and open wireless client environments discussed earlier, as well as the convergence of networks, this development gap is also expected to disappear.

A few examples of new and emerging video related applications that are likely to be popular among wireless consumers are:

Social TV – This is a range of enhancements to today's one-way video viewing experience which will provide people with the ability to share their viewing experience, regardless of location. It is envisioned to include things like integration of presence so you see on your screen not only which of your "buddies" are online, but also what they're watching, and give an easy ability to switch to that content yourself. Unlike today's passive experience, the ability to have a voice or text conversation with your buddies while viewing the content, or sending your rating on whether you like it or not, is supported by the device and 4G wireless network being inherently bi-directional.

See-What-I-See – This is a real-time linking of people's visual experience. One-to-one video telephony is a basic form of this. However, it can be extended to share video among a small group, such as sharing what I see with my fellow construction or firefighting team. Or it might be offered as a fee based service for enhancing the viewing of public events, such as broadcasting point-of-view video from a sports star to fans who have subscribed to it.

User Generated Content – Revenues for the total user generated content market have been estimated to grow between 66% and 99% per year on average over the next 5 years [4]. The success of social networking and blogging sites reflects the desire for people to make, publish, and view their own video content. The ability to do this from a wireless device will accelerate the quantity of content produced. Video blogging will become an extension to today's simple video file upload, giving consumers the ability to easily create multi-media narratives for public or private viewing. Revenue opportunities exist all along the user generated content value chain, from the creation of easy to use clients for creating the content, to the application servers which store catalog, and transmit it.

Access to Personal Content – Mobile wireless enables access to personal content libraries from anywhere. A potential future revenue opportunity for the operator is to provide an easy to use hosting service for storing and managing personal content (perhaps for a flat fee or ad based), as well as integration of a network based Personal Video Recorder (PVR) capability.

Peer-to-Peer Sharing – Like in the wired Internet, peer-to-peer sharing of content among wireless users will likely grow to dominate traffic on the 4G network.

When examining these new and emerging applications, we find an interesting trend that will have significant impact on wireless networks: most of them require vastly more uplink bandwidth (from client to network, or from client to network to client) than has been needed in the past. Earlier we discussed the improved uplink capacity of 4G wireless technologies over previous generations. This will help to ameliorate the network cost impacts of widespread uptake of these new services. However, since the uplink is the limiting direction for wireless, its utilization will need to remain a parameter that is closely watched.

CONCLUSION

With the advent of 4G wireless technologies, operators will have the flexibility and network robustness to economically deliver a truly mobile video and multimedia experience. WiMAX and LTE offer significant performance and economic advances over their 2G and 3G predecessors. These networks are based on OFDMA radio technology and use a flat, IP-based network architecture. WiMAX deployments are well underway and their pace continues to increase. LTE will follow, and bring with it even more advances and capabilities that are applicable to video delivery (e.g., MBMS). Mobile device technology has advanced commensurately to provide a reasonable platform for mobile multimedia.

To best exploit the opportunities for revenue that these Radio Access Network technologies enable, a comprehensive end-to-end service and content delivery architecture is essential, and is of particular benefit in a converged wireline/wireless environment. In addition to the radio access infrastructure, the architecture needs to include the following:

- An open client environment enabling consumer installation of new services and applications, which are deployed either by the network operator, or by 3rd parties in the Internet.

- Content Processing: Encoding and Device Adaptation, Ingest and Storage, Metadata processing, DRM.
- Middleware: Consistent implementation among all clients and network servers of key supporting capabilities such as EPG, content merchandising mechanisms, and interactive features.
- SIP Session Management: Consistent orchestration of multimedia sessions.
- Service Delivery: Management of application introduction, deployment, and charging for services.
- Policy and QoS: Determination of a session's QoS needs and entitlements, and orchestration of this across the end-to-end network via content selection/adaptation, bearer flow establishment, etc.

A unified mobile media solution offers many carrier revenue generation opportunities including ubiquitous always-on access to existing services, location based derivatives such as location based advertising, public services, and increased dependency (stickiness) on existing operator services and content.

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