MediaFLO™

FLO™ TECHNOLOGY OVERVIEW

Revolutionizing Multimedia

More Media. More Mobile. More You.

QUALCOMM®

CONTENTS

Introduction

In recent years, the wireless industry has seen explosive growth in device capability, especially in relation to mobile cellular phones. Ever-increasing computing power, memory, and high-end graphic functionalities have accelerated the development of new and exciting wireless services. However, some of these services, while technically possible, are challenging to implement because of the unfavorable ratio that exists between the cost of delivery and the expected revenue.

A case in point is the simultaneous delivery of large amounts (Mbytes) of consumer multimedia content to vast numbers (millions) of wireless devices. Delivery of this type of content is technically feasible over today's existing (unicast) networks, such as 3G networks. However, market analysis indicates that demand for this type of content, which is similar to that which is available on traditional broadcast services, commands a lower price than other on-demand, Internet-like, bi-directional data services. This leaves operators without a long-term viable business case for offering such content.

The appeal of video and multimedia is enormous, as evidenced by the $87 billion that consumers in the U.S. spent on these services in 2004 alone. For network operators, the challenge has become: "How can large-scale delivery of high-quality multimedia to wireless devices be implemented profitably?"

FLO technology was designed specifically for the efficient and economical distribution of the same multimedia content to millions of wireless subscribers simultaneously. It actually reduces the cost of delivering such content and enhances the user experience, allowing consumers to "surf" channels of content on the same mobile handsets they use for traditional cellular voice and data services. In designing FLO technology, Qualcomm has effectively addressed key challenges involved in the wireless delivery of multimedia content to mass consumers. Unencumbered by legacy terrestrial or satellite delivery formats, FLO offers better performance for mobility and spectral efficiency with minimal power consumption.

This paper provides a brief overview of FLO Technology and its key air interface characteristics.

The User Experience

Before providing a general system and technical overview, it is useful to provide a high-level description of what a user will experience. As currently envisioned, today's wireless operator will offer to consumers a service powered 'behind-the-scenes' by a MediaFLO System based on FLO technology.

For example, a FLO-based programming lineup that utilizes 30 frames-per-second (fps) QVGA (a Quarter Video Graphics Array or 240x320 pixels) with stereo audio includes 14 real-time streaming video channels of wide-area content (ex: national content) and 5 real-time streaming video channels of local market-specific content. This can be delivered concurrently with 50 nationwide non-real-time channels (consisting of pre-recorded content) and 15 local non-real-time channels, with each channel providing up to 20 minutes of content per day. non-real-time content can be delivered in the background seamlessly and made available for viewing in accordance with a provided program guide. The allocation between local and wide-area content is flexible and may vary during the course of the programming day. The delivery of non-real-time content allows immediate access to music, weather or news summaries by topic while real-time streaming services support live events such as sports. In addition to wide-area and local content, a large number of Internet Protocol (IP) data channels can be included in the programming line-up. Such channels may include (but are not limited to) traffic information, financial information or local weather updates.

The ability to change channels quickly is considered a key user requirement. Equally important is watch time, which is designed to be comparable to talk time, if not longer, so as not to compromise the functionality of the mobile device.

The MediaFLO Service is designed to provide the user with a viewing experience similar to a television viewing experience by providing a familiar type of program -guide user interface.

Users simply select a presentation package, or grouping of programs, just as they would select a channel to subscribe to on television. Once the programs are selected and subscribed to, the user can view the available programming content at any time.

In addition to viewing high quality video and audio content and IP data, the user may also have access to related interactive services, including the option to purchase a music album, ring tone, or download of a song featured in a music program. The user may also be able to purchase access to on-demand video programming, above and beyond the content featured on the program guide.

The Media FLO system, based on FLO technology, is able to deliver such a rich variety of content choice to consumers while efficiently utilizing spectrum as well as effectively managing capital and operating expenses for the service provider.

FLO System Architecture

A FLO system is comprised of four sub-systems: the Network Operation Center (which consists of a National Operations Center and one or more Local Operation Centers), FLO Transmitters, 3G Network, and FLO-enabled devices (also known as MediaFLO Handsets). The schematic diagram in Figure 1 shows an example of the FLO network.

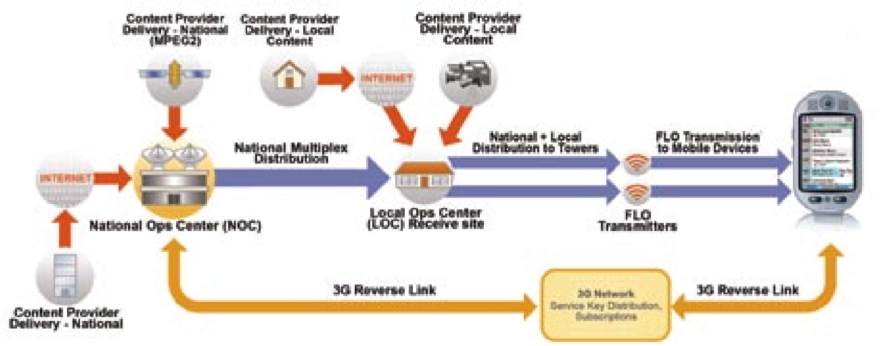

Figure 1 Example of FLO Network

Network Operation Center

The Network Operation Center consists of the central facility(s) of the FLO network, including the National Operations Center (NOC) and one or more Local Operation Centers (LOC). The NOC can include the billing, distribution, and content-management infrastructure for the network. The NOC manages various elements of the network and serves as an access point for national and local content providers to distribute wide area content and program guide information to mobile devices. It also manages user-service subscriptions, the delivery of access and encryption keys, and provides billing information to cellular operators. The Network Operation Center may include one or more LOCs to serve as an access point from which local content providers can distribute local content to mobile devices in the associated market area.

FLO Transmitters

Each transmitter transmits FLO waveforms to deliver content to mobile devices.

3G Network

The 3G network belongs to the wireless operator(s) and supports interactive services to allow mobile devices to communicate with the NOC in order to facilitate service subscriptions and access key distribution.

FLO-Enabled Devices

FLO-enabled devices can receive FLO waveforms containing subscribed content services and program-guide information. FLO-enabled devices are primarily cell phones, which are actually multipurpose devices that serve as telephones, address books, Internet portals, gaming consoles, etc.

Of all the various cell phone functions, the most important remains the ability to make and receive phone calls. Because all applications on a mobile device share common resources—the most important of which is battery power—a service that wastes that power will quickly fail. FLO has been designed specifically to optimize power consumption through intelligent integration on the device and optimized delivery over the network.

FLO System Overview

Content Acquisition and Distribution

In a FLO network, content that is representative of a linear real-time channel is received directly from content providers, typically via a C-band satellite in MPEG-2[1] format (704 or 720 x 480 or 576 pixels), utilizing off-the-shelf infrastructure equipment. This is the most common format utilized by programmers, making it relatively simple for content providers to interface with a FLO System. The use of a standard definition as a source content provides sufficient resolution to allow for efficient transcoding to H.264[2] QVGA resolution supported by the FLO network.

Non-real-time content is received by a content server, typically via an IP link, and then reformatted into FLO packet streams and redistributed over a Single Frequency Network (SFN). This distribution of the FLO packet streams is facilitated by the MediaFLO Media Distribution System (MDS). This non-real-time content is delivered according to a pre-arranged schedule.

The transport mechanism for the distribution of this content to the FLO transmitter may be via satellite, fiber, etc. At one or more locations in the target market, the content is received and the FLO packets are converted to FLO waveforms and radiated out to the devices in the market via FLO Transmitters. If any local content is provided, it will be combined with the wide area content and radiated out to the target market.

Only those devices that have subscribed to the service may receive the content, which in turn can be stored on the mobile device for future viewing, in accordance with a service program guide, or as a linear feed of content, delivered in real-time to the device. This content may consist of high-quality video (QVGA) and audio (MPEG-4 HE-AAC[3]) as well as IP data streams. A 3G cellular network is required to provide control functions to support interactivity and facilitate user authorization to the service. Equally important, the 3G network provides a basis for interactivity, including purchase and download transactions.

1. Motion Picture Experts Group (MPEG). MPEG-2 is a compression standard that allows the coding of studio quality video for digital TV, high-density CD-ROMs and TV-broadcasting.
2. AVC/H.264 – Advanced Video Compression – standardized by ITU and ISO/IEC for enhanced compression performance
3. High Efficiency AAC (HE AAC) audio profile is specified in "ISO/IEC 14496-3:2001 / AMD 1:2003" and is accessible through the ISO/IEC website. The performance of the HE-AAC profile coder is documented in the publicly available formal verification test report WG 11 (MPEG) N 6009.

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Power Consumption Optimization

FLO technology simultaneously optimizes power consumption, frequency diversity[4], and time diversity[5]. Other similar, but less efficient, systems optimize one or two of these parameters but ultimately compromise the others. FLO has a unique capability that allows it to access a small fraction of the total signal transmitted without compromising either frequency or time diversity. As a result of these considerations, it is expected that a FLO-enabled mobile device can achieve comparable battery life to a conventional cellular phone; that is, a few hours of viewing and talk time and a few days of stand-by time per battery charge.

The FLO air interface employs Time Division Multiplexing (TDM) to transmit each content stream at specific intervals within the FLO waveform. The mobile device accesses overhead information to determine at which time intervals a desired content stream is transmitted. The mobile device receiver circuitry only powers up during the time periods in which the desired content stream is transmitted; at all other times it is powered down. The receiver ON/OFF duty cycle is expected to be relatively low or immaterial, depending on the media content size and data rate used.

FLO technology minimizes program channel acquisition time. In most cases, it is under two seconds. Mobile users can channel surf with the same ease as they would using digital satellite or cable systems at home.

Wide- and Local-Area Content

FLO supports the coexistence of local and wide-area coverage within a single Radio Frequency (RF) channel.

The content that is of common interest to all the subscribers in a wide-area network is synchronously transmitted by all of the transmitters. Content of regional or local interest can be carried in a specific market. This per market control is a key feature, offering the ability to blackout and retune based on any contractual obligations associated with specific programming.

4. Frequency diversity provides immunity in a fading environment where a signal spans a wide spectrum and usually does not all fade at the same time.
5. Time diversity: transmission in which signals representing the same information are sent over the same channel at different times – it's often used over systems subject to burst error conditions and at intervals longer than an error burst.

Layered Modulation

To provide the best possible quality of service, FLO technology supports the use of layered modulation. This means the FLO data stream is divided into a base layer that all users can decode, and an enhancement layer that is decoded in areas where a higher Signal to Noise Ratio (SNR) is available. The majority of user devices will be able to receive both layers of the signal to deliver 30 fps video quality. The base layer has superior coverage compared to an un-layered mode of similar total capacity, and it can deliver 15 fps video quality. The combined use of layered modulation and source coding allows for graceful degradation of service and the ability to receive in locations or at speeds that could not otherwise have reception. For the end user, this efficiency means that a FLO network can provide better coverage, offering higher quality services like video, which require significantly greater bandwidth than other multimedia services.

As previously described, FLO systems use H.264 for real-time media. The H.264 encoding is extended H.264 compliant for non-layered applications, and the base layer is H.264 extended compliant in applications in which a layered codec is applied.

FLO Air Interface

FLO Air Interface Protocol Reference Model

The FLO air interface protocol reference model is shown in Figure 2. The FLO air interface specification covers protocols and services corresponding to OSI[6] Layers 1 (physical layer) and Layer 2 (Data Link layer) only. The Data Link layer is further subdivided into two sub-layers, namely, Medium Access (MAC) sub-layer, and Stream sub-layer.

Key Features of Upper Layers

- Compression of multimedia content
- Access control to multimedia
- Content and formatting of control information

The FLO air interface specification does not specify the upper layers to allow for design flexibility in support of various applications and services. These layers are only shown to provide context.

Key Features of Stream Layer

- Multiplexes up to three upper layer flows into one logical channel
- Binding of upper layer packets to streams for each logical channel
- Provides packetization and residual error handling functions

Key Features of Medium Access Control (MAC) Layer

- Controls access to the physical layer
- Performs the mapping between logical channels and physical channels
- Multiplexes logical channels for transmission over the physical channel
- De-multiplexes logical channels at the mobile device
- Enforces Quality of Service (QOS) requirements

Key Features of Physical Layer

- Provides channel structure for the forward link
- Defines frequency, modulation, and encoding requirements

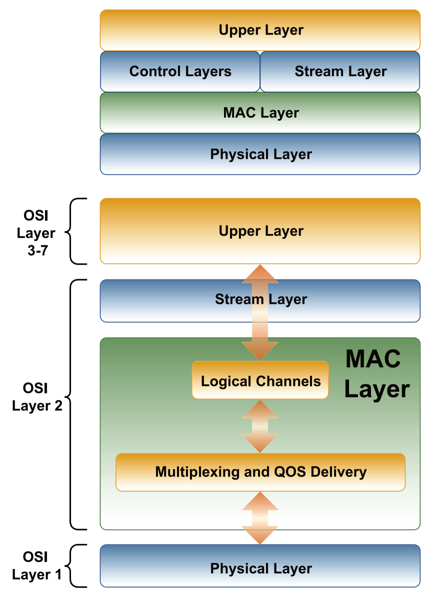

Figure 1 Example of FLO Network

6. International Standard Organization's Open System Interconnect (ISO/OSI) model.

FLO Air Interface Fundamentals

OFDM Modulation

The FLO technology utilizes Orthogonal Frequency Division Multiplexing (OFDM), which is also utilized by Digital Audio Broadcasting (DAB)[7], Terrestrial Digital Video Broadcasting (DVB-T)[8] , and Terrestrial Integrated Services Digital Broadcasting (ISDB-T)[9]. OFDM, as depicted in Figure 3, can achieve high spectral efficiency while effectively meeting mobility requirements in a large cell SFN.

The smallest transmission interval corresponds to one OFDM symbol period, as shown in Figure 3.

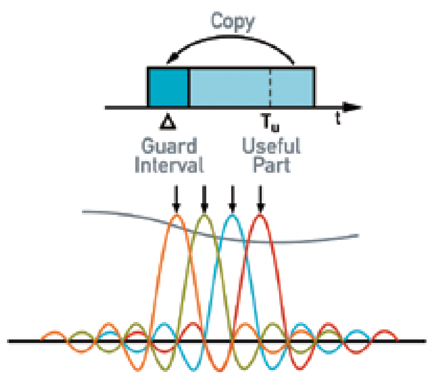

Figure 3: OFDM Symbols

OFDM can handle long delays from multiple transmitters with an appropriate length of cyclic prefix; a guard interval added to the front of the symbol (which is a copy of the last portion of the data symbol) ensures orthogonality and prevents inter-carrier interference. As long as the length of this interval is greater than the maximum channel delay, all reflections of previous symbols are removed and the orthogonality is preserved.

A number of design tradeoffs must be considered when developing an OFDM-based system. These decisions will be governed by the way the system is intended to be used, including the degree of mobility, the data rates required, the services to be supported, the number of users to be supported, and the environment in which the

7. Digital Audio Broadcasting (DAB) system also referred to as Eureka 147 and defined in ETSI EN 300 401: "Digital Audio Broadcasting (DAB); DAB to mobile, portable and fixed receivers."
8. Terrestrial Digital Video Broadcasting (DVB-T) as defined in ETSI EN 300 744: "Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for digital terrestrial television."
9. ISDB family includes System C of Recommendation ITU-R BT.1306, System F of Recommendation ITU-R BS.1114 and IDSB-S of Recommendation ITU-R BO.1408.

system will be used. The most fundamental tradeoff is the basic sub-carrier, or tone characteristics, which involves selection of the number of tones, as well as the cyclic prefix duration.

A key factor in the design of OFDM systems is the size of the transform: the number of separately modulated sub-carriers in each symbol. The FLO physical layer uses a 4K mode (yielding a transform size of 4096 sub-carriers), providing superior mobile performance com-pared to an 8K mode, while retaining a sufficiently long guard interval that is useful in fairly large SFN cells. Robust performance can then be maintained to greater than 200 km/hour. Beyond 200 km/hour, degradation is graceful, creating minimal impact to the overall performance. This is supported by the FLO pilot structure (used for channel estimation), which enables receivers to handle delay spreads greater than the cyclic prefix.

OFDM is a modulation technique in that it enables user data to be modulated onto the tones, or sub-carriers. For each OFDM symbol duration, information-carrying symbols are loaded on each tone. The information is modulated onto a tone by adjusting the tone's phase, amplitude or both. In the most basic form, a tone may be present or disabled to indicate a one or zero bit of information. Either quadrature phase shift keying (QPSK)[10] or quadrature amplitude modulation (QAM)[11] is typically employed. The FLO air interface supports the use of QPSK, 16-QAM[12] and layered modulation techniques. Non-uniform 16-QAM constellations (two layers of QPSK signals) with 2 bits applied per layer are utilized in layered modulation.

Physical Layer Characteristics

Rapid channel acquisition is achieved through an optimized pilot and interleaver structure design. The interleaving schemes incorporated in the FLO air interface simultaneously assure time diversity. The pilot structure and interleaver designs optimize channel utilization without annoying the user with long acquisition times.

10. QPSK is a form of modulation in which a carrier is sent in four phases and the change in phase from one symbol to the next encodes two bits per symbol.
11. QAM is the encoding of information into a carrier wave by variation of the amplitude of both the carrier wave and a 'quadrature' carrier that is 90° out of phase with the main carrier in accordance with two input signals.
12. In 16 QAM 4 different phases and 4 different amplitudes are used for a total of 16 different symbols.

FLO transmitted signals are organized into super frames. Each super frame is comprised of four frames of data, including the TDM pilots, the Overhead Information Symbols (OIS) and frames containing wide-area and local-area data. The TDM pilots are provided to allow for rapid acquisition of the OIS. The OIS describes the location of the data for each media service in the super frame. The structure of a super frame is shown in Figure 4.

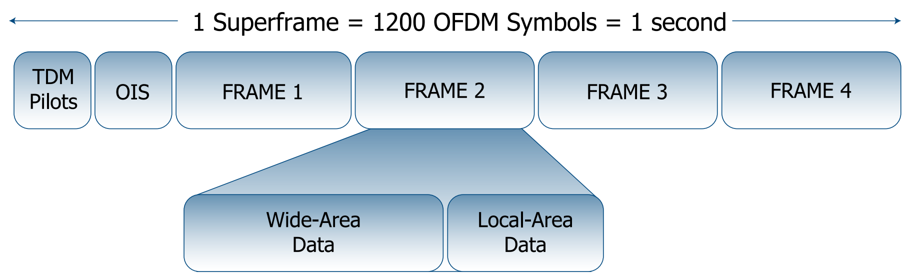

Figure 4: FLO super frame structure

Each super frame consists of 200 OFDM symbols per MHz of allocated bandwidth (1200 symbols for 6 MHz), and each symbol contains 7 interlaces of active sub-carriers. Each interlace is uniformly distributed in frequency, so that it achieves the full frequency diversity within the available bandwidth. These interlaces are assigned to logical channels that vary in terms of duration and number of actual interlaces used. This provides flexibility in the time diversity achieved by any given data source. Lower data rate channels can be assigned fewer interlaces to improve time diversity, while higher data rate channels utilize more interlaces to minimize the radio's on-time and reduce power consumption. The acquisition time for both low and high data rate channels is the same. Both frequency and time diversity can be maintained without compromising acquisition time.

FLO logical channels are used to carry real-time (live streaming) content at variable rates to obtain statistical multiplexing gains possible with variable rate codecs (Compressor and Decompressor all in one). Each logical channel can have different coding rates and modulation to support various reliability and quality of service requirements for different applications. The FLO multiplexing scheme enables device receivers to just demodulate the content of the single logical channel it is interested in to minimize power consumption. Mobile devices can demodulate multiple logical channels concurrently to enable video and associated audio to be sent on different channels.

Error correction and coding techniques

FLO incorporates an inner code and a Reed Solomon (RS)[13] outer code. Each packet contains a Cyclic Redundancy Check (CRC). The RS code need not be calculated for data that is correctly received, which, under favorable signal conditions, results in additional power savings.

As described earlier in the System Overview section, FLO technology supports the use of layered modulation. A given application may divide a data stream into a base layer that all users can decode, and an enhancement layer that users with higher SNR can also decode. Due to the multicast-only nature of the FLO waveform, the majority of devices will receive both layers of the signal, with the base layer having superior coverage and equivalent total capacity mode.

Outer and inner coding is performed independently for the base and enhancement layer, providing adjustment to the relative thresholds of each layer and adjusts the ratio of bandwidths.

Bandwidth Requirements

The FLO air interface is designed to support frequency bandwidths of 5, 6, 7, and 8 MHz. A highly desirable service offering can be achieved with a single Radio Frequency channel. In some regions, the 5 MHz allocations provided for Time Division Duplex (TDD) applications may also be applied to mobile media distribution.

FLO's air interface supports a broad range of data rates, ranging from .47 to 1.87 bits per second per hertz. In a 6 MHz channel, the FLO physical layer can achieve up to 11.2 Mbps at this bandwidth. The different data rates available enable tradeoffs between coverage and throughput.

13. Reed-Solomon codes are block-based error correcting codes with a wide range of applications in digital communications and storage.

Transport Mechanism

FLO incorporates effective means for transporting packets based on content type. IP is used when IP has a quantifiable advantage such as in the delivery of non-real-time content or data (text and graphics). Real-time streaming media is delivered directly to a sync layer that is designed to minimize the impact of lost packets in streaming media. One FLO design objective is to maximize efficiency by eliminating cascading multiple protocols. This results in more capacity being available for media and minimizes power consumption, since receiving fewer total bits conserves power. The FLO transport protocol stack is illustrated in Figure 5 below.

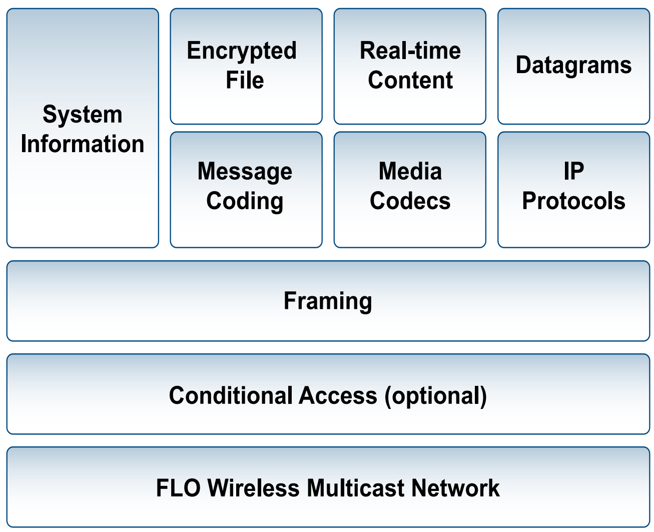

Figure 5: FLO transport protocol stack

Candidate Frequency Bands

FLO can be deployed in a number of frequency bands utilizing various bandwidths and transmit power levels. The relative performance of a given modulation mode is defined by the choice of modulation, turbo, and RS code rates.

The frequency bands suitable for multicast distribution (including FLO technology) are similar to those used for unicast wireless IP and voice. These range from 450 MHz to 3 GHz. The characteristics of these bands for transmission to a device are well understood. A significant difference for video reception is that the device is not placed against the head but held in the hand. This improves the performance in the PCS bands (1900 MHz) by 1-2 dB and in the cellular bands (800 MHz) by 3-4 dB.

For instance, the range of allowable transmission power levels in the United States (U.S.) varies by band, as determined by the Federal Communications Commission (FCC). To maximize coverage area per cell and minimize the cost-per-bit delivered to the user, the design of a network supporting multimedia services benefits from higher power levels than those typically licensed for voice applications. In the U.S. the FCC assigned licenses for 698-746 MHz in 6 MHz blocks for a variety of broadcasting, mobile and fixed services, with a maximum transmit power of 50 kW Effective Radiated Power (ERP).

For each of these bands, the nominal cell diameter supported by a 50kW ERP transmitter 300 meters high is shown in Table 1. The path losses are based on the Okumura-Hata suburban model[14]. It is assumed that an additional external antenna is not desirable or acceptable on the device.

The example of frequency bands from the United States provided in Table 1 shows the bands' relative performance, without consideration of the applied technology. The following assumptions are made:

- Average antenna gain is approximate and includes hand loss.
- Noise Figure is 8 dB.
- Transmit height is 300 meters.
- Receive height is 1 meter.
- Coverage is calculated at 16 dB SNR.
- Propagation model is Okamura Hata suburban.

Frequency (MHz)	ERP (kW)	Average Gain Including Hand Loss	Coverage Area	Area Relative to 716 MHz	Regulation
716	50	-5.4dBi	1937 km2	1	LP UHF TV
788	1	-5.3dBi	153 km2	1/13	Public Service
1672.5	1.2	-4.2d Bi	73 km2	1/26	PCS Like
1992.5	1	-4.1dBi	51 km2	1/37	PCS
2130	1	-4.0dBi	47 km2	1/41	New 3G
2352.5	1.2	-3.9dBi	48 km2	1/40	WCS
2595	1.2	-3.8dBi	43 km2	1/45	LBS/UBS/MBS

Table 1: Potential Frequency Bands for Multimedia Distribution

14. Okumura model was first specified in "Field Strength and Its Variability in VHF and UHF Land-Mobile Radio Service," by Yoshihisa Okumura, et.al., Review of the Electrical Communications Laboratory, Vol. 16, No. 9-10, September-October 1968. Okumura/Hata model is further described in "A Report on Technology Independent Methodology for the Modeling, Simulation and Empirical Verification of Wireless Communications System Performance in Noise and Interference Limited Systems Operating on Frequencies between 30 and 1500MHz", TIA TR8 Working Group, IEEE Vehicular Technology Society Propagation Committee, May 1997.

FLO is being deployed in a 6 MHz block of the lower 700 MHz in the US. This spectrum, as regulated by the FCC, offers significant advantages in terms of coverage per transmitter, which translates to significant infrastructure cost savings. Lowering the average height of the transmit sites to 100 meters decreases the coverage by approximately a factor of 3. The higher frequency bands may require a greater SNR than 16 dB assumed in Table 1 due to the increased Doppler [15].

Comparison with Other Mobile Multicast Media Technologies

A number of technologies address, at least partially, the requirements of mobile multimedia. These technologies are mostly variants or derivatives of an existing digital television broadcast format. This section compares these formats to the dedicated mobile multimedia multicast solution provided by FLO technology. The formats are listed in Table 2.

Format	Description
ISDB-T	Origin: DTV packet data technology (Japan) Modulation/Coding: OFDM, convolutional, Reed-Solomon
T-DMB	Origin: Derivative from European DAB, modified for multimedia (Korea) Modulation/Coding: OFDM, convolutional, Reed-Solomon
S-DMB	Origin: Proprietary format, primarily from Toshiba (Japan) Modulation/Coding: CDM, convolutional, Reed-Solomon
DVB-H	Origin: Derivative from DVB-T (Europe) Modulation/Coding: OFDM, convolutional, Reed-Solomon
FLO	Origin: Qualcomm packet data technology (USA) Modulation/Coding: OFDM and Reed-Solomon

Table 2: Mobile Multimedia Format

All formats utilize OFDM except S-DMB, which is Code Division Modulation (CDM). They also utilize Convolutional coding and Viterbi decoding [16], with the exception of FLO, which has a modern and efficient code. All formats utilize a concatenated Reed Solomon code(s).

15. The Doppler effect is the apparent change in frequency or wavelength of a wave that is perceived by an observer moving relative to the source of the waves.
16. Convolutional codes are widely used to encode digital data before transmission through noisy or error-prone channels. During encoding, k input bits are mapped to n output bits to give a rate k/n coded bitstream. At the receiver, the bitstream can be decoded to recover the original data, correcting errors in the process. The most popular algorithm for maximum-likelihood decoding is the Viterbi Algorithm.

Various factors impact the performance of a mobile multimedia format. The most significant of these are listed in Table 3 (information on non-FLO formats are based on public sources, including those listed in the References section). FLO has effectively addressed all of these key factors, outperforming all competitive formats in the mobile handheld environment, and providing key power saving features. FLO delivers 3-5 db better performance than any other comparable technology. This is because FLO technology was designed first and foremost for the delivery of mobile multimedia rather than being a subset or modification of an existing broadcast format.

Format	Frequency Diversity	Time Diversity	Stat Mux Gains[a]	Time Domain Power Reduction[b]	Frequency or Code Domain Power Reduction[b]	Performance Relative to FLO at 1 bps/Hz
ISDB-T	Poor 430kHz	0.5 sec.	None	No	Yes	-3 to -4 dB
T-DMB	Fair 1.5MHz	<<0.25 sec.	Poor	No	No	-3 to -5 dB
S-DMB	Excellent 25MHz	3.5 sec.	Good	No	Yes	N/A[C]
DVB-H	Good 5-8MHz	~0.25 sec	None	Yes	No	-3 to -4 dB
FLO	Good 5-8MHz	~0.75 sec.	Good	Yes	Yes	0 dB

Table 3: Technical Parameters and Performance

a. This refers to the gains realized by encoding real-time media under bit control of a statistical multiplexer that allocates bandwidth according to content need utilizing variable bit rate video and or audio codecs.

b. Selective access to desired content (if the format is designed such that a device can access the desired data of interest and turns its receiver off) is critical to power efficiency and a key feature to a successful design. Selective access may be achieved in both time and frequency domains.

c. S-DMB cannot achieve one bit per second per Hz.

The technical performance of a format is only one aspect of the user experience.

Additional User Experience Features

Table 4 lists a number of significant features of the individual formats and the implications for the user.

Format	Average Channel Switching Time	Video Watch Time With 850 mAhr Battery	Per Channel QOSa	File Download	Local- and Wide-Area in Single RF Channel
ISDB-T	~1.5 sec.	unknown	Yes	No	No
T-DMB	~1.5 sec.	~2 hours	Possibly[b]	Possibly	No
S-DMB	~5.0 sec.	~1.2 hours	No	No	No
DVB-H	~5.0 sec.	Goal ~4 hours Demo ~2 hours with 1600 mAhr battery	No	Possibly	No
FLO	1.5 sec.	Goal ~3.8 hours (at 360kbps)	Yes	Yes + integrated Clip Casting solution with memory management, conditional access and subscription model	Yes

Table 4: Service Experience and Features

a. Quality of Service in a multicast context is the ability to adjust the Packet Error Rate (PER) on a per-application / service basis. This optimizes capacity for a service mix that includes multiple application types e.g. media, games, software downloads

b. Unequal error protection may be applied at the stream level

The correct balance of technical performance parameters is reflected in the user experience. The ability to change channels quickly is always important to the user. Watch time should be comparable to talk time, if not longer, so as to not compromise the functionality of the device. The capacity of the system is optimized when per application QOS is available in a network. A mix of both real-time and non-real-time media provides the best overall user experience. The delivery of non-real-time content allows immediate access to content such as weather or news summaries by topic while real-time streaming services support live events such as sports. The ability to support both wide-area and local content within a single RF carrier allows an operator to maximize the value of the available spectrum through the flexible allocation of channels.

Additionally, the use of layered modulation, as described the System Overview section, is a unique feature of FLO technology. It provides better coverage (up to 3 db incremental gain) and services of high quality, especially video, which requires significantly more bandwidth than other multimedia services.

Implications to Service Providers

The selection of a multicast technology can have a strong influence on the costs of providing services. A number of factors help determine the cost:

- Number of infrastructure sites that are required.
- Total spectrum required to support a defined channel line up.
- Total number of transmitter assemblies required to achieve a service line up.

Table 5 shows the relative costs of utilizing the various technologies listed in Table 2. This comparison assumes that each system has the same link margin, which forces the capacity constraints. The table attempts to target 20 real-time services at 300kb/sec per service; however, due to structural limitation, some formats cannot achieve the desired link margin at the specified bit rate. In those cases, the product of average bit rate and number of services is held constant.

Format	Channels Per Transmitter	Infrastructure Costs for 20 Channels	Channels per MHz	Required Spectrum for 20 Channels
ISDB-T	13 channels, 6 MHz ~ 230kbps each	~2X	~2	12 MHz (26 lower quality channels)
T-DMB	3 channels, 1.5 MHz ~ 250kbps each	~4-6X	~2	10.5 MHz
S-DMB	~20 channels, 25 MHz	Broadcast satellite plus terrestrial repeaters	<1	25MHz
DVB-H	9 channels, 6 MHz ~ 300kpbs each	~2X	1.5	12MHz
FLO	20 channels, 6 MHz ~ 300kbps each	Reference (1X)	>3	6MHz

Table 5: Required Infrastructure for Comparable Service

This analysis shows that, due to the superior efficiency of the FLO air interface in the areas of Packet Error Rate (PER) performance, protocol efficiency, and the application of layered service and modulation, FLO technology can deliver equivalent or superior service with roughly half the spectrum and less than half the infrastructure. The implications for the user and operator are significant relative to the cost and breadth of services that can be delivered.

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Conclusion

With FLO technology, the broad delivery of wireless multimedia services is now more economical, more efficient, and more accessible than ever before. FLO technology was designed from inception to meet global market demands for wireless multimedia services. The result: wireless subscribers can now have greater access to better multimedia services.

Qualcomm's development and implementation of FLO technology via a single frequency FLO Network provide the critical link between technical feasibility and economic viability, offering wireless operators an excellent delivery mechanism for providing multimedia content to their subscribers. FLO technology is designed to work in combination with the existing cellular data network to drive additional demand through new innovative services—resulting in higher revenues.

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FLO Technology Overview
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