Advanced Optical and Digital Architectures for Video-On-Demand

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Abstract

In the future an increasing amount of video content will be provided to the cable subscriber as an on-demand service rather than a broadcast service. This advanced service can be expected to become a very significant portion of the revenue stream for cable operators.

Historically the high costs of video-on-demand (VOD) have discouraged significant deployment. The falling costs of computing power and digital hardware, combined with innovative hybrid fiber-coax (HFC) transport techniques such as dense wavelength division multiplexing (DWDM), are now making the business case much more appealing.

In this paper we will review how one can centralize the video server hardware in the headend and use DWDM to transport the digital video streams in 'on channel' QAM256 format out to the hubs. Once at the hubs, the VOD channels can be easily combined with the broadcast content and then routed out to the subscriber. The paper will review the technical issues, performance, and approximate costs of a 16 and 32 wavelength DWDM system for VOD transport.

We will also review the latest technical developments in the area of digital stream manipulation required for successful, low-cost VOD deployment: PID filtering and program assignment, DVB/Simulcrypt scrambling, conditional access provisioning and QAM modulation. Particular emphasis will be placed on how this is implemented in an open-standard configuration, taking into account OpenCAS and other standards-based initiatives.

Several such systems are in deployment in trials worldwide. In the last section of the paper we will review the deployment currently underway by Telewest in Britain.

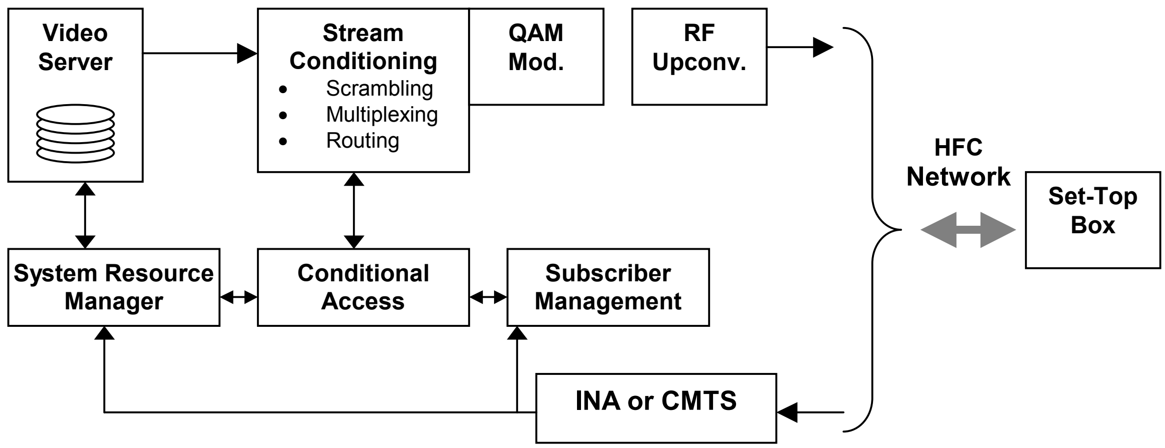
1. A VOD System: The Building Blocks

Before delving into the detail lets first review the overall structure of a VOD deployment. A VOD deployment over an HFC network consists of several functional blocks. Figure 1 shows the functional blocks in a graphical fashion.

From the perspective of the operator it is naturally desirable to implement these functions in the lowest cost and most reliable fashion. One key aspect of a cost-effective system is the use of open standard interfaces between the functional blocks. In this way it is possible to implement best-of-class components, in particular such items as the servers, the interactive network adapter (INA), and the conditional access.

Also, by grouping certain functions onto a single circuit board it is possible to dramatically reduce cost and size. In particular an attractive option is to group the scrambling, multiplexing, and QAM

Figure 1: The building blocks for a VOD system.



modulation together in a single device. This is illustrated in figure 1 by the combined box titled 'stream conditioning' and the smaller adjacent box for QAM modulation. The stream conditioning is covered in section 8.

The transport function is covered in section 4, 'Server Location and Stream Transportation Options'.

2. Cost Goals and the Financial Model

VOD is a service with great strategic competitive advantage for HFC operators. Custom video requires a large amount of narrowcast bandwidth capacity – bandwidth that HFC networks can provide significantly more cost-effectively than competing technologies such as direct broadcast satellite, or twisted pair telephone line. It is also a service with well-known demand – at least to the extent that one can extrapolate from consumer behavior at the local video rental store. It is no surprise that VOD is high on the list of new services that the leading US cable operators are looking to deploy.

However, for VOD to have wide deployment it must provide a return on investment that is compelling when compared to alternative investment options available to the HFC system operator. The key parameter to determine in any discussion of VOD architectures is the delivery cost per stream of video. The 1998 paper "Video-On-Demand, The SeaChange Business Model" [1] outlines a useful financial model for VOD delivery. In that model the target price for the various building blocks includes $350 per stream for the server, $300 per stream for the combined functionality of scrambling, multiplexing, QAM modulation and RF upconversion, and $200 per stream for the transport. Given these costs the Seachange business model shows a return on investment time of less than 18 months.

As we will see in the following sections of the paper the use of open standard conditioning combined with DWDM

[1] "Video-On-Demand, The SeaChange Business Model", 1998, Yvette Gordon, SeaChange International, www.schange.com

transport enables these cost targets to be met, and in fact exceeded.

3. Server Location and Stream Transportation Options

The HFC network operator has two options for server location – the hub or the headend. . Although both options are valid, and both are used by various operators around the world, we believe that there are several advantages to centralizing the equipment in the headend. The three main options for location of the VOD equipment are shown in figure 2.

Option 1:

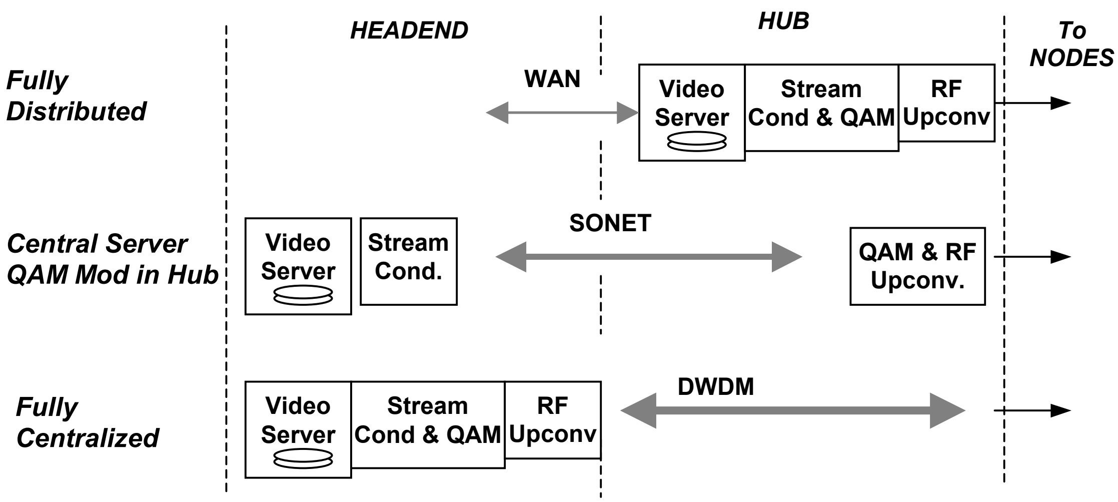
Locate the servers and conditioning equipment in the hub. Use a low or moderate speed Wide Area Network (WAN) to update the servers with the latest content. This minimizes transport costs but has the disadvantage of requiring significant hub space and also requires at least two servers per hub for redundancy.

Option 2:

Locate the servers in the headend, transport the video streams from the headend to the hub using a high quality of service (QOS) baseband digital transport such as SONET or SDH, and place the QAM modulation and RF upconversion in the hub. By centralizing the servers one can minimize the server capacity required – from both the aspect of coping with peak demand rates, and from the aspect of providing a fully redundant system.

Option 3: Locate the servers, QAM modulation, and RF upconversion functions in the headend and move the video streams to the hub, or through the hub, via DWDM transport. In addition to maximizing server efficiency by centralizing the server, this approach also transports the video in set-top ready format from the headend and therefore requires minimal or no processing at the hub.

Figure 2: Options for Server Location and Transport



4. DWDM Transport: Technical Issues

DWDM provides cost effective, high capacity transport in QAM format from a headend to a hub with minimal fiber use. The general architecture is shown in Figure 3 below. Figure 3 illustrates the structure in a ring architecture where one drops off a couple of wavelengths at a hub location and sends the remaining wavelength on the subsequent hubs on the same single fiber. It is straightforward to modify this for a star headend-hub architecture as the optical drop now becomes a terminal optical demux.

The diagram shows 10 QAM modulated channels upconverted and RF combined into a block of channels which then drive one of the ITU grid DWDM transmitters. For consistency throughout the paper the diagram shows 10 RF channels allocated for VOD service.

Once at the hub there are two main techniques for continuing the transport to the node.

1) Receive the optical DWDM signal at the hub and electrically combine with the broadcast signal at the hub. This approach could be used if the operator has an existing 1310 distribution network out of the hub.

2) Unbundle the desired DWDM wavelengths at the hub and optically combine the signal with the distribution network. This arrangement is shown in Figure 5. This architecture is very similar to the general DWDM architecture widely deployed by AT&T BIS for their advanced internet and telephony service.

DWDM has been extensively tested and deployed for the transport of QAM modulated signals. 8 wavelength systems have seen significant recent use in the US and now in Europe. Crosstalk can be kept to a minimum by keeping fiber launch powers at a moderate level plus proper attention to transmitter and filter properties.

16 wavelength systems are also available for deployment. We have tested a 16 wavelength DWDM system over a 100 Km fiber link carrying QAM256. The system is shown in Figure 6. With received power per wavelength of greater than –10 dBm we observed SNR of greater than 40 dB and BER on the QAM256 of better than 10^{-8} without forward error correction.

Figure 3: DWDM transport architecture

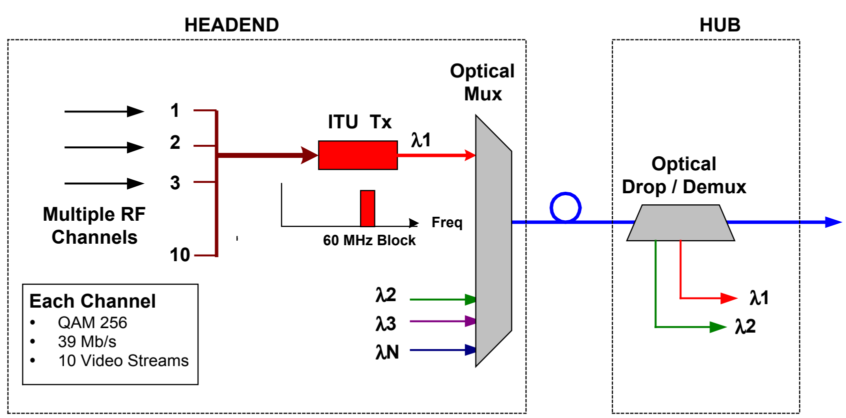


Figure 4 Drop at the hub and RF combine with the broadcast signal

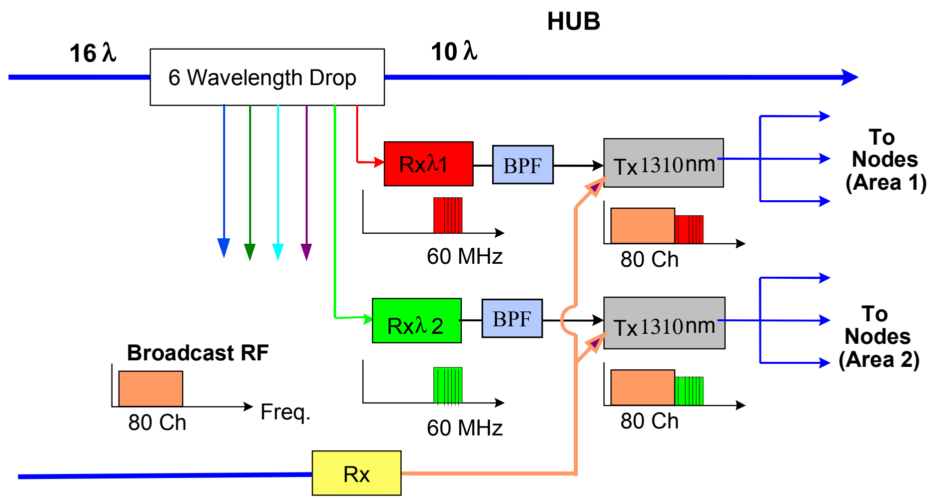


Figure 5 Drop at the hub and optically combine with the broadcast signal

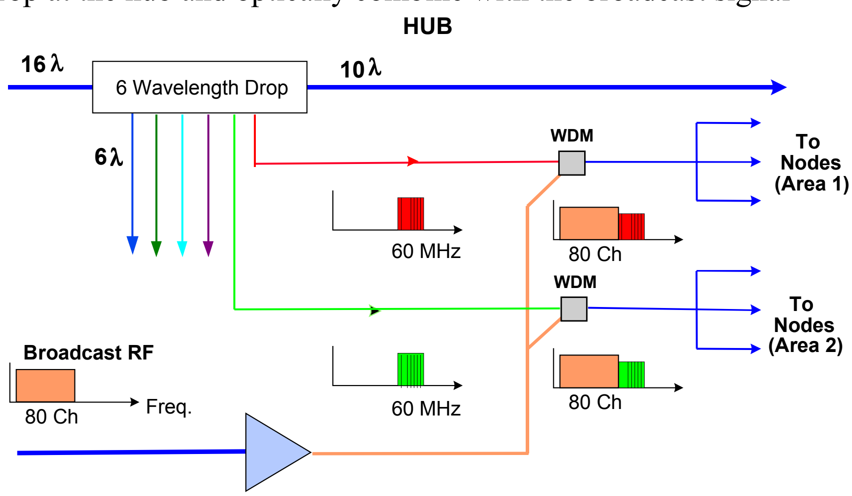
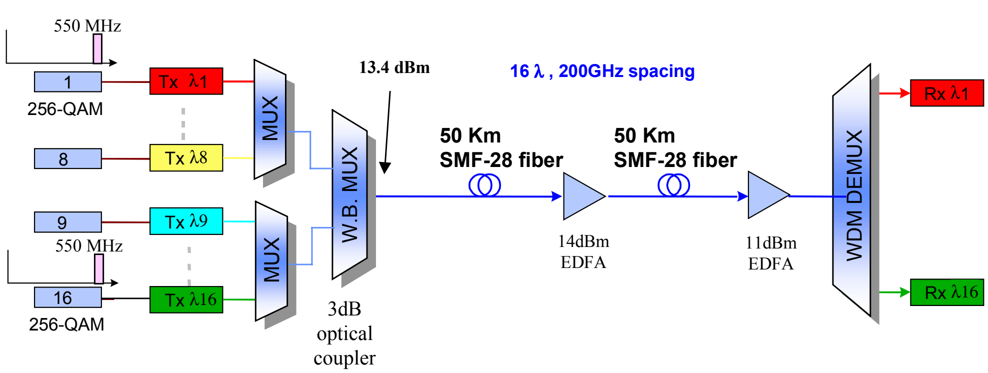


Figure 6 Experimental set up for 16 Wavelength DWDM test over 100 Km with QAM256



5. DWDM Transport: Costs

Optical component costs are falling rapidly in this competitive and rising volume world of optical transport. DWDM costs have been falling at faster than 20% per year and we have no reason to expect this trend to change in the near future. The costs given below are typical at the time of writing but for operators considering this approach we recommend that you contact preferred vendors for latest pricing.

The 'per stream' cost of DWDM transport is easily calculated. First determine the cost of a point to point transport for a single wavelength. A DWDM directly modulated transmitter costs around $5000 including platform and power supply. The average cost for the single port of an 8 or 16 wavelength mux or demux is $800, i.e. $1600 for a Mux and demux pair; and receivers are in the range of $1800. Total point-to-point cost per wavelength is therefore ~ $8400.

The transport cost per stream is a very simple function of QAM format and the number of channels allocated per wavelength. For QAM256 format we assume that, given a typical per stream bit rate of 3.6 Mb/s, one can carry 10 streams per RF channel. With 10 channels allocated to VOD each wavelength would therefore carry 100 streams. The cost per stream is then $8400/100 or $84 per stream. Table 1 below shows the scaling in cost per stream for several other likely combinations.

It is worthwhile comparing these costs with a typical SONET or other high quality of service baseband transport –as would be used in option #2 described in section 4. A single OC12 terminal currently costs of the order of $40,000 to $60,000 with the lower prices coming from newer companies in the market. Therefore even in the best case a point to point baseband link with 622 Mb/s capacity will require two terminals and will cost in the range of $80,000. Using the same typical per stream bit rate as above this capacity corresponds to 170 video streams, or $470 per stream. This SONET cost is significantly higher than the equivalent DWDM cost.

6. The Benefits of a Standards-Based VOD Solution

One key aspect of a cost-effective system is the use of open standard interfaces between the functional blocks shown in Figure 1. In this way it is possible to implement the most appropriate product for the specific cable operator, in particular such items as the servers, the interactive network adapter (INA), and the conditional access.

Table 1: DWDM Transport Cost Per Stream vs Channel Allocation and QAM Format (NTSC)

	Number of Channels Allocated for VOD				
DWDM Cost Per Stream*	**2**	**4**	**6**	**8**	**10**
QAM 64 (7 streams per Ch)	$ 600	$ 300	$ 200	$ 150	$ 120
QAM 256 (10 streams per Ch)	$ 420	$ 210	$ 140	$ 105	$ 84

**Assume cost per wavelength of $8400*

Historically most of the early VOD solutions have been closed systems with perhaps some limited choice of video servers. However if we look at the functions outlined in Figure 1 we note that for many of the functions there are several different vendors offering products with different cost-performance characteristics. Due to the disparity of the core technologies, different vendors are best qualified to provide the individual components. Working with partners who are experts in these core-competencies ensures that the VOD operator is taking advantage of the latest technology advances to drive down the cost.

The key providers of these VOD system components are not only committed to providing the optimum technological solution at the lowest cost, they are also committed to working together to provide an open-standard seamless solution to the network operator. These leading vendors are working together both in the field with real deployments (as we shall see in the example below) and on standards bodies to ensure that in future deployments interoperability is maintained. For example, OpenCAS is a working group established to define standards such that vendors can achieve interoperability between conditional access and content collection subsystems (scheduling, encoding, multiplexing, scrambling) to speed system integration and reduce risk. All the leading vendors are key contributors to this forum and at the present time their recommendations for the interface standards have been submitted to the SCTE.

7. Stream Conditioning

By stream conditioning we are referring to the combined functions of scrambling, PID filtering, and multiplexing. In a broadcast environment the number of unique video streams is low therefore the cost of stream conditioning is not excessive. Historically, the functions – multiplexing and routing, scrambling, QAM modulation and RF upconversion for a VOD deployment, have been handled using equipment tailored for a broadcast system. This is inefficient both in cost and space allocation. A system such as this can quickly grow to occupy most of the space in a headend.

Today, equipment has been designed specifically for the stream conditioning of narrowcast services. This technology dynamically selects program services from the high-speed asynchronous serial interface (ASI) from the media server, automatically routing the services to a QAM channel and the associated RF upconverter. Every time the media server adds or drops a service, the associated service information and program information are updated. The content needs to be scrambled prior to transmission. This functionality has been incorporated in the stream conditioning.

Today the cost-per-stream for the stream conditioning plus QAM modulation and RF upconversion is approximately $450. In the very near future the cost-per-stream for this combined functionality will be driven to under $300, meeting the target set in the SeaChange model. This can be accomplished by combining the stream conditioning, QAM modulation, and RF upconversion for several RF channels on to a single circuit board. The resulting cost and space savings will continue to strengthen the business case for VOD.

8. Current Deployments

This VOD architecture we have described above has recently been deployed by

Telewest in Britain and is about to go online at the time of writing in mid March 2000. The Telewest deployment makes use of the open standard stream conditioning approach we show in Figure 1 and also uses the DWDM transport as shown in Figure 4.

Here are some key technical details. The initial deployment covers 337,000 homes passed. Each serving area contains about 8,400 homes passed and there are 5 channels allocated for VOD service in the delivered spectrum. As this is PAL format, each of the five channels is carrying 9 video streams at 3.6 Mb/s, in 8 MHz of spectrum using QAM 64 modulation. Therefore, the system delivers 45 unique VOD streams per 8,400 homes passed serving area. This capacity is sufficient for the present customer and digital box take rates, however it is expected that the capacity will be scaled up as demand rises..

In keeping with an open-standard approach many of the key functions are provided by different vendors: the media servers are provided by both SeaChange and nCUBE; the scrambling, multiplexing, and QAM conversion are provided using the VSG card from Harmonic; conditional access is provided by NagraVision and the set-top boxes from Pace.

NTL, the other major operator in Britain is also deploying a DWDM architecture. For NTL the primary driver was to enable transport of the out-of-band signaling to the specific serving areas, however going forward NTL intend to make use of this narrowcast capability and offer VOD and other interactive services. NTL in some franchise areas have a 1550 to the node architecture and are using the optical combining method shown in Figure 5. It is worth noting that this optical combining is performed in the streetside cabinets rather than at the hubs.

British cable operators have historically faces intense competition from satellite service providers. By offering a significantly differentiable product in the form of this true VOD service, Telewest expect to significantly improve their competitive position, increase their customer take rate, and increase their revenues per subscriber.

9. Summary

Video-On-Demand is service with a key competitive advantage for HFC operators. New technologies with lower costs enable operators to deploy systems today that provide this competitive edge with an immediate return-on-investment. The business case is there.

In this paper we have reviewed some of the new directions that are enabling this business model.

- Combining several key video stream conditioning functions into a single low cost unit
- Using an open-standard approach which enables the operator to choose the latest and most cost-effective products from a competitive environment
- Using DWDM technology to provide low cost and flexible transport of VOD streams to the serving area

Finally, we reviewed the current deployment by Telewest of a VOD system which has incorporated all of these features discussed above. Stay tuned!

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