



Protecting MPEG-2: FEC schemes in DVB-C, S, T

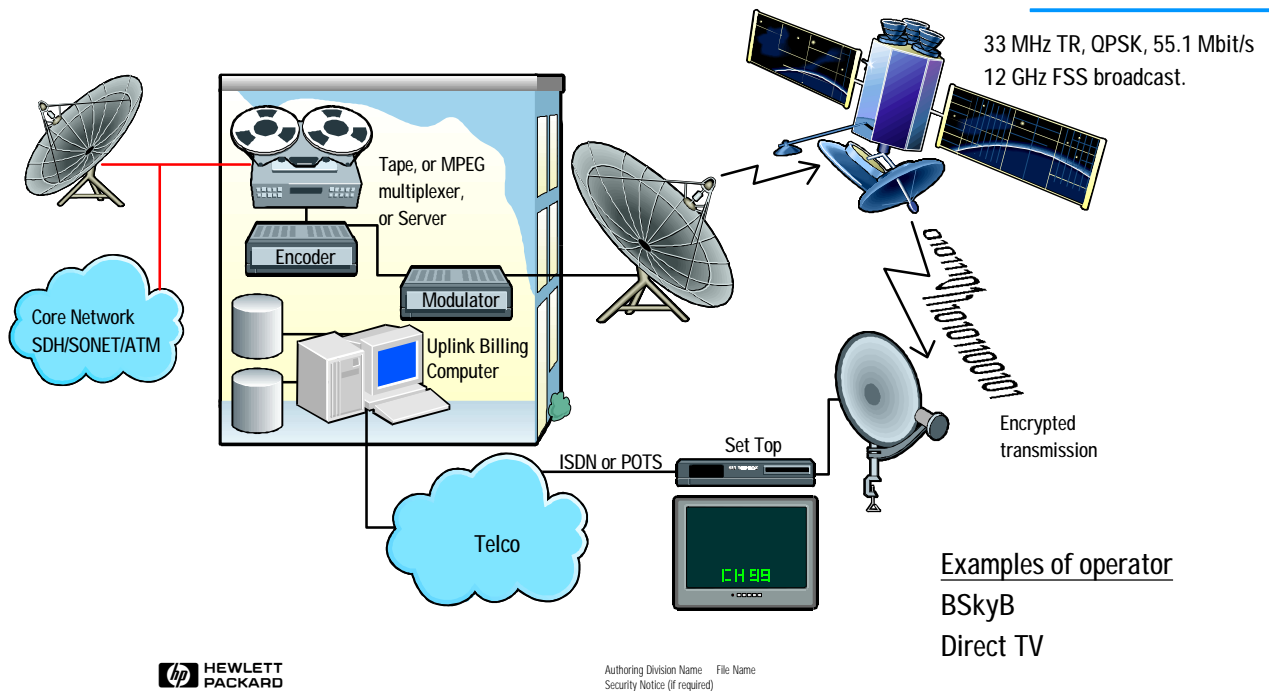


This tutorial introduces the general ideas behind protecting the MPEG-2 transport stream in broadcast systems. As discussed in another tutorial in this series, MPEG-2 has achieved efficiency, but the price is fragility and great susceptibility to errors.

After exhaustive testing, it was realised that a BER of 10^{-11} was required, if MPEG-2 quality of service is to be guaranteed. This is referred to as Quasi-Error-Free (QEF) transmission. To achieve this, Forward Error Correction needs to be added to protect the MPEG-2 transport stream. Depending on which transmission system is used, a different FEC scheme is required.

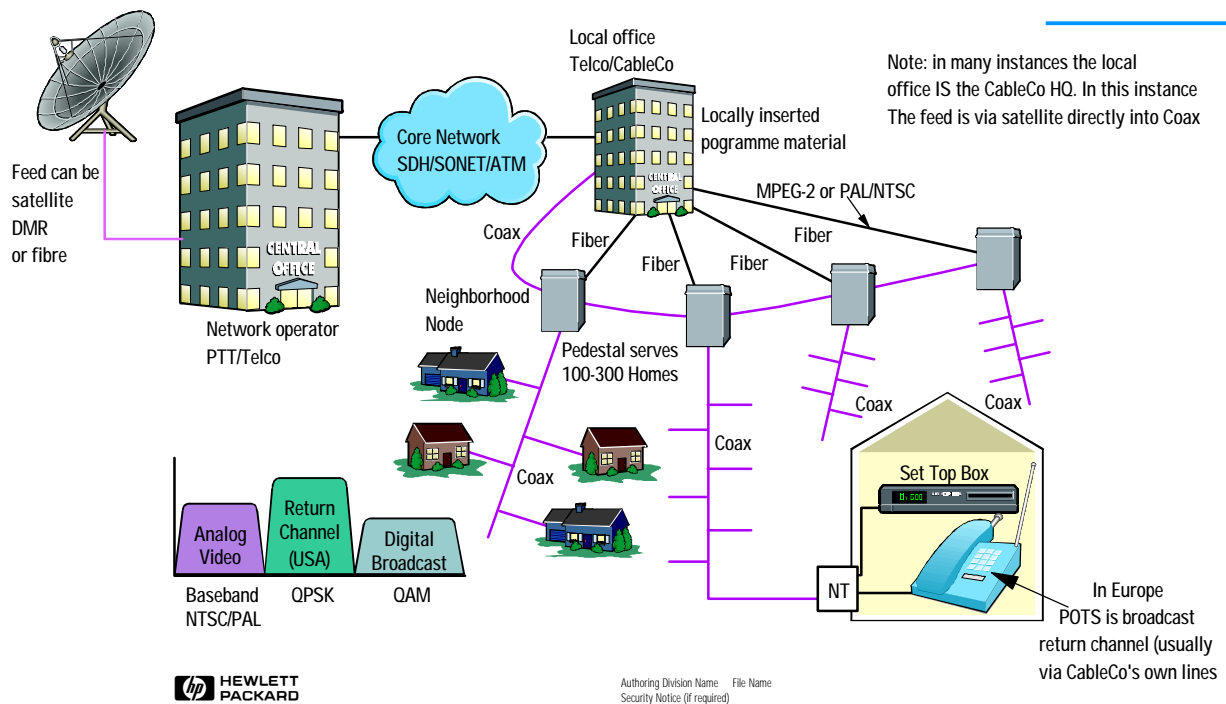
In this paper we first summarize the problems associated with the four main transmission systems. And then discuss the FEC's used in these delivery systems.

Direct Broadcasting Satellite



- Programmes delivered to satellite uplink, SI added and broadcast to the Home
- Using 33 MHz transponder and digital broadcast, gives 8 equivalent quality digital tv channels (38.01 Mbit/s), to one Analog channel/transponder.
- This allows DBS to supply more programming at a lower cost.
- DBS operators will take their programming from many suppliers, put this into their own multiplex, and add their own Service Information (SI).
- Delivery to the uplink site does include PDH/SDH transmission.
- Digital satellite broadcast can be either to a head-end or direct to home.
- The key transmission channel problem for satellite is the sheer distance involved. The attenuation is huge. In addition, precipitation can cause localised fade, and localised shadowing of satellite dishes can be a problem.
- The FEC for satellite's main purpose, is to improve the BER produced by the very low carrier to noise at the satellite receiver.
- The MPEG-2 TS will be checked at the point its purchased from the supplier, and most likely after it has been multiplexed in with other video signals.
- Conditional Access/Encryption control a key issue.

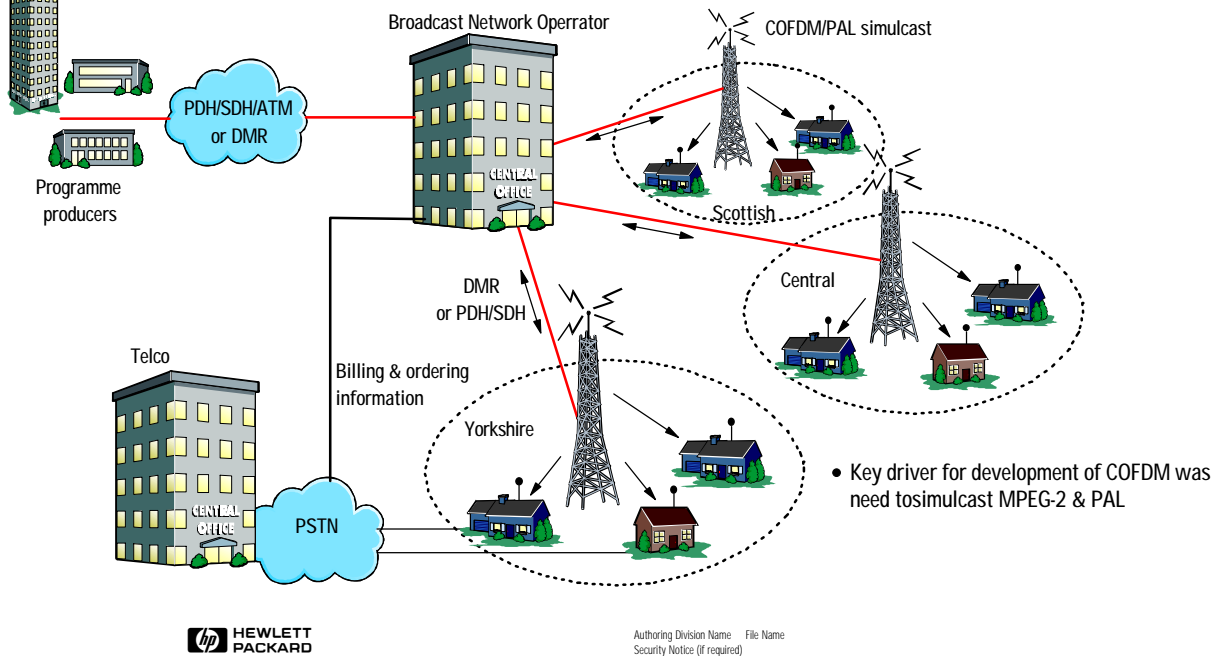
CableCo/Telco architectures



- Hybrid Fibre Coax networks have been a reality for years. Analog tv is delivered over optical networks to regional coaxial networks. The extension to MPEG-2 transmission was logical. This approach is being implemented in Europe.
- The DVB specification for transmission of MPEG-2 over fibre uses ATM AAL-1 over PDH or SDH: AAL-1 as it contains a Reed Solomon FEC.
- At regional sites, MPEG-2 is extracted from the fibre and 64-QAM modulated, to produce a 6.9 MBaud signal, inserted into 8 (6 for NTSC) MHz channels.
- 64-QAM is used, since all coaxial networks are 8 MHz channelised. With the useful bit rate from a satellite being 38.1 MBit/s, this optimizes channel bandwidth usage. Giving 6.9 Mbaut of information delivery.
- The key issue for digital cable is the ability to transmit digital and analog tv in adjacent channels: without one degrading the quality of the other.
- The key channel impairments that can occur are predominantly caused by micro-reflections, non-linearity problems in the network, and interference from adjacent analog channels: which typically are at a much higher power.
- MPEG-2 QoS testing will occur at the satellite headend, at any point where the Service Information is changed, and before insertion into the coaxial plant.
- Attenuation is not as great a problem in HFC delivery as in satellite. But the potential for errors due to faulty components in the network is far greater.

DVB transmission architectures

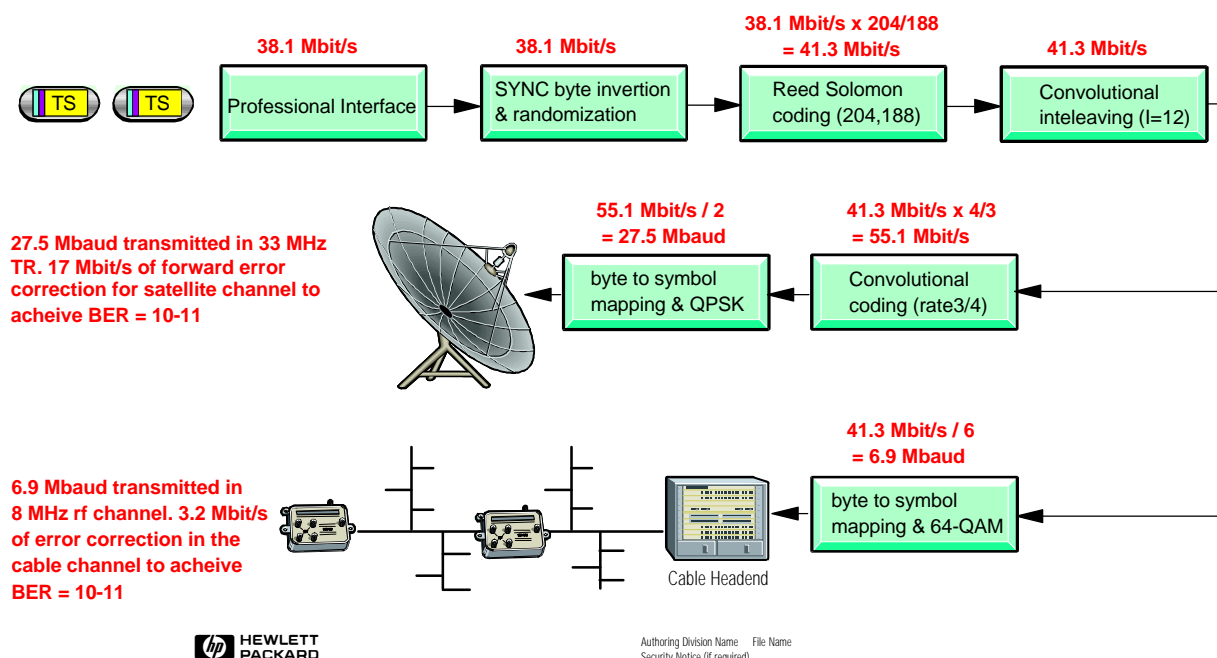
Broadcast delivery of MPEG-2 to the consumer



- A hypothetical broadcast system for the United Kingdom is shown.
- COFDM allows simulcast of PAL & MPEG-2 over Single Frequency Networks.
- Programme material is passed from production houses to the broadcast network operator, who then feeds the tv multiplex to the regional transmitters.
- Digital Microwave Radio feed is used now, this will probably migrate to SDH.
- Back-channel is via PSTN, and controlled by a Telco.
- COFDM is a spread spectrum technique, highly resilient to impairments and able to operate at significantly lower power to PAL transmissions.
- COFDM uses a 2000 carrier (UK) multiplex, onto which MPEG-2 is QAM modulated. an 8000 carrier system is planned for the future.
- Greater QAM order, greater baud rate. More carriers, more impairment resilience.
- For US change PAL to NTSC, COFDM to VSB.
- MPEG-2 QoS must be verified at the point it is extracted from the transmission network, and inserted into the COFDM modulator.
- The terrestrial transmission environment is probably the harshest. With high levels of multipath interference, potential shadowing, weather interference etc.

Protecting the MPEG-2 transport stream

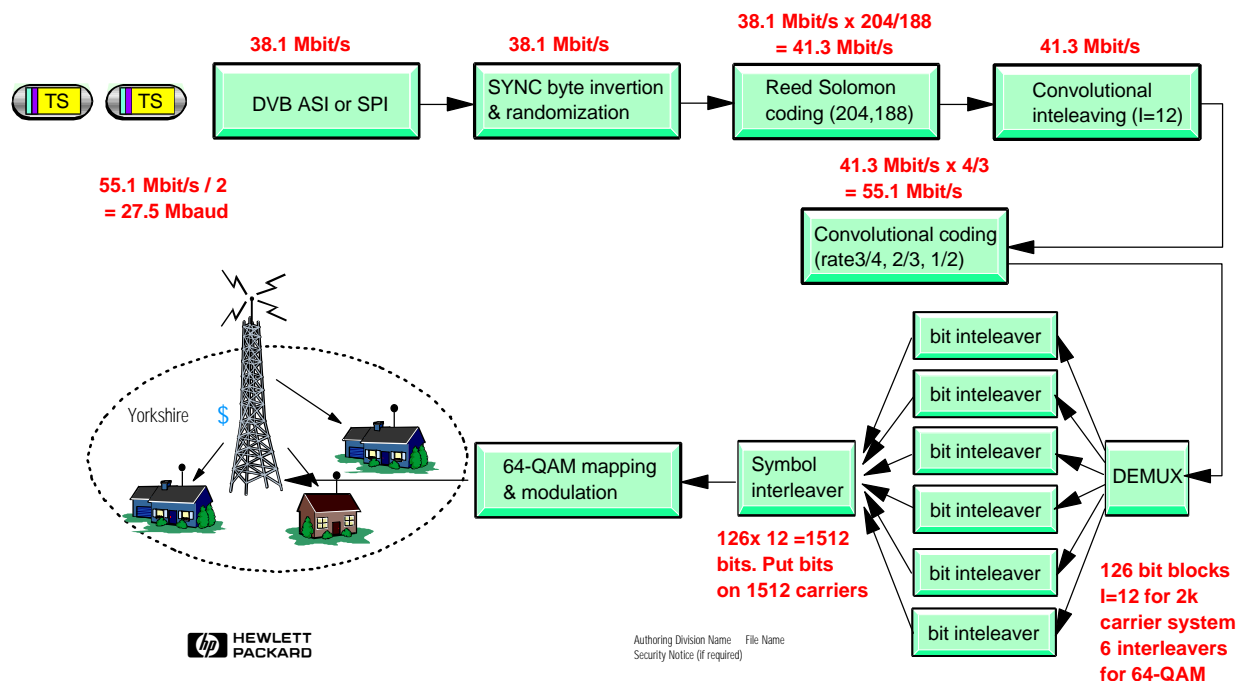
DVB-S/LMDS & DVB-C/MMDS FEC's.



- 188 byte long TS packets are inserted into the Forward Error Correction system.
- The QoS requirement, is to meet a BER of 10⁻¹¹ at the Input to an MPEG decoder. The RS FEC can achieve this with an input BER of 10⁻⁴.
- Every eight TS packets, the SYNC byte is inverted. Using this as a start point, blocks of eight packets are randomised for energy dispersal. Note the SYNC byte stays the same.
- Using the SYNC byte as a reference, a 16 byte long RS code is added to the end of the TS packet. This can correct two errored bytes per TS packet.
- To protect against bursty errors, an interleaver is used to take 12 TS packets in parallel, and feed a byte at a time into a cyclic buffer. Again the SYNC byte is used as the start reference.
- For the satellite system 10⁻⁴ is not good enough, additional coding is required to bring the BER down to 10⁻¹¹. A viterbi convolutional coder is used to do this
- For Cable system byte to symbol mapping takes 6 bits at a time to create the 6x6 matrix required to generate 64 constellation states.
- For satellite system 2 bits are taken at a time to create a 2x2 matrix for QPSK.
- This is a lot of very heavy coding. and puts us well down the BER curve.
- A small change in C/N results in a large change in BER: the brick wall effect. So if a system is close to its threshold BER, a small change in impairment level could kill the system.

Protecting the MPEG-2 transport stream

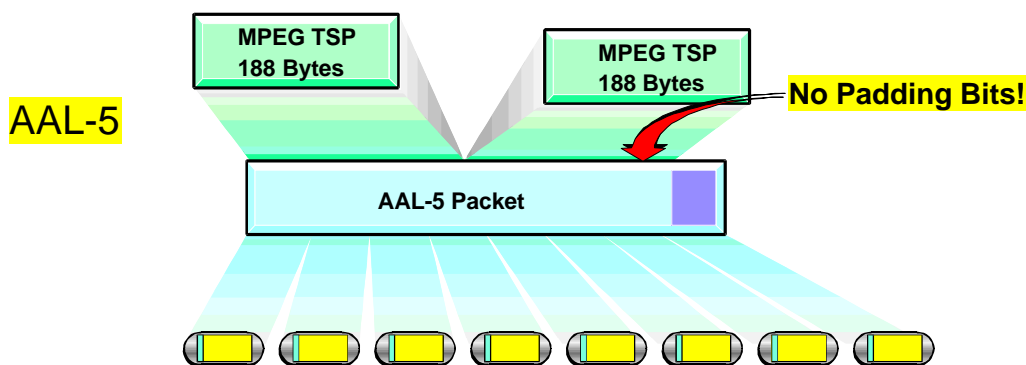
DVB-Terrestrial FEC/modulation



- Again 188 byte long packets are fed into the FEC. The first section of the FEC is identical to the satellite system. But with variable rate convolutional coding for different services.
- Inner interleaver splits stream into 2, 4, 6 streams (for QPSK, 16 or 64 QAM).
- Interleaving block size is 126 bits, I = 12 for 2k system = 1512 bits.
- Symbol interleaver takes the 1512 bits from the interleaver and QAM modulates them on each of the 1512 carriers in the 2k system.
- This digital stream is then passed through a D/A and upconverted into the appropriate output band.
- The system has very impressive error protection capability. It is a form of frequency domain spread spectrum, and can operate at lower power than PAL transmissions in the same frequency band.
- The 2k system is a compromise to allow early introduction, at low enough stb cost. But it cannot create a wide area SFN. This needs the 8k system.
- The first system to go on line is the UK system (end 1997).

Protecting the MPEG-2 transport stream

MPEG-2 protection in ATM: Use of AAL-5 for interactive networks

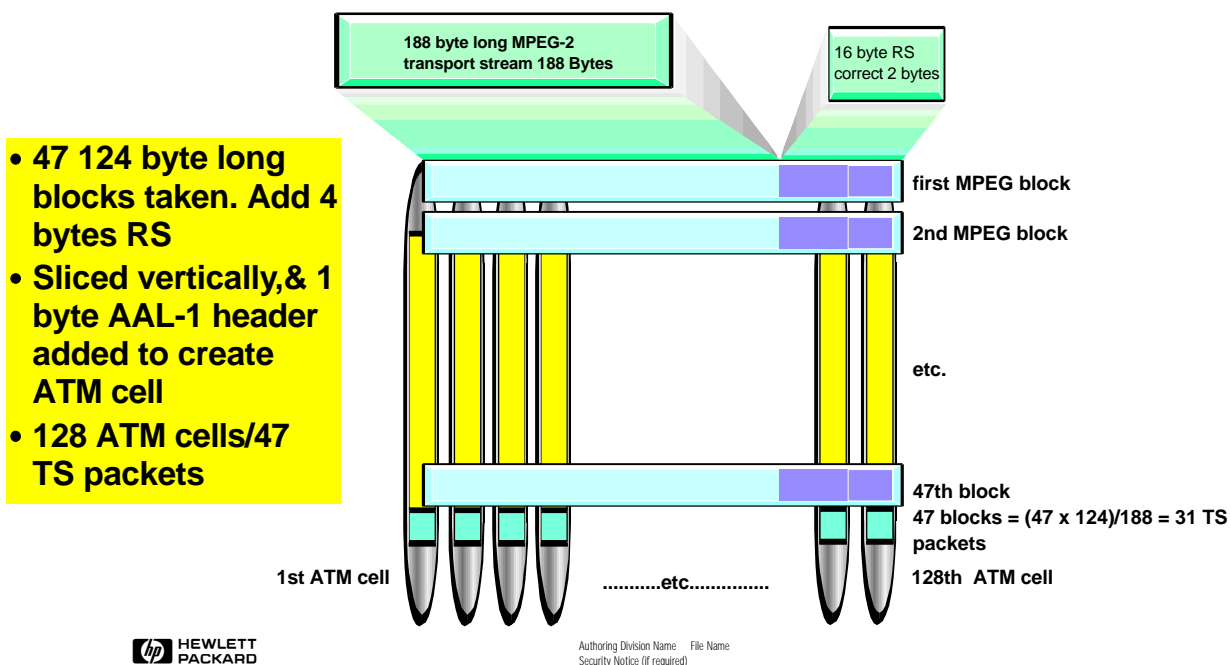


- Ideal for multi-cast situations like VOD.
- But no error correction: bad for broadcast

- This diagram shows how MPEG Transport Stream packets are mapped into AAL-5. Although it is shown that AAL-5 carries two TSP's per AAL-5 frame, vendors are sometimes using one TS packet per AAL-5 frame, and using padding bits.
- $8 \text{ cells} \times 48 \text{ bytes/cell} = 384 \text{ bytes}$
- $2 \text{ TSPs} = 188 \text{ bytes} \times 2 = 376 \text{ bytes}$
- $376 \text{ bytes} + 8 \text{ byte AAL-5 Trailer} = 384 \text{ bytes with no padding bits!}$
- This approach has been adopted for VOD systems, and is being used in the US.
- The issue for Europe has always been guaranteeing quality of service.
- In AAL-5 there is no error correction capability, this is a serious issue in a fragmented infrastructure, where no one vendor controls the network. And so cell congestion could cause cells to be dropped. If the dropped cell contains the SI?
- AAL-1 is a constant bit rate, point to point system: with error correction capability: Which is why its preferred for broadcast applications.
- AAL-5 is better when you have a multi-point to multipoint situation, and can control the overall cell rate. Which is effectively what you've got in VOD.

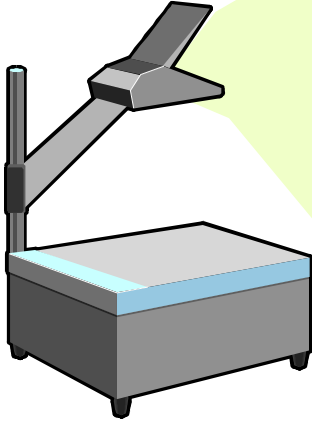
Protecting the MPEG-2 transport stream

Protecting TS in Telecoms networks: The DVB AAL-1 system for PDH/SDH



- This is the approach adopted by Europe to error protect MPEG-2 in a telecommunications transmission system.
- The AAL-1 cells are inserted as per G.804 into the PDH/SDH hierarchy.
- This system is designed for use where no one operator controls the entire link.
- This system is used to provide BER protection upto 10^{-4} . That is as much as is available for coaxial cable systems. And is considered enough for PDH/SDH.
- The idea of this scheme is that even if upto two complete cells of MPEG-2 transport stream information are corrupted (vertical slices). The RS code will exist to correct these ATM cell errors. In addition this approach provides some burst error protection as well.
- An AAL-1 cell carries 47 bytes of data and a 1 byte header.
- We take 47 188 byte long TS packets and add the 16 byte RS code to each.
- We slice these 204 byte long packets vertically Byte-wise, and add an AAL-1 header to each slice.
- That generates 204 AAL-1 ATM cells.
- These are then mapped into the PDH/SDH hierarchy.
- This system allows upto 2 complete 48 byte long ATM cells to be in error.

Conclusion



- No one controls the MPEG-2 TS, so that QoS guarantee's are an issue.
- There is no margin for error in MPEG-2
- Therefore powerfull FEC is needed in the DVB-S, C, T systems & in core networks
- QEF BER of 10⁻¹¹ is required. If a system is close to this BER, it would only need a small change in C/N for failure to occur.
- Therefore QoS test is crucial.

"Good Quality of Service tools are required to ensure the MPEG-2 transport stream is safe"