Digital Set Top Box (STB)

- Open Architecture/Interoperability Issues

B.Sundareshan

The DVB (Digital Video Broadcast) project group has developed a family of interrelated international standards for digital television broadcasting via different transmission media. These are DVB-T for digital terrestrial transmission, DVB – S for digital satellite transmission and DVB – C for digital cable transmission.

A very significant feature of these standards is that all three of them have identical source coding/compression and service multiplexing/transport sections. These two sections are based on the internationally acclaimed MPEG – 2 standard. However channel coding/modulation part of each of the three is optimized for the respective transmission media. Thus whereas satellite and cable transmission are based on single carrier modulation schemes of QPSK and QAM, terrestrial transmission uses a multicarrier modulation scheme called OFDM (Orthogonal Frequency Division Multiplexing).

Till such time integrated digital TV (IDTV) sets become cheaper, digital set top boxes will be utilized in the home for the reception of all three signals. It is thus apparent that, the availability of set top boxes at affordable prices is going to be the major factor which will ensure a fast take up of these services in the country. By adopting the three above mentioned interrelated international standards for digital transmission in India an important goal has been realized, that of ensuring maximum commonality in the components used in the STBs for the three media, leading to an overall decrease in the price of STBs arising from economics of scale.

Yet another important feature which will lead to a cost reduction of STBs is to make the STB, to the extent possible to be based on an "Open Architecture" and also make it ' Interoperable' across different networks.

Before proceeding further it is necessary to explain to explain in some detail the two concepts of 'Open Architecture' and "Interoperability". A STB can be considered to be a collection of a number of small functional blocks or modules, with each module performing a well defined function. A module can be composed of pure hardware or pure software or some combination of the two. An architecture can be considered to be "Open" if and only if the functionality of each and every module in that architecture is available in the public domain in the form of published international standards or defacto industry standards. Put in another way a technique is generally called "Open" if the IPR (Intellectual Property Rights) and the technical information needed to implement, compliant products is available under fair, reasonable and non-discriminatory (FRND) terms. IPR holders are generally required to accept the FRND terms set by the recognized international standardization bodies.

A STB is said to be interoperable if it can receive any service from any network. It is possible to have such an interoperable STB. Before trying to answer this question, let us first take a closer look at the STB architecture.

The diagram in figure – I below gives a simplified over view of the major components of a typical STB.

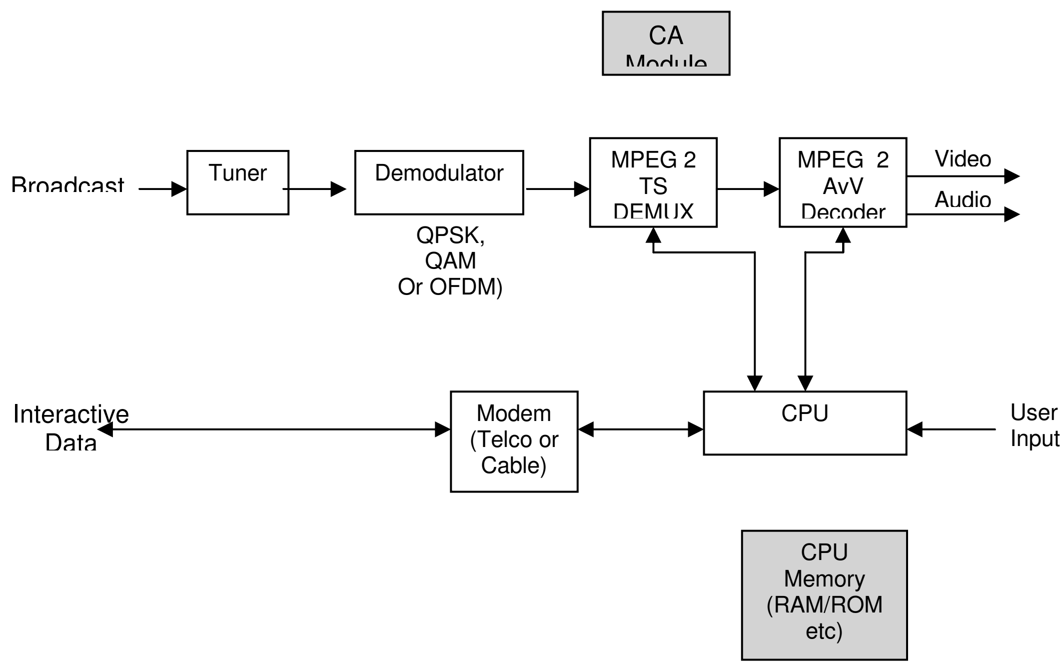

Fig. 1 : Overview of STB Architecture

The STB selects the appropriate broadcast TV information by tuning to one of many input channels. The signal is digitally modulated using Quadrature Phase Shift Key (QPSK) for satellite applications, Quadrature Amplitude Modulation (QAM) for cable and Orthogonal Frequency Division Multiplexing (OFDM) for terrestrial. The information in the selected RF channel is then processed by the demodulator to produce an MPEG-2 Transport Stream (TS) containing the audio, video and other information that relates to the selected TV programme.

The STB generally also contains some form of modern to allow it to send and receive interactive data. Conventional telecommunication modems are typically used in satellite and terrestrial STBs while cable STBs generally have a cable modem. DOCSIS cable modems use QAM demodulator for the downstream data whilst out-of-hand DAVIC cable modems use QPSK demodulator. In both cases, a QPSK modulator is used to transmit the upstream data, though DOCSIS also have a 16 QAM mode.

In general, digital TV information in the MPEG-2 TS may be encrypted to present customers who have not paid for a particular service from being able to view it. The MPEG demultiplexer selects and decrypts the compressed audio and video for the particular programme that the viewer wishes to watch, using decryption keys supplied by the Conditional Access Sub System (CASS). The MPEG decoder then compresses the audio and video information for the selected programme. The Central Processing Unit (CPU) controls the whole operation and performs specific data manipulation function. It generally uses a Real Time Operating System (RTOS) on top of a hardware abstraction layer for the management of the resources and processes of the STB directed by the higher level software.

It is thus obvious from this diagram that, the front-end, which contains the tuner and the demodulator, will be different for the three transmission media. Hence if a STB is to be made interoperable across all the three transmission media it should be fitted with switchable front ends.

Let us now turn our attention to the "CA Module" in the STB. Whenever an MPEG-2 TS carries encrypted (Or scrambled) services, the TS also carries two types of messages called EMM (Entertainment Management Message) and ECM (Entitlement Control Message). An EMM carries a list of Pay TV services which the owner of that STB is entitled to view and also the date upto which he is entitled to receive them. The ECM on the other hand carries a data element called control word (CW), which is used by the 'descrambler' in the STB to descramble the picture and make it intelligible again. Both these messages are carried in the TS in an 'encrypted' form. Whereas DVB has standardized the scrambling algorithm (known as DVB common scrambling algorithm, DVBCSA), algorithms used for ECM/EMM encryption are not standardized for obvious reasons.

Thus the various DVB CSA compliant CA systems available in the market use different ECM/EMM encryption algorithms. Thus the security of a given CA system depends primarily on the efficiency of the algorithm used for ECM, EMM encryption. Such algorithms are closely guarded secret. The CA module in the STB contains the relevant ECM, EMM decryption algorithm. Hence when the CA module is embedded inside a STB it can no longer be considered to have an "Open Architecture". Further such an STB will not be interoperable across different networks which use different CA systems. So the question is how to make a STB interoperable across different networks using different CA systems. The answer is provided by DVB in the form of an international standard called DVB Common Interface (DVB CI).

The diagram in fig – 2 shows the concept. In this case the STB contains only those elements that are needed to receive "clear" broadcasts. The CA system is contained in an external module, which communicates with the STB via the common interface connector provided on the STB. Thus a STB fitted with the DVB CI connector is interoperable across different networks using different CA systems, all that a user has to do is to get the plug-in CA modules from different service providers. In the US, cable labs refer to these cards as Point of Development (POD) modules.

Let us now turn our attention to the different software layers in a STB. An operating system is the most important piece of software in a STB. An OS is a suitable of programmes used to manage the resources in a STB. In particular it is the OS, which talks to the STB hardware and manage their functions such as scheduling real time tasks, managing limited memory resources, etc. A STB OS is arranged in layers with each layer adding new capability. At the heart of any STB OS is the "Kernel" layer, which is stored in ROM. Once the STB is powered up, the kernel will be loaded first and remains in memory until the STB is powered down again. Typically the kernel is

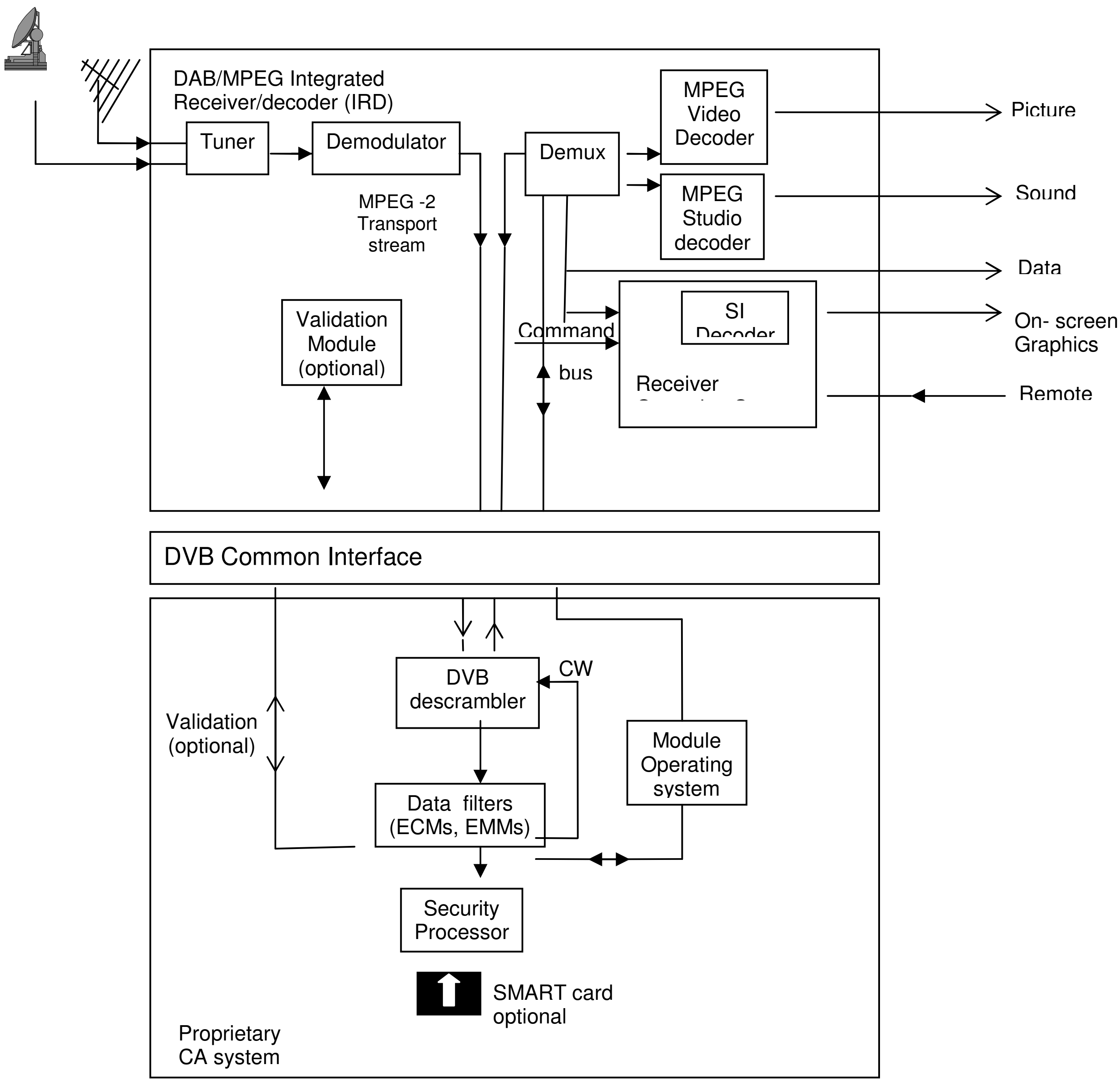

Fig.2 ; DVB Common Interface

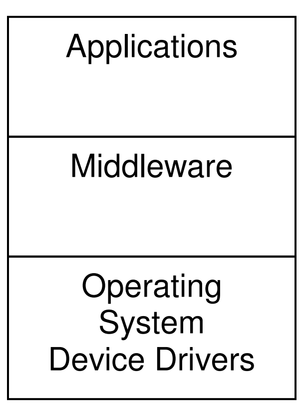

Fig.3 ; Software Layers of a STB

responsible for managing memory resources, real time applications and high-speed data transmission. The kernel supports multi threading and multi tasking which allows a STB to execute different sections of a program and different programmes simultaneously.

In addition to the kernel, a STB needs a 'loader' to enable the TV operator to upgrade 'resident applications' or download 'OS patches' to STB. A resident application is a program or a number of programs that are built into the memory of the STB.

The STB also requires 'drivers' to control the various hardware devices. Every hardware component in the STB must have a driver. A driver is a program that translates commands from the TV viewer to a format that is recognizable by the hardware device.

Finally a STB OS needs to incorporate a set of Application Programme Interfaces which are used by the programmers to write high-level applications for a specific API. AN API is basically a set of building blocks used by software developers to write programs that are specific to a STB OS environment.

At present there is no standard STB OS. Many broadcasters and consumer electronic companies are continuing to promote their own in-house solutions. Some of the available solutions are: Power TV OS, Vx Works pSO System, Microware's DAVID OS-9, Microxoft Windows CE etc.

Central to the new software architecture of a STB is a connection layer that acts as communications bridge between the OS and the 'subscriber applications' called 'Middleware'. Middleware is a relatively new term in the set top business. It represents the logical abstraction of the middle and upper layers of the communication software stack used in set top software and communication system. Middleware is used to isolate set top application programs from the details of the underlying hardware and network components. Thus set top applications can operate transparently across a network without having to be concerned with the underlying network protocols. This considerably reduces the complexity of content development because applications can be written to take advantage of a common API.

The terms API (Application Programmers Interface) and middleware are sometimes interchangeably used. The API is the standard environment that an application program expects to see. The API itself consists of a set of well-defined and specified functions accessed using a well defined and specified called mechanism. Early generation of STBs had no APIs but only a very basic operating system. As costs have fallen and processing power has increased, more recent STBs have included APIs. In order to progress beyond ordinary broadcasting to the new emerging interactive services an API is essential. An Electronic Programme Guide (EPG) for navigating across hundreds of channels of broadcasting also needs an API.

Finally a few words about the type of 'applications' which run in a STB. All the applications can broadly be classified into two main categories **Enhanced** and **Interactive.**

An Enhanced TV application is the one which is based on ‘local interactivity’ and which does not require a return path back to the service provider. As an example of this type of application, consider a situation in which a broadcaster is transmitting pictures of a cricket match as a video data stream in parallel with another stream carrying supplemental but related material such as graphics containing player profiles, batting/bowling coverages etc. Using relatively simple technology it would be possible for a viewer to call up this extra information on demand either as an overlay or in a ‘window’. As for the viewer is concerned, this experience would be unique to the viewer, but it would involve no signal being sent back to the broadcaster to obtain the extra data.

As opposed to this an interactive application is based on ‘two way interactivity’. Here the viewer issues a request for extra information to the service provider, which travels along a return path and the service provider sends the requested data back either via the return path itself or ‘over the air’. What might be termed ‘low-level’ two way interactivity is demonstrated by a ‘pay per view’ service. On the other hand ‘high-level’ two-way interactivity is characterized by a continuing two-way exchange of data between the user and the service provider. A good example of this would be calling up a home shopping application via the TV screen.

After this overview of the software architecture of a STB and the types of applications which could be delivered it is now time to address the most important question “Can a STB be made interoperable as regards its capability to receive and run enhanced/interactive applications delivered over the different networks to which it may be connected?” The answer is yes provided all the service providers agree upon a common open international standard for STB middleware. To serve this purpose DVB has developed the Multimedia Home Platform (MHP) standard.

Fig. 4 shows the MHP reference model. Basically it seeks to create an open middleware based around a hierarchical Java based structure. Java’s major advantage are platform independence and greater sophistication compared with other proprietary APIs. Java is also well established in Internet applications.

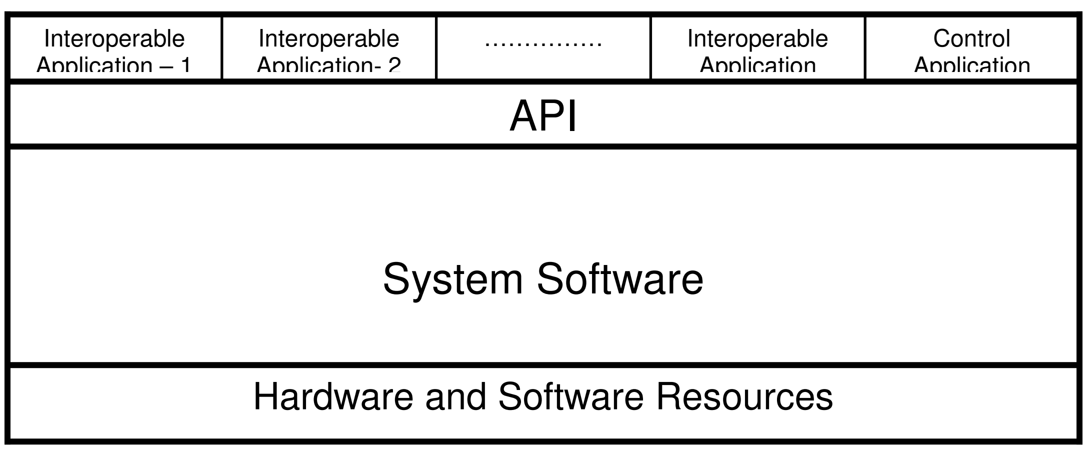

Fig.4 ; MHP Reference Model

In the case of MHP, the API is known as DVB JAVA API and the various interoperable applications are authorized in JAVA. The system software incorporates a Java Virtual Machine (JVM). The JVM is a program that interprets Java byte codes into machine code. JVM is a self contained operating environment that behaves as if it is a separate computer within the digital STB.

A set-top Java application will run in any JVM, regardless of the underlying hardware platform and RTOs.

Three main area of applications are identified.

1. Enhanced broadcasting with local interactivity
2. Interactive broadcasting using a return channel
3. Internet Access

Accordingly the three STB profiles are identified and the software has a hierarchical structure. At the bottom of this hierarchy sits a profile for enhanced TV, the next level up contains this profile and adds the required specifications for interactive TV and on top of that sits and Internet access profile which contains the two below it adds IP and HTML compliant specifications.

In the last section of this paper, we take a close look at a cable digital STB that is based on the concepts of open architecture and interoperability.

Open cable is a US cable industry initiative, which seeks to obtain and deploy a family of interoperable advanced digital set top boxes from multiple vendors. Cablelabs is managing the open cable specifications writing process on behalf of its cable operator members.

The open cable project has developed two key sets of specifications. One for hardware components and one for software components.

The hardware specifications include specifications for a host device, a removable POD (Point of deployment) module in the form of a PCMCIA card and a POD-HOST interface (see figure 5 and 6).

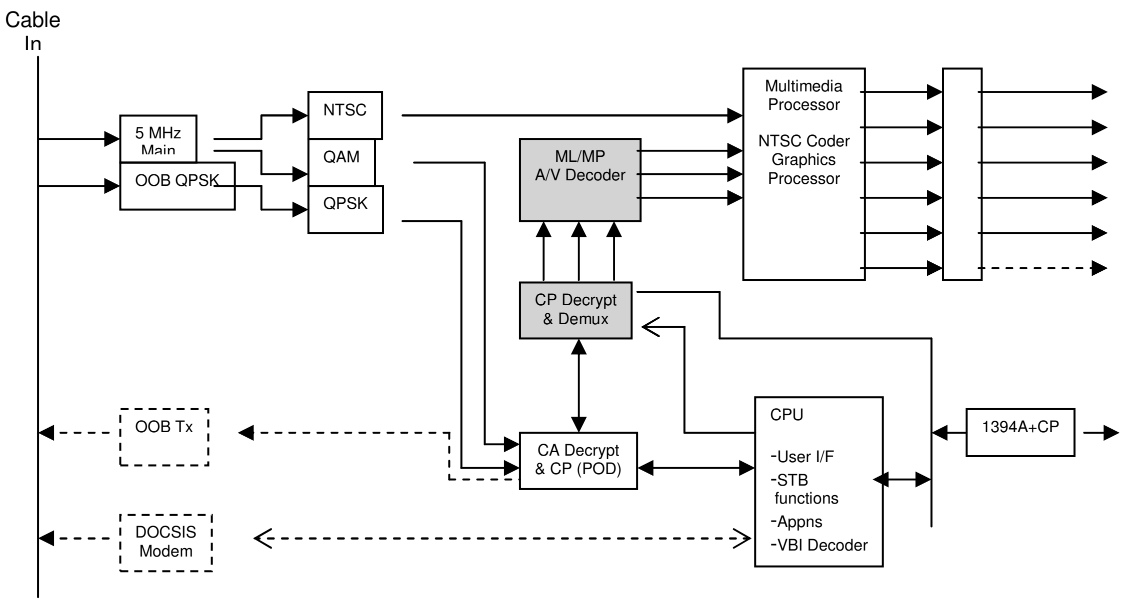

Fig. 5 : Open Cable Digital STB (Host) Architecture

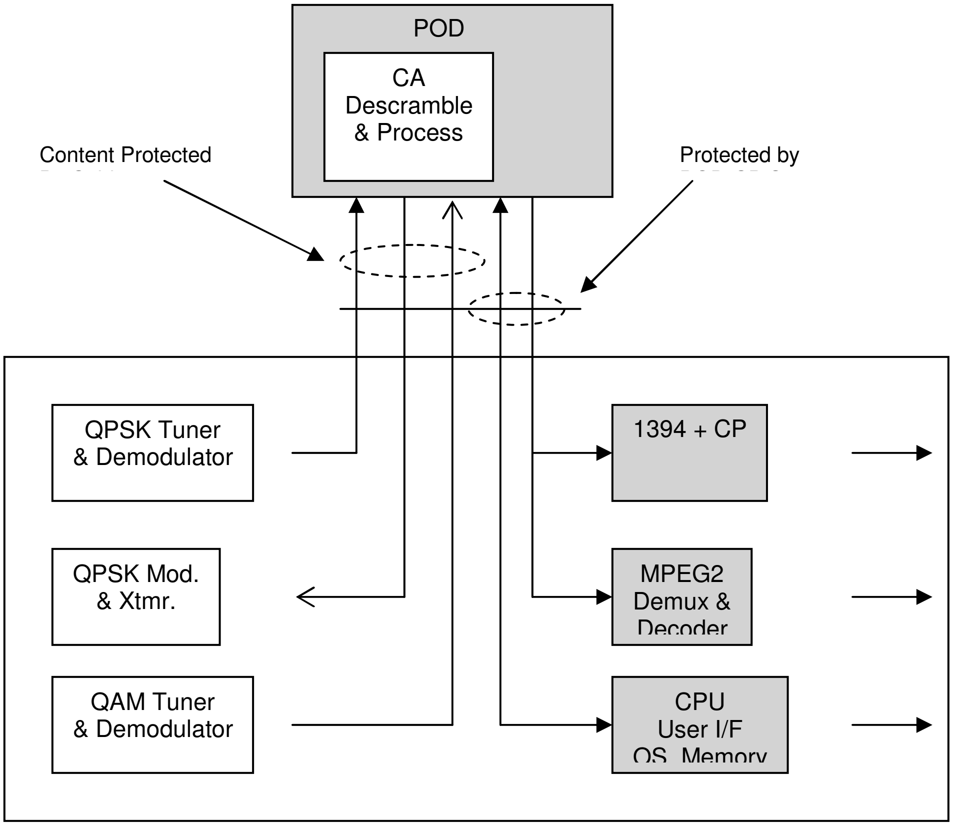

Fig.6 : HOST-POD Interface

When the input channel is a digital channel it is processed via QAM demodulator and then passed on to the POD module where secure and scrambled information is processed. The host also receives control information and other data by tuning to an out of band (OOB) channel and passes it to the POD for processing. The POD also processing the out of band upstream data.

The software component of the Open Cable project called Open Cable Application Platform (OCAP) provides an open interface between the manufacturers operating system and the various applications that will run within the host (See Fig 7). The OCAP API is based on the MHP standard described earlier.

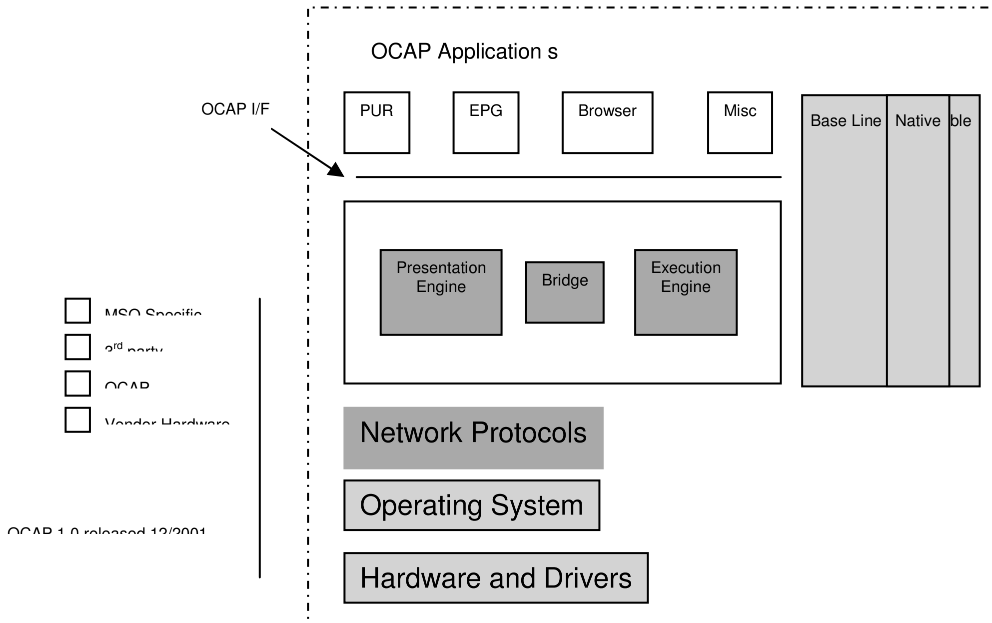

Fig.7 ; OCAP (Open Cable Application Platform) Architecture Overview