The set-top box for interactive services

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This paper describes the work at BT Laboratoriess on set-top boxes (STBs), for the BT interactive multimedia services (IMS) trials. An overview of the trial STB's architecture is described together with a prediction of the future STB architecture following the evolution of standards. The most likely topologies for networks within the home are discussed, and finally a prediction of the functionality for STBs in the future is made.

1. Introduction

The definition of a set-top box (STB), for the purposes of this paper, is an item of consumer electronics which interfaces with a TV to provide an additional service. The earliest high volume digital STBs were probably the first electronic 'tennis' games which emerged in the early 1970s, allowing one or two players to play a game displayed on the TV screen. The most common STBs currently (in the UK market) are video cassette recorders (VCRs), followed by analogue satellite receivers and cable boxes. The cable STBs are currently differentiated by the fact that, almost without exception, they can only be rented and there is little or no choice available to the customer.

The major piece of enabling technology for the emerging digital STBs has been the development of the MPEG (Moving Picture Experts Group) standards [1]. This has enabled low-cost digital decoder ICs to be developed by a number of silicon vendors to ensure healthy competition in the market-place.

Games consoles have grown in complexity, many with CDi™ or CD ROM drives, and are today the most common digital STB. Digital satellite receivers have been developed to the emerging DVB (European Digital Video Broadcasting Project) standards [2], trials being due to start in the UK in 1996, although there will be digital services elsewhere in Europe and in the Pacific rim starting in 1995.

It must be remembered that the success of STBs for any new service will be totally dependent on the amount and quality of the content available. The market is therefore 'content driven'. It is essential to standardise the content format to provide stability to the consumer electronics manufacturers. For this reason many consumer electronics manufacturers have invested in content production facilities.

2. BT IMS trials

2.1 Overview of trials

The IMS technology trial which commenced at Kesgrave, Suffolk, March 1994, was the first truly interactive video on demand (VoD) trial world-wide. The STB for this trial was supplied by Apple Computers Inc (Apple) and was based on a Macintosh computer with an additional 'motherboard' containing the line interface, MPEG decoder, graphics overlay and PAL encoder. The product was developed by Apple in the four months leading up to the trial and was housed in an 'off-the-shelf' metal rack enclosure, with a 'universal' infra-red remote control with custom screen-printed key labels.

The STB was redesigned for the IMS market trial which is due to start late 1995. A new consumer electronic housing was designed, complete with a new infra-red remote handset. The IMS market trial will also provide, in addition to video on demand, many other services including home shopping, home banking, community information, education services and video games download.

The technology trial STBs each had to be manually configured prior to installation at the customer's premises. While this was acceptable for a trial of 60 BT employees, processes will be in place to ensure that the market trial STBs, delivered to 2500 customers, are self- configuring on installation.

2.2 Architecture

To position the STB in the overall IMS architecture (see Fig 1), it can be considered as the client in a client/server system, with the server being located in an exchange building and transmission being via either ADSL (asymmetric digital subscriber line) [3] or APON (ATM passive optical network) fibre to the home.

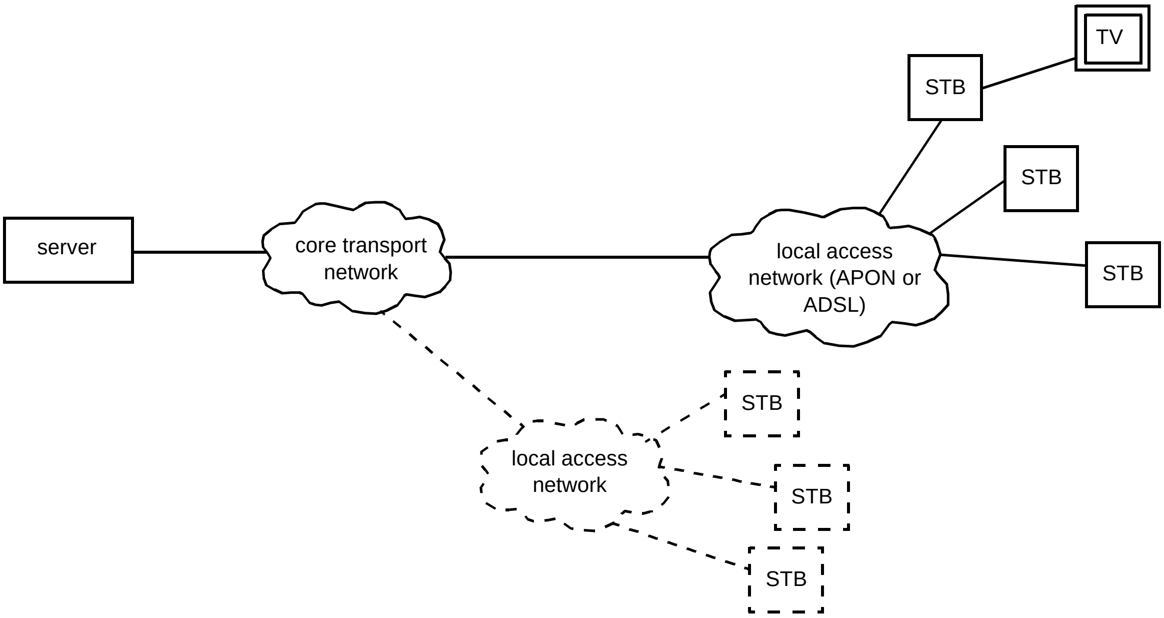

Fig 1 Simple IMS trial architecture.

2.3 STBM overview

The function of the STB is conceptually simple — it acts as a data termination device, converting digitally encoded audio and video to a more readily displayable form (e.g. PAL). Locally generated graphics are overlaid upon the video as required, producing a multimedia display. Within the structure of the IMS trial architecture, the STB provides the 'client' functionality.

The STB provides a focus for the interactive element of a service, interpreting and transmitting a user's commands back to the 'server', e.g. 'fast forward', 'pause', 'rewind' and so on.

The set-top boxes chosen for the IMS trials are 'intelligent' systems based around standard desktop computers from Apple. In developing these units the approach was to leverage Apple's (industry standard) QuickTime™ media software layer, thus providing cost savings, and also some guarantee of design reliability. The additional functionality, i.e. that required by an STB over and above a normal desktop computer, was added by way of peripheral hardware (and associated device software).

STB details

The Apple Macintosh LC475 was chosen as the basis of the STBs because of its strong price/performance characteristics.

The Apple Interactive Television Box (ITV Box) exists in two versions — the 'prototype' model (STB1), as used in the 'IMS technology trial', and the production model (STB3), as used in the 'IMS market trial'. While both of these are based around the same core technology, experience gained from the development and use of the STB1 led to a number of changes in the later developed STB3. The capabilities of these two STBs are summarised in Table 1. Figures 2 and 3 depict the STB1 and STB3, respectively. (Apple considered the development of an STB2; however, this was an interim prototype, which did not go into production).

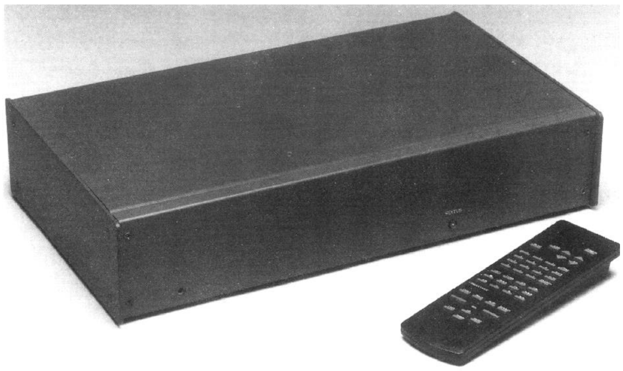

Fig 2 Technology trial set-top box.

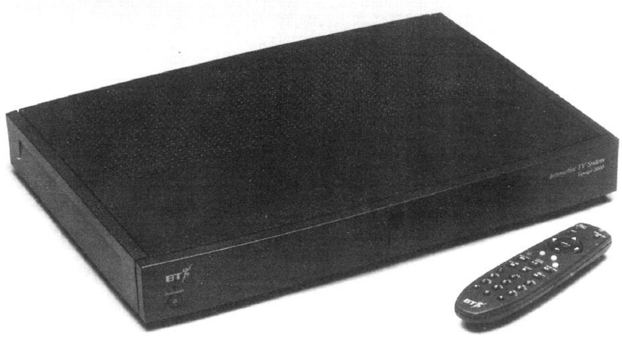

Fig 3 Market trial set-top box.

Table 1 IMS trial set-top box characteristics.

Capability	STB1	STB3	Notes
Base System Microprocessor RAM data interfaces	LC475 68LC040 25 MHz 4 Mbytes none*	LC475 68LC040 25 MHz 4 Mbytes SCSI, RS422/232, Apple Desktop Bus	 expandable to 36 Mbytes *STB3 options were available internally to the STB1
Video Capabilities MPEG decoder number of display planes graphics plane resolution video output	 C-Cube CL450 2 640 × 524, 8-bit colour SCART/UHF	 C-Cube CK450 2 640 × 524, 16-bit colour SCART/UHF/S-video	 MPEG 1 video 1 × MPEG video 1 × local graphics see Fig 6 for overlay details
Audio Capabilities	stereo	stereo	
MPEG Transport Stream	proprietary framing	MPEG2 transport stream	
Network	G.703@2.048 Mbit/s RS232 @ 9.6 kbit/s	G.703@2.048 Mbit/s RS422 at 9.6 kbit/s	G.703 unidirectional (broadband channel to STB) RS422/232 bi-directional (signalling channel to/from STB)
Physical Design	2 PCBs in ‘lab case’	single cost reduced PCB in industrial designed case	
BT Production Requirements	100	2800	approximate figures to date.

The changes between these two set-top box variants are due to a number of factors, some technical and some commercial. The major changes in design policy were:

- the need for increased graphical performance (the market trial providing a multitude of extra multimedia services, against the single video on demand service offered on the technology trial),
- moving to a standardised MPEG2 transport layer,
- the ‘real customer’ needs of production engineering the set-top box into a practical and acceptable enclosure for use by the general public in their homes.

The STB1 circuitry was also cost reduced to produce the STB3, with redundant LC475 functionality being removed and some general performance improvements made.

Hardware and software architectures

The **hardware architecture** of the Apple ITV boxes can best be described as a ‘CPU-centric’ design. All data flows via the 68040 processor, e.g. MPEG data received from the broadband data port passes via the processor, where the MPEG transport stream is software demultiplexed into audio, video and private data (non audio/ video data, e.g. program specific information), to the MPEG decoder module where it is processed. While this design places a high load upon the processor’s resources, it benefits from closely matching Apple’s ‘software-centric’ approach to systems design. A further advantage, especially for the trial units, is that much of the architecture of the unit can be modified without need for major alterations in the unit’s hardware design. Much of this flexibility is achieved through the use of a field programmable gate array (FPGA). The FPGA is used to provide the ‘glue logic’ required to interface the LC475 to the other modules within the set-top box.

The major hardware functionality within an IMS set-top box is shown in Fig 4.

An illustration of the layered **software architecture** within an STB is shown in Fig 5.

The software within the IMS set-top boxes adopted a strictly layered approach. All custom hardware within the STB is configured, and supported by custom software device drivers (system extensions in Apple’s MacOS ™ terminology). All devices are thus made available through the operating system (in this case a reduced version of Apple’s MacOS Operating System) to the application layers.

The device driver, and operating system, software is held as resident software within the STB (in either flash or standard ROMs). Other software is downloaded during a boot process (see ‘STB functionality’ below for further details) by a small resident bootstrap application.

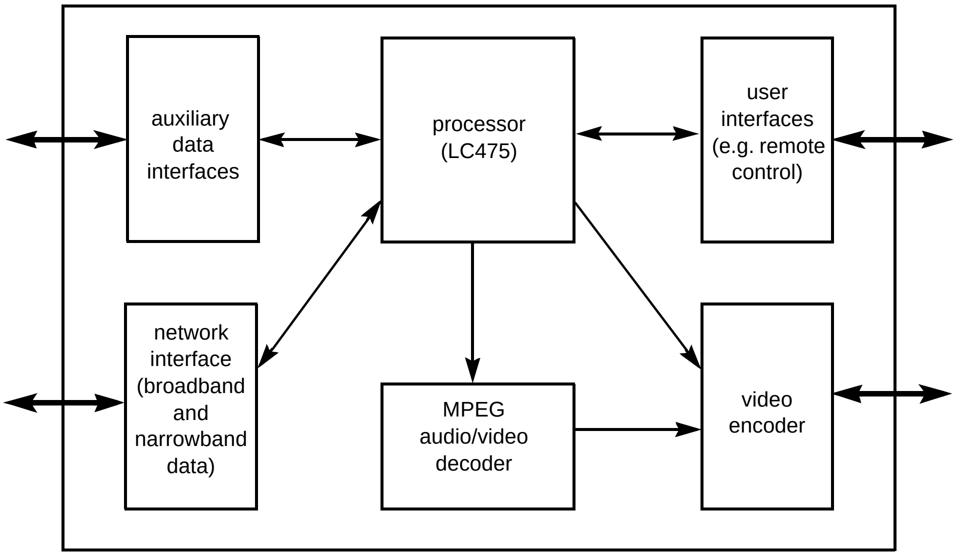

Fig 4 Functional hardware blocks within an IMS set-top box.

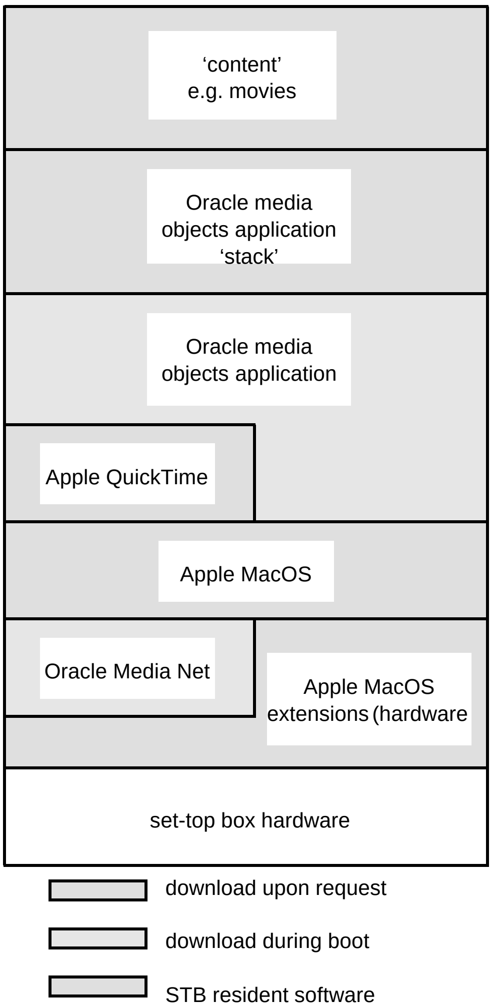

Fig 5 Layered software architecture of an IMS set-top box.

The application environment for the IMS STBs is provided through the use of Oracle Media Objects ™ (OMO). OMO is an object oriented 4th generation language (4GL) specifically designed to handle both stream- and file-based multimedia information (e.g. an MPEG encoded video stream can be represented as an object within Oracle Media Objects) within a client server environment. Applications within OMO exist as stacks of cards in much the same way as Hypercard ™ applications (a stack is a collection of cards, a card is a screen object consisting of both multimedia presentation objects (pictures, sound, buttons) and script code (intelligence for controlling a user's interaction with the card)).

The synchronisation and display issues of multimedia information are handled by Apple's MacOS Quicktime ™ and QuickDraw ™ extensions.

The network transport functionality within an IMS STB is provided by Oracle Media Net ™ (OMN). OMN supports client/server transactions including both the download of both applications (OMO stacks) and also MPEG streams.

MPEG video streams decoded by the STB, are displayed upon the back plane of two display planes. The front display plane is available via the operating system for the display of graphics, with an additional feature of setting any pixel to be transparent (i.e. allowing the video plane 'behind' to be seen). This concept is shown in Fig 6. The operation of the two display planes is under software control, using the inherent capability of MacOS to support multiple displays.

In general, the environment offered to applications within an STB can at best be described as hostile. This is because the STB application must provide excellent

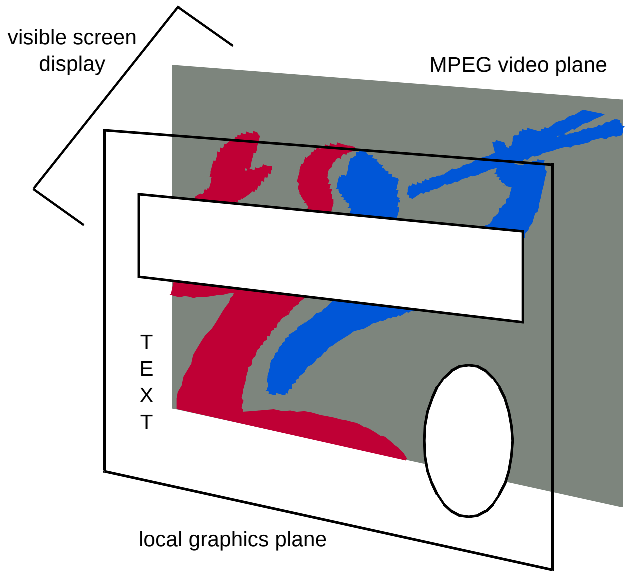

Fig 6 Set-top box screen display planes.

response times while performing extremely complicated multimedia operations upon a system with 4 Mbytes of RAM (this memory must fulfil both application and operating system requirements). The design of the STB allows for the RAM to be expanded, but due to the high cost of memory devices this option was not taken.

STB functionality

The IMS set-top boxes exist in a number of operating states, with the functionality of the STB determined by the current state. Figure 7 shows the major operating states in an IMS set-top box. The initial ('Boot') states are required to successfully download and execute an application. The functionality of the STB during application execution is dependent upon the application (notwithstanding the inherent capabilities of the STB). During STB 'Boot', the user is not required to perform any operations, the concept being the same as for other domestic equipment (compare a domestic video cassette recorder). The STB will, however, accept a 'stand-by' instruction from the user.

While the STB is in fact a computer, the ethos used is to shield the user from this fact wherever possible.

The early stages of STB operation are to prepare the device for application download, as shown in Fig 7. Once downloaded the application has (almost) complete control over the STB. The concept here is that of painting upon a clean piece of canvas. The STB (accepting design limitations) is thus whatever the application requires it to be. This provides advantages to the service provider, but

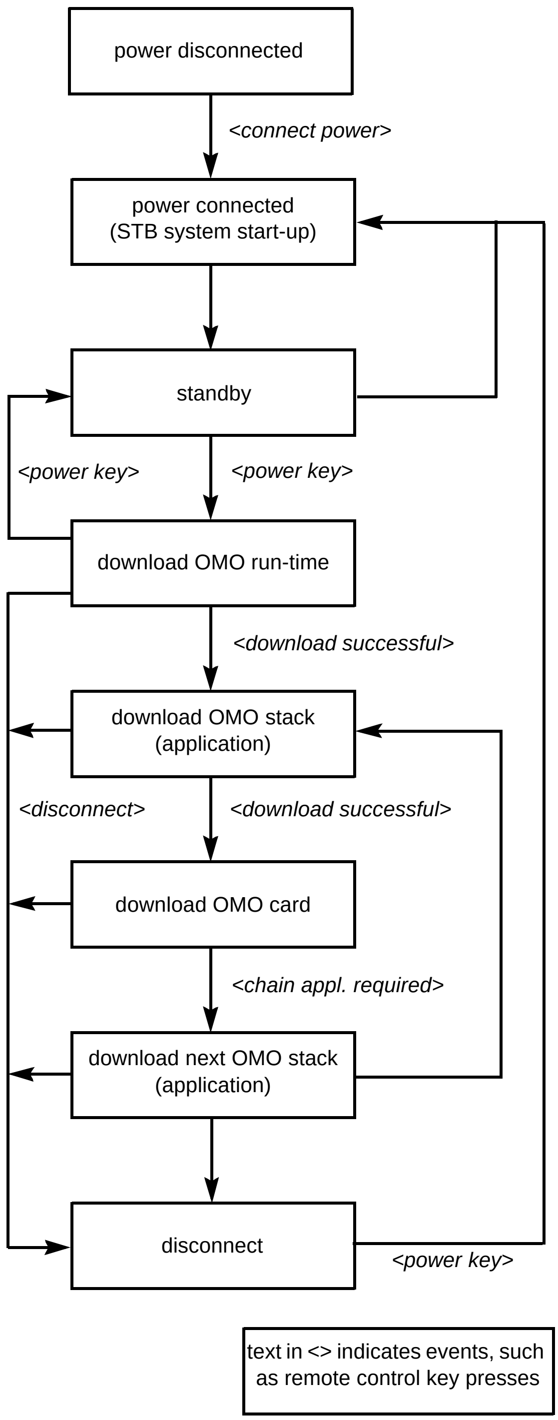

Fig 7 Major operating states for an IMS set-top box.

potential disadvantages to the user, i.e. each service provider may implement their own 'look and feel', or 'branding', of the user interface. This flexibility is a potential confusion for the user, and does not exist with other domestic CPE (customer premises equipment), e.g. if services here are equated to channels on a TV, the remote control on the TV provides the same functions independent of the channel being viewed. This may not be the same for services obtained via an STB.

3. Future STBs

The IMS trial STBs have been specified to ensure that they are sufficiently powerful and rich in functionality to enable a wide range of services to be successfully tested. The future STB for the mass market must be cost effective and, to that end, any redundant or expensive features and functionality would be removed to ensure the entry cost to the consumer is kept to a minimum.

The specification for future STBs must comply with global standards to ensure large production volumes and hence enable prices to fall quickly. This will allow the customer to select the product of their choice from any high street consumer/electronics retailer.

It is expected that residential STBs will split into two categories in the near term:

- high-end STBs based on computing platforms with considerable expansion capabilities and high-resolution graphics capabilities, i.e. high price,
- low-end STBs for ‘VoD-type’ simple services with minimal ‘application download’ capability and low-resolution graphics, i.e. low price.

It should be borne in mind, however, that at the time of writing, digital interactive services are only available as part of limited trials. Limited interactivity is due to be commercially available for the first time as part of either analogue services (interactive TV, analogue cable services), or as an add-on to ‘digital satellite’ delivery (to enable pay-per-view type applications). These market areas are generally focused towards low-end STBs providing access to a single service (provider).

3.1 Interactive service types, and related set-top boxes

The level of interactivity, and also the type of set-top box required, can be categorised, to some extent, by the ‘service type’ concerned. The relationship between these areas is shown, for selected service types, in Table 2.

Table 2 Table of service types and set-top box interactivity.

Service type	Status of service	Interactivity	Set-top box required
‘Interactive TV’	UK service expected to start Q3 1995 (analogue broadcast)	Download to STB via broadcast. Return channel via PSTN modem. Interactivity is for service selection, and feedback of user input (also ‘scores’ for interactive game shows).	Low-end (current trials are initially using high-end STBs based upon a PC platform)
Video on Demand	Trials only	Download/return channel provided by broadband feed to STB. Interactivity is for programme selection, including ‘virtual VCR’ controls.	High-end (may in future be pre-configured low-end STB).
Services on Demand	Trials only	Download/return channel provided by broadband feed to STB. Interactivity is dependent upon the functionality of the service (application) being used.	High-end
Digital Satellite	European service starting October 1995 (Canal+, a French broadcaster)	Limited download to STB via broadcast, return channel via modem. Interactivity is (initially) for customer authentication, and for pay-per-view. Later will support: text/still pictures on demand; transactions; messaging.	Initially low-end, single-purpose STB. May require more complex STB if greater interactivity is used in later services.
‘Interactive Cable’	Digital — trials only Analogue — services currently in operation in a number of locations (e.g. Videotron in London)	Download to STB via broadcast, limited cable return channel (TDM QPSK). Interactivity is for service selection (including software download), and feedback of user input.	Initially high-end (based upon IBM PC), although cost reduction will follow.

As indicated in Table 2, digital fully interactive services are currently limited to trials only. With all service types, the indication is that, over time, functionality will increase, leading to an increase in interactivity and STB complexity.

3.2 Future STB drivers

Future 'interactive' set-top box design is subject to a wide range of driving influences, not only within a technical domain, but also within commercial and consumer-led domains. The main areas within these three domains are given in Table 3.

Table 3 Table of drivers for future set-top boxes.

Technical Domain	Commercial Domain	Consumer Domain
Effect of regional and international standardisation	Need for high sales figure	Need for low purchase/service price
Disparity of network transport architectures	Manufacturer profit margins, on a high cost (to produce) item	Need for ease of use
Introduction of other digital services leading to convergence of CPE	Product differentiation through additional 'features'	Need for wide range of services
	Cost of service roll-out	Adverse reaction to computer technology in the home
	Network bandwidth cost for broadband service	
	Determination of real consumer demand	
	Service provider differentiation through 'branding'	
	Use of interactivity to enable customer billing (e.g. pay per view)	

Future interactive set-top boxes must therefore be designed with much in mind. The requirement for increased interactivity, via a network, is not a main consumer requirement. Indeed, many consumers will not want to know how the system works — they are interested in what they can do with the system, i.e. what services are available to them. The major driver for interactivity is thus from the commercial domain.

Commercial realities

While a proportion of consumers will invest in new technology (the 'early adopters'), the majority will invest in a mature market (an example of this can be seen in domestic video cassette recorders, and also UK satellite decoders). Cost models have predicted that consumer interest will reach 'critical mass' when the retail price for an entry-level, low-end interactive set-top box reaches £200 (or equivalent). This 'critical mass' price is based upon a number of commercial models produced, and also from observation of the UK satellite receiver market (here the £200 threshold was inclusive of installation).

Meeting this price is technically possible, although a great deal of cost reduction must be achieved.

Current cost estimates for a low-end STB would indicate that some of the critical components (microprocessor, MPEG decoder) will need to be reduced to 30—50% of their current cost in order to achieve the required target. The cost reduction required for a higher functionality (high-end) STB is, however, not so critical.

It is essential to 'seed' the market in early stages (as with other similar services) to ensure a 'virtuous circle' — whereby the number of STBs sold encourages further service providers to become involved, who in turn encourage further customers to buy STBs to receive the services. This is depicted in Fig 8.

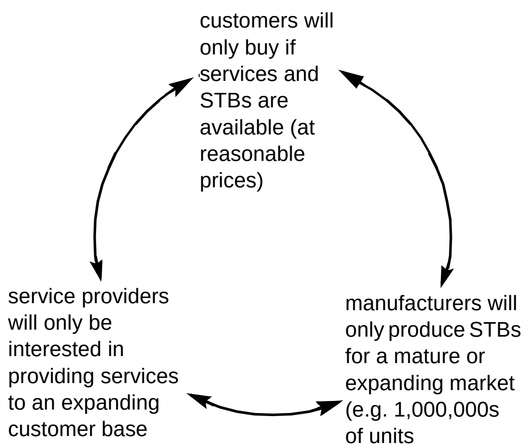

Fig 8 The 'virtuous circle'.

This circle must be initiated through the adoption of risk. In other comparable services, the service provider adopts the risk for the production of equipment for supply to the consumer. In this instance, the service provider is considered to act as a 'broker' for a number of content and information providers. The adoption of risk by the other two parties, for instance 'early adopter' consumers and 'innovative' suppliers, is unlikely to 'kick start' a market in this area.

The average consumer is distrustful of products that 'look' like computers. Many computer system manufacturers interested in moving into the future 'intelligent interactive set-top box' market, view such devices as Trojan horses, i.e. a means of selling a home computer to consumers who would not normally purchase one. Such devices would be capable of upgrade at a later date to offer full computer facilities. Apple's Pippin ™ games console is one example of a commercially available device with such a capability.

STB convergence

There is continuing progression towards digital services in the home. Currently games and CD-ROM are delivered, in digital format, from local mass storage. It is only a matter of time before satellite, terrestrial and cable broadcasters switch to digital transmission in order to make more efficient use of the spectrum.

The customers for digital video services will not want to buy an STB on a per application basis — the stack of consumer electronics in the average home is already in danger of 'toppling' over. For this reason it is important that the popular services are rapidly identified and that STBs offering the most common configurations are available. In the short term, it is expected that some early digital STBs will have an expansion socket to allow for services to be added in the future via an adapter module.

As soon as the dominant combination of digital services is known there will be an integrated STB for the dominant package of services. When broadcast digital terrestrial TV is commonplace, the STB will cease to be a separate unit as all of the functionality will be absorbed into the TV. The likely combination in the future is to combine the following services into the TV:

- digital broadcast (probably terrestrial),
- 'superhighway' socket for highly interactive and 'on demand' services,
- local high density storage such as CD ROM for rarely updated information.

Games consoles will have an integrated 'superhighway' socket for customers whose first requirement will be for game playing, either in stand-alone mode, or more likely competing with other players via the network. STBs will have the ability of downloading games applications from the server to a games console for remote game playing.

Content providers

The importance of the content provider cannot be overstated. Without sufficient content availability, the consumers will not buy an STB and without a potentially large customer base, content will not be made available.

One major concern of the content providers currently, relates to the high quality of the digital material, which makes piracy of the content attractive. It is important to identify 'copy protection' procedures within the STB to prevent digital copies of high-value content being taken. There are several methods of accomplishing copy protection through scrambling and conditional access or by 'fingerprinting' recorded content such that the source is known and it would be possible to only allow replay through STBs at the same address.

3.3 *Standardisation*

It is essential to establish world-wide standards for interactive STBs to enable the manufacturers to invest, with confidence, in the necessary enabling technology to ensure that STB prices fall quickly. To this end BT are currently supporting the consensus-forming and standards bodies listed in Table 4.

Table 4 Table of bodies relating to set-top box standards

Standards body	Name	Area of interest
Digital Audio-Visual Council	DAVIC	Global multimedia systems specifications
Digital Video Broadcast	DVB	European satellite and cable specifications
Asynchronous Transfer Mode Forum, Residential Broadband Group	ATM Forum, RBB	Mainly US body, ATM residential network transport and interfaces
Video Electronics Standards Association (VESA) open set top	VESA-VOST	American standards body, currently looking at physical interfaces and wiring, e.g. home LANs
Moving Pictures Experts Group	MPEG	Digital coding of moving pictures
Digital Storage Media Command and Control	DSM-CC [4]	User/network and user/user control (working group of MPEG)
Multimedia and Hypermedia Experts Group	MHEG [5]	Coding and interaction of multimedia objects

Standardisation is required to ensure interoperability of servers and STBs from a range of manufacturers, independent of the access network. There are currently two schools of thought with regard to the interoperability of STBs within the overall system.

- Standardisation of the format in which objects are delivered to STBs — in this way STB manufacturers know exactly what they have to deal with. The down side is that the STB must become more interpretative by nature and hence the speed of presenting data may be impeded. This problem will recede as STB processor performance increases for the same cost and as the designers become more experienced.
- The server downloads an application and extensions according to the STB make and model, which is passed to the server from the STB during initialisation. Thus there are islands of interoperability, where it is likely that some STBs will not operate on some servers if the service provider does not choose to support those STBs.

3.4 Future STB technology

Architecture — hardware and software

Hardware architecture — the hardware architecture of a future STB is unlikely to vary much from the generic model shown in Fig 4. The major area for change here is in the integration of functionality to achieve cost reduction. Already many STB manufacturers are considering the possibility of highly integrated STBs consisting of a minimal chipset. A three-chip solution is considered feasible by many manufacturers.

The hardware architecture chosen for a future STB will ultimately depend upon the 'model' chosen. Currently two extreme models exist — the hardware processing and software processing model. The hardware processing model assigns hardware blocks to perform functional tasks (e.g. MPEG decoding being performed by a dedicated MPEG decoder chip). The software processing model assumes one or more high-speed microprocessors providing equivalent functionality. The later approach is more flexible, but is also arguably more expensive.

One requirement for a future STB will be the ability to connect to a number of differing service provision media (see STB Convergence in section 3.2), if only because the core of a particular unit may be manufactured for use in a number of countries. The concept of a modular STB with two main modules (the first module comprising the network interface, and the second module comprising all other functions of the STB) is thus likely to be adopted for all but the most basic STBs in the future. The STB will have provision for a conditional access module. This will either be integrated within the unit or, more likely, be a replaceable module, probably via the DVB common interface. The network interface module would enable the remaining STB functionality to be network independent.

The existence of a number of 'grades' of future STB is a certainty. Low-end STBs will be heavily integrated, with minimal functionality and little or no ability to upgrade. Such STBs are likely to be based upon the 'three-chip' architecture. High-end STBs, however, are more likely to be based around a software processing model, with the capacity for expansion.

Software architecture — the move for greater conformance between interactive multimedia service platforms (see section 3.3) will require some form of compliant application interface to be defined. While it is possible to transcode an application into a number of formats (the correct format for an STB being downloaded as required), the appeal of a portable application format has been recognised. This form of coding applications would be independent of the application creation tools and language, and would also hide the STB operating system and hardware. A number of such coding formats exist, or are being developed (e.g. MHEG Part III Script Interchange Format).

The grading of STBs is expected to heavily affect the software architecture; low-end STBs are most likely to be offered supporting only a limited number of services (in that the low-end STB will not support full application download). The layered model shown in Fig 9, would thus be compacted, with the 'middleware' layer absent.

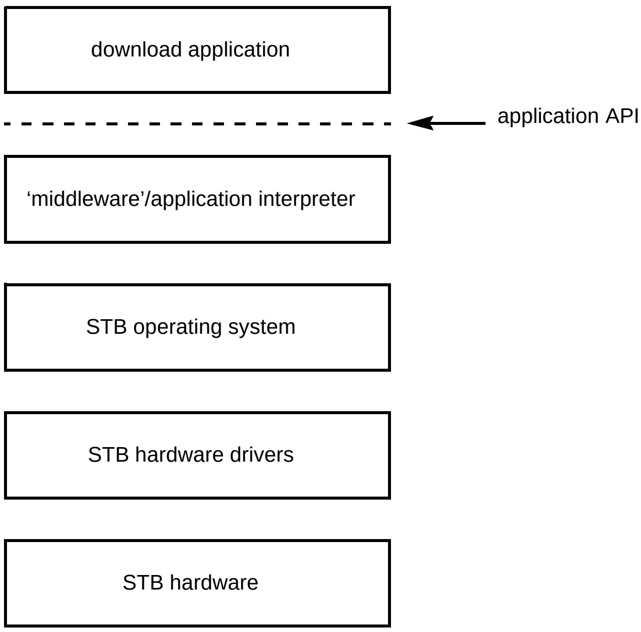

Fig 9 Future set-top box software architecture.

Network interface

The STB of the future is likely to be connected to an ATM network and, as such, it is expected that the ATM Forum will take the leading role in specifying a low-cost physical interface for residential STB applications. The STB network interface will be in the region of 25 Mbit/s symmetrical, although the highest bandwidth entertainment application will probably be high-definition television (HDTV) which will require around 12 Mbit/s.

The STBs developed for the IMS trials have no call set-up capabilities, but rely on 'nailed up' virtual circuits (VCs). The STB is then operated in 'user-to-user' mode to control 'sessions' and navigate through applications.

The emerging DAVIC STB standard is expected to favour DSM-CC user-to-network signalling for call set-up, with translation to the appropriate B-ISDN or ATM protocol stacks being accomplished within the network. The ISDN E.164 specification and MAC addresses are expected to be adopted for addressing STBs.

MPEG decoders

The MPEG1 standard is used for most stored content such as CDi and CD ROM. The total bandwidth is 1.5 Mbit/s — 1.2 Mbit/s for video and 256 kbit/s for audio. MPEG2 was developed mainly for real time encoders for broadcast systems and if main profile/main level is used, as specified by DVB, it is backward compatible with MPEG1.

The majority of the early digital STBs (CDi and CD ROM players) utilise MPEG1 decompression, based on a hardware chip set normally comprising a demux IC to demultiplex the audio video and data streams, an MPEG1 video decoder and an MPEG1 audio decoder. There are already single-chip solutions for this functionality both for MPEG1 and MPEG2 decoders.

MPEG2 decoders are used in digital broadcast receivers both in Europe and North America, although there are also proprietary solutions in use such as General Instrument's Digicypher™. MPEG2 encoders/decoders are able to dynamically change bit rates to enable the most appropriate bandwidth to be used according to the source content, requirements, i.e. talking heads require much less bandwidth than fast moving sports programs such as tennis. MPEG2 decoders are also able to decode MPEG1 content thus ensuring that the large library of content being generated for local storage systems is still usable.

In the future the decoding algorithms will probably be executed on the main CPU together with some hardware assist circuitry to promote a higher degree of product integration.

Physical user interfaces

Future STBs are likely to provide a range of interface options. The basic, or entry level, physical interface will remain the infra-red remote control. The physical user interfaces available, however, are likely to be legion, depending mainly upon the users' requirements, and the constraints of the overall service interface. A potential list of other interface devices could include:

- keypad/keyboard,
- games,
- pads,
- voice activation,
- air mouse,
- personal digital assistant/notepad computers.

Other devices are also likely to be attached to the set-top box for data entry purposes; once again the list of such devices is legion and may include:

- printer,
- PC,
- CD ROM drive,
- disk drive,
- games console adapters,
- encoder/camcorder input,
- digital video cassette recorder.

Service offerings, and consumer requirements will be the main determining factors in what may be a truly diverse market.

Graphical user interfaces

STB graphical interfaces will vary depending upon the service and complexity of the STB. Low-end STBs are likely to have a limited graphics plane (e.g. 16 colours, 320 × 240 pixels) which will determine the format of the graphical interface chosen.

High-end STBs are likely to offer 'workstation' quality graphics (e.g. 32767 colours, 640 × 480 pixels minimum), enabling more complicated interfaces to be supported. This will provide the ability to generate a number of differing styles of interface, allowing the user to choose the style of the user interface according to their personal preferences (e.g. 'cartoon'-type interface for children). This assumes that the application downloaded to the STB can support a choice of user interfaces.

The option of combining functionality in single integrated circuits may be a deciding factor here. Already some MPEG decoder ICs provide for a simple graphics overlay, thus eliminating the need for separate video graphics memory. Combined devices such as these are likely to offer CCIR601 resolutions (or sub-multiples), e.g. 720×576, 360×288.

4. Home wiring

The STB requires to be connected to the network, in a manner acceptable to both customer and access network provider. As digital STBs become more widely used in the home environment, customers are likely to install further STBs or home computers. The sharing of resources (e.g. applications and digitally encoded content) between these devices will require a standardised manner of interconnection. To achieve interconnection between STBs, the consumer's home must be wired to provide a simple local area network.

There is considerable debate on the best approach to home-wiring systems. The simple answer is that there is no single approach that will meet everyone's needs and there is also a considerable degree of personal choice in deciding which system to use. It is intended to specify a simple, low-cost home-wiring solution which is easily installed on a DIY basis, causing minimal damage to existing decor. To this end the choice of cable is Category 5 unscreened twisted pair (UTP), because it has a small diameter and can be formed around quite tight corners, and it is relatively easy to terminate with simple tools. Category 5 UTP can support a 155 Mbit/s bandwidth, and can economically support bandwidths in the range of 25—51 Mbit/s.

A symmetrical system is preferred allowing broadband content to be transmitted in both directions, this will allow for the addition of videotelephony in the future as the costs of this CPE become attractive to the customers.

It is expected that the home network of the future will be based on an asynchronous transfer mode transport layer, thus enabling individual pieces of CPE to be uniquely addressed across the network.

4.1 Entry-level system

An entry-level home-wiring system will simply consist of a point-to-point connection between the network terminating equipment (NTE) and the STB. The STB should then have a high-speed data port to enable download of data and programme information to a second terminal, such as a games console or PC.

4.2 Mid-range system

A typical mid-range home system will probably comprise two STBs (one of which may be a PC) and a digital video cassette recorder (DVC), thus enabling the consumer to have a one-to-many platform in the lounge via the TV, and one-to-one platform elsewhere in the home via a second TV or a PC. The one-to-one platform would be used for transactional and personal services such as banking, e-mail and training, etc, while the one-to-many would be used for reception of broadcast or on-demand broadband video content. Both platforms would be able to record and play back material via a common DVC.

4.3 High-end system

The ultimate home network will comprise a switched hub into which all the mid to broadband communications CPE within the home would connect. This would enable communications between similar CPE within the home to be established, in addition to routeing incoming calls to the required piece of CPE. The cost of this equipment must be considerably lower than an STB, probably about 50% of the cost of a low-end STB, i.e. around £100. It is possible that this functionality may be incorporated into a PC card decoder at a small additional cost.

5. Conclusions

While existing interactive STBs are bespoke items, designed for specific trials, future STBs will be standardised commodity items. Although the evolutionary path between the present and future STB designs may be clear technically, it will, however, be subject to a number of commercial pressures.

The first generations of interactive STBs are likely to have a retail price from around £400 (DVB Broadcast Receiver) to £500 (STB with application download capability). It is thought that this must be reduced to a retail price of £200 to £300.

It is expected that the most likely STB configuration, in the next 5 to 10 years, will integrate broadcast digital terrestrial or digital satellite services with interactive 'superhighway' services (at varying bandwidths). These are likely to be combined with local high-density storage media, such as CD-ROM, for static and 'favourite' information. The integration of these services will enable future content and service providers to produce truly innovative services that will excite and stimulate all sectors of the population.

Appendix

List of acronyms

ADSL	asynchronous digital subscriber line
APON	ATM passive optical network
ATM	asynchronous transfer mode
B-ISDN	broadband integrated services digital network
CDi	compact disk interactive
CD-ROM	compact disk — read only memory
CPE	customer premises equipment
CPU	central processor unit
DAVIC	Digital Audio-Visual Council
DSM-CC	Digital Storage Media — Command and Control
DVB	digital video broadcasting
DVC	digital video cassette
FPGA	field programmable gate array
HDTV	high definition television
IC	integrated circuit
ISDN	integrated services digital network
IMS	interactive multimedia services
MAC	media access control
MHEG	Multimedia Hypermedia Experts Group
MPEG	Moving Picture Experts Group
PAL	phase alternating line
QPSK	quadrature phase shift keying
RAM	random access memory
ROM	read only memory
SCART	common name for peritelevision connector
SCSI	small computer systems interface
STB	set-top box
TDM	time division multiplex
TV	television
UHF	ultra high frequency
UTP	unscreened twisted pair
VCR	video cassette recorder
VESA-VOST	Video Electronics Standards Association — VESA Open Set Top
VoD	video on demand

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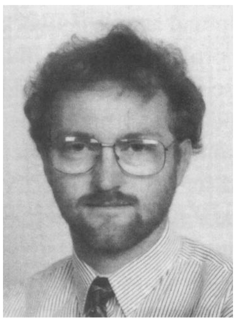
5 Multimedia Hypermedia Experts Group: ISO/IEC13522

Bob Bissell joined BT in 1973 and was involved with the development of electret microphones within the acoustics group. From 1980 he was involved in the design of BT's first 'in-house' designed electronic telephones. He was later involved in the payphone enhancement programme and supported the introduction of new public payphones.

His current activities include supporting the IMS set-top box development and the definition of the 'top-level' architecture for the future broadband customer environment. He also represents BT on the set-top unit technical committee within DAVIC.



Adrian Eales joined BT in 1984 as a sponsored student, and after graduating with a BSc (Hons) in Electronics Engineering from Kent University he worked on the production of electronic office automation systems within BT. This led to an investigation of the concept and development of 'wide area workflow' systems for use within BT.

He joined the IMS terminal applications team in 1993 to work upon the IMS trials, with responsibility for the specification and delivery of set-top boxes for the trials. Subsequently he has represented BT at a number of standards bodies dealing with interactive set-top box issues.

Currently, he is working on the roll-out of multimedia equipment to public locations.