Set-Top-Box for Terrestrial Digital Broadcasting: Compatibility Issues

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***Abstract*—**The Set-Top-Box (STB) has been in use to provide interface between the display device, which could be a television or computer, and the broadcasted digital signals through different transmission media. The Introduction of terrestrial digital broadcasting added a new dimension to STBs of broader demand for all that were receiving analog terrestrial television signals. Costs and interoperability were identified as key factors influencing digital take up in a number of countries that have implemented or are in the process of doing so. This paper provides an overview of STB addressing a number of issues.

***Keywords*—**STB, interoperability, digital broadcasting, conditional access, simulcrypt.

I. Introduction

TRANSMISSION of digital video broadcasting of TV signals can be done over terrestrial (DVB-T), cable (DVB-C), and satellite (DVB-S) using MPEG-2 transmission stream. All data is transmitted in MPEG transport streams. The compression of TV signal was done initial by standard MPEG-2 compression and then MPEG-4 for all three transmission media. However, the modulation scheme used in each case is different. DVB-T use Orthogonal Frequency Division Multiplexing (OFDM), while DVB-C and DVB-S uses Quadrature Amplitude modulation (QAM) and Quadrature Phase shift keying (QPSK). These distribution systems differ mainly in the modulation schemes used and error correcting codes used, due to the different technical constraints. DVB-S (SHF) uses QPSK, 8PSK or 16-QAM. DVB-S2 uses QPSK, 8PSK, 16APSK or 32APSK, at the broadcasters decision. QPSK and 8PSK are the only versions regularly used. DVB-C (VHF/UHF) uses QAM: 16-QAM, 32-QAM, 64-QAM, 128-QAM or 256-QAM. Lastly, DVB-T (VHF/UHF) uses 16-QAM or 64-QAM (or QPSK) in combination with COFDM and can support hierarchical modulation [1-4].

When International Telecommunications Union (ITU) decided to change from analogue to digital terrestrial broadcasting, all its consumers were having analogue TV sets. It was unrealistic to expect the consumers to replace them immediately with digital receivers, moreover during dual illumination period analogue broadcasting continued. Hence, a set-top-box provided the solution. The concept of set-top-box (STB) dates back to the 1960s when the STB known as UHF converter was used to shift down a portion of the UHF-TV spectrum onto low-VHF channels for viewing. Currently STB serves as is an interface to convert transmitted digital video signals transmitted through satellite, cable, terrestrial or networks (IPTV) to the form that can be displayed on the standard LCD, LED, and Analog TVs. The DVB-receivers for different transmission scheme used are the same except for demodulator. Hence, if a single set top box can be used to

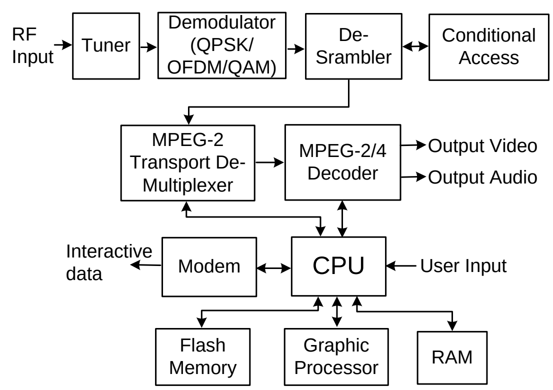

Fig. 1: STB block diagram

receive DVB-T, DVB-S and DVB-C signals it shall be cheaper. There are two concepts for the architecture of the STB; Open Architecture and Interoperable [1,5]. The STB has a number of independent functional modules that are interconnected consisting of hardware and/or software associated to Intellectual property (IP). Open architecture needs all the Intellectual properties used in STB to be governed by the fair reasonable non discriminatory (FRND) terms set by recognized international bodies. Interoperable on the other hand means it should have the capability to receive signals from any of the DVB transmission type. The output from the input modules (tuner and demodulator) is MPEG-2 transport stream. The STBs have some form of modem to allow it to send and receive interactive data [2].

The cost of STB has been an issue for digital migration strategy for terrestrial TV broadcasting in many countries that needed to be addressed to promote quick digital take-up [6-8]. Different strategies were adopted by different countries ranging from providing free set-top-boxes to some house holds to subside to tax relief. Hence, having a single STB to receive all terrestrial broadcasting services from different

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players for FTA and scrambled services is another strategy intended to address consumer needs and convenience [6,8].

II. CONDITIONAL ACCESS

In general, digital TV information in the MPEG-2 TS may be encrypted. The MPEG de-multiplexer selects and decrypts the compressed audio and video for a 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 input module will be different for different transmission media. Hence, interoperability across different transmission media requires switchable input modules [3].

The TS also carries two types of messages; the Entertainment Management Message (EMM) and Entitlement Control Message (ECM) for encrypted services. An EMM carries a list of Pay TV services, who is entitled to view what and the dates for the entitlement. The ECM carries control word (CW), which is used to descramble the picture in the STB to make it intelligible. Both these messages are carried in the TS in an "encrypted" form. While the DVB common scrambling algorithm (DVBCSA) is standardized, the encryption algorithms for ECM/EMM are not [7].

The various DVB CSA compliant CA systems use different ECM/EMM encryption algorithms and the algorithms are closely guarded secret since the security of a given CA system depends primarily on their efficiency. The CA module in the STB contains the relevant ECM/EMM decryption algorithm. When the CA module is embedded in the STB it is not an "Open Architecture". Hence, it is not interoperable across different networks using different CA systems. Therefore, to make a STB interoperable across different networks using different CA systems requires introduction of a standard DVB Common Interface (DVB-CI). DVB-CI is an external module

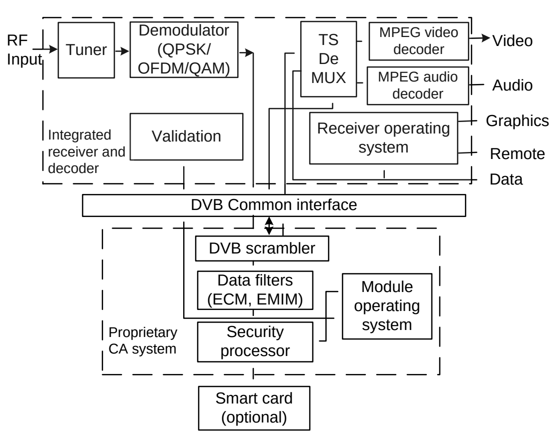

Fig. 2: STB for multiple CA Systems

containing the CA system for accessing the scrambled content. It facilitates communication between the STB/integrated receiver and decoder and the proprietary CA system. DVB-CA providers develop proprietary conditional access systems compatible to DVB-CI. The CI uses the conditional access module (PCMCIA) connector and conforms to the Common Scrambling Algorithm (CSA) [9,10]. It enables the receiver to accept Data Encryption Standard (DES) keys in intervals of some milliseconds and use them to decode private channels according to a specific algorithm. Multiple simultaneous CA systems can be assigned to a scrambled DVB program stream providing operational and commercial flexibility for the service provider enabling reception from different CA systems with a single STB [3].

III. SOFTWARE

STB operating system is present in the "Kernel" layer. It is loaded and remains in memory when the STB is powered until it is switched off. The kernel supports multi threading and multi tasking functionality allowing STB to execute different sections of a program and different programmes simultaneously. At present there is no standard STB OS. Many broadcasters and consumer electronics 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, Microsoft Windows CE etc. Also, STB has a "loader" to enable the TV operator upgrade "resident applications" or download "OS patches" to the STB; "drivers" to control the various hardware devices and an Application Programme Interfaces (API)/middleware to facilitate development of application on the OS [1, 11-13].

Interactive and enhanced are broadly the two types of

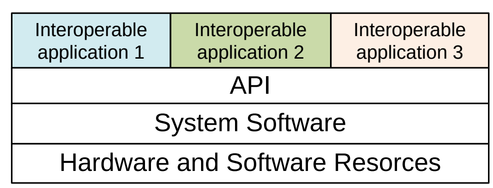

Fig. 3: MPH Reference Model

applications that can be run on STB. The transfer of data in a bidirectional path is not possible in enhanced application while there is data exchange in bidirectional path in interactive application. The two applications inhibit the STB from being interoperable. However, the Multimedia Home Standard (MHP) software architecture can address this problem. API in MHP is based on java that is platform independent. The adoption of this standard however has been resisted by broadcasters in a number of countries like Malaysia, New Zealand, UK and Hongkong that chose to adopt the less powerful MHEG-5 middleware because of licensing issues. However, simple receivers not including interactivity does not nee this application software [12].

IV. SIMULCRYPT

A. Architecture

The DVB-Simulcrypt system architecture shown in fig. 4 has two principal areas: the Host Head-end components that must be in place before simulcrypt CA components can be introduced into a DVB-Simulcrypt head-end and the

Simulcrypt CA components which are brought by a new CA provider to introduce his CA into a DVB-Simulcrypt head-end. It must be noted that the EMMGs, PDGs and Custom SI generators are not necessarily required in a DVB-Simulcrypt system [14].

There are two standards defined for the head-end implementation of DVB Simulcrypt: the Simulcrypt (Part 1) TS 101 197 [15] and the corresponding Simulcrypt (Final) TS 103 197.

B. MPEG-2 and MPEG-4 Compression Technologies

Digital video terrestrial broadcasting used MPEG-2 compression technology initially, however a more efficient technology H.264, MPEG-4-AVC video compression standard was developed jointly by ITU-T and ISO/IEC-MPEG. MPEG-4 compression offers more than twice spectrum efficiency compared to that of MPEG-2. Example, a UHF frequency channel of 8 MHz spectrum with 19 Mbits

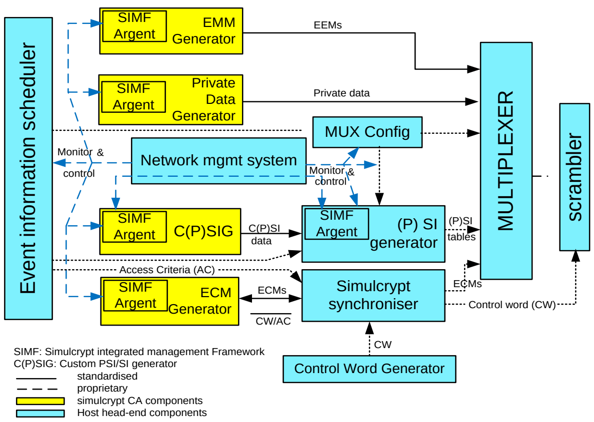

Fig. 4: System Architecture

throughput would allow a nominal 9 standard definition (SD) service channels compared to 4 SDs in MPEG-2. The frequency spectrum being scarce resource the MPEG-4 was adopted for DVB-T in many countries. STBs allowed backward compatibility. Although the MPEG-2 STBs were much cheaper at the time, the decision to adopt them was made to avoid long term legacy issues. Although the nominal number of service channels for UHF 8 MHz for MPEG-2/MPEG-4 are 4/9 respectively broadcasters are squeezing in up to 20 channels [3,14,16]. One observes however that when rate and quantity of change are low there is no observable loss of quality. However, where there are fast changes like in sports the quality degrades below acceptable level. What broadcasters does is to assign dynamically bit rates depending on the activity level of a service channel.

V. STB Specification Adoption

This has remained an area of contention between broadcasters and the regulatory authorities on the minimum mandatory specification of a set-top-box for digital terrestrial broadcasting. The broadcasting technology in use in a given country had bearing on this. The countries with weak economies without high density (HD) TV broadcasting their interest is in standard density (SD) whereas countries with high penetration in pay TV their concern was on the Free-To-Air (FTA) offering capabilities. Hence, in countries like Malaysia and New Zealand HD was considered as mandatory requirement while SD was a backward compatible requirement for Digital Terrestrial receiver for reception of ‘Free-To-Air’, or unencrypted services. What is significant is to define required and optional categories specifications [6-8].

Tanzania adopted the DVB-T standard for digital terrestrial broadcasting. Three MUX Operators have been licensed and all have chosen to offer combined FTA and conditional access services by allocating space in each frequency channel. It has been difficult for the three players to accept using a common cooperation platform to offer services to its customers. Hence, each MUX Operator has opted for different brand of scrambling algorithm. This is not surprising since in other countries that have completed deployment of terrestrial digital broadcasting have gone through the same experience. This problem has been there for cable and satellite broadcasting services offerings. The conditional access algorithm vendors are largely contributors to this fragmentation.

VI. DTT Rollout

The Regulatory Authority responsible for communications in Tanzania adopted a flexible licensing framework that is service and technology neutral. This innovative approach made Tanzania realize exponential growth in the telecommunications sector. It is believed that the same shall assist Tanzania experience similar growth trend in terrestrial digital broadcasting. Three Multiplex Operators (MUXOs) were licensed to provide network facilities to facilitate migration to digital broadcasting while taking into consideration fostering competition for the benefit of end users in terms of variety of services offering and terms and conditions to receiving such services and ensuring feasibility of a business case. The MUXOs have the role of aggregation of different programmes, packaging, distribution to respective transmission sites and transmitting them. These three MOXOs are at different stages; one have covered 26% and the second 7% of the regional headquarters while the last one was yet to start rollout by August 2011. The three licensed MUXOs were intended for three categories; commercial, public and religious organisations. However, financial capabilities of the intended entities made implementation to differ slightly from the ideal plan where all analogue broadcasters were to form a consortium to run the commercial MUX but only a few could afford to join. The same was for the religious organisations. The public broadcaster had problems to finance DTT rollout, hence entered into partnership with a commercial entity where conflict of interest between offering public service and doing business was inevitable. The two MUXOs used different philosophy; one provided real DTT infrastructure while the second followed the Algerian model of combining DTT and satellite to provide countrywide coverage. It is important to mention that satellite coverage for FTA for Tanzanian broadcasted programmes have been on offering in Tanzania for about 10 years. The third MUXO is using DVB-T2 standard while the other two are using DVB-T standard which was adopted for SADC and East African Countries under the cover of technology neutrality aspect of the licensing framework [20].

VII. INTEROPERABILITY OF STBS

Interoperability will facilitate development of horizontal market for end user equipment in digital broadcasting allowing competition between manufacturers to supply equipment directly to consumers (i.e. through third-party retail outlets), rather than consumers being provided with their equipment as part of a bundled tariff arrangement with a pay-TV operator. Such equipment includes STBs, i-DTVs, STB personal video recorders (PVRs), widescreen TVs, and multimedia PCs [12].

In Tanzania, although the third MUXO had not started rollout by August 2011, is planning to use DVB-T2 having ordered equipment for that would add another dimension to the complexity of affordable interoperable STB. All MUXOs plan to carry both encrypted and FTA services in their networks. Furthermore, there is very limited use (hence "penetration") of satellite based encrypted TV services and an even smaller cable TV penetration. An ideal choice is having a single STB that can be used to receive all these services, hence interoperability across networks and scrambling algorithms is required. However, minimum requirement has to be established that takes into account the wish to have a single STB to access different digital broadcasting services on offer and the economical power of the larger part of the targeted customers that are mostly low income earners. To ensure interoperability one has to consider system architecture, timing relationships, messaging structures, extended interoperability and control aspects that much be incorporated in the headend.

Interoperability was an issue in European Union since the beginning of the 2000s even when penetration of DTV in the member states in 2001 ranged from 3 to 40% where there was a separation between pay TV and FTA services. The pay-TV operator had a direct relationship with manufacturers, providing specification of receivers to match the requirements of their network. Due to lack of coordination between the different operators there was no compatibility between them especially in embedded application programming interfaces (APIs) and delivery platforms. The concern at the time was that non-interoperability could inhibit development of the FTA digital sector by reducing the volume of particular form of receiver equipment impeding exploitation of economies of scale to lower receiver prices and content due to re-authoring costs. For the digital take-up in developing economies, Tanzania included, the cost of digital receiver is a paramount factor considering the income level of the majority. Different countries adopted different strategies to facilitate interoperability since the result of study on this suggested different scenarios. Some countries adopted single encryption algorithm scheme/technology while disagreement remained in others. For countries like Sweden where the MUX are operated government entity, interoperability was easily managed. Each had own reasons ranging from investment made to promoting competition and fostering development in the technology [16,17].

Interoperability aims at facilitating choice and affordability of services to end user by different broadcasters. Hence, the STB receiver must give access to all digital Terrestrial television broadcasting services prescribed by a respective country. For example Malaysia, New Zealand and Australia emphasized on free-to-Air and enhanced/interactive/high definition television services including DVB subtitles when broadcast or at viewer request, Digital Text and Enhanced Broadcast elements of all services; manageable output aspect ratio [16-19,21].

VIII. STANDARDS

Some standards were adopted for use in DVB and are being used in STBs. These include compression standards for audio and video signals. MPEG4 for video signal compression the H.264 AVC Encoding standard or ISO/IEC 14496-10 2005 and MPEG2 now an option was the initial compression standard for video signals having a video resolution of 720x576 (PAL) Opt ISO/IEC 13818. The SDTV Formats Resolution / Frame Rate / Scanning / Aspect Ratio are respectively: 576i25 : 720x576 / 25 / Interlaced / 16:9 and 4:3 (obligatory) and 576p25:720x576 / 25 / Progressive / 16:9 and 4:3 (Opt). For audio decoding the common standard is Dolby Digital (AC-3) 32, 44.1 & 48KHz – Pass Through Only, [ISO/IEC 14496-3] and signaled by TS 101 154 standard. In addition, MPEG-4 HE AAC (mono and stereo level 2 bitstreams only), [ISO/IEC 14496-3] applies.

Other important parameters for STB includes: Hardware - RF front end and connection to display, middleware, operating system, user interface, error screen codes & messaging, manufacture selection, cost / time / penalties, manuals and independent conformance testing for hardware and software.

IX. CHALLENGES

There are a number of operation scenarios for offering FTA and CA broadcasting services. For example, the same MUX carrying both FTA and CA as is the case in Tanzania while another scenario is where CA and FTA are in two different MUX. This mode calls for daily re-authorizations of PAY services making subscribers switching to FTA bouquet taking long periods when CA entitlement bandwidth is limited. The best solution to this could that all MUXOs carry other CA.

X. APPLICATION PROGRAM INTERFACE AND DVB SOFTWARE

An application program interface (API) is built in programmer's tool kit for requesting data objects or services resident on a particular operating system. Using the API, a programmer writing an application can make requests of the operating system. Different countries have defined an API/Middleware software standard for digital terrestrial broadcasting using their different digital terrestrial groups. For example in the UK the Digital terrestrial Group (DTG) defined Multimedia and Hypermedia Information Coding Expert Group-5 (MHEG-5) and DSM-CC1, which are Open ISO standards and ETSI approved while Italy adopted the DVB Multi-media Home platform (MHP)3 Open standard of Java for Digital broadcasting. Each of the standards adopted is claimed to offer certain benefits. For example MHEG-5 is claimed to be designed with low cost (zapper) set top boxes in mind, hence requiring and demanding minimum system support or resources for an operational API/Middleware. The MHEG-5 applications reside at the broadcasters head-end. They are transmitted via a broadcast stream to the receiving device (stb or television) having MHEG-5 compliant engine embedded into its software enabling the user to utilise receiver resources. It mainly invokes receivers' graphical On Screen Display (OSD), stream control and DVB Service Information (SI). It is further claimed that MHEG-5 allows greater competition since third party companies can design plug-ins and add-on products for MHEG-5 engine compliant receivers since it is based on open software standards. Many countries adopted readily available simple DVB-T, low cost solution which provides basic Digital TV pictures, sound and with no interactivity capability [9,11,12].

The establishment of digital TV world standard can be traced back to the historic Digital TV standards group and then the defunct Digital Audio Visual Council (DAVIC). The later selected Java TV Virtual machine (VM) and MHEG-6 and pushed to be adopted as the world software standard for Digital TV while ETSI played part in assisting to define the European Digital TV standards. The Digital Video Broadcast group (DVB) that took over from DAVIC; is promoted Java as the core Digital TV software for the Multimedia Home Platform (MHP) standard with optional plug in software modules such as MHEG. The MHEG and MHP are both open software standards and can co-exist inside the same stb, its data formats are backward compatible sharing common software processes, and components such as DSM-CC the broadcast data carouse [3].

The notion of a universal software stack, which could be deployed in many and varied receiver devices including IPTV, DVB-T set top boxes, PCTV plug in cards and televisions with integrated digital tuners has not materialised. The need for cheaper low cost Digital TV hardware & software in emerging countries is important for digital take up. Expensive high end Digital TV hardware and software system providing the sophisticated functionality cannot be popular in developing countries because the major cannot afford them.

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