Trends in Interactive Services for Digital Television Infrastructure

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Abstract: - The challenge of multimedia communications is to provide applications that integrate text, image, and video information and to do it in a way that presents ease of use and interactivity. This paper deals with trends in interactive services for digital television infrastructure from the point of view of return channel and flow of information. We start with a short overview concerning previous work on this hot topic. Then, we deal with the interactive services in digital television infrastructure. After that adequate solutions for return channel are presented. Finally, flow of information in the interactive TV services for mobile devices is described including applications on mobile devices.

Key-Words: Digital TV, DVB, flow of information, interactive services, mobile devices, return channel.

1 Introduction

The superior quality of digital television, the wide acceptance of standards, and the ability of digital television to provide more functions mean that the future of television is undoubtedly digital. The storage and transmission of digital data is only really viable when it is compressed. During post-production a piece of content may be compressed and decompressed many times, great care needs to be taken to ensure that the quality does not suffer as a result of this. However, once data is in a final form, it only needs to be compressed at a central location before being placed in its storage hierarchy ready for transmission. Interactive TV (ITV) is often solely understood as the ability to change a program’s storyline. ITV in general means providing some kind of interactive add-ons or TV-related content and services [1]. If the data is transmitted in its compressed digital form all the way to the receiving television, then decompression has to be done in every single household. Set-top boxes are capable of performing this decompression. For example, the viewer might participate in a game show, gather additional information on news topics, or buy product presented in a commercial. The combination of digital TV and modem set-top boxes facilitates the deployment of such innovative services.

Digital television not only represents progress in terms of communication technology, but also offers a new way of accessing information. Digital TV will enable the transmission of different types of programs that might include high-definition shows, standard-definition programs, audio broadcasts, or any type of multimedia content. One of the major novelties of digital TV is the advent of interactivity between users, broadcasters, and content providers. With digital TV, users can participate in polls, play games, search the Web, and send and receive e-mail, for example. Interactive TV has actually been with us for a long time. If we use a teletext service, for example, we interactively request what data we wish to view. However, in such a system the user is not actually requesting data to be transmitted, but is selectively viewing information that is already broadcast.

Through its history, television has evolved continuously to enhance the reality of the viewing experience. The transition from analog to digital and from passive to interactive is the step in a long series of improvements to the system. Just as with change from black-and-white to color, the evolution to interactivity will require system wide changes, affecting program creation, storage and broadcasting.

Several projects and standards deal with ITV in various forms. The Multimedia Home Platform (MHP) specified a subgroup of Digital Video Broadcasting (DVB) Project [2], as one of the most important platforms [3]. MHP provides a hardware and vendor – independent execution environment for digital applications and services in the context of DVB standards. MHP applications range from simple applications with rudimentary interaction capabilities to powerful and complex applications. Typical applications are new tickers, advanced teletext, education, e-commerce. Other standards, such as Open Cable Application Platform [4], or the Advanced Common Application Platform [5] which are widely used by US TV system operators offer capabilities comparable to those of MHP. A common characteristic of these platforms is the focus on the set-top boxes. Interactive applications are exclusively run on the set-top box. The user can interact through a remote control or a special keyboard. For these applications, the TV screen has to be shared between the user interface and the actual TV program.

Other research projects and standards address the area of mobile TV services in which the mobile device replace the TV set. Examples of these approaches include the Savant project [6] or the DVB-H Electronic Service Guide [7]. The Television and Mobile Phone Assisted Language Learning Environment facilities language learning by combining an ITV learning application with a mobile phone [8]. The learner can access the program summary as well as a list of difficult language items that might appear inside a program.

Also, commercial project have begun to address TV add-on content and services on mobile devices. The business model for these projects focus on chargeable services. The Service 2 Media Company [9] offers several services such as electronic program guides or interactive advertising on mobile devices. Blucom, a product of the Astra Platform Service Company [10], makes use of mobile phones for ITV-related applications. These services are presented in a special browser with the content being offered to the mobile device through a special set-top box via WPAN (Wireless Personal Access Network) or downloaded via a cellular network.

We start with discussing interactive services in digital television infrastructure. The second part will deal with adequate solutions for return channel including Wi-Fi ad hoc, CDMA, WiMAX, PLC, as well as ADSL technologies. Flow of information in the infrastructure TV services for mobile devices together with the corresponding applications concludes the paper.

2 Interactive Services in Digital Television Infrastructure

Digital television (DTV) technology is commercially today in hybrid digital-analog systems, such as digital satellite and cable systems and it serves as the default delivery mechanism for high-definition TV (HDTV). All digital sets, such as HDTV, can display higher resolution in digital format and do not require additional external conversion equipment. For service operators, the key benefit is the high transport efficiency – digital compression packs five or more times as many channels in a given distribution network bandwidth. In turn, this increases the operator’s revenue potential by delivering more content and pay-per-view events, including near video-on-demand movies with multiple, closely spaced start times. End users have a larger program selection with spaced start times.

Fig. 1 shows an example of a satellite-based DTV broadcast system with main components and Public Switch Telephone Network (PSTN) with authentication. A digital video broadcast network distributes audio and video streams to subscriber using a transport protocol. In standard based implementations, the MPEG-2 transport stream carries data over the broadcast network.

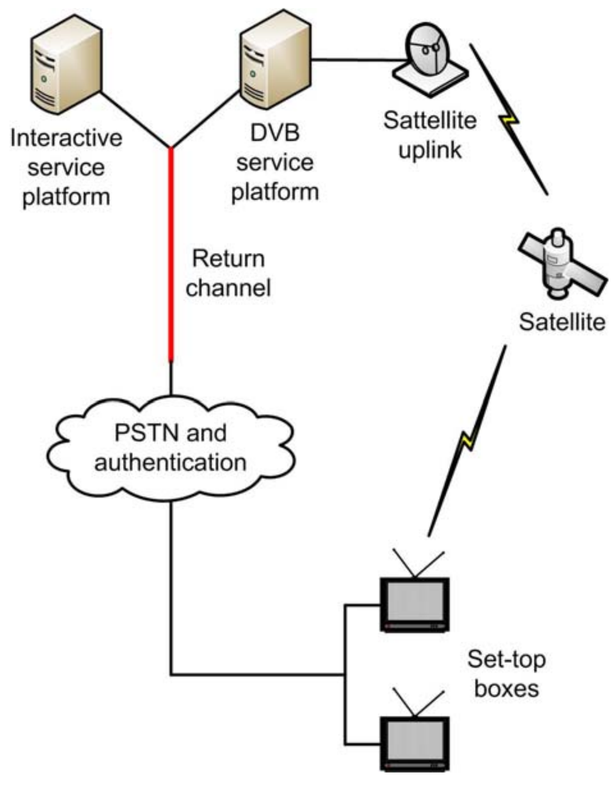

Fig. 1. Satellite-based DTV broadcast system

The MPEG-2 transport structure may contain multiple video and audio channels as well as private data. MPEG packet identifiers (PIDs) uniquely identify all program components. A typical set-top box contains a control microprocessor and memory, a network interface and tuner and demodulator for cable and satellite, a transport stream demultiplexer, and MPEG audio and video decoders. Where appropriate, the conditional access keys distributed to authorized subscribers are used to decrypt the encrypted content in the set-top boxes. Similar functionality can also be packetized into PC-compatible interface cards to let PCs receive digital video, audio and data from the broadcast network.

Table 1. Interactive data services as function of infrastructure capabilities

	Digital broadcast downstream			Point-to-point	
	One-way plant (satellite or cable)			Two-way plant (cable only)	
	No return	Polled return (PSTN)	Real-time return (PSTN)	Cable return (real-time)	
Network	Broadcast one-way	Broadcast polled return	Broadcast phone return	Broadcast two-way HFC	Switched two-way FTTC, ATM
Interactivity	Local	One-way (user response)	Two-way	Two-way	Two-way
User level function	Browse (view interactively)	Browse + batch transactions	Browse + real-time transactions	Browse + real-time transactions	Full service

From the data delivery point of view, the DTV infrastructure provides or broadband distributed network, data transport protocol and digital terminals (set-top decoders) on the user's premises. As such, it provides a powerful platform for delivering information and data services that not only enrich but fundamentally transform the television viewing experience. DTV systems always provide a one-way broadcast path for distributing digital video. Optionally, a return communication link can be provided to allow the upstream of data from users to the service center. The return channel is usually implemented via a narrowband communication link such as a PSTN or an integrated services digital network (ISDN). Cable systems with two-way enabled plants can implement a return channel over the cable infrastructure. Since both cable and satellite DTV systems use the same data transport mechanism and protocol – the MPEG-2 transport stream – the physical nature of the underlying distribution network is transparent to data services.

Data broadband technology enables DTV service providers to enhance their customer's television viewing experience by providing a wide range of interactive services as and incremental add-on to the DTV broadcast infrastructure. Depending on the underlying digital video broadcast system infrastructure, the following classes of interactive services are possible:

- Broadcast-only interactive services,
- Broadcast with a batch return channel,
- Broadcast with an online return channel.

Interactive data series as a function of infrastructure capability are summarized in Table 1. It should be noted that user-level capability and interactivity is a function of the network and connectivity infrastructure. An important challenge facing DTV service designers lies in dividing data services that operate in the most common, broadcast-only environment and scale-up in user-level functions with the increased capability of the DTV infrastructure.

2.1 Interactive Broadcast Data Services

Interactive broadcast data services can be categorized as: interactive data broadcast (IDB) services, interactive video broadcast (IVB) services, unsynchronized video and data as well as synchronized video and data [11].

In IDB, when a user selects such a service, a data-only screen displays. The user may use hot-spot or hyperline-style mechanisms.

IVB services combine video and data channels to provide an enhanced TV viewing experience. Service delivery and user experience of combined video-data services can be further categorized in terms of their temporal relationship.

In unsynchronized video and data may be typically related or unrelated. Common examples include a simple interactive icon overlay, a partial data overlay (for example, ticket display), or a data screen with a video (broadcast) insert.

As for synchronized video and data mode, they are typically related and authorized to be synchronized at playback. Classification of sample concerning interactive services is shown in Table 2 [12].

Many DTV systems use an intermittent batch return channel for billing of impulse pay-per-view (IPPV) events. At specified intervals, the control billing system polls individual set-top boxes to interactive the accumulated information.

2.2 Data Carousel Approach

DTV network acts as a large serial disk for storage. This approach gives rise to what is known as the data carousel. The approach allows clients with a local catching capability to find the necessary data and

Table 2. Classification of sample interactive services

Service	Broadcast (No Return Channel)	Polled Return Channel	Real-Time Return
Primary user-level service capability	Browse		
Broadcast video services			
Broadcast video	Tune	Tune	Tune
Electronic program guide	View, tune to selection	View, tune to selection	View, tune to selection
Impulse PPV, nVoD	View (order by phone)	View, order (smart card log)	View, order
Interactive data broadcast services			
Information services	Browse (data carusel)	Browse and acknowledge	Browse and request
Games	Download and play	Download and play (delayed comparasion of scores)	Download and play (real-time comparasion of scores, multiplayer)
Home shopping	Browse (order by phone)	Browse, order (delayed conformation)	Browse, order
Interactive video broadcast services			
Enhanced program information	Additional information broadcast, synchronized on current video program	Additional information broadcast (delayed requests)	Full interactive, ability to request additional information
Interactive advertising	Browse service information	Browse, order (delayed confirmation)	Browse, order on-line
Play-along programming	Play along, keeps score local	Play along, keeps score local, delayed comparasion	Play along, local and on-line scoring in real-time
Online services			
E-mail, forums	Receipt only	Receipt with delay replay, post	Full interactive receive and replay
Internet access	Internet broadcast		Full service
VoD	Not supported	Not supported	Fully interactive

code on the network at any time, with the worst case access latency equal to the carousel cycle duration. The structural layout of data carousel is shown in Fig. 2. The carousel data stream consists of an indexing and naming mechanism to locate objects within the data carousel, application code to download to the receiver when the user tunes into the carousel data channel, and application data objects that the user terminal retrieves at run time in response to the user's interactive request. A DTV network provides an ideal platform for distributing data broadcast in a carousel fashion. The interactive data services (carousel) are multiplexed in the MPEG-2 transport stream. From the management and distribution points of view, data service files can be handled in exactly the same manner as any other DTV stored content. This lowers system acquisition and operation cost for interactive service because the familiar service center equipment and procedures for TV signal delivery, such as the scheduler and near Video on Demand (nVoD) server, also distribute data services.

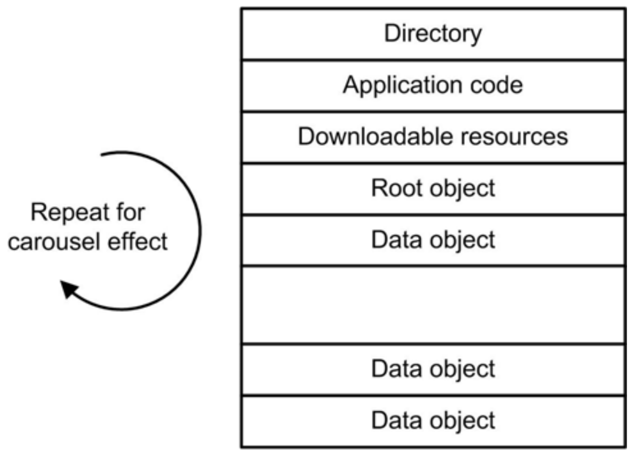

Fig. 2. Structural layout of data carousel

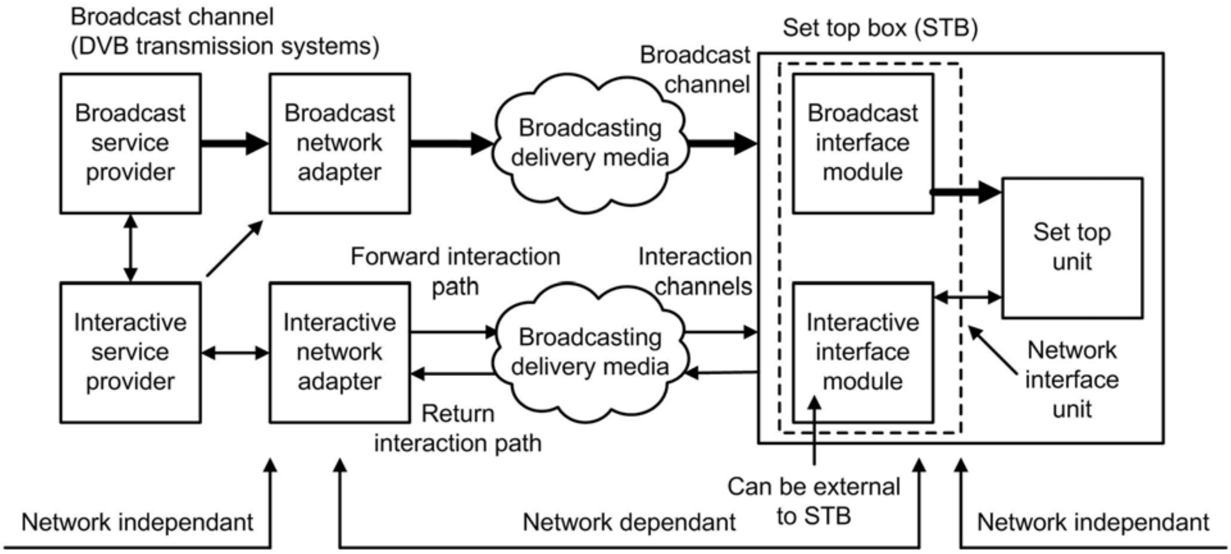

Fig. 3. General DVB return channel reference model

2.3 DVB with Return Channel via Satellite

Customers wish to choose, sort, order, store and manipulate what they receive on their terminals, and ideally also interact from the same terminals. The distribution network becomes an asymmetric interactive network, with a possible evolution towards fully symmetric communication. This convergence between communication and broadcasting leads to an evolution from broadcasting to multicasting or point-to-multipoint communication.

Owing to the recognized need for a specification of a return channel via satellite, the Digital Video Broadcasting – Technical Module (DVB-TM) created an ad hoc group in early 1999, called the DVB – Return Channel via Satellite (DVB-RCS). Fig. 3 gives the general DVB return channel reference model [13]. In this model, the interactive network is depicted as independent from the forward channel. However, often the forward interaction channel, or forward signaling channel, is integrated in the forward transport stream.

A simplified diagram network architecture for DVB-RCS system is shown in Fig. 4 [14]. Usually, several RCS terminals will be connected to the interactive satellite network, consisting of the satellite, an Earth station, and a network control center (NCC). The Earth station antenna acts both as feeder for the forward path and as a gateway for the return path. The NCC shall handle the synchronization, give correction messages to the terminals, and allocate resources. The NCC is in charge of the control of every RCST in the network as well as the network as a whole. A terminal will log on father having received general information by listening to the forward link which provides the network clock reference (NCR). If the terminal is successful with the request, the NCC will forward various tables containing general network and terminal-specific information about necessary frequency, timing and power level corrections to be performed by the terminal before transmission starts. The continuous signaling from the NCC is provided according to MPEG-2 [15].

Many satellite operators have shown their interest in the return channel via satellite technology, and concrete plans for operation of such services exist. As soon as higher volumes of terminals are produced, reasonable prices for the consumer market will be reached.

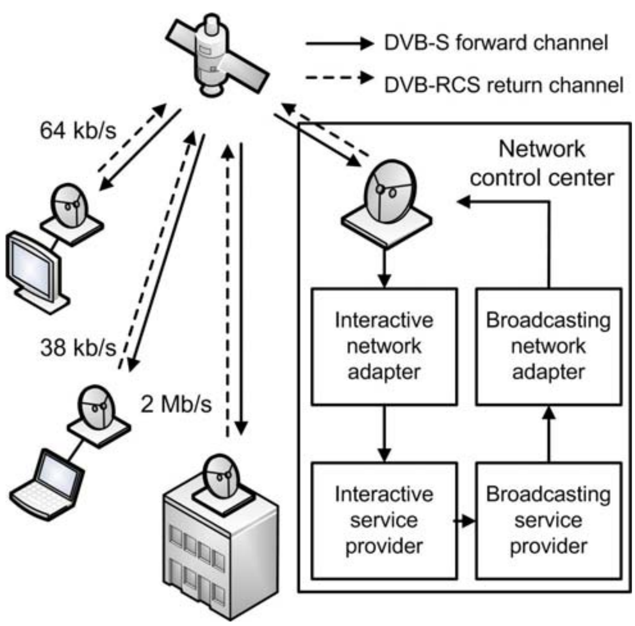

Fig. 4. Simplified diagram of a network architecture for DVB-RCS system

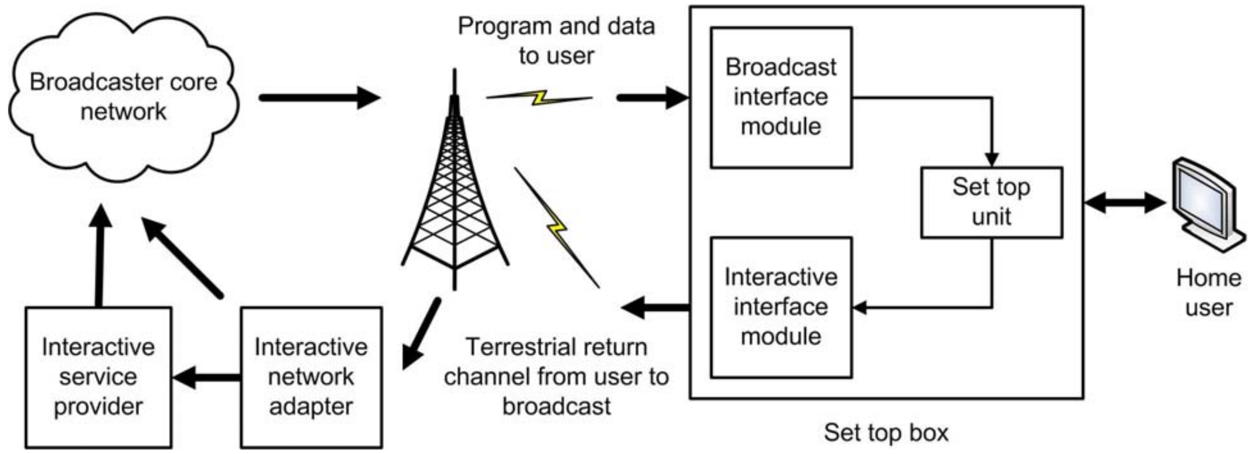

Fig. 5. An example of a system in a DVB-RCT network

Table 3. Main characteristics of promising technologies for return channel

	Wi-Fi	WiMAX	CDMA 1xEV-DO	PLC	ADSL
Subscription	No	Yes	Yes	Yes	Yes
Infrastructure cost	Small	Medium	High	High	High
Network availability	High	High	High	High	Very high
Transmission rate (Mb/s)	54	70	2.4/0.153	200	24/1
Range	Hundreds of meters	Tens of kilometers	Tens of kilometers	Hundreds of meters	A few kilometers

2.4 DVB Terrestrial Return Channel System

The terrestrial return channel system (DVB-RCT) is able to provide interactive services for terrestrial digital TV, using the existing infrastructure already used to broadcast DVB-T services [16], [17]. The terrestrial return channel system (DVB-RCT) is based on in-band (IB) downstream signaling. Accordingly, the forward information path data are embedded into the MPEG-2. TS packet, themselves carried in the DVB-T broadcast channel. The interactive system consists of a forward interaction channel (downstream), which is based upon an MPEG-2 transport stream converged to the user via a DVB-T compliant terrestrial broadcast network, and a return interaction channel based on a VHF/UHF transmission (upstream). An example of a system in a DVB-RCT network is illustrated in Fig. 5.

The DVB-RCT system follows the following rules:

- Each authorized DVB-RCT terminal transmits one or several low bit rate modulated carriers towards the base station;
- The carriers are frequency-locked and power ranged and the timing of the modulation is synchronized by the base station;
- On the base station side, the upstream signal is demodulated using an FFT process, just like the one performed in a DVB-T receiver.

For correct operation, the carriers modulated by each RCT terminal shell be synchronized both in the frequency and time domains.

3 Adequate Solutions for Return Channel

Effective promotion of new interactive services for digital TV is possible with the adoption of a low-cost return channel. This channel allows subscribers to interact by sending data back to the broadcaster. Different technologies can be used for the return channel (e.g., xDSL, CDMA, WiMAX, etc.). Table 3 summarizes the main characteristics of promising technologies for return channel [18].

3.1 Wi-Fi Ad Hoc Return Channel

The Wi-Fi technologies in ad hoc mode eliminates network infrastructure, and consequently stations must communicate directly between each others. If the destination is out of range, the neighbors cooperate as routers and forwards data packets over multiple hops in self-configuration manner. Hence, the ad hoc mode represents a flexible and low-cost solution for the return channel. In the ad hoc return channel, a forwarding node is a set-top box (STB) or access terminal. Gateway must be also implemented to connect community network to the Internet and to the broadcaster. Every node must be able to communicate with the gateway, directly or through multiple hops. The signal of the broadcaster is sent using terrestrial diffusion and the interactivity information must go back through the return channel, as preseented in Fig. 6.

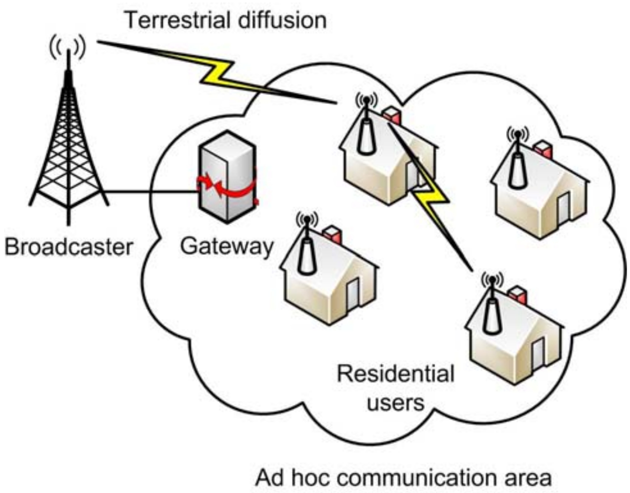

Fig. 6. Wi-Fi ad hoc return channel scenario

Access terminals provide network connectivity, forwarding data packets to the gateway. Obviously, the gateway may become a bottleneck, in which case more gateways can be incrementally deployed. Users with the ad hoc return channel has neither a fixed cost nor a subscription. Hence, the advantages of an ad hoc return channel are four-fold:

(1) it provides the required characteristics for the main interactive TV applications;
(2) ad hoc networking is inexpensive, flexible, and can be incrementally deployed;
(3) even if low-income people have to buy a set-top box, they do not have to pay monthly subscription,
(4) ad hoc community networks can be used in underserved regions to bring digital inclusion to thousands of citizens.

Despite its low deployment cost, the use of an ad hoc network as a return channel has a drawback — namely, connectivity. Unlike the other technologies, the ad hoc network may not be available because it depends on multihop communications. As the nodes rely on each other to send information to the gateway, these must be a minimum number of set-top boxes turned on to guarantee that users are connected to the gateway. The connectivity of the ad hoc network depends on the number of access terminals in a region, their transmission range, and the interval of time that they are on. The number of access terminals is related to the population density in the region. Another key aspect of connectivity is the interval of time during which the terminals are on. Depending on the habits of the viewers, during a large-audience TV show, a high number of terminals are expected to be working.

3.2 Return Channel Based on WiMAX

WiMAX was developed for WMAN environment to solve the last-mile problem, offering an alternative to xDSL and cable broadband access technologies. The main mode of operation is point-to-multipoint, where a base station provides access to several clients with transfer rate up to 70 Mb/s.

A WiMAX tower services users within tens of kilometers. Every service, even those that are not connection oriented, is mapped to a connection, thus easily supporting different levels of Quality of Service (QoS). The point-to-multipoint mode centralizes the traffic in the base station, increasing the infrastructure costs of the system, unlike the ad hoc solution for the return channel.

3.3 CDMA 1xEV-DO Return Channel

The CDMA2000 standard was designed for third generation (3G) cellular networks. CDMA2000 Evolution-Data Optimized (1xEV-DO) is an evolution tailored to support data applications, such as VoIP, HTTP, and file transfers. Assuming that, in Internet applications, most data flows towards users, the downlink and uplink transmission rates are asymmetric.

The commercial Release 0 of CDMA2000 1xEV-DO achieves rates up to 2.4 Mb/s on downlink and 153 kb/s on uplink using single 1.25 MHz CDMA carriers. Revision B will reach rates up to 73.5 and 27 Mb/s on the down and up links, respectively. For the downlink, it uses Time Division Multiplexing (TDM) and a fair scheduling algorithm to assign time slots to users. For the uplink, it applies a CDMA scheme. It also provides adaptive rate, congestion, and power control mechanisms to improve network efficiency.

The use of CDMA as the digital TV return channel requires base stations to provide connectivity to users. Although cellular networks typically have higher ranges than WLAN technologies, every set-top box must be directly connected to a base station, which demands a costly infrastructure. Especially in dense urban scenarios, a higher number of base stations are needed adding to expenses. Besides, CDMA operates in a licensed band reserved for cellular telephony companies. Hence, the CDMA return channel requires commercial agreements between TV broadcasters and cellular telephony companies.

3.4 PLC Return Channel

Most work in power-line communications (PLC) is concentrated in low voltage (LV) networks, such as in-home and last-mile technologies. The in-home technology is concerned with data transmission using residential electrical wiring. Currently, its principal standard is Home Plug Audio/Video, which reaches data rates up to 200 Mb/s. This standard uses a mix of TDMA and CSMA/CA. TDMA reserves the medium, ensuring a limited delay for interactive applications. On the other hand, CSMA/CA is used for reliable file transfers to fully use the medium capacity during bursts of data. To deal with the constraints of the medium, such as attenuation, noise, and impedance variations, Nevertheless, the electrical medium still represents the major obstacle to high-speed data communication, since it was not designed to carry data. Home Plug AV can be extended to medium voltage – low-voltage (MV-LV) transformers to provide network access in the last mile. Nevertheless, the size of the network depends on the number of users, the distance of the residences, and the type of cables in the neighborhood. The use of PLC as a return channel profits from the already available electrical infrastructure.

3.5 ADSL Return Channel

ADSL is currently the technology most used for last-mile Internet access. ADSL was first designed with VoD and related services in mind, where the amount of data transferred to the user are normally larger than the upload traffic. The frequency band reserved for the downlink is larger than that reserved for the uplink, thus allowing higher downlink bit rates. The use of ADSL as a return channel is technically viable. Nevertheless, there are disadvantages. It requires investment from telephone companies, which are not necessarily involved in the digital TV business. Further, TV broadcasters may not be willing to depend on the phone company to implement their return channel. Thus, even if higher transmission rates could be achieved by using ADSL technology, a lower-cost wireless could still be a better solution.

4 Flow of Information in the Interactive TV Services for Mobile Devices

In order to observe flowing of information in the interactive TV for mobile devices, the system has to be divide into to sides: the service provider side and consumer side [19]. The user with the mobile devices (the consumer side) uses the Universal Plug and Play (UPnP) architecture as a control point to find out and use the offered services [20]. This platform is not restricted to TV set-top boxes, but is available on personal mobile devices supporting multi-user access. Infrastructure TV architecture for mobile devices is shown in Fig. 7.

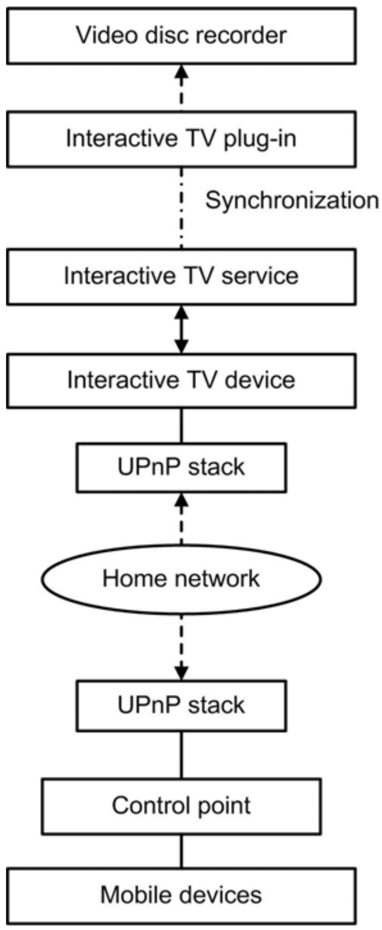

Fig. 7. Interactive TV architecture for mobile devices

Video Disc Recorder (VDR) enables a user terminal to function as a digital receiver and video recorder. Any extendable media center software could be used. The main purpose of the VDR's plug-in interface is to build the synchronization time stamps. After the user starts the media center, it is possible to configure the interactive TV plug-in to extract synchronization information in the live stream, in the playback, or in both modes. For example, if the user watches live TV, the system combines the presentation time stamps with the channel's name and the stream's video ID to allow for proper identification of the corresponding content.

The interactive TV device is the first component of the UPnP framework in the system. It represents an UPnP root device and offers UPnP functions such as the announcing the device and its services in the network, responding to search queries, sending event messages on state changes, and controlling the device. The device forms a container for the service that UPnP defines.

The control point represents the main component on the client side. Its purpose is to reach for UPnP device and services in the network and make them available to the user. At startup, the platform initiates the discovery process for UPnP devices automatically. The user interface displays every discovered device and the user can access further information on devices and their services if desired. If a TV device with ITV service is found, the control point subscribes automatically to ITV events. The event listener takes care of synchronization on the client side.

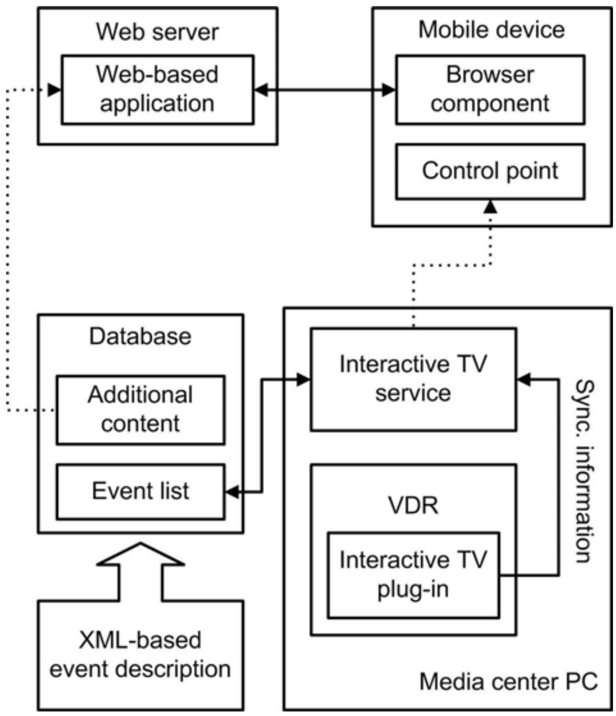

Fig. 8. Information flow in interactive TV

Information flow for the ITV system is shown in Fig. 8. The ITV control point on the mobile device detects the service offered over the UPnP framework and connects to the service. The ITV service receives two types of information:

(1) synchronization information from the VDR plug-in and
(2) list of events from an event database that holds out events concerning the ongoing TV program.

The ITV service notifies the control point whenever an event occurs. Events with the content type of Web-based application cause the mobile device to open the interactive application. These applications are hosted on a Web server, which runs locally on the Internet or on the set-top box. With a local Web server, there is no need for an Internet connection. The mobile devices can then load the application in its browser. The data used in the application is hold in a data base, which can be the same database that holds the events.

5 Concluding Remarks

Multimedia Home Platform (MHP) defines a generic interface between interactive applications and the terminals on which those applications execute. This interface decouples different provider's applications from the specific hardware and software details of different MHP terminal implementations. The interactive TV platform presents an easy way for providing synchronous TV add-on services and interactivity on personal mobile devices.

The UPnP architecture extends this concept to the networks. The main advantage of UPnP's is that users can connect to offered services without any complex configuration. A user-profile based TV guide with an integrated recommendation function for the ITV platforms is an interesting research topic. A platform that uses mobile devices to support multiuser and personalized access for ITV services is described. ITV platform makes use of the UPnP architecture for ITV services.

Compared to other systems that offer interactivity, such as MHP, the interactivity in the described ITV platform is not restricted to TV set-top boxes, but is available on personal mobile devices. This interactive TV platform can support multiuser access. The future work in this area has to be focused on developing services like audio and video for accessing different types of media or a remote-control service.

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