Technologies for DVB Services on the Internet

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Invited Paper

In 2004 DVB approved the first edition of the DVB IP Handbook, intended to support the first commercial deployments of Internet TV services. The specifications in the handbook standardize technologies at the receiver interface, to enable TV, radio, and general interactive multimedia services over IP-based networks. This paper gives an overview of the specifications, beginning with the reference architecture currently used by DVB. The key technologies specified are service discovery and selection, a DVB Real-Time Streaming Protocol client, MPEG-2 transport over IP, IP address allocation and network time services, receiver identification, and a network provisioning option.

***Keywords*—*DHCP options, DVB IP service, DVB Real-Time Streaming Protocol (RTSP) client, DVBSTP, Internet TV, IPTV, IPTV receiver identification, IPTV receiver provisioning, live media broadcast (LMB), MPEG-2 TS over IP, Real-Time Streaming Protocol (RTSP), service discovery (SD), service discovery and selection (SD&S), service selection, service discovery and selection (SD&S) transport.*

I. Introduction

The goal of the DVB IP Handbook [1] is to specify technologies on the interface between an IP network and a digital TV receiver, enabling deployment of TV services over IP-based networks—IPTV for short—and mass production of IPTV receivers by consumer electronics manufacturers. The technologies specified, implemented in a DVB IP receiver, should allow end users to buy such a receiver in any shop, connect it to a broad-band network, switch it on, and, without further ado, start to receive DVB services over IP-based networks.

The regular DVB process is to develop technical specifications based on commercial requirements; however, since TV services over the Internet were almost nonexistent during development of the specification, such requirements did not become available in sufficient detail. Therefore, the Phase 1 DVB IP Handbook is set up to support early service deployments, to investigate service options and customer demands, as first steps toward ubiquitous TV service over the Internet. This paper describes the key technologies specified for this first phase. A consequence of this intended usage of the Handbook is that as much as possible use is made of existing technologies and methods, even when newer and better technologies are in the offing. A further consequence is that a second edition of the handbook is now well advanced.

Since commercial requirements for the DVB IP specifications were incomplete, the starting point of reference for Phase 1 was digital TV service as deployed on traditional media: satellite, cable, and terrestrial transmitters, an area covered extensively by DVB specifications. MPEG-2 was selected as digital A/V content format, because this technology is available everywhere. The new content format AVC, which may reduce the service bit rate by as much as a factor of two, will be addressed in the next edition of the handbook.

Although many technologies for Internet TV services are readily available from the IETF, DVB had to develop suitable protocols for IPTV service discovery and selection (SD&S). Even though seemingly related, existing IETF protocols such as the Session Description Protocol (SDP: RFC 2327) and the Session Announcement Protocol (SAP: RFC 2974) are meant for other services than digital TV and should not be misused, nor do they fully satisfy the DVB requirements. The IETF work on the Internet Service Guide was still in a very early stage at the time of development of the DVB specification, so there was no help there. Naturally, DVB fosters close relations with the groups working on these subjects in the IETF, where several DVB members are participating. Future versions of the DVB IP Handbook may well take into account the IETF service discovery (SD) protocols that are currently in development.

The first edition of the DVB IP Handbook deals with three basic types of service: live media broadcast (LMB), i.e., TV or radio style, media broadcast with trick modes (enabling a user to, e.g., pause a service), and content on demand. The structure of the handbook, mirrored in the succession of paragraphs in this paper, is as follows.

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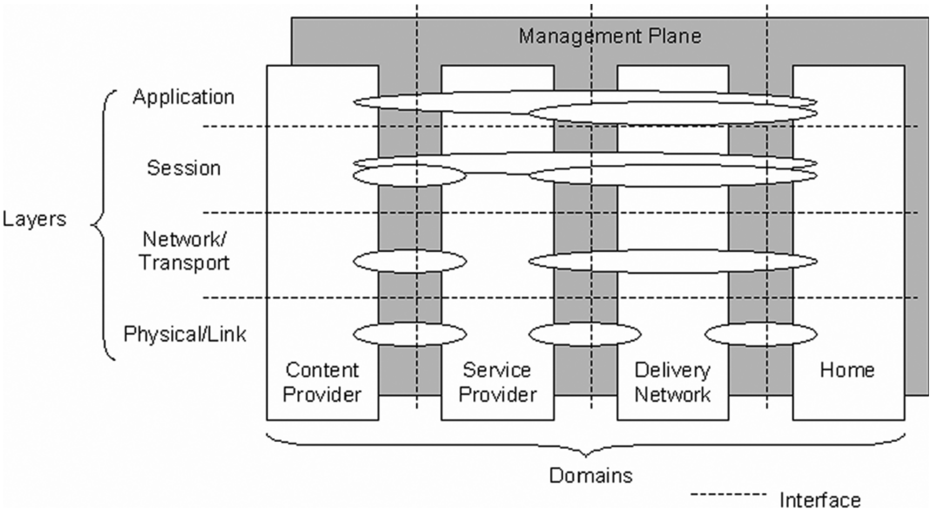

Fig. 1. System architecture.

- General sections, dealing with scope, references, and notation. Formal definition of the used textual notation is especially important in some places, because key parts of the specification consist of XML schemas and document type declarations (DTDs). The notation follows the augmented Backus–Nauer form (ABNF) according to [13].
- A chapter on architecture. Although the specification only deals with technologies on the interface to the IPTV receiver, the architectural references help to explain the nature of the interface and the interrelations between the elements of the end-to-end system.
- A chapter on SD&S. Technologies are specified for what is defined as LMB, media broadcast with trick modes, and content on demand. Since there is currently not an IETF transport protocol available for DVB IP SD&S, this chapter also defines a lightweight DVB SD&S transport protocol.
- Definition of the Real-Time Streaming Protocol (RTSP) client. This definition is required because on the one hand the IETF RTSP specification is too complex for complete implementation in DVB IP services; on the other hand, some technologies are not sufficiently strictly specified to achieve the desired interoperability among consumer IPTV receivers and DVB IP services.
- A chapter defining how the MPEG-2 transport stream shall be used with IPTV services. At the time of specification the AVC codec (also known as MPEG-4 Part 10 or H.264) was not yet finished. Additionally, hardware and software for MPEG-2 TS is ubiquitous, which is not yet the case for AVC.
- Specification of IP address allocation and network time services. This chapter specifies the usage of DHCP in IP address assignment. In this context it should be noted that the DVB IP Handbook specifies IPv4 [5] only. This chapter also defines which protocols to use for network time services.
- Definition of an identification agent in the receiver. This agent is required to enable service providers to recognize whether receivers can be correctly provisioned, in case the service provider makes use of the network provisioning option. This chapter also describes a congestion avoidance mechanism.
- Specification of optional network provisioning technology. This specification consists of protocols and references to normative XML DTDs. These DTDs are supplied as electronic files attached to the DVB IP Handbook.

The DVB IP Handbook also specifies Ethernet and IEEE 1394 physical layers for use in IP-based home networking. For the purpose of this paper, these subjects are not discussed. Finally, the DVB IP Handbook provides informative annexes on MPEG-2 timing reconstruction and on the data model used for development of the SD&S protocols. This data model is derived from existing digital TV services as operated over traditional media such as satellite, cable, and terrestrial transmitters.

II. Architecture

The overall system architecture for delivery of DVB services over IP-based networks is depicted in Fig. 1. In this architecture, four domains can be discerned: the content provider, the service provider, the delivery network, and the home. The communication between these domains is structured in four layers, labeled from the top down: application, session, network and transport, and physical layer. Although in IPTV service by far the greater part of the data transport will take place from the content provider domain to the home, it is important to recognize that the communication is bidirectional, as required on IP-based networks.

Most of the communication takes place between service provider and the home, in all communication layers, with the network domain as interconnect. In the application layer some end-to-end communication is shown between content provider and the home. this was included with digital rights management (DRM) in mind. However, DRM is still far from standardization, it could not be specified as technology in this edition of the DVB IP Handbook.

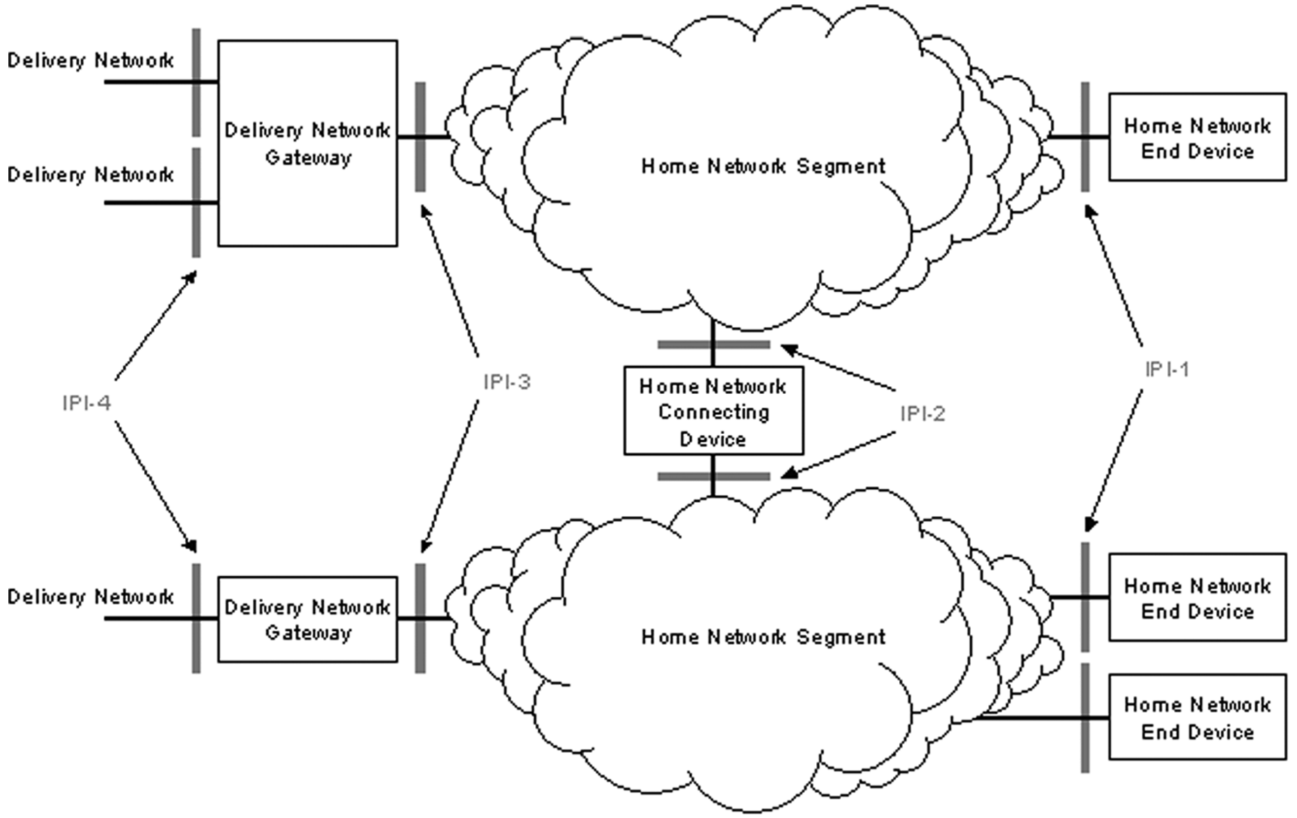

Fig. 2. Home reference model.

The service provider in Fig. 1 is the entity organizing and providing the TV service to the end user at home. This activity may include the role of the internet service provider (ISP), who normally provides Internet connectivity. However, this is not a subject in the DVB IP Handbook; a working broad-band Internet connection is taken for granted. In the context of this paper, a service provider offers TV services—or more generally, multimedia services—to consumers over IP-based networks.

The content provider domain is the collection of entities providing content assets for digital TV services. Examples of such entities are movie studios, broadcasters, information providers, game developers, etc.

The delivery network to the home consists of an IP-based network. At this time, this will most likely be an access network on bidirectional cable or xDSL systems, although bidirectional satellite and wireless networks also offer possibilities. As bandwidth increases in the course of time, the reach of IPTV services across the "wild" Internet will increase.

The home domain contains the standardization focus of the DVB IP Handbook in the form of the interface on the DVB IP receiver. The paradigm of DVB standardization is to specify technologies on the interface only and to specify the minimum necessary for interoperability. This way, the implementation of the receiver system is left free for the manufacturers. Also, there is freedom of implementation of networking and service provider systems by telecommunication and service provider companies, as long as they ensure their implementations will work on the standardized receiver interface.

Although home networking is not a subject in this first edition of the DVB IP Handbook, a reference model of the home network is defined with some key interfaces and definitions, illustrated in Fig. 2. The key interface for standardization in this model is the "IP Infrastructure-1" (IPI-1) interface. The other interfaces may be standardized at a later stage, as required. DVB uses the term "home network end device" to convey that the IPI-1 interface may exist on other types of equipment than traditional TV receivers.

A diagram of the protocol stack for DVB IP services is given in Fig. 3. Since a DVB IP receiver is assumed to be an IP-compliant device, it supports at its IPI-1 interface the protocol requirements as laid down in RFC 1122 [7], making available the HTTP, HTTPs, TCP, UDP, and IP networking and transport protocols. These protocols are not discussed in the DVB IP Handbook.

The top layer of the protocol stack consists of the DVB IP service offering. The various protocols shown connected to this from below constitute a kind of "service API" for the DVB service provider. In the diagram some protocols appear to cover several OSI layers, but their position in the OSI hierarchy is given by the bottom of the column. The top is shown connected to the "service offering" layer only to indicate that the protocol is part of the service API and needs to be dealt with by the service provider.

A simplification in the Phase 1 reference architecture is the restriction that a DVB IP receiver is connected to the

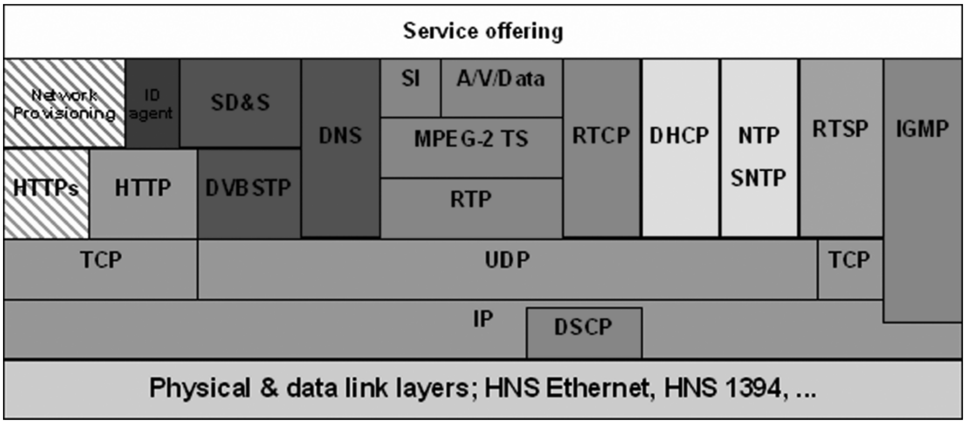

Fig. 3. Diagram of the protocol stack for DVB IP services.

outside world via a single home gateway, possibly with a home network in between. This is to evade problems in IP address allocation, which becomes quite troublesome when a home network contains several gateways, each with a DHCP server.

Hooks for QoS management are provided by support for differentiated service codepoint (DSCP) values.

III. Service Discovery and Selection (SD&S)

A. *Overview*

A key process, required to start using IPTV services, is discovery of the services available at the location of the end user. The result of this discovery process is a list of services, combined with information for the user how to select the service and for the receiver how to gain access to the selected services.

The specification covers LMB—including LMB with trick modes—and content on demand services. Within LMB two types of service are taken into account: services with full DVB service information (DVB-SI) embedded in the MPEG-2 transport stream (MPEG-2 TS) and services without embedded DVB-SI, but only carrying the necessary MPEG program specific information (PSI) to ensure full MPEG compliance of the stream.

TS-full-SI service is offered when a service provider selects transport streams from existing traditional DVB broadcasts and encapsulates these as they are for delivery over IP to the end user. In this case the provider only needs to generate the minimum discovery information to enable location of these transport streams at the receiver end. User information about the actual programs within the service is then acquired through traditional means from DVB-SI after reception of the transport stream.

When a service provider wants to present its offering directly on the Internet, full discovery information about each service must be made available, including the information about location and selection of the service. In this case bandwidth can be saved by keeping only the mandatory PSI in the MPEG-2 TS and leaving out the DVB-SI.

Information for SD&S is represented with and carried as XML records [21].

B. *Service Discovery (SD)*

The mechanism for globally unique identification of IPTV services and service providers makes use of the Internet domain name system (DNS). Identification of a service provider is through the DNS domain it controls, as registered with the Internet Assigned Numbers Authority (IANA). A service is identified by concatenation of a service name, uniquely managed by the service provider, and the service provider's DNS domain name. The syntax of the complete textual identifier then is:

$$\langle \text{service\_name} \rangle``."\langle \text{service\_provider\_DNS\_domain\_name} \rangle$$

where $\langle$service_name$\rangle$ follows the rules for Internet DNS names as laid down in RFC 1035 [6].

The successive steps in the SD process are summarized as follows:

1) find SD entry points;
2) for each SD entry point, collect service provider information;
3) for each service provider, collect SD information.

The SD process is bootstrapped by automatic determination of the SD entry points. The IPTV receiver looks for these entry points in the following order:

- if the network provisioning option is implemented, addresses of SD entry points are supplied by the configuration agent (cf. Section VIII on network provisioning);
- DVB IP service provider addresses supplied by a local DNS server in the access network;
- addresses supplied by services.dvb.org according to service location RFC 2728;
- addresses supplied at IP address 224.0.23.14, an IANA-registered well-known multicast address, administered by DVB.

The data model used for definition of the various types of SD&S information is shown in Fig. 4. Service provider information is carried in a "service provider discovery record." A DVB-IP offering is made up from services of type LMB (TS_full_SI or TS_optional_SI) or content on demand. The service provider can also reference services

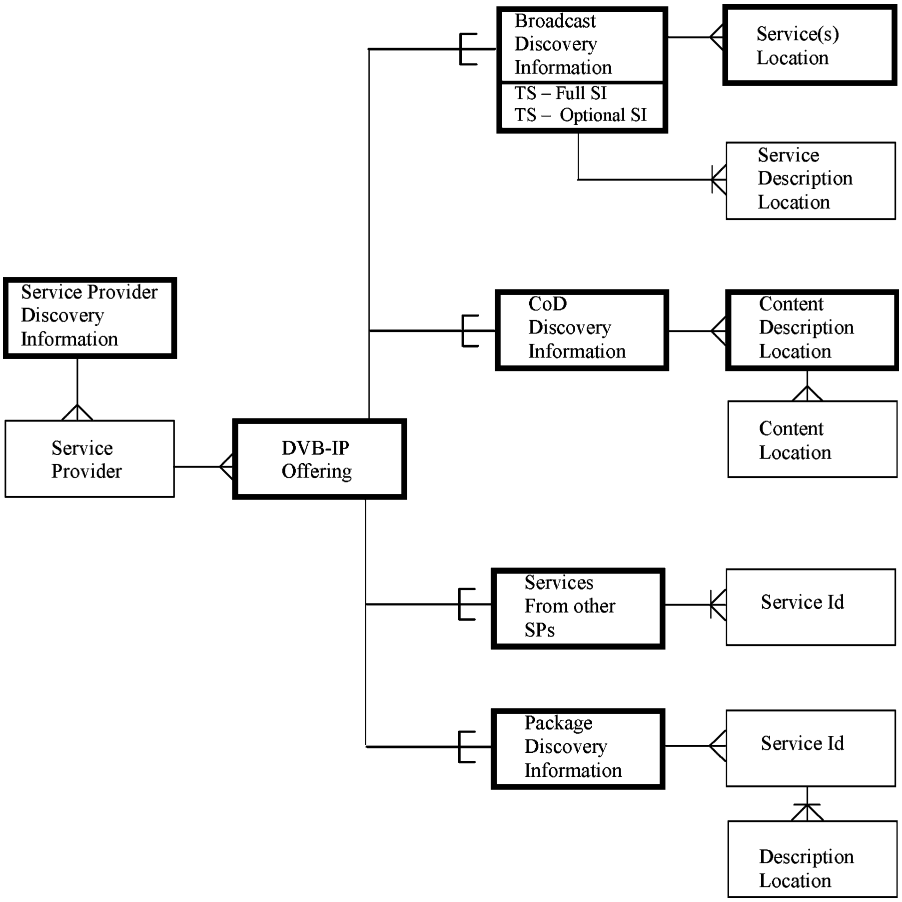

Fig. 4. Data model for SD&S.

Table 1
SD&S Information Types and Payload IDs

Payload ID value	SD & S record carried
0x00	Reserved
0x01	Service Provider Discovery Information
0x02	Broadcast Discovery Information
0x03	COD Discovery Information
0x04	Services from other Service Providers
0x05	Package Discovery Information
0x06-0xEF	Reserved
0xF0-0xFF	User Private

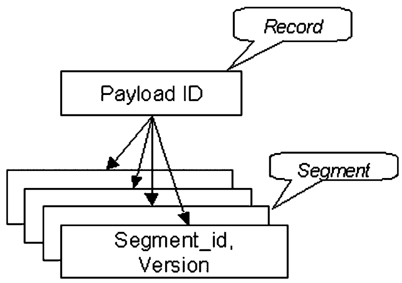

Fig. 5. Relationship between record, payload_ID, and segments.

from other providers. In addition, a package can be provided, grouping several services and presenting this as a single entity. To create records for these specific types of service the DVB-IP Handbook [1] defines XML schemas [21], structuring the information to be provided. The data model in Fig. 4 shows how information from the DVB-IP offering record is inherited by subsequent records.

Since the amount of information is much too large for this paper, the reader is referred to [1] for more detailed descriptions of the XML schemas. It should be noted, that the normative specification of the XML schemas is provided as an electronic file, attached to the DVB IP Handbook.

Table 1 lists the different types of SD&S information a service provider may use. Each type is identified by its associated payload ID.

The SD&S records may be of substantial size, but the IPTV receiver only needs part of the information at any one point in time. Additionally, changes and updates of the SD&S information are most likely localized to a relatively small part of the records. For these two reasons and to allow an SD&S record to be managed as a collection of smaller units, a method is specified for segmentation of the SD&S records. The segments are defined in the context of a single SD&S record with payload ID according to Table 1. Each segment is identified by a 16-b segment ID. To aid localized update of a record, the current version of a segment is defined by a version number, which is an 8-b value keyed on the combination of Payload_ID/Segment_ID. As soon as the data in a segment changes, its version number must be incremented. The relation between records, payload ID, and segments is given in Fig. 5.

The time required to transmit all segments of the complete set of SD&S information from a service provider is defined as

```
0                   1                   2                   3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Ver|Resrv|Enc|C|             Total_Segment_Size                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Payload ID    | Segment ID                    |Segment_Version|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Section_Number        | Last Section Number   |Compr|P|HDR_LEN|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              (Conditional) ServiceProviderID                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
:                       (Optional) Private Header Data          :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
:                            payload                            :
|                                               +-+-+-+-+-+-+-+-+
|                                               |(Optional) CRC |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|       (Optional)      CRC (Cont)              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Fig. 6. DVBSTP packet format.

the SD&S cycle time. The maximum cycle time is set to 30 s. This value is selected as a reasonable compromise between the time required to send an extensive set of information and a waiting time that should be acceptable. When a receiver has just begun taking in a service, it may have very incomplete or outdated SD&S information until 30 s has passed. It is up to the service provider to organize the SD&S information in the most effective way.

C. Service Selection

The IPTV receiver may access a service using either the Internet Group Management Protocol (IGMP) version 3 [20] or the Real-Time Streaming Protocol (RTSP) [16]. LMB services are delivered over IP multicast; they are streamed continuously and do not need to be initiated by the receiver. A receiver can join or leave such a service by issuing the appropriate IGMP commands. Content on demand services, however, are delivered to a specific user via IP unicast and need to be initiated explicitly by the IPTV receiver. The receiver accesses such services with RTSP, using methods defined in the DVB RTSP client, described in the RTSP section of this paper.

D. SD&S Transport

Since the IETF SAP must not be used for anything else but announcements of multicast multimedia conferences, DVB defined a lightweight transport protocol for carriage of the SD&S XML records over IP-multicast, referred to as DVB SD&S transport protocol (DVBSTP). The DVBSTP packet format is shown in Fig. 6. For transport of the SD&S records over IP-unicast HTTP [18] is used as transport protocol.

Because the size of record segments may be substantially larger than supported by the maximum transfer unit of the underlying network, a section mechanism is defined. Using the section mechanism, segments can be defined into smaller units for efficient delivery of the data. Each section must be sent in exactly one UDP datagram, and a UDP datagram may carry one section only. The relation between sections, segments, Payload_IDs, and records is illustrated in Fig. 7.

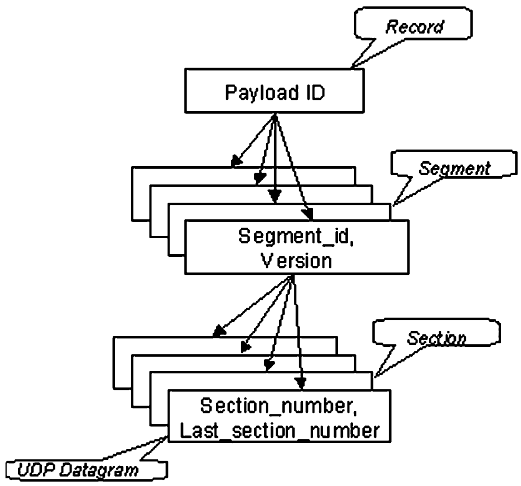

Fig. 7. Relationship between records, segments, and sections.

Changes of the SD information are signaled by incrementing the version number of the discovery record. A change in the service offering will translate into changes in one or more segments, the version numbers of which then must be incremented. The receiver monitors the SD&S records to detect changes in the version numbers, updating its information database by acquiring the changed segments only.

For more details about SD&S information transport over IP-multicast and -unicast, the reader is referred to the DVB IP Handbook [1]. The SD&S protocols are shown in the protocol stack of Fig. 3, on top of DVBSTP and HTTP.

IV. RTSP Client

The IETF RTSP [16] is an application-level protocol for control of the delivery of real-time data. The DVB RTSP client defines the usage of RTSP for LMB and content on demand services.

The SD&S process, described in the previous paragraph, provides the IPTV receiver with the RTSP URL required for gaining access to an RTSP-based service, e.g., content on demand. Multimedia streams can be transmitted from the RTSP server both over IP-multicast and -unicast. Obviously, when

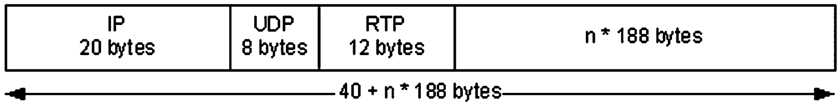

Fig. 8. RTP packet format with MPEG-2 payload.

using IP-multicast, trick modes like "pause" and "fast forward" cannot be used. However, in addition to LMB and content on demand DVB defined a service type "media broadcast with trick modes," where the actual media streams should be delivered over IP-unicast. The difference with content on demand service is that the user cannot initiate media broadcast with trick modes.

The DVB RTSP client defines the RTSP methods to be supported by the IPTV receiver, for each of the three service types mentioned above. Special attention is given to DVB-specific usage of the RTSP methods `ANNOUNCE`, `DESCRIBE`, `GET_PARAMETER`, and `SETUP`. The DVB specification also clearly points out where DVB requirements differ from those of the IETF. For details, the reader is referred to the DVB IP Handbook text [1]. The RTSP can be found at the right-hand side of the protocol stack of Fig. 3.

V. Transport of MPEG-2 TS Over IP

DVB selected MPEG-2 as content format for the first edition of its IP handbook, because hardware and software for this technology is universally available. With the imminent arrival of AVC, also known as MPEG-4 Part 10 or ITU H.264, the handbook is being extended while still using the MPEG-2 transport stream as system layer [2].

A service provider may have at its disposal MPEG-2 transport streams containing multiple programs, originally intended for, e.g., satellite, cable, or terrestrial transmission. Such multiple program transport streams may be encapsulated in IP as they are, or they may be rearranged into transport streams each containing a single program; this operational decision is up to the service provider. The transport chapter of the DVB IP Handbook can be used to encapsulate both single and multiple program streams. Multiple program streams containing multiple program clock references (PCRs) must, by definition, be constant bit rate. Single program streams can be either constant or variable bit rate. However, the rate of the PCRs in variable bit rate streams must be constant, to ensure MPEG-2 compliance.

The MPEG-2 transport streams are encapsulated in the IETF Real-Time Protocol (RTP), according to RFC 1889 [9] and RFC 2250 [15]. Each IP packet is made up of the standard IPv4 header [5], a UDP header [4], an RTP header, and an integer number of 188-B MPEG-2 TS packets, as illustrated in Fig. 8. The number of TS packets that can be encapsulated in an RTP packet has a theoretical limit set by the maximum size of the IP datagram, 65 535 octets. However, care should be taken not to exceed the maximum transmission unit (MTU) of the underlying data network. Exceeding a network's MTU will lead to IP packet fragmentation, significantly decreasing transmission efficiency. If one fragment is lost, all fragments already stored by the receiver will have to be discarded. Fragmentation also puts a load on routers and end systems performing fragmentation and reassembly. For an Ethernet-based network, with its MTU of about 1500 B, the number of MPEG-2 TS packets should be limited to seven, resulting in a maximum RTP packet length of 1356 B. For this case, payload/packet efficiency is 97%.

The Real Time Control Protocol (RTCP), associated with RTP, is also specified in RFC 1889 [9]. RTCP is intended to provide information on the quality of the end-to-end communication. For this purpose RTCP employs two kinds of messages: sender reports and receiver reports. Sender reports, containing transmission statistics (the number of packets and bytes sent), are sent by the transmitter to each receiver. Receiver reports with reception statistics (delay and packet jitter) are generated by each receiver and sent periodically to the transmitter. In the interest of scalability, i.e., to prevent network congestion at the server end in case of large scale deployments of IPTV receivers, the DVB IP Handbook specifies that RTCP receiver reports shall not be supported on the IPI-1 interface.

The transport chapter defines some network requirements, which should be fulfilled to guarantee adequate reception quality for DVB services. A mandatory constraint is that the peak-to-peak RTP packet jitter must be less than 40 ms. This constraint must be set for compliance to the MPEG-2 Real Time Interface Specification [3]. It is recommended to ensure network QoS resulting in no more than one noticeable artifact per hour on the display of the IPTV receiver. For a 4 Mb/s TS with seven TS bytes per IP packet, this recommendation is satisfied with a packet error rate of less than 1×10^{-6}. Multicast `LEAVE` and `JOIN` times are recommended to be limited to 500 ms each, to ensure a reasonable maximum TV channel change time of the order of 1 s.

To enable QoS DVB specifies a method to determine the type of data sent by each datagram, with prioritization based on a classification of the types of data. The classification method follows the differentiated services model described in RFC 2475 [17]. According to this model, IP packets passing over IPI interfaces are marked according to their traffic type, using the 8-b type of service field in the IP packet header. The various traffic types, markings, and priorities are shown in Table 2. The protocols for transport of MPEG-2 TS can be found in the middle of the protocol stack of Fig. 3.

VI. IP Address Allocation

IP addresses are allocated to DVB IP receivers using dynamic addressing, managed by a Dynamic Host Configuration Protocol (DHCP) server. Dynamic addressing means that when a receiver is switched and it requests an IP address, this is allocated from the pool of at that time available addresses. The consequence is that a receiver's IP address is

Table 2
Traffic Types, DSCP Markings, and Priorities

Traffic Type	IP DSCP Value	Corresponding IP Precedence
Voice Bearer (see note 1)	0b101110	0b101
Video Bearer (high priority) (see note 2)	0b100010	0b100
Video Bearer (lower priority) (see note 3)	0b100100	0b100
Voice and Video Signaling	0b011010	0b011
Best effort data	0b000000	0b000
NOTE 1: The voice bearer is listed here to ensure that there is no interference with DVB-IP services NOTE 2: Normal marking for video NOTE 3: Use of this marking is application dependent. It is intended to allow a Service Provider to suggest that some video packets are less important than others		

very likely to change over time, unless it is always on and active. DVB does not recommend any kind of static address allocation.

DHCP as used today is defined in a number of IETF RFCs, the main ones being RFC 2131 [11] and RFC 2132 [12]. In addition to IP addresses, a DHCP server may provide other kinds of information, depending on which DHCP options are supported.

The DVB IP Handbook specifies a list of DHCP options to be supported on the IPI-1 receiver interface. DHCP must be used not only for allocation of the IP address, but also for the subnet mask, DNS server address(es), default gateway, gateway, and, if necessary, WINS/NetBIOS server addresses.

The IP Address Allocation chapter also specifies support for real-time clocks in the DVB IP receiver. Real-time clocks with an accuracy of 100 ms should be implemented according to the Simple Network Time Protocol (SNTP), as laid down in RFC 2030 [10]. The DHCP server should provide the addresses of the SNTP servers, according to the DHCP time server option (no. 4), which must be supported on the IPI-1 interface. When accurate time services with accuracy of 1–50 ms are required (e.g., for the transport stream), these should be implemented according to the Network Time Protocol, specified in RFC 1305 [8]. The DHCP server should also provide the addresses of accurate time servers, according to the DHCP network time option (no. 42).

The protocols for IP address allocation and network time services are shaded in light gray in the protocol stack of Fig. 3.

VII. IDENTIFICATION AGENT

Identification of all IPTV receivers is required to enable the option of network provisioning, which some service providers may wish to implement. Although in the interest of a low receiver price, popular IPTV receivers may not support the optional provisioning technologies, a "network provisioning" service provider may still allow such receivers on its network after type testing for correct operation. DVB specifies an identification agent for the purpose of receiver identification.

The receiver checks the "siaddr" field in the DHCP messages. If the field is set zero or to an invalid IP address, there is no provisioning server available and the receiver will send no data. When there is a valid IP address, the receiver sends a device ID made up from the manufacturer name, the unique receiver model name and the Ethernet MAC address (or IEEE 1394 identifier). Optionally, additional information may be sent about the installed amount of RAM, flash memory, and the software version running in the receiver.

The data is sent according to the requirements in the HTTP 1.1 specification [18] and taking into account a congestion avoidance mechanism. This mechanism is required to prevent overloading the network servers in case of a power cut or similar, when a large number of IPTV receivers may attempt to access the servers at the same time.

The congestion avoidance mechanism works as follows. Each time a receiver attempts to contact a server, a Backoff timer is initialized to a value of 2 s. Immediately before each attempt to establish a connection, a random delay of between Backoff and 2 $\times$Backoff seconds is imposed. Upon failure to establish this connection, the Backoff timer value is doubled and the connection will be retried. When doubling of the Backoff timer results in an arithmetic overflow (i.e., just before the 16th attempt when Backoff is a 16-b unsigned integer), retry attempts should be abandoned.

The identification agent is shown in the protocol stack of Fig. 3, on top of HTTP.

VIII. NETWORK PROVISIONING

It should be noted that network provisioning, as a means to provision and manage the network configuration of the IPTV receiver, is an optional component in the DVB IP handbook. The network provisioning chapter specifies the protocols and XML DTDs that must be supported when the receiver manufacturer implements the option. The normative DTDs are supplied in an electronic file, attached to the DVB IP Handbook.

Protocols used for network provisioning are HTTP [18] for communication in the clear and HTTP over TLS [14], [19] for secure communication. Only two HTTP commands must be supported on the IPI-1 interface: GET and POST, respectively, to obtain and to send information in XML form. GET and POST formats are specified in detail in [1]. When communicating, the receiver always observes the same congestion avoidance mechanism as described in Section VII.

The provisioning process is started by the receiver sending a special form of the HTTP GET command after boot up. When the response action is "none," the receiver will HTTP GET a configuration and start regular event polling, otherwise the receiver follows the actions as communicated until the server response is "none." Event polling is done by the receiver regularly sending an HTPP GET at intervals, set by the "configuration" DTD. Polling intervals start after reception by the receiver of the action "none." After the interval has passed, the process will repeat. When a receiver has not sent an HTTP GET after three polling intervals have passed, it will be considered "missing" by the network management system.

XML DTDs are specified for "event," "configuration," "failure," "success," "inventory," and "status." The optional network provisioning protocols are shown with a diagonally striped texture in the protocol stack of Fig. 3.

IX. Conclusion

The technologies described in this paper provide a solution for DVB services on IP-based networks, using MPEG-2 as content format. Digital TV services can be started on IP access networks such as DSL and cable, with receivers implementing the interface as specified. The specification also provides an optional solution for network provisioning of the IPTV receiver. An essential contribution for successful IPTV services is made by the SD&S technologies. These enable service providers to let prospective customers easily find the services they want on the IP network.

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