TRANSPARENT TRANSPORT OF IP AND MPEG

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Abstract

Convergence of IP and MPEG technology has gained momentum in many sectors of the Cable, Satellite, and Terrestrial Broadcast industry worldwide. With increasing cross-flows between IP and MPEG traffic, the Set-Top Terminal now has to recognize IP Multicast addresses, in addition to other essential information. New descriptors, new tables and IP-Control Channel protocol have been contemplated. The DVB Multi-Protocol Encapsulation standard is extended for implementation efficiency. Other much-proliferated new protocols for the MPEG stream are also investigated, treating IP data transport as an equal, if not the primary service to video.

The issues at stake are compatibility of IP and MPEG, network pre-determined conditions, scalability, and future evolution in anticipation that Internet streams might play a major role in the broadcast video channel space.

This paper concerns the end-to-end signal flow from the program server to user receiver. Critical issues for IP and MPEG interworking are reviewed from an STT perspective.

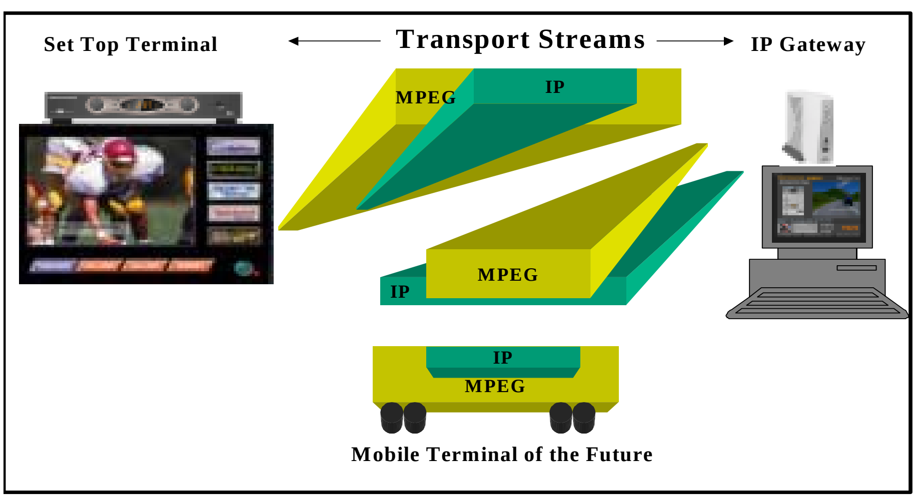
INTRODUCTION

The scope of transparent transport of IP and MPEG streams involve at least 3 aspects:

(1) IP over MPEG,
(2) MPEG over IP, and
(3) IP over MPEG with Terminal Mobility.

Figure 1 illustrates the concept of these various transport streams and the receiving terminal devices.

FIGURE 1. IP AND MPEG TRANSPORT



This paper provides an overview of the critical issues for IP over MPEG interworking (shown in the top part of Figure 1) for transparent transport of data and video streams. Other possible transport streams, also under active development, are only briefly mentioned with references provided at the end.

Market forces from not only America, but also Europe, are reviewed for services based on an integrated transport of MPEG and IP streams. Technical proposals associated with IP transported over MPEG streams are investigated. These proposals reflect on-going discussions within the Advanced Television Systems Committee (ATSC), Digital Video Broadcast (DVB) Forum, Internet Engineering Task Force (IETF), International Telecommunications Union (ITU) and Society of Cable Telecommunications Engineers (SCTE). Some evaluations are described and future directions are suggested regarding applications, implementations, transport stream management and services.

This paper does not intend to address all network essential issues with respect to MPEG over IP, nor MPEG over Mobile transport. This paper concentrates on IP over MPEG transport impact to the STT from the perspective of required Service Information signalling; acknowledging that future network transformation could generate other impact on the STT. These future factors are identified for further exploration along with directions that technical solutions might eventually converge.

MARKET BACKGROUND

The Internet access has been enabled via the evolving telecommunications infrastructure since the 1950's, supported by the TCP/IP transport flow. However, the vast majority (80%) of IP transport has been via narrowband connections based on the traditional telephony networks [1].

Almost fifty-four million households (or 50.5% of all households in the US) had Internet access as of September 2001 [1].

The introduction of cable modem since 1998, in conjunction with Digital Subscriber Loop (DSL) upgrades in the copper wire networks, provides high-speed Internet access in a leap-frog fashion to a range in megabits per second.

Digital transport streams carried over cable and satellite networks have been conditioned with MPEG streams since 1998. Terrestrial broadcast networks have followed suit in parallel.

Cable Modem Market Penetration

The rapid emergence of cable modems allows major influx of IP streams onto the MPEG facilities, as cable networks have demonstrated. The latest FCC report [1] has highlighted the demand of high-speed Internet delivered over Hybrid Fiber Coaxial (HFC) systems in the last mile. Fifty-four percent of the total high-speed lines were carried on cable by the end of June 2001. Cable companies report almost 5.2 million high-speed lines in service using cable modem technology at the end of June 2001, compared to 1.4 million at the end of 1999 [1].

High-speed Digital Network Readiness

Regarding the network readiness, i.e., about the availability of cable modem-ready plant, publicly available sources estimate that cable modem service is now available to about 70% of US homes.

Other broadcast networks are also shown enthusiasm to join the cable modem success story in receiving both data and video with STT(s), particularly in areas outside of the US. Even within the US, satellite technologies account for between 50,000 and 150,000 high-speed lines as of June 2001.

High-speed satellite services are now available in all 50 states, and multipoint microwave data distribution systems currently reach 55% of the population [1].

MPEG and IP Cross-flow

The typical MPEG network and the IP network start to converge as applications converge between TV STT and computer network gateway controllers. The underlining delivery system has employed sophisticated protocols, in order to present a transparent experience to the viewer for entertainment access and information retrieval. As the number of channels and bandwidths increases, the form to mix MPEG and IP streams has increased as well. The push for standardization in conjunction with implementation efficiency has received significant attention recently.

Some market data suggest, without the consideration of the content involved, that the residential high-speed subscription will increase from 1.9 million in 2000 to 40 million in 2005. By 2004, 29 % of households will access the Internet through cable modem services, 21% through DSL and 5.7 % through wireless and satellite technologies [1].

Forecasts also said that in 2005, the average Broadband household would download about 70 Mbits of files, consume more than 20 minutes of streaming per day, and download 32-hour long movies per month [1].

Cable modem subscription reached 3.9 million in 2000 with a projected rate of double the current increase to reach 28-30 million by 2006 [1]. This calls for more than a quarter of IP streams ready to be transported via MPEG networks.

INTERWORKING TECHNOLOGY ACCELERATION

Based on the above mentioned market trends, convergence of IP and MPEG technology has since gained momentum in many sectors of the Cable, Satellite and Terrestrial Broadcast industry; be it the International Standards Body, Manufacturers' Development Planning Process, Operators' Forum, or New Service Offering.

With increasing cross-flows between IP and MPEG traffic, the Set-Top Terminal (STT) that receives MPEG streams, now needs to recognize IP Multicast addresses, in addition to other essential information. Realizing the shortcoming of the broadcast data standards, new descriptors (e.g., MAC_address_list descriptor, multiprotocol_encapsulation_broadcast_descriptor), new tables (e.g., IP Map Table) and new IP Control Channel (IP-CC) have been designed to transport IP over MPEG in a manner that calls for innovative services, efficient implementation and backward compatibility. Some make use of the DVB Multi-Protocol Encapsulation (MPE) standard to achieve efficient tuning in the STT, within the existing MPEG framework. Others express a much-proliferated scope for the MPEG stream, treating IP data transport as an equal, if not the primary service.

It is un-disputable that IP streams traverse through MPEG established transport streams would find numerous applications beyond simple video association. The industry is far from a lack of imagination, as recent mobile demonstrations about digital MPEG over IP [17] and Multimedia Car Platform [18] applications suggest.

However, one has to:

(1) understand the service requirements first,
(2) analyze the scope of the technology challenge,
(3) evaluate, step-by-step, available tools and frameworks, e.g., descriptors and tables, that can facilitate an effective solution,
(4) compromise for standards to achieve economics of scale, and
(5) implement efficiently.

Therefore, the issues at stake are:

1. How do cable, satellite and terrestrial broadcast networks differ in transport of IP within the MPEG framework?
2. How does transport of IP over MPEG or MPEG over IP differ in protocol architecture?
3. Can one afford a clean slate, abandoning the prior implementation of MPEG-2 in the field?
4. Can one ignore, initially, the network pre-determined conditions, scalability, and future evolution in anticipation that Internet traffic could out-number the broadcast video traffic?
5. What is the protocol overhead involved in converging MPEG and IP transport? Or is this a new Protocol?
6. What is the viability of MPEG-Mobile applications?

These concerns suggest that one begin with a solid base on realistic requirements which can give proper guidance to the evaluation of the appropriate technical alternatives and their extensions to identify those immediate incremental revenue streams for the near term; with open and migrateable standards in mind for future realization of grandeur applications, without placing unnecessary technical obstacles along an evolutionary development process. In this capacity, IP over MPEG transport appears more familiar for the broadcast industry to tackle than MPEG over IP, Home Networking or MPEG over Universal Mobile Telecommunications System (UMTS). Therefore, with focus on IP over MPEG, an evaluation of alternatives is described below.

ALTERNATIVES FOR TRANSPARENT TRANSPORT

Within the years of 2001-2002, significant momentum has been established in addressing IP and MPEG (the latter being the baseline transport stream to the framework of ATSC, DVB, SCTE and ITU-T/SG9) interworking and interoperability. The technical conventions considering MPEG applications include ATSC and SCTE in North America and DVB in Europe, while that for IP extensions is typically IETF. Example technical discussions are shown in 15 references cited at the end of this paper.

Some of these references address requirements and others, technical designs. Requirements issues are first discussed as follows.

REQUIREMENTS ASSESSMENT

References [2] to [5] identify requirements for carrying IP over MPEG. Requirements can be put in 2 categories:

1. Commercial requirements brought forth by Service Providers.

2. Technical requirements brought forth by Manufacturers.

Businesses have emerged based on Advanced Television Enhanced Forum (ATVEF) applications where IP data were carried within the MPEG-2 video component for linking specific video to a corresponding Internet Web access [2]. Some applications were introduced as early as in 1999. In 2000, commercial requirements were identified by the European broadcast operators of the DVB project to offer Internet services via satellite broadcast channels [6]. These cross-continental requirements were compared in Reference [2].

References [5] and [7] provide a broader brush of the scope involving IP and DVB. As these references continue in development, it becomes clear that IP over MPEG can easily enlarge the traditional video bound services into Internet value-added services.

The above identified requirements have been carried out in both America and Europe in business offers from cable and satellite broadcast operators with limited success to date. A few technical alternatives are discussed with foreseeable enhancements below, to improve the service prospect for the future.

IP OVER MPEG ALTERNATIVES

Essential information for the broadcast network and the Set-Top Terminal to access IP Multicast addresses are described in References [6] to [13] for carrying IP data over MPEG streams (The DVB stream and the MPEG stream can be used interchangeably here.) Many of these references start with the DVB Multi-Protocol Encapsulation (MPE). An all-encompassing table has been created to cover network specific parameters, the IP Map Table (IMT)[6].

IP Map Table

When IP data are carried within MPEG Transport Streams (TS), the transmitted network addresses have to be made known to the STT. Currently many proprietary mechanisms exist to signal this information. “The situation becomes confusing especially when the MPEG network carries split IP data across Packet IDentifiers (PIDs) in the same TS and sometimes even across transport streams” [6]. This is a familiar case in the satellite and terrestrial broadcast environment, not so much needed in the cable environment.

The IMT mechanism signals to the STT for a mapping of IP/MAC unicast and multicast addresses to the MPEG parameters of network ID, original network ID, transport stream ID, service ID and PID. This mechanism allows a fully automated tuning for DVB-DATA receivers.

Table 1 contains an IP Platform ID and IP_platform_descriptor to track IP/MAC addresses for unicast and multicast, IPv4 as well as IPv6 addressing schemes [6]. The advantage here is that all network and address resolution information is consolidated and clearly specified with the PID, original network ID, transport stream ID and service ID by the IMT.

TABLE 1. IP_MAP_TABLE (IMT) SECTION [6]

(Extracted from Reference [6] for ease of comparison)

Syntax	No. of bits	Mnemonic
IP_MAP_TABLE{		
table_id	8	uimsbf
section_syntax_indicator	1	bslbf
private_indicator	1	bslbf
Reserved	2	bslbf
section_length	12	uimsbf
IP_platform_id	16	uimsbf
Reserved	2	bslbf
version_number	5	uimsbf
current_next_indicator	1	bslbf
section_number	8	uimsbf
last_section_number	8	uimsbf
reserved_future_use	4	bslbf
IP_platform_descriptor_length	12	uimsbf
for(i=0;i<N;i++){		
Descriptor()		
}		
network_loop_count	8	uimsbf
for(i=0; i< network_loop_count; i++){		
network_id	16	uimsbf
transport_stream_loop_count	8	uimsbf
for(i=0; i< transport_stream_loop_count; i++){		
original_network_id	16	uimsbf
transport_stream_id	16	uimsbf
service_loop_count	8	uimsbf
for (i=0; i< Service_loop_count; i++){		
service_id	16	uimsbf
PID_loop_count	8	uimsbf
for (i=0; i< PID_loop_count; i++){		
elementary_PID	13	uimsbf
address_type	2	bslbf
Reserved	1	bslbf
address_loop_count	16	uimsbf
for (i=0; i< address_loop_count; i++){		
If address_type == 0x00 {		
IPv4_address	32	
IPv4_slash_mask	8	
}		
If address_type == 0x01 {		
IPv6_address	128	
Ipv6_slash_mask	8	
}		
If address_type == 0x02 {		
MAC_address_range	1	bslbf
Reserved	2	bslbf
Reserved	5	bslbf
If MAC_address_range == 0 {		
MAC_address	48	
}		

```
                         Else {
                            Lowest_MAC_address                    48
                            Highest_MAC_address                   48
                         }
                      }
                   }
                }
             }
          }
       }
   CRC_32                                                       32      Rpchof
}
```

IMT is compact and this method avoids advertising MAC addresses on the broadcast link. It also avoids frequent recompiling of the tables and is transparent to the transition of IPv4 to IPv6 [6].

However, MPEG fundamentally recommends that no elementary PID should appear in any table other than the Program Map Table (PMT). The IMT thus deviates from the traditional MPEG rule. One cannot deny the advantage of introducing the IMT where pure IP traffic is allowed in an independent, unused video channel. Up to 24 digital channels, depending on the modulation scheme, can be made available at the operator's disposal, after the analog channel is transformed.

As the IMT is made optional, the operator will have a choice to either use existing SI tables with special descriptors or to render the IMT for complete IP routing information.

When dealing with the cable network, it is a more coordinated and well-informed network due to the knowledge stored in the Headend with respect to addressing to the individual STT. The network controller generally knows the configurations of the STT and their Headend association in a large network. With applications such as ATVEF, most of the addressing issues would be resolved by the applications before the STT has to get involved in the consideration of which IP router or bridge it has to communicate with.

Therefore, cable STT would direct its resource for fast tuning as its primary responsibility, leaving aside IP stream management function for the IP protocol to resolve. Reference [10] takes advantage of this well-informed cable environment.

Use of Descriptors

Reference [10] makes use of DVB MPE standard and created a MAC_address_list descriptor for multicasting. This descriptor has recently become an SCTE standard [11]. It has also being considered by the ATSC [12]. The largest cable service operator in North America has endorsed it based on its expected implementation efficiency. Table 2 shows its current form for such IP data multicasting.

TABLE 2. MAC_ADDRESS_LIST_DESCRIPTOR [10]

Syntax	No. of bits	Mnemonic
MAC_Address_List_descriptor() {		
descriptor_tag	8	Uimsbf
descriptor_length	8	Uimsbf (L)
mac_addr_list	1	Uimsbf
mac_addr_range	1	Uimsbf
pdu_size	2	Uimsbf {1024 bytes, reserved1, reserved2, 4096 bytes}
encapsulation_type	2	Uimsbf {DVB, reserved1, reserved2, ATSC }
reserved	2	Uimsbf
if (mac_addr_list == 1) {		
num_in_mac_list	8	Uimsbf (m)
M = m*sizeof(mac_address)		
L = L – M		
For (i=0; i < m; i++) {		
mac_address	48	Uimsbf
}		
}		
if (mac_addr_range == 1) {		
Num_of_mac_ranges	8	Uimsbf (n)
N = (n*sizeof(mac_address)*2)		
L = L – N		
for (i=0; i< n; i++) {		
Highest_mac_address	48	Uimsbf
Lowest_mac_address	48	Uimsbf
}		
}		
for (i=0; i< L – 1; i++) {		
Private_data_byte	8	Uimsbf
}		
}		

Although not specifically mentioned, extending this descriptor for unicasting should be straight-forward. It is possible to extend for coverage of IPv6 address scheme as well, if necessary. These additional capabilities do not impose un-stoppable obstacles when using the MAC_Address_List descriptor.

Another use of descriptor [13] creates a Multiprotocol Encapsulation Broadcast descriptor to be used associated with the Service Definition Table (SDT). This is different from use in a Network Information Table (NIT) coupled with the IMT as per Reference [6], or in the Program Map Table (PMT) as suggested in Reference [10]. Table 3 shows the current proposal of the multiportocol_encaspsulation_broadcast descriptor.

TABLE 3. MULTIPROTOCAL ENCAPSULATION BROADCAST DESCRIPTOR [13]
(Extracted from Reference [13] for ease of comparison)

Syntax	No. of bits	Mnemonic
multiprotocol_encapsulation_broadcast_descriptor(){		
descriptor tag	8	uimsbf
descriptor_length	8	uimsbf
data_broadcast_id	16	uimsbf
component_tag	8	uimsbf
service_id	16	uimsbf
for(i=0; i<N; i++){		
address_type	8	uimsbf
address_length	8	uimsbf
for(j=0; j<N; j++){		
address_byte	8	uimsbf
}		
}		
}		

"Using the descriptor in the SDT, it is possible to associate any type of unicast/multicast address to any service within a network. Using the optional component_tag it is further possible to define the elementary stream to which the MAC/IP address references. This descriptor is the same as the data_broadcast_id_descriptor, with the id_selector_bytes being utilized from the *component_tag* field onwards" [16].

Comparison of Table and Descriptor Usage

Use of the IMT [6] starts with a clean slat for IP network addressing. Use of the MAC Descriptor [10] in the PMT advocates a fundamental adherence to the MPEG principle, thus fully taking advantage of the MPEG efficiency, leading to ease of implementation and tuning efficiency. Use of the Multiprotocol Descriptor [13] in the SDT appears elegant, however it can restrict services to be only within one transponder. Table 4 compares the characteristics of these transport-enabling mechanisms.

TABLE 4. COMPARISON OF ALTERNATIVE PROTOCOLS FOR IP OVER MPEG TRANSPORT AS OF MARCH, 2002

(Information might change, as these techniques are being consolidated and harmonized.)

	IMT [6]	MAC Descriptor [10]	Multiprotocol Descriptor [13]	IP- CC [4]
Application	Broadcast/ Internet Service Provider	ATVEF	None specified	Broadcast Mobile
Network Focus	Satellite with multiple transponders	Cable	Satellite with single transponder	Mobile
MPEG Efficiency	Ignored	Adherent	Adherent	Unknown
MPEG Table Association	New	PMT	SDT[1] and PMT	In development
IPv4/ IPv6	Yes	Extendable	Yes	Yes
IP Address Resolution	Required	Not required	Required	Required
Multicast/Unicast	Yes	Extendable	Yes	Yes
Receiver Implementation Efficiency	No	Yes	No	Unknown

The trade-off among these various mechanisms seems to be between the tuning performance and the ability to manage the IP streams within the MPEG streams across all networks.

Reference [9] calculated the overhead for IP and MPEG streams. In a pure engineering fashion, Reference [9] brings up an objective comparison of the protocol overhead involved in MPEG and IP transport. The overhead and performance penalty warrants more elaborate examinations with respect to various transport alternatives.

The IP network management is yet another area requiring further studies. Does the MPEG Service Information need to track router and bridge addresses while IP data are carried in and out of the broadcast networks?

Other Extensions

Mobile requirements are also generated from the perspective of carrying IP over MPEG streams [4].

A recent proposal, IP-Control Channel (IP-CC), has taken into account merits from both the IMT and the two Descriptors described above. It also acknowledges network pre-determined conditions, scalability, and future evolution in anticipation of the vast Internet traffic on Mobile networks with video services.

The subject of IP over MPEG is not just addressed by the DVB group alone. IETF also attempted a Birds-Of-the-same-Feather (BOF) session creating IP over MPEG functional requirements [3].

[1] This table is not available for North American SI practice.

From the other perspective, the DVB-IPI group on Internet Protocol Infrastructure has actively pursued protocols for MPEG transport over IP [14]. ITU-T, Study Group 9 has published "Webcasting", J.120 [15], which defines the transmission protocol and system configuration for distributing sound and television programs over the Internet. It concerns the end-to-end signal flow from the program server to user's receiver. This transmission chain contains the signal encoding/decoding, packet mapping as well as session control and network transmission.

SUMMARY AND FUTURE DIRECTIONS

Future directions are suggested:

1. IP data can be carried in conjunction with video components.
2. MPEG channel can carry pure and full IP data.
3. IP stream can be systematically encapsulated within the MPEG stream.
4. IP and MPEG flow can be transported and intermixed, with peer relationship.

Technical solutions to enable any of the above directions to flourish are summarized as follows.

Recognition, resolution, and routing of IP addresses within the MPEG video component or in an independent data component have been investigated. The MAC_Address_List descriptor could fulfill the video related IP data broadcast. To meet the expanded Internet traffic, the IMT, with or without the MAC and/or the Multiprotocol descriptor can be employed to introduce full-fledged high-speed data services in a ground-breaking mode. The establishment of the IMT implied some IP network management capability would be established in the MPEG SI for extended utilization of freed-up digital channels. Conceivably, video and data can be intermixed, linked, or transported side-by-side. Applications based on transport of IP over MPEG, or vice versa have been demonstrated [17], and services are in active pursuit by some operators.

This trend of service expansion begs the question about combining control for signalling of video and data transport: Would the future form of Service Information (SI) [16] be carried through in either MPEG or DOCSIS format?

As Mobile begins receiving video services, the IP-CC represents one method to share MPEG Service Information with the complex mobility network; in particular, handling of roaming can be a major challenge. The advent of IP and MPEG network interoperability for services beyond the traditional video boundary, to be enhanced with mobility capability, opens up enormous potential for the communication, entertainment and information industry.

It behooves service providers to cooperate and direct the technical community in the latest standardization of IP versus MPEG interoperability.

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