# Dynamic IP Configuration for Interactive Digital Television Terminals

G. Gardikis†, G. Kormentzas† and A. Kourtis*

† University of the Aegean, Department of Information and Communication Systems Engineering
GR-83200, Karlovassi, Samos, Greece
* National Centre for Scientific Research "Demokritos", Institute of Informatics and Telecommunications, Patriarchou Gregoriou str., Ag. Paraskevi, Athens 165 10, Greece

*Abstract* - **During the last years, digital television networks are shifting from the mere transport of native MPEG-2 streams to the provision of IP-based services, either unidirectional or fully interactive. The inclusion of an IPv4/IPv6 stack in a DTV terminal requires that certain parameters, such as Host, Gateway and DNS IP addresses are configured either statically or dynamically. The paper discusses issues of dynamic configuration of IP parameters for interactive DTV terminals, based on an overview of relevant mechanisms usually used in access networks. It proposes an IP-based protocol tailored to the needs of an IP/DTV access platform.**

## I. Introduction

The worldwide emergence of digital television (DTV) networks, as successors to analog TV systems, has brought up the perspective of DTV being used as an access network for interactive services. The common digital baseband format, namely the MPEG-2 Transport Stream, previously used for the mere transport of encoded audio/visual streams, has extended its functionality to support all types of digital information, including IP data ("Datacasting"). The adoption of adaptation protocols such as Multi Protocol Encapsulation [1] and Unidirectional Lightweight Encapsulation [2] for the insertion of IP data into the MPEG-2 TS, has greatly contributed to the migration of native IPv4/IPv6 applications to the world of digital broadcasting, either satellite, or terrestrial.

The use of DTV terminals for accessing IP services requires the implementation of an IPv4/IPv6 stack. For the proper operation of the latter, it is essential that certain parameters have to be configured, such as IPv4/IPv6 host, gateway and DNS addresses. These parameters are until now set in a static manner, a rational approach if one considers that satellite DTV systems held the dominant place in IP service provision, where fixed terminals almost never require re-configuration. Nevertheless, with the migration of digital television to the terrestrial segment also, where mobile use from portable terminals aiming to ubiquitous access is anticipated [3], a dynamic/automatic mechanism IP configuration is essential. In this context, the paper discusses the issue of dynamic IP set-up of interactive DTV/IP terminals. It shows why widely used mechanisms like DHCP are inadequate due to the unique nature of digital television networks, and proposes an IP-based protocol approach.

The article proceeds as follows: Section II presents a general topology of IP/DTV networks and divides them into three rough categories, outlining the configuration needs of each case. Section III discusses the requirements that an IP auto-configuration mechanism should fulfil in a DTV network and investigates whether existing solutions, such as DHCP, can be used. Section IV proposes a novel approach for an IP-based dynamic configuration protocol, describing its functionality and suggesting a state diagram. Finally, Section V concludes the paper.

## II. IP-over-DTV Network Topologies

For simplicity reasons, in this article, the term "Digital Television Network" is assumed to refer to a single DTV downlink conveying a single MPEG-2 TS to a certain coverage area (e.g. a satellite footprint). However, the modelling and the mechanisms described in this paper can be easily expanded to include multi-bouquet, multi-transmitter infrastructures.

At the broadcaster's site, an IP-to-DTV encapsulator is used to adapt IPv4/IPv6 traffic to the MPEG-2 Transport Stream. On the other side, the terminal, following demodulation, decoding and demultiplexing, decapsulates the datacast streams and feeds them to its IP stack for processing. Since the digital broadcast channel is unidirectional, the support for fully interactive services requires the presence of an interaction channel [4]. The existence and nature of the latter is crucial to the IP configuration process and, in this context, the DTV network topologies can be categorised into three discrete generalised architectures (See Fig.1).

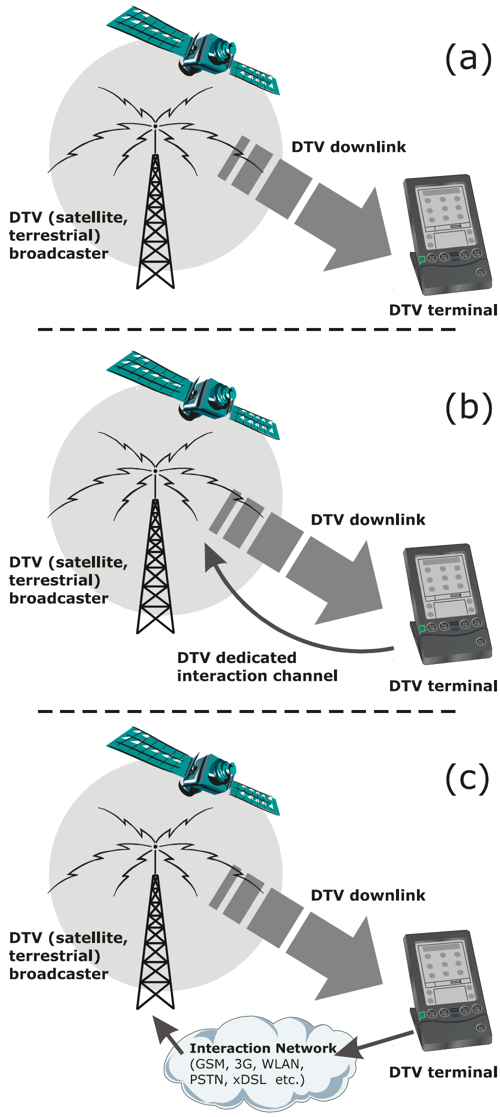


Figure 1. IP/DTV network topologies regarding to the type of return channel. (a): Unidirectional, (b): Bi-directional with native DTV interactivity and (c):Hybrid Bi-directional with an external interaction network

*A. Unidirectional topology*

This case is the most usual nowadays and includes all broadcast-only platforms, satellite or terrestrial, where no return link (from the terminal back to the broadcaster) exists. The terminals operate in a receive-only mode and receive DTV programs multiplexed with datacast IP data. Data services are not fully interactive, they can only provide pseudo-interactivity by means of off-line local access. In this case, the terminals have no way to interact with a network entity at the broadcaster's side to request configuration information. The latter can only be "pushed" to all receivers. DNS and gateway addresses are of no use, and a common IP host address can be assigned to all terminals for functionality reasons only. Since the DTV receivers cannot send data, this common address does not raise any conflict issues.

*B. Bi-directional topology with native DTV interactivity*

In this case, the terminals support full interactivity by utilising a unidirectional interaction (return) channel that has been specially developed to integrate with DTV networks, such as DVB-RCS (Return Channel via Satellite) or DVB-RCT (Return Channel-Terrestrial). Unlike the previous scenario, it is essential in this case that the terminals' IP parameters are fully configured and their host addresses are unique. Until now, native DTV interactive solutions [5] are commonly based on the static configuration approach, i.e. the terminal comes pre-configured by the installer/service provider. This solution is satisfactory for certain cases, e.g. where a satellite terminal is fixed (no handovers) and bound to a single service provider. However, for moving terrestrial or satellite transceivers performing handovers or in cases that multiple service providers are supported, a dynamic solution is essential. It is possible, for instance, that channel zapping in a terrestrial receiver could need each time to invoke a change in the IP settings of the device, to match the broadcaster's configuration.

*C. Bi-directional topology with an external interaction network*

This scenario corresponds to a hybrid interactive topology [6] where the DTV broadcast channel is used for forward datacasting, and a foreign IP network is utilized to support interaction. The latter can be any wired or wireless IP-enabled infrastructure, such as GPRS/3G, WLAN, PSTN or xDSL. The terminal is equipped with a dual-interface front end: one for the broadcast network (i.e. a DTV receiver) and one for the interaction channel (e.g. a 3G modem or a WLAN interface). In this scenario, the interface bound to the interaction network anyway receives the IP configuration from its own infrastructure via a standardized mechanism (e.g. via DHCP for a WLAN interface). However, if the broadcaster is to provide interactive services, it is essential that the DTV receiver module must also be configured. Otherwise, the broadcaster will have to deal with a large pool of heterogeneous IP addresses, different according to the interaction network provider used by each client, and handling of interaction data will be rather complicated. So, an IP/DTV dynamic configuration mechanism is also required in this case.

## III. Requirements for an IP/DTV Dynamic Configuration Protocol

DHCP (Dynamic Host Configuration Protocol) [7], and DHCPv6 [8] are the most common IETF-standardized protocols for dynamic configuration of host IPv4 and IPv6 parameters respectively. These protocols are used in a huge spectrum of IP-enabled networks. Unfortunately, IP/DTV networks, due to their particular nature, have certain requirements that exceed the scope of plain DHCP-like mechanisms. The most important ones are:

- *Support of all three generic topologies* described in (II) via a unified approach.

- *IP-unicast-only requests.* Due to the heterogeneity of a composite interactive DTV network, there is no common link-layer so that requests and responses can be broadcast. The communication from the terminal to the broadcaster should be entirely based on unicast IP and should be independent from any underlying link technologies.
- *Scalability.* Unlike a LAN or even a cellular network, a DTV platform should be capable to accommodate even hundreds of thousands of users. The proposed mechanism must be scalable enough to support a large pool of end users.
- *Simultaneous IPv4 and IPv6 support.* The parameters, which are dynamically configured, should correspond to both versions of the Internet Protocol. This means e.g., that the client terminal is assigned at the same time both a v4 and a v6 global unicast host address via the same protocol. Stateless IPv6 autoconfiguration also has to be supported.
- *Authenticated access.* Since, unlike a wired LAN, a broadcast network is "open" to anyone, security from unauthorised requests is a major issue. The usage of a standardized authentication method such as the one described in [9] can be considered.
- *Utilisation of native DTV signalling* so that broadcast configuration data can be located in the broadcast MPEG-2 TS.
- *Relatively low complexity,* so that i) the protocol can be implemented even in handheld terminals and ii) the computational cost at the broadcaster due to the large number of request processes can be minimised. There are many options of DHCP, such as Relaying and Solicitation, which are of no use in either of the aforementioned scenarios.
- *Easy and modular implementation* on existing satellite/terrestrial/handheld digital television terminals without modifications in their hardware or their lower layers (demultiplexing/decapsulation modules)

It is obvious that DHCP-like protocols, which exist and are used in networks with a common link layer cannot be used "as-is" in our case, where the communication between the terminal and the configuration server cannot be established in a link-layer basis, since they do not belong to a common link. This holds especially in the case where the interaction channel is implemented by an external IP network. A new mechanism needs to be introduced, based on the philosophy of existing dynamic configuration protocols, but implemented under a different perspective.

## IV. A PROPOSED IP-BASED DYNAMIC CONFIGURATION MECHANISM

The paper proposes an IP-based mechanism for dynamic configuration of the DTV terminals, which fulfills all the requirements stated in the previous section. For reference reasons, this mechanism/protocol will be referred to as IDDCP (IP-over-DTV Dynamic Configuration Protocol). This section presents the principles of operation, the message types, the algorithm and the state diagram of the IDDCP protocol. The philosophy followed and the message types are mainly derived from the operation of DHCPv4/DHCPv6. Nevertheless, many adaptations have been introduced to match the requirements of an interactive DTV network.

The approach is based on a client-server model, where all IDDCP messages are conveyed over UDP/IP, either over the broadcast channel or the interaction network. The IP-based model allows for easy, IP-level implementation on any existing terrestrial or satellite DTV terminal, without any modification in its RF/demultiplexing/decapsulation stack. The client is considered to be the DTV terminal whose parameters are to be set, and the server is a separate network entity located in the broadcaster's premises. The role of the IDDCP server will be the management and allocation of IP parameters to terminals. Since the number of clients can be in the order of tenths or thousands, it would be convenient to use an open database (e.g. SQL-based) to store the assigned parameters than an internal table, as most DHCP servers use. Regarding the UDP ports used, the numbers used by DHCPv6 could be adopted: 546 for the client and 547 for the server.

The message types, which are required are:

- *ADVERTISE:* It is broadcast at regular intervals by the server to all clients over the DTV channel and contains its own IPv4/IPv6 global address (or multiple addresses if multiple servers exist), a subnet prefix/mask for all clients and a common temporary IP address, which is used by all clients during the configuration procedure.
- *REQUEST:* It is sent by the client to the server over the interaction channel to request configuration parameters. It contains the MAC address of the DTV interface and a UID (Unique Identifier), similar to DHCPv6's DUID, which is used by the server to uniquely identify clients.
- *REPLY:* It is sent by the server via the broadcast channel as a response to a REQUEST command. It contains a set of configuration parameters: IPv4 and IPv6 addresses of the network Gateway, the DNS server and of course of the client terminal itself. It also contains a "lease" value, i.e. a time duration after which the parameters assigned are invalid and they need to be renewed via a RENEW message (see below).
- *CONFIRM:* It is sent by the client to the server as a confirmation that the REPLY message has been promptly received and accepted.
- *RENEW:* It is sent by the client upon the expiration of the lease timer, as a request to the server in order to renew the assigned parameters.
- *RECONFIGURE:* It is send by the server to the client if any of the parameters assigned need to be changed. Upon reception of RECONFIGURE, the client has to re-initiate the dynamic configuration process.

For simplicity reasons, it is assumed that, for a first approach, neither the client's request nor the server's offer can be declined. If this is so (an unlikely case), then the appropriate message types will have to be added.

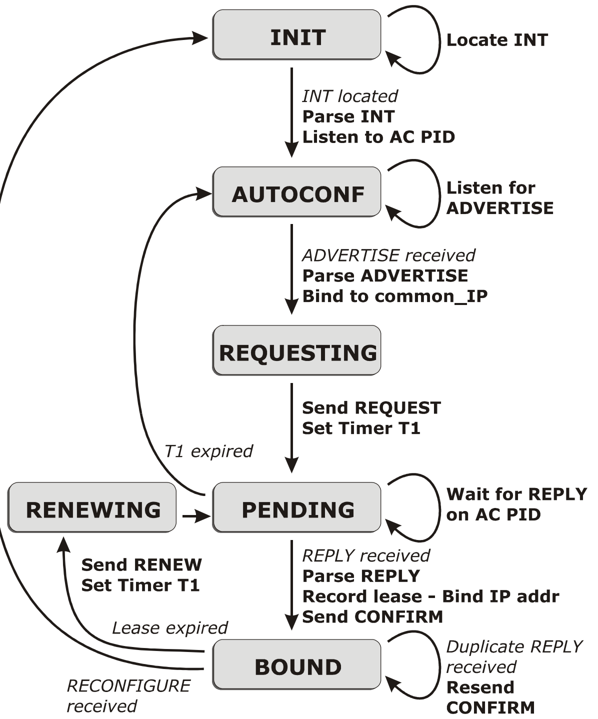


Figure 2. IDDCP state diagram (client)

The state diagram of the proposed mechanism, from the client side, is depicted in Fig.2.

IDDCP is based on a four-way handshake. Its operation is described as follows:

Firstly, a client, which needs to be configured (e.g. after power-up, after a handover or when IP services are activated) listens to the broadcast stream to locate a server ADVERTISE message. In general, it would be convenient that a dedicated DTV AC (AutoConfiguration) Program Number (corresponding to a certain AC PID) is devoted to the transport of IDDCP messages. This Program Number can be declared via native DTV signalling. For example, in the case of DVB networks, the standardised INT (IP/MAC Notification Table) [1] can be used, where the IDDCP Program can be declared as having a target_IP of 255.255.255.255 and a target_MAC of 0xff:ff:ff:ff:ff:ff (broadcast) so that it is processed by all terminals. ADVERTISE will be contained in a UDP packet, having the broadcast IP address in its "destination" field.

By parsing ADVERTISE, the client specifies the server's IP, the subnet prefix/mask and assigns to the DTV interface a common_IP address, which is temporary and is the same for all configuring terminals. In the unidirectional case with "receive-only" terminals, this common_IP is sufficient as described in Section II and the process ends here. In the case of IPv6, stateless autoconfiguration can take place, using the advertised prefix.

In the case that a return channel exists (cases (b) and (c) of Section II), this temporary address is used by the client to form the REQUEST message, which will also contain its own MAC address and a globally unique UID. The latter can be locally generated as described in [8]. These two values, the MAC address and the UID are used to uniqely identify the terminal throughout the entire IDDCP process. Upon sending REQUEST, the client initialises and keeps a timer. If the timer expires and no reply is received, it is assumed that the message was lost and it is re-sent.

The client listens to the AC Program and waits for a REPLY message from the server. REPLY is sent also with a broadcast "destination IP" address, since the client parameters are not yet set. Among the messages carried in the program, the client can locate its own REPLY by matching the UID found in the body of the message with its own. It is recommended that for security reasons, REPLY messages do not contain the MAC addresses of the client. If this happened, an eavesdropper could easily record the addresses of all configured clients, and could possibly use them to generate unauthorised REQUESTs. When received, the REPLY will contain all necessary information, as aforementioned, and the client uses them to configure itself.

When configuration is complete, the client will respond with a CONFIRM message, now using its new IP address. If a duplicate REPLY is received, it is assumed that CONFIRM was lost and it is re-sent. At the same time, a lease timer is initialised, as declared in REPLY. The configuration is considered valid until the lease expires. When this happens, the client will have to send a RENEW message to the server and receive another REPLY with the same or updated configuration information.

Finally, the server will have the option of sending a (unicast or broadcast) RECONFIGURE message to the client(s), to force them re-initiate the dynamic configuration process before the lease expires.

After the completion of the process, the client is in the BOUND state, and the IP parameters of its DTV interface are properly set. The terminal has now been enabled for interactive IP-based DTV services.

The aforementioned procedure is an initial proposed approach to the required dynamic configuration protocol and can be further enhanced to support additional functionality, such as authentication and security. However, it has to be kept at relatively low complexity so that it can be easily implemented even in handheld terminals and so that computational demands in the server are kept at reasonable levels.

## V. CONCLUSIONS

This article discussed the issue of dynamic configuration of IP parameters in interactive DTV terminals. Via an overview of digital television network topologies the need of such a mechanism is emerged, particularly in terrestrial networks, where handovers and switches among broadcasters are common. Through an overview of the particularities of a DTV interactive network and the requirements for dynamic configuration, it was explained why existing protocols such as DHCP cannot be used "as-is". A new client-server mechanism is proposed, namely IDDCP (IP-over-DTV Dynamic Configuration Protocol) and is extensively described via its message types, operational description and state diagram. This protocol is designed to provide simultaneous IPv4/IPv6 configuration and is well tailored to suit the requirements of an IP/DTV interactive network via a simplified yet fully functional and scalable approach, which can be easily implemented at IP level in all existing satellite and terrestrial/handheld terminals. The research effort referred to in this paper is carried out in the frame of the “IP-over-DVB” workgroup of the IETF and has so far produced an Internet Draft [10].

## ACKNOWLEDGMENT

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