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OF TELEVISION, SOUND PROGRAMME AND OTHER
MULTIMEDIA SIGNALS

Interactive systems for digital television distribution

Cable modem IPv4 and IPv6 eRouter specification

ITU-T Recommendation J.218

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Cable modem IPv4 and IPv6 eRouter specification

Summary

ITU-T Recommendation J.218 defines a core set of features that enables multiple subscriber devices to gain access to operator-provided high speed data service using DOCSIS. This core set of features allows for both IPv4 and IPv6 enabled devices to gain connectivity to the Internet.

The eRouter is specified as an embedded service/application functional entity (eSAFE) device as defined in ITU-T Recommendation J.126 that is implemented in conjunction with a DOCSIS cable modem device.

The core set of features defined in this Recommendation includes the ability to provision multiple CPE devices, a description of how to forward data to and from CPE devices and also the ability to forward IP multicast traffic to CPE devices.

Source

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ITU-T Recommendation J.218

Cable modem IPv4 and IPv6 eRouter specification

1 Scope

This Recommendation defines a core set of features that enables multiple subscriber devices to gain access to operator-provided high speed data service using DOCSIS. This core set of features allows for both IPv4 and IPv6 enabled devices to gain connectivity to the Internet.

The eRouter is specified as an embedded service/application functional entity (eSAFE) device as defined in [ITU-T J.126] that is implemented in conjunction with a DOCSIS Cable Modem device.

The core set of features defined in this Recommendation includes the ability to provision multiple CPE devices, a description of how to forward data to and from CPE devices and also the ability to forward IP multicast traffic to CPE devices.

NOTE – The structure and content of this Recommendation have been organized for ease of use by those familiar with the original source material; as such, the usual style of ITU-T recommendations has not been applied.

2 References

2.1 Normative references

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

- [ITU-T J.126] ITU-T Recommendation J.126 (2007), *Embedded cable modem device specification*.
- [ITU-T J.222.2] ITU-T Recommendation J.222.2 (2007), *Third-generation transmission systems for interactive cable television services – IP cable modems: MAC and upper layer protocols*.
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- [IETF RFC 2132] IETF RFC 2132 (1997), *DHCP Options and BOOTP Vendor Extensions*.
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- [IETF RFC 3419] IETF RFC 3419 (2002), *Textual Conventions for Transport Addresses*.
- [IETF RFC 3489] IETF RFC 3489 (2003), *STUN – Simple Traversal of User Datagram Protocol (UDP) Through Network Address Translators (NATs)*.
- [IETF RFC 3513] IETF RFC 3513 (2003), *Internet Protocol Version 6 (IPv6) Addressing Architecture*.
- [IETF RFC 3584] IETF RFC 3584 (2003), *Coexistence between Version 1, Version 2, and Version 3 of the Internet-standard Network Management Framework*.
- [IETF RFC 3633] IETF RFC 3633 (2003), *IPv6 Prefix Options for Dynamic Host Configuration Protocol (DHCP) version 6*.
- [IETF RFC 3646] IETF RFC 3646 (2003), *DNS Configuration options for Dynamic Host Configuration Protocol for IPv6 (DHCPv6)*.
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- [IETF RFC 3810] IETF RFC 3810 (2004), *Multicast Listener Discovery Version 2 (MLDv2) for IPv6*.
- [IETF RFC 4075] IETF RFC 4075 (2005), *Simple Network Time Protocol (SNTP) Configuration Option for DHCPv6*.
- [IETF RFC 4242] IETF RFC 4242 (2005), *Information Refresh Time Option for Dynamic Host Configuration Protocol for IPv6 (DHCPv6)*.

- [IETF RFC 4293] IETF RFC 4293 (2006), *Management Information Base for the Internet Protocol (IP)*.
- [IETF RFC 4361] IETF RFC 4361 (2006), *Node-specific Client Identifiers for Dynamic Host Configuration Protocol Version Four (DHCPv4)*.

2.2 Informative references

This Recommendation uses the following informative references:

- [OSSIV3.0] DOCSIS Operations Support System Interface Specification, CM-SP-OSSIV3.0-I02-070223, February 23, 2007, Cable Television Laboratories, Inc.
- [CANN DHCP] CableLabs DHCP Options Registry Specification, CL-SP-CANN-DHCP-Reg-I01-061117, November 17, 2006, Cable Television Laboratories, Inc.

2.3 Reference acquisition

Cable Television Laboratories, Inc., 858 Coal Creek Circle, Louisville, CO 80027; Phone +1 303-661-9100; Fax: +1 303-661-9199; Internet: <http://www.cablelabs.com/>

IETF Standards, Internet Engineering Task Force (IETF) Secretariat c/o Corporation for National Research Initiatives, 1895 Preston White Drive, Suite 100, Reston, VA 20191-5434, Phone: +1 703-620-8990, Fax: +1 703-620-9071, Internet: <http://www.ietf.org/>

3 Terms and definitions

This Recommendation defines the following terms:

- 3.1 customer-facing interface:** An eRouter interface used for connecting CPE devices.
- 3.2 customer-facing IP interface:** An IP interface connected to the eRouter which is not necessarily mapped one-to-one with the number of customer-facing ports on the eRouter.
- 3.3 customer-facing logical IP interface:** A logical interface connected to the eRouter which is not necessarily mapped one-to-one with the number of customer-facing ports on the eRouter.
- 3.4 eDOCSIS:** Embedding another functional device within a cable modem.
- 3.5 eRouter:** An eSAFE device that is implemented in conjunction with the DOCSIS embedded cable modem.
- 3.6 multicast subscription database:** A simple table of entries for the IPv4 or IPv6 multicast group membership information maintained by the eRouter on respective interfaces. Implementation details for storage of records is completely vendor-defined.
- 3.7 operator-facing interface:** The eRouter interface which is connected to the embedded cable modem.
- 3.8 operator-facing IP interface:** IP interface that is connected to the embedded cable modem and is provisioning with an IP address provided by the operator.

4 Abbreviations, acronyms and conventions

4.1 Abbreviations and acronyms

This Recommendation defines the following abbreviations:

- ALG Application Level Gateway
- ARP Address Resolution Protocol
- ASN.1 Abstract Syntax Notation One

CPE	Customer Premises Equipment
CM	Cable Modem
DAD	Duplicate Address Detection
DNS	Domain Name System
DUID	DHCP Unique Identifier
EAE	Early Authentication and Encryption
eSAFE	embedded Service/Application Functional Entity
EUI	Extended Unique Identifier
FTP	File Transfer Protocol
ID	Identifier
IP	Internet Protocol
IRT	Initial Retransmission Time
LAN	Local Area Network
MAC	Media Access Control
MIB	Management Information Base
MLD	Multicast Listener Discovery
MRC	Maximum Retransmission Count
MRD	Maximum Retransmission Duration
MRT	Maximum Retransmission Time
NAT	Network Address Translation
NAPT	Network Address Port Translation
ND	Neighbour Discovery
OID	Object ID
OUI	Organization Unique Identifier
RA	Router Advertisement
RD	Router Discovery
SIP	Session Initiation Protocol
SLAAC	Stateless Address Autoconfiguration
TCP	Transmission Control Protocol
TLV	Type/Length/Value
TTL	Time To Live
UDP	User Datagram Protocol
WAN	Wide Area Network

4.2 Conventions

Throughout this Recommendation, the words that are used to define the significance of particular requirements are capitalized. These words are:

- "MUST"

This word means that the item is an absolute requirement of this Recommendation.
- "MUST NOT"

This phrase means that the item is an absolute prohibition of this Recommendation.
- "SHOULD"

This word means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighed before choosing a different course.
- "SHOULD NOT"

This phrase means that there may exist valid reasons in particular circumstances when the listed behaviour is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behaviour described with this label.
- "MAY"

This word means that this item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because it enhances the product, for example; another vendor may omit the same item.

5 Theory of operation

The eRouter device is intended to provide home networking functionality in conjunction with a DOCSIS eCM in an eDOCSIS device.

This Recommendation defines a set of features for an IPv4 eRouter and a set of features for an IPv6 eRouter. Both sets of features can be implemented together as an IPv4 + IPv6 eRouter.

Figures 5-1 to 5-3 depict implementations of eDOCSIS devices with an IPv4 eRouter, an IPv6 eRouter and an IPv4 + IPv6 eRouter.

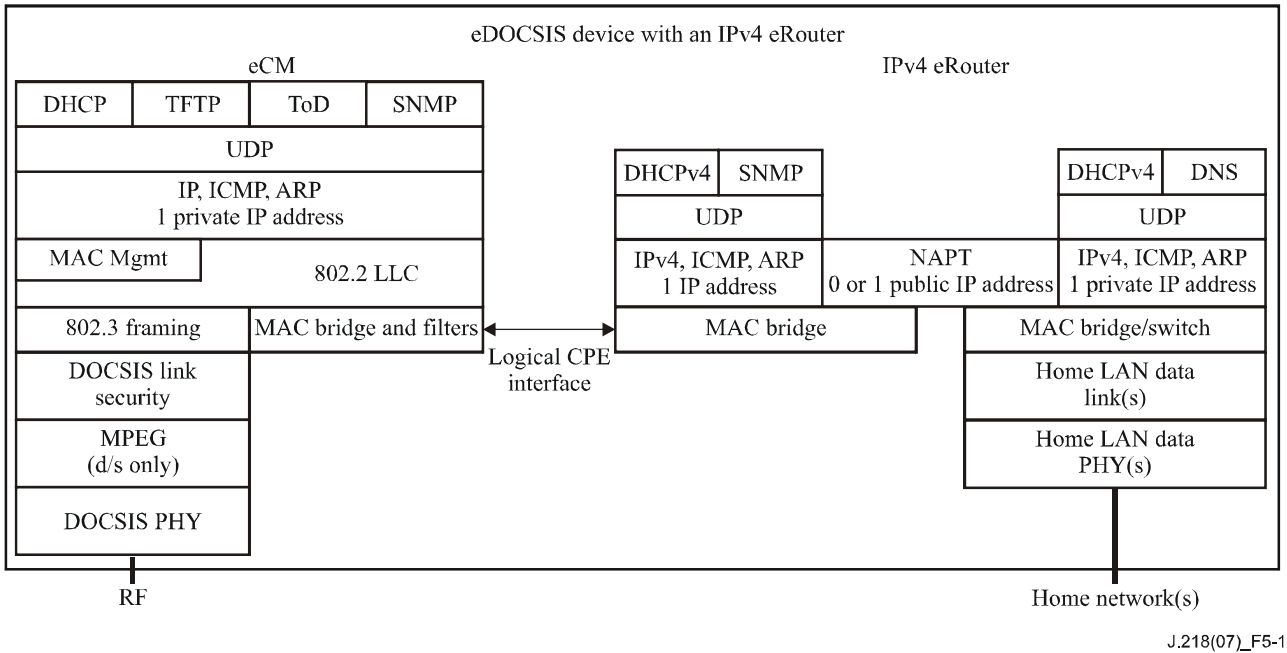


Figure 5-1 – Logical components of an eDOCSIS device with an IPv4 eRouter

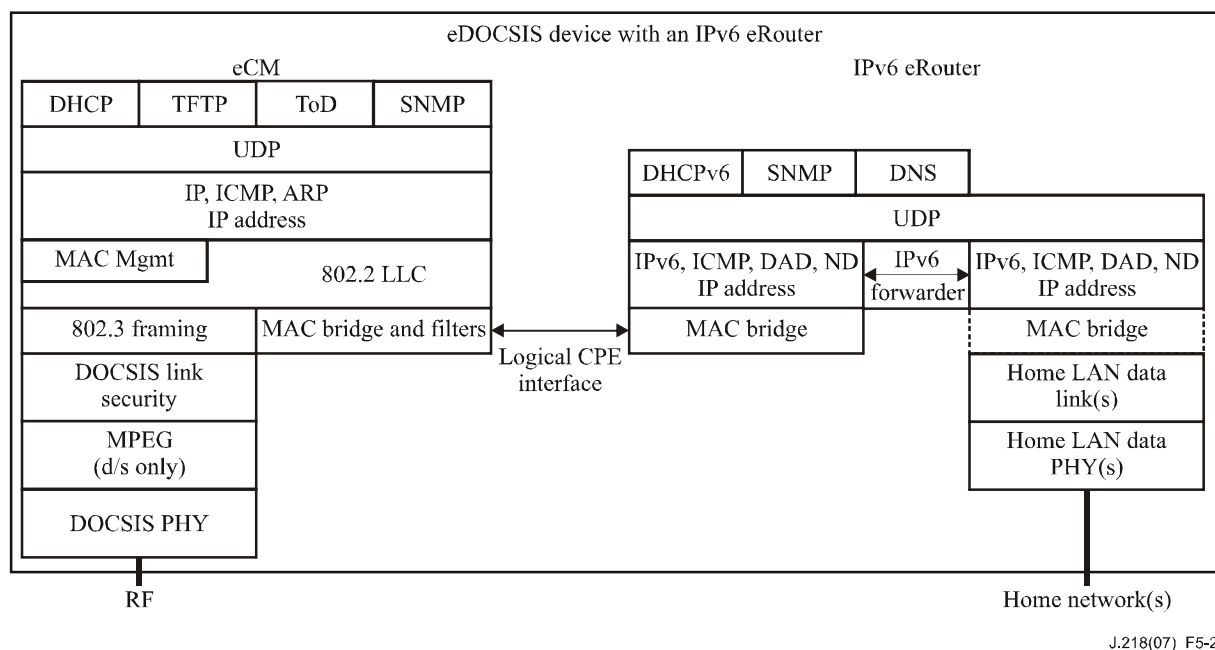


Figure 5-2 – Logical components of an eDOCSIS device with an IPv6 eRouter

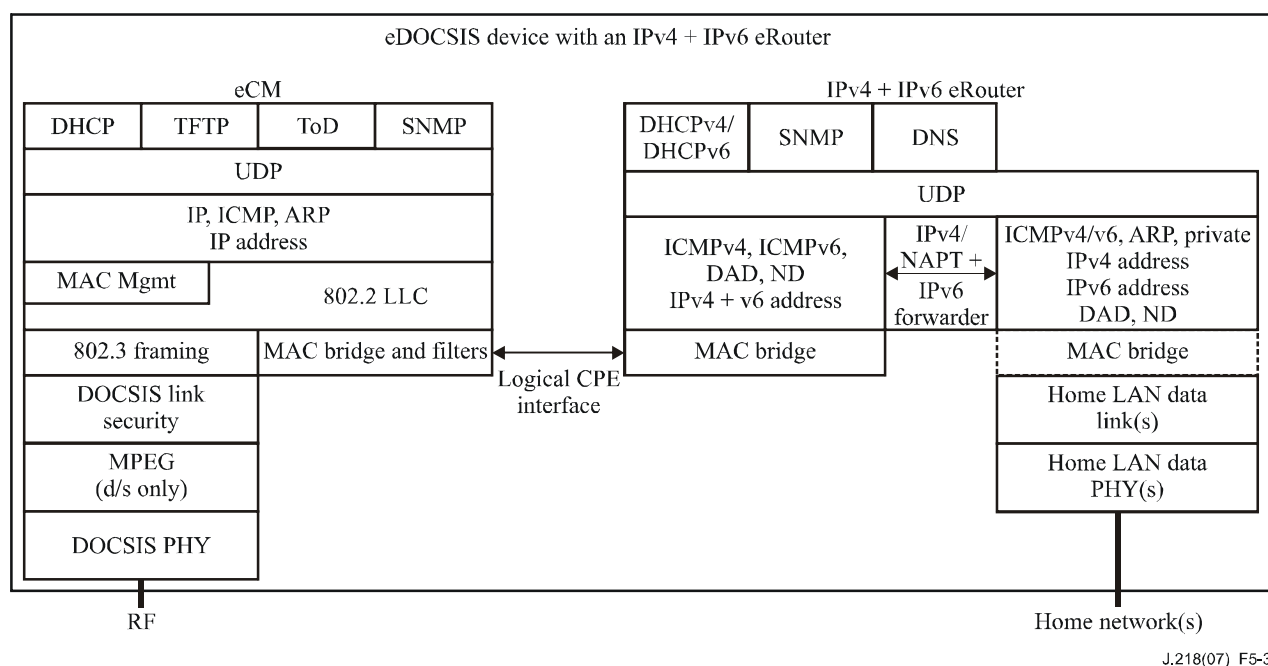


Figure 5-3 – Logical components of an eDOCSIS device with an IPv4 + IPv6 eRouter

The primary function of the eRouter device is to allow subscribers to connect multiple CPE devices to the operator-provided DOCSIS high-speed Internet service. DOCSIS specifications allow subscribers to directly connect multiple CPE devices to the cable modem; however, operators are required to provide provisioning to each of the CPE devices. The eRouter takes over the provisioning aspect of multiple CPE devices at the subscriber end. Depending on which version of the eRouter is included with the eDOCSIS implementation, the eRouter allows provisioning of IPv4 CPEs, IPv6 CPEs or both IPv4 and IPv6 CPEs simultaneously.

This Recommendation defines the core set of functions that are performed by the eRouter; however, in most implementations vendors would include additional features that would enhance the eRouter

device. This may include additional home-networking features as well as the ability to provision and manage the eRouter from the subscriber side.

This Recommendation defines:

- a) CPE provisioning with IPv4 and IPv6 addresses;
- b) IPv4 data forwarding with NAPT and IPv6 data forwarding;
- c) ability to forward IP Multicast traffic; and
- d) preserve IP QoS markings on IP data to and from the CPE devices.

This Recommendation uses the terms customer-facing interface and operator-facing interface as defined in clause 3.

This Recommendation defines requirements for an eRouter device with a single operator-facing IP interface. This Recommendation defines requirements for an eRouter device with a single customer-facing logical IP interface which is not necessarily mapped one-to-one with the number of customer-facing ports on the eRouter. Though it is possible that an eRouter could have multiple customer-facing IP interfaces, it is vendor specific how to forward traffic between customer-facing interfaces and the operator-facing IP interface when there are multiple customer-facing IP interfaces.

6 eRouter initialization

Prior to its initialization, the eRouter is enabled or disabled through the TLVs in Annex B. The eRouter may operate in any one of four possible modes – Disabled, IPv4 Protocol Enabled, IPv6 Protocol-Enabled or Dual IP Protocol-Enabled, summarized in Table 6-1. The eRouter **MUST** support the Disabled Mode and at least one other Mode. The eRouter **MAY** support the IPv4 Protocol Enabled Mode. The eRouter **MAY** support the IPv6 Protocol Enabled Mode. The eRouter **MAY** support the Dual IP Protocol Enabled Mode.

Table 6-1 – eRouter modes

Mode	IPv4	IPv6
Disabled	CM bridges all traffic per ITU-T Rec. J.222.2	CM bridges all traffic per ITU-T Rec. J.222.2
IPv4 Protocol Enabled	eRouter forwards IPv4 traffic with NAPT.	eRouter does not forward IPv6 traffic.
IPv6 Protocol Enabled	eRouter does not forward IPv4 traffic.	eRouter forwards IPv6 traffic.
Dual IP Protocol Enabled	eRouter forwards IPv4 packets using NAPT.	eRouter forwards IPv6 packets.

In Disabled Mode, the eRouter transparently forwards all traffic directly between its customer-facing interface and its operator-facing interface. In this mode, it appears as if there is no eRouter present. The CM bridges all traffic (regardless of IP protocol version) to the CPE ports that would have been behind the eRouter had it been enabled. In this mode, the eRouter specification is irrelevant – the interfaces become part of the cable modem. All behaviour will occur according to the DOCSIS specifications.

When configured to operate in IPv4 Protocol Enabled Mode, the eRouter performs IPv4 provisioning and forwards IPv4 traffic between its customer-facing interface and its operator-facing interface. The eRouter operating in IPv4 Protocol Enabled Mode will not perform any IPv6 provisioning. An eRouter configured to operate in IPv4 Protocol Enabled Mode will not forward any IPv6 traffic. The IPv4 traffic is forwarded using NAPT according to clause 9.

When configured to operate in IPv6 Protocol Enabled Mode, the eRouter performs IPv6 provisioning and forwards IPv6 traffic between its customer-facing interface and its operator-facing interface. The eRouter operating in IPv6 Protocol Enabled Mode will not perform any IPv4 provisioning. An eRouter configured to operate in IPv6 Protocol Enabled Mode will not forward any IPv4 traffic.

In Dual IP Protocol Enabled Mode, the eRouter is configured to forward both IPv4 and IPv6 traffic between its customer-facing interface and its operator-facing interface. IPv4 traffic is forwarded using NAT, according to clause 9. IPv6 traffic is forwarded according to clause 10.

7 IPv4 provisioning

The normative requirements of this clause are mandatory for an eRouter that implements the IPv4 Protocol Enabled Mode and/or the Dual IP Protocol Enabled Mode as defined in clause 6.

After the CM has completed provisioning, if the eRouter is configured to route IPv4 packets, the eRouter **MUST** use DHCPv4 [IETF RFC 2131] via its operator-facing interface in order to obtain an IP address and any other parameters needed to establish IP connectivity, as illustrated in Figure 7-1.

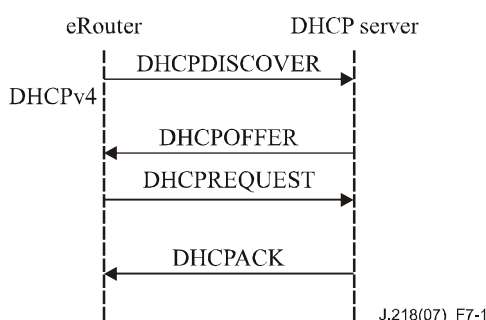


Figure 7-1 – IPv4 provisioning message flow

The eRouter may receive multiple DHCPOFFER messages in response to its DHCPDISCOVER message. If a received DHCPOFFER message does not include all of the required DHCPv4 fields and options as described in clause 7.1, the eRouter **MUST** discard the DHCPOFFER message and wait for another DHCPOFFER message. If none of the received DHCPOFFER messages contain all the required DHCPv4 fields and options, the eRouter **MUST** retransmit the DHCPDISCOVER message.

The back-off values for retransmission of DHCPDISCOVER messages **SHOULD** be chosen according to a uniform distribution between the minimum and maximum values in the rows of Table 7-1.

Table 7-1 – eRouter DHCP retransmission interval

Back-off number	Minimum (s)	Maximum (s)
1	3	5
2	7	9
3	15	17
4	31	33
5	63	65

The eRouter SHOULD also implement a different retransmission strategy for the RENEWING and REBINDING states, as recommended in [IETF RFC 2131], which is based on one-half of the remaining lease time.

The eRouter MUST limit the number of retransmissions of the DHCPDISCOVER and DHCPREQUEST messages to five or fewer. The eRouter MUST NOT forward IPv4 traffic between its customer-facing interface and its operator-facing interface until it has completed IPv4 provisioning, including the successful receipt of a DHCPACK message. The eRouter MUST NOT forward IPv4 traffic if, at any time, it does not have an IPv4 address for its operator-facing interface.

The eRouter MUST be able to accept a unicast response from the DHCP server/relay agent.

[IETF RFC 3203] describes an extension to DHCPv4 that allows a server to send a FORCERENEW message that forces a client to renew its lease. The eRouter MUST ignore all received FORCERENEW messages.

7.1 DHCPv4 fields used by the eRouter

The eRouter MUST include the following fields in the DHCPDISCOVER and DHCPREQUEST messages:

- The hardware type (htype) MUST be set to 1.
- The hardware length (hlen) MUST be set to 6.
- The client hardware address (chaddr) MUST be set to the 48-bit MAC address associated with the IPv4 CM-facing interface of the eRouter.
- The Broadcast bit MUST NOT be set.
- The client identifier option MUST be included, using the format defined in [IETF RFC 4361].
- The parameter request list option MUST be included. The following option codes (defined in [IETF RFC 2132] and [IETF RFC 4361]) MUST be included in the list:
 - Option code 1 (Subnet Mask)
 - Option code 3 (Router Option)
 - Option code 6 (DNS Server Option)
 - Option code 60 (Vendor Class Identifier) (see clause 8.3)
 - Option code 43 (see [ITU-T J.126])
 - Option code 55 Parameter Request List

The following fields are expected in the DHCPPOFFER and DHCPACK messages returned to the eRouter. The eRouter MUST configure itself with the listed fields from the DHCPACK:

- The IP address to be used by the eRouter (yiaddr) (critical).
- The IP Address lease time, option 51 (critical).
- The Server identifier, option 54 (critical).
- The subnet mask to be used by the eRouter (Subnet Mask, option 1) (critical).
- A list of addresses of one or more routers to be used for forwarding eRouter-originated IP traffic (Router Option, option 3). The eRouter is not required to use more than one router IP address for forwarding (critical):
 - A list of DNS Server addresses (critical).
 - A list of options under the CL_V4EROUTER_CONTAINER_OPTION option which are passed on to CPE devices as defined in Annex C.

If a critical field is missing or invalid in the DHCPACK received during initialization, the eRouter MUST restart the DHCP cycle, beginning with an initial DHCPDISCOVER.

If a non-critical field is missing or invalid in the DHCPACK received during initialization, the eRouter MUST ignore the field, and continue the provisioning process.

If the yiaddr, Server Address, or Lease Time field is missing or invalid in the DHCPACK received during a renew or rebind operation, the eRouter MUST retry the renew or rebind operation until either:

- 1) it receives a response containing valid values of the yiaddr, Server Address, and Lease Time fields; or
- 2) the lease expires.

If the lease expires, the eRouter MUST restart the DHCP cycle, beginning with an initial DHCPDISCOVER.

If any field other than the yiaddr, Server Address or Lease Time is missing, or is invalid in the DHCPACK received during a renew or rebind operation, the eRouter MUST ignore the field if it is invalid, and remain operational.

7.2 Router DHCPv4 server sub-element

The DHCP server is responsible for assigning network address leases to LAN IP devices associated with customer-facing interfaces. It is also responsible for providing LAN IP devices with configuration information via DHCP option codes, as specified in [IETF RFC 2132].

7.2.1 DHCPv4 server function goals

Goals for the DHCP server include the following:

- Assign network address leases to CPE devices according to [IETF RFC 2131].
- Assign private CPE addresses according to [IETF RFC 1918].
- Assign configuration information according to [IETF RFC 2132].

7.2.2 DHCPv4 server function system description

The eRouter DHCPv4 server responsibilities include:

- Assigning IP Addresses and delivering DHCP configuration parameters to CPE devices. The server relies on built-in default values for initial IP Address pool configuration, lease parameter configuration, and DHCP options values.
- Optional logging of DHCPv4 server errors to a local event log.

7.2.3 DHCPv4 server function requirements

The eRouter MUST include a DHCPv4 server compliant with [IETF RFC 2131].

In addition, the following requirements apply to the DHCPv4 server function:

- When the DHCP server assigns an active lease for an IP address to a CPE device, the server MUST remove that IP address from the pool of IP addresses available for assignment.
- The DHCP server function of the eRouter MUST support the DHCP options indicated as mandatory in Table 7-2.
- The DHCP server function of the eRouter MUST NOT respond to DHCP messages that are received through the operator-facing interface, nor originate DHCP messages from the operator-facing interface.
- The DHCP server function of the eRouter MUST NOT deliver any DHCP option with null value to any CPE device.