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#### Abstract

This RFC provides a framework for transporting ANSI C12.22/IEEE 1703/MC1222 Advanced Metering Infrastructure (AMI) Application-Layer Messages on an IP network.

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## 1. Introduction

The ANSI C12.22 standard [1] provides a set of application layer messaging services that are applicable for the enterprise and End Device components of an Advanced Metering Infrastructure (AMI) for the SmartGrid. The messaging services are tailored for, but not limited to, the exchange of the data Tables Elements defined and co-published in ANSI C12.19 [2], IEEE P1377/D1 [3], and MC1219 [4].

ANSI C12.22, which is an application-level messaging protocol, may be transported over any underlying transport network. This RFC defines

the requirements governing the transmission of ANSI C12.22 Messages via the TCP and UDP transports and the IP networking.

### 1.1. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [5].

Throughout this document we use terms like ANSI C12.22 or ANSI C12.19, as in C12.22 Relay or ANSI C12.19 Device. These terms are interchangeable with the terms IEEE 1703 Relay and IEEE 1377 IEEE 1377 Device, respectively. However, the recent versions of the Utility End Device communication standards were developed under the auspices of ANSI C12 SC17 WG1 and ANSI C12 SC17 WG2. For that reason, the terminology used in this document is based on the ANSI C12.22-2008 [1] and ANSI C12.19-2008 [2] definitions as revised by IEEE 1703-2009 [6] and IEEE 1377-2009 [3].

### 1.2. Definitions

This specification uses a number of terms to refer to the roles played by participants (actors) in, and objects of, the ANSI C12.22 [1], IEEE 1703 [6], and MC1222 [7] protocol.

Terms prefixed by C12.22 or C12.19, which are not defined here, can be resolved in [1] [6] [7] or [2] [3] [4].

#### ACSE

Association Control Service Element. In the context of this specification and of [1], ACSEs are encoded per ISO/IEC 10035-1 [8] using the ASN.1 BER [9].

#### APDU

Application Protocol Data Unit. In the context of the ANSI C12.22 Application, it is an ACSE C12.22 Message.

#### ACSE PDU

ACSE Protocol Data Unit; same as APDU.

#### ApTitle

An ANSI C12.22 Application-process Title. An ApTitle is a name for a system-independent application activity that exposes application services to the application agent; e.g., a set of

application service elements that together perform all or part of the communication aspects of an application process. An ApTitle is encoded as a unique registered (as per [1]) object identifier.

#### C12.22 IP Node

A C12.22 Node that is located on an C12.22 IP Network Segment and communicates using the IP protocol.

#### C12.22 IP Network Segment

A collection of all C12.22 IP Nodes that implement the IP-based protocols, as defined in this specification, and can communicate with each other using IP routers, switches, and bridges and without the use of a C12.22 Relay.

#### C12.22 IP Relay

A C12.22 IP Node that performs the functions of a C12.22 Relay. A C12.22 IP Relay acts as a bridge between a C12.22 IP Network Segment and an adjacent, C12.22 Network Segment.

#### C12.22 Message

An APDU that is also a C12.22 Request Message or a C12.22 Response Message. The C12.22 Message described in this specification MUST be encoded using [9].

#### C12.22 Request Message

A fully assembled C12.22 APDU that contains an ACSE user information element, which includes one or more EPSEM service requests.

#### C12.22 Response Message

A fully assembled C12.22 Message APDU that contains an ACSE user information element, which includes one or more EPSEM service responses.

#### Connection

A logical and physical binding between two or more users of a service (ref. [1]).

#### EPSEM

Extended Protocol Specification for Electronic Metering. EPSEM defines structures and services used to encode multiple requests and responses for use by devices such as gas, water, electricity, and related electronic modules or appliances.

#### Initiating C12.22 IP Node

A temporary role of a C12.22 IP Node in which it initiates the transmission of a C12.22 Message that contains a C12.22 EPSEM Service Request.

#### Native Address

The term Native Address refers to the network address of a C12.22 Node on its C12.22 Network Segment. In this specification, the Native Address is the IP address plus the associated port number used in communications by a C12.22 IP Node on the C12.22 IP Network Segment.

#### Responding C12.22 IP Node

A temporary role of a C12.22 IP Node in which it responds to the transmission of a C12.22 Message that contained a C12.22 EPSEM Service Request.

#### Source C12.22 IP Node

The C12.22 IP Node that originates of a C12.22 Message.

#### Target C12.22 IP Node

The C12.22 IP Node that is the destination for a C12.22 Message.

## 2. The C12.22 IP Network Segment

This section defines the characteristics of the C12.22 IP Network Segment.

### 2.1. Composition of a C12.22 IP Network Segment

A C12.22 Network Segment is a collection of C12.22 Nodes that can communicate with each other directly - without having to forward C12.22 Messages through a C12.22 Relay.

A C12.22 IP Network Segment comprises C12.22 IP Nodes and the network infrastructure that enables any one node to reach all other nodes on the same segment. All the C12.22 IP Nodes on the C12.22 IP Network Segment employ the same IP address encoding scheme and the same

network and transport protocols in accordance with this specification.

There is no restriction on the size of a C12.22 IP Network Segment. It MAY be as small as a single LAN or subnet, or it MAY include numerous, heterogeneous LANs and WANs connected by routers, bridges, and switches. The C12.22 IP Network Segment MAY be completely private, or include communication across the global Internet.

## 2.2. IP Native Address

The IP address and the port number used by a C12.22 Node on a C12.22 Network Segment is referred to as a Native Address. The Native Address of a C12.22 IP Node SHALL include an IP Address (version 4 or version 6) and an optional port number, which is assumed to be zero if not present. The IP address of the C12.22 IP Node SHOULD be configured before the node attempts to send or receive any C12.22 Message on its C12.22 IP Network Segment.

The IP address MAY be hard-coded, manually entered, or allocated automatically and/or dynamically by an IP network mechanism such as DHCP. It is beyond the scope of this specification to define the method of configuration, the configuration parameters, or any administrative controls that the system administrator may wish to implement.

## 2.3. Encoding of Native Addresses

ANSI C12.22 defines a field for encoding a C12.22 Native Address for transport within C12.22 Messages. The field consists of up to 20-octets of a binary native network address field (e.g., C12.22 Registration Service <native-address> parameter), whose extent is qualified by an address length field (e.g., C12.22 Registration Service <address-length> parameter). Binary native address fields SHALL be encoded network byte order and interpreted as shown in Figure 1.

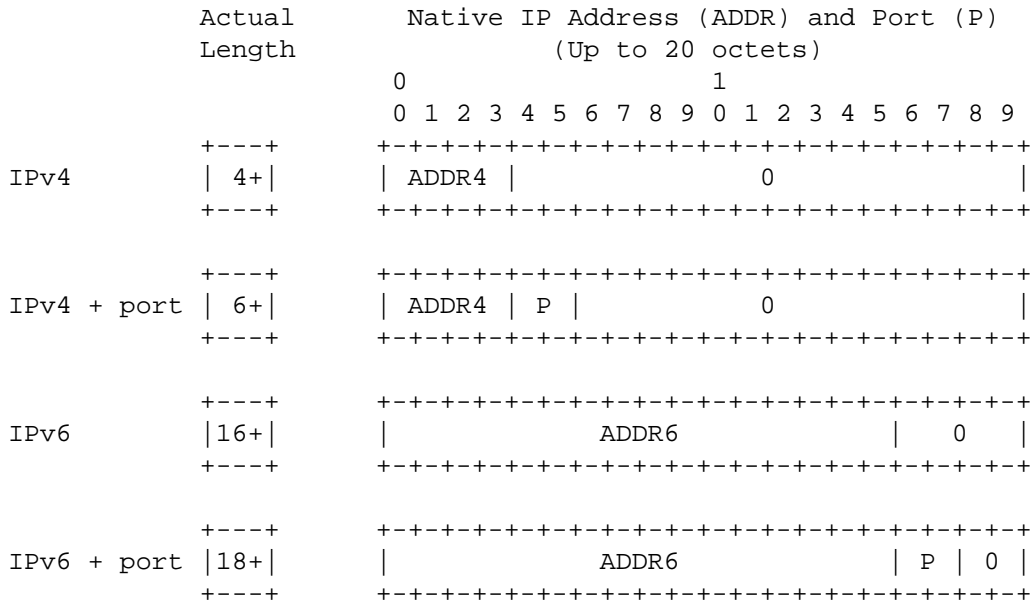


Figure 1: Encoding of the native IP addresses for ANSI C12.22

The notation n+ in the Actual Length field indicates n or more, octets, to a maximum of 20 octets. The port number, P, is OPTIONAL, and when not present it SHALL be assumed to be zero (0). IPv6 addresses SHALL NOT contain all zeros (0) in octet offset positions 6 through 15 when the port number (P) is absent or is set to zero (0).

When a Native Address is encoded in ANSI C12.19 Tables' BINARY data Elements then the size of the native address Element transmitted is defined by ACT\_NETWORK\_TBL.NATIVE\_ADDRESS\_LEN (See [1] [2] Table 121). It is the actual number of octets that are placed inside the C12.19 BINARY Element. This value is common across all of the node's interfaces, including those that are not IP based (thus not conforming to this specification). The encoding of the native address of C12.19 BINARY Elements SHALL conform to Figure 1. When ACT\_NETWORK\_TBL.NATIVE\_ADDRESS\_LEN is greater than the actual native address required to encode a native IP address, then all trailing octets shall be set to zero (0).

#### 2.4. Standardized Port Numbers

IANA (Internet Assigned Numbers Authority) has assigned port 1153 for UDP [10] and TCP [11] C12.22 IP Messages.

By default, C12.22 IP Nodes SHALL send all C12.22 Application Association initiation message requests set with 1153 as the destination port number.

To ensure interoperability among C12.22 IP Nodes, all C12.22 IP Relays and Master Relays SHALL monitor and accept UDP and TCP messages destined to port 1153.

Any IP firewalls or Access Control Lists (ACLs) shielding a C12.22 device MUST be configured to forward UDP and TCP traffic destined to port 1153 and other ports that are assigned and registered by the LAN administrator, in order to maintain the continuity of the C12.22 IP Network Segment.

#### 2.5. Use of UDP Source Port 0

When sending messages via UDP, the sender MAY set the source port to zero. According to the User Datagram Protocol [10], the Source Port is an optional field. When meaningful, it indicates the port of the sending process to which a reply SHOULD be addressed in the absence of any other information. If not used, a value of zero is inserted.

In the context of this specification, the use of UDP port zero (0) is an indication to the target that any responses to a C12.22 Request Message SHALL be sent to the requester's registered port number, or if unknown, then it SHALL be sent to the default port: 1153.

#### 2.6. IP Multicast

In addition to unicast, the ANSI C12.22 protocol requires the support of a multicast message delivery services from the network. In the cases where C12.22 IP Nodes MUST perform IP address discovery (e.g., the discovery of the IP address of C12.22 IP Relays that provide a route out of the C12.22 IP Network Segment, or the discovery of the IP address of a C12.22 IP Master Relay on the C12.22 IP Network), the C12.22 IP Nodes uses IP Multicast to send a C12.22 Message that contains an EPSEM Resolve Service Request on the IP LAN.

IP multicast is also desirable, for example, when a C12.22 Host needs to read efficiently a multitude of C12.22 Nodes (e.g., meters), configured with a common C12.22 multicast group ApTitle. Using IP multicast, the C12.22 sends one C12.22 Message containing an EPSEM Read Service Request that reaches all C12.22 Nodes on the C12.22 IP Network Segment.

For these reasons, all C12.22 IP Relays and Master Relays SHALL support IP multicast and it is RECOMMENDED that all C12.22 Nodes support IP multicast. Any IPv4 C12.22 IP Node that supports IP multicast SHALL use the Internet Group Management Protocol IGMP version 1 (IGMPv1) [12] as a minimum, to report (i.e., request) membership in the C12.22 multicast group to its local router(s). It



is RECOMMENDED that C12.22 IP Nodes implement IGMPv3 [13].  
Implementation of IGMPv3 [14] is OPTIONAL.

Any IPv6 C12.22 IP Node that supports IP multicast SHALL use  
Multicast Listener Discovery version 2 (MLDv2) (RFC 3810 [15]  
possibly within ICMPv6 RFC 4443 [16]) to report membership.

Routers that interconnect C12.22 IP Nodes on the C12.22 IP Network  
Segment, MUST support Protocol Independent Multicast Sparse Mode (PIM  
SM) (RFC 4601 [16]) along with IGMPv1 (RFC 1112 [12]) as a minimum  
for IPv4, or MLDv2 for IPv6 (RFC 3810 [14]). It is RECOMMENDED that  
they implement IGMPv2. It is beyond the scope of this specification  
to define the mechanism for selecting an initial Rendezvous Point  
(RP) for the C12.22 multicast group, the use of shared versus source  
trees, or the mechanism for inter-domain multicast routing.

The requirements of this section indicate a need for an IPv4 and an  
IPv6 multicast address to be dedicated for ANSI C12.22 use. See  
Section 5 IANA Considerations.

## 2.7. IP Broadcast

IP broadcast is not generally suitable as a replacement or an  
alternative for multicast in a C12.22 IP Network Segment. IP  
broadcast is not supported in IPv6 and it suffers from limited scope  
in IPv4. This specification, however, does not preclude the use of  
IP directed broadcast, and specifies a minimum requirement in Section  
2.8.

## 2.8. Encoding of Multicast and Broadcast Addresses

ANSI C12.22 Tables provide Elements for encoding a Native Broadcast  
or Multicast Address for transport within a C12.22 Message. The  
Elements consist of up to 20-octets. The encoding of these Table  
Elements is identical to that defined in Section 2.3. These fields  
SHALL be used and interpreted as shown in Figure 2.

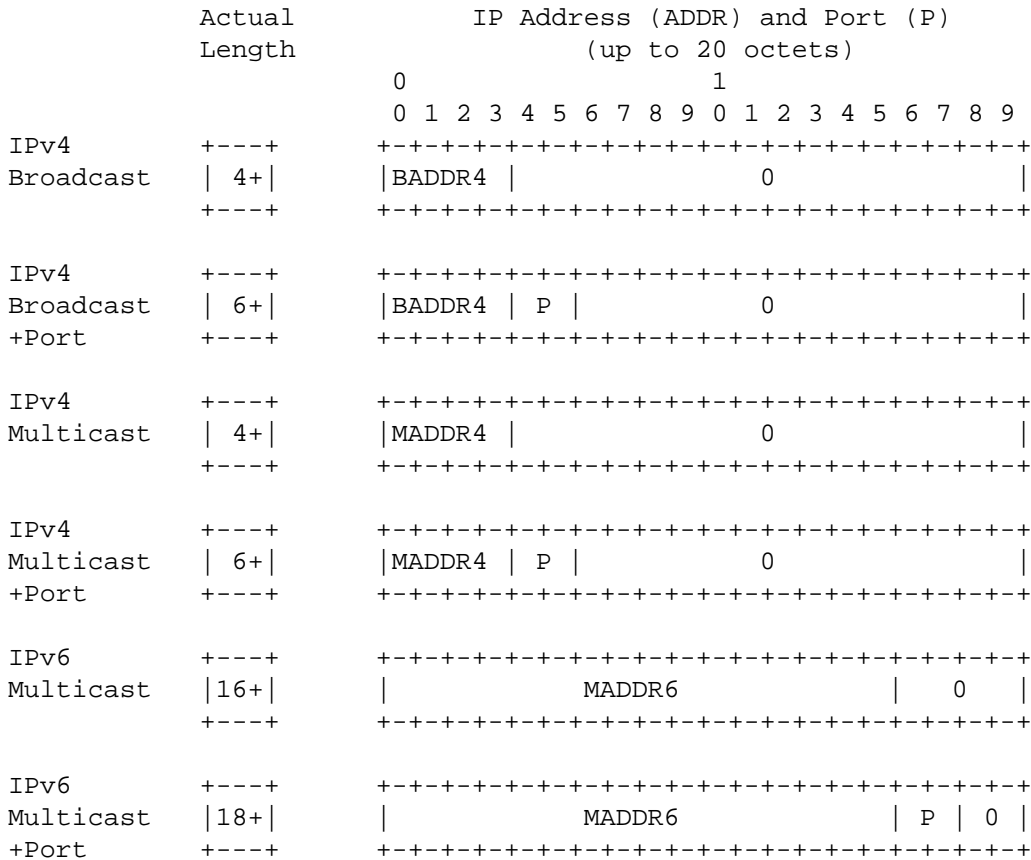


Figure 2: Encoding of broadcast/multicast native IP addresses

The notation n+ in the Actual Length field indicates n or more, octets, to a maximum of 20 octets. The IPv4 and IPv6 multicast addresses, MADDR4 and MADDR6, respectively, are those to be assigned by IANA for use by ANSI C12.22. IPv6 multicast IP addresses SHALL NOT contain all zeros (0) in octet offset positions 6 through 15 when the port number (P) is absent or is set to zero (0).

When a broadcast/multicast Native Address is encoded in ANSI C12.19 Tables' BINARY data Elements then the size of the native address Element transmitted is defined by ACT\_NETWORK\_TBL.NATIVE\_ADDRESS\_LEN (See [1] [2] Table 121). It is the actual number of octets that are placed inside the C12.19 BINARY Element. This value is common across all of the node's interfaces, including those that are not IP based (thus not conforming to this specification). The encoding of the native broadcast/multicast address of C12.19 BINARY Elements SHALL conform to Figure 2. When ACT\_NETWORK\_TBL.NATIVE\_ADDRESS\_LEN is greater than the actual native address required to encode a native

broadcast/multicast address, then all trailing octets shall be set to zero (0).

The IPV4 network directed broadcast address can be computed by performing a bitwise OR between the bit complement of the subnet mask of the target IP subnet and the IP address of any host on that IP subnet.

### 3. IP Message Transport

This section defines a C12.22 Node's usage of the Connection-Oriented (CO) and Connectionless (CL) transport layer protocols, TCP and UDP, respectively.

#### 3.1. C12.22 Connection Types and TCP/UDP Transport Modes

A C12.22 IP Node's use of TCP and UDP is based on its capabilities as defined in its configuration parameters (flags) and as expressed in the Node's accepted registration attributes [1] (CL Flag = <connection-type>.CONNECTIONLESS\_MODE\_SUPPORTED; CL Accept Flag = <connection-type>.ACCEPT\_CONNECTIONLESS; CO Flag = <connection-type>. CONNECTION\_MODE\_SUPPORTED; and CO Accept Flag = <connection-type>.ACCEPT\_CONNECTIONS). The mapping of the connection-type parameters to the type of IP transport that the node supports is defined in Table 1.

Table 1: C12.22 Node Parameters to IP Transport Mapping

CL Flag	CO Flag	CL Accept Flag	CO Accept Flag	IP Transport Mode Supported
0	0	x	x	Invalid configuration
0	1	0	0	Single-channel TCP. UDP not supported
0	1	0	1	Multi-channel TCP. UDP not supported
0	1	1	0	Invalid configuration
0	1	1	1	Invalid configuration
1	0	0	0	Single-channel UDP. TCP not supported
1	0	0	1	Invalid configuration
1	0	1	0	Multi-channel UDP. TCP not supported
1	0	1	1	Invalid configuration
1	1	0	0	Single-channel UDP and TCP
1	1	0	1	Single-channel UDP, Multi-channel TCP
1	1	1	0	Single-channel TCP, Multi-channel UDP
1	1	1	1	Multi-channel UDP and TCP

Every C12.22 IP Node MUST support at least one of unicast CO or CL operating capabilities (as advertized in Decade 12, Network Tables

[1], where available, and as registered using the C12.22 Registration Service [1]).

### 3.1.1. IP Message Transport Details

#### 3.1.1.1. Single-channel UDP

A C12.22 IP Node that operates in this mode SHALL NOT monitor UDP Port 1153. As a result, the node is incapable of receiving unsolicited C12.22 Request Messages from other C12.22 Nodes using UDP.

A transaction in this mode is characterized by an initiating C12.22 IP Node sending a C12.22 Request message to a target C12.22 IP Node, followed by the target node sending a C12.22 Response message back to the initiating node, addressing the message to the source IP address and source port in the C12.22 Request Message.

When the source port in the C12.22 Request Message is set to zero (0), the C12.22 Response Message SHALL be sent to the port that was registered for the originating node (per ANSI C12.22 Registration Service, in which the initiating node MAY include within the C12.22 EPSEM Service Request, an IP address and port), or to the default port, 1153, if the native address was not registered. Further details are provided in Section 3.3. , Transport Protocol Decisions.

#### 3.1.1.2. Multi-channel UDP

A C12.22 IP Node that supports this mode monitors by default UDP Port 1153 and thus is capable of receiving unsolicited C12.22 messages. The default monitored LAN IP native address (thus port number) may be changed on a per-node basis via ANSI C12.22 Registration Service, in which the registering node MAY include within the C12.22 EPSEM Service Request, an alternate IP address and port to be registered.

When an initiating C12.22 IP Node is configured for multi-channel UDP, it SHOULD expect that the response from the target node MAY arrive on UDP Port 1153, unless otherwise specified by the EPSEM Registration Service for the initiating C12.22 IP Node. To enable the initiating node to communicate this expectation to the target node, this specification RECOMMENDS that the initiating node use port 1153 as the source port in its UDP request message. Further details are provided in Section 3.3. Transport Protocol Decisions.

All C12.22 IP Relays SHALL support Multi-channel UDP. Of the two UDP modes, Multi-channel UDP is the RECOMMENDED mode for all other C12.22 IP Nodes.

#### 3.1.1.3. Single-channel TCP

In this mode, C12.22 Request and Response Messages between a pair of C12.22 IP Nodes can only arrive through one established TCP connection from the Initiating C12.22 IP Node. The loss or closure of the connection SHALL NOT automatically result in the termination of the C12.22 associations between the peer nodes. The termination of the associations is dependent upon C12.22 application timeout attributes. The C12.22 Host SHALL implement Multi-channel IP in order to accept incoming connections (See Section 3.1.1.4. Multi-channel TCP for details). A C12.22 IP Node that supports this mode monitors by default TCP Port 1153 and thus is capable of receiving unsolicited TCP connections.

The default monitored LAN IP native address (thus port number) MAY be changed on a per-node basis via ANSI C12.22 Registration Service, in which the registering node MAY include within the C12.22 EPSEM Service Request, an alternate IP address and port to be registered and used to establish a TCP connection.

#### 3.1.1.4. Multi-channel TCP

In this mode, C12.22 Request and Response Messages between a pair of C12.22 IP Nodes can arrive through multiple established TCP connections. The monitored LAN IP native addresses, and thus port numbers, are defined in the previous section.

All C12.22 IP Relays SHALL support Multi-channel TCP. For all other C12.22 IP Nodes, Multi-channel TCP is the RECOMMENDED mode.

#### 3.1.1.5. TCP and C12.22 Message Directionality

C12.22 IP Nodes MAY use TCP in a one of two ways: bi-directional traffic flow or uni-directional traffic flow.

When used bi-directionally, any established TCP connection MAY be used to send and received C12.22 APDUs. This is the RECOMMENDED and default mode operation, because ANSI C12.22 requires the Transport network to be reliable and connectionless (per connectionless-mode ACSE). ANSI C12.22 implements peer-to-peer Application Association and not peer-to-peer connections.

It is known that some C12.22 implementations have been deployed using uni-directionally TCP. When used uni-directionally, an established TCP connection SHALL be used by the initiator of that connection strictly to send C12.22 APDUs and by the target node (who accepted the connection) strictly to received C12.22 APDUs. It is

RECOMMENDED, for increased interoperability, that the initiator of the connection also accepts incoming C12.22 APDUs on that connection.

Uni-directional TCP is a special mode of operation; it is not the RECOMMENDED mode of operation because it is not defined in ANSI C12.22. While this mode of operation is not explicitly supported in the C12.22 standard, it MAY be made possible through mutual operating agreements. The means by which nodes are configured to enact the uni-directional TCP messaging protocol is not defined in this specification or in the C12.22 standard; it is left for future consideration by ANSI C12.22 configuration.

### 3.2. Using IP Broadcast/Multicast

A C12.22 IP Node's use of Broadcast/Multicast is based on its capabilities as defined in its configuration parameters (flags) and as expressed in the Node's accepted registration attributes [1] (<connection-type>.BROADCAST\_AND\_MULTICAST\_SUPPORTED). The mapping of the C12.22 IP Node's Broadcast/Multicast parameter (flag) to IP Broadcast/Multicast usage is defined in Table 2.

Table 2: C12.22 to IP Broadcast/Multicast Mapping

C12.22 Broadcast and Multicast Supported Flag	IP Broadcast/Multicast Supported
----	-----
0	The C12.22 IP Node does not accept IP broadcast And IP multicast messages
1	The C12.22 IP Node accepts IP broadcast and IP multicast messages

If a C12.22 IP Node is configured to accept IP broadcast and multicast messages, it SHALL join the multicast group whose address is assigned by IANA, and SHALL use the default port 1153. In addition it shall accept IP Network directed broadcast messages sent to port 1153.

### 3.3. Transport Protocol Decisions

#### 3.3.1. Unicast Versus Multicast Versus Broadcast

An initiating C12.22 IP Node MAY send any C12.22 Message using UDP or TCP. However, in accordance with Section 5.3.2.4.12, Resolve Service, of ANSI C12.22, it is RECOMMENDED that the C12.22 Resolve Request message be transported using UDP/IP multicast when the Native Address of the target C12.22 Node is not known. Use of UDP/IP multicast is preferred over the use of IP Network directed broadcast;

therefore when UDP/IP multicast is supported its use is RECOMMENDED over network broadcast.

### 3.3.2. Sending Large C12.22 APDUs Using UDP

When sending a large C12.22 Message via UDP, whereby the ACSE PDU size exceeds the UDP maximum transmission unit (MTU), then the initiating C12.22 IP Node SHALL segment the ACSE PDU in accordance with ANSI C12.22 Datagram Segmentation and Reassembly algorithm, such that each APDU segment fits within the UDP MTU.

### 3.3.3. Choice of Protocol for C12.22 Response APDUs

When a target C12.22 IP Node receives a C12.22 Request Message from an initiating C12.22 IP Node, it SHALL send a C12.22 Response Message using the same transport protocol (i.e., TCP to TCP, UDP to UDP).

In the case of UDP, the target SHALL send the C12.22 Response message to the source IP address, with the destination port assigned as follows:

If source port is non-zero then send the response to source port;

Otherwise, when the source port is zero and the initiating source Node's port number is not registered or the registration attribute <address-length> of the parameter <native-address> is set to zero (0), then send the response to port 1153;

Otherwise, when the source port is zero and the initiating source Node's registered port number is not zero, then send the response to the registered port number;

Otherwise, when the source port is zero and the source Node's registered port number is zero or cannot be determined, then send the response to port 1153.

It is RECOMMENDED that the source port always be set to the registered port number value instead of setting it to zero (0).

## 3.4. Quality of Service

The ANSI C12.22 standard provides a configuration parameter in the APDU's <calling-AE-qualifier>.URGENT to mark a message as urgent. There are numerous IP-based technologies that enable enhanced levels of message delivery and quality of service. This specification does not define the technology to be used to send urgent messages over IP.

#### 4. Security Considerations

The ANSI C12.22 Application layer security is defined in Section 5.3.4.13, C12.22 Security Mechanism, of the ANSI C12.22 standard. The security mechanisms include provisions for AES-128/EAX message privacy and authentication, playback rejection, and message acceptance windows as well as ANSI C12.19 [2] role-based data access and secured register mechanisms. Additional Transport or Network layer security protocols are not required but MAY be provided transparently by network integrators. However, any added Transport or IP Network layer security features SHALL act only to enhance and preserve (i.e., not be a substitute or an alteration of) the ANSI C12.22 and ANSI C12.19 (interoperable) security provisions.

#### 5. IANA Considerations

UDP and TCP port 1153, which is used by the C12.22 standard, is already registered with IANA.

Based on the requirements in this RFC, and the need to globally route C12.22 messages through the Internet, this specification requests IANA to assign one IPv4 and one IPv6 multicast address for C12.22 communication over IP.

#### 6. References

##### 6.1. Normative References

- [1] ANSI, "Protocol Specification For Interfacing to Data Communication Networks", ANSI C12.22-2008, approved January 9, 2009.
- [2] ANSI, "Utility Industry End Device Data Tables", ANSI C12.19-2008, approved February 24, 2009.
- [3] IEEE, "Draft Standard for Utility Industry Metering Communication Protocol Application Layer (End Device Data Tables)", IEEE P1377/D1, June 2009.
- [4] Measurement Canada, "Specification for Utility Industry Metering Communication Protocol Application Layer (End Device Data Tables)", MC1219, 2009.
- [5] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.



- [6] IEEE, "Draft Standard for Local Area Network/Wide Area Network (LAN/WAN) Node Communication Protocol to Complement the Utility Industry End Device Data Tables", IEEE 1703/D4, March 2009.
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## 6.2. Informative References

[Will be added as appropriate]

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