

INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Low-voltage switchgear and controlgear – Controller-device interfaces (CDIs) –
Part 3: DeviceNet**

**Appareillage à basse tension – Interfaces appareil de commande-appareil (CDI) –
Partie 3: DeviceNet**

Withdrawing



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –
CONTROLLER-DEVICE INTERFACES (CDIs) –****Part 3: DeviceNet**

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International Standard IEC 62026-3 has been prepared by subcommittee 17B: Low-voltage switchgear and controlgear, of IEC technical committee 17: Switchgear and controlgear.

This second edition of IEC 62026-3 cancels and replaces the first edition published in 2000. This second edition constitutes a technical revision.

The main changes with respect to the previous edition are listed below:

- addition of new services to the base messaging protocol in 5.2;
- replacement of detailed application layer requirements in former annexes by references in 5.3 to corresponding specifications in the new edition of IEC 61158 (2007);
- addition of requirements for a corresponding safety protocol in 5.6 (by reference to IEC 61784-3);
- modified presentation of cable and connector specifications in 8.2 and 8.4, and addition of a new type;
- addition of references for safety tests for both EMC and logical tests in 8.10 and 9.3.

This bilingual version, published in 2009-11, corresponds to the English version.

The text of this standard is based on the first edition and the following documents.

FDIS	Report on voting
17B/1580/FDIS	17B/1585/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

The French version of this standard has not been voted upon.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 62026, under the general title *Low-voltage switchgear and controlgear – Controller-device interfaces (CDIs)*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

DeviceNet™¹⁾ is intended for use in, but is not limited to, industrial automation applications. These applications may include devices such as limit switches, proximity sensors, electro-pneumatic valves, relays, motor starters, operator interface panels, analogue inputs, analogue outputs and controllers.

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¹⁾ DeviceNet™ is a trade name of Open DeviceNet Vendor Association, Inc. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance to this standard does not require use of the trade name DeviceNet™. Use of the trade name DeviceNet™ requires permission of Open DeviceNet Vendor Association, Inc.

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR – CONTROLLER-DEVICE INTERFACES (CDIs) –

Part 3: DeviceNet

1 Scope

This part of IEC 62026 specifies an interface system between single or multiple controllers, and control circuit devices or switching elements. The interface system uses two twisted shielded conductor pairs within one cable – one of these pairs provides a differential communication medium and the other pair provides power to the devices. This part establishes requirements for the interchangeability of components with such interfaces.

This part of IEC 62026 specifies the following particular requirements for DeviceNet:

- requirements for interfaces between controllers and switching elements;
 - normal service conditions for devices;
 - constructional and performance requirements;
- tests to verify conformance to requirements.

These particular requirements apply in addition to the general requirements of IEC 62026-1.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*
Amendment 1 (1999)

IEC 60947-5-2:1997, *Low-voltage switchgear and controlgear – Part 5-2: Control circuit devices and switching elements – Proximity switches*
Amendment 1 (1999)
Amendment 2 (2003)

IEC 61000-4-2:1995, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*
Amendment 1 (1998)
Amendment 2 (2000)

IEC 61000-4-3:2006, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61000-4-4:2004, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-4-5:2005, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

IEC 61000-4-6:2003, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

Amendment 1 (2004)

Amendment 2 (2006)

IEC 61158 (all parts), *Digital data communications for measurement and control – Fieldbus for use in industrial control systems*

IEC 61158-4-2, *Industrial communication networks – Fieldbus specifications – Part 4-2: Data-link layer protocol specification – Type 2 elements*

IEC 61158-5-2, *Industrial communication networks – Fieldbus specifications – Part 5-2: Application layer service definition – Type 2 elements*

IEC 61158-6-2, *Industrial communication networks – Fieldbus specifications – Part 6-2: Application layer protocol specification – Type 2 elements*

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

IEC 61784-3-2, *Industrial communication networks – Profiles – Part 3-2: Functional safety fieldbuses – Additional specifications for CPF 2*

IEC 62026-1:2007, *Low-voltage switchgear and controlgear – Controller-device interfaces (CDIs) – Part 1: General rules*

ISO/IEC 7498-1:1994, *Information technology – Open Systems Interconnection – Basic Reference Model: The Basic Model*

ISO 11898-1:2003, *Road vehicles – Controller area network (CAN) – Part 1: Data link layer and physical signalling*

ISO 11898-2:2003, *Road vehicles – Controller area network (CAN) – Part 2: High-speed medium access unit*

CISPR 11:2003, *Industrial, scientific and medical (ISM) radio-frequency equipment – Electromagnetic disturbance characteristics – Limits and methods of measurement*

Amendment 1 (2004)

Amendment 2 (2006)

3 Terms, definitions, symbols and abbreviated terms

For the purposes of this part of IEC 62026, the following terms, definitions, symbols and abbreviations, in addition to those given in IEC 62026-1, apply.

3.1 Terms and definitions

3.1.1

acknowledged fragmentation

fragmentation performed on an explicit message, in which the transmission of a fragment from the transmitting object is followed by the transmission of an acknowledgement by the receiving object

NOTE The reception of each fragment is acknowledged by the receiving object.

3.1.2

ack status

field within an acknowledgement/response message format that indicates whether or not an error has been encountered by the receiver of a fragmented message

NOTE This applies specifically to the DeviceNet fragmentation protocol.

3.1.3

application objects

set of object classes and their object instances that are available within the node

NOTE These objects manage and provide the exchange of data and messages across DeviceNet controller-device interfaces (CDIs) and within the DeviceNet compliant node.

3.1.4

attribute

description of an externally accessible characteristic or feature of an object

NOTE Attributes typically provide status information or govern the operation of an object.

3.1.5

bit-strobe

communication using strobing

3.1.6

broadcast

communication from one node to all other nodes

3.1.7

CAN (Controller Area Network)

ISO specification that defines a generic physical layer and data link medium access procedure based on non-destructive bit-wise arbitration, see ISO 11898-1 and ISO 11898-2

3.1.8

CAN_H

positive half of the differential physical CAN signal

3.1.9

CAN_L

negative half of the differential physical CAN signal

3.1.10

client

(1) object which uses the services of another (server) object to perform a task, see server (3.1.43)

(2) initiator of a message to which a server reacts

3.1.11

common service

CIP service used by DeviceNet objects (see IEC 61158-5-2, 6.2.1.3 and IEC 61158-6-2, 4.1.8)

3.1.12

communication objects

objects that manage and provide run-time exchange of messages across DeviceNet

3.1.13

connection

logical binding between two or more application objects

NOTE These application objects may be located at the same node or at different nodes.

3.1.14

connection ID (CID)

connection identifier assigned to all transmissions that are associated with a particular connection between multiple nodes

3.1.15

connection object

manages the communication-specific aspects associated with connections between nodes

3.1.16

consumer

end point of a connection that is responsible for receiving data

3.1.17

destination MAC ID

MAC ID of a node that is to receive a message

3.1.18

device tap

physical point of attachment from a DeviceNet device to a trunk cable or a drop cable

3.1.19

device type

identification of a collection of device-dependent information describing a viable combination of options selected for all layers in the communication stack

3.1.20

dominant

one of two complementary logic levels on the physical signal

NOTE The dominant level is a logical "0".

3.1.21

duplicate MAC ID detection

DeviceNet-defined protocol that ensures no two nodes on the same link are assigned the same MAC ID

3.1.22

explicit messaging

each explicit message commands the performance of a particular task and the return of the results of the task performance to the requester

3.1.23

fragmentation

DeviceNet protocol provided by the connection object that defines a method by which data greater than eight (8) bytes in length may be transmitted

3.1.24

group 2 client

unconnected message manager (UCMM)capable device that has gained ownership of the predefined master/slave connection set within a server such that it may act as the client on those connections

3.1.25

group 2 only client

device that is acting as a group 2 client to a group 2 only server

NOTE The group 2 only client provides the UCMM functionality for group 2 only servers that it has allocated.

3.1.26

group 2 server

unconnected message manager (UCMM) capable device that has been configured to act as the server for the predefined master/slave identifier connections

3.1.27

group 2 only server

slave device that is UCMM incapable and uses the predefined master/slave connection set to establish communications

NOTE A group 2 only device can transmit and receive only those identifiers defined by the predefined master/slave connection set.

3.1.28

I/O connection

connection between a producer and one or more consumers for the purpose of exchanging application-specific, time-critical I/O data

3.1.29

I/O data

information which is transferred between I/O points and the controllers which use and set the values

3.1.30

I/O messaging

exchange of data in a previously defined format

3.1.31

isolated device

device in which some of its components are not referenced to the V- of the physical layer, see non-isolated device (3.1.36)

3.1.32

master

node which gathers and distributes I/O using the predefined master/slave connection set

3.1.33

Medium Access Control (MAC) ID

link address of a DeviceNet node

3.1.34

multicast connection

logical connection from one object to multiple other objects

NOTE A multicast connection allows data to be transferred in a single transaction from a producer to multiple consumers sharing the same connection.

3.1.35

node

DeviceNet entity which is identified at the data link level by a unique MAC ID

NOTE Multiple DeviceNet nodes may be implemented in one device but they appear as logically distinct nodes on the DeviceNet link.

3.1.36

non-isolated device

device in which all components are referenced to the V- of the physical layer, see isolated device (3.1.31)

3.1.37**object**

1) abstract representation of a device's capabilities

NOTE Objects may be composed of any or all of the following components:

- a) Data (information which changes with time);
- b) Configuration (parameters for behaviour);
- c) Procedures (actions that may be performed using data and configuration).

2) collection of related data (in the form of variables) and procedures for operating on that data

3.1.38**point-to-point connection**

connection that exists between two objects only

NOTE Explicit messaging connections are always point-to-point. I/O connections may be either point-to-point or multicast, see multicast connection (3.1.34).

3.1.39**predefined master/slave connection set**

utilization of an explicit messaging connection to create and configure connection objects within each connection end-point

NOTE Uses the general rules as a basis for the definition of a set of connections which facilitate communications typically seen in a master/slave relationship.

3.1.40**producer**

end point of a connection that is responsible for sending data

3.1.41**recessive**

one of two complementary logic levels on the physical signal

NOTE The recessive level is a logical "1".

3.1.42**serial number**

unique 32-bit integer assigned by each manufacturer to every DeviceNet device

NOTE The number is stored within the device as an attribute of the identity object and is unique with respect to the manufacturer.

3.1.43**server**

object which provides services to another (client) object, see client (3.1.10)

3.1.44**service**

operation or function that an object performs upon request from another object

3.1.45**slave**

node that returns data to its master using the predefined master/slave connection set and a communication method set by the master

3.1.46**source MAC ID**

MAC ID of a node that is transmitting a message

3.1.47

trigger

service used by an application to initiate the production of data

3.1.48

UCMM capable device

device that supports the UCMM (see 3.1.51)

3.1.49

UCMM incapable device

device that does not support the UCMM (see 3.1.51)

3.1.50

unconnected explicit message

explicit message between nodes that have not yet established a connection between each other

3.1.51

Unconnected Message Manager (UCMM)

function within a node that receives and processes unconnected explicit messages

3.1.52

Unsigned Short Integer (USINT)

8-bit integer

3.1.53

Unsigned Integer (UINT)

16-bit integer

3.2 Symbols and abbreviated terms

CAN	Controller Area Network
CDI	Controller-Device Interface
CID	Connection Identifier
CIP™	Common Industrial Protocol
CRC	Cyclic Redundancy Check
DCR	DC Resistance
EUT	Equipment Under Test
MAC ID	Medium Access layer Identifier
UCMM	Unconnected Message Manager

4 Classification

4.1 General

DeviceNet interfaces controlling devices to control circuit devices or switching elements. DeviceNet uses two twisted shielded conductor pairs within one cable - one of these pairs provides a differential communication medium, and the other pair provides power to the devices. The maximum current supported is 8 A at 24 V d.c. Data is transmitted at bit rates of 125 kbit/s, 250 kbit/s or 500 kbit/s with maximum cable lengths of 500 m, 250 m and 100 m respectively. A maximum of 8 bytes of data may be transmitted without fragmentation. A maximum of 64 nodes may be connected using a linear topology with a trunk line and drop lines (see Figure 1). DeviceNet supports the transmission of I/O data, diagnostics, messaging and programming/configuration. Data exchange may be event driven (change of state), cyclic, polled, or multicast.

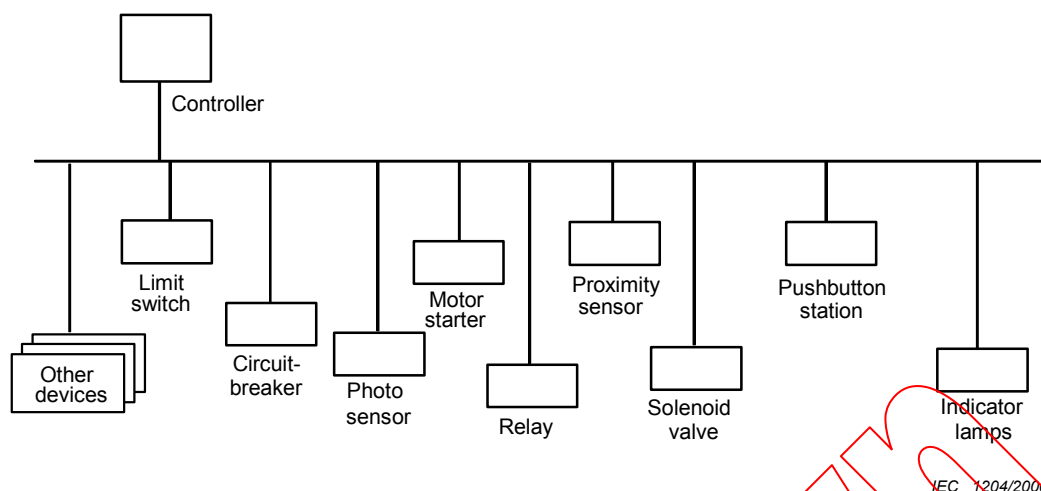


Figure 1 – Typical DeviceNet controller-device interfaces

This part of IEC 62026 defines a connection based scheme to facilitate all application communications. A DeviceNet connection provides a communication path between multiple end-points. The end-points of a connection are applications that need to share data. Transmissions associated with a particular connection are assigned an identification value when a connection is established. This identification value is called the connection ID (CID).

Connection objects model the communication characteristics of a particular application-to-application(s) relationship.

DeviceNet's connection based scheme defines a dynamic means by which the following two types of connections may be established.

- **I/O connections:** Provide dedicated, special purpose communication paths between a producing application and one or more consuming applications. Application specific I/O data moves through these paths.

I/O messages are exchanged across I/O connections. An I/O message consists of a CID and associated I/O data. The connection end-points shall have knowledge of the intended use or meaning of the I/O message.

This part of IEC 62026 does not define any particular use for I/O messaging. There are a wide variety of functions that may be accomplished using I/O messaging. The meaning and/or intended use of all I/O messages shall be made known to the system either by the particular type of product transmitting an I/O message, or based upon configuration performed using explicit messaging.

- **Explicit messaging connections:** Provide generic, multi-purpose communication paths between two devices. Explicit messages provide the typical request/response oriented communications.

Explicit messages are exchanged across explicit messaging connections. Explicit messages are used to command the performance of a particular task and to report the results of performing the task.

DeviceNet defines an explicit messaging protocol that states the meaning of the message. An explicit message consists of a CID and associated messaging protocol information.

The rules that govern the dynamic establishment of these connections are used as a foundation upon which a predefined set of connections is defined.

4.2 DeviceNet communication model

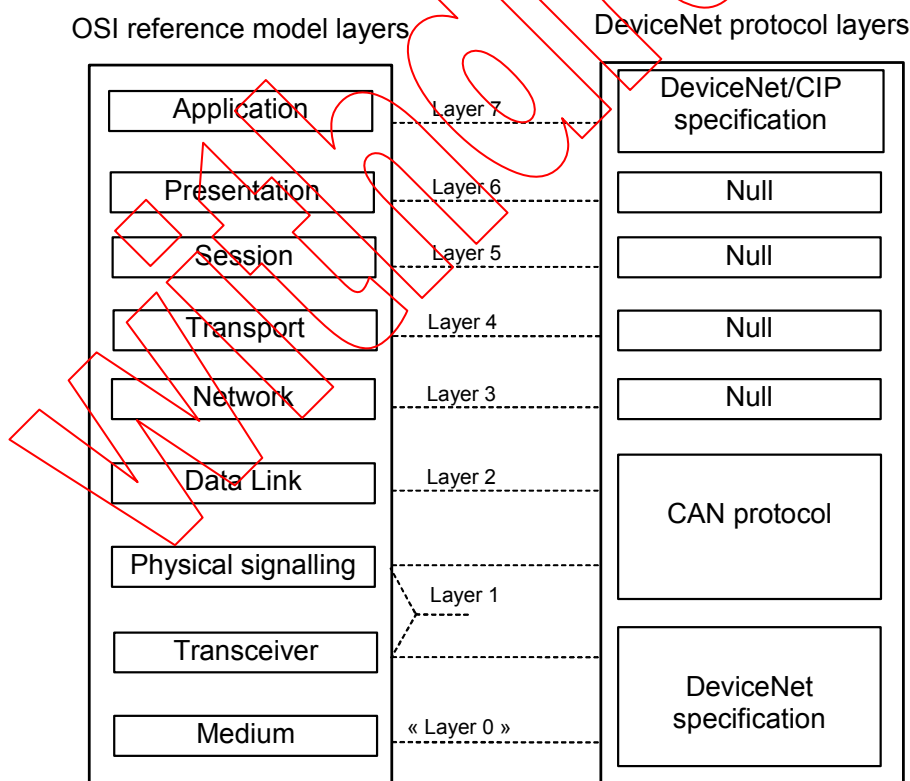
The abstract object oriented communication model of a DeviceNet node includes the following:

- **unconnected message manager (UCMM):** processes DeviceNet unconnected explicit messages;
- **identity object:** identifies and provides general information about the device;
- **connection class:** allocates and manages internal resources associated with both I/O and explicit messaging connections;
- **connection object:** manages the communication specific aspects associated with a particular application-to-application relationship;
- **DeviceNet object:** provides the configuration and status of a physical DeviceNet CDI;
- **message router:** forwards an explicit request message to the appropriate object;
- **application objects:** implement the intended purpose of the product.

4.3 DeviceNet, CAN and CIP

DeviceNet lower layers are based on ISO 11898-1 and ISO 11898-2 and use the Controller Area Network (CAN) technology. DeviceNet upper layers use a subset of the Common Industrial Protocol (CIP™²⁾) protocol and services specified in IEC 61158.

The relationships between DeviceNet, CAN, CIP and the OSI reference model (ISO/IEC 7498-1) are shown in Figure 2.



IEC 1205/2000

Figure 2 – DeviceNet protocol architecture compared with the OSI reference model

2) CIP™ is a trade name of Open DeviceNet Vendor Association, Inc. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance to this profile does not require use of the trade name CIP™. Use of the trade name CIP™ requires permission of Open DeviceNet Vendor Association, Inc.

5 Characteristics

5.1 DeviceNet connections

5.1.1 General

DeviceNet is a connection based controller-device interface. DeviceNet connections are used to provide logical paths between multiple applications. When a connection is established, the transmissions associated with that connection are assigned a connection ID (CID). If the connection involves a bi-directional exchange, then two CID values shall be assigned to the connection.

DeviceNet uses the CAN identifier field and defines the steps involved in the dynamic establishment of I/O and explicit messaging connections.

5.1.2 DeviceNet's use of the CAN identifier field

NOTE DeviceNet uses the 11 bit CAN Identifier field ("Standard Frame Format") as described in ISO 11898.

The 11 CAN identifier bits available within DeviceNet are subdivided into four separate message groups: group 1, group 2, group 3 and group 4.

For connection based messages, the CID is placed within the CAN identifier field. Figure 3 also describes the components of a DeviceNet CID.

IDENTIFIER BITS											HEX RANGE	IDENTITY USAGE
10	9	8	7	6	5	4	3	2	1	0		
0	Group 1 message ID				Source MAC ID						000 - 3ff	Message group 1
1	0	MAC ID					Group 2 message ID				400 - 5ff	Message group 2
1	1	Group 3 message ID			Source MAC ID						600 - 7bf	Message group 3
1	1	1	1	1	Group 4 message ID (0 - 2f)						7c0 - 7ef	Message group 4
1	1	1	1	1	1	1	X	X	X	X	7f0 - 7ff	Invalid CAN identifiers
10	9	8	7	6	5	4	3	2	1	0		

IEC 1206/2000

Figure 3 – DeviceNet's use of the CAN identifier field

As shown in Figure 3 the CAN identifier field on DeviceNet contains the following:

- **message ID:** Identifies a message within a message group inside a particular node. When a connection is established, the nodes utilise a message ID in combination with a MAC ID to generate a CID. The resulting CID is specified in the CAN identifier field associated with related transmissions;
- **source MAC ID:** Groups 1 and 3 require the specification of a source MAC ID within the CAN identifier field;
- **MAC ID:** Message group 2 allows the specification of either source or destination within the MAC ID portion of the CAN identifier field.

Both explicit messaging and I/O connections may be established in message groups 1, 2 and 3.

Group 2 message ID values 6 and 7 are used as follows:

- group 2 message ID 6 is used for the configuration of the communications utilised in a master/slave application (see 5.5);
- group 2 message ID 7 is used in the detection of nodes that have been assigned identical MAC IDs (see 5.3.6).

Group 3 message ID values 5, 6 and 7 are used as follows:

- group 3 message ID 5 is used when sending responses associated with unconnected explicit messaging requests, as well as device heartbeat and device shutdown messages;
- group 3 message ID 6 is used when sending unconnected explicit messaging requests;
- group 3 message ID 7 is invalid and shall not be used.

Group 4 is reserved for future use.

5.1.3 Connection establishment

5.1.3.1 Explicit messaging connections and the UCMM

Message group 3 defines the identifier codings to support unconnected explicit messaging. Unconnected explicit messages establish and manage explicit messaging connections. Unconnected request messages are specified by transmitting a group 3 message whose message ID component is set to 6. The only valid services that can be transmitted as unconnected explicit request messages are:

- open explicit messaging connection request;
- close connection request.

The messages listed above are never transmitted as connection based messages (see connection based explicit messaging in 5.2.1.6).

Responses to unconnected explicit requests are transmitted as unconnected response messages. Unconnected response messages are specified by transmitting a group 3 message whose message ID component is set to 5. The only valid services that can be transmitted as unconnected explicit response messages are:

- open explicit messaging connection response;
- close connection response;
- error response;
- device heartbeat message;
- device shutdown message.

5.1.3.2 I/O connections

I/O connections are dynamically established by interfacing with the connection class across a previously established explicit messaging connection. A connection instance shall be created and configured at each node.

5.2 DeviceNet messaging protocol

5.2.1 Explicit messaging

5.2.1.1 General

This subclause describes the explicit messaging protocol and presents details associated with the dynamic establishment of explicit messaging connections (see Figure 4).

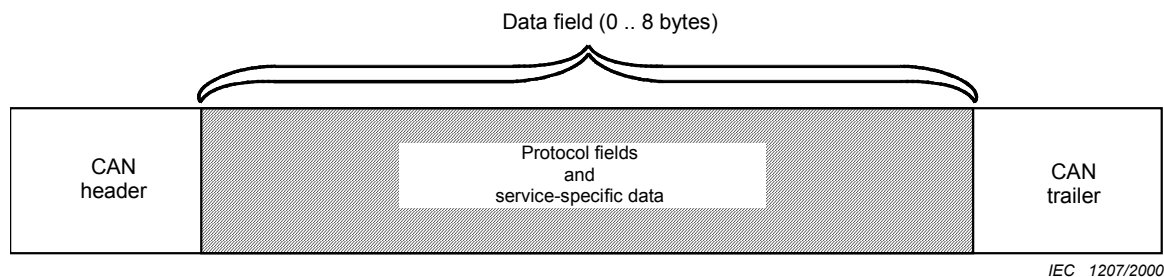


Figure 4 – Explicit message CAN data field use

Figure 5 provides the format of the CAN data field associated with explicit messages:

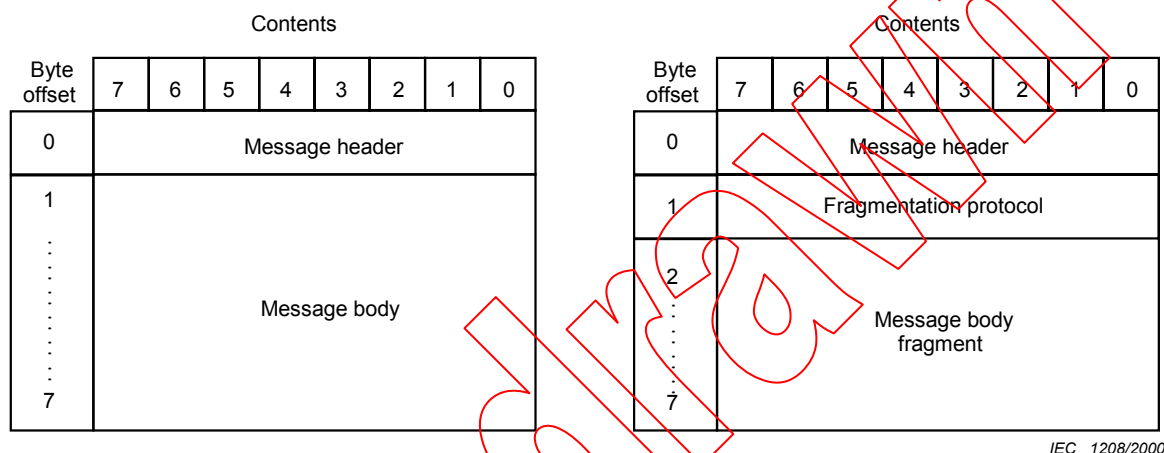


Figure 5 – Explicit message data field format

The data field of a transmission that contains the complete explicit message includes:

- a message header;
- the entire message body.

If the explicit message is greater than eight bytes in length, it shall be transmitted in a fragmented manner. The fragmentation/re-assembly function is provided by the connection object. A piece of a fragmented explicit message includes:

- a message header;
- the fragmentation protocol (see 5.2.3.2);
- a message body fragment.

5.2.1.2 Message header

The message header is located within byte offset zero in the CAN data field of an explicit message and shall be formatted as shown in Figure 6:

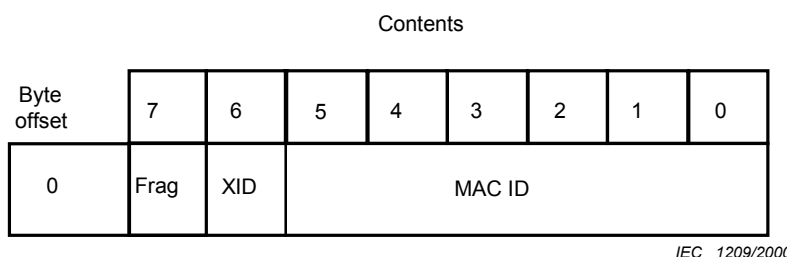


Figure 6 – Explicit message header format

Message header contents:

- **frag** (fragment bit): Indicates whether or not this transmission is a piece of a fragmented explicit message.
 - 0 = non-fragmented
 - 1 = fragmented
- **XID (transaction ID)**: This field is utilised by an application to match a response with the associated request. This field is simply echoed by the server in a response message. The server module does not utilise this field to perform any type of duplicate message detection logic;
- **MAC ID**: Contains either the source or destination MAC ID.

When an explicit message is received, the MAC ID field within the message header is examined. If the destination MAC ID is specified in the CID, then the source MAC ID of the other end-point shall be specified in the message header. If the source MAC ID is specified in the CID, then the receiving module's MAC ID shall be specified in the message header. If neither of these conditions are true, then the message shall be discarded.

5.2.1.3 Message body

The message body contains a service field and service specific arguments.

The first argument specified within the message body is the service field which identifies the particular request or response being delivered. Figure 7 illustrates the format of the service field.

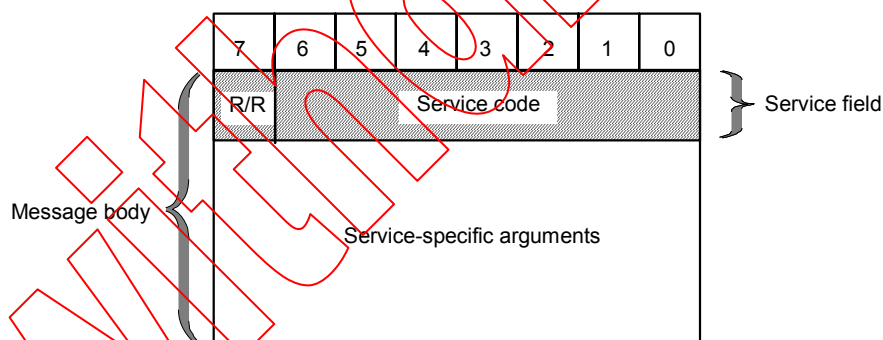


Figure 7 – Service field format

Service field contents:

- **service code**: the value specified within the least significant 7 bits of the service field byte that indicates the type of service being transmitted;
- **R/R**: the most significant bit in the service field. Its value determines whether a message is a request or a response.
 - 0 = request
 - 1 = response

DeviceNet defines a set of common services. DeviceNet common services are the open set whose parameters and required behaviours are defined in IEC 61158-5-2, 6.2.1.3 and IEC 61158-6-2, 4.1.8).

Information following the service field is specific to the particular type of service being transmitted.

5.2.1.4 Fragmentation protocol

If the transmission is a piece of a fragmented explicit message, then the data field shall contain the message header, the fragmentation protocol and a message body fragment. The fragmentation protocol facilitates the fragmentation and reassembly of explicit messages which have a message body greater than 8 bytes (see 5.2.3).

5.2.1.5 UCMM services

5.2.1.5.1 General

The Unconnected Message Manager (UCMM) provides for the dynamic establishment of explicit messaging connections. This subclause presents a detailed description of the service specific arguments associated with the open explicit messaging connection and close connection services provided by the UCMM. See 9.3.3 for test specifications regarding establishment of explicit messaging connections.

The UCMM processes two services which manage the allocation and deallocation of explicit messaging connections:

- **open explicit messaging connection:** service code = 4B_{Hex}. Used to establish an explicit messaging connection;
- **close connection:** service code = 4C_{Hex}. Used to delete a connection object and deallocate all associated resources.

These services are accessed using the unconnected explicit request and response CAN identifier fields shown in Figure 3. When processing an unconnected explicit request the UCMM may need to return an error indication to the requestor and, as such, the error response explicit message may be transmitted with the unconnected explicit response CAN identifier.

5.2.1.5.2 Open explicit messaging connection request

This service requests the establishment of a logical connection between two nodes across which explicit messages will be transmitted. This service is transmitted as an unconnected request message (message group 3, message ID 6) (see Figure 8).

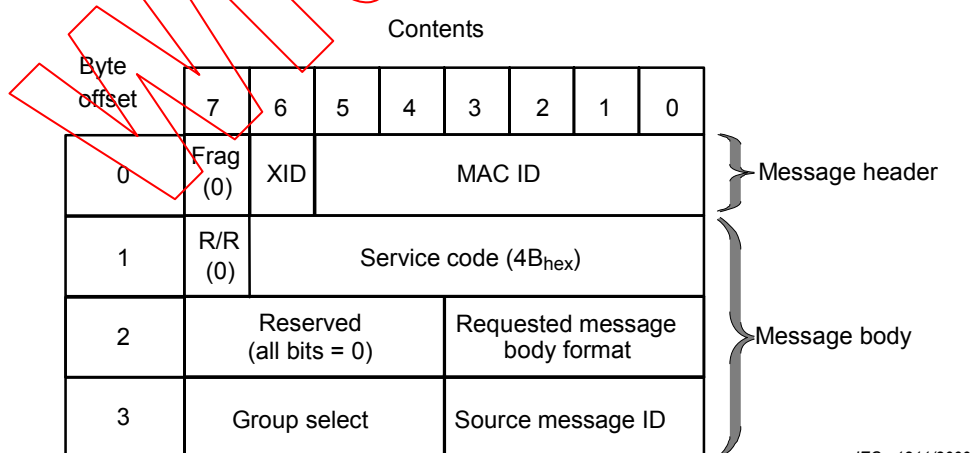


Figure 8 – Open explicit messaging connection request format

Open explicit messaging connection request contents:

- **frag (0)/transaction ID/MAC ID:** See 5.2.1.2. The destination MAC ID is always specified in the message header associated with an open explicit messaging connection request/response;

- **R/R bit (0):** Indicates this is a request message;
- **service code (4B_{Hex}):** Identifies this message as an open explicit messaging connection service;
- **reserved bits:** These bits shall be ignored by the receiver and shall be set to zero by the transmitter;
- **requested message body format:** The field used by the client to request a particular message body format for subsequent explicit messages transmitted over this connection. A server shall support at least one of the DeviceNet message body formats (values 0 - 3).

The server node responding to this open explicit messaging request defines the actual message body format to be used over this connection. See Table 1 for message body format values. Servers shall do one of the following:

- refuse the request and return a supported format value in the open explicit messaging connection response; the returned format shall be one of the DeviceNet message body formats (values 0 - 3);
- accept this request by echoing the same format value in the open explicit messaging connection response;

Table 1 – Message body format values

Value	Meaning
0	DeviceNet (8/8). Class ID = 8 bit integer, Instance ID = 8 bit integer
1	DeviceNet (8/16). Class ID = 8 bit integer, Instance ID = 16 bit integer
2	DeviceNet (16/16). Class ID = 16 bit integer, Instance ID = 16 bit integer
3	DeviceNet (16/8). Class ID = 16 bit integer, Instance ID = 8 bit integer
4	CIP path. The addressing size is variable and is provided as a packed EPATH on each request ^a
5 - F _{Hex}	Reserved
NOTE Messages transmitted across this connection are formatted as described in 5.2.1.6.	
^a The CIP Path is specified as an 8-bit path length (USINT) followed by the path (packed EPATH). See IEC 61158-6-2, 4.1.9 for information on EPATH. The server shall support, as a minimum, the most efficient encoding for any logical segment within the EPATH (for example 8-bit class encoding for class code 0x01).	

- **group select:** The field that indicates the message group across which messages associated with this connection are to be exchanged. The following values are shown in Table 2:

Table 2 – Group select values

Value	Meaning
0	Message group 1
1	Message group 2 ^a
2	Reserved
3	Message group 3
4 - F _{Hex}	Reserved
^a The message group 2 identifier allows for specification of either the source or destination MAC ID. For explicit messaging connections established across message group 2, the client places the MAC ID of the server in the connection ID when transmitting messages across this connection. The server places its own MAC ID in the connection ID when transmitting messages across this connection. This process requires the server to allocate two separate message IDs from its group 2 pool.	

The client selects the message group across which the transmissions associated with this explicit messaging connection will take place. If the server cannot satisfy the request, then it shall reject the request and return an error response.

- **source message ID:** The use of this field depends on the value within the group select field (see Table 3):

Table 3 – Source message ID in open explicit messaging connection request

If group select equals:	Then the source message ID:
0 or 3	Specifies the message ID the client has allocated from its group 1 or 3 message ID pool. The client shall use this message ID in combination with its own MAC ID to generate the connection ID specified when it transmits a message across this connection ^a
1	Is ignored/set to the value zero (0) ^b
^a The client places this value within the message ID component of the message group 1 or 3 Identifier. ^b Explicit messaging connections established across message group 2 require the server to allocate two group 2 message IDs and return them in the open explicit messaging connection response message. The client shall use one of these message IDs to generate the connection ID it specifies when transmitting a message across this connection. The other shall be used by the server to generate the connection ID it specifies when transmitting a message across this connection.	

The UCMM within the server validates the open explicit messaging connection request arguments. If they are valid, the UCMM invokes the create service of the connection class to obtain a connection object instance (see IEC 61158-5-2, 6.2.3). The resulting connection object is automatically configured to be an explicit messaging connection object.

If the server supports multiple message body formats and the client has requested one of those formats, then the server shall echo the requested message body format in the open explicit response message. If the server does not support multiple message body formats, then the server shall specify its default format in the open explicit messaging connection response.

If no errors are detected, then an open explicit messaging connection success response shall be returned. If an error is detected, then an error response message shall be returned.

5.2.1.5.3 Open explicit messaging connection success response

This service is used to respond to a successful open explicit messaging connection request message (see Figure 9).

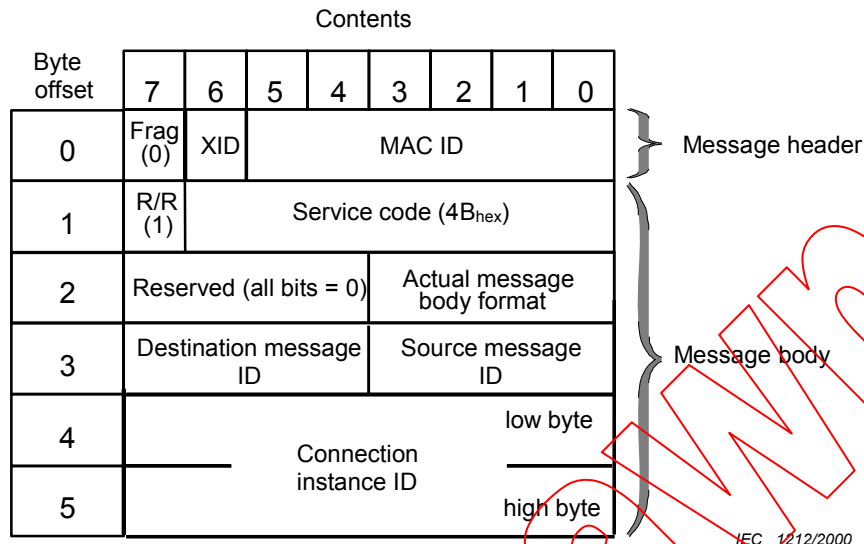


Figure 9 – Open explicit messaging connection response format

Open explicit messaging connection response contents:

- **frag (0)/transaction ID/MAC ID:** See 5.2.1.2. The destination MAC ID is always specified in the message header associated with an open explicit messaging connection request/response;
- **R/R bit (1):** Indicates that this is a response message;
- **service code (4B_{Hex}):** Identifies this message as an open explicit messaging connection service;
- **reserved bits:** These shall be set to zero by the transmitter;
- **actual message body format:** The field used by the server to define the format of the message body associated with subsequent explicit messages transmitted over this connection (as described in Table 1);
- **destination message ID:** The use of this field depends on the message group across which the connection takes place (as described in Table 4);

Table 4 – Destination message ID in open explicit messaging connection response

If group select within the open request was set to:	Then the destination message ID in the open response:
0 or 3	Is ignored and shall be set to the value zero (0)
1	Is used by the client in combination with the server's MAC ID to generate the connection ID it specifies when transmitting across this connection

- **source message ID:** The message ID value that the server has allocated. The server allocates a message ID from its group 1, 2, or 3 message ID pool that is used in conjunction with its own MAC ID (source MAC ID) to generate the connection ID that is specified when it transmits a message across this connection;

- **connection instance ID:** The server creates an explicit messaging connection object when it successfully services an open request. This field holds the instance ID value (16 bit integer field) assigned to that explicit messaging connection object.

5.2.1.5.4 Close connection request

This service is used to terminate a connection (either I/O or messaging) within one of the end points. The reception of the close connection request message by the UCMM results in the invocation of the connection class's delete service (see IEC 61158-5-2, 6.2.3). A close connection request message is transmitted as an unconnected request message.

The responder verifies that the specified connection instance exists. If the connection instance exists, and it can be deleted, then it shall be deleted. All resources associated with the connection instance are freed. If the request is successfully serviced, then a close connection response shall be returned. If the request is not successful, an error response shall be returned.

Close connection request contents (see Figure 10):

- **frag (0)/transaction ID/MAC ID:** See 5.2.1.2;
- **R/R bit (0):** Indicates that this is a request message;
- **service code (4C_{Hex}):** Identifies that this is a close connection service;
- **connection instance ID:** The field that specifies the connection instance to be deleted. The format for the connection instance ID within this message is always specified as a 16 bit integer.

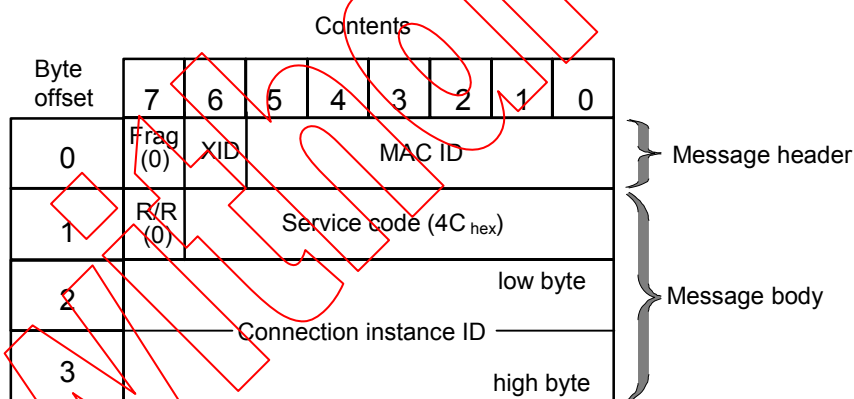


Figure 10 – Close connection request format

5.2.1.5.5 Close connection response

This service is used to respond to a successful close connection request message.

Close connection response format contents (see Figure 11):

- **frag (0)/transaction ID/MAC ID:** See 5.2.1.2;
- **R/R bit (1):** Indicates that this is a response message;
- **service code (4C_{Hex}):** Identifies this message as a close connection service.

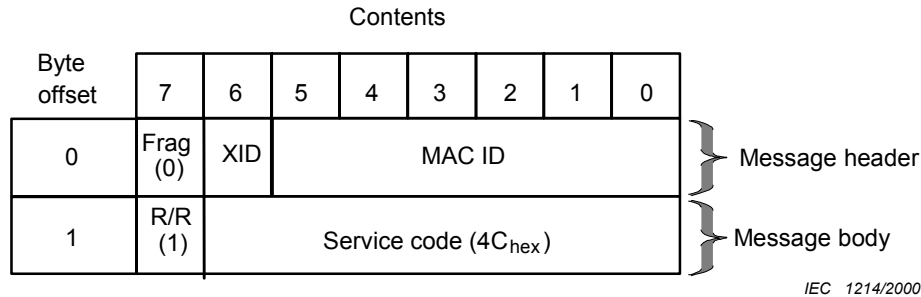


Figure 11 – Close connection response format

5.2.1.5.6 Error response

Table 5 shows a standard set of UCMM related error conditions and the error code (both general error code and additional error code) information to be used in an associated error response message. The format of an error response message is described in 5.2.1.6.5.

Table 5 – UCMM error conditions/codes

Error condition	General error name	General error code (hex)	Additional error code (hex)
Service code not open or closed	Service not supported	08	FF
Group select resource error	Resource unavailable	02	01
Group select out of range	Invalid parameter	20	01
No server connections available	Resource unavailable	02	02
No server message IDs available	Resource unavailable	02	03
Client source message ID invalid	Invalid parameter	20	02
Duplicate client source message ID	Resource unavailable	02	04
Connection instance ID invalid	Object does not exist	16	FF

Error condition descriptions:

- **service not open or closed:** A service received across the UCMM port is not of type open or closed and is therefore not supported by UCMM;
- **group select resource error:** The group select argument indicates utilising a message group which is not supported by the device;
- **group select out of range:** The group select field contains an invalid value;
- **no server connections available:** The maximum number of connections supported by this server has already been reached;
- **no server message IDs available:** The server has allocated all message IDs within the message group requested by the client;
- **client source message ID invalid:** The source message ID received with an open explicit message connection request is invalid for the specified message group;
- **duplicate client source message ID:** The source message ID and source MAC ID received within an open explicit messaging connection request are already in use for a group 1 or group 3 explicit messaging connection;
- **connection instance ID invalid:** The connection instance ID received with the close connection request does not exist.

5.2.1.6 Connection based explicit messaging

5.2.1.6.1 General

A connection based explicit message is a message transmitted over an explicit messaging connection. A connection based explicit message shall conform to the formats described in this subclause.

5.2.1.6.2 Explicit request message contents (message body format values 0 – 3)

Figure 12 shows the format for the message associated with a non-fragmented explicit request for message body format values 0 - 3:

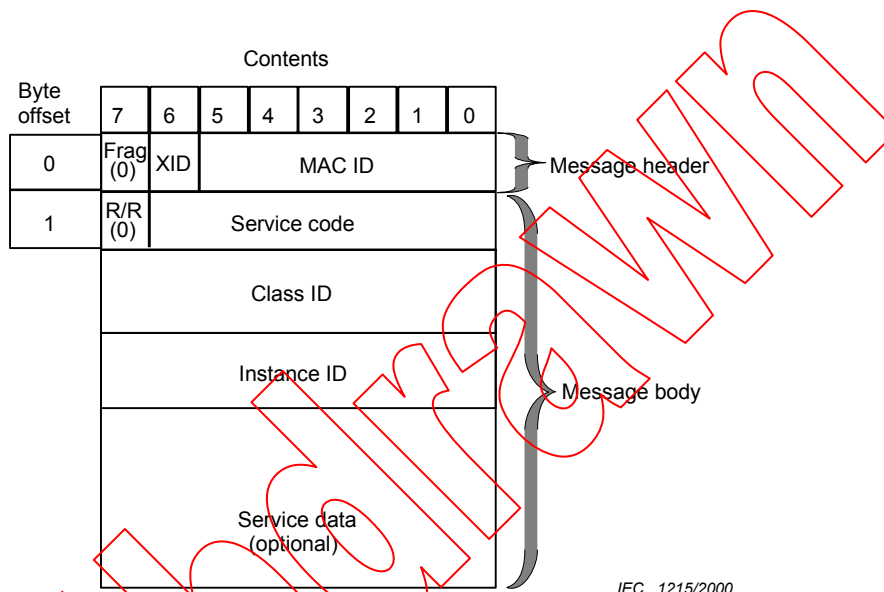


Figure 12 – Non-fragmented explicit request message format, values 0 - 3

Non-fragmented explicit request message contents:

- **frag (0)/transaction ID/MAC ID:** See 5.2.1.2;
- **R/R bit (0):** Indicates that this is a request message;
- **service code:** Defines the service being requested;
- **class ID:** Defines the object class towards which this request is directed. The class ID is specified within either an 8 bit or 16 bit integer field based on the actual message body format value returned in the open explicit messaging connection response;
- **instance ID:** Defines the particular instance within the object class towards which this request is directed. The instance ID is specified within either an 8 bit or 16 bit integer field based on the actual message body format value returned in the open explicit messaging connection response. DeviceNet uses the value zero to denote that the request is directed towards the class itself rather than a specific instance within the class;
- **service data:** Carries request specific data. Formats for the DeviceNet common services are described in IEC 61158-6-2, 4.1.8. Class-specific and object-specific service definitions include the format of this field.

5.2.1.6.3 Explicit request message contents (message body format value 4)

Figure 13 shows the format for the message associated with a non-fragmented explicit request for message body format value 4:

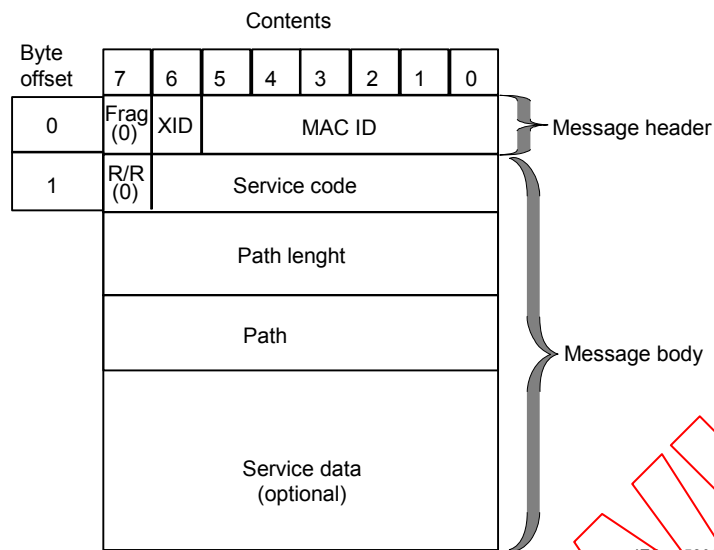


Figure 13 – Non-fragmented explicit request message format, value 4

Non-fragmented explicit request message contents:

- **frag (0)/transaction ID/MAC ID:** See 5.2.1.2;
- **R/R bit (0):** Indicates that this is a request message;
- **service code:** Defines the service being requested;
- **path length:** This 8-bit integer value (USINT) provides the length of the message request path;
- **path:** Defines the path of the message request (packed EPATH);
- **service data:** Carries request specific data. Formats for the DeviceNet common services are described in IEC 61158-6-2, 4.1.8. Class-specific and object-specific service definitions include the format of this field.

5.2.1.6.4 Success response explicit message

Figure 14 shows the format for the message associated with a non-fragmented success response:

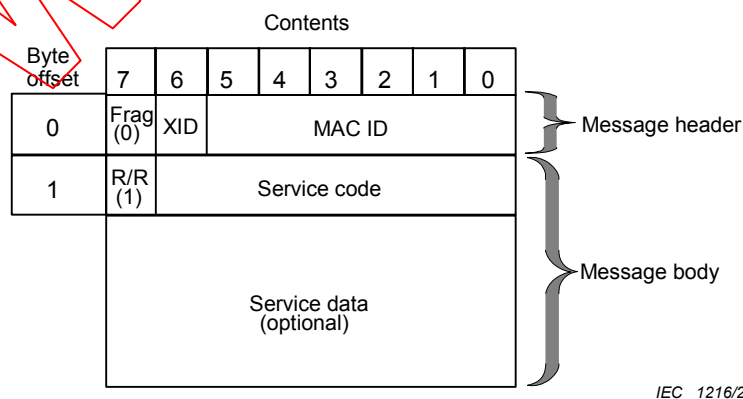


Figure 14 – Non-fragmented success response message format

Non-fragmented success response message contents:

- **frag (0)/transaction ID/MAC ID:** See 5.2.1.2;

- **R/R bit (1):** Indicates that this is a response message;
- **service code:** Contains the service code sent in the request message;
- **service data:** Carries request-specific data.

5.2.1.6.5 Error response message

The error response message is returned when an error is encountered while attempting to service a previously received explicit request message. The error response may be sent as either a connection based (request was received across an explicit messaging connection) or unconnected (request was an unconnected explicit request message) response message. Figure 15 shows the format of an error response message.

		Contents							
Byte offset		7	6	5	4	3	2	1	0
0	Frag (0)	XID	MAC ID						
1	R/R (1)	Service code (14 _{hex})							
2	General error code								
3	Additional code								

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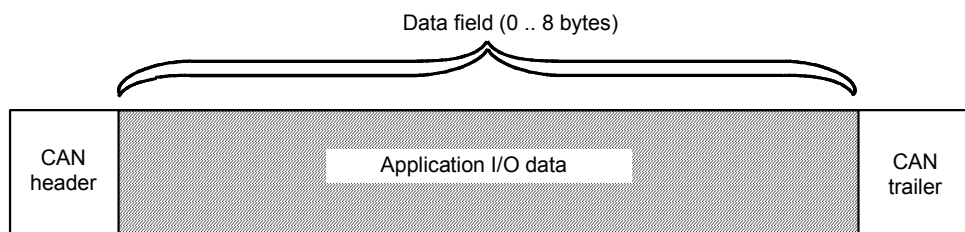
Figure 15 – Error response message

Error response message contents:

- **frag (0)/transaction ID/MAC ID:** See 5.2.1.2;
- **R/R bit (1):** Indicates that this is a response message;
- **service code (14_{Hex}):** Identifies this message as an error response;
- **general error code:** Identifies the encountered error. See IEC 61158-5-2, 6.2.1.3.3 and IEC 61158-6-2, 4.1.11 for a list of general error codes;
- **additional code:** Contains an object-specific or service-specific value that further describes the error condition. If the responding object has no additional information to specify, then the value FF_{Hex} shall be placed within this field.

5.2.2 Input/output messaging

DeviceNet defines a fragmentation protocol for transfer of an I/O message greater than eight bytes in length. This is the only protocol information carried within the data field of an I/O message (see Figure 16).



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Figure 16 – Data field of an I/O message

5.2.3 Fragmentation/reassembly

5.2.3.1 General

This subclause defines the means by which a message whose length is greater than eight bytes is fragmented and reassembled. The fragmentation/reassembly function is provided by the DeviceNet connection object.

The logic that triggers a fragmented transmission is:

- explicit messaging connection object instances examine the length of each message to be transmitted. If the message is greater than eight bytes in length, then the fragmentation protocol shall be used;
- I/O connection object instances examine the `produced_connection_size` attribute of the connection object (see 5.3.2). If the `produced_connection_size` attribute is greater than eight, then the fragmentation protocol shall be used.

Two types of fragmentation are defined:

- **acknowledged:** performed when fragmenting an explicit message.
- **unacknowledged:** performed when fragmenting an I/O message.

5.2.3.2 Fragmentation protocol

The fragmentation protocol is located within a single byte in the CAN data field, and is formatted as shown in Figure 17:

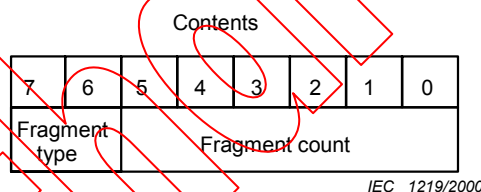


Figure 17 – Format of DeviceNet fragmentation protocol

Fragmentation protocol contents:

- **fragment type:** Indicates whether this is the first fragment, one of the middle fragments, or the last fragment (see Table 6).

Table 6 – Fragment type bit values

Value	Meaning
0	First fragment. The fragment count field shall contain the value 0 or 3F ^a
1	Middle fragment ^b
2	Last fragment ^c
3	Fragment acknowledge ^d
^a If the fragment count contains the value zero (0), then this is the first in a series of fragments. If the fragment count field contains the value 3F, then this is also the last transmission in the series.	
^b This fragment is neither the first nor the last fragment in the series.	
^c Marks this as the last fragment.	
^d The value the receiver of a fragmented message uses to acknowledge the reception of a fragment.	

- **fragment count:** Marks each separate fragment such that the receiver may determine whether or not a fragment has been missed. If the fragment type is first fragment, then this field takes on a special meaning (as described in Table 6). The fragment count is increased by one for each successive fragment in a series and resets to zero at overflow ($\text{fragmentcount} = (\text{fragmentcount} + 1) \bmod 64$).

For I/O message fragmentation, the fragmentation protocol information is placed within byte offset 0 (see Figure 18).

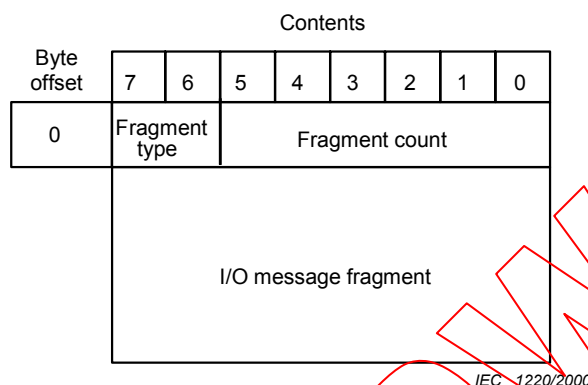


Figure 18 – I/O message fragment format

For explicit message fragmentation, the fragmentation protocol information is placed within byte offset 1 (see Figure 19).

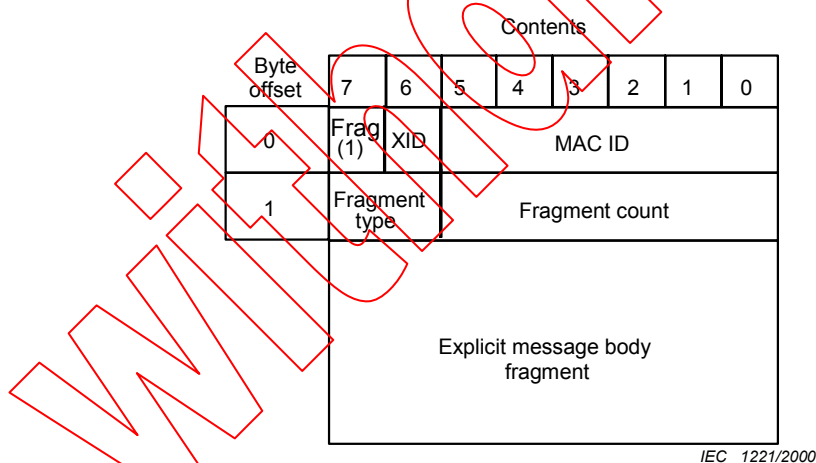


Figure 19 – Explicit message fragment format

The Frag bit within the message header in Figure 19 is set to 1 to indicate that this is a piece of the explicit message, not the entire message. The value 1 here also indicates that the next byte contains the fragmentation protocol.

The receiver of a fragmented series of transmissions parses the fragmented message as defined in this subclause. This procedure applies to both I/O and explicit message fragmentation.

If the first transmission is expected by the connection and the fragment type is equal to first fragment:

- if the fragment count is $3F_{\text{Hex}}$, then this is the only transmission in the series, and the connection processes the message and awaits the beginning of a new series;

- if the fragment count is 0, then this is the first in a series of transmissions and the connection stores the fragment and saves the fragment count.

If the first transmission is expected by the connection and either the fragment type is not equal to first fragment or the fragment count is not equal to 0 or 3F_{Hex} ; the connection discards the transmission and awaits the beginning of a new message.

If the first transmission is not expected by the connection, then the connection verifies:

- that the fragment type is not first fragment, and
- that the fragment count is numerically one (1) greater than the previous value received.

If one of these checks fails, then an error has been detected. If both checks pass, then the fragment is appended to the previously received fragment(s), and the fragment type is parsed to determine whether or not more fragments are to be expected.

If more fragments are forthcoming, then the connection saves the received fragment count and waits for the next fragment. If this is the last transmission in the series and an error has not been detected, then the connection processes the message and resets to looking for the beginning of a new series.

If an explicit message is being fragmented, then the receiver shall generate and transmit an acknowledgement after the reception of each fragment.

If an error is detected, then error recovery specific to whether this is a fragmented I/O or explicit message takes place.

If the detection of a missed fragment was triggered by the reception of the first fragment in the next series, then any processing associated with the current series is immediately discontinued, the fragments stored in memory are discarded, and processing immediately begins on the new series.

5.2.3.3 Unacknowledged fragmentation

Fragmentation of an I/O message is performed in an unacknowledged fashion. Unacknowledged fragmentation consists of the back-to-back transmission of the fragments from the transmitting module. The receiving module(s) returns no acknowledgements.

When an I/O connection's send_message service is invoked, it examines its connection_size attribute to determine whether or not a fragmented series of messages is to be transmitted. If the connection_size attribute is greater than eight (8), then the fragmentation protocol is placed within the I/O.

If the connection_size attribute is less than or equal to eight (8) bytes, then the raw data is transmitted without the presence of the fragmentation protocol.

If the application requests to transmit a piece of data whose length is greater than the connection_size attribute, then an internal error is indicated and the transmission does not occur. If the receiving I/O connection object detects a missed fragment by determining that the received fragment count is not equal to the previously received fragment count plus one (1), then the following error recovery steps are taken:

- all subsequent fragments in this series are dropped and the application is not informed of an I/O message reception;
- the connection object begins looking for the beginning of a new fragmented series of transmissions and discards the remaining fragments in this series.

5.2.3.4 Acknowledged fragmentation

Acknowledged fragmentation is used for fragmented explicit messages. Acknowledged fragmentation consists of the transmission of a fragment from the transmitting node followed by the transmission of an acknowledgement by the receiving node. The receiving node acknowledges the reception of each fragment.

Figure 20 shows the format for the acknowledgement message transmitted by the receiver after each explicit message fragment is received.

Byte offset	Contents							
	7	6	5	4	3	2	1	0
0	Frag (1)	XID	MAC ID					
1	Fragment type (3)		Fragment count					
2	Ack status							

IEC 1222/2000

Figure 20 – Acknowledgement message format

Acknowledgement message contents:

- **fragment type:** Indicates that this is a fragment acknowledged by placing the value 3 within this field;
- **fragment count:** Echoes the last fragment count value received;
- **ack status:** Indicates whether or not an error has been detected by the receiver of the fragmented message. The ack status bit values are defined in Table 7:

Table 7 – Ack status bit values

Value	Meaning
0	Success. No errors have been detected and the fragmented transmission shall continue
1	Too much data. The maximum amount of data the receiver can receive across this connection has been exceeded
2–255	Reserved

The transmitting node functions as specified below:

- the connection object formulates the message header by setting the Frag bit to one (1), the XID (transaction ID) field to the value specified by the application, and initializes the MAC ID field in the same manner it would a non-fragmented explicit message. The message headers associated with each separate fragment are identical;
- the connection object then places the appropriate fragmentation protocol information into the message. The connection object stores the fragment count that was inserted into the message;
- the connection object then takes the next piece of the message body and places it into the message;
- the message is transmitted and a wait for acknowledgement timer is started. The amount of time to wait is application specific;
- if the wait for acknowledgement timer expires, then the connection object automatically retries the last transmission. The connection object retries once. If the timer expires once

again (two consecutive wait for acknowledgement time-outs), then the application is informed that an error has been detected and the requested transmission cannot take place;

- if an acknowledgement is received, then the connection object determines whether or not the fragment count in the acknowledgement is equal to the last fragment count it transmitted. If they are equal, then the fragment was successfully delivered and acknowledged, and normal processing continues. If the values are not equal, then the connection object continues to wait for an acknowledgement with a matching fragment count.

The initial state associated with the receiving module entails waiting for either the first fragment in a fragmented transmission or waiting for the reception of a complete explicit message. The receiving side functions as specified below:

- if the message header indicates that this is a fragmented portion of an explicit message, then the connection object examines the fragmentation protocol to determine its validity. If the connection has yet to receive the first transmission in the series (in the initial state) and the fragment type field is not equal to the first fragment, then the fragment is dropped and no acknowledgement is returned;
- if the fragment type indicates that this is the first fragment, then the fragment count shall equal zero (0). If this is the case, then the message fragment is stored and an acknowledgement is returned. If the fragment type indicates first fragment and the fragment count is not zero (0), then the fragment is dropped and no acknowledgement is returned;
- if the fragment count is one (1) greater than the previously received count and the fragment type does not indicate that this is the first fragment, then the next fragment has been received. The fragment is appended to the previously received fragment(s) and an acknowledgement is returned. The fragment count associated with this fragment is stored;
- if the fragment count is neither one (1) greater nor equal to the previously received count, then the fragment is discarded and no acknowledgement is returned. The receiver resets to the initial state;
- when the final fragment is received and the acknowledgement is transmitted, the connection object continues processing the message as if it were non-fragmented.

5.2.4 Offline connection set

5.2.4.1 General

This section describes the offline connection set messaging protocol and presents details associated with the establishment of offline connection set ownership. Support of the offline connection set is optional for all types of devices. The group 4 offline connection set messages are used by client tool(s) to recover nodes in the communication faulted state. Using the offline connection set messages a client (tool) shall be able to:

- a) visually identify the faulted node(s) to which it is communicating with by flashing an LED;
- b) send fault recovery messages to the faulted node, and when possible;
- c) recover the faulted node without having to unplug it from the subnet.

At any point in time, only one (1) client node shall communicate with nodes in the communication faulted state, connected to a single subnet. Ownership of communication faulted nodes is gained via a dialog between clients (tools) using the offline ownership request/response messages.

Table 8 shows the group 4 identifiers associated with the offline connection set.

Table 8 – Offline connection set

Identifier bits (Connection ID)											Identity usage
Group ID					Message ID						
10	9	8	7	6	5	4	3	2	1	0	Group 4 messages
1	1	1	1	1	2C						Communication faulted response message
1	1	1	1	1	2D						Communication faulted request message
1	1	1	1	1	2E						Offline ownership response message
1	1	1	1	1	2F						Offline ownership request message

Only clients wishing to support the offline connection set shall produce messages using group 4 message ID 2F and consume response messages with group 4 message ID 2E. Once ownership is gained, the client shall produce all messages destined for communication faulted node(s) using group 4 message ID 2D.

NOTE A client may NOT produce a “Communication faulted request message” until it has gained ownership of the “Offline connection set”.

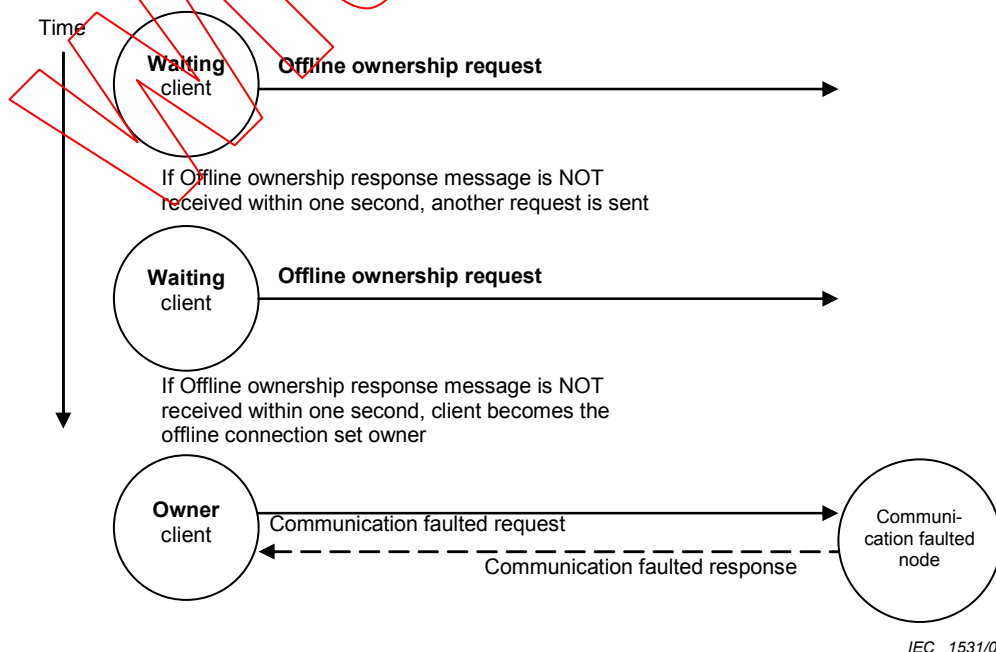
Once a client (tool) establishes offline connection set ownership, it is able to transmit communication faulted request messages with group 4 message ID 2D and receive communication faulted response messages with group 4 message ID 2C.

While in the communication faulted state, a node supporting this feature is only required to consume a single connection ID; group 4 message ID 2D. A faulted node shall produce its communication fault response messages on group 4 message ID 2C.

Offline connection set messages are low priority and may be subject to delays due to other network traffic.

5.2.4.2 Offline ownership

Figure 21 and Figure 22 illustrate the steps involved for a client (tool) to gain ownership of the offline connection set.

**Figure 21 – Establishing the offline ownership**

To gain control of the offline connection set a client (tool) shall produce its offline ownership request message. Upon successful transmission, the client (tool) shall wait for an offline ownership response message for a period of 1 s. If a response is not received, it shall produce a second offline ownership request message and shall wait another second. If a response is not received, it shall become the owner of the offline request message. If an offline ownership response message is received during either wait period, it shall not become the owner of the offline connection set and shall wait to become the owner.

NOTE Only one client tool shall have ownership of the offline connection set at any point in time.

The scenario where one client (tool) has previously claimed ownership of the offline connection set, and additional client nodes are arbitrating for ownership, the current owner shall reply to any offline ownership request messages with an offline ownership response message.

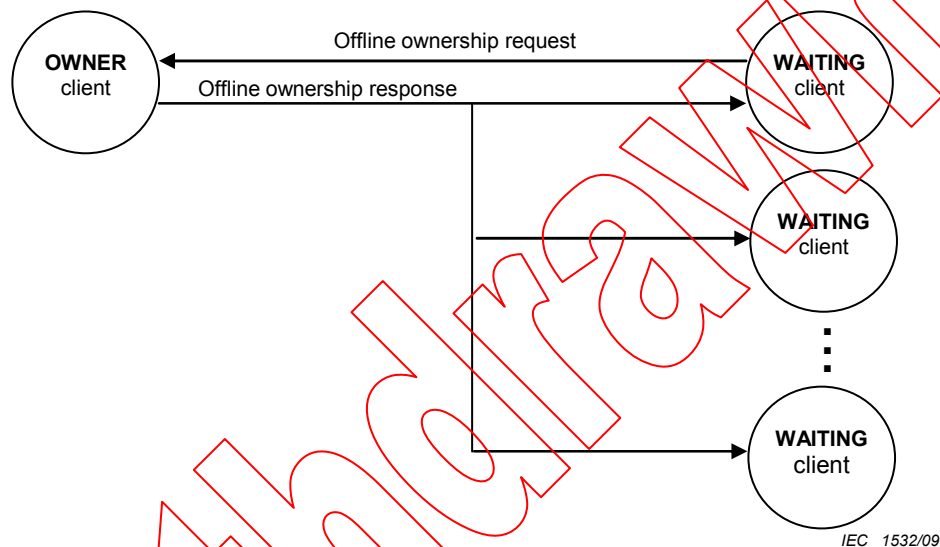


Figure 22 – Multicast nature of the offline ownership

A waiting client shall not attempt to send an offline ownership request message for a minimum of two seconds after receiving an offline ownership response message.

5.2.4.3 Offline ownership messages

5.2.4.3.1 General

The two messages used to manage the offline connection set are only produced and consumed by client nodes supporting this functionality. These messages are only serviced while a client is participating in a recovery activity, otherwise they are ignored by a client.

5.2.4.3.2 Offline ownership request message (client only)

To gain ownership of the offline connection set, a client tool shall produce an offline ownership request message with group 4 message ID 2F, see Figure 23.

Byte Offset	Contents							
	7	6	5	4	3	2	1	0
0	Reserved [0]		Client MAC ID					
1	R/R [0]	Allocate [0x4B]						
2	Vendor ID						Low byte	
3							High byte	
4	Serial number						Low byte	
5								
6								
7							High byte	

IEC 1533/09

Figure 23 – Offline ownership request message

Upon successful transmission, the client (tool) shall wait for an offline ownership response message for at least 1 s. If a response is not received, it shall produce a second offline ownership request message and shall wait at least 1 s. If a response is not received, it shall become the owner of the offline connection set. If an offline ownership response message is received during either time period, it shall not become the owner of the offline connection set and shall wait to become the owner.

Once a client is the owner of the offline connection set, if it receives an offline ownership request message, it shall produce an offline ownership response message within 1 s.

If a client is waiting to become the owner of the offline connection set, it shall not produce an offline ownership request message at a rate faster than once every 2 s. This 2 s delay shall be reset upon the receipt of any message using an offline ownership request or response connection ID.

5.2.4.3.3 Offline ownership response message (client only)

The format of the offline ownership response message is the same as the offline ownership request message, except it is produced at group 4 message ID 2E, see Figure 24, and the R/R bit is set (1).

Byte offset	Contents							
	7	6	5	4	3	2	1	0
0	Reserved [0]		Client MAC ID					
1	R/R [1]	Allocate [0x4B]						
2	Vendor ID						Low byte	
3							High byte	
4	Serial number						Low byte	
5								
6								
7							High byte	

IEC 1534/09

Figure 24 – Offline ownership response message protocol

Once a client (tool) is in the owner of the offline connection set, it may produce communication faulted request messages to all faulted nodes. Any node supporting the offline connection set shall service the communication faulted request message only while in the communication faulted state.

5.2.4.4 Communication faulted messages

5.2.4.4.1 General

All nodes in the communication faulted state, which support the faulted node recovery mechanism, shall receive the communication faulted request messages produced at group 4 message ID 2D. When appropriate, communication faulted nodes shall produce a communication faulted response message at group 4 message ID 2C.

Communication faulted request messages are consumed by all faulted nodes supporting this functionality. Depending upon the request message, any number of the faulted nodes may reply to a single request.

5.2.4.4.2 Communication faulted message protocols

To support the communication faulted message protocols a node shall support the “Network Status” LED or “Combined Module/Network Status” LED, or have a suitable device-specific method of indicating the network and module status externally (such as a display screen or text readout). It shall also have a network settable MAC ID.

The protocol of all the communication faulted request messages fall into two forms, multicast protocol (see Figure 25) and point-to-point protocol (see Figure 26).

Byte offset	Contents							
	7	6	5	4	3	2	1	0
0	Reserved [0]	Match	Value					
1	R/R [0]	Service						

IEC 1535/09a

IEC 1535/09

Figure 25 – Communication faulted request message – Multicast protocol

The multicast protocol is used by a client to perform requests to all communication faulted node(s) to acquire their serial number(s) and vendor ID(s). Once this information is known by the client, a point-to-point protocol may be used.

When a communication faulted node receives a multicast communication faulted request message, it shall perform the following checks to determine whether the message should be accepted and serviced:

Multicast match protocol

IF match bit is set (1)

AND value equals its MAC ID

AND the length of the message is two (2) bytes

THEN accept and service the communication faulted request message

Multicast mask protocol

IF match bit is reset (0)

AND value (logically AND'd with its MAC ID) equals its MAC ID

AND the length of the message is two (2) bytes

THEN accept and service the communication faulted request message

The multicast mask protocol (logical AND) is used for dialogs where a range of MAC ID's are requested to respond. Table 9 indicates some, but not all, of the 64 possible mask values.

Table 9 – Addresses reporting based upon mask

5	4	3	2	1	0	Faulted nodes with
1	1	1	1	1	1	MAC ID < 64
0	1	1	1	1	1	MAC ID < 32
0	0	1	1	1	1	MAC ID < 16
0	0	0	1	1	1	MAC ID < 8
0	0	0	0	1	1	MAC ID < 4
0	0	0	0	0	1	MAC ID < 2

The multicast mask protocol is used to reduce the number of messages, which shall be sent on a subnet to determine if, and at what MAC ID, a communication faulted node resides.

The point-to-point protocol follows.

Byte offset	Contents							
	7	6	5	4	3	2	1	0
0	Reserved (service determines usage)							
1	R/R	Service						
2	Vendor ID						Low byte	
3							High byte	
4	Serial number						Low byte	
5								
6								
7							High byte	

IEC 1536/09

Figure 26 – Communication faulted request message – Point-to-point protocol

When a communication faulted node receives a point-to-point communication faulted request message, it shall perform the following checks to determine whether the message should be accepted and serviced:

Point-to-point match protocol

IF the length of the message is equal to eight (8) bytes

AND the serial number and vendor ID match its own

THEN accept and service the communication faulted request message

The following services are currently defined for the communication faulted request messages.

Identify communication faulted request message - Multicast protocol:

Used when the client is attempting to identify the existence of any communication faulted nodes, which support the offline connection set feature, on a subnet.

Identify communication faulted request message - Point-to-point protocol:

Used when the client detects multiple communication faulted nodes on a subnet, and wishes to visually identify a specific communication faulted node.

Who communication faulted request message:

Used when the client has detected communication faulted node(s) on a subnet, and wishes to acquire their serial number and vendor ID.

Change MACID communication faulted request message:

Used when the client has detected a specific communication faulted node and wishes to change its MAC ID and have it attempt to come On-line at a specified MAC ID.

A device that implements the communication faulted message protocols shall implement support for all four of the above communication faulted message protocols.

5.2.4.5 Identify communication faulted messages

5.2.4.5.1 General

The client may solicit an identify communication faulted response message from

- 1) ALL communication faulted nodes, or
- 2) communication faulted nodes at one or more specific MAC IDs, or
- 3) a communication faulted node with a specific vendor ID and serial number.

5.2.4.5.2 Identify request message – Multicast protocol

The identify communication faulted request message - multicast protocol shall be produced at group 4 message ID 2D, see Figure 27. The client produces this message when it is attempting to identify the existence of any nodes in the communications faulted state.

If the length of the identify communication faulted request message is two (2) bytes long, any communication faulted node(s) servicing this message shall respond but not flash their LEDs.

Byte offset	Contents							
	7	6	5	4	3	2	1	0
0	Reserved [0]	Match	Value					
1	R/R [0]	Identify [0x4C]						

IEC 1537/09

Figure 27 – Identify communication faulted request message – Multicast protocol

5.2.4.5.3 Identify response message – Multicast protocol

The format of the identify communication faulted response message is the same as the received identify communication faulted request message (with the match and value information the same as the information in the received request), except it is produced at group 4 message ID 2C, see Figure 28 and the R/R bit is set (1). The response message shall be initiated within 100 ms, upon the receipt of the request message.

Byte offset	Contents							
	7	6	5	4	3	2	1	0
0	Reserved [0]	Match	Value					
1	R/R [1]	Identify [0x4C]						

IEC 1538/09

Figure 28 – Communication faulted identify response message

If more than one node responds to the request, collisions will not occur on the subnet. This is a result of all communication faulted nodes producing the same message (connection ID and data field). However, when more than one node replies, multiple messages may be received by the client.

5.2.4.5.4 Identify request message – Point-to-point protocol

The identify communication faulted request message - point-to-point protocol shall be produced with group 4 message ID 2D, see Figure 29. If a client (tool) detects communication faulted node(s) on a subnet, and the user wishes to visually identify a communication faulted node at a specific MAC ID, then the client (tool) shall produce the identify communication faulted request message - point-to-point protocol.

Byte offset	Contents							
	7	6	5	4	3	2	1	0
0	Reserved [0]	Match [0]	Value [0x3f]					
1	R/R [0]	Identify [0x4C]						
2	Vendor ID							Low byte
3								High byte
4	Serial number							Low byte
5								
6								
7								High byte

IEC 1539/09

Figure 29 – Identify communication faulted request message – Point-to-point protocol

A client shall always set “match” to 0 and “value” to the 3F. A server may ignore the contents of byte 0 (checking vendor ID and serial number are sufficient for uniqueness).

IF a node accepts an identify communication faulted request message – point-to-point protocol AND is in the communication faulted state, it shall respond as follows:

1. Flash its bi-colour network status LED or combined module/network status LED. The flash rate shall alternate the red LED ON for 250 ms, followed by the green LED turning ON for 250 ms. If the device does not have a bi-colour network status LED or combined module/network status LED, a suitable device-specific externally viewable indication shall be provided (e.g. via a display screen) to show that the identify message has been accepted.
2. Produce an identify communication faulted response message, within 100 ms.

IF a node has accepted an identify communication faulted request message - point-to-point protocol AND is flashing its LED, it shall stop flashing its LED under the following conditions. Similarly, if the device does not have a bi-colour network status LED or combined module/network status LED and the device-specific indication used to indicate that an identify message had been accepted is ON, it shall be turned OFF under these conditions:

1. Another identify communication faulted request message – point-to-point protocol is not accepted within 500 ms.
2. Another identify communication faulted request message – point-to-point protocol is received and NOT accepted (and another serial number or vendor ID).

If a node uses a network status LED or combined module/network status LED for the identify message indication, then, after it stops flashing the LED, the node shall turn off the LED for a minimum of 500 ms, but less than 1 s, prior to returning to its normal operation.

5.2.4.5.5 Identify response message – Point-to-point protocol

The identify communication faulted response message - point-to-point protocol is the same as the identify communication faulted response message - multicast protocol response.

5.2.4.5.6 Who communication faulted request message

The who communication faulted request message shall be produced at group 4 message ID 2D, see Figure 30. The who communication faulted request message is used to acquire the serial number and vendor ID of a communication faulted node.

Byte offset	Contents							
	7	6	5	4	3	2	1	0
0	Reserved [0]	Match	Value					
1	R/R [0]	Identify who [0x4B]						
2	Time delay byte offset [0-6]							

IEC 1540/09

IEC 1540/09

Figure 30 – Who communication faulted request message

IF the consuming node

1. is in the communication faulted state, and
2. detects the who communication faulted request message, and
3. meets the match and value criteria.

THEN the communication faulted node

1. shall wait a duration derived from the time delay byte offset,
2. produce a single who response message at the group 4 message ID 2C, and
3. remain in the communication faulted state.

The client shall consume the duplicate MAC ID request message produced at the communication faulted response message ID 2C, thus acquiring the communication faulted node's serial number and vendor ID.

The accuracy of the wait period shall be dependent upon the timer resolution of the internal timer within the communication faulted node.

The interval the faulted node waits before responding is determined as follows:

1. get the value at the time delay byte offset within the who communication faulted request message (0-6 are valid values),
2. use this value as an offset into the who response message shown in Figure 31, then
3. multiply the byte value at that offset times 50 ms, and
4. delay the response for that period of time.

5.2.4.5.7 Who communication response

The who response message, produced following the specified delay, is the same protocol as a duplicate MAC ID request message, except it is produced at a group 4 message ID 2C, see Figure 31.

Byte offset	Contents							
	7	6	5	4	3	2	1	0
0	R/R [0]	Physical port number						
1	Vendor ID							Low byte
2								High byte
3	Serial number							Low byte
4								
5								
6								High byte

IEC 1541/09

Figure 31 – Who response message

5.2.4.5.8 Change MAC ID communication faulted request message

The purpose of this message is to modify the MAC ID of a node in the communication faulted state. This message shall be produced using the group 4 message ID 2D, see Figure 32.

Byte offset	Contents							
	7	6	5	4	3	2	1	0
0	Reserved [0]		Value [New MAC ID]					
1	R/R [0]	Change MAC ID [0x4D]						
2	Vendor ID							Low byte
3								High byte
4	Serial number							Low byte
5								
6								
7								High byte

IEC 1542/09

Figure 32 – Change MAC ID communication faulted request message

Nodes which support the change MAC ID communication faulted request message feature shall not produce a communication faulted response message.

IF the consuming node

1. is in the communication faulted state, AND
2. detects the change MAC ID communication faulted request message, AND
3. verifies that the serial number, and the vendor ID matches its own,

THEN the faulted node

1. changes its MAC ID to the new MAC ID , AND
2. enters the sending duplicate MAC ID state (see 5.4.3).

If, at the new MAC ID, the node fails the duplicate MAC ID check, the node shall retain the new MAC ID and re-enter the faulted state.

The contents of byte zero (0), bits 6 and 7 are ignored by the faulted node. Production of a value other than zero in this location is a client error, indicating non-conformance.

5.2.5 Device heartbeat

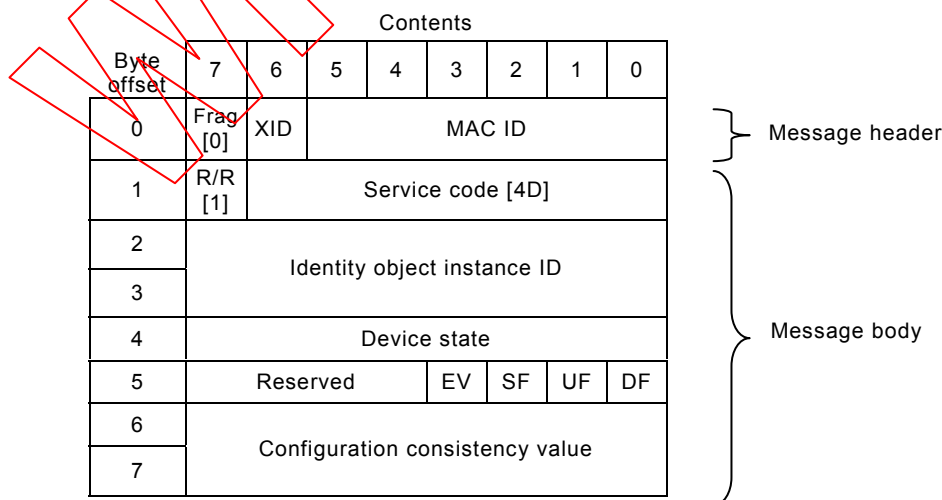
5.2.5.1 General

This subclause defines the protocol associated with optional device heartbeat message. The device heartbeat message is triggered by the identity object, which is defined in 5.3.2.

The device heartbeat message is optional.

5.2.5.2 Device heartbeat message

This message broadcasts the current state of the device. This message is transmitted by a UCMM capable device as an unconnected response message (message group 3, message ID 5) and by a group 2 only server as an unconnected response message (message group 2, message ID 3). The format of the heartbeat message is shown in Figure 33.



IEC 1543/09

Figure 33 – Device heartbeat message

5.2.5.3 Data frame contents, device heartbeat message

Frag (0)/Transaction ID/MAC ID - The heartbeat message is an unsolicited broadcast message; there is no destination MAC ID. The source MAC ID is specified in the message header. This is an exception to the general rule that the message header shall not contain the same MAC ID as the CAN identifier field.

R/R Bit (1) - Indicates this is a response message.

Service Code (4D_{Hex}) - Identifies this as a device heartbeat message.

Identity Object Instance ID - The instance ID of the identity object producing the device heartbeat message. This field shall be 2 bytes in length.

Device State - Attribute 8 of the associated identity object instance. If attribute 8 is not supported, device state shall be 3 (device operational).

EV- Event Flag, use is to be developed. This bit is ignored by the receiver and shall be set to zero by the transmitter.

SF- System Fault, - a fault in the device caused by bus interaction (e.g. connection timeout). This flag is set when a system fault is present.

UF- User Fault, - a fault in the device caused by user interaction. This flag is set when a user fault is present. The conditions under which this is set are vendor specific.

DF- Device Fault, - an internal fault in the device not caused by user or bus interaction (e.g. hardware fault). This flag is set when a device fault is present.

Reserved bits - Use is to be developed. These bits currently are ignored by the receiver and shall be set to zero by the transmitter.

Configuration consistency value - Attribute 9 of the associated identity object instance. If attribute 9 is not supported configuration consistency value shall be zero.

5.2.6 Device shutdown message

5.2.6.1 General

This subclause defines the protocol associated with optional device shutdown message. The device shutdown message is produced by a device when it transitions to the offline state.

The device shutdown message is optional.

5.2.6.2 Device shutdown message

This message broadcasts the transition of a device to the offline or non-existent state. This message is transmitted by a UCMM capable device as an unconnected response message (message group 3, message ID 5) and by a group 2 only server as an unconnected response message (message group 2, message ID 3). The format of the device shutdown message is shown in Figure 34.

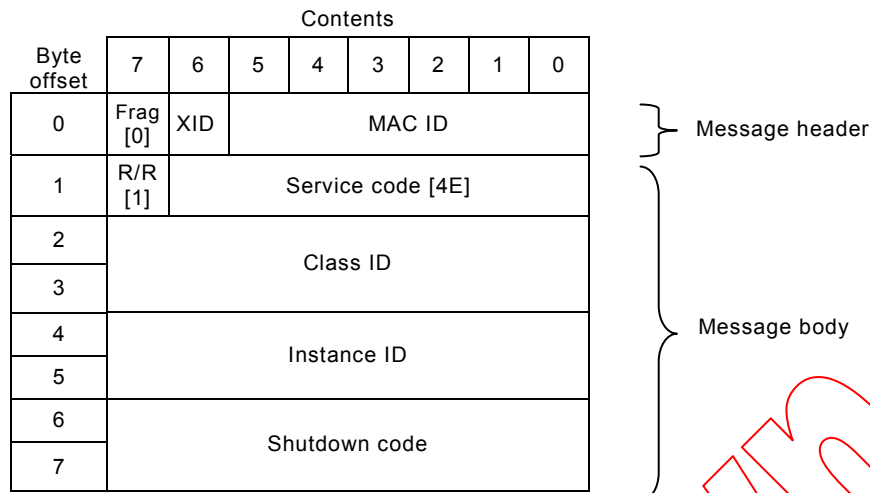


Figure 34 – Device shutdown message

5.2.6.3 Data frame contents, device shutdown message

Frag (0)/Transaction ID/MAC ID - The shutdown message is an unsolicited broadcast message, there is no destination MAC ID. The source (MAC ID) is specified in the message header. This is an exception to the general rule that the message header shall not contain the same MAC ID as the CAN identifier field.

R/R Bit (1) - Indicates this is a response message.

Service Code (4E_{Hex}) - Identifies this as a device shutdown message.

Class ID / Instance ID - These two values identify the object class / instance responsible for the device's transition to the offline state. If the shutdown is not caused by a specific class, Class ID shall be 0. These fields shall each be 2 bytes in length.

Shutdown Code - This value which indicates the reason for the device's transition to the offline state is shown in Table 10 and Table 11.

Table 10 – Device shutdown message shutdown code ranges

Value	Meaning
0 _{Hex} -1FF _{Hex}	Open
200 _{Hex} -2FF _{Hex}	Vendor specific
300 _{Hex} -4FF _{Hex}	Object class specific
500 _{Hex} -FFF _{Hex}	Reserved by DeviceNet for future use