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Tractors and machinery for agriculture and forestry — Serial control and communications data network —

Part 4: Network layer

Tracteurs et matériels agricoles et forestiers — Réseaux de commande et de communication de données en série —

Partie 4: Couche réseau

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 11783-4 was prepared by Technical Committee ISO/TC 23, *Tractors and machinery for agriculture and forestry*, Subcommittee SC 19, *Agricultural electronics*.

ISO 11783 consists of the following parts, under the general title *Tractors and machinery for agriculture and forestry — Serial control and communications data network*:

— *Part 1: General standard for mobile data communication*

— *Part 2: Physical layer*

— *Part 3: Data link layer*

— *Part 4: Network layer*

— *Part 5: Network management*

— *Part 6: Virtual terminal*

— *Part 7: Implement messages application layer*

— *Part 8: Power train messages*

— *Part 9: Tractor ECU*

— *Part 10: Task controller and management information system data interchange*

— *Part 11: Data dictionary*

Introduction

Parts 1 to 11 of ISO 11783 specify a communications system for agricultural equipment based on the CAN 2.0 B [1] protocol. SAE J 1939 documents, on which parts of ISO 11783 are based, were developed jointly for use in truck and bus applications and for construction and agricultural applications. Joint documents were completed to allow electronic units that meet the truck and bus SAE J 1939 specifications to be used by agricultural and forestry equipment with minimal changes. This part of ISO 11783 is harmonized with SAE J 1939/31 [2]. General information on ISO 11783 is to be found in ISO 11783-1.

The purpose of ISO 11783 is to provide an open interconnected system for on-board electronic systems. It is intended to enable electronic control units (ECUs) to communicate with each other, providing a standardized system.

The International Organization for Standardization (ISO) draws attention to the fact that it is claimed that compliance with this part of ISO 11783 may involve the use of a patent concerning the controller area network (CAN) protocol referred to throughout the document.

ISO takes no position concerning the evidence, validity and scope of this patent.

The holder of this patent right has assured ISO that he is willing to negotiate licences under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statement of the holder of this patent right is registered with ISO. Information may be obtained from:

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Attention is drawn to the possibility that some of the elements of this part of ISO 11783 may be the subject of patent rights other than those identified above. ISO shall not be held responsible for identifying any or all such patent rights.

Tractors and machinery for agriculture and forestry — Serial control and communications data network —

Part 4: Network layer

1 Scope

This part of ISO 11783 specifies a serial data network for control and communications on forestry or agricultural tractors and mounted, semi-mounted, towed or self-propelled implements. Its purpose is to standardize the method and format of transfer of data between sensor, actuators, control elements, and information-storage and -display units, whether mounted on, or part of, the tractor or implement. This part of ISO 11783 describes the network layer, which defines the requirements and services needed for communication between electronic control units (ECUs) in different segments of the ISO 11783 network. The various types of network interconnection unit are defined in this part of ISO 11783.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 11783. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 11783 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 11783-1:—[1)], *Tractors and machinery for agriculture and forestry — Serial control and communications data network — Part 1: General standard for mobile data communication*

ISO 11783-3:1998, *Tractors and machinery for agriculture and forestry — Serial control and communications data network — Part 3: Data link layer*

ISO 11783-5, *Tractors and machinery for agriculture and forestry — Serial control and communications data network — Part 5: Network management*

1) To be published.

3 Description

3.1 Role of the network interconnection unit

3.1.1 Message transfer

3.1.1.1 General

When multiple segments exist in a network, the network interconnection unit provides the means of transferring messages from one segment to another. The unit transfers individual message frames between two or more nodes, of which there is one per segment.

3.1.1.2 Depending on its type (see 3.2 and clause 6), the interconnection unit can perform one or more of the following message-transfer tasks:

— forwarding (5.1)

— filtering (5.2)

— address translation (5.3)

— repackaging (5.4).

3.1.1.3 There are three main performance criteria for determining the suitability of a network interconnection unit for a given application.

a) Maximum number of messages guaranteed to be forwarded per second: if exceeded due to average or peak bus loads, messages can be lost.

b) Maximum number of messages guaranteed to be filtered per second: if exceeded due to the number of entries in the database, messages can be excessively delayed.

c) Maximum transit delay: used to determine the worst-case latency for a message transmitted by one ECU and received by another ECU in another bus segment.

3.1.2 Database management

The network interconnection unit can also support bridge and database management (5.5), enabling access to, and configuration of, internal databases within the interconnection unit itself.

EXAMPLE Although a bridge separates two media segments and the message traffic on each, the network will still be considered a single network in terms of its address space and identifiers, thanks to the communication made possible by the interconnection unit.

3.1.3 Other network layer functions

Network interconnection units can perform other functions beyond those defined in this part of ISO 11783, as provided by the supplier or as dictated by the network configuration. ISO 11783-1 gives examples of these other functions.

3.2 Role of the network layer

The main role of the network layer is management of the transfer of messages between segments. The network layer includes a number of different types of network interconnection unit, which, depending on the functions required, can provide these services:

— the repeater forwards the messages (6.1);

— the bridge (6.2) filters messages and manages the message-filter database;

— the router (6.3) uses address translation to enable a network segment to appear as a single ECU to other parts of the network;

— the gateway (6.4) repackages parameters into different messages for easier transfer, reception and interpretation by ECUs;

— a special network interconnection unit, the tractor ECU, connects the implement and tractor buses on a tractor or self-propelled implement (see Figure 1, 4.1.3 and ISO 11783-9 [4]).

As well as these message-transfer functions, the network layer gives access to, and allows configuration of databases within, the network interconnection unit (3.1.2, 5.5, and ISO 11783-1).

NOTE The network interconnection unit can also participate in the address-claim procedure on behalf of ECUs in a subnetwork (ISO 11783-5). However, because the use of a router or gateway for interfacing with a proprietary subnetwork is application-dependent, it is not defined in ISO 11783. Specific implementations may be developed by the component manufacturer, subsystem supplier or the OEM (original equipment manufacturer).

Figure 1 illustrates the topology of a typical network in agriculture and forestry that uses serial control and communications data network interconnection units. The maximum number of nodes per implement is specified in ISO 11783-1.

4 Requirements

4.1 Network interconnection unit

4.1.1 General requirements

4.1.1.1 The network interconnection unit shall provide guaranteed filtering and forwarding rates.

4.1.1.2 It shall not exceed the maximum transit-delay values.

4.1.1.3 In order to avoid excessive delays, the order in which a frame is received on one node and transmitted to another shall follow its given priority.

4.1.1.4 The network interconnection unit shall forward messages having a higher priority before forwarding those of a lower priority.

4.1.1.5 It shall forward the messages, according to their given priority, in the same order as they are received.

4.1.1.6 A simple first-in-first-out (FIFO) message queue shall not be used.

4.1.1.7 The network interconnection unit shall not go “bus off” when forwarding an address-claimed message or when contention occurs.

4.1.2 General recommendations

4.1.2.1 The network interconnection unit should provide the capability to read and modify the filter database.

4.1.2.2 It should support database management by providing standard access for configuration of message forwarding, filtering, address translation and repackaging, as they pertain to bridge, router or gateway management, accordingly.

4.1.2.3 When in operation, the network interconnection unit should be transparent to any ECU on the network.

4.1.2.4 The transport protocol should be used whenever a message length is greater than 8 bytes.

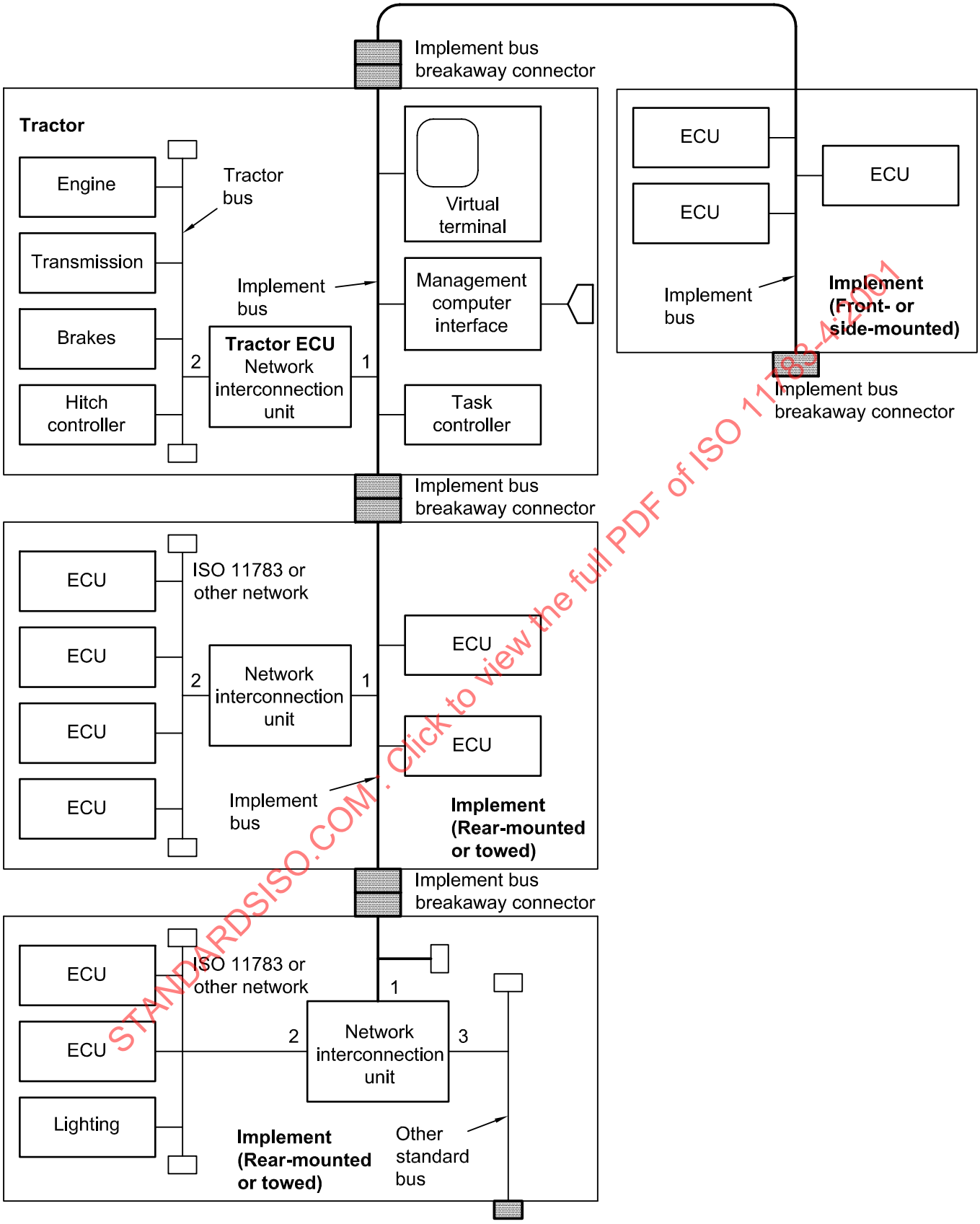

Figure 1 — Typical ISO 11783 network

4.1.3 Tractor ECU

There shall be a special type of network interconnection unit, the tractor ECU, located between the tractor's power-train and implement segments, which shall provide isolation and protect the power-train segment. Similar to a gateway, the tractor ECU represents the tractor to any other ECU on the implement network (see Figure 1).

4.2 Network topology

The system network topology (5.5.5) shall be constructed so that there is only one path between ECUs.

NOTE Although this part of ISO 11783 does not require that network loops be detected or duplicate messages be prevented from being generated or replicated indefinitely, it is the responsibility of the OEM to ensure there are no loops in the network. Redundant bus segments for fault tolerance can be used, but the provision of mechanisms for detecting, selecting and automatically reconfiguring the message routing path is the responsibility of the network interconnection unit supplier.

4.3 Network addressing

The data link layer of the network (ISO 11783-3) provides for 255 source addresses. The theoretical number of controllers permitted on the network is 254 when the null and global addresses are not used. Where there is no network interconnection unit, the electrical loading on the bus from each ECU can restrict this number.

4.4 Proprietary messages

The network shall allow for proprietary messages to reside directly on the tractor-implement segment. If bus traffic and latency pose a problem, a separate segment should be used to handle these messages. The supplier of this segment and its related ECUs shall provide the router function within one of the ECUs.

All ECUs on the tractor-implement segment shall support CAN 2.0B [1], which defines 29-bit identifiers.

Subnetworks may support either CAN 2.0B or CAN 2.0A [1] with 11-bit identifiers. However, in these cases, a router or gateway shall exist to selectively permit the transfer of messages between the two segments, and, because ISO 11783 does not utilize 11-bit identifiers, to perform any needed diagnostics on the subnetwork.

OEMs and suppliers are responsible for using such identifiers, as there are no means of assuring the assignment of unique identifiers. A CAN 2.0B 11-bit subnetwork can reside on the same segment as the ISO 11783 network. Nevertheless, bus loading and reliability issues will have to be considered.

5 Network interconnection unit functions

5.1 Forwarding

A network interconnection unit transfers individual message frames between two or more nodes (one node for each network segment). The order of frames received on one node and transmitted on another shall be preserved for a given priority level. A network interconnection unit shall forward all queued messages of a higher priority before those of a lower priority. Otherwise, all messages being forwarded to a specific node could be excessively delayed. A simple FIFO queue shall not be used to meet this requirement.

When a network interconnection unit forwards (6.1 and 6.2) a message to another segment, it uses an address identical to that of the originator of the message. Ordinarily, this will not cause arbitration problems, as the unit will not retransmit the message to the segment it originally came from and, moreover, the addresses are unique on a given ISO 11783 network.

The sole exception is when an address-claim message is forwarded to a segment in which another ECU is simultaneously claiming the same address. In such a low-probability situation, the network interconnection unit shall be able to detect a bus error when transmitting the message and stop the automatic retransmission sequence within the CAN controller chip. Otherwise, the network interconnection unit will experience multiple collisions and go "bus off", thereby preventing other messages from being forwarded until the network interconnection unit is able to recover from the bus off condition.

A network interconnection unit may begin to forward messages from one segment to another before it has claimed an address (i.e. it will not perform address translations) if it is simply acting as a repeater or bridge.

NOTE Until a network interconnection unit has completed a power up and self test (POST) sequence and connected it to the network, the subnetwork and the ECUs connected to it cannot receive other messages.

5.2 Filtering

5.2.1 Block mode

In block filter mode (0), the network interconnection unit shall default to forwarding all messages (6.2). Bus utilization (traffic) may be higher on each bus segment, but if it is within acceptable limits, the message filtering algorithm will be non-existent. The filter database within the network interconnection unit can contain identifier entries, parameter group number (PGN) values, for messages which ought not to be forwarded (blocked). This can be used to reduce the overall bus traffic on a given segment, and is the preferred mode of operation for bridges conforming to ISO 11783. Filter database entries are typically made during assembly or initial configuration and retained in non-volatile memory.

5.2.2 Pass mode

In pass filter mode (1), the network interconnection unit shall default to not forwarding messages (6.2). Then, in order for a message to be forwarded, an entry must exist with a specific identifier (PGN value) for that particular message. This mode is best for nodes on network interconnection units that link subnetworks performing specific functions. It demands prior knowledge of the ECUs and the functions of the whole network; or else the ECUs must be able to add entries to the filter database, in which case the network interconnection unit may need more memory and processing power if it is to accommodate a large filter database. Moreover, some entries within the database will need to be permanent (i.e. configured to be always present), so that corresponding messages will always be forwarded across the whole network. Typical applications are network management, diagnostics, and global requests.

5.3 Address translation

A network interconnection unit can provide address translation for particular messages (6.3), permitting a single address to be used for referencing a particular segment (trailer) even without knowledge of a particular function address on the segment (lighting). For this, an address translation database must exist in order to identify, through a “look-up” table, the corresponding source address or destination address. The network interconnection unit will need to have a valid claimed address before it can provide this service.

5.4 Message repackaging

A network interconnection unit can repackage messages (6.4) when transferring them from one segment to another. This provides a potential reduction in bus traffic by improving the amount of useful parameters per message, while reducing the number of different messages received by a particular controller. A message repackaging database or processing routine should exist in order to determine how the messages are to be repackaged.

5.5 Database management

5.5.1 General

A standard method should be provided for accessing and configuring the various databases within a network interconnection unit, including the unit’s parametrics (status and statistics), and the network topology. All the functions concerned should use non-volatile memory to retain the data values through power loss. This is particularly important if a static filter database is to be maintained.

NOTE This part of ISO 11783 leaves undefined provision for a separate, dynamic filter database, cleared upon power loss to permit easy reconfiguration as ECUs are added and removed from the network.

5.5.2 Network message

This message provides a means for accessing and configuring the database, and accessing bridge status and statistics, within the network interconnection unit. When a request or command is made to a specific destination (i.e. it is not global), a response is always required, even if only an acknowledgement indicating that the particular control function is not supported or could not be performed (see ISO 11783-3). In the case of multi-packet PGNs, several CAN data frames can occur as a result of a single request. After sending a request or command, the controller should always wait for a response or the “no response” timeout before sending another request or command.

The definition and specifications of the network message are given in Table 1.

Table 1 — Network message

Parameter group name	Network
Definition	Used to access network interconnection unit parametrics and databases
Transmission repetition rate	Per user requirements, should not exceed 5 times per second.
Data length	8 bytes
Data page	0
PDU format	237
PDU-specific field	Destination address
Default priority	6
PGN	60672 (00ED00h)
NOTE Data ranges for parameters used by this group function: Control byte: 0-6, 64-65, 128-130 See 5.5.3 and 5.5.4 for definitions 7-63, 66-127, 131-255 Reserved for assignment by ISO	

5.5.3 Configuration of the network-interconnection-unit message filter database

5.5.3.1 The message filter database can be configured by the following means.

5.5.3.1.1 The supplier provides the network interconnection unit with a fixed filter database.

Bridge design permits the OEM to preconfigure the filter database at the time of manufacture. This will demand prior knowledge of the whole network, including the ECUs and messages present, and may not be adequate for coping with additions or changes to the network over time without reconfiguration of the network interconnection unit during service.

5.5.3.1.2 The bridge is configured over the network using a diagnostic tool as part of a service procedure.

5.5.3.1.3 The network interconnection unit is configured at any time by any controller on the network. A separate security procedure to enable the modification of the database may be needed, and restrictions on access for reconfiguration will depend on the application.

5.5.3.2 A source address (SA) shall be appended to each filter-database entry for those entries created using the N.MFDB_Create_Entry database management function (see Table 4). This SA represents the controller that placed the entry: the same one that should remove it. This will not prevent controllers from entering conflicting requests, but it will avoid the unexpected deletion of entries. Nevertheless, provision should also be made to enable the overriding of this requirement when diagnostic tools are to be used.

5.5.3.3 Each filter database entry should identify a PGN for filtering and mark it to be either passed or blocked (5.2.1 and 5.2.2). Also to be identified is the node pair (direction), necessary for restricting traffic to specific subnetworks while allowing particular messages to be forwarded from them.

EXAMPLE The tractor ECU filters out engine data to prevent it from going to the tractor-implement segment, while allowing requests from the tractor-implement segment to be forwarded to the tractor.

5.5.3.4 When configuring the filter database, the first byte in the data field used is the control code that identifies the function, and those that follow are dependent on the function. The node pair (from/to) is represented by a nibble for each numbered node, as shown in Table 2.

Table 2 — Node numbers

Node no.	Definition
0	Local
1-14	Assignable
15	Global (all nodes)

Node number 0 (local) is used to enable a controller to direct a message to and from a network interconnection unit when the number of the connecting node is unknown: it is merely directed to the “local” node at which the message is received.

The node number 15 (global) is used to facilitate the directing of a message by a controller to a network interconnection unit without the controller being required to know the number of nodes of the network interconnection unit. If either of the node numbers within a message (from/to) is set to global, multiple responses from the network interconnection unit for each node pair may be provided. The transport protocol is used whenever a message length is greater than 8 bytes.

When either of a pair (from/to) of node numbers is set to 15 (global), a message can be directed, even when the node number of the network interconnecting unit is unknown, because of multiple responses from the network interconnection unit for every node pair. ISO 11783-1 presents a list of the node numbers of network interconnection units used in an ISO 11783 network.

The network interconnection unit should be capable of configuring the filter database using either of these methods.

5.5.3.5 The Filter_Mode byte is defined in Table 3.

Table 3 — Filter mode

Filter_Mode byte	Definition
0	Block-specific PGNs (default = pass all)
1	Pass-specific PGNs (default = block all)

5.5.3.6 The functions needed to support filter database configuration are defined in Table 4.

Table 4 — Message filter database (MFDB) configuration functions

Function	Description	PGN	Control code	Other data fields
N.MFDB_Request	Message used to request a filter database copy	60672	0	Node_Pair
N.MFDB_Response	Response to N.MFDB_Request containing the filter database entries	60672	1	Node_Pair Filter_Mode PGNs
N.MFDB_Add	Command used to add one or more entries in a filter database [a]	60672	2	Node_Pair PGNs
N.MFDB_Delete	Command used to delete one or more entries in a filter database	60672	3	Node_Pair PGNs
N.MFDB_Clear	Command used to clear one or more filter databases based on node pair and direction	60672	4	Node_Pair
N.MFDB_Set_Mode	Command used to set the filter mode of one or more filter databases based on node pair and direction [b]	60672	5	Node_Pair Filter_Mode
N.MFDB_Create_Entry	Command used to create one or more entries in a filter database [c]	60672	6	Node_Pair Filter_Mode PGNs

NOTE Commands listed here are acknowledged by the acknowledgement message (PGN = 59392).

[a] If the “to” node is set to global, multiple entries are made in the filter database, one for each node pair. Any controller using this function must already know the filter mode of the filter database concerned before making an entry, as the filter mode is not included with this command.

[b] Filter_Mode should not be changed without first clearing the filter database.

[c] If the “to” node is set to global, multiple entries are made in the filter database, one for each node pair. As the filter mode is included with this command, an ECU can explicitly indicate whether a new entry is to be blocked or passed, allowing the network interconnection unit to determine how to add the entry to the existing filter database.

EXAMPLE The messages in Table 5 are transmitted to obtain the entries of the filter database within the tractor ECU (SA = 032). The destination-specific request is initiated from an off-board diagnostic tool (SA = 249). The request is for a list of only those PGNs being filtered when going to a trailer or implement (node 1 to node 2). The destination specific-response indicates that the only blocked message (Filter_Mode = 0) is engine configuration ($003EE3_{HEX}$).

Table 5 — Example of message filter database access

Function	Identifier						Data	Node pair	Filter_Mode	PGN
	PRI	R	P	PF	DA	SA	Control Code	HEX		HEX
N.MFDB_Request	110	0	0	237	032	249	0	12	—	—
N.MFDB_Response	110	0	0	237	249	032	1	12	0	003EE3

5.5.4 Parametrics

5.5.4.1 Network interconnection unit parametrics (status and statistics)

These are given in Table 6.

Table 6 — Network interconnection unit parametrics (status and statistics)

Able to be reset?	Parametric identifier	Number of bytes	Definition
—	1	2	Buffer size (bytes)
—	2	2	Filter database size (bytes)
Yes	3	2	Number of database entries
—	4	2	Maximum number of messages received per second
—	5	2	Maximum number of messages forwarded per second (guaranteed minimum)
—	6	2	Maximum number of messages filtered per second (guaranteed minimum)
—	7	2	Maximum transit delay time (ms) (50 ms max.)
Yes	8	2	Average transit delay time (ms)
Yes	9	2	Number of messages lost due to buffer overflow
Yes	10	2	Number of messages with excess transit delay time
Yes	11	2	Average number of messages received per second
Yes	12	2	Average number of messages forwarded per second
Yes	13	2	Average number of messages filtered per second
—	14	1	Number of nodes

NOTE Parametrics within a response list are in the same order as the parametric identifiers in the request list (no delimiters are required since all parametrics and parametric identifiers are of fixed length). Although a response to a request message must be received before another request can be sent to a given address, this request can be for multiple parametrics.

Parametrics can be accessed through a node-pair parametric request. Their valid value ranges are in accordance with ISO 11783-7 [3] with all bit values set to "1" to indicate "not available", and each parameter number 1 byte in length.

5.5.4.2 General parametrics (GP)

The functions required to support access to general parametrics are defined in Table 7. The transport protocol is used whenever a message length is greater than 8 bytes.

Table 7 — Functions used to access network-interconnection-unit general parametrics (GP)

Function	Description	PGN	Control code	Other data fields
N.GP_Request	Message used to request one or more network-interconnection-unit parametrics [a]	60672	128 (80_{HEX})	Parametric identifier
N.GP_Response	Response to N.GP_Request containing requested network-interconnection-unit parametrics	60672	129 (81_{HEX})	Numeric value of parametrics
N.GP_Reset_Statistics	Command used to clear any statistical parameters able to be reset [b]	60672	130 (82_{HEX})	—

[a] A request of parametric 0 returns the full list of parametrics.

[b] Acknowledged by the acknowledgement message (PGN = 59392).

5.5.4.3 Specific parametrics (SP)

Certain parametrics are applicable to a particular controller or node pair or both. The functions required to support access to these node-pair specific parametrics (SP), for a given network interconnection unit node pair, are defined in Table 8.

The transport protocol is used whenever a message length is greater than 8 bytes.

Table 8 — Functions used to access network-interconnection-unit node-specific parametrics (SP)

Function	Description	PGN	Control code	Other data fields
N.SP_Request	Message used to request one or more network-interconnection-unit parametrics [a]	60672	131 (83_{HEX})	Node pair Parametric identifier
N.SP_Response	Response to N.SP_Request containing requested network-interconnection-unit parametrics	60672	132 (84_{HEX})	Node pair Numeric value of parametrics
N.SP_Reset_Statistics	Command used to clear any statistical parameters able to be reset [b]	60672	133 (85_{HEX})	Node pair

[a] A request of parametric 0 returns the full list of parametrics. Each parameter number is one byte long.

[b] Acknowledged by acknowledgement message (PGN = 59392)

5.5.5 Network topology information

All network interconnection units conforming to this part of ISO 11783 will be essentially transparent to other ECUs on the network. Nevertheless, knowledge of the topology of a network may still be necessary. The control functions defined in Table 9 enable this missing information to be obtained.

Table 9 — Network topology (NT) information

Function	Description	PGN	Control code	Other data fields
N.NT_Request	Message used to request the list of source addresses on a network-interconnection-unit node	60672	64 (40_{HEX})	Node
N.NT_Response	Response to N.NT_Request containing requested node number and list of source addresses found on a network-interconnection-unit node	60672	65 (41_{HEX})	Node SA(s)

NOTE A 300 ms (one network-interconnection-unit delay plus ECU response time) is used as the time-out for an address request.

The node number, contained in the lower nibble of the data byte, is used in identifying the addresses associated with network interconnection unit nodes. Where there is more than one network interconnection unit on a network, it will be able to identify only the “side” on which a source address is located. A particular source address may actually reside on a remote bus segment, and responses from each of the network interconnection units will have to be compared in order to determine which local bus segment contains the source address. Moreover, the unit may first have to perform a request-for-address claim and construct a list of source addresses associated with each node.