Low Level Reader Protocol (LLRP), Version 1.0.1

Ratified Standard with Approved Fixed Errata

August 13, 2007

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Abstract

This document specifies an interface between RFID Readers and Clients. The interface protocol is called *low-level* because it provides control of RFID air protocol operation timing and access to air protocol command parameters. The design of this interface recognizes that in some RFID systems, there is a requirement for explicit knowledge of RFID air protocols and the ability to control Readers that implement RFID air protocol communications. It also recognizes that coupling control to the physical layers of an RFID infrastructure may be useful for the purpose of mitigating RFID interference.

Audience for this document

The target audience for this specification includes:

RFID Network Infrastructure vendors

Reader vendors

EPC Middleware vendors

System integrators

Status of this document

This section describes the status of this document at the time of its publication. Other documents may supersede this document. The latest status of this document series is maintained at EPCglobal. See `www.epcglobalinc.org` for more information.

This draft fixes errata in version 1.0 of LLRP that was ratified on April 12, 2007. A summary of the fixed errata is contained in the table below. Note that Section and Line numbers referenced are per version 1 of LLRP. Line numbers may be slightly different in this version 1.0.1.

Comments on this document should be sent to the EPCglobal Software Action Group Reader Operations Working Group mailing list at `sag readerop@epclinklist.epcglobalinc.org`.

Fixed Errata

Section#	Line #	Description	Disposition
16.2.3.4.1	2921	It should be a generic UHF RFModeTable Parameter (1-n) with Notes under the parameter that for C1G2 it is UHFC1G2RFModeTable	Replace with UHF RFMode Table Parameter (1-n)
15.2.1.3.1.1	2402	No length field	Remove the length field from the abstract
15.2.1.2.1.1.1	2309	No length field	Remove the length field from the abstract
9.2.1.1	1269	Range of Rx sensitivity	0-128 (relative to max sensitivity)

16.1.2	2593	C1G2LLRPCapabilities should be replaced by AirProtocolLLRPCapabilities Parameter (0-1)	Replace with AirProtocolLLRPCapabilties Parameter (0-1)
9.2.4.1.2.1	1336	This is followed by a list of the frequencies (in Khz) in hop table order. The position of a frequency in the list is its ChannelIndex. (These are used by the hopping event parameter)	This is followed by a list of the frequencies (in Khz) in hop table order. The one-based position of a frequency in the list is its ChannelIndex (i.e. the first frequency is referred to as ChannelIndex 1)
9.2.4.1.2.2	1343	This parameter carries the fixed frequency list that can be used by the Reader. The position of a frequency in the list is its ChannelIndex.	This parameter carries the fixed frequency list that can be used by the Reader. The one-based position of a frequency in the list is its ChannelIndex (i.e. the first frequency is refered to as ChannelIndex 1…)
12.2.6.2, 13.2.3.8, 13.2.6.2	1825, 2013, 2105	TheseChannelIndexes are used by the RfTransmitter Parameter , Channel Index Parameter, HoppingEventParameter	Possibly denote in these usages that they are 1-based
11.1.3	1552	Delete access spec does not allow 0 like all other access spec commands. This is believed to be an errata	Possibly add zero to mean all access specs, as in other access spec commands.
16.2.7.1	3088	Custom parameter is 0-1. All others are 0-N. This is believed to be an errata	Extend this to 0-N to correct errata
16	2535, 2538	Encoding example:: message length is 32 bits, but shown as 16 bits and 32-bit messageID is not shown	Correct figures to match documentation
14.2.2, 16.2.8.1	2215, 3270	The abstract LLRPStatusParameter contains a field called statusCode. The binding references the same field as ErrorCode	Correct binding section to match abstract
16.4	3480	In 16.4, table 5, "ReaderSensitivityTableEntry" should be ReceiveSensitivyTableElement	Change ReaderSensitivity to ReceiveSensitivity
10.2.1, 16.2.4.1	1452, 2947	In 10.2.1, the field "Current State" is listed as the last element of the ROSpec Parameter, the binding lists the same field as the 4th last element.	Change position of "Current State" field in abstract ROSpec Parameter
16.4	3742	ReadEventNotification	Change to ReaderEventNotification
8.2	1194	Possible Values 0-255	Remove possible values. Changed to unsigned integer
6.1	717	An AISpec binds a stop trigger and a set of antennas to a set of InventoryParameterSpecs and is identified by a spec Identifier	Change the spec Identifyer to a "one-based index called the SpecIndex"

various	various	multiple instances of Khz	Replace with kHz

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1 (Informative) Glossary

This section provides a non-normative summary of terms used within this specification.

Term	Meaning
Access	The operation of communicating with (reading from and/or writing to) a Tag. An individual Tag must be uniquely identified prior to access. Access comprises multiple commands, some of which employ one-time-pad based cover-coding of the R=>T link.
Air Interface	The complete communication link between a Reader and a Tag including the physical layer, collision arbitration algorithm, command and response structure, and data-coding methodology.
Antenna	An atomic, specifically-addressable RF transmission and/or reception device used for communication with RFID tags. For the purposes of this spec, multiplicity of antenna is going to be referred to as antennas.
Capabilities	The set of intrinsic Reader properties relevant to protocol operation. This may include physical, functional, or protocol support information.
Compatibility	A general term used to describe a consistency of terminology and/or operation between one or more specifications and/or implementations. It is specifically not intended to be used to define expectations on protocol operation. The proper term for this is 'Interoperability' as defined below.
Configuration	Data and parameters to control specific operation of a Reader or the Client that is typically instantiated at boot time or as a result of specific management actions on a timescale much greater than the operations of LLRP. It is possible that certain parameters may be controlled via LLRP and have corresponding default configuration parameters.
Client	From the perspective of LLRP, a *Client* is synonymous with *Controller* (see below). The specification uses the term Client to identify the endpoint opposite to the Reader.
Controller	The function that implements the Reader Protocol (Interface) opposite the Reader (i.e., an LLRP endpoint). In the EPCGlobal Architecture, this function could comprise part of the Filtering & Collection (Role), but it may be implemented in a wide range of devices, including dedicated RFID infrastructure, Readers, and middleware running on server hardware.

Term	Meaning
GPI	General purpose input
GPO	General purpose output
Interference	There are two types of interference that impact a RFID system's operating capacity: Reader-to-tag, and Reader-to-Reader. Reader-to-tag interference happens when a tag receives signals of comparable strengths from more than one Reader at the same time. This causes the tag to respond arbitrarily to the Readers, and makes its state unpredictable. Reader-to-Reader interference happens when a Reader in the midst of listening to a tag's reply at a particular frequency, receives signals much stronger than the tag's reply, from another Reader operating at the same frequency at the same time. This causes the Reader's receiver logic to not be able to correctly decode the tag's reply. Both these interference scenarios can potentially degrade the system performance.
Interoperability	The ability for two implementations of protocol endpoints to properly function with each other. Proper function may require negotiation of supported capabilities between the two endpoints.
Interrogator	Synonymous with Reader. The EPCglobal Class-1 Gen-2 air protocol specification refers to Readers as Interrogators. However, since the term Reader is included in the title of this specification *Low Level Reader Protocol*, the term Reader is used instead of Interrogator.
Inventory	The operation of identifying Tags. A Reader begins an inventory round by transmitting a Query command (Query starts the round) in one of four sessions. One or more Tags may reply. The Reader detects a single Tag reply and requests the PC, EPC, and CRC-16 from the Tag. Inventory comprises multiple commands. An inventory round operates in one and only one session (defined below) at a time.
LLRP	Low Level Reader Protocol
LLRP connection	Instance of LLRP between the Reader and the Client.
LLRP endpoint	The endpoints of a LLRP instance (i.e., either a Reader or a Client).

Term	Meaning
Q	A parameter that a Reader uses to regulate the probability of Tag response. A Reader commands Tags in an inventory round to load a Q-bit random (or pseudo-random) number into their slot counter; the Reader may also command Tags to decrement their slot counter. Tags reply when the value in their slot counter is zero. Q is an integer in the range (0,15); the corresponding Tag-response probabilities range from 20 = 1 to 2-15 = 0.000031.
Q algorithm	A collision-arbitration algorithm where Tags load a random (or pseudo-random) number into a slot counter, decrement this slot counter based on Reader commands, and reply to the Reader when their slot counter reaches zero.
Reader	The function that implements the RFID Reader (Role) in the EPCGlobal Architecture Specification. It is one of the two endpoints of the Reader Protocol (Interface) which is, for the purposes of this specification, LLRP. The Reader comprises of one or more antennas which are used to communicate with RFID tags. Note that a Reader can not only read RFID tags, it can perform other operations on tags such as write and kill.
Receive Sensitivity	Receiver sensitivity is a measure of the weakest tag signal an RFID reader is able to detect and demodulate. Changing this affects the minimum detectable signal (MDS) so as to prevent weaker responses from tying up the receiver. The other commonly used term for such a control is squelch.
Select	The operation of choosing a tag population for inventory and access. A Select command may be applied successively to select a particular Tag population based on user-specified criteria. This operation is analogous to selecting records from a database.
Session	An inventory process comprising a Reader and an associated Tag population. A Reader chooses one of four sessions and inventories Tags within that session. The Reader and associated Tag population operate in one and only one session for the duration of an inventory round. For each session, Tags maintain a corresponding inventoried flag. Sessions allow Tags to keep track of their inventoried status separately for each of four possible time-interleaved inventory processes, using an independent inventoried flag for each process.
Singulation	Identifying an individual Tag in a multiple-Tag environment.
Spec	The document uses the term ‘Spec’ to denote the parameter specification for an operation.

Term	Meaning
UTC	Coordinated Universal Time (UTC) is the international time standard as maintained by the Bureau International des Poids et Mesures (BIPM).

2 Introduction

This document specifies an interface between RFID Readers and Clients. The design of this interface recognizes that in some RFID systems, there is a requirement for explicit knowledge of RFID air protocols and the ability to control Readers that implement RFID air protocol communications. It also recognizes that coupling control to the physical layers of an RFID infrastructure may be useful for the purpose of mitigating RFID interference. The interface described herein, and the functionality it implies, is called "Low Level Reader Protocol," or LLRP.

Following are the responsibilities of this interface:

- Provide means to command an RFID Reader to inventory tags (read the EPC codes carried on tags), read tags (read other data on the tags apart from the EPC code), write tags, and execute other protocol-dependent access commands (such as 'kill' and 'lock' from EPCglobal Class 1 Generation 2).
- Provide means for robust status reporting and error handling during tag access operations.
- Provide means for conveying tag passwords necessary to effect commands that may require them, such as the 'Kill' command in the EPCglobal Class 1 Generation 2 UHF Air Interface Protocol.
- Provide means to control the forward and reverse RF link operation to manage RF power levels and spectrum utilization, and assess RF interference, among RFID Readers in a system.
- Provide means to control aspects of Tag Protocol operation, including protocol parameters and singulation parameters.
- Provide means to facilitate the addition of support for new air protocols.
- Provide means for the retrieval of Reader device capabilities.
- Provide means for vendors of Reader devices to define vendor-specific extensions to the protocol in a manner that is non-interfering among vendors, and which, to the extent possible, is vendor-administered.

In addition LLRP is "regulatory requirements-aware," such that its functions are applicable in regulatory jurisdictions worldwide.

The overall organization of this specification is as follows: - General Overview (sections 3-6); Abstract Model (sections 7-15, 17), which describes the protocol, its message types and contents without specifying the protocol syntax; Binary Encoding (section 16), which specifies the syntax for representing the abstract protocol; Tranport Binding (section 18), which specifies the mechanism for delivery of protocol messages; Informative Descriptions (sections 19-21). Guidelines for adding support of a new air protocol to LLRP are presented in section 15.1.

3 Role within the EPCglobal Network Architecture

The RFID infrastructure consists of network elements that participate in the management (e.g., read/write/lock) and transmission of tag data. The consumers of the tag data are the Client network elements (e.g., end-user applications). The network elements between the tag and the Clients form the conduit to transport tag data over the network to the applications, and convey tag operational commands over the network to the tags. The EPCGlobal Architecture (ARC) framework has outlined the roles and the associated functions performed by the various elements in this network. The elements relevant to the LLRP specification are the Tags, Readers and F&C Role.

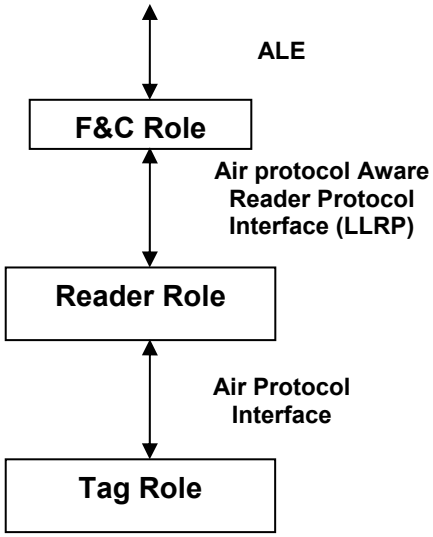


Figure 1: LLRP in the EPCGlobal Architecture

Figure 1 illustrates the position of LLRP in the EPCGlobal architecture stack between the F&C role and the Tag role.

The responsibilities of the elements and interfaces below the F&C role can be classified into three broad functional groups: tag data processing (*Data path*), Reader device management (*Management path*) and Reader control and coordination (*Control path).*

With the advent of sophisticated air protocols like UHF Class-1 Gen-2, and deployments of larger numbers of Readers, the need for Reader control and coordination (*Control path*) of the network of Readers in the architecture becomes important. The LLRP interface facilitates the control path function by exposing air protocol relevant control

knobs to the F&C role. To that effect, LLRP is designed to be extensible in terms of supporting multiple air protocols.

The physical and logical requirements for the communication between the Reader and the tag are defined by the air protocol. Specifically, the air protocol defines the signaling layer of the communication link, the Reader and tag operating procedures and commands, and the collision arbitration (also known as singulation) scheme to identify a specific tag in a multiple-tag environment. One such air protocol is the EPCGlobal Class-1 Generation 2 (C1G2) protocol. The tag memory in the C1G2 protocol is logically separated into four distinct banks: reserved memory, EPC memory, TID memory and user memory. The physical memory map of the tag is vendor-specific. The air protocol commands that access memory have a parameter that selects the bank, and an address parameter to select a particular memory location within that bank.

The fundamental operations a Reader performs on a tag population are inventory and access. Inventory is the operation of identifying tags, and comprises multiple air protocol commands. Using the singulation scheme, the Reader detects a single tag reply and requests the EPC memory contents from the tag. Access is the operation of communicating with (reading from and/or writing to) a tag. An individual tag must be uniquely identified prior to access. Similar to the inventory operation, access comprises multiple air protocol commands. In addition, a Reader can choose a subset of the tag population for inventory and access. This operation is called Select in the C1G2 protocol. The select operation is used to select and/or de-select a particular tag population for the subsequent inventory and/or access operation. This helps focus the operations on the desired subset of tags, and also thins the tag population participating in the singulation operation, thereby improving the overall singulation rate.

It is anticipated that overall system performance may be optimized by tuning the RF, singulation and air protocol parameters within and across Readers. The performance can be further optimized if the tuning is done cognizant of the RF environment in the vicinity of the Reader.

The LLRP interface between the Client and the Reader facilitates the management of Reader devices to mitigate Reader-to-tag and Reader-to-Reader interference and maximize the efficiency of singulation and data operations over the tag population. This is achieved by enabling the Reader device operation at the full performance level of the air protocol. In addition, LLRP provides the interface to transport the results of RF monitoring (a.k.a RF survey) if the Reader device is capable of performing that function.

In addition, there will be a number of applications that perform operations on the RFID tag data. Operations may range from reading EPC IDs to performing other tag access operations exposed by the air protocol like read, write, kill, lock, etc. Multiple application requirements translate into a set of access operations that a Reader or a set of Readers perform on tags as and when they are in the field of view. The LLRP interface provides a scalable mechanism to manage the access operations at the Reader devices.

Lastly, scalable device management capabilities are critical for operations of a large network of Reader devices. The LLRP interface facilitates device status and error reporting, and device capabilities discovery.

4 Terminology and Typographical Conventions

Within this specification, the terms SHALL, SHALL NOT, SHOULD, SHOULD NOT, MAY, NEED NOT, CAN, and CANNOT are to be interpreted as specified in Annex G of the ISO/IEC Directives, Part 2, 2001, 4th edition [ISODir2]. When used in this way, these terms will always be shown in ALL CAPS; when these words appear in ordinary typeface they are intended to have their ordinary English meaning. However in this document only a subset of the terms listed above SHALL be used. The subset of acceptable terms includes the following: SHALL, SHALL NOT and MAY. The terms SHOULD, SHOULD NOT, NEED NOT, CAN, and CANNOT, SHALL NOT be used.

All sections of this document, with the exception of section 1-3, 19-21, are normative, except where explicitly noted as non-normative. All figures within the document are non-normative unless otherwise specified.

The following typographical conventions are used throughout the document:

ALL CAPS type is used for the special terms from [ISODir2] enumerated above.

ALL_CAPS_UNDERSCORE type is used for LLRP message names.

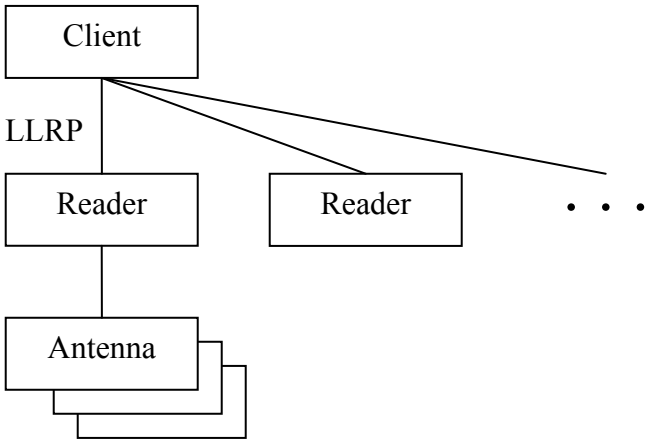
CamelBackType is used for LLRP parameter and data field names.

`Monospace` type is used to denote programming language, UML, and XML identifiers, as well as for the text of XML documents.

5 Overview of LLRP

LLRP is specifically concerned with providing the formats and procedures of communications between a Client and a Reader. The LLRP protocol data units are called messages. Messages from the Client to the Reader include getting and setting configuration of Readers, capabilities discovery of Readers and managing the inventory and access operations at the Readers. Messages from the Reader to the Client include the reporting of Reader status, RF survey, and inventory and access results.

LLRP is an application layer protocol and does not provide retransmission, or reordering facilities. State consistency between the Client and the Reader is critical for the correct functioning of the system. Using LLRP messages, the Client updates the Reader state which includes Reader configuration parameters, dynamically created data structures (e.g., ROSpecs, AccessSpecs, etc), and possibly vendor defined data. For this reason, LLRP requires acknowledgements for the Client to Reader transactions – this provides a fail-safe mechanism at the LLRP layer to cope with network error situations. Also, to cope with intermittent connections, a Client can request a Reader's configuration state to confirm that a Reader's state is consistent with the Client after the Client reconnects (see LLRPConfigurationStateValue in section 12.2.1). The Reader to Client messages are primarily reports, status notifications or keepalives. Only the keepalives are acknowledged by the Client.



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669 **Figure 2: LLRP Endpoints**

670 As shown in Figure 2, from LLRP's perspective, a Reader contains a collection of one or
671 more antennas. Moreover, Readers as used in this specification may not necessarily be in
672 one-to-one correspondence with hardware devices.

673 ## 5.1 Typical LLRP Timeline

674 LLRP operation consists of the following phases of execution:

675 • Capability discovery

676 • Device configuration

677 • [optional] Inventory and access operations setup

678 • Inventory cycles executed

679 If tag conditions matched, access operations will be executed during inventory
680 cycle execution. Access operations include reading, writing, and locking tag
681 memory, killing tags, etc.

682 • RF Survey operations executed

683 • Reports returned to the Client

684 A typical timeline of both LLRP and air protocol interactions between a Client, a Reader
685 and a population of tags is depicted in Figure 3.

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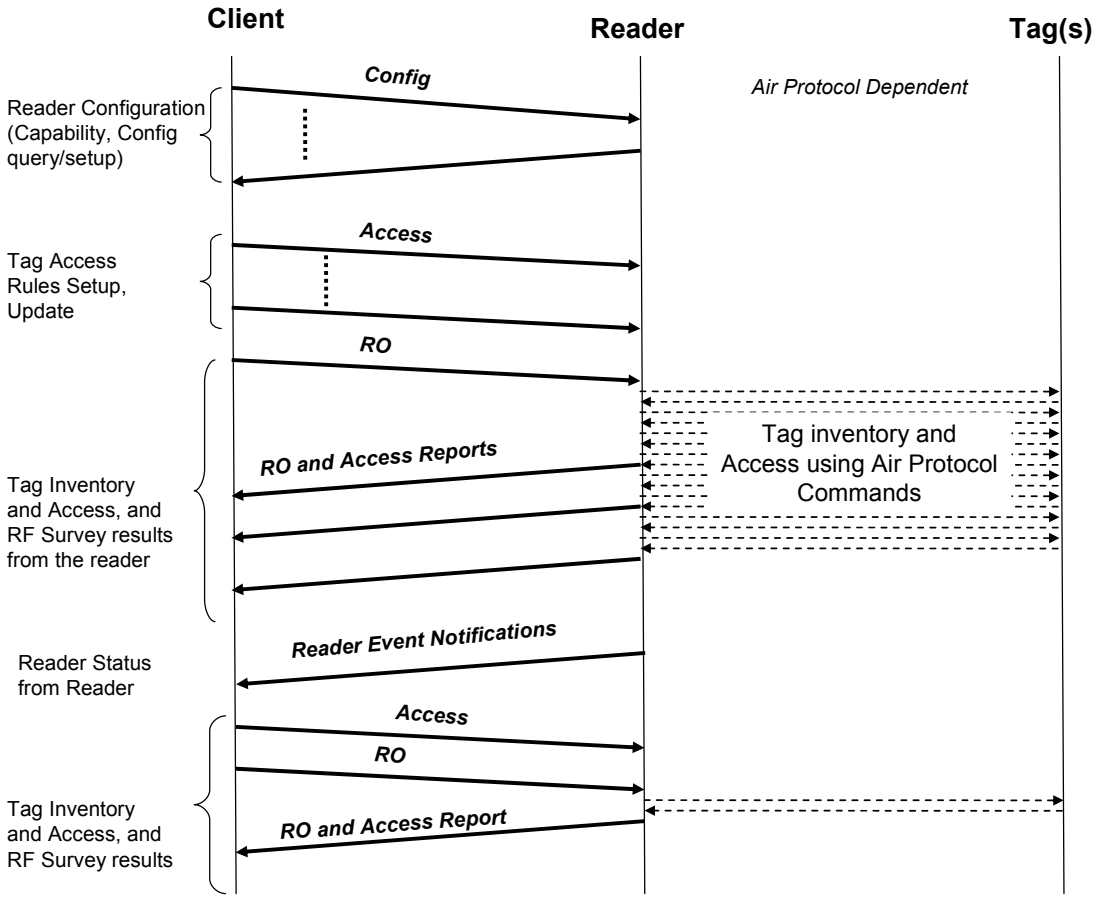


Figure 3: Typical LLRP Timeline

6 LLRP Operation

LLRP uses protocol data units called messages (See section 7.1.2 for details) to communicate between the Client and the Reader. Using LLRP, the Client updates or retrieves configuration of the Reader; by doing so, it controls the Reader's operation. This section provides an overview of the abstract model of the LLRP interface, and the data structures used in LLRP to and from the Reader.

Section 19 presents an informative description of the LLRP object model based upon UML notation.

6.1 Inventory, RF Survey and Access Operations

LLRP is based upon an abstraction of RFID air protocols and their respective commands. There are two principal concepts to the LLRP abstraction of RF operations by a Reader: 1) Reader Operations, and 2) Access operations. The remainder of this section provides a detailed description of these LLRP concepts.

Reader Operations (RO) define the parameters for operations such as Antenna Inventory and RF Survey. Access Operations define the parameters for performing data access operations to and from a tag.

The timing control of an operation is specified using boundary specification, which specifies how the beginning (using start trigger) and the end (using stop trigger) of the operation is to be determined.

An *antenna inventory* (AI) is the smallest unit of interaction between a Reader and tags in the antenna's *field-of-view (FOV)*. An *InventoryParameterSpec* defines the parameters to be used during the inventory operation including protocol, protocol-specific parameters, and RF parameters. During an AI, the tags in the FOV of the antennas are singulated using air protocol commands based on the contents of the *InventoryParameterSpec*. An *AISpec* binds a stop trigger and a set of antennas to a set of *InventoryParameterSpecs*, and is identified by a one based index called the SpecIndex. The stop trigger defines the termination condition of the aggregate *AISpec* operation comprising of N * M antenna inventory operations, where N and M are the cardinality of the antenna set and *InventoryParameterSpecs* set respectively. For example, if there is a single antenna and a single *InventoryParameterSpec* defined in an *AISpec*, the AI operation specified by the <antenna, *InventoryParameterSpec*> tuple is bounded by the stop trigger specification.

It should be noted that the stop trigger specification of each individual AI is not specified, which means the Reader is not limited to execute the AIs in the order in which they appear in an AISpec. The timing control and the sequencing of the individual AIs within an AISpec will be determined by the Reader.

RF Survey is an operation during which the Reader performs a scan and measures the power levels across a set of frequencies at an antenna. The RF survey operational parameters are described in a RFSurveySpec and it defines the survey operation at a single antenna. It comprises an identifier for the spec, an antenna identifier, stop trigger and set of parameters for the survey operation.

A *Reader Operation (RO)* describes the operations to be executed at one or more antennas of the Reader. A *RO* comprises at least one Spec, where a Spec is either an *AISpec* or a *RFSurveySpec*. If a *RO* comprises multiple Specs, each Spec is an *AISpec* or a *RFSurveySpec*. Each RO's operational parameters are described in a *ROSpec*. The *ROSpec* contains a spec identifier, the boundary specification for the entire RO operation, priority, a list of *AISpecs* and/or *RFSurveySpecs*, and optionally a reporting specification. The reporting specification defines the contents of RO Report and the trigger conditions when to send the inventory report and survey report. The order of *AISpec* and *RFSurveySpec* execution within a *ROSpec* is the order in which they appear in the *ROSpec*.

Figure 4 illustrates the statechart of a *ROSpec*. The *ROSpec* has three states: Disabled, Inactive and Active. The Client configures a new *ROSpec* using an ADD_ROSPEC message for the *ROSpec*. The *ROSpec* starts at the Disabled state waiting for the ENABLE_ROSPEC message for the *ROSpec* from the Client, upon which it transitions to the Inactive state. The ROSpec does not respond to start or stop triggers in the Disabled state. The Client disables a *ROSpec* using a DISABLE_ROSPEC message for the *ROSpec*.

The *ROSpec* transitions from the Inactive state to the Active state when ROSpecStartCondition occurs for the *ROSpec*. The *ROSpec* transitions back to the inactive state when ROSpecDoneCondition happens.

ROSpecStartCondition = ROSpecStartTrigger or START_ROSPEC

ROSpecDoneCondition = AllSpecsDone or ROSpecStopTrigger or preempted or (STOP_ROSPEC message for the ROSpec from the Client)

The *ROSpec* when undefined is no longer considered for execution. The Client undefines the *ROSpec* using a DELETE_ROSPEC message for the *ROSpec*.

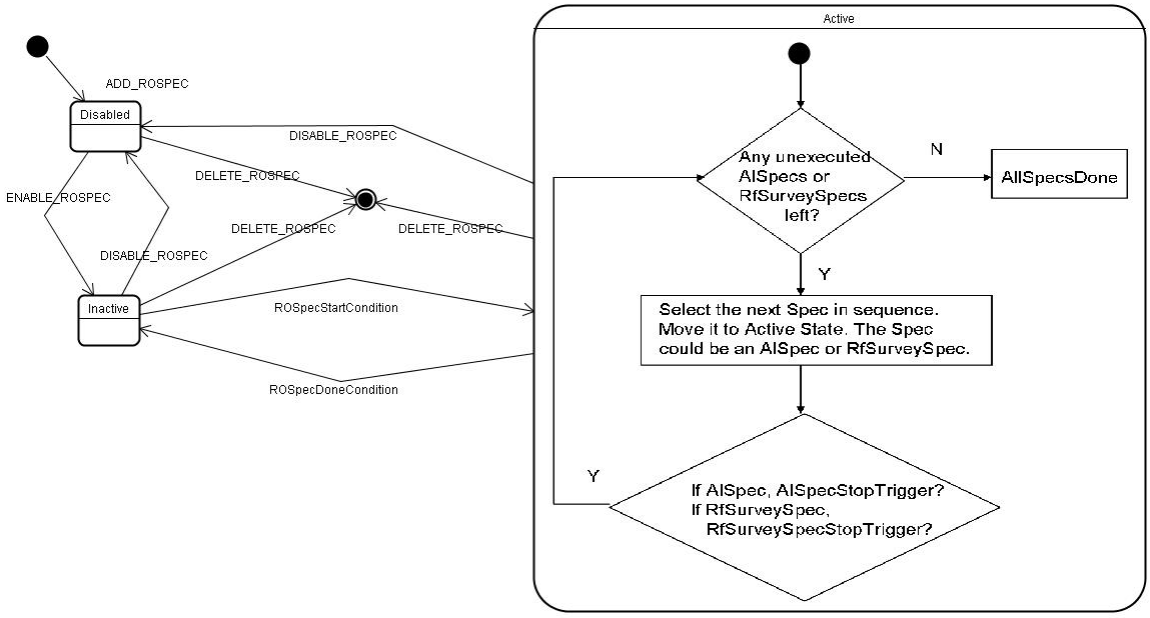


Figure 4: ROSpec Statechart

LLRP supports configuring multiple *ROSpecs*. Each *ROSpec* has a priority field. The default is for all the *ROSpecs* to have the same priority. Since the start trigger for the *ROSpec* can be an asynchronous event, there may be situations where a *ROSpec's* start trigger event occurs when the Reader is busy executing another *ROSpec*. The Client, when setting up a *ROSpec,* can set the appropriate priority so that a high priority *ROSpec* can preempt a currently active lower priority *ROSpec* and start execution as soon as the ROSpecStartCondition for the higher priority, inactive *ROSpec* occurs. The *ROSpec* that got preempted transitions to the Inactive state.

Figure 5 illustrates the *AISpec* statechart. When the parent *ROSpec* moves to the active state, each *AISpec* in the *ROSpec* starts at the inactive state. During an active *ROSpec's* execution, when an inactive *AISpec* is selected for execution, that *AISpec* moves to the active state. If there are multiple antennas and *InventoryParameterSpecs* in that *AISpec*, the Reader picks the next <antenna, *InventoryParameterSpec*> to execute. In the figure,

the ID of the selected antenna is A, and the protocol for the selected *InventoryParameterSpec* is P. The Reader starts tag singulation for air protocol P on antenna A using the operational parameters specified in the *InventoryParameterSpec*. This involves one or more air protocol commands from the Reader via the antenna to the tags in the antenna's FOV. The tags get singulated and each tag's EPC information is received by the antenna. If further tag memory operations are to be performed, such as writing or reading other memory regions, it will be performed at this point. As illustrated in Figure 6, these access operations are interleaved with the execution of an *AISpec*. Access operations are described using *AccessSpecs*. AccessSpecs describe the tags (*TagSpec*) on which some operations are to be performed, the operations to be performed (*OpSpec*), the boundary specification, and optionally a reporting specification for the Access operation. The AccessSpec may contain antenna information at which this access operation needs to be executed and contains the air protocol to be used to perform the access operations. In addition, to accommodate scenarios where an access operation needs to be performed only during a particular *ROSpec* execution, the AccessSpec optionally contains the *ROSpec* information. There can be one or more AccessSpecs set up at the Reader.

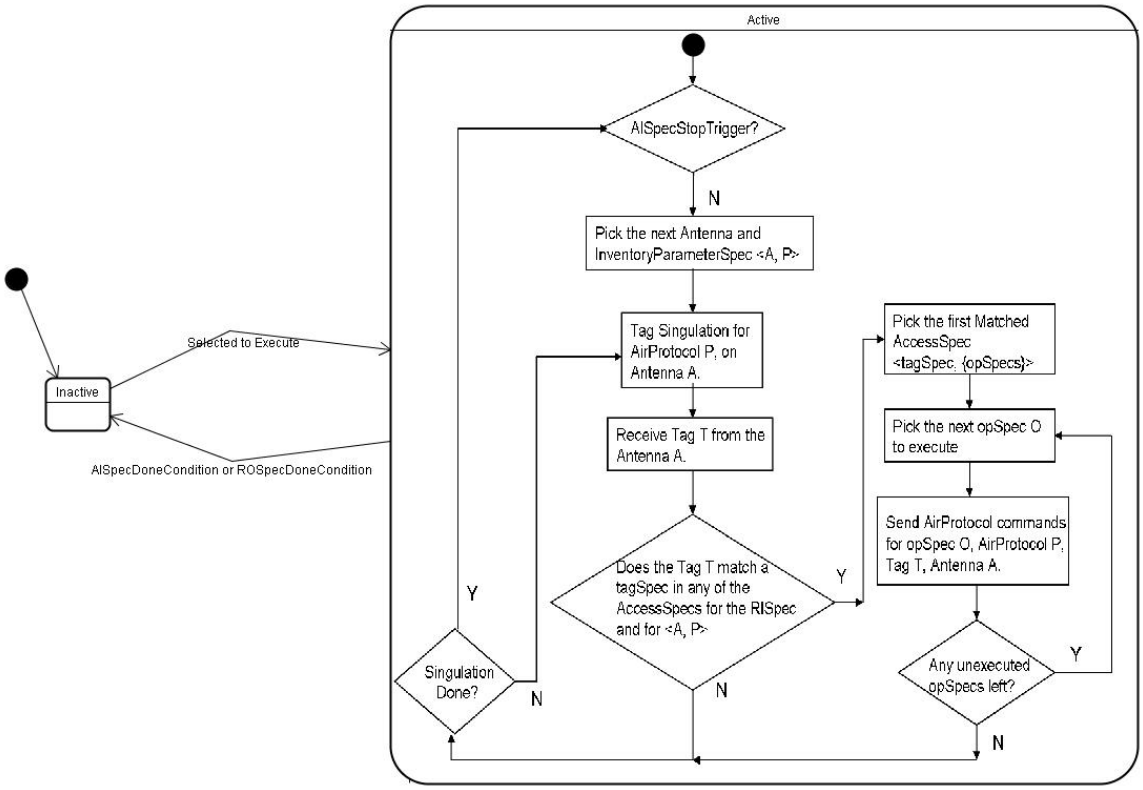
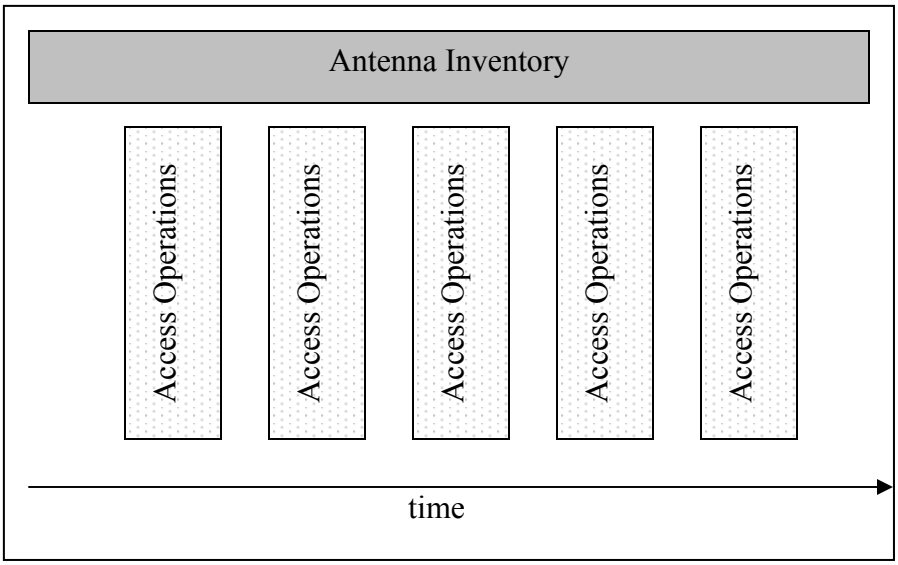


Figure 5: Antenna Inventory Spec States



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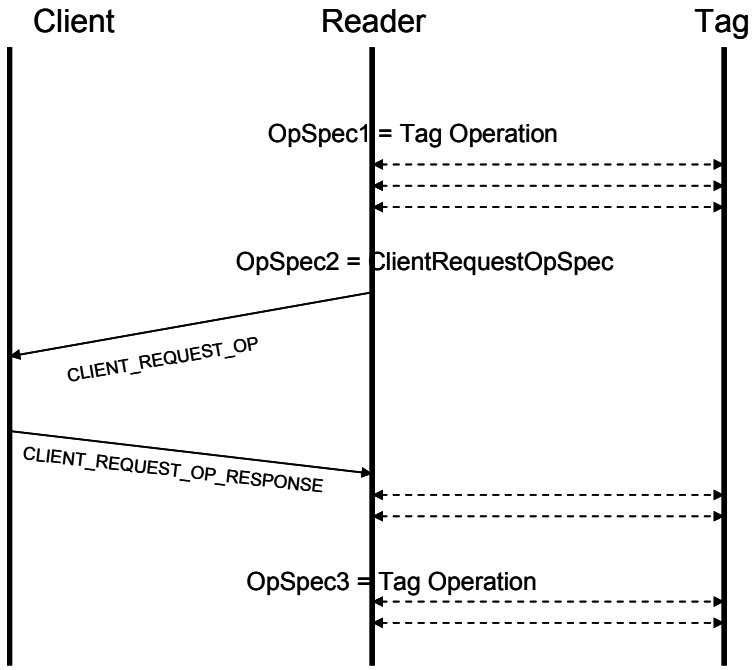
789 **Figure 6: Access Operations Interleaved in an Antenna Inventory Operation**

790 In Figure 5, when tags are received as a result of singulation, a check is performed to
791 determine if the received tag matches the TagSpec defined in any of the Active (See
792 statechart in Figure 8) *AccessSpecs*. In case there are multiple *AccessSpecs* that get
793 matched during a tagSpec lookup, the Reader will execute the first *AccessSpec* that
794 matches, where the ordering of the *AccessSpecs* is the order in which the *AccessSpecs*
795 were created by the Client.

796 When an AccessSpec is executed, the set of operations as specified in OpSpecs of the
797 *AccessSpec* are performed on the tag, which results in one or more air protocol
798 commands and responses transacted between the Reader and the tag via antenna A over
799 air protocol P. In order to support cases where the Reader needs to query the Client for
800 further information to complete the operation on the tag, there is an OpSpec called the
801 ClientRequestOpSpec.



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803 **Figure 7: Client Request OpSpec**

804 Figure 7 illustrates the message interaction between the Client, Reader and Tag for a
805 ClientRequestOpSpec. For OpSpecs that are not ClientRequestOpSpec, the Reader
806 performs the operations on the tag using the the air protocol commands. If an OpSpec is
807 of the ClientRequestOpSpec, the Reader sends the result of the ongoing AccessSpec till
808 that point in a CLIENT_REQUEST_OP message, so that the Client has all the relevant
809 information to send a response. The client response is carried in a
810 CLIENT_REQUEST_OP_RESPONSE message. This message is the set of OpSpecs that
811 the reader should execute. The reader continues to execute the OpSpecs within an
812 AccessSpec until all opSpecs have been executed or until an error occurs. When
813 execution completes, the reader resumes the inventory operation.

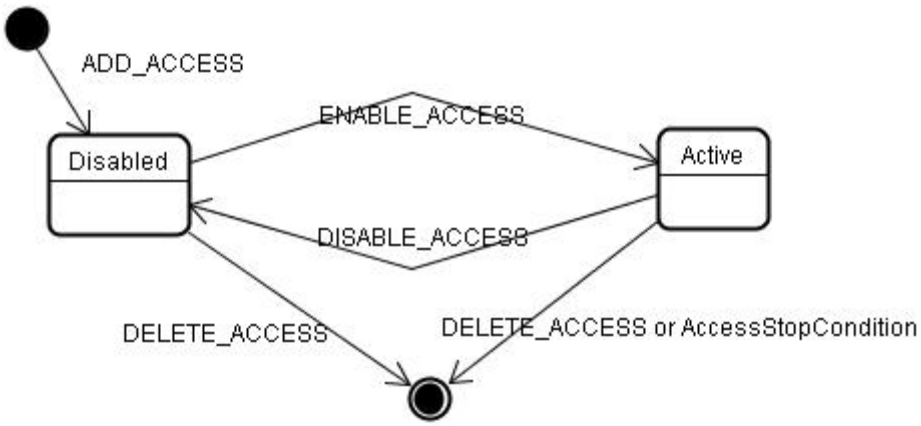
814 The AISpec transitions back to the inactive state when AISpecDoneCondition occurs or
815 when the parent *ROSpec*'s ROSpecDoneCondition occurs.

816

AISpecDoneCondition = AISpecStopTrigger

817

818



819

820 **Figure 8: Access Spec States**

821 Figure 8 illustrates the *AccessSpec's* states. The Client configures an *AccessSpec* using an
822 ADD_ACCESS_SPEC message for the *AccessSpec*. The *AccessSpec* starts at the
823 Disabled state, waiting for an ENABLE_ACCESS_SPEC message from the Client for
824 that *AccessSpec*, upon which it enters the Active state. It is only in the Active state that
825 the *AccessSpec* is considered for execution. The Client can disable an *AccessSpec* using a
826 DISABLE_ACCESS_SPEC message for the *AccessSpec*. The *AccessSpec* when
827 undefined is no longer considered for execution. The Client undefines the *AccessSpec*
828 using a DELETE_ACCESS_SPEC message for the *AccessSpec*.

829 In order for the Reader to take a local action to limit the validity of an *AccessSpec*, the
830 Client can configure a stop trigger for the *AccessSpec*. An example use case of the stop
831 trigger is when an AccessSpec is defined on all the antennas, and the desired behavior is
832 to operate on the tag only once, the first time it is seen at any antenna. When the
833 AccessStopCondition occurs, the *AccessSpec* transitions to undefined and is no longer
834 considered for execution.

835

AccessStopCondition = AccessSpecStopTrigger

836

837

838 Figure 9 illustrates the *RFSurveySpec* statechart. When the parent *ROSpec* moves to the
839 active state, each *RFSurveySpec* in the *ROSpec* starts at the inactive state. During an
840 active *ROSpec's* execution, when an inactive *RFSurveySpec* is selected for execution,
841 that *RFSurveySpec* moves to the active state. In the active state, the Reader executes the
842 survey operation as specified by the *RFSurveySpec*. The *RFSurveySpec* transitions back
843 to the inactive state when the RFSurveySpecDoneCondition occurs or when the parent
844 *ROSpec*'s ROSpecDoneCondition occurs.

845

RFSurveyStopCondition = RFSurveySpecStopTrigger

846

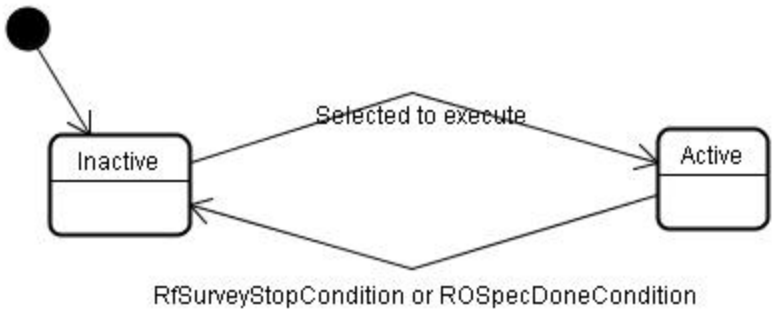


Figure 9: RFSurveySpec States

In summary, the Reader operation and Access operation specific data structures pass the following information between a Client and a Reader:

ROSpec: Details of a Reader operation

- ROSpecID: This identifier is generated by the Client. This identifier is used by the Client to perform operations on this ROSpec, like start, stop, enable, disable and delete. Reports that are generated as a result of the execution of this ROSpec also carry this identifier.
- ROBoundarySpec:
  - ROSpecStartTrigger, ROSpecStopTrigger: This is the start and stop trigger for this ROSpec. The triggers that are specifiable for a ROSpec are listed in Table 1.
- Priority: This is the priority of this ROSpec.
- CurrentState: This is the current state of the ROSpec – disabled, inactive, active. This field is kept up to date by the Reader based on the ROSpec's current state.
- Set of Specs: Each Spec is either an *AISpec* or *RFSurveySpec*. The Specs are executed in the order in which it is defined in the ROSpec. The position of the Spec (AISpec or RFSurveySpec) in the ROSpec is called the SpecIndex. The SpecIndex is used during reporting to identify the spec inside of ROSpec whose execution generated the data in the report. The numbering of SpecIndex is 1 based.
- ROReportingSpec: If specified, this defines when to send the results of this ROSpec, and also the contents and format of the report.

AISpec: Details of one of more antenna inventory operations

- AISpecStopTrigger: This is the stop trigger for the AISpec. The triggers that are specifiable for an AISpec are listed in Table 1.
- Set of Antenna IDs: This is the set of antennas at which the inventory operations described in the InventoryParameterSpecs are executed. If there are N antennas and M InventoryParameterSpecs, the Reader will execute the M inventory operations at each of the specified antennas. Thus, in aggregate, the Reader will

execute N * M *AIs* (Antenna inventory operations). The ordering of the *AI*s is determined by the Reader.

- Set of InventoryParameterSpecs: There can be one or more InventoryParameterSpecs specified as part of the AISpec. Collectively, they are bound by the AISpecStopTrigger. The order in which the antenna inventory operations described as <Antenna, InventoryParameterSpec> are executed is determined in a proprietary manner inside the Reader.

InventoryParameterSpec: Operational parameters for an inventory using a single air protocol.

- InventoryParameterSpecID: This identifier is generated by the Client. Reports that are generated as a result of the execution of this InventoryParameterSpec carry this identifier.
- Air Protocol: This is the air protocol that is used to inventory the tags in the field of view of the antenna.
- Set of Antenna Configuration Settings: Each Antenna Configuration setting comprises of
    - Antenna ID: The identifier of the antenna
    - RFTransmitterSettings: This describes the configuration of the transmitter during the inventory operation.
    - RFReceiverSettings: This describes the configuration of the receiver during the inventory operation.
    - AirProtocolInventoryCommandSettings parameters: This describes the configuration of the air protocol parameters for the inventory operation.

RFSurveySpec: Details of a RF Survey operation

- RFSurveySpecID: This identifier is generated by the Client. Reports that are generated as a result of the survey operation carry this identifier.
- RFSurveySpecStopTrigger: This is the stop trigger for the RFSurveySpec. The triggers that are specifiable for a RFSurveySpec are listed in Table 1.
- AntennaID: This is the antenna at which the survey operation is to be executed.
- StartFrequency: This is the starting channel for which power levels need to be measured during this RF survey operation.
- EndFrequency: This is the ending channel for which power levels need to be measured during this RF survey operation. The RF survey operation is performed on frequency channels between the specified Start Frequency and End frequency.

AccessSpec: Details of an access operation.

- AccessSpecID: This identifier is generated by the Client upon creation of this AccessSpec. This identifier is used by the Client to perform operations on this AccessSpec, like start, stop and delete. Reports that are generated as a result of the execution of this AccessSpec also carry this identifier.
- AntennaID: This is the identifier of the antenna for whose tag observations this AccessSpec is executed.
- Air Protocol: This is the air protocol used to perform access operations on the tag.
- ROSpecID: This is the identifier of the ROSpec during whose tag observations this AccessSpec is executed.
- CurrentState: This is the current state of the AccessSpec – disabled, active. This field is kept up to date by the Reader based on the AccessSpec's current state.
- AccessSpecStopTrigger: If specified, this is the trigger to undefine the AccessSpec upon the occurrence of the stop trigger.
- AccessCommand: This parameter is used to configure the air protocol parameters for the access operation. At a minimum, this specifies the tag filters for which the access operations are to be performed, and the list of operations to be performed on the tag.
    - TagSpec: This describes the tag filters and is specified in terms of the air protocol's tag memory layout.
    - List of OpSpecs: This is specified in terms of the air protocol's tag access operations. The order of execution is determined by the order in which it is configured in the AccessSpec.
- AccessReportSpec: If specified, this defines when to send the results of this AccessSpec, and also the contents and format of the report.

6.1.1 Operation Triggers

This section describes the triggers that can be configured using LLRP to control the various operations.

6.1.1.1 Summary

The specific triggers used to control the various operations are presented in a tabular fashion.

Table 1: Operation Triggers

Trigger Name	*ROSpecStart*	*ROSpecStop*	*AISpecStop*	*AccessSpecStop*	*RFSurveySpec Stop*
GPI Trigger	X	-	-	-	-
GPI Trigger with Timeout	-	X	X	-	-
N attempts	-	-	X	-	-

N tag observations	-	-	X	-	-
No tag observations for t ms	-	-	X	-	-
Immediate	X	-	-	-	-
Null	X	X	X	X	X
Time Based Periodic	X	-	-	-	-
Time Based Duration	-	X	X	-	X
Operation Count	-	-	-	X	X

6.1.1.2 Reader Operation Triggers

The triggers SHALL operate as follows:

- Null: When used as a start or a stop trigger, it implies no start or stop conditions have been specified, respectively.
- Immediate: This is used as a start trigger. Operations using this trigger will start immediately.
- Time-based: There are two different types of time-based triggers defined in LLRP – periodic and duration.
    - Periodic: This is used as a start trigger. This is specified using UTC time [UTC], offset and period. For one-shot inventory, period is set to 0, and for periodic inventory operation, period > 0. If UTC time is not specified, the first start time is determined as (time of message receipt + offset), else, the first start time is determined as (UTC time + offset). Subsequent start times = first start time + k * period (where, k > 0).
    - Duration: This is used as a stop trigger.
- Tag observation based: There are three different types of tag-observation based triggers defined in LLRP. They are all used only as stop triggers. Each of these trigger types have a timeout value. So the trigger event happens when either the tag observation event happens or the timeout expires.
    - Upon seeing N tags, or timeout.
    - Upon seeing no more new tags for t milliseconds, or timeout
    - N attempts to see all the tags in the field of view, or timeout
- External events: These are due to events received at Reader interfaces like signal transition on a GPI port or a message on the network port.
    - GPI event at a GPI port, or a timeout
    - Client triggers: A Client can instruct the Reader to start/stop a particular operation using LLRP messages.

- Operation count: This is used as a stop trigger for RFSurvey. This trigger limits the number of times the Reader takes survey measurements across the specified frequency range.

AI and RFSurvey specs do not contain start triggers. The first spec (AISpec or RFSurveySpec) starts when the ROSpec enters the active state. The kth Spec in the ROSpec starts immediately after the completion of the k-1th Spec.

When Null is specified as a stop trigger for a Spec ((either AISpec or RFSurveySpec), the execution of the Spec is stopped only when the parent ROSpec's ROSpecDoneCondition occurs.

6.1.1.3 Access Operation Triggers

AccessSpecs do not contain start triggers. An AccessSpec when enabled using ENABLE_ACCESS_SPEC will transition to the active state. There is only one type of stop trigger for controlling the validity of an AccessSpec:

- Operation count: This is used as a stop trigger. This trigger is useful to limit the number of times the instance of the operation is executed during its lifetime.

6.2 Reporting, Event Notification and Keepalives

The results of the inventory, access and RF survey operations, will be sent by the Reader to the Client in the form of reports. Using LLRP, the Client is capable of setting up the triggers that determine when the report is to be sent by the Reader, and also the contents and format of the report. The report message is RO_ACCESS_REPORT. The triggers and report contents can be configured in one of the following ways:

- Differently for each ROSpec and AccessSpec when creating them using the ADD_ROSPEC and ADD_ACCESSSPEC messages, respectively.
- Global default using the SET_READER_CONFIG message.

Table 2 summarizes the triggers available in LLRP to control when the RO report and the AccessReport is to be generated and sent by the Reader.

Table 2: Reporting Triggers

Trigger Name	*ROReport*	*AccessReport*
None	X	-
(Upon N tags or End of Spec), where Spec = AISpec or RFSurveySpec	X	-
Upon N tags or End of ROSpec	X	-
End of AccessSpec	-	X
Whenever ROReport is generated for the RO that triggered the execution of	-	X

this AccessSpec		

In addition to data reports, the Client can configure the Reader to enable or disable notification of events as and when it happens at the Reader. Some examples of events are frequency hop, buffer overflow, etc.

In order to monitor the LLRP-layer connectivity with the Reader, the Client can configure the Reader to send Keepalives periodically. The Keepalive message is acknowledged by the Client, using which, the Reader can also monitor the LLRP-layer connectivity with a Client. The Keepalives can be disabled. If enabled, the periodicity of the message is specified by the Client.

7 Messages, Parameters and Fields

LLRP is a message-oriented protocol made up of data elements called protocol data units. This section provides the details of each message type and parameter type, and expresses them in an abstract manner. The section starts with an overview of the message types and parameters, where the messages are grouped into separate functional groups.

7.1 Overview

LLRP provides an extensible mechanism to support existing and new air protocols. It is achieved by decoupling messages from parameters – using a common message structure across air protocols, and providing extensibility in the form of parameters.

7.1.1 Formatting Conventions

LLRP messages and parameters are defined using the graphical notation below.

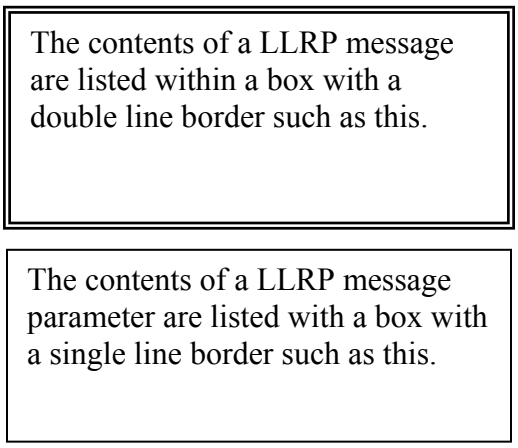


Figure 10: Box Formats for Messages and Parameters

Contained within the box is an ordered list of sub-parameters and fields contained within the message or parameter. The field/parameter names are shown in **boldface**, followed

by the data type and a brief description of the field/parameter when necessary. Fields with values that are restricted to a subset of the range of their data type have their possible and legal values shown in *italics* below the field name.

Fields are composed of one of the following basic data types:

Bit – An integer with only two possible values, 0 or 1

Bit Array – A sequence of bits.

Byte Array – A sequence of bytes.

Boolean – A field that can take the values TRUE or FALSE.

Integer – An integer can take any whole number. When this value is used in the abstract specification, the *Possible Values* element will specify the possible and legal value for a particular field.

Short Array – A sequence of unsigned short integers

Signed Integer – A signed integer can take any whole number value between -2^{31} through $2^{31}-1$ inclusive. Within the abstract specification, the *Possible Values* element will enumerate any restrictions beyond these limits for a particular field.

Signed Short Integer – A signed short integer can take any whole number value between -2^{15} through $2^{15}-1$ inclusive. Within the abstract specification, the *Possible Values* element will enumerate any restrictions beyond these limits for a particular field

Unsigned Integer – An unsigned integer is a value that is between 0 through $2^{32}-1$ inclusive. Within the abstract specification, the *Possible Values* element will enumerate any restrictions beyond these limits for a particular field.

Unsigned Long Integer – An unsigned long integer is a value that is between 0 through $2^{64}-1$ inclusive. Within the abstract specification, the *Possible Values* element will enumerate any restrictions beyond these limits for a particular field.

Unsigned Short Integer – An unsigned short integer is a value that is between 0 through $2^{16}-1$ inclusive. Within the abstract specification, the *Possible Values* element will enumerate any restrictions beyond these limits for a particular field.

UTF-8 String – A sequence of UTF-8 [UTF8] encoded characters.

In addition to the basic types, fields can be defined as 'lists' of a basic type. A list is an ordered set of a basic type. The order is preserved by all bindings.

7.1.2 Messages

Each Message contains:

- Version value that indicates the version of the protocol for this message.
- Message Type value that uniquely identifies it within a protocol message.
- Message ID: The Reader behavior SHALL be based upon starting the processing of messages in the order received over LLRP, however, the completion of

execution of the message processing MAY not necessarily be in the same order inside the Reader. Hence, the Reader responses to the messages may be in a different order than the order of the Client messages. The Message ID is to facilitate multiple outstanding messages/requests from Client or Reader. The communications between the Client and the Reader is primarily of a request-response type - requests/commands from the Client to the Reader, and response from the Reader to the Client. The Message ID is used to associate a Reader response with the original Client message.

- In addition, it may contain mandatory or optional parameters.

7.1.3 Parameters

LLRP Parameters are used to communicate specific details of LLRP operation in LLRP Messages. Each Parameter contains:

- Parameter Type value that uniquely identifies it within a Message.
- In addition, it may contain individual fields or sub-parameters.

7.1.3.1 General Parameters

This section describes the set of parameters that are used in multiple messages or parameters.

7.1.3.1.1 Timestamp

The timestamps in LLRP messages or parameters can be either the uptime or the UTC time [UTC]. If a Reader has an UTC clock, all timestamps reported by the Reader SHALL use an UTC timestamp parameter. If a Reader has no UTC clock capability, all timestamps reported by the Reader SHALL use the uptime parameter.

7.1.3.1.1.1 UTCTimestamp Parameter

Compliance requirement: Compliant Readers and Clients that have UTC clocks SHALL implement this parameter.

UTCTimestamp Parameter

MicroSeconds: Unsigned Long Integer. This is the time elapsed since the Epoch (00:00:00 UTC, January 1, 1970) measured in microseconds.

7.1.3.1.1.2 Uptime Parameter

Compliance requirement: Compliant Readers and Clients that do not have UTC clocks SHALL implement this parameter. Compliant Readers and Clients that have UTC clocks MAY implement this parameter.

Uptime Parameter

Microseconds: Unsigned Long Integer. This is the time elapsed since boot, measured in microseconds.

7.1.4 Fields

Messages and parameters may contain individual fields. In this section, we present the enumerations and the interpretation of the value of zero for certain fields.

ProtocolID: This is the identifier of the air protocol. The air protocol enumerations used in the LLRP protocol are as follows:

Table 3: Air Protocol Enumerations used in LLRP

Air Protocol Enumerations

Protocol ID : Integer

Possible Values:

Value	Protocol
0	Unspecified air protocol
1	EPCGlobal Class 1 Gen 2
2-255	Reserved for future use

Compliance requirement: Compliant Readers and Clients SHALL use this enumeration.

AntennaID, ROSpecID, AccessSpecID, GPIPort, GPOPort: These fields are identifiers for LLRP-related objects within the Reader. For example, AntennaID is the identifier of the antenna; ROSpecID is the identifier of the ROSpec. The objects are indexed from 1. A value of non-zero for a field is a specific instance of the respective object. A value of zero means all instances of the respective object.

7.1.5 Functional Grouping

The LLRP messages are grouped into:

- **Reader device capabilities**: Messages that query Reader capabilities. They include
  - GET_READER_CAPABILITIES
  - GET_READER_CAPABILITIES_RESPONSE
- **Reader operations control**: Messages that control the Reader's air protocol inventory and RF operations. They include
  - ADD_ROSPEC
  - ADD_ROSPEC_RESPONSE
  - DELETE_ROSPEC

- DELETE_ROSPEC_RESPONSE
- START_ROSPEC
- START_ROSPEC_RESPONSE
- STOP_ROSPEC
- STOP_ROSPEC_RESPONSE
- ENABLE_ROSPEC
- ENABLE_ROSPEC_RESPONSE
- DISABLE_ROSPEC
- DISABLE_ROSPEC_RESPONSE
- GET_ROSPECS
- GET_ROSPECS_RESPONSE

- **Access control**: Messages that control the tag access operations performed by the Reader. They include
  - ADD_ACCESSSPEC
  - ADD_ACCESSSPEC_RESPONSE
  - DELETE_ACCESSSPEC
  - DELETE_ACCESSSPEC_RESPONSE
  - ENABLE_ACCESSSPEC
  - ENABLE_ACCESSSPEC_RESPONSE
  - DISABLE_ACCESSSPEC
  - DISABLE_ACCESSSPEC_RESPONSE
  - GET_ACCESSSPECS
  - GET_ACCESSSPECS_RESPONSE
  - CLIENT_REQUEST_OP
  - CLIENT_REQUEST_OP_RESPONSE
- **Reader device configuration**: Messages that query/set Reader configuration, and close LLRP connection. They include
  - GET_READER_CONFIG
  - GET_READER_CONFIG_RESPONSE
  - SET_READER_CONFIG
  - SET_READER_CONFIG_RESPONSE
  - CLOSE_CONNECTION
  - CLOSE_CONNECTION_RESPONSE

- **Reports**: These are messages that carry different reports from the Reader to the Client. Reports include Reader device status, tag data, RF analysis report. They include
    - GET_REPORT
    - RO_ACCESS_REPORT
    - READER_EVENT_NOTIFICATION
    - KEEPALIVE
    - KEEPALIVE_ACK
    - ENABLE_EVENTS_AND_REPORTS
- **Custom Extension**: This is a common mechanism for messages that contain vendor defined content.
    - CUSTOM_MESSAGE
- **Errors:** Typically the errors in the LLRP defined messages are conveyed inside of the responses from the Reader. However, in cases where the message received by the Reader contains an unsupported message type, or a CUSTOM_MESSAGE with unsupported parameters or fields, the Reader SHALL respond with this generic error message.
    - ERROR_MESSAGE

LLRP parameters are used to communicate specific settings of LLRP operation in the messages. A parameter contains one or more fields, and in some cases also may nest one or more other parameters.

Typically, each message type has its own set of parameters; however, there may be exceptions in some cases, where two different message types use the same parameter because they require the same setting exposed by the parameter.

7.1.6 LLRP Messages and Actions

This section describes the corresponding LLRP-related actions in the Reader upon receiving the various LLRP protocol messages. Figure 11 uses UML synchronous messaging notation. Messages are asynchronous.

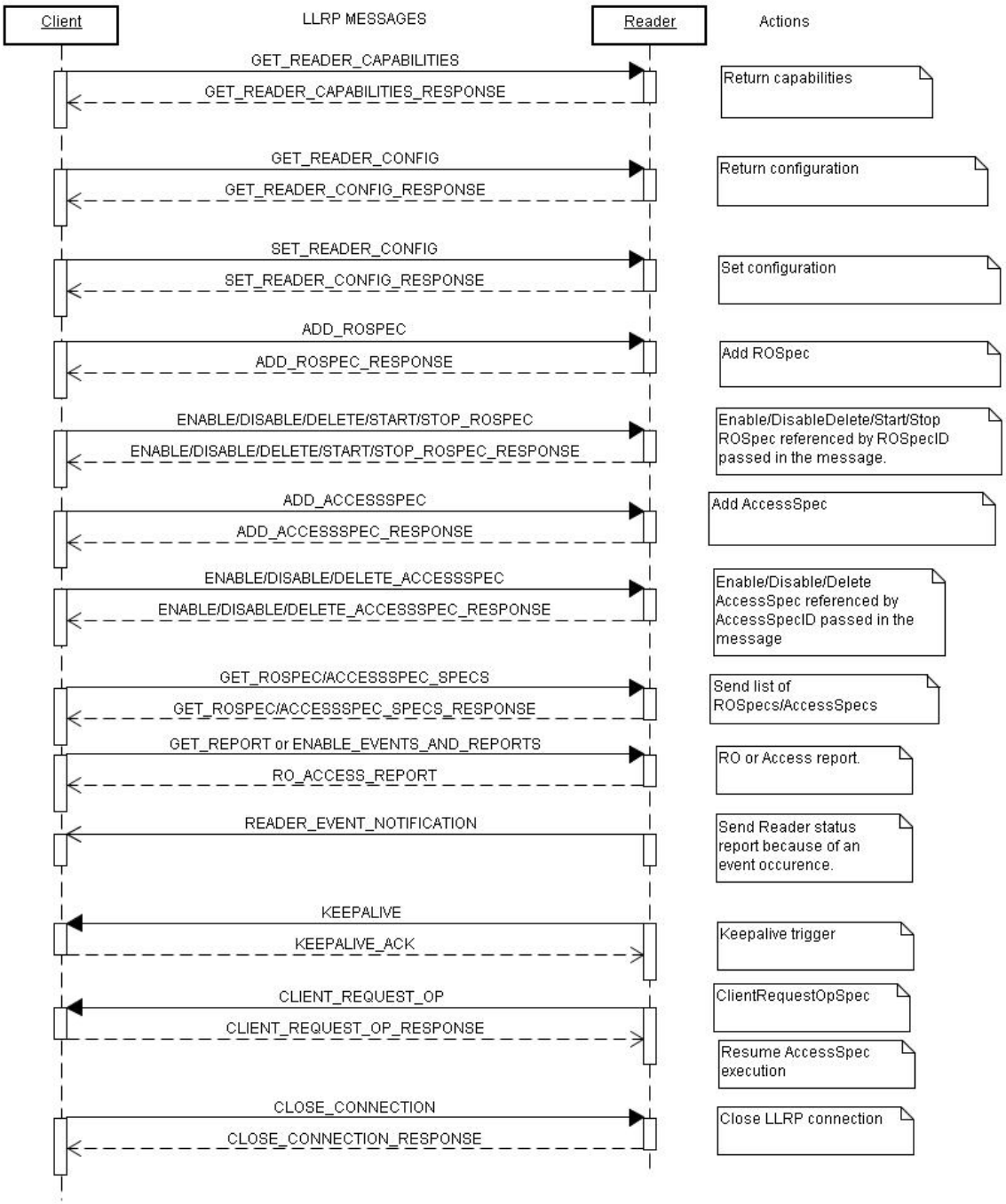


Figure 11: LLRP Messages and Reader Actions

8 Custom Extension

LLRP supports vendor extensions for defining commands and parameters within certain commands. All LLRP bindings support these extension mechanisms.

8.1 CUSTOM_MESSAGE

This message carries a vendor defined format from Reader to Client or Client to Reader. In addition to the version and messageID, the custom message also carries the information below.

CUSTOM_MESSAGE
Vendor Identifier: Unsigned Integer**.** IANA Private Enterprise Number
Message Subtype: Integer
Possible Values: 0-255.
Data: vendor specific format

No requirements are made as to the content or parameters contained within the Data portion of these messages. Clients MAY ignore CUSTOM_MESSAGEs. Readers SHALL accept CUSTOM_MESSAGE and return an ERROR_MESSAGE if CUSTOM_MESSAGE is unsupported by the Reader or the CUSTOM_MESSAGE contains fields and/or parameters that are unsupported by the Reader.

8.2 Custom Parameter

Certain Messages and Parameter Sets within LLRP allow for the insertion of vendor defined parameters. These custom parameters have the following format.

Custom Parameter
Vendor Identifier: Unsigned Integer**.** IANA Private Enterprise Number
Parameter Subtype: Unsigned Integer**Data**: vendor specific format

Clients SHALL accept messages (except for CUSTOM_MESSAGE) that contain custom parameters but MAY ignore all custom parameters within these messages. Readers SHALL accept messages (except for CUSTOM_MESSAGE) that contain custom parameters and SHALL return an error when such parameters are unsupported.

8.3 Custom Extension in Commands

The following commands allow one or more custom Parameters in their message structure:

GET_READER_CAPABILITIES

GET_READER_CONFIG

GET_READER_CAPABILITIES_RESPONSE

GET_READER_CONFIG_RESPONSE

SET_READER_CONFIG

8.4 Custom Extension in Individual LLRP Parameters

LLRP only allows extension to parameters where the parameter set is defined with a custom Parameter type in the abstract model. All custom extension points will be marked in the abstract standard using the notation

Custom Extension Point List: List of <custom Parameter> [optional]

The following example illustrates a fictitious parameter that allows the embedding of custom extension parameters.

> **Example Parameter**
>
> **Field1**: Unsigned Integer
>
> **relatedData**: Example Sub Parameter
>
> **Custom Extension Point List**: List of <custom Parameter> [optional]

This example shows that the Example Parameter could contain an optional custom parameter that must adhere to the custom Parameter format.

8.5 Allowable Parameter Extension

All parameter values are specified within the abstract binding. A Reader or Client SHALL NOT extend the range of fields defined within the abstract specification unless the possible values indicate ranges for user defined options.

For example, the Indentification Parameter defines a field to carry the ID type.

IDType: Integer

Possible Values:

IDType	ID
0	MAC address
1	EPC

A Client or Reader adhering to the standard SHALL generate an **IDType** field with only those values shown (0-1). A Reader or Client implementation SHALL generate an error upon receiving a value outside this range.

9 Reader Device Capabilities

There are four broad categories of capabilities that are advertised by the Reader: general device, LLRP, regulatory, and air protocol capabilities.

9.1 Messages

9.1.1 GET_READER_CAPABILITIES

This message is sent from the Client to the Reader. The Client is able to request only a subset or all the capabilities from the Reader.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

GET_READER_CAPABILITIES

RequestedData: Integer

Possible Values:

Value	Requested Data
0	All
1	General Device Capabilities
2	LLRP Capabilities
3	Regulatory Capabilities
4	Air Protocol LLRP Capabilities

Custom Extension Point List: List of <custom Parameter> [optional]

9.1.2 GET_READER_CAPABILITIES_RESPONSE

This is the response from the Reader to the GET_READER_CAPABILITIES message. The response contains the LLRPStatus Parameter and the list of parameters for the requested capabilities conveyed via RequestedData in the GET_READER_CAPABILITIES message.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

GET_READER_CAPABILITIES_RESPONSE

Response Data: Set of LLRP Parameters.

Possible Values: The possible members are

<LLRPStatus Parameter>, and,

one or more from the set

< GeneralDeviceCapabilities Parameter,

LLRPCapabilities Parameter,

RegulatoryCapabilities Parameter,

AirProtocolLLRPCapabilities Parameter >.

Custom Extension Point List: List of <custom Parameter> [optional]

9.2 Parameters

9.2.1 GeneralDeviceCapabilities Parameter

This parameter carries the general capabilities of the device like supported air protocols, version of the Reader firmware, device hardware and software information, and receive sensitivity table.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

GeneralDeviceCapabilities Parameter

Device manufacturer name: Unsigned Integer. The IANA Private Enterprise Number (PEN).

Model name: Unsigned Integer

Firmware version: UTF-8 String

Maximum number of antennas supported: Unsigned Short Integer

CanSetAntennaProperties: Boolean. If set to true, the Client can set antenna properties (Section 12.2.5), else, the Client can not set it, but only query it using GET_READER_CONFIG.

Receive Sensitivity Table: List of <ReceiveSensitivityTableEntry Parameter>

Per Antenna Receive Sensitivity Range: List of <PerAntennaReceiveSensivityRange Parameter>

Air protocol supported per antenna: N instances of<PerAntennaAirProtocol Parameter>, where N = Maximum number of antennae supported.

GPIO Support: <GPIO Capabilities Parameter>

HasUTCClockCapability: Boolean. If set to true, the Reader reports time based on UTC timestamps (Section 7.1.3.1.1.1) in its reports, else, the Reader reports time based on Uptime (Section 7.1.3.1.1.2) in its reports.

9.2.1.1 ReceiveSensitivityTableEntry Parameter

This parameter specifies the index into the Receive Sensitivity Table for a receive sensitivity value. The receive sensitivity is expressed in dB and the value is relative to the maximum sensitivity. If the Reader does not allow control of receive sensitivity, a table of one entry is returned, the entry having the value of zero.

If the Reader allows control of receive sensitivity and the Reader also supports multiple antennas where the antennas can have different receive sensitivity values, then the Receive Sensitivity Table should be a set of values representing the union of sensitivity values for all antennas.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

ReceiveSensitivityTableEntry Parameter

Index: Unsigned Short Integer

Receive sensitivity value: Integer. The value is in dB relative to the maximum sensitivity.

Possible Values: 0 to 128.

9.2.1.2 PerAntennaReceiveSensitivityRange Parameter

For a particular antenna, this parameter specifies the Reader's valid index range in the Receive Sensitivity Table. A Reader should report this parameter if the Reader allows control of receive sensitivity (i.e., the Reader reports a Receive Sensitivity Table with more than one entry) and the Reader supports multiple antennas where the antennas can have different receive sensitivity values.

If this parameter is omitted, then the Client SHALL assume that for all of the Reader's antennas the index range is the same as in the Receive Sensitivity Table.

Compliance requirement: Compliant Readers and Clients MAY implement this parameter.

PerAntennaReceiveSensitivityRange Parameter

Antenna ID: Unsigned Short Integer

Possible Values:

1 to N, where N is the maximum number of antennas supported by the device.

ReceiveSensitivityIndexMin: Unsigned Short Integer

Possible Values:

0 to S, where S is the number of Receive Sensitivity Table entries reported by the Reader.

ReceiveSensitivityIndexMax: Unsigned Short Integer

Possible Values:

Mn to S, where Mn is the ReceiveSensitivityIndexMin and S is the number of Receive Sensitivity Table entries reported by the Reader.

9.2.1.3 PerAntennaAirProtocol Parameter

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

PerAntennaAirProtocol Parameter

Antenna ID: Unsigned Short Integer

Possible Values:

1 to N, where N is the maximum number of antennas supported by the device.

Air protocols supported: List of Protocol Ids enumerated based on Table 3.

9.2.1.4 GPIOCapabilities Parameter

This parameter describes the GPIO capabilities of the Reader. A value of zero for NumGPIs indicates that the Reader does not have general purpose inputs. A value of zero for NumGPOs indicates that the Reader does not have general purpose outputs.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

GPIOCapabilities Parameter

NumGPIs: Unsigned Short Integer. Number of general purpose inputs supported by the device.

NumGPOs: Unsigned Short Integer. Number of general purpose outputs supported by the device.

9.2.2 LLRPCapabilities Parameter

This parameter describes the LLRP protocol capabilities of the Reader. These include optional LLRP commands and parameters, capacities of data structures used in LLRP operations, and air protocol specific capabilities used by LLRP.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter. Readers MAY support RFSurvey, MAY support tag inventory state aware singulation, MAY support UTC clocks, MAY support buffer fill warning reports, MAY support EventAndReportHolding upon reconnect, and MAY support ClientRequestOpspec. Readers SHALL support at least one ROSpec, one AISpec per ROSpec, one InventoryParameterSpec per AISpec, one AccessSpec, and one OpSpec per AccessSpec.

LLRPCapabilities Parameter

CanDoRFSurvey: Boolean. If set to true, the Reader can perform RFSurvey operations (Section 10.2.3).

CanDoTagInventoryStateAwareSingulation: Boolean. If set to true, the Reader can support tag inventory state aware singulation.

CanReportBufferFillWarning: Boolean. If set to true, the Reader can report buffer fill warning in the reader event notification (Section 13.2.6.5).

MaxNumROSpecs: Integer. If zero, there is no limit. This is the maximum number of ROSpecs that can be configured at the Reader.

MaxNumSpecsPerROSpec: Integer. If zero, there is no limit. This is the maximum number of Specs (either AISpec or RFSurveySpec) that can be configured as part of a

ROSpec at the Reader.

MaxNumInventoryParameterSpecsPerAISpec: Integer. If zero, there is no limit. This is the maximum number of InventoryParameterSpecs that can be configured per AISpec.

MaxPriorityLevelSupported: Integer. This is the maximum priority level supported in the reader. If set to less than or equal to 1, the Reader has no preemption support.

Possible Values: 0-7.

MaxNumAccessSpecs: Integer. If zero, there is no limit. This is the maximum number of AccessSpecs that can be configured at the Reader.

MaxNumOpSpecsPerAccessSpec: Integer. If zero, there is no limit. This is the maximum number of OpSpecs that can be configured per AccessSpec at the Reader.

SupportsClientRequestOpSpec: Boolean. If set to true, the Reader supports client request OpSpecs (Section 11.2.1.2.1).

ClientRequestOpSpecTimeout: Unsigned Short Integer (in milliseconds). The time the Reader will wait for the CLIENT_REQUEST_OP_RESPONSE from the Client after sending a RO_ACCESS_REPORT message upon executing the ClientRequestOpSpec OpSpec. This field is valid only if the Reader supports ClientRequestOpSpec (Section 11.2.1.2.1). If this field is 0, there is no limit.

SupportsEventAndReportHolding: Boolean. If set to True, the Reader supports the EventsAndReports Parameter and the ENABLE_EVENTS_AND_REPORTS message. If set to false, the Reader does not support the ENABLE_EVENTS_AND_REPORTS message or the EventsAndReports Parameter.

9.2.3 AirProtocolLLRPCapabilities Parameter

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

AirProtocolLLRPCapabilities Parameter

Each air protocol's capabilities are expressed in a different LLRP Parameter. Each protocol's air protocol capabilities parameter SHALL be referenced not more than once. The air protocol specific capabilities LLRP Parameters are defined in section 15.1.

9.2.4 RegulatoryCapabilities Parameter

This parameter carries the RF regulation specific attributes. They include regulatory standard, frequency band information, power levels supported, frequencies supported, and any air protocol specific values that are determined based on regulatory restriction.

The regulatory standard is encoded using two Integer fields, <Country Code, Communications standard> and it specifies the current operational regulatory mode of the device. This should not be used to reflect the ability to operate in regulatory environments which require configuration different from the current. This version of the LLRP protocol will have support for only the UHF band.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

RegulatoryCapabilities Parameter

Country Code: Unsigned Short Integer. This field carries the numeric code of the country as specified in ISO 3166 [ISO3166]. 0 means unspecified.

Communications Standard: Unsigned Short Integer. This field carries the enumerations of the communications standard as specified below.

Possible Values:

Value	Communications Standard
0	Unspecified
1	US FCC Part 15
2	ETSI 302-208
3	ETSI 300-220
4	Australia LIPD 1W
5	Australia LIPD 4W
6	Japan: ARIB STD T89
7	Hong Kong: OFTA 1049
8	Taiwan: DGT LP0002
9	Korea: MIC Article 5-2
10-65535	Reserved for future use

UHFBandCapabilities: <UHFBandCapabilities Parameter> [optional]

Custom Extension Point List: List of <custom Parameter> [optional]

9.2.4.1 UHFBandCapabilities Parameter

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

UHFBandCapabilities Parameter

TransmitPowerTable: List of <TransmitPowerLevelTableEntry Parameter>

Frequency Information: <FrequencyInformation Parameter>

UHF_RFModeTable: List of LLRP Parameter.

Possible Values:

Each air protocol's UHF RF mode table is expressed as a different LLRP parameter. Each protocol SHALL be referenced not more than once. The air protocol's UHF RF mode table capabilities LLRP Parameters are defined in section 15.1.

9.2.4.1.1 TransmitPowerLevelTableEntry Parameter

This parameter specifies the index into the TransmitPowerLevelTable for a transmit power value. The transmit power is expressed in dBm*100 to allow fractional dBm representation and is the conducted power at the connector of the Reader.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

TransmitPowerLevelTableEntry Parameter

Index: Integer

Possible Values: 0-255

Transmit power value: Signed short integer. Transmit power expressed in dBm*100 to allow fractional dBm representation.

9.2.4.1.2 FrequencyInformation Parameter

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

Frequency Information Parameter

Hopping: Boolean

Freq Hop Info: Zero or more instances of <FrequencyHopTable Parameter>. This is transmitted only when Hopping = true.

Fixed Freq Info: At most one instance of <FixedFrequencyTable>. This is transmitted only when Hopping = false.

9.2.4.1.2.1 FrequencyHopTable Parameter

This parameter carries the frequency hop table parameters. This is used for Readers operating in regions with frequency hopping regulatory requirements. If the Reader is capable of storing multiple hop tables, the Reader may send all of them to the Client. Each hop table contains:

- HopTableID which is the index of the frequency hop table returned by the Reader.
- This is followed by a list of the frequencies (in kHz) in hop table order. The one-based position of a frequency in the list is defined as its ChannelIndex (i.e. the first frequency is referred to as ChannelIndex one).

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter when operating in frequency hopping regulatory regions.

FrequencyHopTable Parameter

HopTableID : Integer

Possible Values: 0 - 255

Frequency Hop List: List of unsigned integers. Frequency in kHz.

If multiple frequency hop tables are supported by the Reader, each table can be sent using a separate Frequency Hop Table Parameter.

9.2.4.1.2.2 FixedFrequencyTable Parameter

This parameter carries the fixed frequency list that can be used by the Reader. The one-based position of a frequency in the list is defined as its ChannelIndex (i.e. the first frequency is referred to as ChannelIndex one).

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter when operating in fixed frequency regulatory regions.

Fixed Frequency Parameter
Frequency List: List of unsigned integers. Frequency in kHz.

10 Reader Operation (RO)

This section presents the messages and the parameters used by the Client for specifying RO.

10.1 Messages

10.1.1 ADD_ROSPEC

An ADD_ROSPEC message communicates the information of a *ROSpec* to the Reader. LLRP supports configuration of multiple ROSpecs. Each ROSpec is uniquely identified using a ROSpecID, generated by the Client. The *ROSpec* starts at the Disabled state waiting for the ENABLE_ROSPEC message for the *ROSpec* from the Client, upon which it transitions to the Inactive state.

The Client SHALL add a ROSpec in a Disabled State – i.e., CurrentState field in the ROSpec Parameter (section 10.2.1) SHALL be set to disabled. If the CurrentState value is different than disabled, an error SHALL be returned in the ADD_ROSPEC_RESPONSE (e.g. P_FieldError).

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

ADD_ROSPEC
ROSpec: ROSpec Parameter

10.1.2 ADD_ROSPEC_RESPONSE

This is the response by the Reader to an ADD_ROSPEC message. If all the parameters specified in the ADD_ROSPEC command are successfully set, then the success code is returned in the LLRPStatus parameter. If there is an error, the appropriate error code is returned in the LLRPStatus parameter.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

ADD_ROSPEC_RESPONSE
Response: LLRPStatus Parameter

10.1.3 DELETE_ROSPEC

This command is issued by the Client to the Reader. This command deletes the ROSpec at the Reader corresponding to ROSpecID passed in this message.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

DELETE_ROSPEC

ROSpecID: Unsigned Integer. The identifier of the ROSpec to delete. 0 indicates to delete all ROSpecs.

10.1.4 DELETE_ROSPEC_RESPONSE

This is the response by the Reader to a DELETE_ROSPEC command. If there was a ROSpec corresponding to the ROSpecID that the Reader was presently executing, and the Reader was successful in stopping that execution, then the success code is returned in the LLRPStatus parameter. If there is an error, the appropriate error code is returned in the LLRPStatus parameter.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

DELETE_ROSPEC_RESPONSE

Response: LLRPStatus Parameter

10.1.5 START_ROSPEC

This message is issued by the Client to the Reader. Upon receiving the message, the Reader starts the ROSpec corresponding to ROSpecID passed in this message, if the ROSpec is in the enabled state.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

START_ROSPEC

ROSpecID: Unsigned Integer. The identifier of the ROSpec to start.

Possible Values: 0 is disallowed.

10.1.6 START_ROSPEC_RESPONSE

This is the response by the Reader to a START_ROSPEC command. If there was a ROSpec corresponding to the ROSpecID in the enabled state, and the Reader was able to start executing that ROSpec, then the success code is returned in the LLRPStatus parameter. If there is an error, the appropriate error code is returned in the LLRPStatus parameter.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

START_ROSPEC_RESPONSE

Response: LLRPStatus Parameter

10.1.7 STOP_ROSPEC

This message is issued by the Client to the Reader. Upon receiving the message, the Reader stops the execution of the ROSpec corresponding to the ROSpecID passed in this message. STOP_ROSPEC overrides all other priorities and stops the execution. This basically moves the ROSpec's state to Inactive. This message does not the delete the ROSpec.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

STOP_ROSPEC

ROSpecID: Unsigned Integer. The identifier of the ROSpec to stop.

Possible Values: 0 is disallowed.

10.1.8 STOP_ROSPEC_RESPONSE

This is the response by the Reader to a STOP_ROSPEC command. If the Reader was currently executing the ROSpec corresponding to the ROSpecID, and the Reader was able to stop executing that ROSpec, then the success code is returned in the LLRPStatus parameter. If there is an error, the appropriate error code is returned in the LLRPStatus parameter.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

STOP_ROSPEC_RESPONSE

Response: LLRPStatus Parameter

10.1.9 ENABLE_ROSPEC

This message is issued by the Client to the Reader. Upon receiving the message, the Reader moves the ROSpec corresponding to the ROSpecID passed in this message from the disabled to the inactive state.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

ENABLE_ROSPEC

ROSpecID: Unsigned Integer. The identifier of the ROSpec to enable. If set to 0, all ROSpecs are enabled.

10.1.10 ENABLE_ROSPEC_RESPONSE

This is the response by the Reader to a ENABLE_ROSPEC command. If there was a ROSpec corresponding to the ROSpecID, and the Reader was able to enable that ROSpec, then the success code is returned in the LLRPStatus parameter. If there is an error, the appropriate error code is returned in the LLRPStatus parameter.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

ENABLE_ROSPEC_RESPONSE
Response: LLRPStatus Parameter

10.1.11 DISABLE_ROSPEC

This message is issued by the Client to the Reader. Upon receiving the message, the Reader moves the ROSpec corresponding to the ROSpecID passed in this message to the disabled state.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

DISABLE_ROSPEC
ROSpecID: Unsigned Integer. The identifier of the ROSpec to disable. If set to 0, all ROSpecs are disabled.

10.1.12 DISABLE_ROSPEC_RESPONSE

This is the response by the Reader to a DISABLE_ROSPEC command. If there was a ROSpec corresponding to the ROSpecID, and the Reader was able to disable that ROSpec, then the success code is returned in the LLRPStatus parameter. If there is an error, the appropriate error code is returned in the LLRPStatus parameter.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

DISABLE_ROSPEC_RESPONSE
Response: LLRPStatus Parameter

10.1.13 GET_ROSPECS

This is the request from the Client to the Reader to retrieve all the ROSpecs that have been configured at the Reader.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

GET_ROSPECS

10.1.14 GET_ROSPECS_RESPONSE

This is the response by the Reader to a GET_ROSPECS command. If there are no ROSpecs configured at the Reader, the response is just the LLRPStatus parameter with the success code. Else, a list of ROSpec parameter is returned by the Reader, along with the success code in the LLRPStatus parameter.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

GET_ROSPECS_RESPONSE
Status: LLRPStatus Parameter
Response: List of <ROSpec Parameter> that are in the order in which they are added.

10.2 Parameters

10.2.1 ROSpec Parameter

This parameter carries the information of the Reader inventory and survey operation.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

ROSpec Parameter

ROSpecID: Unsigned Integer; 0 is an illegal ROSpecID for a ROSpec.

Priority: Integer. Lower numbered priority values are given higher priority.

Possible Values: 0-7.

CurrentState: Integer

Possible Values:

Value	Definition
0	Disabled
1	Inactive
2	Active

ROBoundarySpec: ROBoundarySpec Parameter**ListOfSpecs:** List of <AISpec Parameter> and/or <RFSurveySpec Parameter> and/or Custom Parameter.

ROReportSpec: ROReportSpec Parameter [optional] (Section 13.2.1)

10.2.1.1 ROBoundarySpec Parameter

This parameter carries the lifetime of the command, ROStartTrigger and ROStopTrigger parameters.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

ROBoundarySpec Parameter

ROSpecStartTrigger: ROSpecStartTrigger Parameter

ROSpecStopTrigger: ROSpecStopTrigger Parameter

10.2.1.1.1 ROSpecStartTrigger Parameter

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

ROSpecStartTrigger Parameter

ROSpecStartTriggerType: Integer

Possible Values:

Value	Definition
0	Null – No start trigger. The only way to start the ROSpec is with a START_ROSPEC from the Client.
1	Immediate
2	Periodic
3	GPI

PeriodicTriggerValue: PeriodicTriggerValue Parameter [Optional]. This parameter SHALL be present when ROSpecStartTriggerType = 2.

GPITriggerValue: GPITriggerValue Parameter [Optional]. This parameter SHALL be present when ROSpecStartTriggerType = 3.

10.2.1.1.1.1 PeriodicTriggerValue Parameter

Periodic trigger is specified using UTC time, offset and period.

For one-shot inventory, period is set to 0, and for periodic inventory operation period > 0.

If UTC time is not specified, the first start time is determined as (time of message receipt + offset), else, the first start time is determined as (UTC time + offset). Subsequent start times = first start time + k * period (where, k > 0).

If the Reader does not support UTC clock (as indicated by HasUTCClockCapability), and it receives the UTC time as part of the PeriodicTriggerValue parameter from the Client, the Reader SHALL return an error.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter. Compliant Readers and Clients MAY implement the UTCTimestamp parameter.

PeriodicTriggerValue Parameter

UTC Time: <UTCTimestamp Parameter> [Optional]

Offset: Unsigned Integer. Time offset specified in milliseconds.

Period: Unsigned Integer. Time period specified in milliseconds

10.2.1.1.1.2 GPITriggerValue Parameter

This trigger is tied to an event on the General Purpose Input (GPI) of the Reader. The event is represented as a boolean type, and it is up to the internal implementation of the Reader to map exact physical event to a boolean type. For example, a 0 → 1 and a 1 → 0 transition on an input pin of the Reader could be mapped to a boolean true and a boolean false event respectively.

This trigger parameter has a timeout value field. The timeout is useful for specifying a fail-safe timeout when this trigger is used as a stop trigger. When the timeout is 0, it indicates that there is no timeout. When used as a start trigger, the timeout value SHALL be ignored.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter. Readers that do not support GPIs SHALL return zero for numGPIs in the capabilities discovery. If the Client sets up the GPI trigger for such a Reader, the Reader SHALL send an error message for the ADD_ROSPEC message and not add the ROSpec.

GPITriggerValue Parameter

GPIPortNum: Unsigned Short Integer.

Possible Values: 1-65535. Zero is invalid.

GPIEvent: Boolean. The Boolean value that causes a GPI event to trigger.

Timeout: Unsigned Integer. Trigger timeout in milliseconds. If set to zero, it indicates there is no timeout.

10.2.1.1.2 ROSpecStopTrigger Parameter

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

ROSpecStopTrigger Parameter

ROSpecStopTriggerType: Integer

Possible Values:

Value	Definition
0	Null – Stop when all AISpecs are done, or when Preempted, or with a STOP_ROSPEC from the Client.
1	Duration
2	GPI with a timeout value

DurationTriggerValue: Duration in milliseconds. This field is ignored when ROSpecStopTriggerType != 1.

GPITriggerValue: GPITriggerValue Parameter [Optional]. This parameter SHALL be present when ROSpecStopTriggerType = 2.

10.2.2 AISpec Parameter

This parameter defines antenna inventory operations.

Compliance Requirement: Compliant Readers and Clients SHALL implement this parameter.

AISpec Parameter

AISpecStopTrigger: <AISpecStopTrigger Parameter>

AntennaIDs: Short Array. If this set contains an antenna ID of zero, this AISpec will utilize all the antennas of the Reader.

InventoryParameterSpecs: <List of InventoryParameterSpec Parameter>

Custom Extension Point List: List of <custom Parameter> [Optional]

10.2.2.1 AISpecStopTrigger Parameter

This parameter defines the stop (i.e., terminating boundary) of an antenna inventory operation.

Compliance Requirement: Compliant Readers and Clients SHALL implement this parameter. If a Reader reports NumGPIs (see GPIO Capabilities Parameter) greater than zero, then the Reader SHALL support GPI Trigger.

AISpecStopTrigger Parameter

AISpecStopTriggerType: Integer

*Possible Values***:**

Value	Definition
0	Null – Stop when ROSpec is done.
1	Duration
2	GPI with a timeout value
3	Tag observation

Duration Trigger: Unsigned Integer. Duration of AISpec in milliseconds. This field SHALL be ignored when AISpecStopTriggerType != 1.

GPI Trigger : GPITrigger value Parameter [Optional]. This field SHALL be present when AISpecStopTriggerType = 2.

TagObservation Trigger : TagObservation Trigger Parameter [Optional]. This field SHALL be present when AISpecStopTriggerType = 3.

10.2.2.1.1 TagObservationTrigger Parameter

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

Tag ObservationTrigger Parameter

TriggerType: Integer

Possible Values:

Value	Modulation
0	Upon seeing N tag observations, or timeout

1	Upon seeing no more new tag observations for t ms, or timeout
2	N attempts to see all tags in the FOV, or timeout

NumberOfTags: Unsigned Short Integer. This field SHALL be ignored when TriggerType != 0.

NumberOfAttempts; Unsigned Short Integer. This field SHALL be ignored when TriggerType != 2.

T : Unsigned Short Integer. Idle time between tag responses in milliseconds. This field SHALL be ignored when TriggerType != 1.

Timeout : Unsigned Integer; Trigger timeout value in milliseconds. If set to zero, it indicates that there is no timeout.

10.2.2.2 InventoryParameterSpec Parameter

This parameter defines the inventory operation to be performed at all antennas specified in the corresponding AISpec. This parameter is composed of an InventoryParameterSpecID, a ProtocolID, and zero or more optional antenna configuration parameters. Antenna configurations for antennas not indicated by the AntennaIDs within the AISpec are ignored by the reader.

Compliance Requirement: Compliant Readers and Clients SHALL implement this parameter.

InventoryParameterSpec Parameter

InventoryParameterSpecID: Unsigned Short Integer. 0 is illegal.

ProtocolID: Integer. Enumeration based on Table 3.

AntennaConfiguration: List of <AntennaConfiguration Parameter> (Section 12.2.6) [Optional]

Custom Extension Point List: List of <Custom Parameter> [Optional]

10.2.3 RFSurveySpec Parameter

This parameter defines RF Survey operations. RF Survey is an operation during which the Reader performs a scan and measures the power levels across a set of frequencies at an antenna. This parameter defines the identifier of the antenna where this survey is to be performed, the duration of the survey operation (specified via stop trigger), and the range of frequencies to measure power levels of.

Compliance Requirement: Compliant Readers and Clients MAY implement this parameter.

RFSurveySpec Parameter

Antenna ID: Unsigned Short Integer.

Possible Values: 1 to N, where N is the maximum number of antennas supported

by the Reader.

RFSurveySpecStopTrigger: RFSurveySpecStopTrigger parameter

StartFrequency: Unsigned Integer. The start (lower bound) frequency to survey specified in kHz.

EndFrequency: Unsigned Integer in kHz. The end (upper bound) frequency to survey specified in kHz.

Custom Extension Point List: List of <custom Parameter> [Optional]

10.2.3.1 RFSurveySpecStopTrigger Parameter

This parameter defines the stop trigger for RF Survey operations.

Compliance Requirement: Compliant Readers and Clients MAY implement this parameter.

RFSurveySpecStopTrigger Parameter

StopTriggerType: Integer

Possible Values:

Value	Definition
0	Null
1	Duration
2	N iterations through the frequency range

Duration: Unsigned Integer; The maximum duration of the RFSurvey operation specified in milliseconds. This field SHALL be ignored when StopTriggerType != 1. When StopTriggerType = 1, the value SHALL be greater than zero.

N: Unsigned Integer. The maximum number of iterations through the specified frequency range. This field SHALL be ignored when StopTriggerType != 2. When StopTriggerType = 2, the value SHALL be greater than zero.

11 Access Operation

This section presents the messages and the parameters used by the Client for specifying access operation.

11.1 Messages

11.1.1 ADD_ACCESSSPEC

This command creates a new AccessSpec at the Reader. The *AccessSpec* starts at the Disabled state waiting for the ENABLE_ACCESSSPEC message for the *AccessSpec* from the Client, upon which it transitions to the Active state. The AccessSpecID is generated by the Client.

The Client SHALL add an AccessSpec in a Disabled State – i.e., CurrentState field in the AccessSpec Parameter (section 11.2.1) SHALL be set to false. If the CurrentState value

is different than false, an error SHALL be returned in the ADD_ACCESSSPEC_RESPONSE (e.g. P_FieldError).

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

ADD_ACCESSSPEC

AccessSpec: AccessSpec parameter

11.1.2 ADD_ACCESSSPEC_RESPONSE

This is the response by the Reader to an ADD_ACCESSSPEC command. If the parameters passed in that ADD_ACCESSSPEC command were successfully accepted and set at the Reader, then the success code is returned in the LLRPStatus parameter. However, if the *AccessSpec* was not successfully created at the Reader, the Reader sends a LLRPStatus parameter describing the error in the message.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

ADD_ACCESSSPEC_RESPONSE

Response: LLRPStatus Parameter

11.1.3 DELETE_ACCESSSPEC

This command is issued by the Client to the Reader. The Reader deletes the AccessSpec corresponding to the AccessSpecId, and this AccessSpec will stop taking effect from the next inventory round.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

DELETE_ACCESSSPEC

AccessSpecID : Unsigned Integer.

Possible Values: If set to 0, all AccessSpecs are deleted.

11.1.4 DELETE_ACCESSSPEC_RESPONSE

This is the response by the Reader to a DELETE_ACCESSSPEC command. If there was an AccessSpec at the Reader corresponding to the AccessSpecID passed in the DELETE_ACCESSSPEC command, and the Reader was successful in deleting that AccessSpec, then the success code is returned in the LLRPStatus parameter. If there is an error, the appropriate error code is returned in the LLRPStatus parameter.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

DELETE_ACCESSSPEC_RESPONSE

Response: LLRPStatus Parameter

11.1.5 ENABLE_ACCESSSPEC

This message is issued by the Client to the Reader. Upon receiving the message, the Reader moves the AccessSpec corresponding to the AccessSpecID in this message from the Disabled state to the Active state. The Reader executes this access-spec until it gets a DISABLE_ACCESSSPEC or a DELETE_ACCESSSPEC from the Client. The AccessSpec takes effect with the next (and subsequent) inventory rounds.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

ENABLE_ACCESSSPEC

AccessSpecID: Unsigned Integer. If set to 0, all AccessSpecs are enabled.

11.1.6 ENABLE_ACCESSSPEC_RESPONSE

This is the response by the Reader to a START_ACCESSSPEC command. If there was an AccessSpec corresponding to the AccessSpecID, and the Reader was able to move that AccessSpec from the disabled to the active state, then the success code is returned in the LLRPStatus parameter. If there is an error, the appropriate error code is returned in the LLRPStatus parameter.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

ENABLE_ACCESSSPEC_RESPONSE

Response: LLRPStatus Parameter

11.1.7 DISABLE_ACCESSSPEC

This message is issued by the Client to the Reader. Upon receiving the message, the Reader stops the execution of the AccessSpec corresponding to AccessSpecID in this message. This basically moves the AccessSpec's state to Disabled. This message does not delete the AccessSpec. The AccessSpec will stop taking effect from the next inventory round.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

DISABLE_ACCESSSPEC

AccessSpecID: Unsigned Integer. If set to 0, all AccessSpecs are disabled.

11.1.8 DISABLE_ACCESSSPEC_RESPONSE

This is the response by the Reader to a STOP_ACCESSSPEC command. If the Reader was currently executing the AccessSpec corresponding to the AccessSpecID, and the Reader was able to disable that AccessSpec, then the success code is returned in the LLRPStatus parameter. If there is an error, the appropriate error code is returned in the LLRPStatus parameter.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

DISABLE_ACCESSSPEC_RESPONSE
Response: LLRPStatus Parameter

11.1.9 GET_ACCESSSPECS

This is the request from the Client to the Reader to retrieve all the AccessSpecs that have been configured at the Reader.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

GET_ACCESSSPECS

11.1.10 GET_ACCESSSPECS_RESPONSE

This is the response by the Reader to a GET_ACCESSSPECS command. If there are no AccessSpecs configured at the Reader, the response is just the LLRPStatus parameter with the success code. Else, a list of <AccessSpecID, AccessSpec parameter> is returned by the Reader, along with the LLRPStatus parameter containing the success code. The order of the AccessSpecs listed in the message is normatively the order in which the AccessSpecs were created at the Reader.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

GET_ACCESSSPECS_RESPONSE
Status: LLRPStatus Parameter
Response: List of <AccessSpec Parameter>. The ordering of the AccessSpecs in this list is the order in which the AccessSpecs were created at the Reader.

11.1.11 CLIENT_REQUEST_OP

This message is sent by the Reader to the Client upon executing a ClientRequestOpSpec OpSpec (section 11.2.1.2.1). This message carries the TagReportData (section 13.2.3) that contains information collected for the tag which includes singulation results and the results of OpSpecs executed till that point.

Compliance requirement: Compliant Readers and Clients MAY implement this message.

CLIENT_REQUEST_OP
TagReport: <TagReportData Parameter> (Section 13.2.3)

11.1.12 CLIENT_REQUEST_OP_RESPONSE

This is the response by the Client to the Reader. This is in response to the CLIENT_REQUEST_OP sent by the Reader due to the execution of a ClientRequestOpSpec. This is a response to the CLIENT_REQUEST_OP message; thus, the messageID in this message is the messageID of the CLIENT_REQUEST_OP.

Compliance requirement: Compliant Readers and Clients MAY implement this message. Readers that do not support ClientRequestOpSpec MAY ignore this message.

CLIENT_REQUEST_OP_RESPONSE
Response: ClientRequestResponse Parameter

11.2 Parameters

11.2.1 AccessSpec Parameter

This parameter carries information of the Reader access operation.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

AccessSpec Parameter
AccessSpecID: Unsigned Integer. 0 is illegal.
Antenna ID: Unsigned Short Integer. If 0, this spec is operational on all antennas.
ProtocolID: Integer**.**
*Possible Values***:** Enumeration based on Table 3.
CurrentState: Boolean. This is the current state of the AccessSpec. false = Disabled, true = Active.
ROSpecID: Unsigned Integer. If 0, this spec is operational for all ROSpecs.
AccessSpecStopTrigger: AccessSpecStopTrigger Parameter
Access Command Operation: AccessCommand Parameter
AccessReportSpec: AccessReportSpec Parameter [Optional]
Custom Extension Point List: List of <custom Parameter> [Optional]

11.2.1.1 AccessSpecStopTrigger Parameter

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

AccessSpecStopTrigger Parameter

AccessSpecStopTriggerType: Integer

Possible Values:

Value	Definition
0	Null - No stop trigger defined.
1	Operation count

OperationCountValue: Unsigned Short Integer. A count to indicate the number of times this Spec is executed before it is deleted. If set to 0, this is equivalent to no stop trigger defined.

11.2.1.2 AccessCommand Parameter

This parameter defines the air protocol access-specific settings. It contains a TagSpec and an OpSpec Parameter. The TagSpec specifies the tag filters in terms of air protocol specific memory capabilities (e.g., memory banks, pointer and length). The OpSpec specifies all the details of the operations required for the air protocol specific access operation commands.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

AccessCommand Parameter

TagSpec: LLRP Parameter

Possible Values:

Each air protocol's TagSpec parameter is expressed as a different LLRP Parameter. The air protocol specific TagSpec LLRP Parameters are defined in section 15.1. This field carries a single TagSpec parameter corresponding to the air protocol referenced by the ProtocolID in the AccessSpec Parameter.

OpSpec: List of LLRP Parameters

Possible Values:

Each parameter can be either an air protocol specific OpSpec LLRP Parameter or a <ClientRequestOpSpec Parameter>.

Regarding the air protocol specific OpSpec LLRP Parameter: Each air protocol's OpSpec parameter is expressed as a different LLRP Parameter. The air protocol specific OpSpec LLRP Parameters are defined in section 15.1. The list of OpSpecs in this field is comprised of OpSpec parameters corresponding to the air protocol referenced by the ProtocolID in the AccessSpec Parameter.

Custom Extension Point List: List of <Custom Parameter> [Optional]

In case there are multiple AccessSpecs that get matched during a TagSpec lookup, the Reader SHALL only execute the first enabled AccessSpec that matches, where the ordering of the AccessSpecs is the order in which the AccessSpecs were created by the Client.

The order of execution of OpSpecs within an AccessSpec is the order in which the OpSpecs were set up in the AccessSpec. If an OpSpec execution fails, the Reader SHALL stop the execution of the AccessSpec.

11.2.1.2.1 ClientRequestOpSpec Parameter

This parameter is sent as part of the possible values for the AccessSpec OpSpec list. One or more ClientRequestOpSpec operations may be performed on a tag in succession. Upon executing a ClientRequestOpSpec Parameter, a Reader will immediately send the CLIENT_REQUEST_OP message to the Client. This CLIENT_REQUEST_OP message carries the TagReportData (section 13.2.3) that contains information collected for the tag which includes singulation results and the results of OpSpecs executed till that point.

A global timeout is associated with this request. If the Client does not return a ClientRequestResponse within the *ClientRequestOpSpecTimeout* (LLRP Capabilities) period, or the AirProtocolOpSpec List is empty in the ClientRequestResponse, the execution of the AccessSpec is cancelled.

Compliance requirement: Compliant Readers and Clients MAY implement this parameter. Readers that do not support ClientRequestOpSpec SHALL set SupportClientRequestOpSpec to false in LLRPCapabilities. If such a Reader receives an ADD_ACCESSSPEC with an AccessSpec that contained this OpSpec parameter, the Reader SHALL return an error for that message, and not add the AccessSpec.

ClientRequestOpSpec Parameter

OpSpecID: Unsigned Short Integer.

Possible Values: 0 is an illegal value.

11.2.2 ClientRequestResponse Parameter

This parameter describes the list of OpSpecs that the Reader has to execute on the tag for which a Client request was initiated. The AccessSpecID is the identifier of the AccessSpec that had the Client request; the EPC data is the singulated data of the tag for which this Client request was initiated. The AirProtocolOpSpec list contained in the ClientRequestResponse SHALL be processed as the next OpSpecs sent over the air interface. If the AirProtocolOpSpec List is empty, then the execution of the AccessSpec specified by AccessSpecID is cancelled.

Compliance requirement: Compliant Readers MAY implement this parameter. Readers that do not support ClientRequestOpSpec MAY ignore this parameter.

ClientRequestResponse Parameter

AccessSpecID: Unsigned Integer. The ID of the AccessSpec that triggered this request.

EPCdata: <EPCData Parameter>. The electronic product code of the RFID tag that triggered this request.

AirProtocolOpSpecList: List of LLRP OpSpec Parameter.

Possible Values:

Each air protocol's OpSpec parameter is expressed as a different LLRP Parameter. The air protocol specific OpSpec LLRP Parameters are defined in section 15.1. This field carries a list of OpSpec parameters corresponding to the air protocol referenced by ProtocolID in the AccessSpec that generated the Client request.

12 Reader Device Configuration

This section contains the messages and parameters for getting and setting configuration.

12.1 Messages

12.1.1 GET_READER_CONFIG

This command is issued by the Client to get the current configuration information of the Reader. The Requested Data passed in the command represents the parameter(s) of interest to the Client that has to be returned by the Reader.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

GET_READER_CONFIG

RequestedData : Integer

Possible Values:

Value	Requested Data
0	All
1	Identification
2	AntennaProperties
3	AntennaConfiguration
4	ROReportSpec
5	ReaderEventNotificationSpec
6	AccessReportSpec
7	LLRPConfigurationStateValue
8	KeepaliveSpec
9	GPIPortCurrentState
10	GPOWriteData
11	EventsAndReports

AntennaID: Unsigned Short Integer. This field is ignored when RequestedData != 0 or 2 or 3. If the AntennaID is 0, get antenna information (AntennaProperties, AntennaConfiguration) for all antennas.

GPIPortNum: Unsigned Short Integer. This field is ignored when RequestedData != 0 or 9. If the GPIPortNum is 0, get GPI port current state for all GPI ports.

GPOPortNum: Unsigned Short Integer. This field is ignored when RequestedData != 0 or 10. If the GPOPortNum is 0, get GPO port current state for all GPO ports.

Custom Extension Point List: List of <custom Parameter> [Optional]

12.1.2 GET_READER_CONFIG_RESPONSE

This is the response by the Reader to the GET_READER_CONFIG message. The response is the LLRPStatus Parameter and the list of configuration parameters based on the RequestedData in GET_READER_CONFIG. If the GET_READER_CONFIG message did not have any errors, the success code is returned in the LLRPStatus parameter, and in addition the requested configuration parameters are returned. If there is an error, the appropriate error code is returned in the LLRPStatus parameter. The response contains at most one instance of each configuration parameter except for two cases, which are as follows:

- If RequestedData is 0, 2 or 3, and AntennaID is set to 0 in the GET_READER_CONFIG message, the Reader SHALL return one instance of AntennaProperties Parameter or AntennaConfiguration Parameter per requested antenna.
- If RequestedData is 0 or 9 (10), and GPIPortNum (GPOPortNum) is set to 0 in the GET_READER_CONFIG message, and, if the Reader supports GPI (GPO), the Reader SHALL return one instance of GPIPortCurrentState (GPOWriteData) Parameter per requested GPI Port (GPO Port).

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

GET_READER_CONFIG_RESPONSE

Status: LLRPStatus Parameter

Response Data: Set of LLRP Parameters.

Possible Values: The possible members are zero or more of

{< LLRPConfigurationStateValue Parameter>,

<ReaderEventNotificationSpec Parameter>,

<Antenna Properties Parameter>,

<Antenna Configuration Parameter>,

<ROReportSpec Parameter>,

<AccessReportSpec Parameter>,

<Identification Parameter>,

<KeepaliveSpec Parameter>,

<GPIPortCurrentState Parameter>,

<GPOWriteData Parameter>,

<EventsAndReports Parameter>

}

Custom Extension Point List: List of <custom Parameter> [Optional]

12.1.3 SET_READER_CONFIG

This command is issued by the Client to the Reader. This command sets the Reader configuration using the parameters specified in this command. Values passed by the SET_READER_CONFIG SHALL apply for the duration of the LLRP connection, or until the values are changed by additional SET_READER_CONFIG messages.

For example, ROReportSpec defines the reporting of ROReport format and trigger for a ROSpec. ROReportSpec sent as part of SET_READER_CONFIG becomes the default ROReportSpec for the Reader. A ROReportSpec sent as part of ROSpec in the ADD_ROSPEC command overrides the default value for that ROSpec. However, in cases where there is no ROReportSpec specified in a ROSpec sent as part of ADD_ROSPEC, that particular ROSpec inherits the default ROReportSpec.

The data field ResetToFactoryDefault informs the Reader to set all configurable values to factory defaults before applying the remaining parameters.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

SET_READER_CONFIG

ResetToFactoryDefault: Boolean. If true, the Reader will set all configurable values to factory defaults before applying the remaining parameters.

Configuration Data: Set of LLRP Parameters

Possible Values: The possible members of the set are

{<ReaderEventNotificationSpec Parameter>,

<Antenna Properties Parameter>,

<Antenna Configuration Parameter>,

<ROReportSpec Parameter>,

<AccessReportSpec Parameter>,

<KeepaliveSpec Parameter>,

<GPOWriteData Parameter>,

<GPIPortCurrentState Parameter>,

<EventsAndReports Parameter>}

Custom Extension Point List: List of <custom Parameter> [Optional]

12.1.4 SET_READER_CONFIG_RESPONSE

This is the response by the Reader to a SET_READER_CONFIG command. If all the parameters specified in the SET_READER_CONFIG command are successfully set, then the success code is returned in the LLRPStatus parameter. If there is an error, the appropriate error code is returned in the LLRPStatus parameter.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

SET_READER_CONFIG_RESPONSE

Response: < LLRPStatus Parameter>

12.1.5 CLOSE_CONNECTION

This command is issued by the Client to the Reader. This command instructs the Reader to gracefully close its connection with the Client. Under normal operating conditions, a Client SHALL attempt to send this command before closing an LLRP connection. A Client should wait briefly for the Reader to respond with a CLOSE_CONNECTION_RESPONSE.

Upon receipt of this command, the Reader SHALL respond with the CLOSE_CONNECTION_REPONSE message and it should then attempt to close the connection between the Reader and Client.

Having executed a CLOSE_CONNECTION command, a Reader MAY persist its configuration state as defined by the ReaderConfigurationStateValue parameter specified in section 12.2.1.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

CLOSE_CONNECTION

12.1.6 CLOSE_CONNECTION_RESPONSE

This is the response by the Reader to a CLOSE_CONNECTON command from the Client. Upon receiving a CLOSE_CONNECTION command, the Reader SHALL attempt to send this response to the Client. After attempting to send this response, the Reader SHALL close its connection with the Client.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

CLOSE_CONNECTION_RESPONSE
Status: <LLRPStatus Parameter>

12.2 Parameters

12.2.1 LLRPConfigurationStateValue Parameter

This parameter, LLRPConfigurationStateValue, is a 32-bit value which represents a Reader's entire LLRP configuration state including: LLRP configuration parameters, vendor extension configuration parameters, ROSpecs, and AccessSpecs. A Reader SHALL change this value only:

- Upon successful execution of any of the following messages:
  - ADD_ROSPEC
  - DELETE_ROSPEC
  - ADD_ACCESSSPEC
  - DELETE_ACCESSSPEC
  - SET_READER_CONFIG
  - Any CUSTOM_MESSAGE command that alters the reader's internal configuration.
- Upon an automatically deleted AccessSpec due to completion of OperationCountValue number of operations (Section 11.2.1.1).

A Reader SHALL not change this value when the CurrentState of a ROSpec or AccessSpec changes.

The mechanism used to compute the LLRP configuration state value is implementation dependent. However, a good implementation will insure that there's a high probability that the value will change when the Reader's configuration state changes.

It is expected that a Client will configure the Reader and then request the Reader's configuration state value. The Client will then save this state value. If this value does not change between two requests for it, then a Client may assume that the above components of the LLRP configuration have also not changed.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter. When requested by a Client, the Reader SHALL compute a state value based upon the Reader's current configuration state. Upon each request, the Reader SHALL return the same state value provided a Client has not altered the Reader's configuration state between requests. Aside from this requirement, the computation of the state value is implementation dependent.

LLRPConfigurationStateValue Parameter

LLRPConfigurationStateValue: Unsigned Integer

12.2.2 Identification Parameter

This parameter carries an identification parameter that is unique within the local administration domain. The identifier could be the Reader MAC address or EPC. The IDType defines the type of the identification value contained in this Parameter.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

Identification Parameter

IDType: Integer

Possible Values:

IDType	ID
0	MAC address
1	EPC

Reader ID: Byte array. If IDType=0, the MAC address SHALL be encoded as EUI-64.[EUI64]

12.2.3 GPOWriteData Parameter

This parameter carries the data pertinent to perform the write to a general purpose output port.

Compliance requirement: Compliant Readers and Clients MAY implement this parameter. Readers that do not support GPOs SHALL set NumGPOs in the GPIOCapabilities to zero. If such a Reader receives a SET_READER_CONFIG with

1791 GPOWriteData Parameter, the Reader SHALL return an error message and not process
1792 any of the parameters in that message.

GPOWriteData Parameter

GPO Port Number : Unsigned Short Integer. 0 is invalid.

GPO Data: Boolean. The state to output on the specified GPO port.

1793 12.2.4 KeepaliveSpec Parameter

1794 This parameter carries the specification for the keepalive message generation by the
1795 Reader. This includes the definition of the periodic trigger to send the keepalive message.

1796 **Compliance requirement**: Compliant Readers and Clients SHALL implement this
1797 parameter.

KeepaliveSpec Parameter

KeepaliveTriggerType: Integer

Possible Values:

Value	Definition
0	Null – No keepalives SHALL be sent by the Reader
1	Periodic

PeriodicTriggerValue: Integer. Time interval in milliseconds. This field is ignored when KeepaliveTriggerType is not 1.

1798 12.2.5 AntennaProperties Parameter

1799 This parameter carries a single antenna's properties. The properties include the gain and
1800 the connectivity status of the antenna.The antenna gain is the composite gain and includes
1801 the loss of the associated cable from the Reader to the antenna. The gain is represented in
1802 dBi*100 to allow fractional dBi representation.

1803 **Compliance requirement**: Compliant Readers and Clients MAY implement this
1804 parameter.

AntennaProperties Parameter

AntennaID: Unsigned Short Integer

Possible Values:

1 to N, where N is the maximum number of antennas supported by the device.

AntennaGain: Signed short integer. The gain of the antenna in dBI*100 (dB relative to Isotropic) to allow for fractional dBi representation.

AntennaConnected: Boolean. False = not connected, True = connected.

12.2.6 AntennaConfiguration Parameter

This parameter carries a single antenna's configuration and it specifies the default values for the parameter set that are passed in this parameter block. The scope of the default values is the antenna. The default values are used for parameters during an operation on this antenna if the parameter was unspecified in the spec that describes the operation.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

AntennaConfiguration Parameter

Antenna ID: Unsigned Short Integer. If set to zero, this configuration applies to all the antennas.

RFReceiverSettings: <RFReceiver Parameter> [Optional]

RFTransmitterSettings: <RFTransmitter Parameter> [Optional]

AirProtocolInventoryCommandSettings: List of LLRP parameters. [Optional]

Possible Values:

Each air protocol's inventory command parameter is expressed as a different LLRP Parameter. The air protocol specific inventory command LLRP Parameters are defined in section 15.1. This field is a list of inventory command LLRP Parameters, one per air protocol, that the Client would like to use as the default inventory command setting for inventory operations using the air protocol on this antenna.

12.2.6.1 RFReceiver Parameter

This Parameter carries the RF receiver information. The Receiver Sensitivity defines the sensitivity setting at the receiver. The value is the index into the ReceiveSensitivityTable (section 9.2.1.1).

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

RFReceiver Parameter

ReceiverSensitivity: Unsigned Short Integer - an index into the ReceiveSensitivity Table (section 9.2.1.1)

12.2.6.2 RFTransmitter Parameter

This Parameter carries the RF transmitter information. The Transmit Power defines the transmit power for the antenna expressed as an index into the TransmitPowerTable (section 9.2.4.1.1). The HopTableID is the index of the frequency hop table to be used by the Reader (section 9.2.4.1.2.1) and is used when operating in frequency-hopping regulatory regions. This field is ignored in non-frequency-hopping regulatory regions. The ChannelIndex is the one-based channel index in the FixedFrequencyTable to use during transmission (section 9.2.4.1.2.2) and is used when operating in non-frequency-

hopping regulatory regions. This field is ignored in frequency-hopping regulatory regions.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

RFTransmitter Parameter
Transmit Power: Unsigned Short Integer - an index into the Transmit Power table.
HopTableID : Unsigned Short Integer
ChannelIndex : Unsigned Short Integer. This is the index of the frequency to use.

12.2.6.3 GPIPortCurrentState Parameter

This Parameter carries the current configuration and state of a single GPI port. In a SET_READER_CONFIG message, this parameter is used to enable or disable the GPI port using the GPIConfig field; the GPIState field is ignored by the reader. In a GET_READER_CONFIG message, this parameter reports both the configuration and state of the GPI port.

When a ROSpec or AISpec is configured on a GPI-capable reader with GPI start and/or stop triggers, those GPIs must be enabled by the client with a SET_READER_CONFIG message for the triggers to function.

Compliance requirement: Compliant Readers and Clients MAY implement this parameter. Readers that do not support GPIs SHALL set NumGPIs in the GPIOCapabilities to zero. If such a Reader receives a GET_READER_CONFIG with a GPIPortCurrentState Parameter, the Reader SHALL return an error message and not process any of the parameters in that message.

GPIPortCurrentState Parameter

GPIPortNum: Unsigned Short Integer. Zero is illegal.

GPIConfig : Boolean (0 for disabled, 1 for enabled)

GPIState : Integer (ignored in SET_READER_CONFIG messages)

Possible Values:

Value	Definition
0	GPI state is low
1	GPI state is high
2	GPI state is unknown

12.2.6.4 EventsAndReports Parameter

This parameter controls the behavior of the Reader when a new LLRP connection is established. In a SET_READER_CONFIG message, this parameter is used to enable or disable the holding of events and reports upon connection using the HoldEventsAndReportsUponReconnect field. In a GET_READER_CONFIG message, this parameter reports the current configuration. If the

HoldEventsAndReportsUponReconnect is true, the reader will not deliver any reports or events (except the ConnectionAttemptEvent) to the Client until the Client issues an ENABLE_EVENTS_AND_REPORTS message. Once the ENABLE_EVENTS_AND_REPORTS message is received the reader ceases its hold on events and reports for the duration of the connection.

Compliance requirement: Compliant Readers and Clients MAY implement this parameter.

EventsAndReports Parameter
HoldEventsAndReportsUponReconnect: Boolean. (False does not hold reports and events, True holds reports and events)

13 Reports, Notifications and Keepalives

This section describes the messages and parameters used in reports, event notifications and keepalives that are generated by the Reader and sent to the Client.

The Reader SHALL send reports only when

- A reporting trigger (ROReportTrigger or AccessReportTrigger) generates a report while a connection is open, or
- In response to an explicit Client request (GET_REPORT or ENABLE_EVENTS_AND_REPORTS), or
- A notification event occurs and the event is enabled.

The triggers may be specified per ROSpec and AccessSpec using ROReportSpec and AccessReportSpec parameters. In a report, the Reader SHALL send new data (results of ROSpecs and/or AccessSpecs) acquired since the last report message. The tag report data generated by the AccessReport trigger SHALL NOT duplicate the tag report data generated by the ROReportTrigger, and vice-versa.

13.1 Messages

13.1.1 GET_REPORT

This message is issued by the Client to the Reader to get the tag reports. In response to this message, the Reader SHALL return tag reports accumulated.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

GET_REPORT

13.1.2 RO_ACCESS_REPORT

This message is issued by the Reader to the Client, and it contains the results of the RO and Access operations. The ROReportSpec and AccessReportSpec parameters define the contents and triggers for this message.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

RO_ACCESS_REPORT
InventoryAccessReportData: List of <TagReportData Parameter> [Optional]
RFSurveyReportData: List of <RFSurveyReportData Parameter> [Optional]
Custom Extension Point List: List of <custom Parameter> [Optional]

13.1.3 KEEPALIVE

This message is issued by the Reader to the Client. This message can be used by the Client to monitor the LLRP-layer connectivity with the Reader. The Client configures the trigger at the Reader to send the Keepalive message. The configuration is done using the KeepaliveSpec parameter (section 12.2.4).

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

KEEPALIVE

13.1.4 KEEPALIVE_ACK

A Client SHALL generate a KEEPALIVE_ACK in response to each KEEPALIVE received by the reader.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

KEEPALIVE_ACK

13.1.5 READER_EVENT_NOTIFICATION

This message is issued by the Reader to the Client whenever an event that the Client subscribed to occurs. The pertinent event data is conveyed using the ReaderEventNotificationData parameter.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

READER_EVENT_NOTIFICATION
ReaderEventNotificationData: ReaderEventNotificationData Parameter

13.1.6 ENABLE_EVENTS_AND_REPORTS

This message can be issued by the Client to the Reader after a LLRP connection is established. The Client uses this message to inform the Reader that it can remove its hold on event and report messages. Readers that are configured to hold events and reports on reconnection (See Section 12.2.6.4) respond to this message by returning the tag reports accumulated (same way they respond to GET_REPORT (See Section 13.1.1)).

Compliance requirement: Compliant Readers and Clients MAY implement this message.

ENABLE_EVENTS_AND_REPORTS

13.2 Parameters

13.2.1 ROReportSpec Parameter

This Parameter carries the Reader inventory and RF survey reporting definition for the antenna. This parameter describes the contents of the report sent by the Reader and defines the events that cause the report to be sent.

The ROReportTrigger field defines the events that cause the report to be sent.

The TagReportContentSelector parameter defines the desired contents of the report. The ROReportTrigger defines the event that causes the report to be sent by the Reader to the Client.

See section 13.2.6.1 for details about the order that reports are to be sent with respect to Reader event notifications.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

ROReportSpec Parameter

ROReportTrigger: Integer

Possible Values:

Value	Definition
0	None
1	(Upon N TagReportData Parameters or End of AISpec) Or (End of RFSurveySpec) - N=0 is unlimited.
2	Upon N TagReportData Parameters or End of ROSpec - N=0 is unlimited.

N: Unsigned Short Integer. This is the number of TagReportData Parameters used in ROReportTrigger = 1 and 2. If N = 0, there is no limit on the number of TagReportData Parameters. This field SHALL be ignored when ROReportTrigger =

0.

ReportContents: <TagReportContentSelector Parameter>

Custom Extension Point List: List of <Custom Parameter> [Optional]

13.2.1.1 TagReportContentSelector Parameter

This parameter is used to configure the contents that are of interest in TagReportData. If enabled, the field is reported along with the tag data in the TagReportData.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

TagReportContentSelector

EnableROSpecID: Boolean

EnableSpecIndex: Boolean

EnableInventoryParameterSpecID: Boolean

EnableAntennaID: Boolean

EnableChannelIndex: Boolean

EnablePeakRSSI: Boolean

EnableFirstSeenTimestamp: Boolean

EnableLastSeenTimestamp: Boolean

EnableTagSeenCount: Boolean

AirProtocolSpecificEPCMemorySelector: LLRP parameter.

Possible Values:

Each air protocol's EPC memory selector parameter is expressed as a different LLRP Parameter. The air protocol specific EPC memory selector LLRP Parameters are defined in section 15.1. This field is the EPC memory selector LLRP Parameter corresponding to the air protocol referenced by the ProtocolID in the ROSpec that the ROReportSpec is part of.

EnableAccessSpecID: Boolean

13.2.2 AccessReportSpec Parameter

This parameter sets up the triggers for the Reader to send the access results to the Client. In addition, the Client can enable or disable reporting of ROSpec details in the access results.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

AccessReportSpec

AccessReportTrigger: Integer

Possible Values:

Value	Definition
0	Whenever ROReport is generated for the RO that triggered the execution of this AccessSpec.
1	End of AccessSpec

13.2.3 TagReportData Parameter

This report parameter is generated per tag per accumulation scope. The only mandatory portion of this parameter is the EPCData parameter. If there was an access operation performed on the tag, the results of the OpSpecs are mandatory in the report. The other sub-parameters in this report are optional. LLRP provides three ways to make the tag reporting efficient:

(i) Allow parameters to be enabled or disabled via TagReportContentSelector (section 13.2.1.1) in TagReportSpec.

(ii) If an optional parameter is enabled, and is absent in the report, the Client SHALL assume that the value is identical to the last parameter of the same type received. For example, this allows the Readers to not send a parameter in the report whose value has not changed since the last time it was sent by the Reader.

(iii) Allow accumulation of tag reports. See next section for details of accumulation.

Compliance Requirement: Compliant Readers and Clients SHALL implement this parameter.

TagReportData Parameter

EPCData: <EPCData Parameter>

ROSpecID: <ROSpecID Parameter> [Optional]

SpecIndex: <SpecIndex Parameter> [Optional]

InventoryParameterSpecID: <InventoryParameterSpecID Parameter> [Optional]

AntennaID: <AntennaID Parameter> [Optional]

PeakRSSI: <PeakRSSI Parameter> [Optional]

ChannelIndex: <ChannelIndex Parameter> [Optional]

FirstSeenTimestampUTC: <UTCFirstSeenTimestamp Parameter> [Optional]

FirstSeenTimeStampUptime: <UptimeFirstSeenTimestamp Parameter> [Optional]

LastSeenTimestampUTC: <UTCLastSeenTimestamp Parameter> [Optional]

LastSeenTimeStampUptime: <UptimeLastSeenTimestamp Parameter> [Optional]

TagSeenCount: <TagSeenCount Parameter> [Optional]

AirProtocolTagData: LLRP Parameters (e.g., C1G2EPC-PC, C1G2EPC-CRC) [Optional]

Possible Values:

Each air protocol's AirProtocolTagData parameter is expressed as a different LLRP Parameter. The air protocol specific AirProtocolTagData LLRP Parameters are defined in section 15.1. This field is the AirProtocolTagData LLRP Parameter corresponding to the air protocol referenced by the ProtocolID of the InventoryParameterSpec during whose execution this tag was observed.

AccessSpecID: <AccessSpecID Parameter> [Optional]

OpSpecResultList: List of LLRP parameters [Optional]

Possible Values of each LLRP Parameter: Air protocol specific OpSpecResult parameter or <ClientRequestOpSpecResult Parameter>.

Regarding the air protocol specific OpSpecResult parameter: Each air protocol's OpSpecResult parameter is expressed as a different LLRP Parameter. The air protocol specific OpSpecResult LLRP Parameters are defined in section 15.1. This field is a list of OpSpecResult LLRP Parameters corresponding to the air protocol referenced by the ProtocolID of the AccessSpec.

Custom Extension Point List: List of <Custom Parameter> [Optional]

13.2.3.1 Accumulation of TagReportData

A Reader MAY accumulate multiple tag reports into a single tag report.. If a Reader accumulates, the Reader SHALL follow the accumulation rules specified in this section. The following specifies the rules for accumulating multiple tag observations into a single TagReportData:

- EPCData:
  - The Reader SHALL not accumulate tag reports that do not have the same EPCData value.
- OpSpecResultList:
  - The Reader SHALL not accumulate tag reports that do not have the same value for the OpSpec results in the OpSpecResultList.
- SpecID, SpecIndex, InventoryParameterSpecID, AntennaID, AirProtocolTagData, AccessSpecID:
  - These fields are optional, and their reporting can be enabled by the Client. If the Client has enabled one or more fields listed above, the Reader SHALL not accumulate tag reports that do not have the same value for all the enabled fields.
- FirstSeenTimestamp, LastSeenTimestamp, PeakRSSI, TagSeenCount, ChannelIndex

- These fields are optional, and their reporting can be enabled by the Client. If the field is enabled, the Reader sets the value of these fields as follows:
  - FirstSeenTimestamp: The Reader SHALL set it to the time of the first observation amongst the tag reports that get accumulated in the TagReportData.
  - LastSeenTimestamp: The Reader SHALL set it to the time of the last observation amongst the tag reports that get accumulated in the TagReportData.
  - PeakRSSI: The Reader SHALL set it to the maximum RSSI value observed amongst the tag reports that get accumulated in the TagReportData.
  - ChannelIndex: The Reader MAY set it to the index of the first channel the tag was seen.
  - TagSeenCount: The Reader SHALL set it to the number of tag reports that get accumulated in the TagReportData.

13.2.3.2 EPCData Parameter

This parameter carries the EPC identifier information.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

EPCData Parameter

EPC: Bit array

13.2.3.3 ROSpecID Parameter

This parameter carries the ROSpecID information.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

ROSpecID Parameter

ROSpecID: Unsigned Integer

13.2.3.4 SpecIndex Parameter

This parameter carries the SpecIndex information. The SpecIndex indicates the item within the ROSpec that was being executed at the time the tag was observed.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

SpecIndex Parameter

SpecIndex: Unsigned Short Integer

13.2.3.5 InventoryParameterSpecID Parameter

This parameter carries the InventoryParameterSpecID information.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

InventoryParameterSpecID Parameter

InventoryParameterSpecID: Unsigned Short Integer

13.2.3.6 AntennaID Parameter

This parameter carries the AntennaID information.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

AntennaID Parameter

AntennaID: Unsigned Short Integer

13.2.3.7 PeakRSSI Parameter

This parameter carries the PeakRSSI information.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

PeakRSSI Parameter

PeakRSSI: Signed Integer. The peak received power of the EPC backscatter in dBm.

Possible Values:

-128 to +127.

13.2.3.8 ChannelIndex Parameter

This parameter carries the one-based ChannelIndex value.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

ChannelIndex Parameter

ChannelIndex: Unsigned Integer

Possible Values: 0 to 255.

13.2.3.9 FirstSeenTimestampUTC Parameter

This parameter carries the FirstSeenTimestamp information in UTC.

Compliance requirement: Compliant Readers and Clients that have UTC clocks SHALL implement this parameter.

FirstSeenTimestampUTC Parameter

Microseconds: Unsigned long Integer. This is the time elapsed since the Epoch (00:00:00 UTC, January 1, 1970) measured in microseconds.

13.2.3.10 FirstSeenTimestampUptime Parameter

This parameter carries the FirstSeenTimestamp information in Uptime.

Compliance requirement: Compliant Readers and Clients that do not have UTC clocks SHALL implement this parameter. Compliant Readers and Clients that have UTC clocks MAY implement this parameter.

FirstSeenTimestampUptime Parameter

Microseconds: Unsigned long Integer. This is the time elapsed since boot, measured in microseconds.

13.2.3.11 LastSeenTimestampUTC Parameter

This parameter carries the LastSeenTimestamp information in UTC.

Compliance requirement: Compliant Readers and Clients that have UTC clocks SHALL implement this parameter.

LastSeenTimestampUTC Parameter

Microseconds: Unsigned long Integer. This is the time elapsed since the Epoch (00:00:00 UTC, January 1, 1970) measured in microseconds.

13.2.3.12 LastSeenTimestampUptime Parameter

This parameter carries the LastSeenTimestamp information in Uptime.

Compliance requirement: Compliant Readers and Clients that do not have UTC clocks SHALL implement this parameter. Compliant Readers and Clients that have UTC clocks MAY implement this parameter.

LastSeenTimestampUptime Parameter

Microseconds: Unsigned long Integer. This is the time elapsed since boot, measured in microseconds.

13.2.3.13 TagSeenCount Parameter

This parameter carries the tag seen count information. If TagSeenCount > 65535 for the report period, the reader SHALL report 65535.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

TagSeenCount Parameter

Count: Unsigned Short Integer

13.2.3.14 ClientRequestOpSpecResult Parameter

Compliance requirement: Compliant Readers and Clients MAY implement this parameter.

ClientRequestOpSpecResult Parameter

OpSpecID: Unsigned Short Integer. 0 is illegal.

13.2.3.15 AccessSpecID Parameter

This parameter carries the AccessSpecID information.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

AccessSpecID Parameter

AccessSpecID: Unsigned Integer

13.2.4 RFSurveyReportData Parameter

This describes the content of the RF Survey Report.

Compliance requirement: Compliant Readers and Clients MAY implement this parameter.

RFSurveyReportData Parameter

ROSpecID: <ROSpecID Parameter> [Optional]

SpecIndex: <SpecIndex Parameter> [Optional]

FrequencyPowerLevelList: List of <FrequencyRSSILevelEntry Parameter>

Custom Extension Point List: List of <custom Parameter> [Optional]

13.2.4.1 FrequencyRSSILevelEntry Parameter

Compliance requirement: Compliant Readers and Clients MAY implement this parameter.

FrequencyRSSILevelEntry Parameter

Timestamp: Either <UTCTimestamp Parameter> or <Uptime Parameter>

Frequency: Unsigned Integer. The frequency on which the measurement was taken, specified in kHz.

Bandwidth: Unsigned Integer. The measurement bandwidth of the measurement in kHz.

Average RSSI: Integer in dBm. The average power level observed at this frequency.

Possible Values:

-128 to + 127

Peak RSSI: Integer in dBm. The peak power level observed at this frequency.

Possible Values:

-128 to + 127

13.2.5 ReaderEventNotificationSpec Parameter

This parameter is used by the Client to enable or disable notification of one or more Reader events. Notification of buffer overflow events and connection events (attempt/close) are mandatory, and not configurable.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

ReaderEventNotificationSpec Parameter

EventNotificationSpecTable: List of <EventNotificationState Parameter>

13.2.5.1 EventNotificationState Parameter

This parameter is used to enable or disable notification of a single Reader event type.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

EventNotificationState Parameter

EventType:

Possible Values:

Value	Definition
0	Upon hopping to next channel (e.g., in FCC regulatory region)
1	GPI event
2	ROSpec event (start/end/preempt)
3	Report buffer fill warning
4	Reader exception event
5	RFSurvey event (start/end)
6	AISpec event (end)
7	AISpec event (end) with singulation details
8	Antenna event (disconnect/connect)

NotificationState: Boolean; enable = true, disable = false.

13.2.6 ReaderEventNotificationData Parameter

This parameter describes the contents of the event notification sent by the Reader, and defines the events that cause the notification to be sent. Event notification messages may be sent by the Reader due to connection establishment/closing event, critical events such as hopping, fault-detection in a Reader functional block, buffer overflow, due to the activation of a Reader accessory trigger input (e.g. motion detection), or due to performance monitoring events such as abnormalities in the RF environment.

Timestamp is the time that the events reported occurred.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

ReaderEventNotificationData Parameter

Timestamp: Either <UTCTimestamp Parameter> or <Uptime Parameter>

Events: List of events.

Possible Values: The possible members of the list are

{

<HoppingEventParameter>,

<GPIEvent Parameter>,

<ROSpecEvent Parameter>,

<ReportBufferLevelWarningEvent Parameter>,

<ReportBufferOverflowErrorEvent Parameter>,

<ReaderExceptionEvent Parameter>,

<RFSurveyEvent Parameter>,

<AISpecEvent Parameter>,

<AntennaEvent Parameter>,

<ConnectionAttemptEvent Parameter>,

<ConnectionCloseEvent Parameter>

}

Custom Extension Point List: List of <custom Parameter> [optional]

13.2.6.1 Requirements for Ordering of Event Reporting

LLRP assumes a reliable stream transport mechanism. Messages sent through LLRP will arrive in the order that they were sent over the transport and binding utilized. Status events within the same message SHALL be ordered chronologically.

Status events delivered by reader event notifications are useful, especially in conjunction with the tag report data. The following describes the requirements of the reader event notifications ordering with respect to the ordering of tag reports and Reader Event Notifications.

The following requirements are made on the ordering of Event Parameters with respect to each other and to tag report Parameters. These statements apply if the respective status events and report triggers are enabled.

If the start of an ROSpec is triggered by a GPI, the GPIEvent Parameter SHALL be sent before the ROSpecEvent Parameter signaling the start of the ROSpec.

If the end of an ROSpec is triggered by a GPI, the GPIEvent Parameter SHALL be sent before the ROSpecEvent Parameter signaling the end of the ROSpec.

If an ROSpec contains one or more AISpecs, the ROSpecEvent parameter signaling the end of an ROSpec SHALL be sent after the AISpecEvent Parameter signaling the end of the last AISpec within that ROSpec.

If one ROSpec pre-empts another ROSpec, the ROSpecEvent parameter signaling the preemption of the first ROSpec SHALL be sent before the ROSpecEvent parameter signaling the start of the next ROSpec.

Tag data received during an ROSpec execution SHALL be sent between the ROSpecEvent parameter signaling the start of the ROSpec and the ROSpecEvent parameter signaling the end or preemption of the ROSpec if the ROReportTrigger is not set to 'None'.

Tag data received during an AISpec execution SHALL be sent before the AISpecEvent Parameter signaling the end of the AISpec if the ROReportTrigger is not 'None' or 'end of RO Spec'

Tag data received during the time on a channel SHALL be sent after the HoppingEvent parameter that announced this channel and before the next HoppingEvent parameter when the ROReportTrigger is not 'None' and N=1.

13.2.6.2 HoppingEvent Parameter

A Reader reports this event every time it hops frequency.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

HoppingEvent Parameter

HopTableID: Unsigned Short Integer

NextChannelIndex: Unsigned Short Integer. This is the one-based ChannelIndex of the next channel to which the Reader is going to change.

13.2.6.3 GPIEvent Parameter

A reader reports this event every time an enabled GPI changes GPIstate.

Compliance requirement: Compliant Readers and Clients MAY implement this parameter.

GPIEvent Parameter

GPIPortNumber: Unsigned Short Integer

GPIEvent: Boolean – True/False.

13.2.6.4 ROSpecEvent Parameter

This parameter carries the ROSpec event details. The EventType could be start or end of the ROSpec.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

ROSpecEvent Parameter

ROSpecID: Unsigned Integer. This is the ID of the ROSpec that started, ended or got preempted.

EventType: Integer

Possible Values:

Value	Definition
0	Start of ROSpec
1	End of ROSpec
2	Preemption of ROSpec

PreemptingROSpecID: Integer. This field is ignored when EventType != 2. This field carries the ID of the preempting ROSpec.

13.2.6.5 ReportBufferLevelWarningEvent Parameter

A Reader can warn the Client that the Reader's report buffer is filling up. A Client can act upon this warning by requesting report data from the Reader, thereby freeing the Reader's report memory resources.

ReportBufferLevelWarningEvent Parameter

ReportBufferPercentageFull: Integer

Possible Values: 0-100

Compliance requirement: Compliant Readers and Clients MAY implement this parameter. A Reader MAY send a report buffer level warning event whenever the Reader senses that its report memory resources are running short. The buffer level at which a warning is reported is Reader implementation dependent. A Client MAY act upon a report buffer level warning event by requesting report data from the Reader and thereby free report memory resources in the Reader.

13.2.6.6 ReportBufferOverflowErrorEvent Parameter

A Reader reports a buffer overflow event whenever report data is lost due to lack of memory resources.

ReportBufferOverflowErrorEvent Parameter

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter. A Reader SHALL report a buffer overflow event whenever report data is lost due to lack of memory resources.

13.2.6.7 ReaderExceptionEvent Parameter

The reader exception status event notifies the client that an unexpected event has occurred on the reader. Optional parameters provide more detail to the client as to the nature and scope of the event.

Compliance requirement: Compliant Readers and Clients MAY implement this parameter.

ReaderExceptionEvent Parameter

ROSpecID: <ROSpecID Parameter> [Optional]

SpecIndex: <Spec Index Parameter> [Optional]

InventoryParameterSpecID: <InventoryParameterSpecID Parameter> [Optional]

AntennaID: <AntennaID Parameter> [Optional]

AccessSpecID: <AccessSpecID Parameter> [Optional]

OpSpecID: <OpSpecID Parameter> [Optional]

Message: UTF-8 String

Custom Extension Point List: List of <custom Parameter> [Optional]

13.2.6.7.1 OpSpecID Parameter

Compliance requirement: Compliant Readers and Clients MAY implement this parameter.

OpSpecID Parameter

OpSpecId: Unsigned Short Integer. 0 is illegal.

13.2.6.8 RFSurveyEvent Parameter

Compliance requirement: Compliant Readers and Clients MAY implement this parameter.

RFSurveyEvent Parameter

ROSpecID: Unsigned Integer. The identifier of the ROSpec that contains the RFSurveySpec.

SpecIndex: Unsigned Short Integer. The index of the spec in the ROSpec.

EventType: Integer

Possible Values:

Value	Definition
0	Start of RFSurvey
1	End of RFSurvey

13.2.6.9 AISpecEvent Parameter

This parameter carries the AISpec event details. The EventType is the end of the AISpec. When reporting the end event, the AirProtocolSingulationDetails MAY be reported if it is supported by the Reader and EventType of 7 has been enabled (Section 13.2.5.1).

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

AISpecEvent Parameter

ROSpecID: Unsigned Integer. The identifier of the ROSpec that contains the AISpec.

SpecIndex: Unsigned Short Integer. The index of the spec in the ROSpec.

EventType: Integer

Possible Values:

Value	Definition
0	End of AISpec

AirProtocolSingulationDetails: LLRP parameter [Optional]

Possible Values:

Each air protocol's AirProtocolSingulationDetails parameter is expressed as a different LLRP Parameter. The air protocol specific AirProtocolSingulationDetails LLRP Parameters are defined in section 15.1. This field is the AirProtocolSingulationDetails LLRP Parameter corresponding to the air protocol referenced by the ProtocolID of the InventoryParameterSpec upon whose execution completion this event report was generated.

13.2.6.10 AntennaEvent Parameter

This event is generated when the Reader detects that an antenna is connected or disconnected.

Compliance requirement: Compliant Readers and Clients MAY implement this parameter.

AntennaEvent Parameter

AntennaID: Unsigned Short Integer

EventType: Integer

Possible Values:

Value	Definition
0	Antenna disconnected
1	Antenna connected

13.2.6.11 ConnectionAttemptEvent Parameter

This status report parameter establishes Reader connection status when the Client or Reader initiates a connection. See section 18.1, TCP Transport, for more details regarding the use of this report.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

ConnectionAttemptEvent Parameter

Status: Integer

Possible Values:

Value	Definition
0	Success
1	Failed (a Reader initiated connection already exists)
2	Failed (a Client initiated connection already exists)
3	Failed (any reason other than a connection already exists
4	Another connection attempted

13.2.6.12 ConnectionCloseEvent Parameter

This status report parameter informs the Client that, unsolicited by the Client, the Reader will close the connection between the Reader and Client. Before the Reader closes a connection with the Client that is not solicited by the Client, the Reader SHALL first attempt to send a READER_EVENT_NOTIFICATION containing this parameter to the Client.

Once the Reader sends this event to the Client, the Reader SHALL close the connection to the Client. This is also to say that, once the Reader sends this event, the Reader SHALL send no additional messages to the Client and the Reader SHALL ignore any messages received from the Client until another new connection is established.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

ConnectionCloseEvent Parameter

14 Errors

This section describes the errors that are solely based on LLRP protocol message parsing. The Reader SHALL discard the message if there is at least one error in the message, or cannot be fully processed. In addition, no portion of the message containing an error SHALL be executed by the Reader. In case the message has one or more errors, the Reader SHALL return at least one error parameter for one of the errors. The Reader MAY return more than one error parameter, one for each error. The errors are conveyed using a combination of 'generic error codes', a pointer to the culprit parameter/field, and a description of the error encoded as a string of UTF-8 characters.

Typically the errors in the LLRP defined messages are conveyed inside of the responses from the Reader. However, in cases where the message received by the Reader contains an unsupported message type, or a CUSTOM_MESSAGE with unsupported parameters or fields, the Reader SHALL respond with the ERROR_MESSAGE.

When a Reader or Client receives a command or notification with a version that is not supported, the receiver SHALL send an ERROR_MESSAGE in reply consisting of: A version that is the same as the received message, the message ID that matches the received message, and an LLRPStatusParameter with the ErrorCode set to M_UnsupportedVersion. This message SHALL contain no sub-parameters (such as Field Error, Parameter Error).

Readers and Clients SHALL not respond to an ERROR_MESSAGE.

14.1 Messages

14.1.1 ERROR_MESSAGE

This message is issued by the Reader to the Client, and it contains the LLRPStatus parameter that describes the error in the message.

Compliance requirement: Compliant Readers and Clients SHALL implement this message.

ERROR_MESSAGE
Error: <LLRPStatus Parameter>

14.2 Parameters

First, the error codes are presented, and then later, error parameters are presented that identify the culprit field in the message.

14.2.1 LLRP Status Codes

Status can be a success or one of the error conditions. This section lists a set of generic error conditions that, in combination with the identifier of the culprit field, conveys the error condition. The codes are broken into four scopes: message, parameter, field and device. The device code indicates that the error is in the Reader device rather than the message, parameter or field.

StatusCode	Name	Scope	Description
0	M_Success	**Message**	This code SHALL indicate that the message was received and processed successfully.
100	M_ParameterError		This code SHALL indicate that an error occurred with a parameter of this message.

101	M_FieldError		This code SHALL indicate that an error occurred with a field of this message.
102	M_UnexpectedParameter		This code SHALL indicate that an unexpected parameter was received with this message.
103	M_MissingParameter		This code SHALL indicate that a required parameter was missing from this message.
104	M_DuplicateParameter		This code SHALL indicate that a parameter, for which there must only be one instance at the Reader, was seen more than once in this message.
105	M_OverflowParameter		This code SHALL indicate that the maximum number of instances of the parameter has been exceeded at the Reader.
106	M_OverflowField		This code SHALL indicate that the maximum number of instances of the field has been exceeded at the Reader.
107	M_UnknownParameter		This code SHALL indicate that an unknown parameter was received in the message.
108	M_UnknownField		This code SHALL indicate that the field is unknown or not found at the Reader.
109	M_UnsupportedMessage		This code SHALL indicate that an unsupported message type was received.
110	M_UnsupportedVersion		This code SHALL indicate that the LLRP version in the received message is not supported by the Reader.
111	M_UnsupportedParameter		This code MAY indicate that the Parameter in the received message is not supported by the Reader.
200	P_ParameterError	**Parameter**	This code SHALL indicate that an error occurred with a parameter of this parameter.
201	P_FieldError		This code SHALL indicate that an error occurred with a field of this parameter.
202	P_UnexpectedParameter		This code SHALL indicate that an unexpected parameter was

			received with this message.
203	P_MissingParameter		This code SHALL indicate that a required parameter was missing from this parameter.
204	P_DuplicateParameter		This code SHALL indicate that a parameter, for which there must only be one instance, was seen more than once in this parameter.
205	P_OverflowParameter		This code SHALL indicate that the maximum number of instances of the parameter has been exceeded at the Reader.
206	P_OverflowField		This code SHALL indicate that the maximum number of instances of the field has been exceeded at the Reader.
207	P_UnknownParameter		This code SHALL indicate that an unknown parameter was received with this message.
208	P_UnknownField		This code SHALL indicate that the field is unknown or not found at the Reader.
209	P_UnsupportedParameter		This code SHALL indicate that an unsupported parameter was received.
300	A_Invalid	**Field**	This code SHALL indicate that the field value was considered invalid for a non specific reason. An example is a message with invalid SpecID for a ROSpec or AccessSpec.
301	A_OutOfRange		This code SHALL indicate that the field value did not fall within an acceptable range.
401	R_DeviceError	**Reader**	This code MAY indicate that there is a problem on the Reader rather than with a message, parameter, or field.

14.2.2 LLRPStatus Parameter

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

LLRPStatus Parameter

StatusCode: Integer.

Possible Values:

See the error code table (section 14.2.1) for possible values within the Message, Parameter or Field scope.

FieldError: <FieldError Parameter> [Optional]

ParameterError: <ParameterError Parameter> [Optional]

ErrorDescription: UTF-8 String

14.2.2.1 FieldError Parameter

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

FieldError Parameter

FieldNum: Integer. Field number for which the error applies. The fields are numbered after the order in which they appear in the parameter or message body.

Possible Values:

0-65535

ErrorCode: Integer.

Possible Values:

See the error code table (section 14.2.1) for possible values within the Argument scope.

14.2.2.2 ParameterError Parameter

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

ParameterError Parameter

ParameterType: Integer. The parameter type that caused this error.

Possible Values:

0 - 1023

ErrorCode: Integer.

Possible Values:

See the error code table (section 14.2.1) for possible values within the Parameter scope.

FieldError: <FieldError Parameter> [Optional]

ParameterError: <ParameterError Parameter> [Optional]

15 Air Protocol Specific Parameters

For each air protocol supported by LLRP, the following subsection, 15.1, provides a table cross-referencing LLRP parameters and their corresponding air protocol specific parameters. All LLRP air protocol specific parameters are specified in the next subsection, 15.2.

15.1 LLRP Air Protocol Cross-Reference Tables

Within this section there is a separate subsection for each air protocol specified by LLRP. Each air protocol subsection includes a table cross-referencing LLRP parameters and their corresponding air protocol specific parameters.

Support for a new air protocol can be added to LLRP by adding new subsections to this section e.g., 15.1.2 and 15.1.3.

15.1.1 Class-1 Generation-2 (C1G2) Air Protocol

The Class-1 Generation-2 (C1G2) Air Protocol is specified by the EPCglobal Class-1 Generation-2 UHF RFID Protocol v1.1.0 specification.

The following table cross-references LLRP parameters to C1G2 air protocol specific parameters.

LLRP Parameter (Section #)	C1G2 Parameter (Section #)
AirProtocolLLRPCapabilities (9.2.3)	C1G2LLRPCapabilities 15.2.1.1.1
UHF_RFModeTable (9.2.4.1)	UHFC1G2RFModeTable (15.2.1.1.2)
AirProtocolInventoryCommandSettings (12.2.6)	C1G2InventoryCommand (15.2.1.2.1)
TagSpec (11.2.1.2)	C1G2TagSpec (15.2.1.3.1)
OpSpec (11.2.1.2)	C1G2OpSpec (15.2.1.3.2)
AirProtocolOpSpecList (11.2.2)	C1G2OpSpec (15.2.1.3.2)
AirProtocolSpecificEPCMemorySelector (13.2.1.1)	C1G2EPCMemorySelector (15.2.1.5.1)
AirProtocolTagData (13.2.3)	C1G2PC and C1G2CRC (15.2.1.5.2, 15.2.1.5.3)
AirProtocolSingulationDetails (13.2.6.9)	C1G2SingulationDetails (15.2.1.5.4)
Op Spec Results (13.2.3)	C1G2OpSpecResult (15.2.1.5.5)

15.2 LLRP Air Protocol Specific Parameters

Within this section there is a separate subsection for each air protocol specified by LLRP. Each air protocol subsection includes a definition for each air protocol specific parameter. Section 15.1 above cross-references LLRP parameters to the air protocol specific parameters specified in this section.

Support for a new air protocol can be added to LLRP by adding new subsections to this section e.g., 15.2.2 and 15.2.3.

15.2.1 Class-1 Generation-2 (C1G2) Air Protocol

The Class-1 Generation-2 (C1G2) Air Protocol is specified by EPCglobal Class-1 Generation-2 UHF RFID Protocol v1.1.0 specification.

The following subsections specify LLRP air protocol specific parameters. These subsections are partitioned to correlate with major sections of the LLRP specification:

- Reader Device Capabilities
- Inventory Operation
- Access Operation
- Reader Device Configuration
- Reports

15.2.1.1 Reader Device Capabilities

This section of air protocol specific parameters corresponds to LLRP parameters specified in section 9.

15.2.1.1.1 C1G2LLRPCapabilities Parameter

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter. Readers MAY support BlockErase, and MAY support BlockWrite. Readers SHALL support at least one select filter per query.

C1G2LLRPCapabilities Parameter

CanSupportBlockErase: Boolean

CanSupportBlockWrite: Boolean

MaxNumSelectFiltersPerQuery: Unsigned Short Integer. If set to zero, it indicates there is no maximum limit.

15.2.1.1.2 UHFC1G2RFModeTable Parameter

This parameter carries the set of C1G2 RF modes that the Reader is capable of operating.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

UHFC1G2RFModeTable Parameter

UHFC1G2RFModeSet: List of <UHFC1G2RFModeTableEntry Parameter>

15.2.1.1.2.1 UHFC1G2RFModeTableEntry Parameter

This parameter carries the information for each UHFC1G2 RF mode. A mode that has been tested for conformance by the EPCGlobal Hardware Action Group's Testing and Conformance (HAG T&C) group, is indicated using a conformance flag.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

UHFC1G2RFModeTableEntry Parameter

Mode identifier: Unsigned Integer. This is a Reader defined identifier that the client may use to set the Gen2 operating parameters.

DR Value: Integer. Divide ratio.

Possible Values:

Value	DR
0	8
1	64/3

BDR Value: Integer. Backscatter data rate in bps.

Possible Values:

40000 – 640000 bps

M value: Integer. Modulation.

Possible Values:

Value	M
0	FM0
1	2
2	4
3	8

Forward link modulation: Integer

Possible Values:

Value	Modulation
0	PR-ASK
1	SSB-ASK
2	DSB-ASK

PIE Value: Integer. One thousand times the ratio of data-0 symbol length and data-1 symbol length in pulse-interval encoding. The C1G2 spec specifies a ratio range of 1.5 – 2.0. (see section 6.3.1.2.4 in [C1G2]).

Possible Values:

1500-2000

MinTariValue: Integer. Minimum Tari time in nanoseconds (see section 6.3.1.2.4 in [C1G2])

Possible Values:

6250-25000

MaxTariValue: Integer. Maximum Tari time in nanoseconds. (see section 6.3.1.2.4 in [C1G2]).

Possible Values:

6250-25000

StepTariValue: Integer. Tari Step size in nanoseconds.(see section 6.3.1.2.4 in [C1G2])

Possible Values:

0 – 18750 nsec

Spectral Mask Indicator: Integer. Spectral mask characteristics of the mode. The Reader SHALL advertise this value if and only if the spectral mask value is valid for all the Tari steps in the range.

Possible Values:

Value	Modulation
0	Unknown
1	SI - Meets [C1G2] Single-Interrogator Mode Mask
2	MI - Meets [C1G2] Multi-Interrogator Mode Mask
3	DI - Meets [C1G2] Dense-Interrogator Mode Mask

EPC HAG T&C Conformance: Boolean. This flag indicates if the Reader vendor has received the certification for the parameter sets specified in this mode. The Reader SHALL set this flag to true only if the Reader vendor has received EPCGlobal conformance for this mode as specified in EPCGlobal Testing and Conformance.

15.2.1.2 Inventory Operation

This section of air protocol specific parameters corresponds to LLRP parameters specified in section 10.

15.2.1.2.1 C1G2InventoryCommand Parameter

This parameter defines the C1G2 inventory-specific settings to be used during a particular C1G2 inventory operation. This comprises of C1G2Filter Parameter, C1G2RF Parameter and C1G2Singulation Parameter. It is not necessary that the Filter, RF Control and Singulation Control Parameters be specified in each and every inventory command. They are optional parameters. If not specified, the default values in the Reader are used during the inventory operation. If multiple C1G2Filter parameters are encapsulated by the Client in the C1G2InventoryCommand parameter, the ordering of the filter parameters determine the order of C1G2 air-protocol commands (e.g., Select command) generated by the Reader.

The TagInventoryStateAware flag is used to determine how to process all the C1G2Filter and C1G2Singulation parameters in this command. At a functional level, if the Client is managing the tag states during an inventory operation, it would set that flag to true and pass the appropriate fields in the C1G2 Filter and C1G2 Singulation parameters. If a reader set CanDoTagInventoryStateAwareSingulation to False in LLRPCapabilities (section 9.2.2), it SHALL ignore the TagInventoryStateAware flag.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

C1G2InventoryCommand Parameter
TagInventoryStateAware: Boolean
C1G2 Filter : List of <C1G2Filter Parameter> [if absent, use default]
C1G2 RF: <C1G2RFControl Parameter> [if absent, use default]
C1G2 Singulation Control : <C1G2SingulationControl Parameter> [if absent, use default]
Custom Extension Point List: List of <Custom Parameter> (optional)

15.2.1.2.1.1 C1G2Filter Parameter

This parameter carries information specific to C1G2 filter (in particular, the parameters for the select command) operation, and are optionally sent with each inventory command from the Client to the Reader. This sets up the target tag population that gets inventoried. For an inventory operation with multiple filters, multiple instances of filter parameters are sent. A filter parameter contains the following fields:

- Target tag mask: This contains the information for the tag memory data pattern used for the select operation.
- T: This value is set if the Client is interested in only a truncated portion of the tag to be backscattered by the tag. The portion that gets backscattered includes the portion of the tag ID following the mask. This bit has to be set only in the last filter-spec.
- TagInventoryStateAwareFilterAction: This is used if the TagInventoryStateAware flag is set to true in the InventoryParameterSpec.
- TagInventoryStateUnawareFilterAction: This is used if the TagInventoryStateAware flag is set to false in the InventoryParameterSpec.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

C1G2Filter Parameter
Target Tag Mask: <C1G2TagInventoryMask Parameter>
T: Integer
Possible Values:

Value	Truncate action
0	Unspecified: The Reader decides what truncate action to take.
1	Do not truncate
2	Truncate

TagInventoryStateAwareAction: C1G2TagInventoryStateAwareFilterAction Parameter (optional)

TagInventoryStateUnawareAction: C1G2TagInventoryStateUnawareFilterAction Parameter (optional)

15.2.1.2.1.1.1 C1G2TagInventoryMask Parameter

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

C1G2TagInventoryMask Parameter

MB: Integer. C1G2 Tag memory bank.

Possible Values:

1-3. The mask used for the C1G2 select command applies only to EPC, TID or User memory, and not to Reserved memory (MB 0).

Pointer: Unsigned Short Integer. The first (msb) bit location of the specified memory bank against which to compare the TagMask.

TagMask: Bit array. The pattern against which to compare.

15.2.1.2.1.1.2 C1G2TagInventoryStateAwareFilterAction Parameter

This parameter is used by the Client to manage the tag states during an inventory operation. In order to use this parameter during inventory, the TagInventoryStateAware flag is set to true in the InventoryParameterSpec. This parameter contains:

- Target: This value indicates which flag in the tag to modify – whether the SL flag or its inventoried flag for a particular session.
- Action describes the action for matching and non-matching tags. The actions are specific about the tag-inventory states - e.g., do nothing, assert or deassert SL, assign inventoried S0/S1/S2/S3 to A or B.

Compliance requirement: Compliant Readers and Clients MAY implement this parameter. Readers that do not support tag inventory state aware singulation SHALL set CanDoTagInventoryStateAwareSingulation to false in LLRPCapabilities.

C1G2TagInventoryStateAwareFilterAction Parameter

Target: Integer

Possible Values:

Value	Definition

Value	Definition
0	SL
1	Inventoried state for session S0
2	Inventoried state for session S1
3	Inventoried state for session S2
4	Inventoried state for session S3

Action : Integer

Possible Values:

Value	Definition
0	Matching tags: assert SL or inventoried state → A. Non-matching tags: deassert SL or inventoried state → B.
1	Matching tags: assert SL or inventoried state → A. Non-matching tags: do nothing
2	Matching tags: do nothing Non-matching tags: deassert SL or inventoried state → B
3	Matching tags: negate SL or (A→B, B→A) Non-matching tags: do nothing
4	Matching tags: deassert SL or inventoried state → B Non-matching tags: assert SL or inventoried state → A
5	Matching tags: deassert SL or inventoried state → B Non-matching tags: do nothing
6	Matching tags: do nothing Non-matching tags: assert SL or inventoried state → A
7	Matching tags: do nothing Non-matching tags: negate SL or (A→B, B→A)

15.2.1.2.1.1.3 C1G2TagInventoryStateUnawareFilterAction Parameter

This parameter is used by the Client if it does not want to manage the tag states during an inventory operation. Using this parameter, the Client instructs the Reader about the tags that should and should not participate in the inventory action. In order to use this parameter during inventory, the TagInventoryStateAware flag is set to false in the InventoryParameterSpec. This parameter contains:

- Action describes the action for matching and non-matching tags. However, the action is simply specifying whether matching or non-matching tags partake in this inventory. The Reader is expected to handle the tag inventory states to facilitate this.

In this parameter, Action=Select means search for pattern in Inventory, and Action=Unselect means do not search for pattern in Inventory.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

C1G2TagInventoryStateUnawareFilterAction Parameter

Action : Integer

Possible Values:

Value	Matching Tags	Non-matching Tags
0	Select	Unselect
1	Select	Do nothing
2	Do nothing	Unselect
3	Unselect	Do nothing
4	Unselect	Select
5	Do nothing	Select

15.2.1.2.1.2 C1G2RF Control Parameter

This Parameter carries the settings relevant to RF forward and reverse link control in the C1G2 air protocol. This is basically the C1G2 RF Mode and the Tari value to use for the inventory operation.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

C1G2RFControl Parameter

ModeIndex: Unsigned Integer. This is an index into the UHFC1G2RFModeTable.

Tari: Integer. Value of Tari to use for this mode specified in nsec. This is specified if the mode selected has a Tari range. If the selected mode has a range, and the Tari is set to zero, the Reader implementation picks up any Tari value within the range. If the selected mode has a range, and the specified Tari is out of that range and is not set to zero, an error message is generated.

Possible Values:

0 or 6250-25000 nsec

15.2.1.2.1.3 C1G2SingulationControl Parameter

This C1G2SingulationControl Parameter provides controls particular to the singulation process in the C1G2 air protocol. The singulation process is started using a Query command in the C1G2 protocol. The Query command describes the session number, tag state, the start Q value to use, and the RF link parameters. The RF link parameters are specified using the C1G2RFControl Parameter (see section 15.2.1.2.1.2). This Singulation Parameter specifies the session, tag state and description of the target singulation environment. The following attributes are specified to provide guidance to the Reader for the singulation algorithm:

- Tag transit time: This is the measure of expected tag mobility in the field of view of the antenna where this inventory operation is getting executed.
- Tag population: This is the expected tag population in the field of view of the antenna.

In addition, the Singulation Parameter allows setting of the following:

- Session ID: This is the C1G2 session number that the tags use to update the inventory state upon successful singulation.

- TagInventoryStateAwareSingulationAction: This is used if the TagInventoryStateAware flag is set to true in the InventoryParameterSpec.
    - I: This is the inventoried state of the target tag population in the selected session. Only tags that match the session state participate in the inventory round. If the Ignore value is specified, the Reader ignores this field, and its up to the Reader implementation to determine the value of I used in the inventory round.
    - S: This is the state of the SL flag in the tag. Only tags that match that tag state participate in the inventory round. If the Ignore value is specified, the Reader ignores this field, and its up to the Reader implementation to determine the value of S used in the inventory round.

If a reader sets CanDoTagInventoryStateAwareSingulation to False in LLRPCapabilities (section 9.2.2), it SHALL ignore the TagInventoryStateAwareSingulationAction field.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

C1G2SingulationControl Parameter

Session: Integer. Session number to use for the inventory operation.

Possible Values:

0-3

Tag population: Unsigned Short Integer. An estimate of the tag population in view of the RF field of the antenna.

Tag transit time: Unsigned Integer. An estimate of the time a tag will typically remain in the RF field of the antenna specified in milliseconds.

TagInventoryStateAwareSingulationAction:
<C1G2TagInventoryStateAwareSingulationAction Parameter> (optional)

15.2.1.2.1.3.1 C1G2TagInventoryStateAwareSingulationAction Parameter

Compliance requirement: Compliant Readers and Clients MAY implement this parameter. Readers that do not support tag inventory state aware singulation SHALL set CanDoTagInventoryStateAwareSingulation to false in LLRPCapabilities.

C1G2TagInventoryStateAwareSingulationAction Parameter

I : Integer

Possible Values:

Value	Definition
0	State A
1	State B

S : Integer

Possible Values:

Value	Definition
0	SL
1	~SL

15.2.1.3 Access Operation

This section of air protocol specific parameters corresponds to LLRP parameters specified in section 11.

15.2.1.3.1 C1G2TagSpec Parameter

This parameter describes the target tag population on which certain operations have to be performed. This Parameter is similar to the selection C1G2Filter Parameter described earlier. However, because these tags are stored in the Reader's memory and ternary comparisons are to be allowed for, each bit i in the target tag is represented using 2 bits - bit i in mask, and bit i in tag pattern. If bit i in the mask is zero, then bit i of the target tag is a don't care (X); if bit i in the mask is one, then bit i of the target tag is bit i of the tag pattern. For example, "all tags" is specified using a mask length of zero.

This parameter can carry up to two tag patterns. If more than one pattern is present, a Boolean AND is implied. Each tag pattern has a match or a non-match flag, allowing (A and B,!A and B, !A and !B, A and !B), where A and B are the tag patterns.

The tagSpec contains:

- TagPattern1
- TagPattern2

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

C1G2TagSpec Parameter

TagPattern1: <C1G2TargetTag Parameter>

TagPattern2: <C1G2TargetTag Parameter> [optional]

15.2.1.3.1.1 C1G2TargetTag Parameter

If Length is zero, this pattern will match all tags regardless of MB, pointer, mask and data.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

C1G2TargetTag Parameter

MB: Integer. Memory bank.

Possible Values: 0-3.

Pointer: Unsigned Short Integer. The address of the first (msb) bit against which to apply

the Tag Mask and compare with the value.

TagMask : Bit array

TagData: Bit array

Match: Boolean

15.2.1.3.2 C1G2 OpSpec Parameters

This section describes the C1G2 specific OpSpec parameters that are sent as part of the AccessSpec. Each OpSpec parameter has an OpSpecID that is used when reporting results of the operation.

15.2.1.3.2.1 C1G2Read Parameter

MB is the memory bank to use. WordPtr is the starting word address. WordCount is the number of 16-bit words to be read. Following is text reproduced from the C1G2 specification regarding WordCount=0. [If WordCount = 0, the tag backscatters the contents of the chosen memory bank starting at WordPtr and ending at the end of the bank, unless MB = 1, in which case the Tag shall backscatter the EPC memory contents starting at WordPtr and ending at the length of the EPC specified by the first 5 bits of the PC if WordPtr lies within the EPC, and shall backscatter the EPC memory contents starting at WordPtr and ending at the end of EPC memory if WordPtr lies outside the EPC.]

Access Password is the password used by the Reader to transition the tag to the secure state so that it can read protected tag memory regions. For example, the Tag's Reserved memory is locked but not permalocked, meaning that the Reader must issue the access password and transition the Tag to the secured state before performing the read operation.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

C1G2Read Parameter

OpSpecID: Unsigned Short Integer

MB: Integer. Memory bank.

Possible Values: 0-3

WordPtr: Unsigned Short Integer. The word addresss of the first word to read from the chosen memory bank.

WordCount: Unsigned Short Integer

AccessPassword: Unsigned Integer

15.2.1.3.2.2 C1G2Write Parameter

MB is the memory bank to use. WordPtr is the starting word address. Write Data is the data to be written to the tag. Word Count is the number of words to be written. Depending on the word count, the Reader may have to execute multiple C1G2 air

protocol Write commands. Access Password is the password used by the Reader to transition the tag to the secure state so that it can write to protected tag memory regions.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

C1G2Write Parameter

OpSpecID : Unsigned Short Integer

MB: Integer. Memory bank.

Possible Values: 0-3

WordPtr: Unsigned Short Integer. The word addresss of the first word to be written to the chosen memory bank.

Write Data: Short array. The data to write to the chosen memory bank.

AccessPassword: Unsigned Integer

15.2.1.3.2.3 C1G2Kill Parameter

Kill Password is the value of the kill password to be used or set.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

C1G2Kill Parameter

OpSpecID : Unsigned Short Integer

Kill Password: Unsigned Integer

15.2.1.3.2.4 C1G2Lock Parameter

This parameter contains the definition of the access privilege updates (read/write/permalock) to be performed in various locations of the memory. The five data fields for which we can define access control using the lock command are: Kill Password, Access Password, EPC memory, TID memory and User memory. The access privilege updates are expressed as a list of C1G2LockPayload Parameters, one for each memory location.

The Access Password provides the password to enter the *secured* state. A Reader can perform a lock operation on a tag only if the tag is in the *secured* state. The tag enters the secured state only using the Access Password (if a non-zero value).

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

C1G2Lock Parameter

OpSpecID : Unsigned Short Integer

LockCommandPayloadList: List of <C1G2LockPayload Parameter>

Access Password: Unsigned Integer

15.2.1.3.2.4.1 C1G2LockPayload Parameter

This parameter contains the definition of the access privilege updates (read/write/permalock) to be performed for a single location of the tag memory. The five data fields for which we can define access control using the lock command are: Kill Password, Access Password, EPC memory, TID memory and User memory.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

C1G2LockPayload Parameter

OpSpecID : Unsigned Short Integer

Privilege: Integer. Value indicates the access privilege to be applied.
Possible Values:

Value	Access Privilege
0	Read/Write
1	Permalock
2	Permaunlock
3	Unlock

DataField: Unsigned Integer. Value indicates to which data field the access privilege will be applied.
Possible Values:

Value	Field
0	Kill Password
1	Access Password
2	EPC Memory
3	TID Memory
4	User Memory

15.2.1.3.2.5 C1G2BlockErase Parameter

MB is the memory bank to use. WordPtr is the starting word address. Word Count is the number of 16-bit words to be read. Access Password is the password used by the Reader to transition the tag to the secure state so that it can erase protected tag memory regions.

Compliance requirement: Compliant Readers and Clients MAY implement this parameter. Readers that do not support C1G2BlockErase SHALL set CanSupportBlockErase to false in C1G2LLRPCapabilities. If such a Reader receives an ADD_ACCESSSPEC with an AccessSpec that contained this OpSpec parameter, the Reader SHALL return an error for that message and not add the AccessSpec.

C1G2BlockErase Parameter

OpSpecID : Unsigned Short Integer

MB: Integer. Memory bank.

Possible Values: 0-3

WordPtr: Unsigned Short Integer. Word address of first word to be erased.

Word Count: Unsigned Short Integer. Number of words to erase.

Access Password: Unsigned Integer

15.2.1.3.2.6 C1G2BlockWrite Parameter

MB is the memory bank to use. WordPtr is the starting word address. Word Count is the number of 16-bit words to be written. Depending on the word count, the Reader may have to execute multiple C1G2 air protocol block write commands. Write Data is the data to be written to the tag. Access Password is the password used by the Reader to transition the tag to the secure state so that it can write to protected tag memory regions.

Compliance requirement: Compliant Readers and Clients MAY implement this parameter. Readers that do not support C1G2BlockWrite SHALL set CanSupportBlockWrite to false in C1G2LLRPCapabilities. If such a Reader receives an ADD_ACCESSSPEC with an AccessSpec that contained this OpSpec parameter, the Reader SHALL return an error for that message and not add the AccessSpec.

C1G2BlockWrite Parameter

OpSpecID : Unsigned Short Integer

MB: Integer. Memory bank.

Possible Values: 0-3

WordPtr: Unsigned Short Integer. Word address of first word to be written.

Write Data: Short array

Access Password: Unsigned Integer

15.2.1.4 Reader Device Configuration

This section of air protocol specific parameters corresponds to LLRP parameters specified in section 12. The only air protocol specific parameter is AirProtocolInventoryCommandSettings parameter in the AntennaConfiguration (section 12.2.6). The C1G2 specific InventoryCommand is already defined in section 15.2.1.2.1.

15.2.1.5 Reports

This section of air protocol specific parameters corresponds to LLRP parameters specified in section 13.2.1.1.

15.2.1.5.1 C1G2EPCMemorySelector Parameter

This parameter is used to determine what contents are of interest in the C1G2EPC memory bank for reporting. If enableCRC and enablePC is set to false, only the EPC is returned in the RO Report. If enablePC is set to true, the PC bits and the EPC are returned in the RO Report. If enablePC and enableCRC is set to true, the EPC, PC bits and CRC are returned in the RO Report.

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

C1G2EPCMemorySelector

enablePC: Boolean

enableCRC: Boolean

15.2.1.5.2 C1G2PC Parameter

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

C1G2PC Parameter

PC bits: Unsigned Short Integer

15.2.1.5.3 C1G2CRC Parameter

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

C1G2CRC Parameter

CRC: Unsigned Short Integer

15.2.1.5.4 C1G2SingulationDetails Parameter

Compliance requirement: Compliant Readers and Clients MAY implement this parameter.

C1G2SingulationDetails Parameter

NumCollisionSlots: Unsigned Short Integer. The number of slots detected as collided over the duration of this report.

NumEmptySlots: Unsigned Short Integer. The number of slots detected as empty over the duration of this report.

15.2.1.5.5 C1G2 OpSpec Results

15.2.1.5.5.1 C1G2ReadOpSpecResult Parameter

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

C1G2ReadOpSpecResult Parameter

OpSpecID: Unsigned Short Integer

ReadData: Short Array. The data read from the RFID tag.

Result: Integer

Possible Values:

Value	Definition
0	Success
1	Non-specific tag error
2	No response from tag
3	Non-specific reader error

15.2.1.5.5.2 C1G2WriteOpSpecResult Parameter

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

C1G2WriteOpSpecResult Parameter

OpSpecID: Unsigned Short Integer

NumWordsWritten: Unsigned Short Integer. The number of words written as a result of this OpSpec. If the number of words written is not equal to the length of the data pattern to write, the Result below SHALL be non-zero.

Result: Integer

Possible Values:

Value	Definition
0	Success
1	Tag memory overrun error
2	Tag memory locked error
3	Insufficient power to perform memory-write operation
4	Non-specific tag error
5	No response from tag
6	Non-specific reader error

15.2.1.5.5.3 C1G2KillOpSpecResult Parameter

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

C1G2KillOpSpecResult Parameter

OpSpecID: Unsigned Short Integer

Result: Integer

Possible Values:

Value	Definition
0	Success
1	Zero kill password error
2	Insufficient power to perform kill operation
3	Non-specific tag error
4	No response from tag
5	Non-specific reader error

15.2.1.5.5.4 C1G2LockOpSpecResult Parameter

Compliance requirement: Compliant Readers and Clients SHALL implement this parameter.

C1G2LockOpSpecResult Parameter

OpSpecID: Unsigned Short Integer

Result: Integer

Possible Values:

Value	Definition
0	Success
1	Insufficient power to perform lock operation
2	Non-specific tag error
3	No response from tag
4	Non-specific reader error

15.2.1.5.5.5 C1G2BlockEraseOpSpecResult Parameter

Compliance requirement: Compliant Readers and Clients MAY implement this parameter. Readers that do not support C1G2 Block Erase SHALL set CanSupportBlockErase to false in C1G2LLRPCapabilities. If such a Reader receives an ADD_ACCESSSPEC with an AccessSpec that contains this OpSpec parameter, the Reader SHALL return an error for that message and not add the AccessSpec.

C1G2BlockEraseOpSpecResult Parameter

OpSpecID: Unsigned Short Integer

Result: Integer

Possible Values:

Value	Definition
0	Success
1	Tag memory overrun error
2	Tag memory locked error
3	Insufficient power to perform block erase operation
4	Non-specific tag error
5	No response from tag
6	Non-specific reader error

15.2.1.5.5.6 C1G2BlockWriteOpSpecResult Parameter

Compliance requirement: Compliant Readers and Clients MAY implement this parameter. Readers that do not support C1G2 Block Write SHALL set CanSupportBlockWrite to false in C1G2LLRPCapabilities. If such a Reader receives an ADD_ACCESSSPEC with an AccessSpec that contains this OpSpec parameter, the Reader SHALL return an error for that message and not add the AccessSpec.

C1G2BlockWriteOpSpecResult Parameter

OpSpecID: Unsigned Short Integer

NumWordsWritten: Unsigned Short Integer

Result: Integer

Possible Values:

Value	Definition
0	Success
1	Tag memory overrun error
2	Tag memory locked error
3	Insufficient power to perform memory-write operation
4	Non-specific tag error
5	No response from tag
6	Non-specific reader error

16 Binary Encoding for LLRP

This section contains the specific formats and operations for the binary encoding of the Low Level Reader Protocol. All fields and parameters must be encoded in the order shown in the diagrams in this section. This section does not contain information that has been generalized in the main body of the document. Refer to sections 8-15 for the description of the messages and the parameters and fields in the messages.

The binary encoding is based on a stream of octets. Each octet represents 8 bits of information. Octets within the data stream are serialized according to the particular transport mechanism over which this binding is carried. Octet numbering shown in this section is in network order. For example, in Figure 12, the first octet that a LLRP endpoint receives contains Rsvd, Ver and 2 bits of Message type.

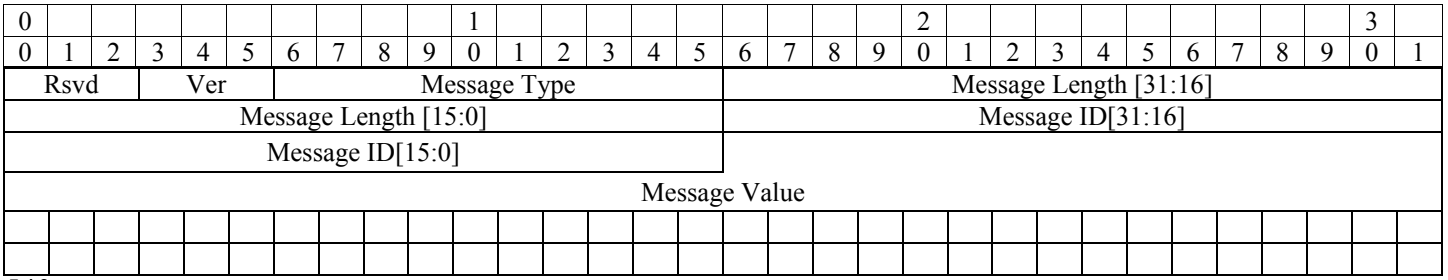


Figure 12: Network Order

Figure 13 illustrates the bit order inside the fields.

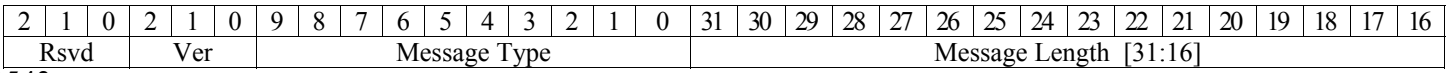


Figure 13: Bit Order in Fields

Integer numbers SHALL be encoded in network byte order with the most significant byte of the integer being sent first (big-Endian). Bit arrays are aligned to the most significant bit. Bit arrays are padded to an octet boundary. Pad bits SHALL be ignored by the Reader and Client.

The length of all messages within the binary encoding SHALL be multiples of octets. This means all parameters within the binary encoding SHALL be multiples of octets. This includes any custom or vendor specific parameter. All the messages and parameters in this section have been padded with zero to ensure that the length is a multiple of octets.

Notations

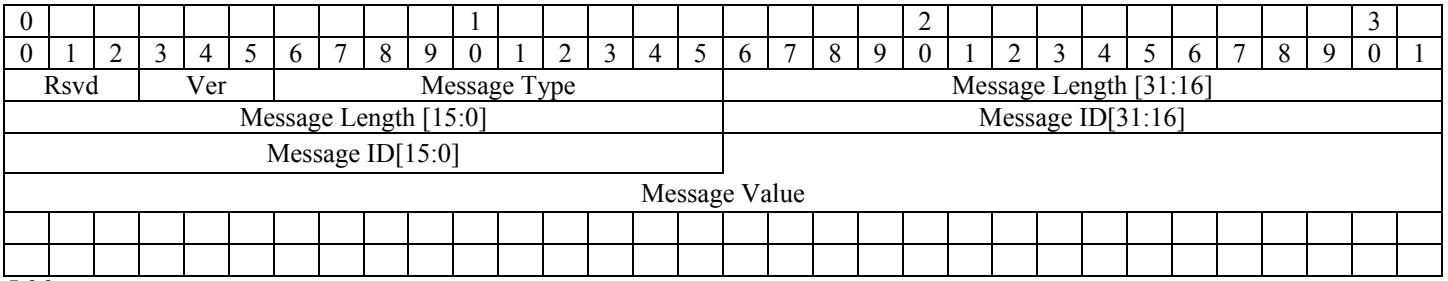
Inside a message or a parameter,

- If a parameter X is denoted simply as X, it means that X is mandatory and appears once in the message.
- If a parameter X is denoted as X (0-n), it means that X is optional in the message, and it can appear multiple times in the message.
- If a parameter X is denoted as X (0-1), it means that X is optional in the message and that it can appear at most once in the message.
- If a parameter X is denoted as X (1-n), it means that X is mandatory and can appear multiple times in the message.

Negative Numbers

Negative numbers are represented using twos complement notation.

16.1 Messages



Reserved bits: 3 bits
The reserved bits are reserved for future extensions. All reserved bits in messages SHALL be set to 0 in outgoing messages.

Ver: 3 bits
The version of LLRP. Implementations of LLRP based on this specification are using the value 0x1. Other values are reserved for future use.

Message Type: 10 bits
The type of LLRP message being carried in the message.

Message Length: 32 bits
This value represents the size of the entire message in octets starting from bit offset 0 of the first word. Therefore, if the Message Value field is zero-length, the Length field will be set to 10.

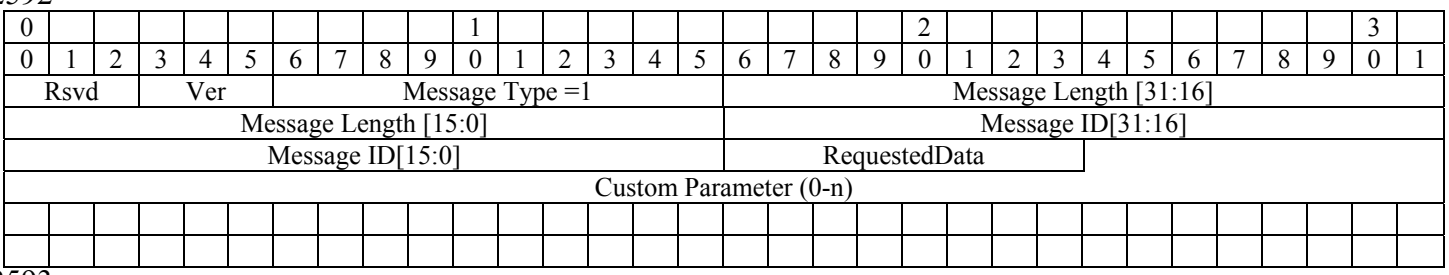
Message ID: 32 bits

As stated earlier, the communications between the Client and the Reader are primarily of a request-response type - requests/commands from the Client to the Reader, and responses from the Reader to the Client. In order to facilitate multiple outstanding commands/requests from the Client, LLRP uses a Message sequence number in each message. The Message sequence number is used to correlate a response with the original request. This sequence number is local to the LLRP channel.

Message Value: variable length

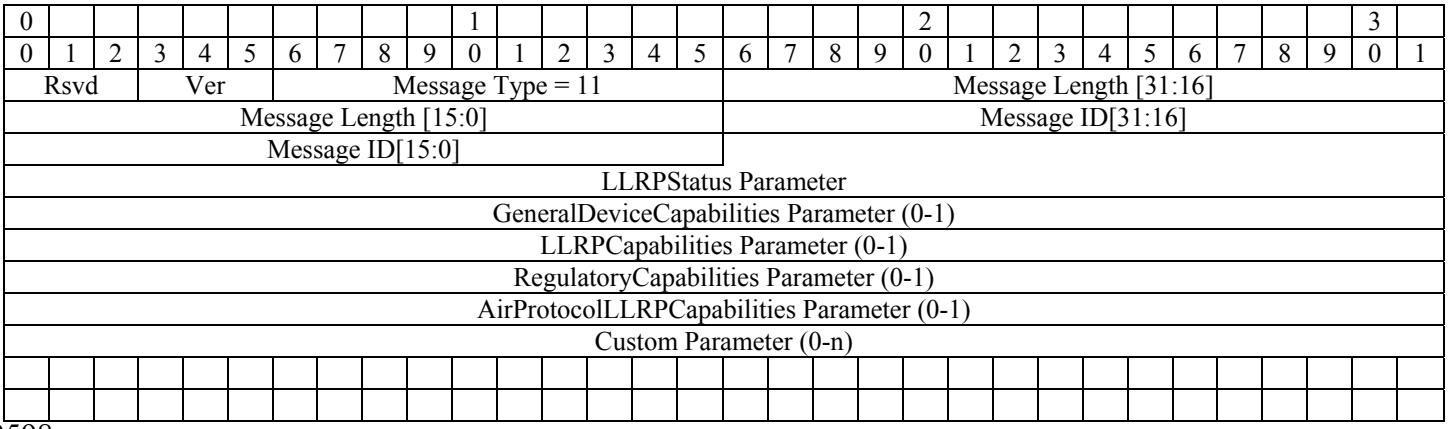
Dependent on the Message Type.

16.1.1 GET_READER_CAPABILITIES



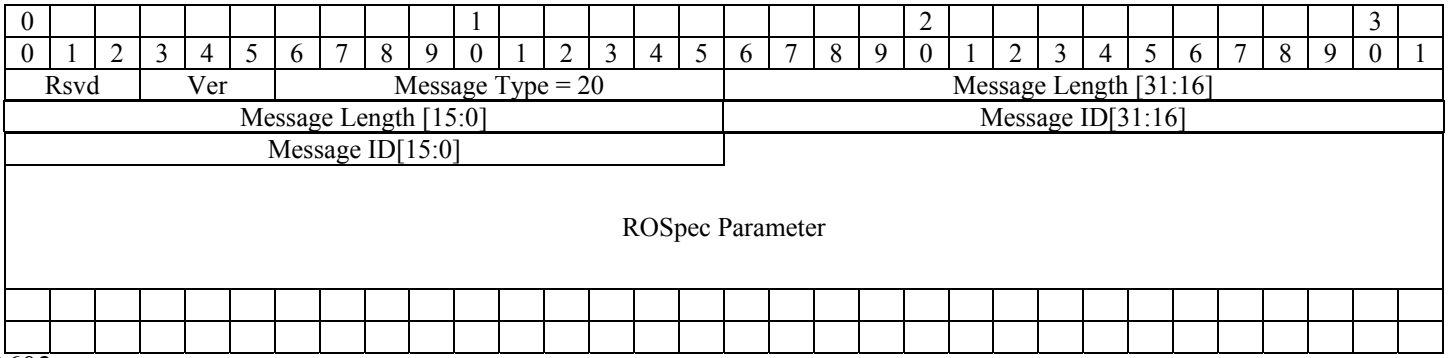
See Section 9.1.1.

16.1.2 GET_READER_CAPABILITIES_RESPONSE



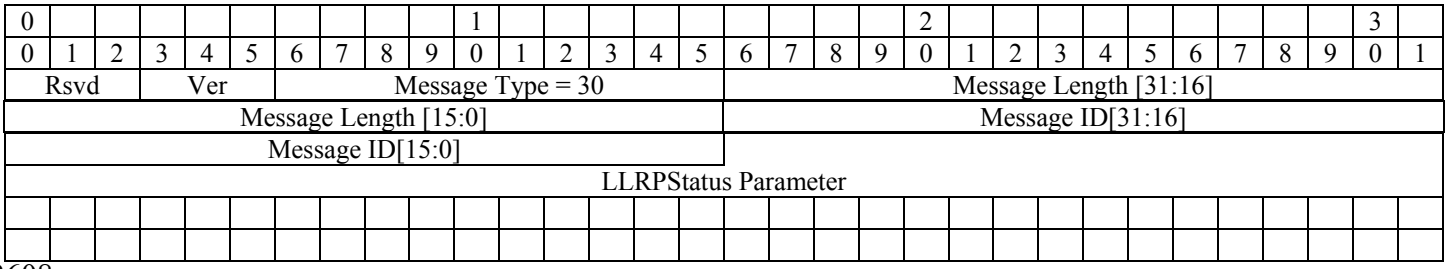
See Section 9.1.2.

16.1.3 ADD_ROSPEC



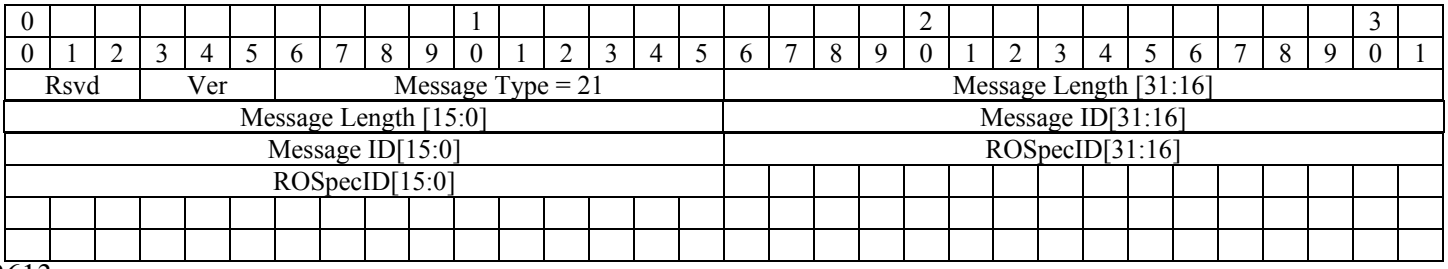
See section 10.1.1.

16.1.4 ADD_ROSPEC_RESPONSE



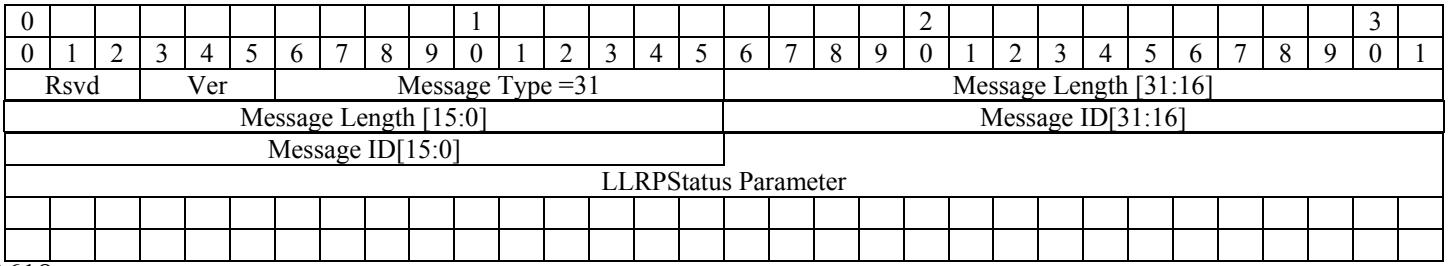
See section 10.1.2.

16.1.5 DELETE_ROSPEC



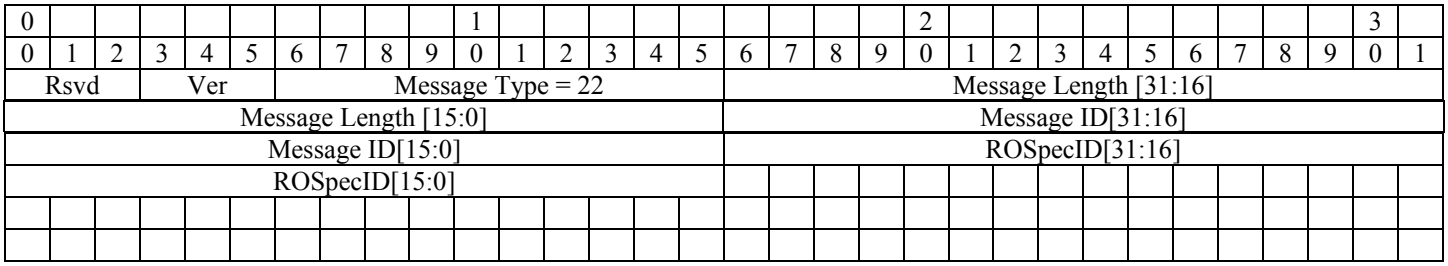
See section 10.1.3.

16.1.6 DELETE_ROSPEC_RESPONSE



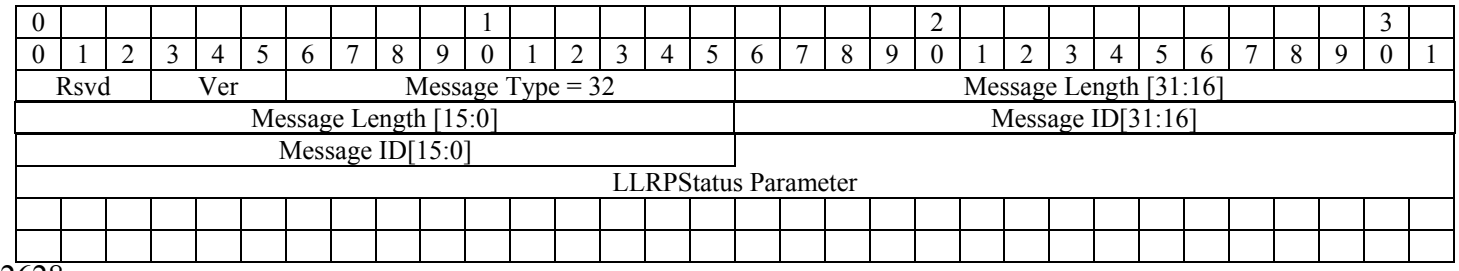
See section 10.1.4.

16.1.7 START_ROSPEC



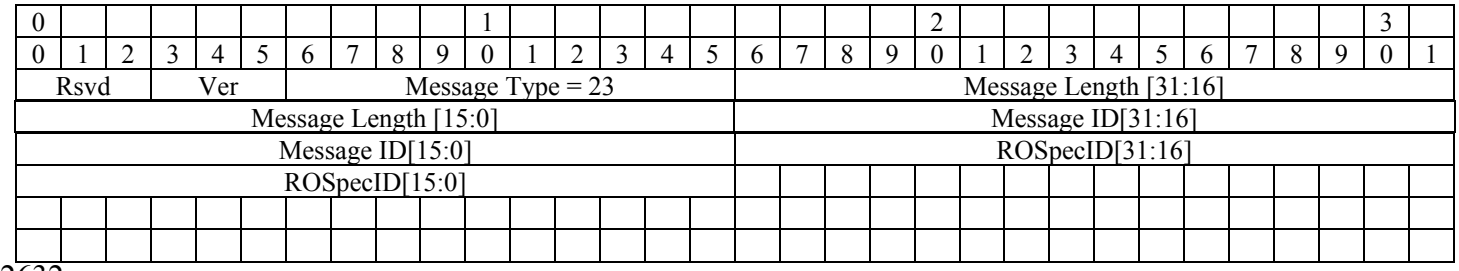
See section 10.1.5.

16.1.8 START_ROSPEC_RESPONSE



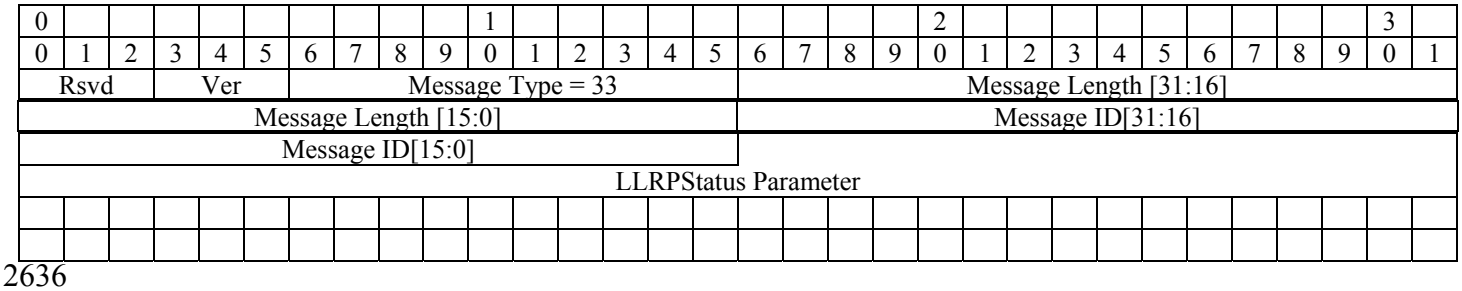
See section 10.1.6.

16.1.9 STOP_ROSPEC



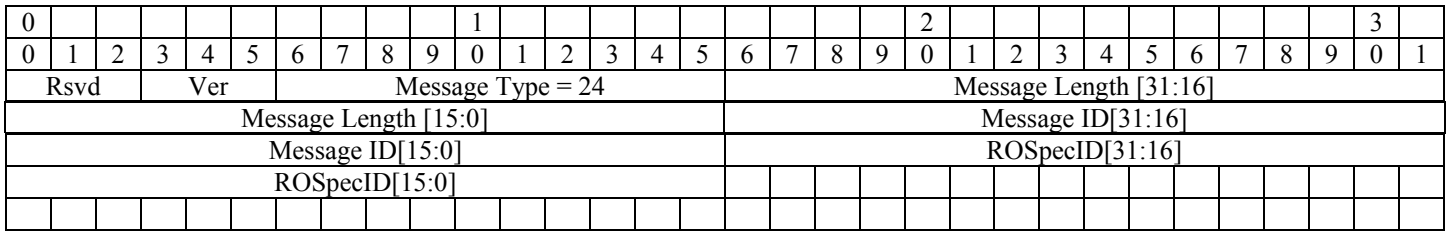
See section 10.1.7.

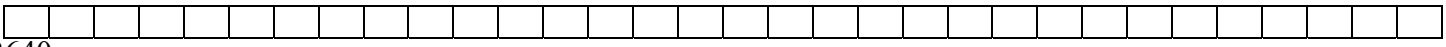
16.1.10 STOP_ROSPEC_RESPONSE



See section 10.1.8.

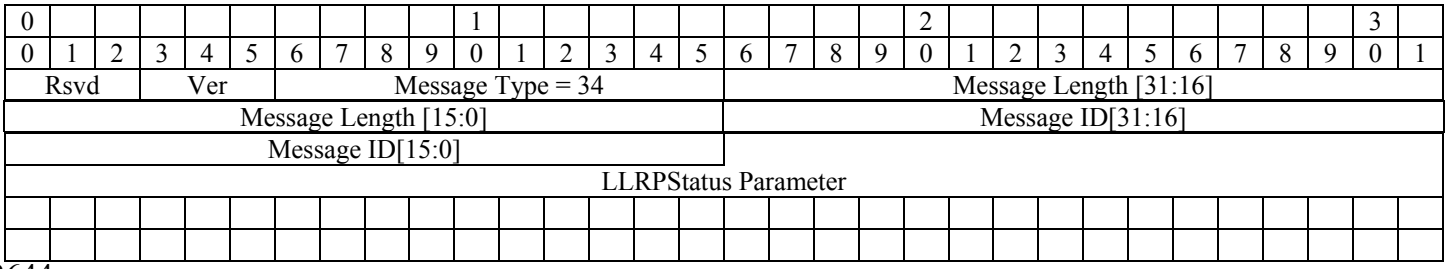
16.1.11 ENABLE_ROSPEC





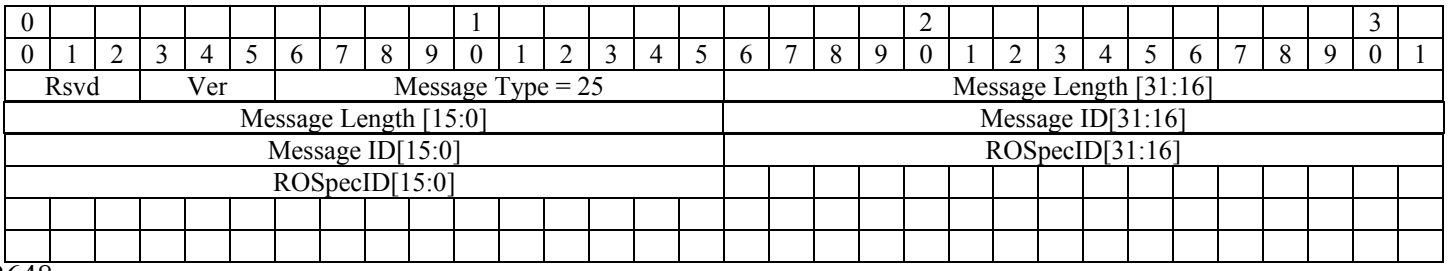
See section 10.1.9.

16.1.12 ENABLE_ROSPEC_RESPONSE



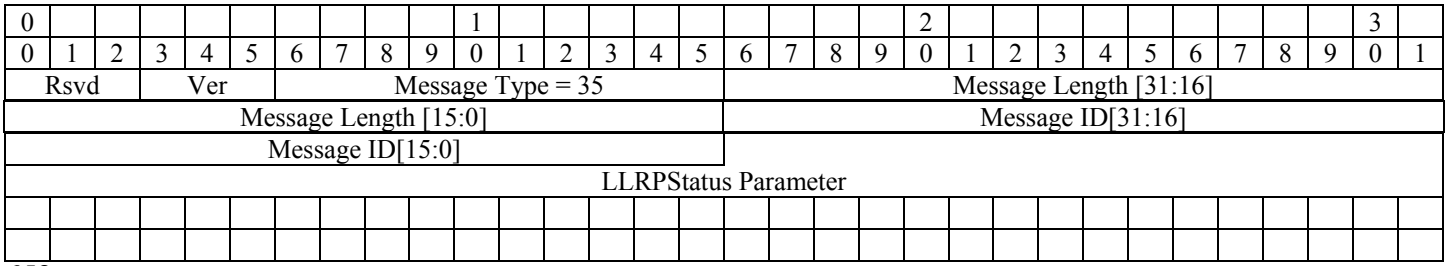
See section 10.1.10.

16.1.13 DISABLE_ROSPEC



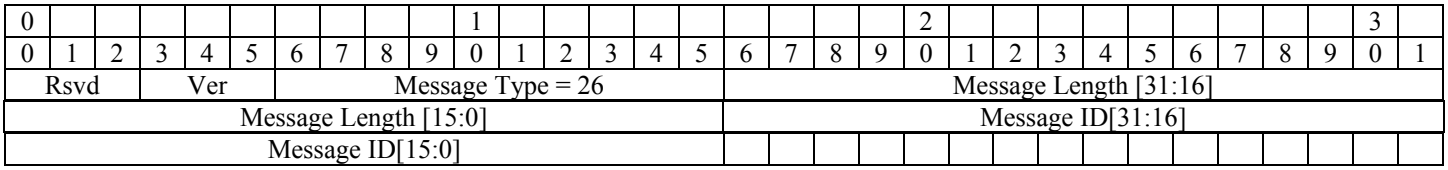
See section 10.1.11.

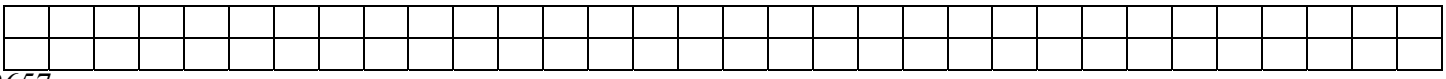
16.1.14 DISABLE_ROSPEC_RESPONSE



See section 10.1.12.

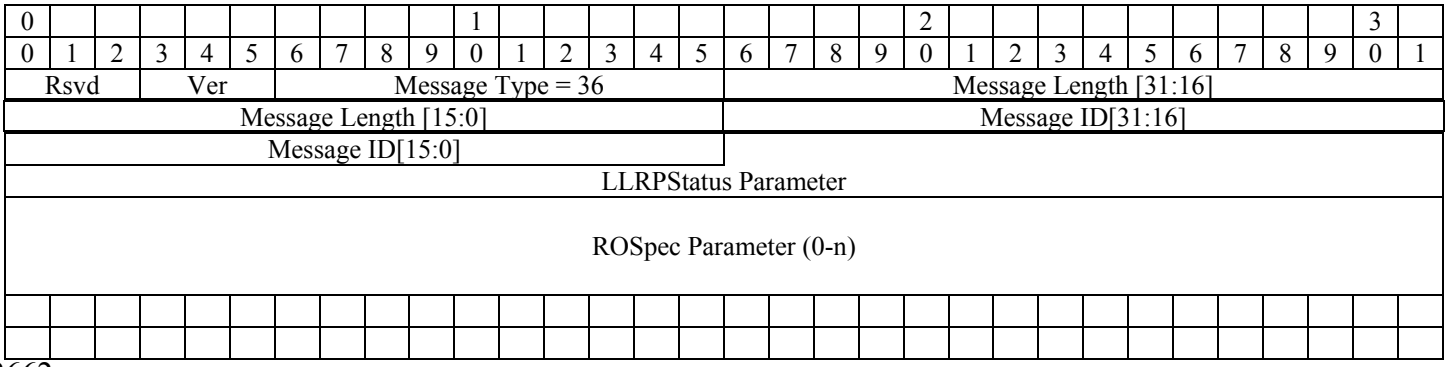
16.1.15 GET_ROSPECS





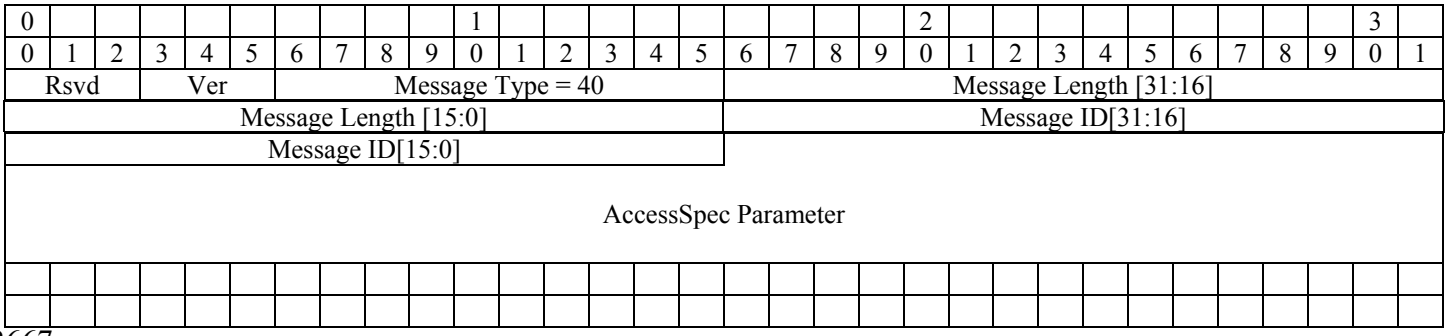
See section 10.1.13.

16.1.16 GET_ROSPECS_RESPONSE



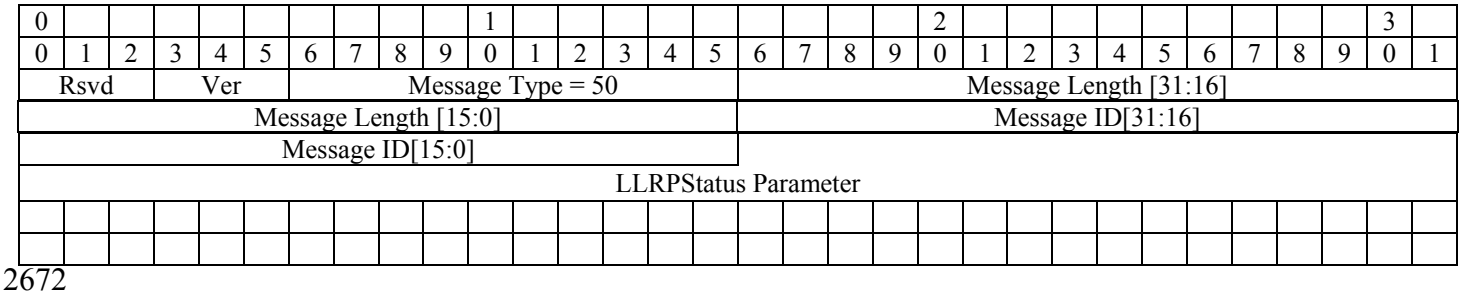
See Section 10.1.14.

16.1.17 ADD_ACCESSSPEC



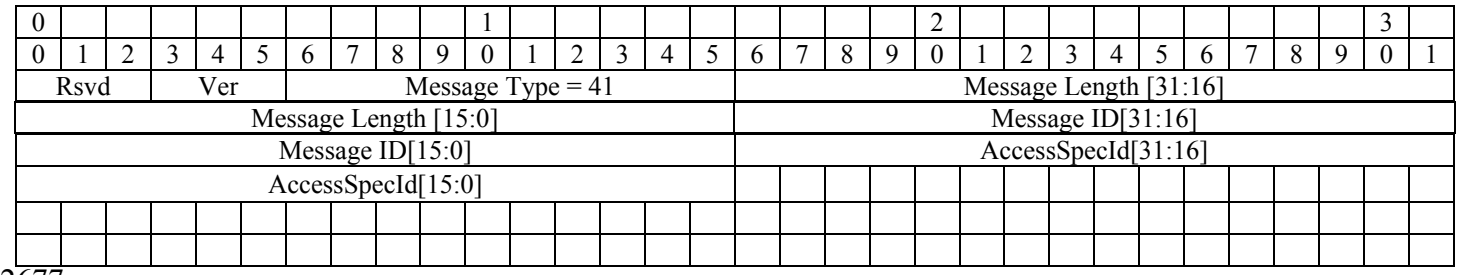
See Section 11.1.1.

16.1.18 ADD_ACCESSSPEC_RESPONSE



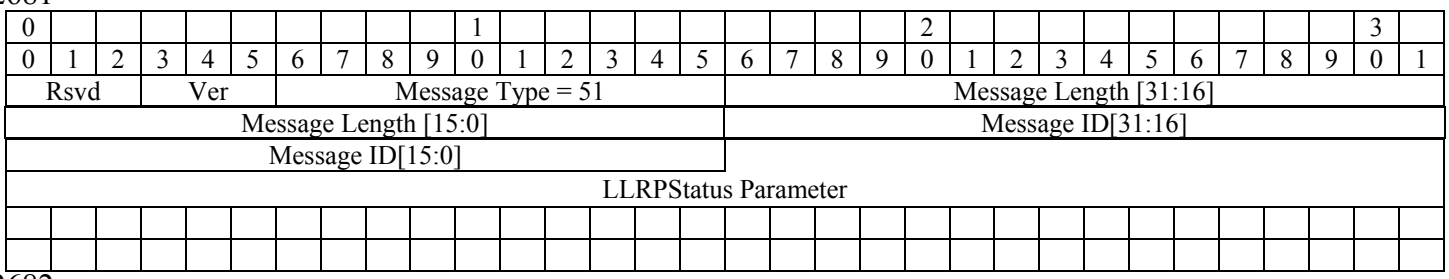
See Section 11.1.2.

16.1.19 DELETE_ACCESSSPEC



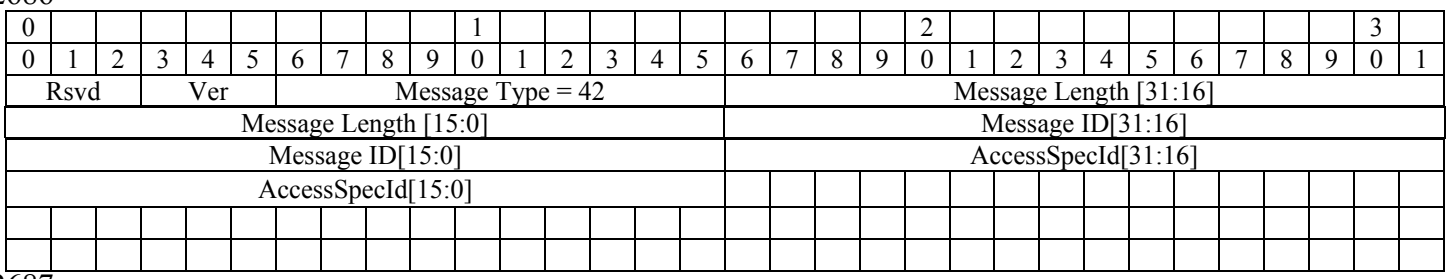
See Section 11.1.3.

16.1.20 DELETE_ACCESSSPEC_RESPONSE



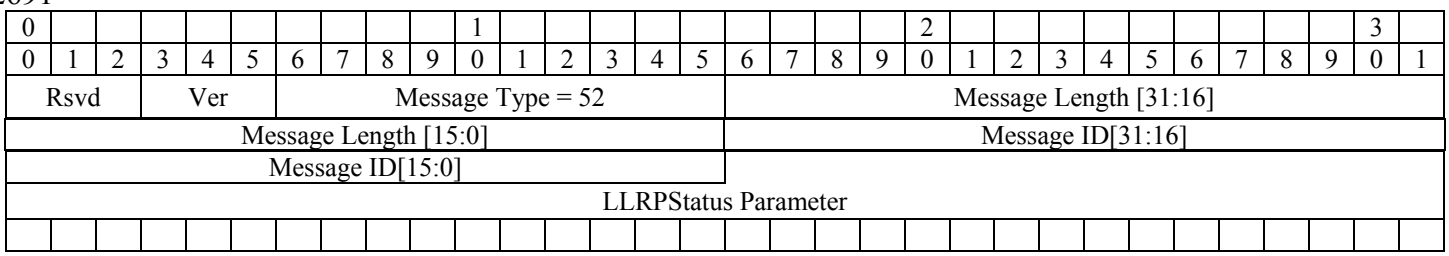
See Section 11.1.4.

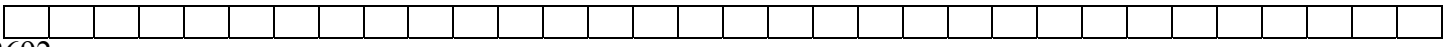
16.1.21 ENABLE_ACCESSSPEC



See Section 11.1.5.

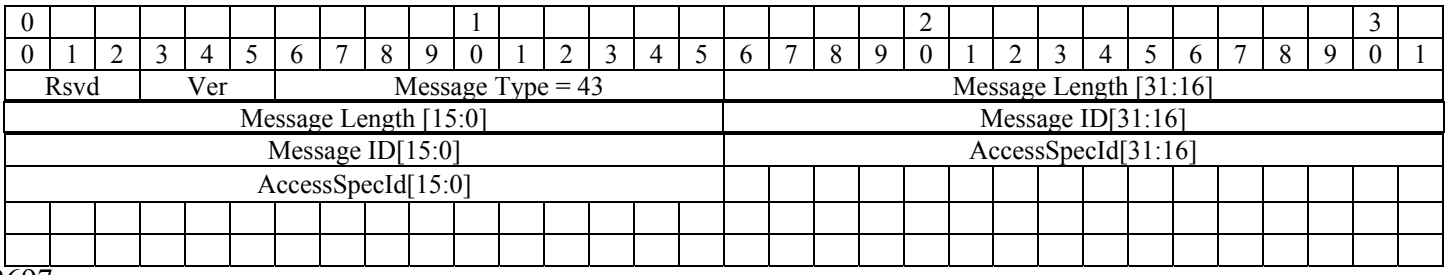
16.1.22 ENABLE_ACCESSSPEC_RESPONSE





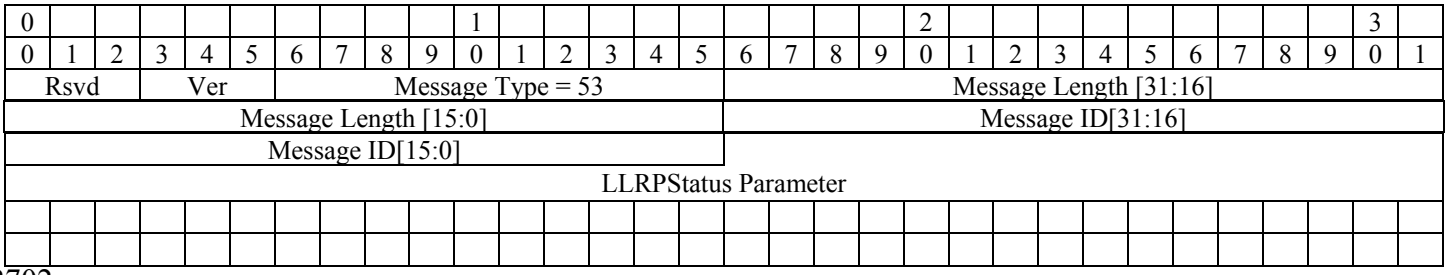
See Section 11.1.6.

16.1.23 DISABLE_ACCESSSPEC



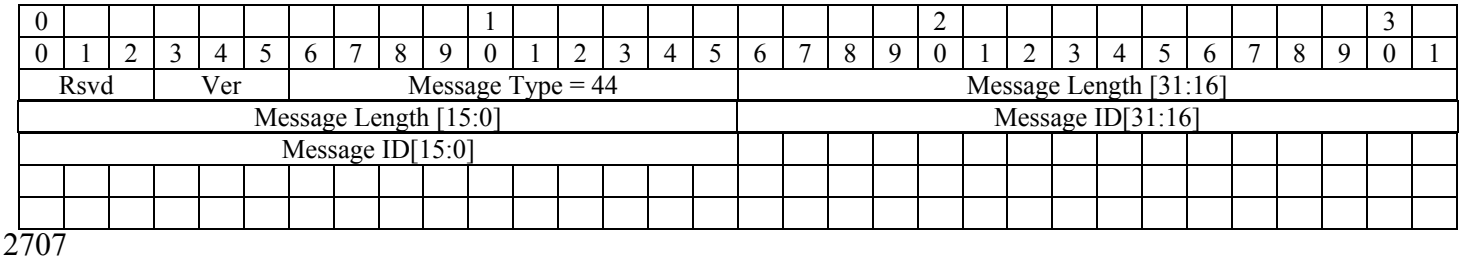
See Section 11.1.7.

16.1.24 DISABLE_ACCESSSPEC_RESPONSE



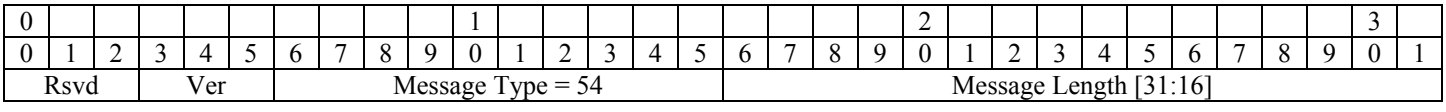
See Section 11.1.8.

16.1.25 GET_ACCESSSPECS



See Section 11.1.9.

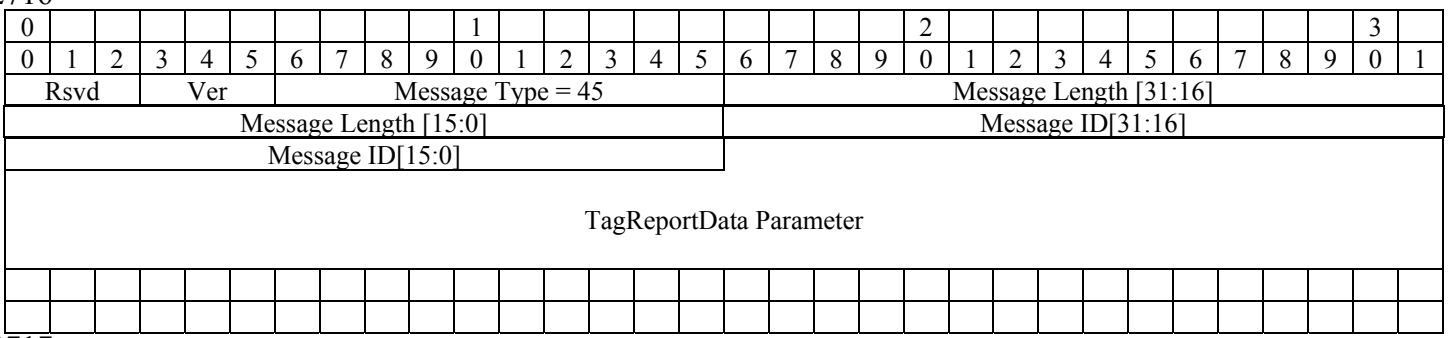
16.1.26 GET_ACCESSSPECS_RESPONSE



Message Length [15:0]	Message ID[31:16]
Message ID[15:0]	
LLRPStatus Parameter	
AccessSpec Parameter (0-n)	

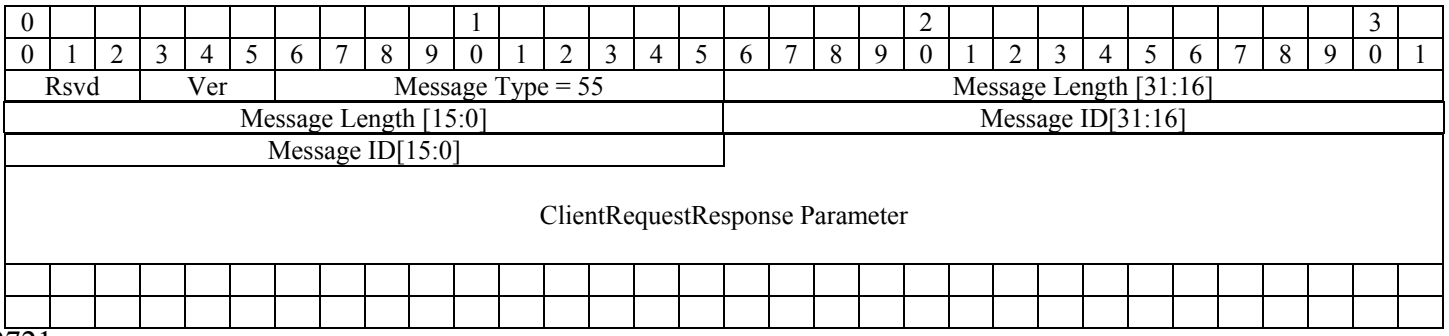
See Section 11.1.10.

16.1.27 CLIENT_REQUEST_OP



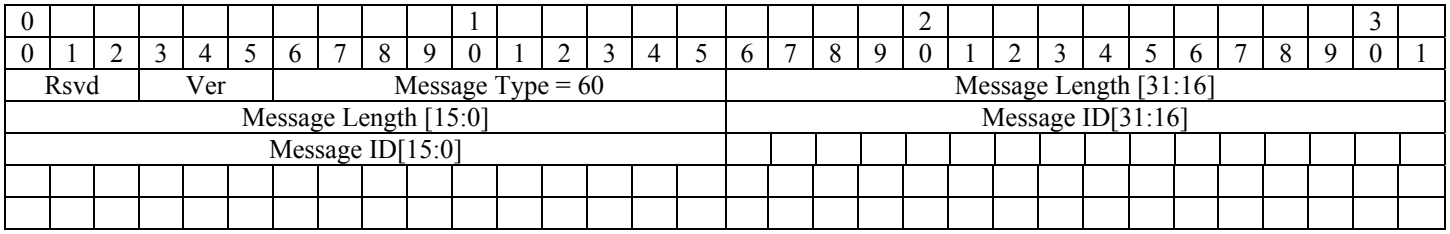
See Section 11.1.11.

16.1.28 CLIENT_REQUEST_OP_RESPONSE



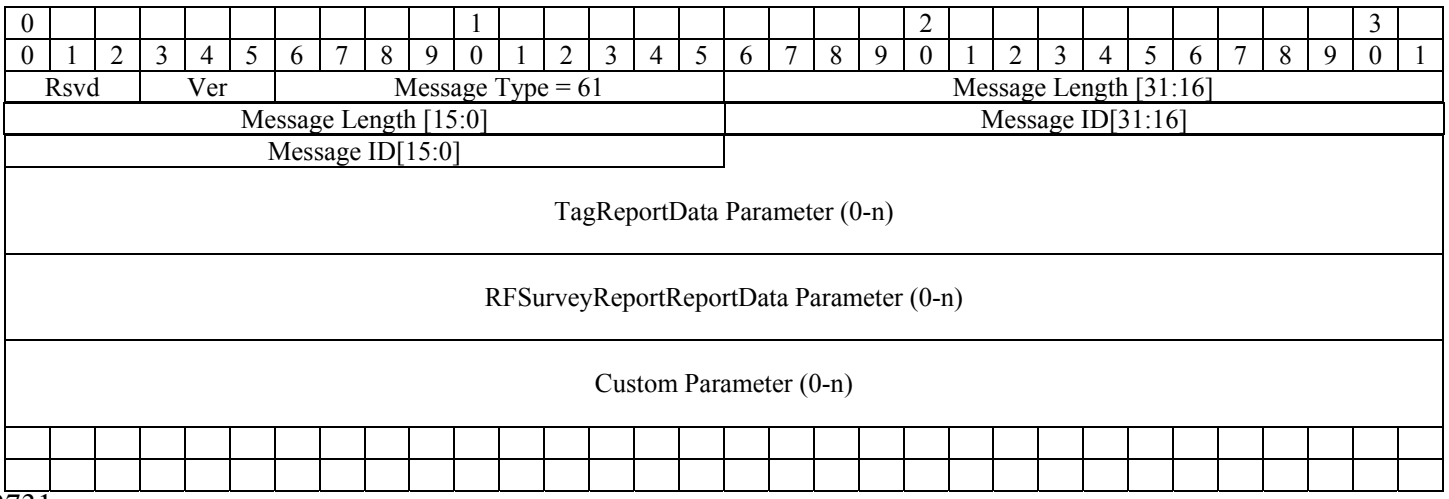
See Section 11.1.12.

16.1.29 GET_REPORT



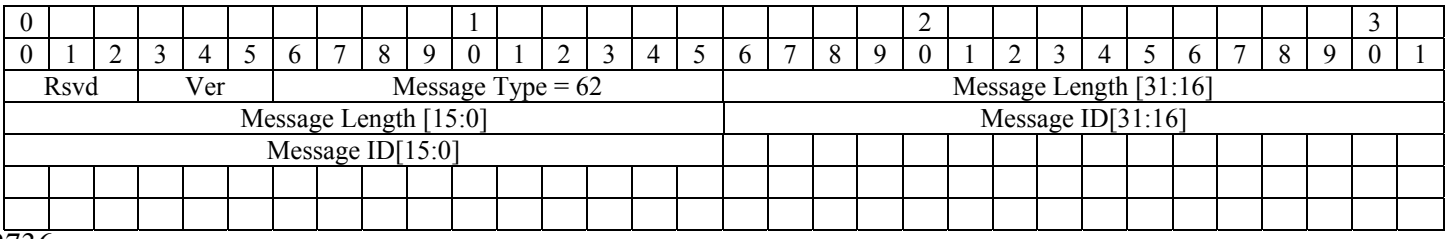
See Section 13.1.1.

16.1.30 RO_ACCESS_REPORT



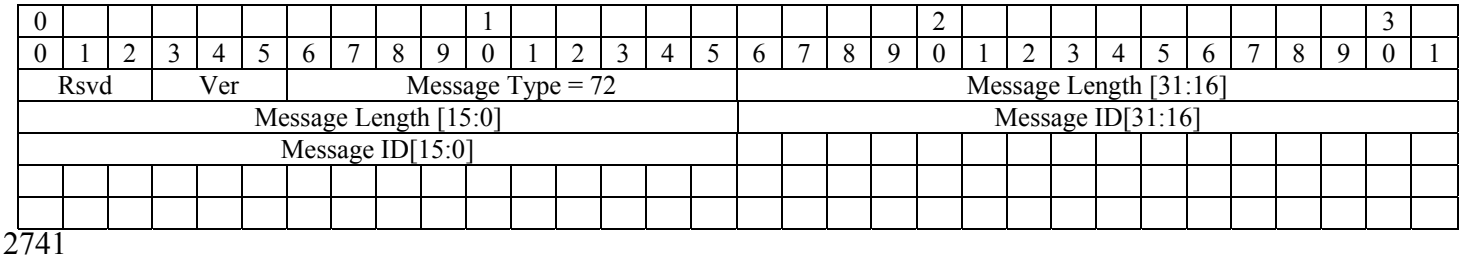
See Section 13.1.2.

16.1.31 KEEPALIVE



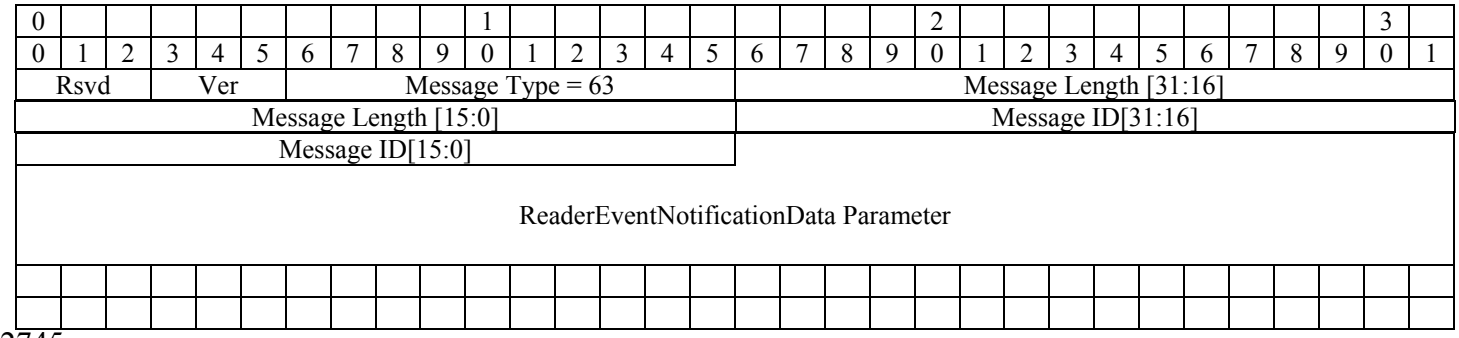
See Section 13.1.3.

16.1.32 KEEPALIVE_ACK



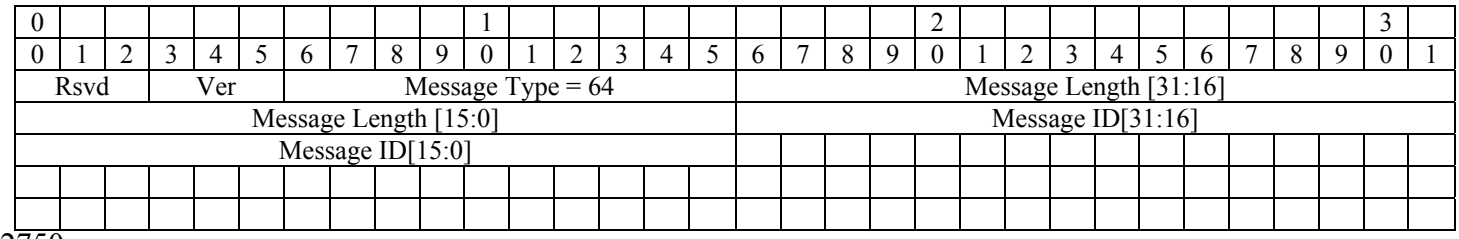
See Section 13.1.4.

16.1.33 READER_EVENT_NOTIFICATION



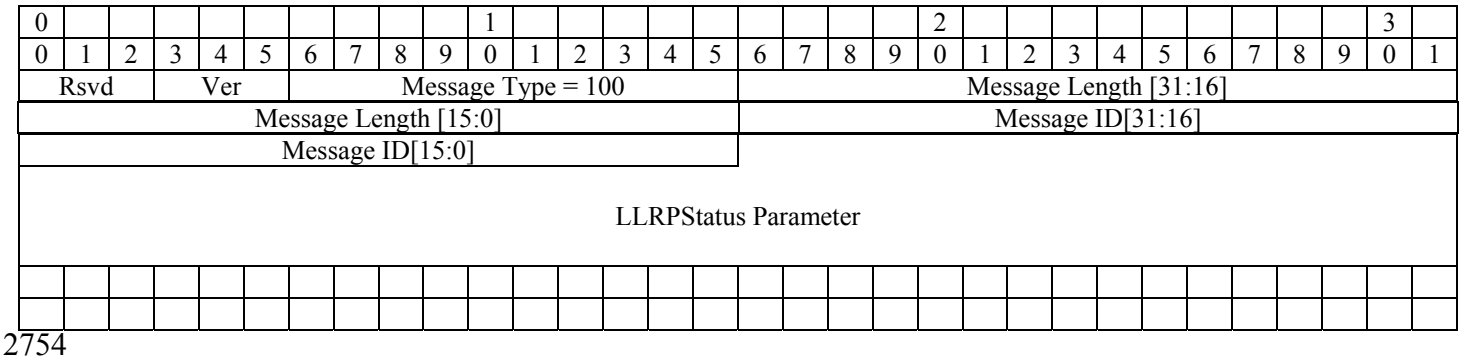
See Section 13.1.5.

16.1.34 ENABLE_EVENTS_AND_REPORTS



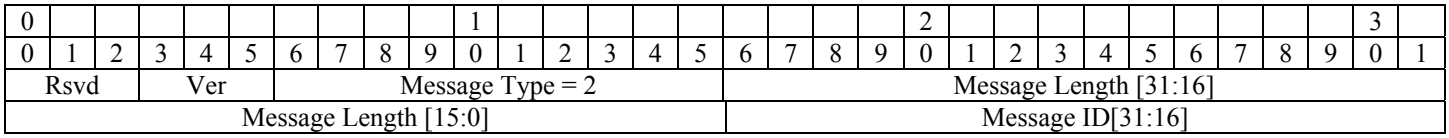
See Section 13.1.6.

16.1.35 ERROR_MESSAGE



See Section 14.1.1.

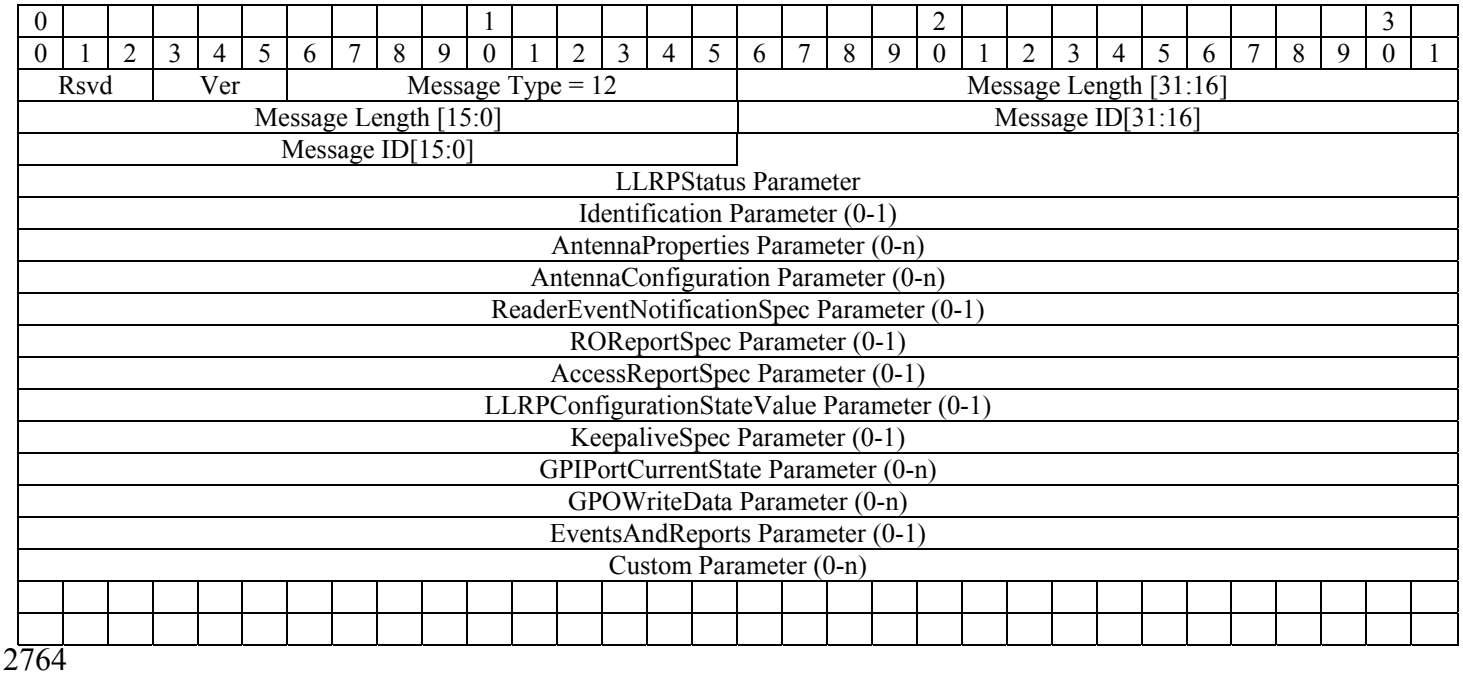
16.1.36 GET_READER_CONFIG



Message ID[15:0]	Antenna ID
RequestedData	GPIPortNum	GPOPortNum[15:8]
GPOPortNum[7:0]	
Custom Parameter (0-n)	

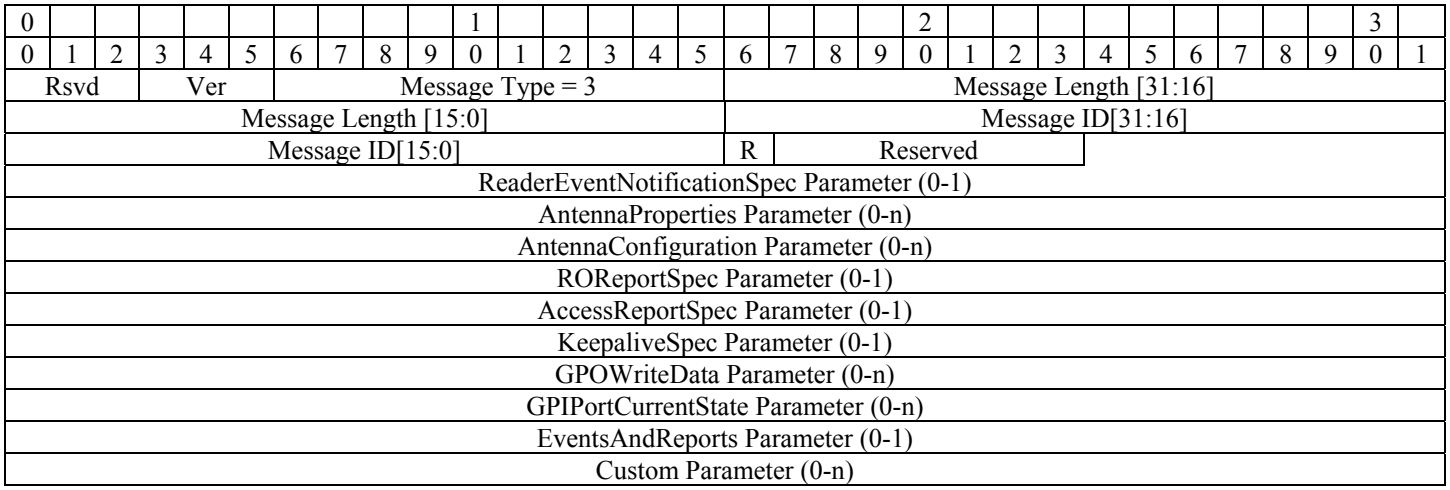
See Section 12.1.1.

16.1.37 GET_READER_CONFIG_RESPONSE



See Section 12.1.2.

16.1.38 SET_READER_CONFIG



Abbreviations

R - ResetToFactoryDefaults

See section 12.1.3.

16.1.39 SET_READER_CONFIG_RESPONSE

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Rsvd			Ver			Message Type = 13										Message Length [31:16]															
Message Length [15:0]																Message ID[31:16]															
Message ID[15:0]																															
LLRPStatus Parameter																															

See section 12.1.4.

16.1.40 CLOSE_CONNECTION

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Rsvd			Ver			Message Type = 14										Message Length [31:16]															
Message Length [15:0]																Message ID[31:16]															
Message ID[15:0]																															

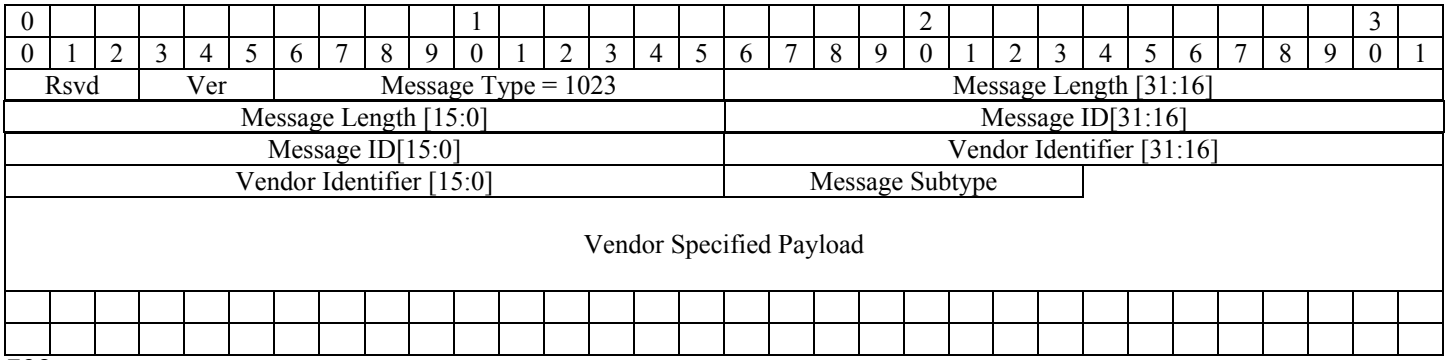
See section 12.1.5.

16.1.41 CLOSE_CONNECTION_RESPONSE

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Rsvd			Ver			Message Type = 4										Message Length [31:16]															
Message Length [15:0]																Message ID[31:16]															
Message ID[15:0]																															
LLRPStatus Parameter																															

See section 12.1.6.

16.1.42 CUSTOM_MESSAGE



See Section 8.1.

16.2 LLRP Parameters

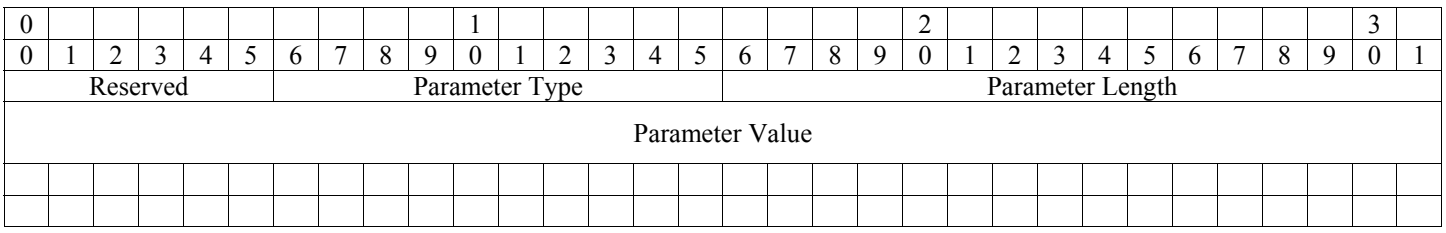
LLRP parameters are defined in the following subsections with the exception that the air protocol specific LLRP parameters are defined in Section 16.3. The binary encoding of LLRP uses two different encodings of parameters: Type-length-value (TLV) encoded parameters, and Type-value (TV) encoded parameters. The TV encoding is only used for encoding parameters that are fixed-length, and are in Reports and Notifications from the Reader. The use of a compact encoding (i.e., TV) for the Reports and Notifications helps improve the network efficiency.

16.2.1 TLV and TV Encoding of LLRP Parameter

The type of encoding (TLV or TV) is determined based on the value of bit 0 in the parameter header. All TLV-encoded Parameters SHALL have a 0 in bit 0 of the header. All TV-encoded Parameters SHALL have a 1 in bit 0 of the header.

16.2.1.1 TLV-Parameters

LLRP TLV-Parameters have the following encoding structure.



Reserved bits: 6 bits

The reserved bits are reserved for future extensions. All reserved bits SHALL be set to 0.

Parameter Type: 10 bits

This is the type of LLRP parameter being carried in the message. The parameter number space for the

TLV-parameters is 128 – 2047. The number space 0-127 is reserved for TV-parameters.

Parameter Length: 16 bits
This value represents the size of the entire parameter in bytes starting from bit offset 0 of the first word. Therefore, if the Parameter Value field is zero-length, the Parameter Length field will be set to 4.

Parameter Value: variable length
Dependent on the Parameter Type.

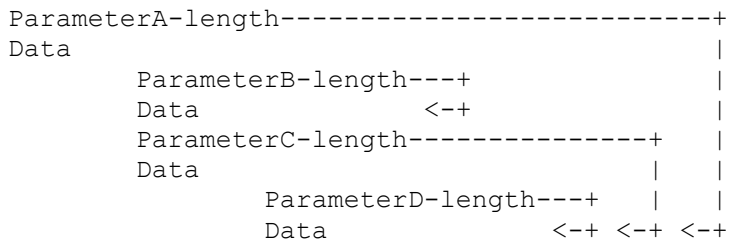
16.2.1.1.1 Encoding Guidelines for TLV-Parameters

The following rules apply to TLV-Parameters:

- Parameters may contain mandatory and optional fields.
- Parameter fields may be passed by value or by sub-parameter.
- Mandatory fields will always be present and optional fields may or may not be present.
- Mandatory fields of fixed length will be passed by value only, using the order, size and alignment defined in this document.
- A mandatory field of variable length must be passed by value if it is the only field, mandatory or optional, of variable length in that parameter.
- A parameter with multiple mandatory or optional fields of variable length must pass them as sub-parameters.
- A parameter containing a field of variable length being passed by value may not contain sub-parameters.
- Optional fields will always be passed as sub-parameters.

The following rules apply to sub-parameters:

- Sub-parameters follow all parameter rules.
- A sub-parameter is a parameter that is encompassed within the length of a preceeding parameter and adds to the dataset of the encapsulating parameter.



- Sub-parameters may be mandatory or optional.

16.2.1.2 TV-Parameters

LLRP TV-Parameters have the following encoding structure.

0										1										2										3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1

1	Parameter Type	
Parameter Value		

Parameter Type: 8 bits
This is the type of LLRP parameter being carried in the message. The parameter number space for the TV-parameters is 1 – 127. The number space 128-2047 is reserved for TLV-parameters.

Parameter Value: variable length
Dependent on the Parameter Type.

16.2.1.2.1 Encoding Guidelines for TV-Parameters

The following rule applies to TV-Parameters:

- TV-Parameters cannot contain sub-parameters (TLV or TV-Parameters).

16.2.2 General Parameters

16.2.2.1 UTCTimestamp Parameter

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 128										Length															
Microseconds [63:32]																															
Microseconds [31:0]																															

See Section 7.1.3.1.1.1.

16.2.2.2 Uptime Parameter

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 129										Length															
MicroSeconds [63:32]																															
Microseconds [31:0]																															

See section 7.1.3.1.1.2.

16.2.3 Reader Device Capabilities Parameters

16.2.3.1 GeneralDeviceCapabilities Parameter

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 137										Length															
MaxNumberOfAntennaSupported																C	T	Reserved													
Device manufacturer name																															
Model Name																															
FirmwareVersionByteCount																															
Reader Firmware Version: Variable length UTF-8 String																															
ReceiveSensitivityTableEntry Parameter (1-n)																															
PerAntennaReceiveSensitivityRange Parameter (0-n)																															
GPIOCapabilities Parameter																															
PerAntennaAirProtocol Parameter (1-n)																															

See Section 9.2.1.

Abbreviations

C – CanSetAntennaProperties

T - HasUTCClockCapability

16.2.3.1.1 ReceiveSensitivityTableEntry Parameter

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 139										Length															
Index																Receive Sensitivity Value															

See Section 9.2.1.11.

16.2.3.1.2 PerAntennaReceiveSensitivityRange Parameter

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 149										Length															
AntennaID																ReceiveSensitivityIndexMin															
ReceiveSensitivityIndexMax																															

See Section 9.2.1.22.

16.2.3.1.3 PerAntennaAirProtocol Parameter

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 140										Length															
AntennaId																NumProtocols															
ProtocolID#1						ProtocolID#2										…..										ProtocolID#P					

See Section 9.2.1.33.

16.2.3.1.4 GPIOCapabilities Parameter

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 141										Length															
NumGPIs																NumGPOs															

See section 9.2.1.44.

16.2.3.2 LLRPCapabilities Parameter

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 142										Length															
C	R	S	T	H	Reserved					MaxPriorityLevelSupported						ClientRequestOpSpecTimeout															
MaxNumROSpecs																															
MaxNumSpecsPerROSpec																															
MaxNumInventoryParameterSpecsPerAISpec																															
MaxNumAccessSpecs																															
MaxNumOpSpecsPerAccessSpec																															

Abbreviations

C – CanDoRFSurvey
R – CanReportBufferFillWarning
S – SupportsClientRequestOpSpec
T – CanDoTagInventoryStateAwareSingulation
H – SupportsEventAndReportHolding
MaxNumPriority – MaxNumPriorityLevelsSupported

See Section 9.2.2.

16.2.3.3 AirProtocolLLRPCapabilities Parameter

See section 9.2.3.

There is no separate binary encoding for AirProtocolLLRPCapabilities. Each Air protocol's capabilities are expressed in a different LLRP Parameter. Refer to Section 16.3 for air protocol specific capability parameters. For example, the C1G2LLRPCapabiltities Parameter (Section 16.3.1.1.1) carries the C1G2 air protocol capabilities.

16.2.3.4 RegulatoryCapabilities Parameter

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 143										Length															
Country Code																Communications Standard															
UHFBandCapabilities Parameter (0-1)																															

Custom Paramter (0-n)

See Section 9.2.4.

16.2.3.4.1 UHFBandCapabilities Parameter

0										1										2										3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 144										Length															
TransmitPowerLevelTableEntry Parameter (1-n)																															
FrequencyInformation Parameter																															
UHFRFModeTable Parameter (1-n)																															

See Section 9.2.4.1.

16.2.3.4.1.1 TransmitPowerLevelTableEntry Parameter

0										1										2										3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 145										Length															
Index																TransmitPowerValue															

See Section 9.2.4.1.1.

16.2.3.4.1.2 FrequencyInformation Parameter

0										1										2										3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 146										Length															
H	Reserved																														
FrequencyHopTable Parameter (0-n)																															
FixedFrequencyTable (0-1)																															

Abbreviations

H – Hopping

See Section 9.2.4.1.2.

16.2.3.4.1.2.1 FrequencyHopTable Parameter

0										1										2										3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 147										Length															
HopTableId										Reserved										NumHops											
Frequency#1																															

….
Frequency#n

2941
2942 NumHops: Number of entries in the List of Frequencies.
2943
2944 See Section 9.2.4.1.2.1.

2945 16.2.3.4.1.2.2 FixedFrequencyTable Parameter

0										1										2										3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 148										Length															
NumFrequencies																Frequency#1[31:16]															
Frequency#1[15:0]																….															
….																															
Frequency#n [15:0]																															

2946 NumFrequencies: Number of entries in the List of Frequencies.
2947
2948 See Section 9.2.4.1.2.2.
2949

2950 16.2.4 Reader Operations Parameters

2951 16.2.4.1 ROSpec Parameter

0										1										2										3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 177										Length															
ROSpecID																															
Priority						CurrentState																									
ROBoundarySpec Parameter																															
SpecParameter (1-n) [See notes below]																															
ROReportSpec Parameter (0-1)																															

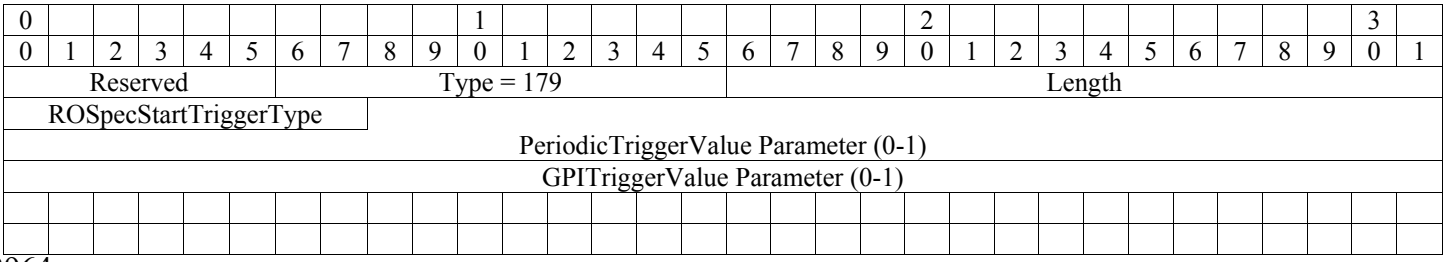
2952
2953 **Notes**
2954 Each SpecParameter can be one of the following types: AISpec Parameter or RFSurveySpec Parameter or
2955 Custom Parameter.
2956
2957 See Section 10.2.1.
2958

2959 *16.2.4.1.1 ROBoundarySpec Parameter*

0										1										2										3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 178										Length															
ROSpecStartTrigger Parameter																															
ROSpecStopTrigger Parameter																															

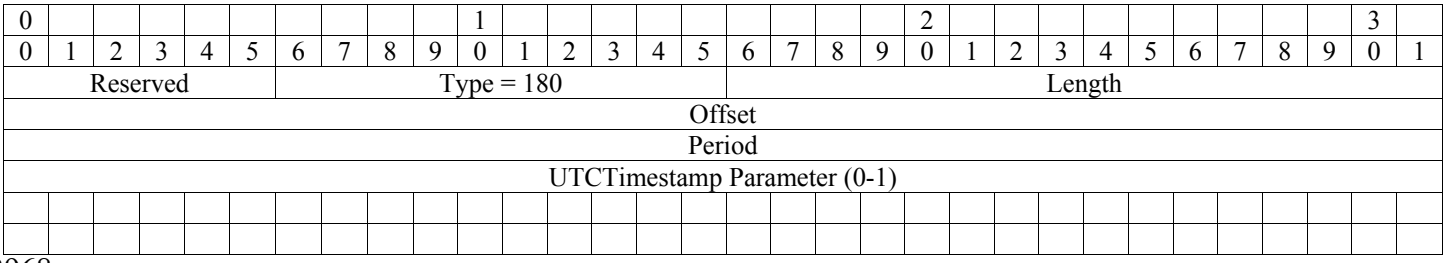
See Section 10.2.1.1.

16.2.4.1.1.1 ROSpecStartTrigger Parameter



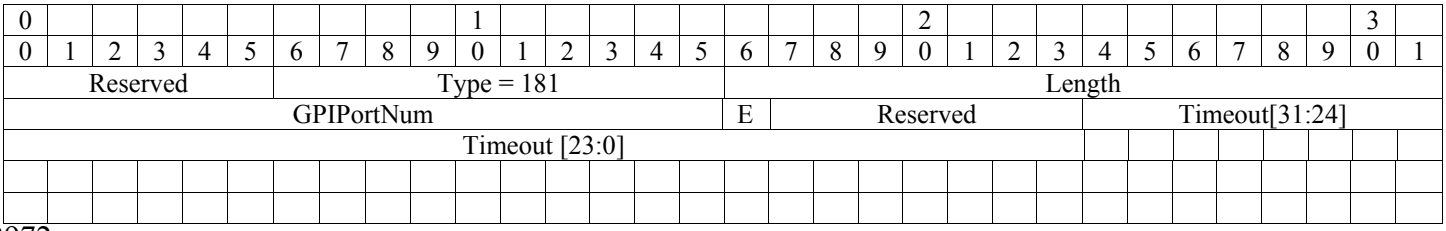
See Section 10.2.1.1.1.

16.2.4.1.1.1.1 PeriodicTriggerValue Parameter



See Section 10.2.1.1.1.1.

16.2.4.1.1.1.2 GPITriggerValue Parameter

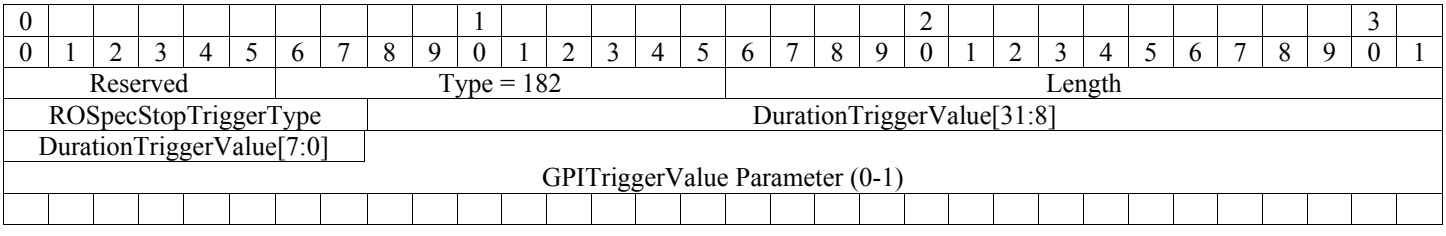


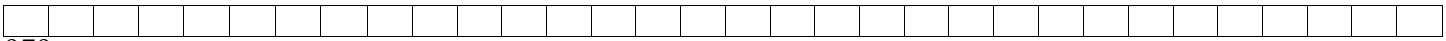
Abbreviations

E – GPIEvent

See section 10.2.1.1.1.2.

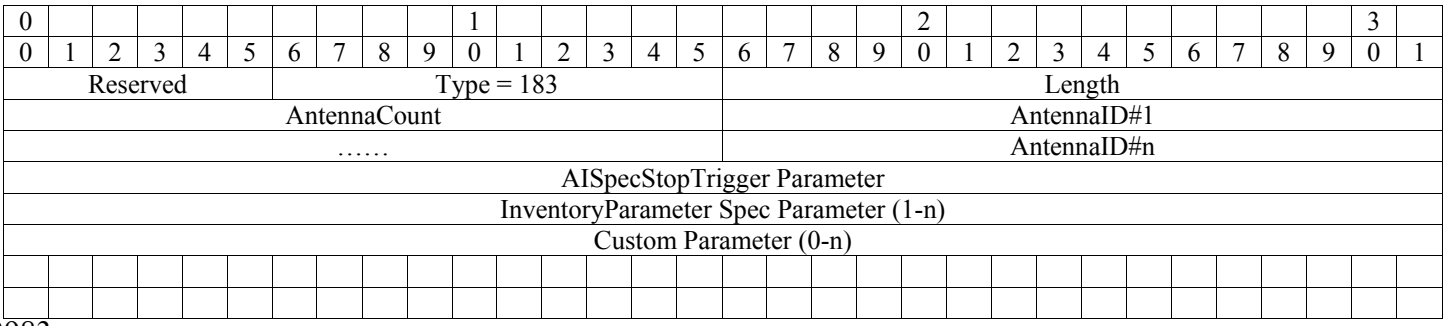
16.2.4.1.1.2 ROSpecStopTrigger Parameter





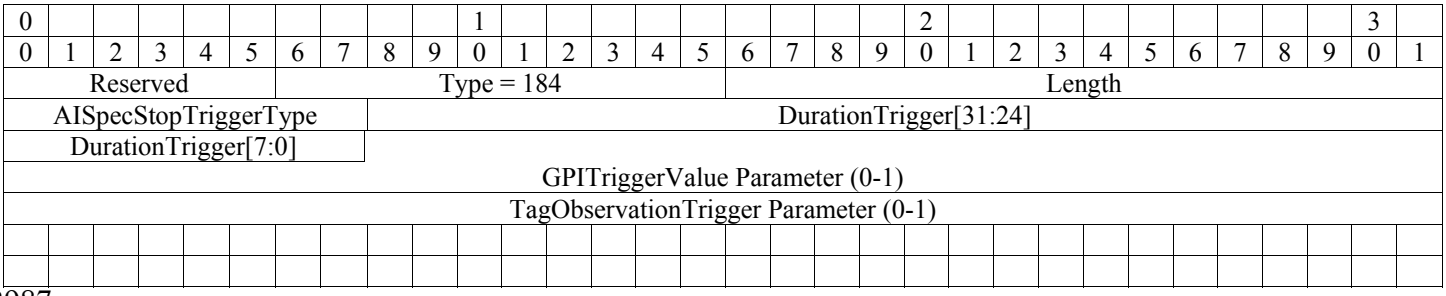
See section 10.2.1.1.2.

16.2.4.2 AISpec Parameter



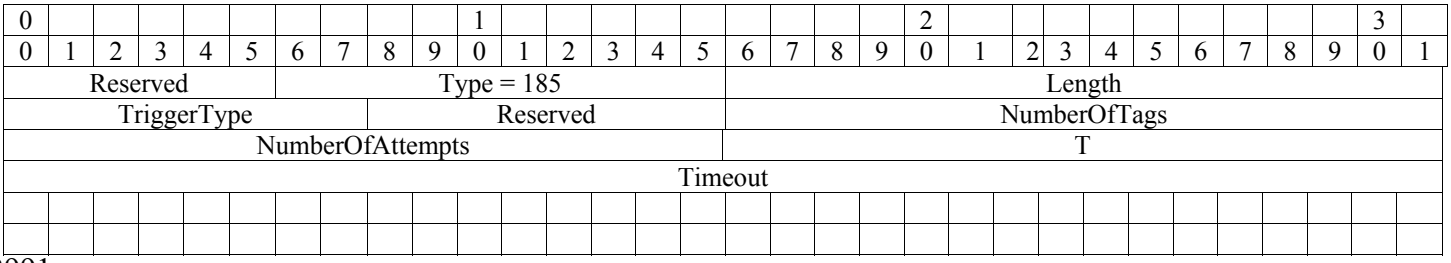
See section 10.2.2.

16.2.4.2.1 AISpecStopTrigger Parameter



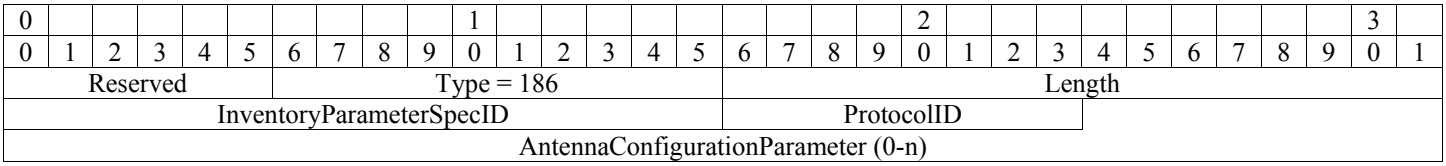
See section 10.2.2.1.

16.2.4.2.1.1 TagObservationTrigger Parameter



See section 10.2.2.1.1.

16.2.4.2.2 InventoryParameterSpec Parameter



Custom Parameter (0-n)

See section 10.2.2.2.

16.2.4.3 RFSurveySpec Parameter

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 187										Length															
AntennaID																StartFrequency[31:16]															
StartFrequency[15:0]																EndFrequency[31:16]															
EndFrequecy[15:0]																															
RFSurveySpecStopTrigger Parameter																															
Custom Parameter (0-n)																															

See Section 10.2.3.

16.2.4.3.1 RFSurveySpecStopTrigger Parameter

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 188										Length															
StopTriggerType						Duration [31:24]																									
Duration [7:0]						N[31:8]																									
N[7:0]																															

See Section 10.2.3.1.

16.2.5 Access Operation Parameters

16.2.5.1 AccessSpec Parameter

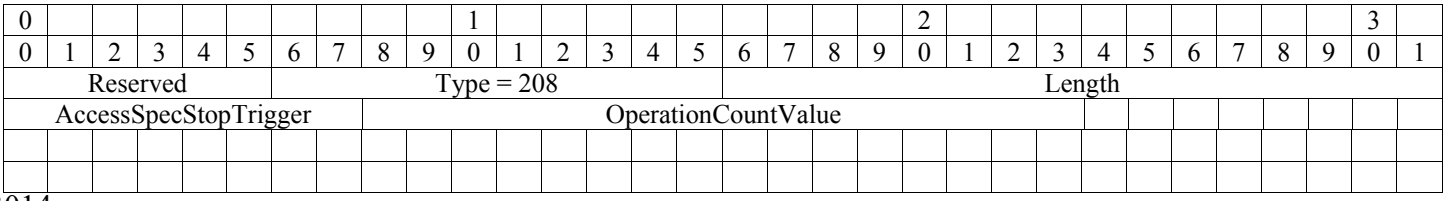
0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 207										Length															
AccessSpecID																															
AntennaId																ProtocolId								C		Reserved					
ROSpecID																															
AccessSpecStopTrigger Parameter																															
AccessCommand Parameter																															
AccessReportSpec Parameter (0-1)																															
Custom Parameter (0-n)																															

Abbreviations

C – CurrentState

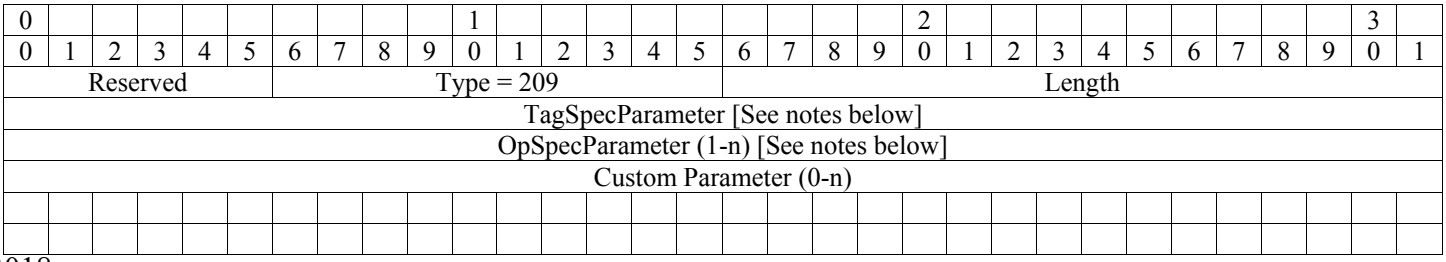
See section 11.2.1.

16.2.5.1.1 AccessSpecStopTrigger Parameter



See Section 11.2.1.1.

16.2.5.1.2 AccessCommand Parameter



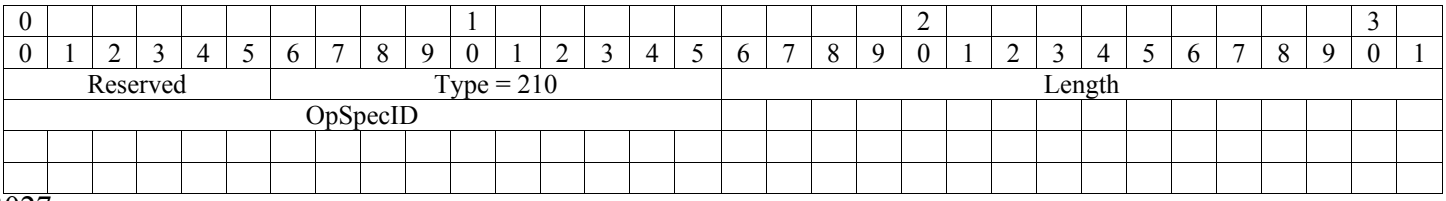
Notes

TagSpecParameter is the air protocol specific tag spec parameter. For C1G2, it is C1G2TagSpec Parameter.

Each OpSpecParameter can be one of two types: Air protocol specific OpSpec (e.g., C1G2OpSpec Parameter) or ClientRequestOpSpec Parameter.

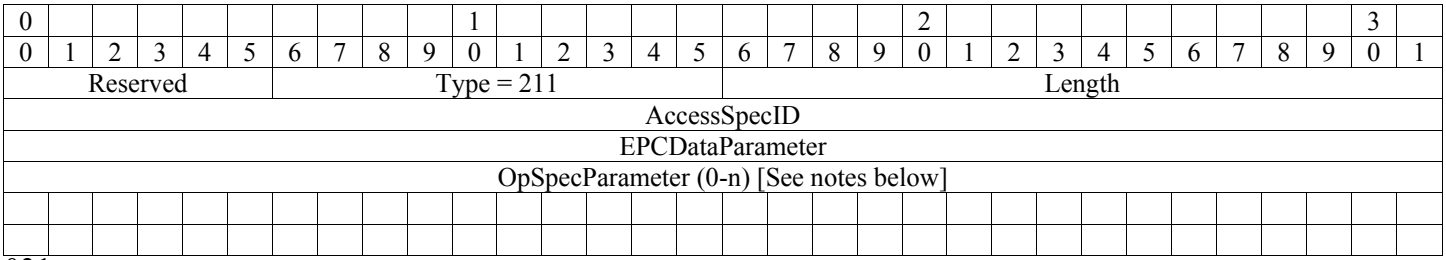
See Section 11.2.1.2.

16.2.5.1.3 ClientRequestOpSpec Parameter



See Section 11.2.1.2.1.

16.2.5.1.3.1 ClientRequestResponse Parameter



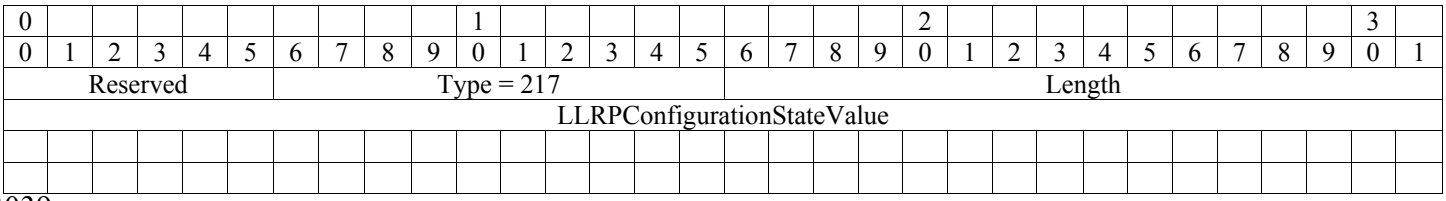
Notes

Each OpSpecParameter is an Air protocol specific opspec (e.g., C1G2OpSpec Parameter).

See Section 11.2.2.

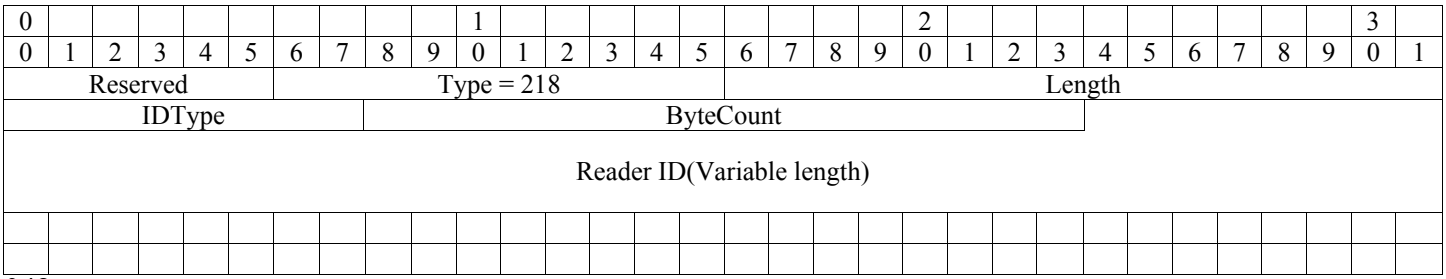
16.2.6 Configuration Parameters

16.2.6.1 LLRPConfigurationStateValue Parameter



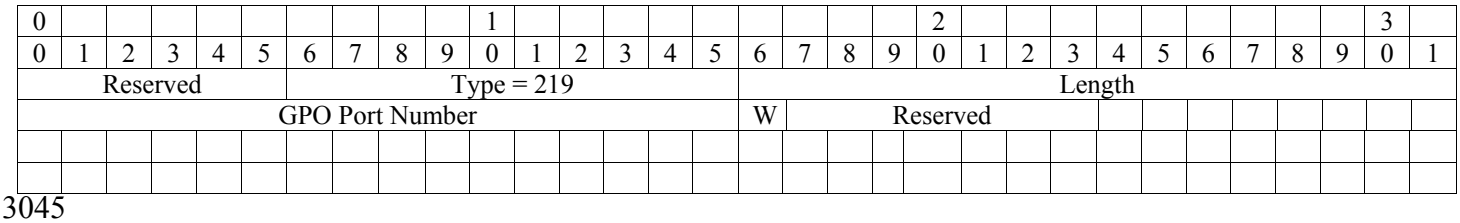
See section 12.2.1.

16.2.6.2 Identification Parameter



See Section 12.2.2.

16.2.6.3 GPOWriteData Parameter

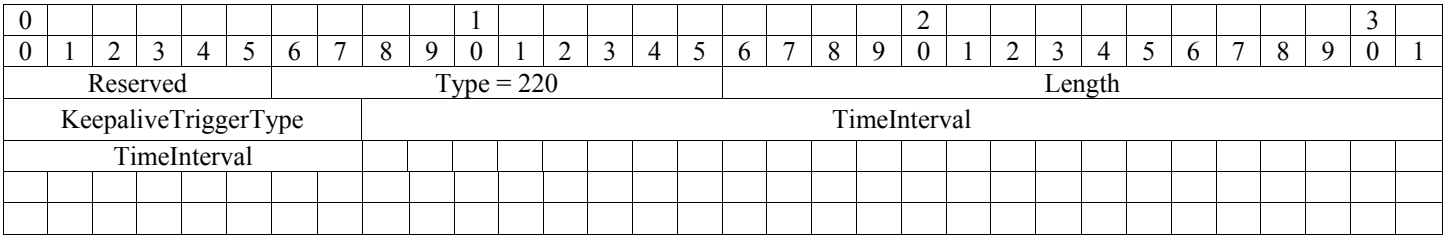


Abbreviations

W – GPO Data

See Section 12.2.3.

16.2.6.4 KeepaliveSpec Parameter



See Section 12.2.4.

16.2.6.5 AntennaProperties Parameter

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 221										Length															
C	Reserved									AntennaId															AntennaGain[15:8]						
AntennaGain[7:0]																															

Abbreviations

C – Antenna connected

See Section 12.2.5.

16.2.6.6 AntennaConfiguration Parameter

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 222										Length															
AntennaId																															
RFReceiver Parameter (0-1)																															
RFTransmitter Parameter (0-1)																															
AirProtocolInventoryCommandSettings Parameter (0-n)																															

Notes:

Each AirProtocolInventoryCommandSettingsParameter instance is an Air protocol specific Parameter (e.g., C1G2InventoryCommand Parameter).

See Section 12.2.6.

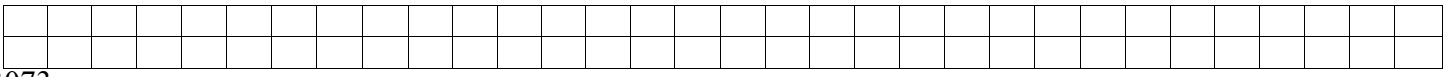
16.2.6.7 RFReceiver Parameter

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 223										Length															
Receiver Sensitivity																															

See Section 12.2.6.1.

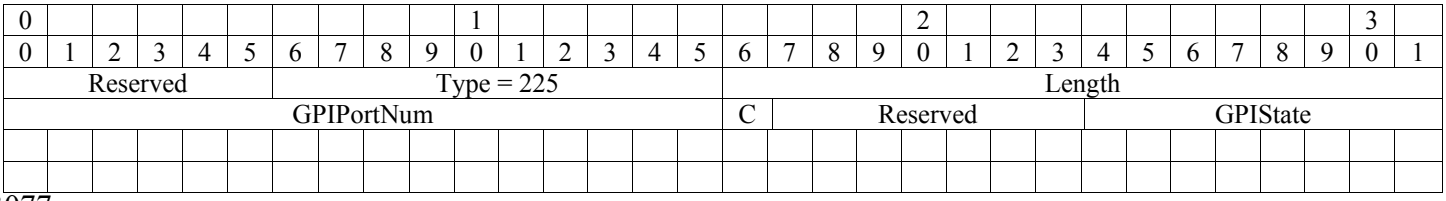
16.2.6.8 RFTransmitter Parameter

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 224										Length															
HopTableId																ChannelIndex															
TransmitPower																															



See Section 12.2.6.2.

16.2.6.9 GPIPortCurrentState Parameter

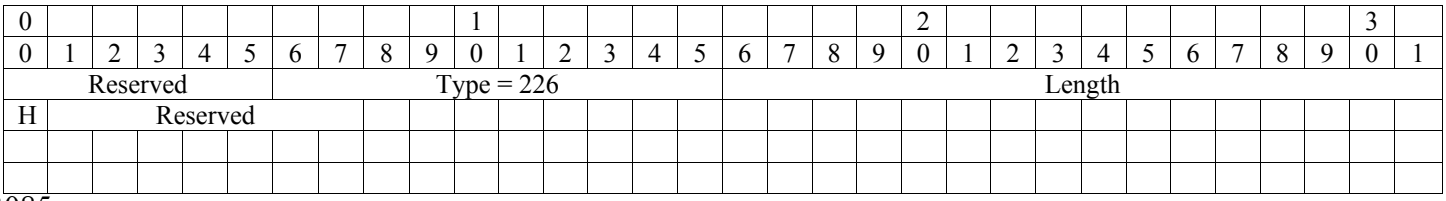


Abbreviations

C – GPIConfig

See Section 12.2.6.3.

16.2.6.10 EventsAndReports Parameter



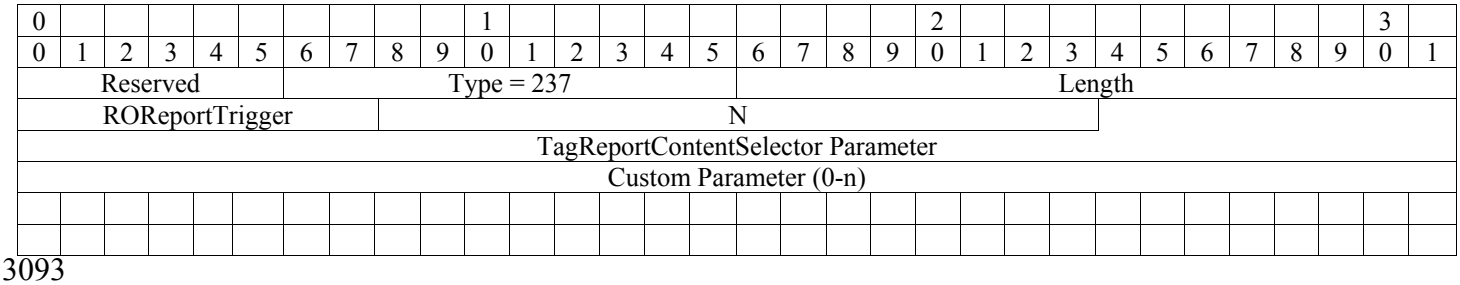
Abbreviations

H – HoldEventsAndReportsUponReconnect

See Section 12.2.6.4

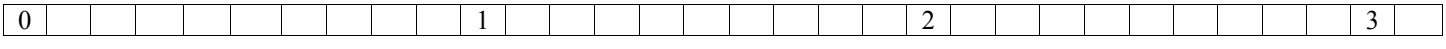
16.2.7 Reporting Parameters

16.2.7.1 ROReportSpec Parameter



See Section 13.2.1.

16.2.7.1.1 TagReportContentSelector Parameter



0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 238										Length															
R	I	P	A	C	R	F	L	T	S	Reserved																					
AirProtocolSpecificEPCMemorySelectorParameter (0-n) [See notes below]																															

3097 **Abbreviations**
3098
3099 R – EnableROSpecID
3100 I – EnableSpecIndex
3101 P – EnableInventoryParameterSpecID
3102 A – EnableAntennaID
3103 C – EnableChannelIndex
3104 R – EnablePeakRSSI
3105 F – EnableFirstSeenTimestamp
3106 L – EnableLastSeenTimestamp
3107 T – EnableTagSeenCount
3108 S – EnableAccessSpecID
3109
3110 **Notes:**
3111 Each instance of AirProtocolSpecificEPCMemorySelectorParameter is one of the air protocol specific
3112 selector parameters (e.g., C1G2EPCMemorySelector Parameter).
3113
3114 See section 13.2.1.1.
3115

3116 16.2.7.2 AccessReportSpec Parameter

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 239										Length															
AccessReportTrigger																															

3117
3118 See section 13.2.2.

3119 16.2.7.3 TagReportData Parameter

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 240										Length															
EPCDataParameter [See notes below]																															
ROSpecID Parameter (0-1)																															
SpecIndex Parameter (0-1)																															
InventoryParameterSpecID Parameter (0-1)																															
AntennaID Parameter (0-1)																															
PeakRSSI Parameter (0-1)																															
ChannelIndex Parameter (0-1)																															
FirstSeenTimestampUTC Parameter (0-1)																															
FirstSeenTimestampUptime Parameter (0-1)																															
LastSeenTimestampUTC Parameter (0-1)																															
LastSeenTimestampUptime Parameter (0-1)																															
TagSeenCount Parameter (0-1)																															
AirProtocolTagDataParameter (0-n)[See Notes below]																															
AccessSpecID Parameter (0-1)																															

OpSpecResultParameter (0-n) [See notes below]
Custom Parameter (0-n)

Notes:
The EPCDataParameter is either the EPCData Parameter (Section 16.2.7.3.1) or EPC-96 Parameter (Section 16.2.7.3.2). The EPCData Parameter SHALL be used for encoding a non-96 bit EPC, whereas the EPC-96 Parameter SHALL be used for encoding a 96-bit EPC.

The AirProtocolTagDataParameter is one or more air protocol specific tag data parameters (e.g., C1G2PC and C1G2CRC). In the C1G2 case, each parameter, C1G2PC and C1G2CRC, is optional in the TagReportData Parameter.

OpSpecResultParameter: Either an air protocol specific OpSpec result parameter (e.g., C1G2OpSpecResult Parameter) or ClientRequestOpSpecResult Parameter.

See section 13.2.3.

16.2.7.3.1 EPCData Parameter

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 241										Length															
EPCLengthBits																															
EPC																															

EPCLengthBits: Number of bits in the EPC.
See Section 13.2.3.2.

16.2.7.3.2 EPC-96 Parameter (TV-Encoding)

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
1	Type=13							EPC[95:72]																							
EPC[71:40]																															
EPC[39:8]																															
EPC[7:0]																															

See Section 13.2.3.2.

16.2.7.3.3 ROSpecID Parameter (TV-Encoding)

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
1	Type=9							ROSpecID[31:8]																							
ROSpecID[7:0]																															

See Section 13.2.3.3.

16.2.7.3.4 SpecIndex Parameter (TV-Encoding)

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
1	Type=14							SpecIndex																							

See Section 13.2.3.4.

16.2.7.3.5 InventoryParameterSpecID Parameter (TV-Encoding)

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
1	Type=10							InventoryParameterSpecId																							

See Section 13.2.3.5.

16.2.7.3.6 AntennaID Parameter (TV-Encoding)

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
1	Type=1							AntennaId																							

See Section 13.2.3.6.

16.2.7.3.7 PeakRSSI Parameter (TV-Encoding)

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
1	Type=6							PeakRSSI																							

See Section 13.2.3.7.

16.2.7.3.8 ChannelIndex Parameter (TV-Encoding)

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
1	Type=7							ChannelIndex																							

See Section 13.2.3.8.

16.2.7.3.9 FirstSeenTimestampUTC Parameter (TV-Encoding)

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
1	Type=2							Microseconds [63:40]																							
Microseconds [39:8]																															
Microseconds[7:0]																															

See Section 13.2.3.9.

16.2.7.3.10 FirstSeenTimestampUptime Parameter (TV-Encoding)

0										1										2									3	

0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
1	Type=3							Microseconds[63:40]																							
Microseconds [39:8]																															
Microseconds[7:0]																															

3165

3166 See Section 13.2.3.10.

3167 *16.2.7.3.11 LastSeenTimestampUTC Parameter (TV-Encoding)*

0										1										2										3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
1	Type=4							Microseconds[63:40]																							
Microseconds[39:8]																															
Microseconds[7:0]																															

3168

3169 See Section 13.2.3.11.

3170 *16.2.7.3.12 LastSeenTimestampUptime Parameter (TV-Encoding)*

0										1										2										3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
1	Type=5							Microseconds[63:40]																							
Microseconds[39:8]																															
Microseconds[7:0]																															

3171

3172 See Section 13.2.3.12.

3173 *16.2.7.3.13 TagSeenCount Parameter (TV-Encoding)*

0										1										2										3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
1	Type=8							TagCount																							

3174

3175 See Section 13.2.3.13.

3176 *16.2.7.3.14 ClientRequestOpSpecResult Parameter (TV-Encoding)*

0										1										2										3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
1	Type=15							OpSpecID																							

3177

3178 See Section 13.2.3.14.

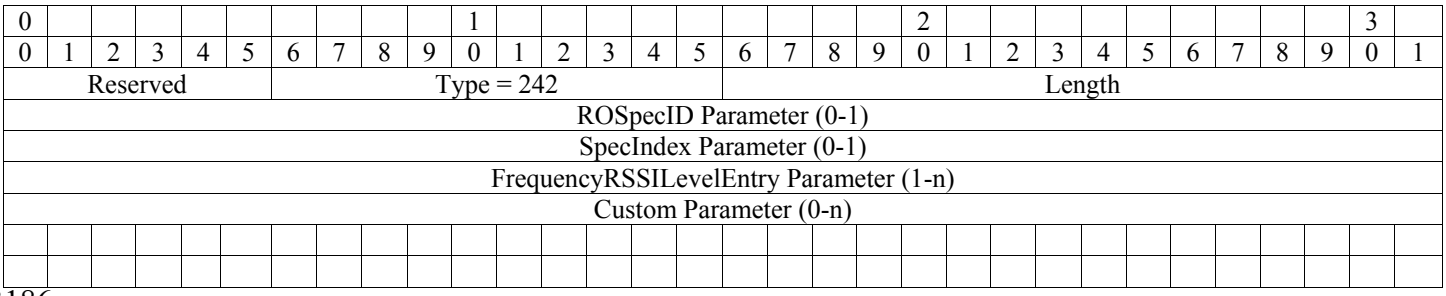
3179 *16.2.7.3.15 AccessSpecID Parameter (TV-Encoding)*

0										1										2										3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
1	Type=16							AccessSpecID[31:8]																							
AccessSpecID[7:0]																															

3180

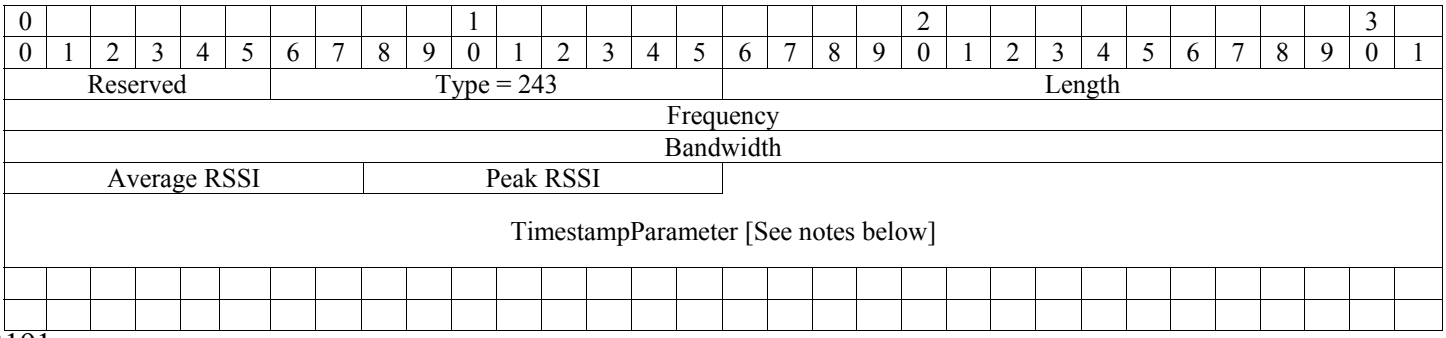
3181 See Section 13.2.3.15.

16.2.7.4 RFSurveyReportData Parameter



See Section 13.2.3.15.

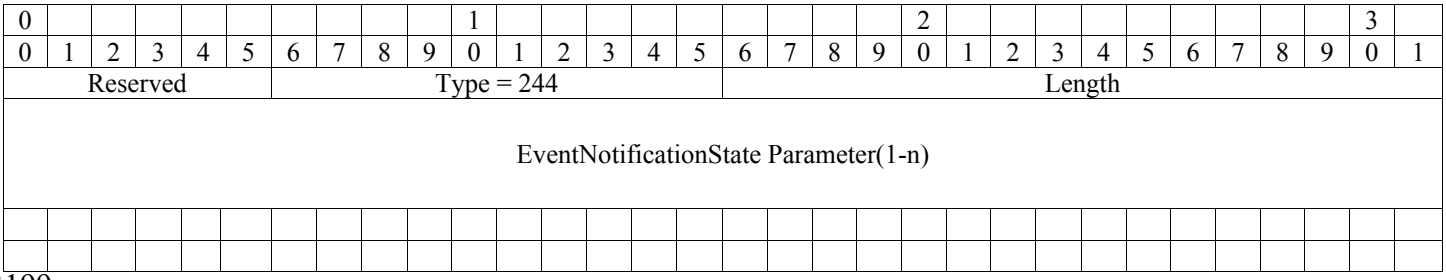
16.2.7.4.1 FrequencyRSSILevelEntry Parameter



Notes:
TimestampParameter: Either UTCTimestamp Parameter or UptimeParameter.

See section 13.2.4.1

16.2.7.5 ReaderEventNotificationSpec Parameter



See Section 13.2.5.

3203 *16.2.7.5.1 EventNotificationState Parameter*

3204

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 245										Length															
EventType																S	Reserved														

3205

3206 **Abbreviations**:
3207 S – NotificationState
3208
3209 See Section 13.2.5.1.
3210

3211 16.2.7.6 ReaderEventNotificationData Parameter

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 246										Length															
TimestampParameter [See notes below]																															
HoppingEvent Parameter (0-1)																															
GPIEvent Parameter (0-1)																															
ROSpecEvent Parameter (0-1)																															
ReportBufferLevelWarningEvent Parameter (0-1)																															
ReportBufferOverflowErrorEvent Parameter (0-1)																															
ReaderExceptionEvent Parameter (0-1)																															
RFSurveyEvent Parameter (0-1)																															
AISpecEvent Parameter (0-1)																															
AntennaEvent Parameter (0-1)																															
ConnectionAttemptEvent Parameter (0-1)																															
ConnectionCloseEvent Parameter (0-1)																															
Custom Parameter (0-n)																															

3212

3213 **Notes:**
3214 TimestampParameter: Either UTCTimestamp Parameter or Uptime Parameter.
3215
3216 See section 13.2.6.
3217

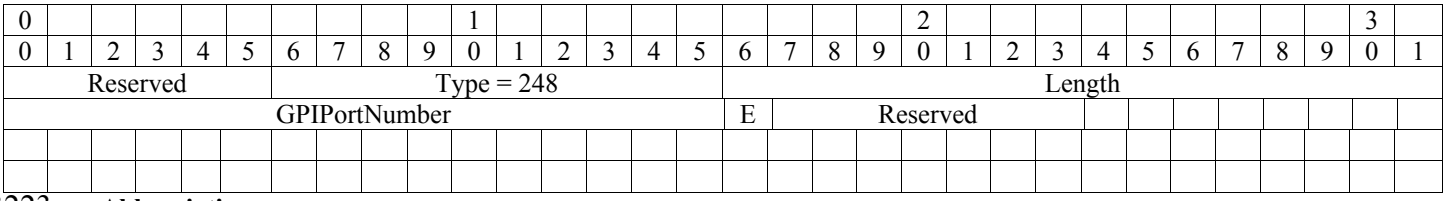
3218 *16.2.7.6.1 HoppingEvent Parameter*

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 247										Length															
HopTableID																NextChannelIndex															

3219

3220 See section 13.2.6.2.
3221

16.2.7.6.2 GPIEvent Parameter

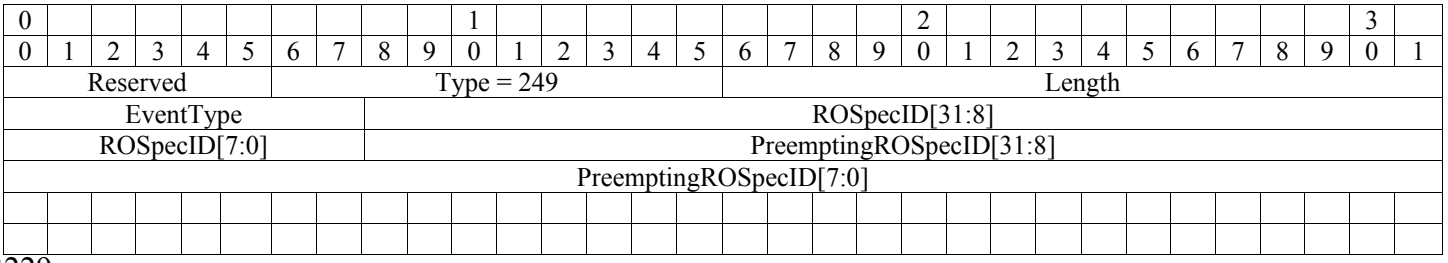


Abbreviations

E – GPIEvent

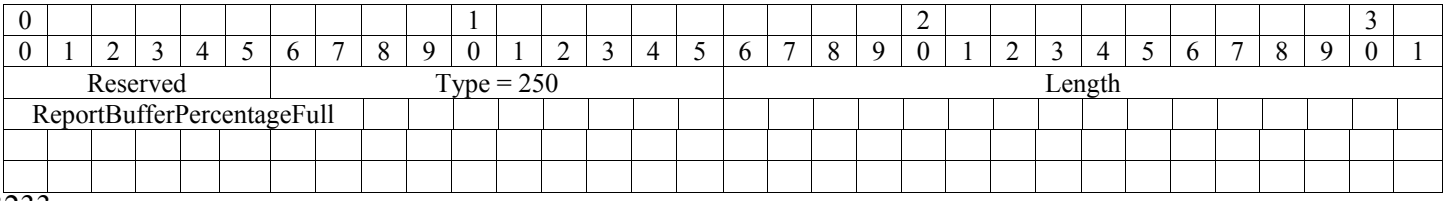
See section 13.2.6.3.

16.2.7.6.3 ROSpecEvent Parameter



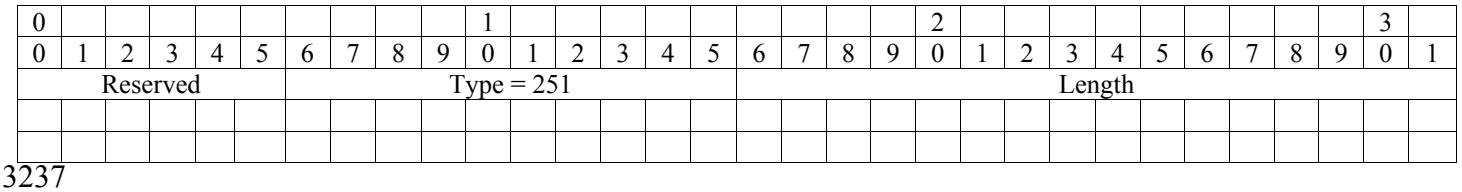
See section 13.2.6.4.

16.2.7.6.4 ReportBufferLevelWarningEvent Parameter



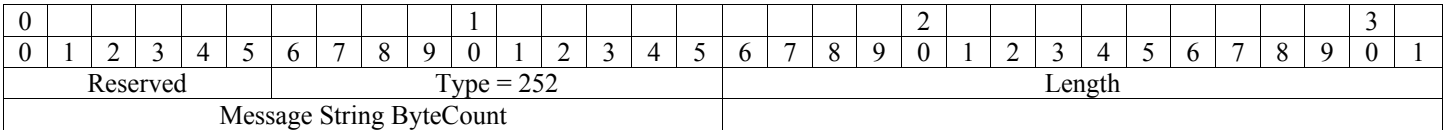
See section 13.2.6.5.

16.2.7.6.5 ReportBufferOverflowErrorEvent Parameter



See section 13.2.6.6.

16.2.7.6.6 ReaderExceptionEvent Parameter



Message: Variable length UTF-8String
ROSpecID Parameter (0-1)
SpecIndex Parameter (0-1)
InventoryParameterSpecID Parameter (0-1)
AntennaID Parameter (0-1)
AccessSpecID Parameter (0-1)
OpSpecID Parameter (0-1)
Custom Parameter (0-n)

See Section 13.2.6.7.

16.2.7.6.6.1 OpSpecID Parameter (TV-Encoding)

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
1	Type=17							OpSpecID																							

See Section 13.2.5.7.1.

16.2.7.6.7 *RFSurveyEvent Parameter*

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 253										Length															
EventType										ROSpecID[31:8]																					
ROSpecID[7:0]										SpecIndex[15:0]																					

See Section 13.2.6.7.1.

16.2.7.6.8 *AISpecEvent Parameter*

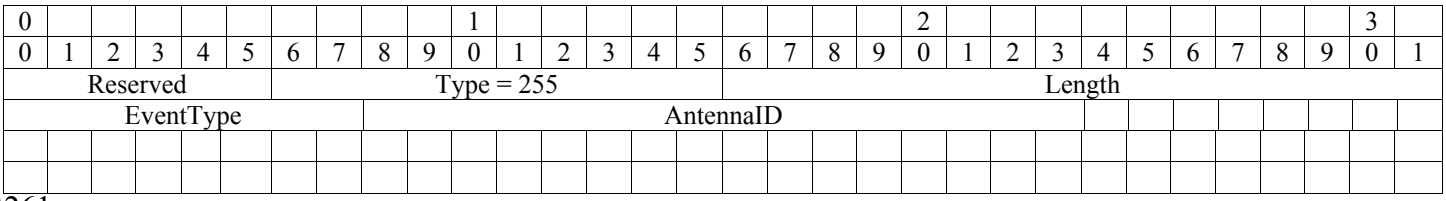
0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 254										Length															
EventType										ROSpecID[31:8]																					
ROSpecID[7:0]										SpecIndex[15:0]																					
AirProtocolSingulationDetailsParameter (0-1) [See notes below]																															

See section 13.2.6.9.

Notes:

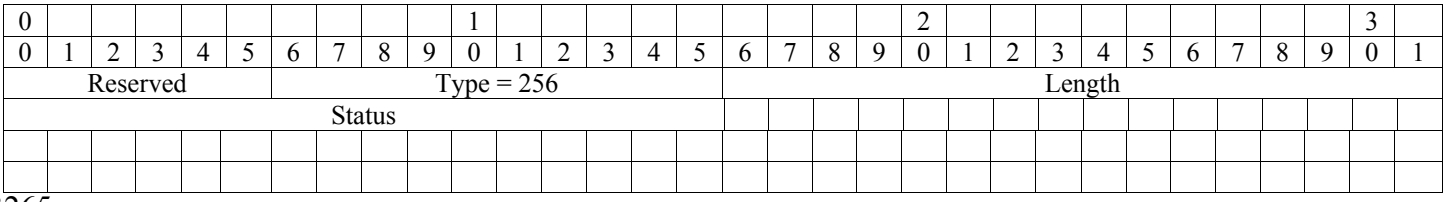
AirProtocolSingulationDetailsParameter is one of the air protocol specific singulation parameters (e.g., C1G2SingulationDetails Parameter).

16.2.7.6.9 *AntennaEvent Parameter*



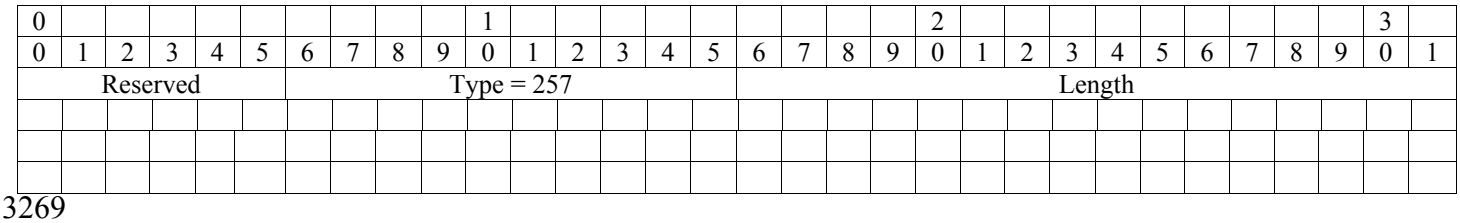
See Section 13.2.6.10.

16.2.7.6.10 ConnectionAttemptEvent Parameter



See Section 13.2.6.11.

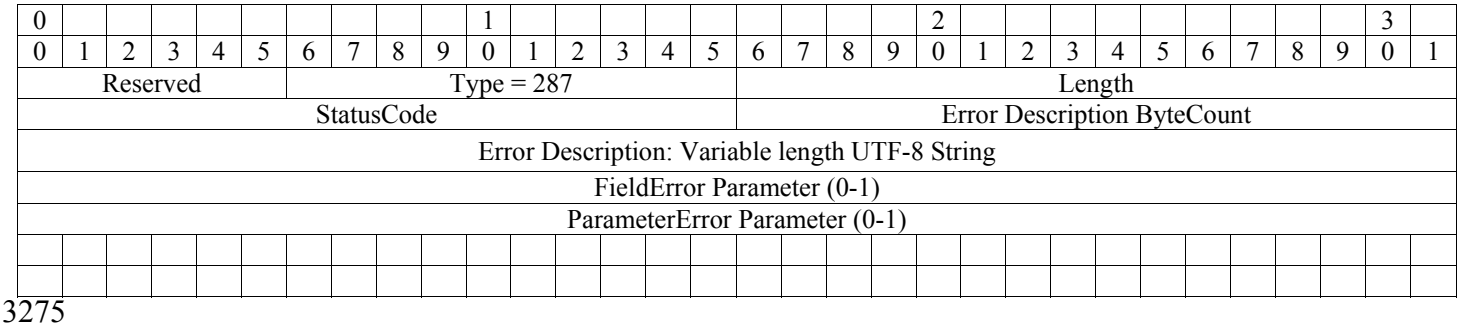
16.2.7.6.11 ConnectionCloseEvent Parameter



See Section 13.2.6.12.

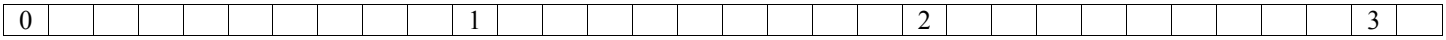
16.2.8 LLRP Error Parameters

16.2.8.1 LLRPStatus Parameter



See Section 14.2.2.

16.2.8.1.1 FieldError Parameter



0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 288										Length															
FieldNum																ErrorCode															

See section 14.2.2.1.

16.2.8.1.2 ParameterError Parameter

0										1										2										3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 289										Length															
ParameterType																ErrorCode															
Field Error Parameter (0-1)																															
Parameter Error Parameter (0-1)																															

See Section 14.2.2.2.

16.2.9 Custom Parameter

0										1										2										3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type=1023										Parameter Length															
Vendor ID																															
Subtype																															
VendorParameter Value																															

See Section 8.2.

16.3 Air Protocol Specific Parameters

This section defines air protocol specific parameter encodings. There is a separate subsection here for each air protocol defined by LLRP. See section 15, in the LLRP abstract specification, for more information regarding air protocol specific parameters.

16.3.1 Class-1 Generation-2 (C1G2) Protocol Parameters

The Class-1 Generation-2 (C1G2) Air Protocol is specified by the EPCglobal Class-1 Generation-2 UHF RFID Protocol v1.1.0 specification.

The following subsections specify LLRP air protocol specific parameter encodings. These subsections are partitioned to correlate with subsections of section 16.2:

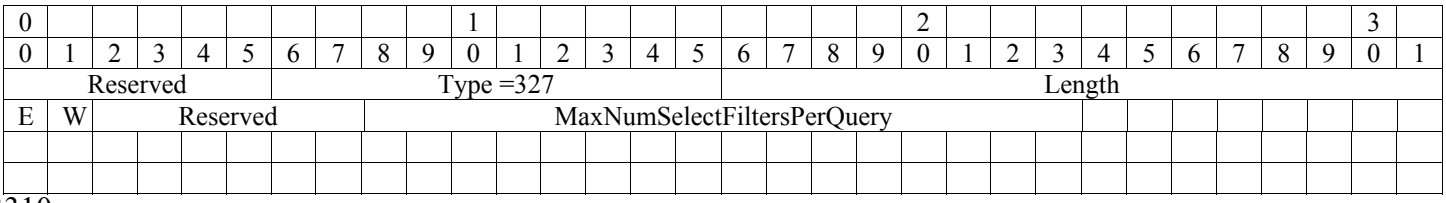
- Capabilities Parameters
- Reader Operations Parameters

- Access Operation Parameters
- Configuration Parameters
- Reporting Parameters

16.3.1.1 Capabilities Parameters

This section of air protocol specific parameters corresponds to LLRP parameters encodings specified in section 15.2.1.1.

16.3.1.1.1 C1G2LLRPCapabilities Parameter

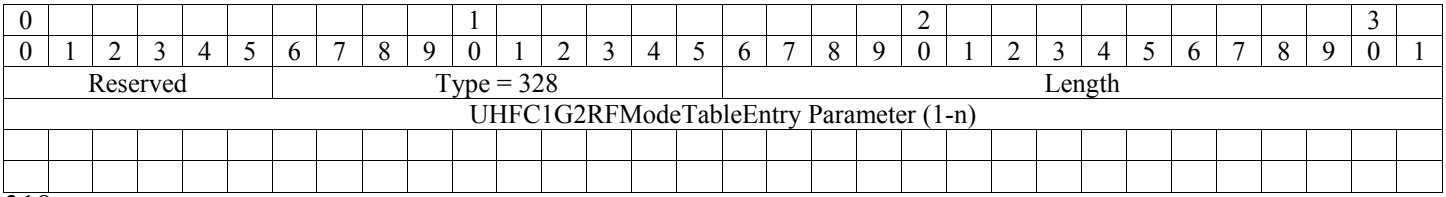


Abbreviations

E – CanSupportBlockErase
W – CanSupportBlockWrite

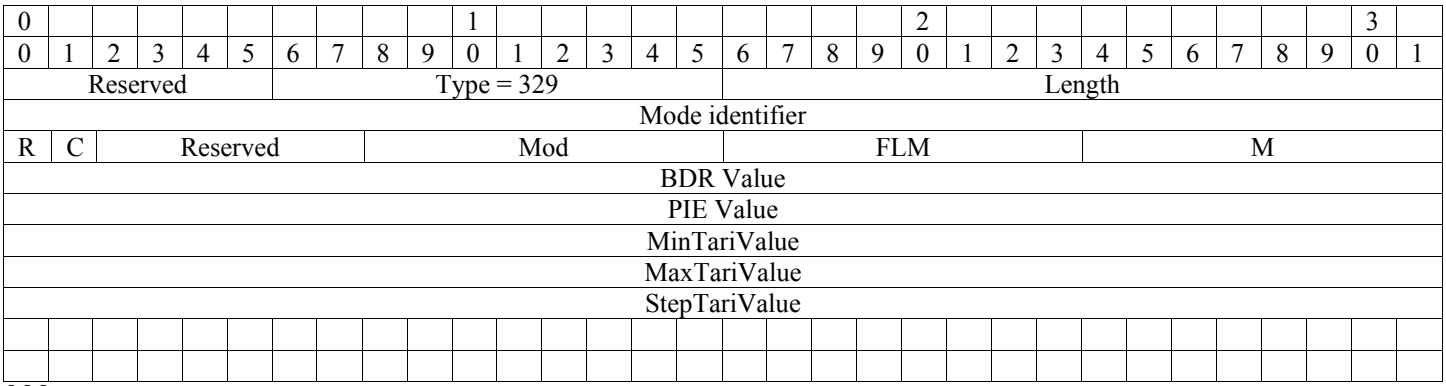
See Section 15.2.1.1.1.

16.3.1.1.2 UHFC1G2RFModeTable Parameter



See Section 15.2.1.1.2.

16.3.1.1.2.1 UHFC1G2RFModeTableEntry Parameter



Abbreviations

R – DR Value

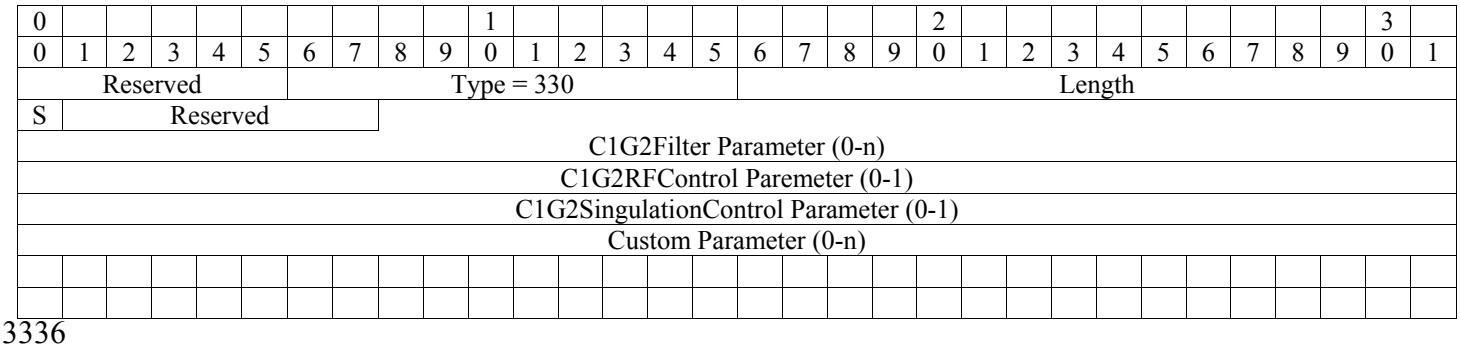
M– Spectral Mask Indicator
Mod – M value / Modulation
FLM – Forward Link Modulation
C – EPC HAG T&C Conformance

See section 15.2.1.1.2.1.

16.3.1.2 Reader Operations Parameters

This section of air protocol specific parameters corresponds to LLRP parameters encodings specified in section 15.2.1.2.

16.3.1.2.1 C1G2InventoryCommand Parameter

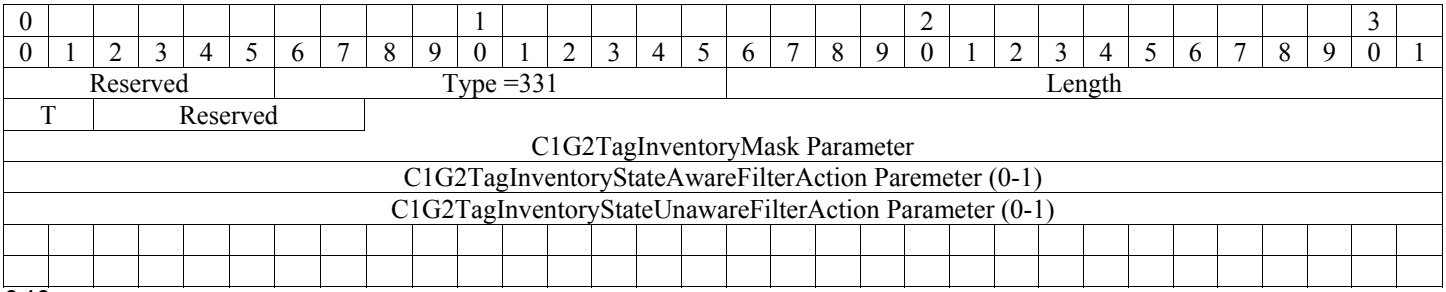


Abbreviations

S – TagInventoryStateAware

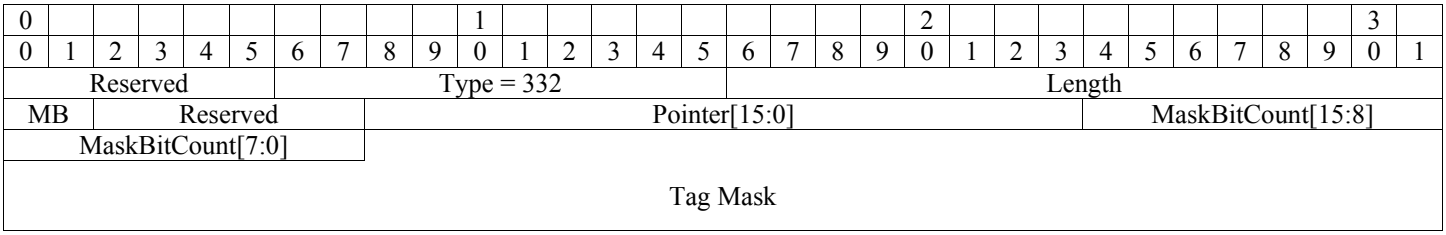
See Section 15.2.1.2.1

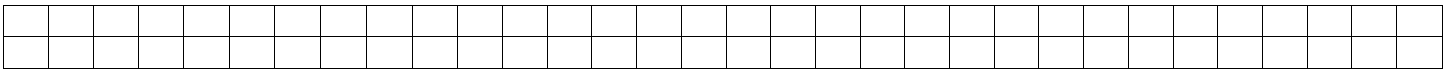
16.3.1.2.1.1 C1G2Filter Parameter



See Section 15.2.1.2.1.1.

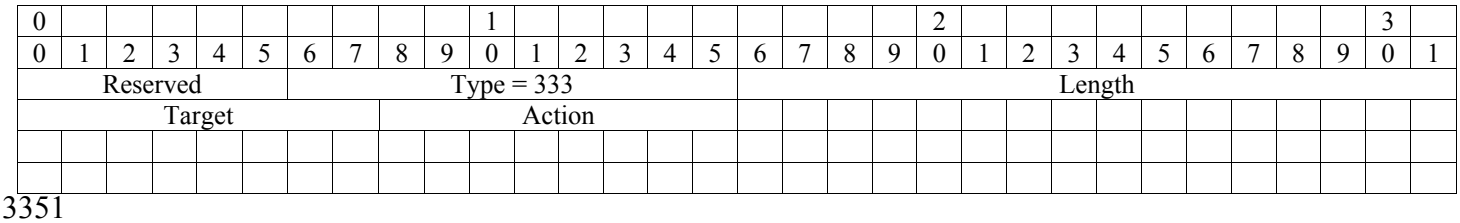
16.3.1.2.1.1.1 C1G2TagInventoryMask Parameter





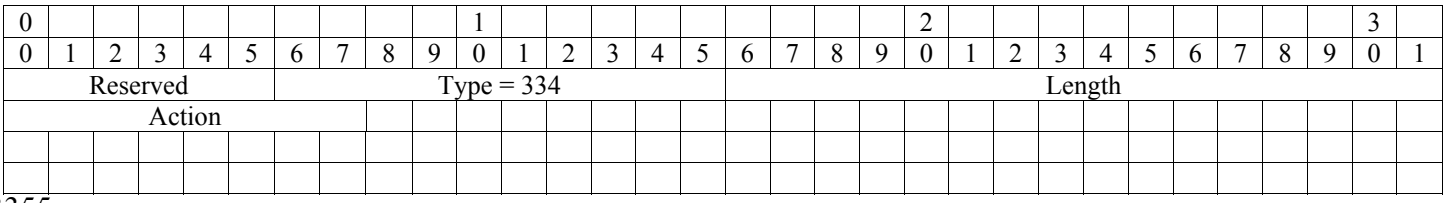
See section 15.2.1.2.1.1.1.

16.3.1.2.1.1.2 C1G2TagInventoryStateAwareFilterAction Parameter



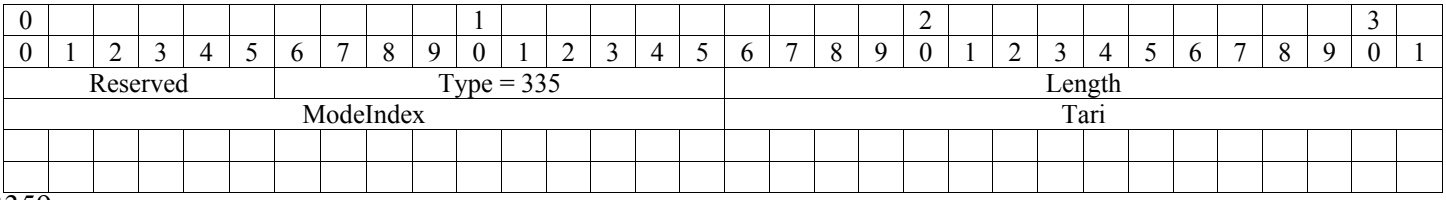
See section 15.2.1.2.1.1.2.

16.3.1.2.1.1.3 C1G2TagInventoryStateUnawareFilterAction Parameter



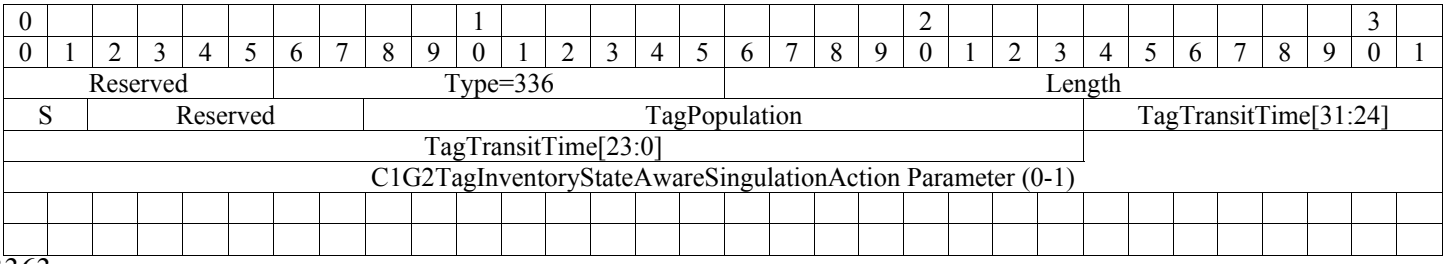
See section 15.2.1.2.1.1.3.

16.3.1.2.1.2 C1G2RFControl Parameter



See section 15.2.1.2.1.2.

16.3.1.2.1.3 C1G2SingulationControl Parameter

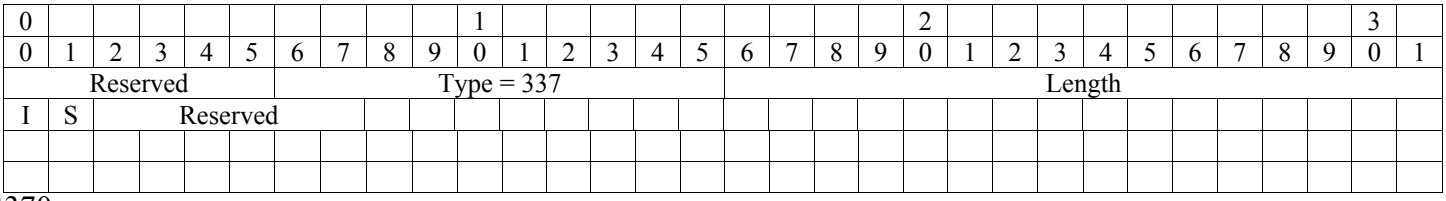


Abbreviations:
S – Session

See section 15.2.1.2.1.3.

3368

3369 16.3.1.2.1.3.1 C1G2TagInventoryStateAwareSingulationAction Parameter

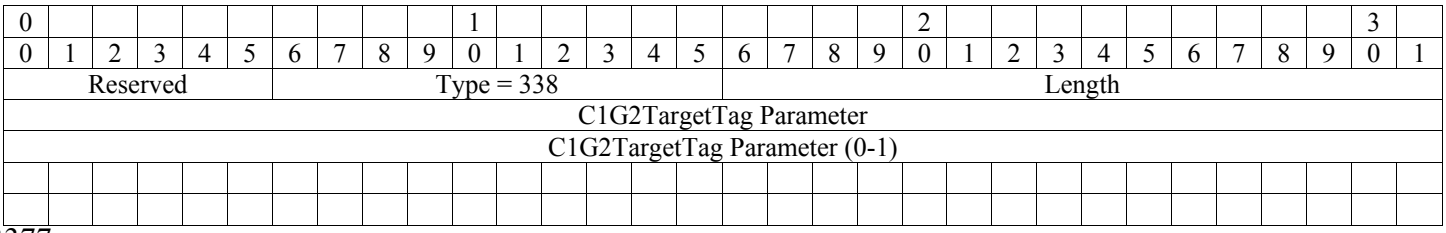


3370
3371 See section 15.2.1.2.1.3.1.
3372

3373 ## 16.3.1.3 Access Operation Parameters

3374 This section of air protocol specific parameters corresponds to LLRP parameters
3375 encodings specified in section 15.2.1.3.

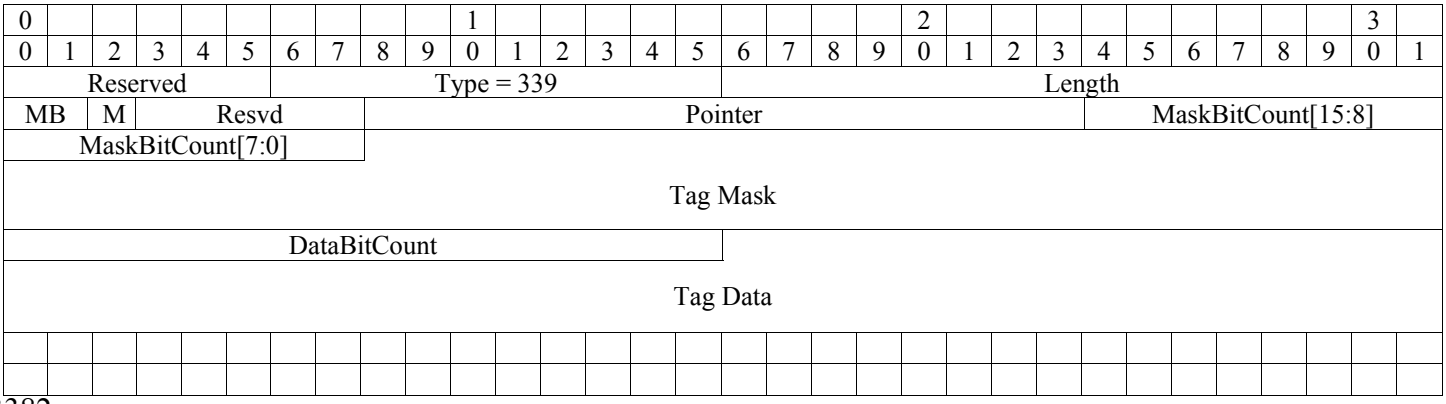
3376 ### *16.3.1.3.1 C1G2TagSpec Parameter*



3377
3378 See section 15.2.1.3.1.
3379

3380 #### 16.3.1.3.1.1 C1G2TargetTag Parameter

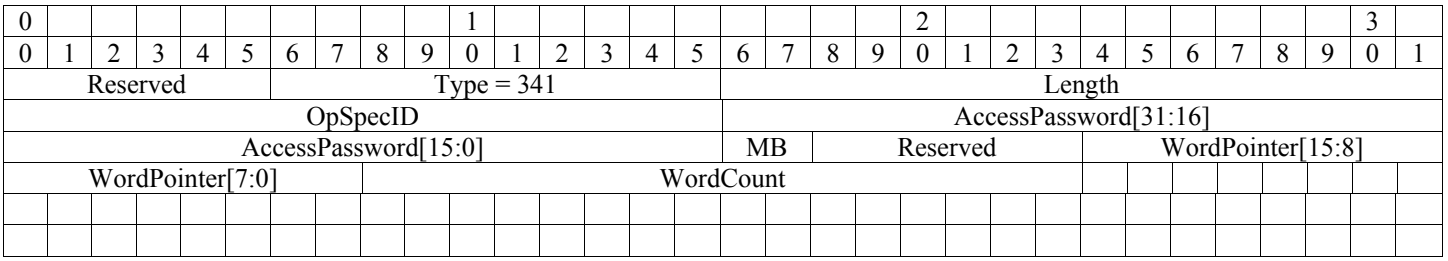
3381



3382
3383 **Abbreviations**
3384 M – Match.
3385
3386 See section 15.2.1.3.1.1.
3387

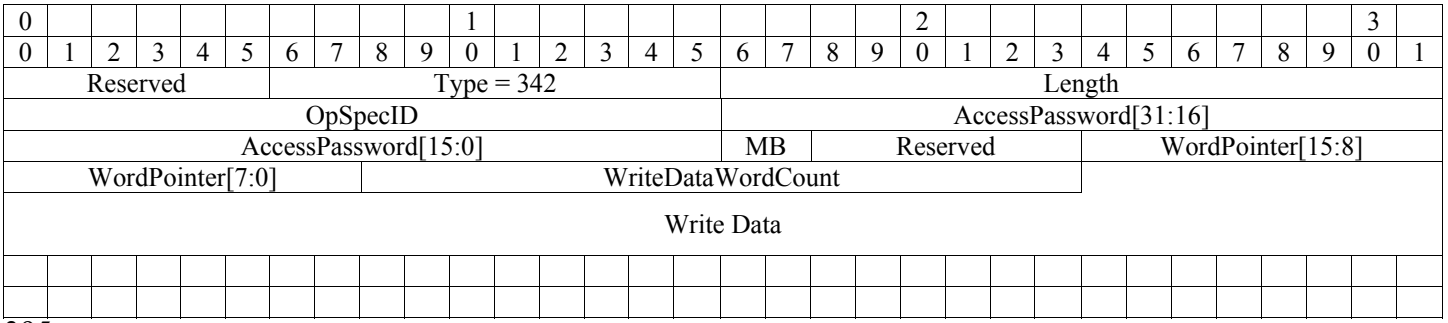
3388 ### *16.3.1.3.2 C1G2 OpSpecs*

16.3.1.3.2.1 C1G2Read Parameter



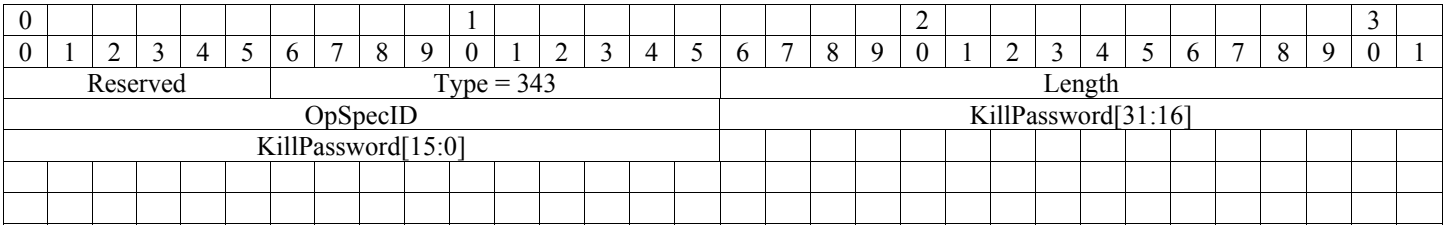
See section 15.2.1.3.2.2.

16.3.1.3.2.2 C1G2Write Parameter



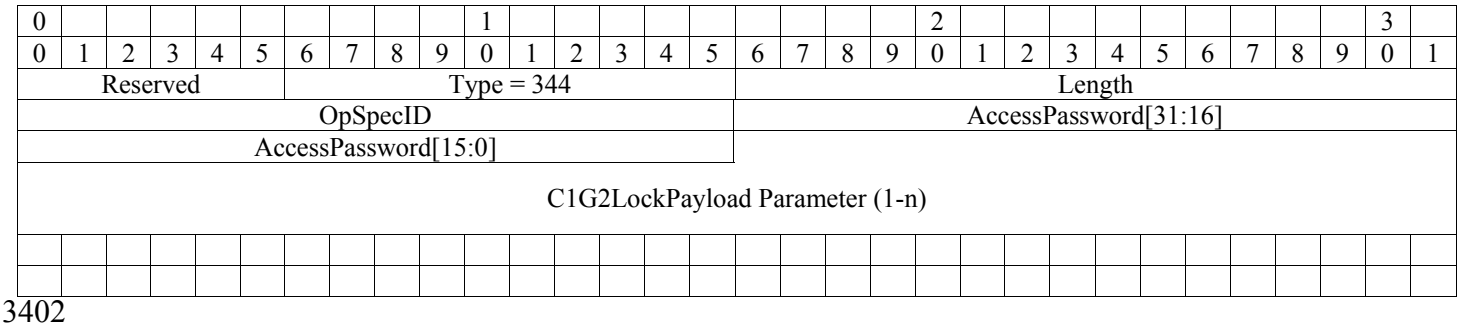
See section 15.2.1.3.2.2.

16.3.1.3.2.3 C1G2Kill Parameter



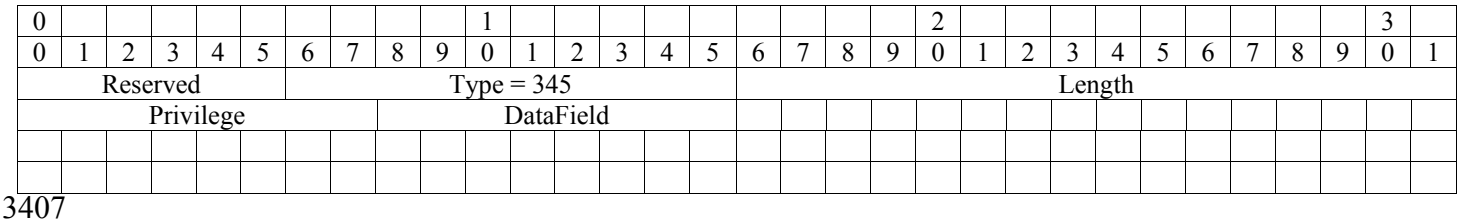
See section 15.2.1.3.2.3.

16.3.1.3.2.4 C1G2Lock Parameter



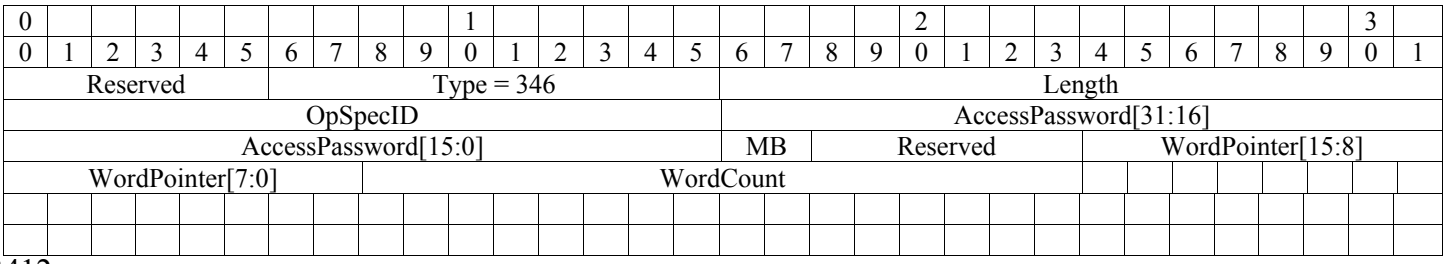
See section 15.2.1.3.2.4.

16.3.1.3.2.4.1 C1G2LockPayload Parameter



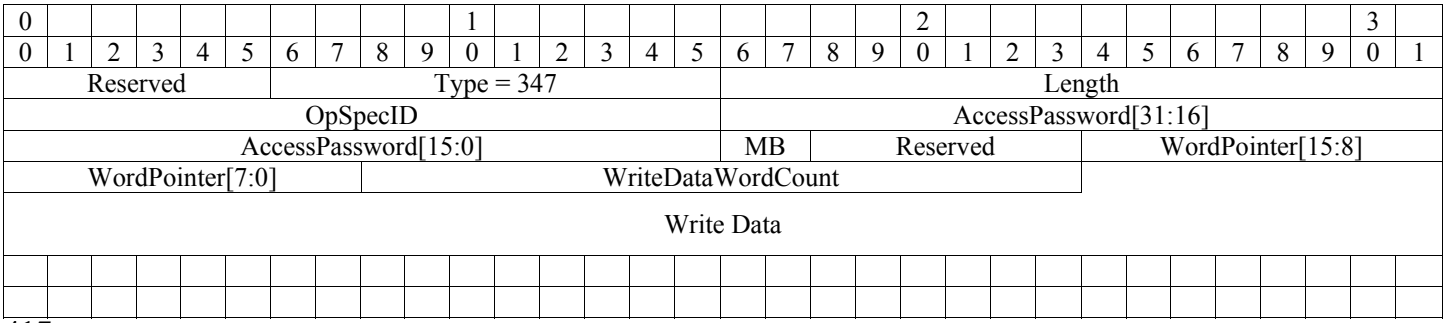
See section 15.2.1.3.2.4.1.

16.3.1.3.2.5 C1G2BlockErase Parameter



See section 16.3.1.3.2.5.

16.3.1.3.2.6 C1G2BlockWrite Parameter



See section 15.2.1.3.2.6.

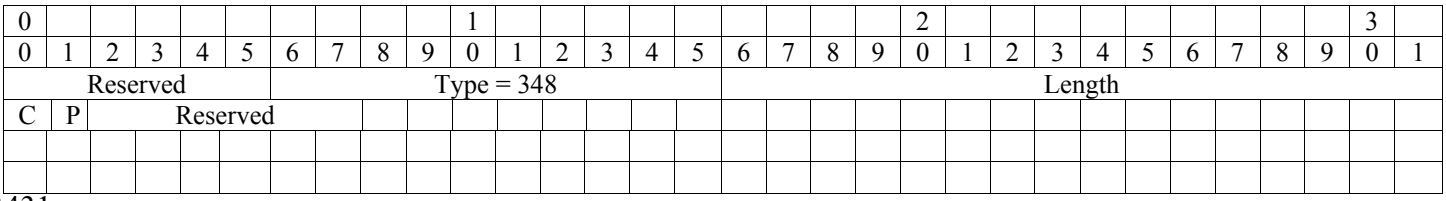
16.3.1.4 Configuration Parameters

This section of air protocol specific parameters corresponds to LLRP parameters specified in Section 12.2. The only air protocol specific parameter is the AirProtocolInventoryCommandSettings parameter in the AntennaConfiguration (Section 12.2.6). The C1G2 specific InventoryCommand is already defined in Section 16.3.1.2.1.

16.3.1.5 Reporting Parameters

This section of air protocol specific parameters corresponds to LLRP parameters encodings specified in section 15.2.1.5.

16.3.1.5.1 C1G2EPCMemorySelector Parameter

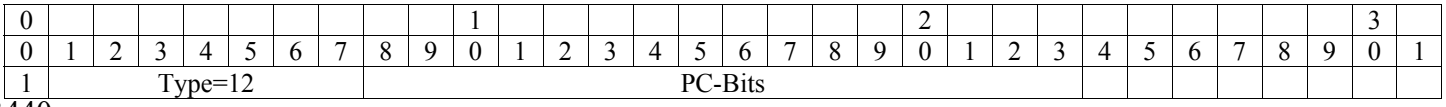


Abbreviations

C – EnableCRC
P – EnablePCBits

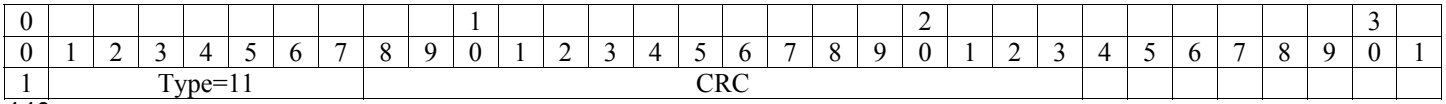
See section 15.2.1.5.1.

16.3.1.5.2 C1G2PC Parameter (TV-Encoding)



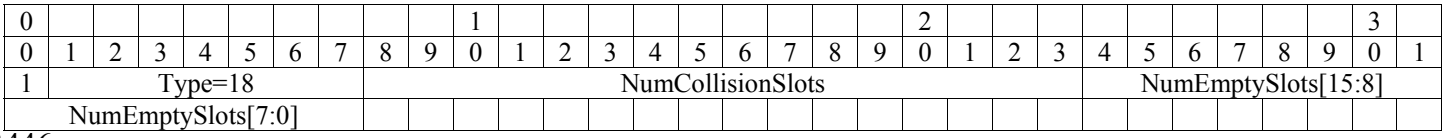
See section 15.2.1.5.2.

16.3.1.5.3 C1G2CRC Parameter (TV-Encoding)



See section 15.2.1.5.3.

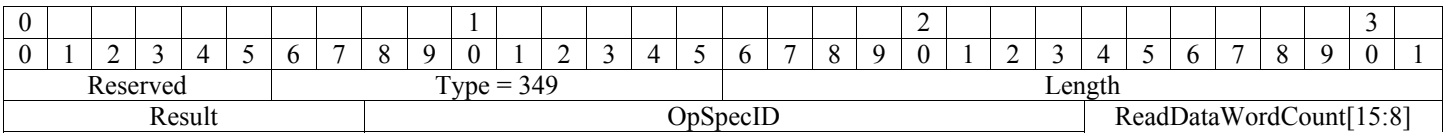
16.3.1.5.4 C1G2SingulationDetails Parameter (TV-Encoding)



See section 15.2.1.5.4.

16.3.1.5.5 C1G2 OpSpec Results

16.3.1.5.5.1 C1G2ReadOpSpecResult Parameter



ReadDataWordCount[7:0]	ReadData

See section 15.2.1.5.5.1.

16.3.1.5.5.2 C1G2WriteOpSpecResult Parameter

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 350										Length															
Result						OpSpecID										NumWordsWritten[15:8]															
NumWordsWritten[7:0]																															

See section 15.2.1.5.5.2.

16.3.1.5.5.3 C1G2KillOpSpecResult Parameter

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 351										Length															
Result						OpSpecID																									

See section 15.2.1.5.5.3.

16.3.1.5.5.4 C1G2LockOpSpecResult Parameter

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 352										Length															
Result						OpSpecID																									

See section 15.2.1.5.5.4.

16.3.1.5.5.5 C1G2BlockEraseOpSpecResult Parameter

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 353										Length															
Result						OpSpecID																									

See section 15.2.1.5.5.5.

3468

3469 **16.3.1.5.5.6 C1G2BlockWriteOpSpecResult Parameter**

0										1										2									3	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
Reserved						Type = 354										Length															
Result								OpSpecID																NumWordsWritten[15:8]							
NumWordsWritten[7:0]																															

3470

3471 See section 15.2.1.5.5.6.

3472 16.4 Listing of Message and Parameter Types

3473 This section lists the parameter and message types used in the binary encoding.

3474 **Table 4: Message Listing**

Message Name	Type
GET_READER_CAPABILITIES	1
GET_READER_CAPABILITIES_RESPONSE	11
ADD_ROSPEC	20
ADD_ROSPEC_RESPONSE	30
DELETE_ROSPEC	21
DELETE_ROSPEC_RESPONSE	31
START_ROSPEC	22
START_ROSPEC_RESPONSE	32
STOP_ROSPEC	23
STOP_ROSPEC_RESPONSE	33
ENABLE_ROSPEC	24
ENABLE_ROSPEC_RESPONSE	34
DISABLE_ROSPEC	25
DISABLE_ROSPEC_RESPONSE	35
GET_ROSPECS	26
GET_ROSPECS_RESPONSE	36
ADD_ACCESSSPEC	40
ADD_ACCESSSPEC_RESPONSE	50
DELETE_ACCESSSPEC	41
DELETE_ACCESSSPEC_RESPONSE	51
ENABLE_ACCESSSPEC	42
ENABLE_ACCESSSPEC_RESPONSE	52

DISABLE_ACCESSSPEC	43
DISABLE_ACCESSSPEC_RESPONSE	53
GET_ACCESSSPECS	44
GET_ACCESSSPECS_RESPONSE	54
CLIENT_REQUEST_OP	45
CLIENT_REQUEST_OP_RESPONSE	55
GET_REPORT	60
RO_ACCESS_REPORT	61
KEEPALIVE	62
KEEPALIVE_ACK	72
READER_EVENT_NOTIFICATION	63
ENABLE_EVENTS_AND_REPORTS	64
ERROR_MESSAGE	100
GET_READER_CONFIG	2
GET_READER_CONFIG_RESPONSE	12
SET_READER_CONFIG	3
SET_READER_CONFIG_RESPONSE	13
CLOSE_CONNECTION	14
CLOSE_CONNECTION_RESPONSE	4
CUSTOM_MESSAGE	1023

Table 5: Parameter Listing

Parameter Name	Type	TV-Encoded?
UTCTimeStamp	128	
Uptime	129	
GeneralDeviceCapabilities	137	
ReceiveSensitivityTableEntry	139	
PerAntennaAirProtocol	140	
GPIOCapabilities	141	
LLRPCapabilities	142	
RegulatoryCapabilities	143	
UHFBandCapabilities	144	
TransmitPowerLevelTableEntry	145	
FrequencyInformation	146	
FrequencyHopTable	147	

FixedFrequencyTable	148	
PerAntennaReceiveSensitivityRange	149	
ROSpec	177	
ROBoundarySpec	178	
ROSpecStartTrigger	179	
PeriodicTriggerValue	180	
GPITriggerValue	181	
ROSpecStopTrigger	182	
AISpec	183	
AISpecStopTrigger	184	
TagObservationTrigger	185	
InventoryParameterSpec	186	
RFSurveySpec	187	
RFSurveySpecStopTrigger	188	
AccessSpec	207	
AccessSpecStopTrigger	208	
AccessCommand	209	
ClientRequestOpSpec	210	
ClientRequestResponse	211	
LLRPConfigurationStateValue	217	
Identification	218	
GPOWriteData	219	
KeepaliveSpec	220	
AntennaProperties	221	
AntennaConfiguration	222	
RFReceiver	223	
RFTransmitter	224	
GPIPortCurrentState	225	
EventsAndReports	226	
ROReportSpec	237	
TagReportContentSelector	238	
AccessReportSpec	239	
TagReportData	240	
EPCData	241	
EPC-96	13	X

ROSpecID	9	X
SpecIndex	14	X
InventoryParameterSpecID	10	X
AntennaID	1	X
PeakRSSI	6	X
ChannelIndex	7	X
FirstSeenTimestampUTC	2	X
FirstSeenTimestampUptime	3	X
LastSeenTimestampUTC	4	X
LastSeenTimestampUptime	5	X
TagSeenCount	8	X
ClientRequestOpSpecResult	15	X
AccessSpecID	16	X
RFSurveyReportData	242	
FrequencyRSSILevelEntry	243	
ReaderEventNotificationSpec	244	
EventNotificationState	245	
ReaderEventNotificationData	246	
HoppingEvent	247	
GPIEvent	248	
ROSpecEvent	249	
ReportBufferLevelWarningEvent	250	
ReportBufferOverflowErrorEvent	251	
ReaderExceptionEvent	252	
OpSpecID	17	X
RFSurveyEvent	253	
AISpecEvent	254	
AntennaEvent	255	
ConnectionAttemptEvent	256	
ConnectionCloseEvent	257	
LLRPStatus	287	
FieldError	288	
ParameterError	289	
Custom	1023	
C1G2LLRPCapabilities	327	

UHFC1G2RFModeTable	328	
UHFC1G2RFModeTableEntry	329	
C1G2InventoryCommand	330	
C1G2Filter	331	
C1G2TagInventoryMask	332	
C1G2TagInventoryStateAwareFilterAction	333	
C1G2TagInventoryStateUnawareFilterAction	334	
C1G2RFControl	335	
C1G2SingulationControl	336	
C1G2TagInventoryStateAwareSingulationAction	337	
C1G2TagSpec	338	
C1G2TargetTag	339	
C1G2Read	341	
C1G2Write	342	
C1G2Kill	343	
C1G2Lock	344	
C1G2LockPayload	345	
C1G2BlockErase	346	
C1G2BlockWrite	347	
C1G2EPCMemorySelector	348	
C1G2PC	12	X
C1G2CRC	11	X
C1G2SingulationDetails	18	X
C1G2ReadOpSpecResult	349	
C1G2WriteOpSpecResult	350	
C1G2KillOpSpecResult	351	
C1G2LockOpSpecResult	352	
C1G2BlockEraseOpSpecResult	353	
C1G2BlockWriteOpSpecResult	354	

17 Transmitter Behavior of a Reader

A Reader SHALL enable its transmitter only under the following conditions:

- When an ROSpec is in the active state.

- Between a GET/SET_READER_CONFIG containing a RequestedData field with value 0 (All) or 2 (Antenna Properties) and the corresponding GET/SET_READER_CONFIG_RESPONSE.

18 Connection and Transport

The Reader SHALL maintain LLRP configuration state during an LLRP connection.

The Reader MAY maintain configuration or data state when a connection fails, or across LLRP connections.

18.1 TCP Transport

LLRP end-to-end communications based on TCP/IP connections SHALL be implemented in accordance with the requirements specified in this section. These requirements are defined as the LLRP *TCP Transport*.

Readers SHALL be able to both initiate and accept LLRP TCP connections. Readers MAY be configured such that, at any given time, they only either initiate or accept an LLRP connection. If so, the mechanism for configuring a Reader to either initiate or accept an LLRP connection is not specified by LLRP.

Clients SHALL be able both to initiate and accept LLRP TCP connections. Clients MAY be configured such that, at any given time, they only either initiate or accept an LLRP connection. If so, the mechanism for configuring a Client to either initiate or accept an LLRP connection is not specified by LLRP.

For Readers and Clients, that are configured to accept connections, the default port is 5084, as established by IANA (see http://www.iana.org/assignments/port-numbers), but other ports can be used.

When a TCP connection (called the *established connection*) is initiated by either the Reader or the Client, the Reader SHALL reply with a status report message before communicating any other information. This report's status parameter, ConnectionAttemptEvent, SHALL be set to indicate connection success (see section 13.2.6.11). No other parameters may be contained within this message. The Client SHALL not send any information to the Reader until this status report message is received.

Readers SHALL limit communications to a single established connection on a Reader IP address and TCP port. Readers MAY momentarily accept TCP connections (called *momentary connections*) in addition to the Reader's one established connection on a Reader IP address and TCP port. If a momentary connection is accepted, then the Reader SHALL send a status report message on the Reader's established connection. This report's status parameter, ConnectionAttemptEvent, SHALL be set to indicate that another connection was attempted (see section 13.2.6.11). If this action results in a TCP error, then the Reader MAY close the established connection and then treat the momentary connection as a new established connection. In this case, the Reader SHALL reply with a status report message on the newly created established connection, as specified above, indicating connection success.

If the established connection is not closed, then the Reader SHALL reply on the momentary connection with a status report message. This report's status parameter, ConnectionAttemptEvent, SHALL be set to indicate connection failure. The Reader SHALL use the appropriate connection failed status value as defined in section 13.2.6.11. Once the connection failure message is sent, the Reader SHALL close the momentary connection.

The following UML sequence diagrams illustrate different scenarios of a Reader and Client initiating TCP connections.

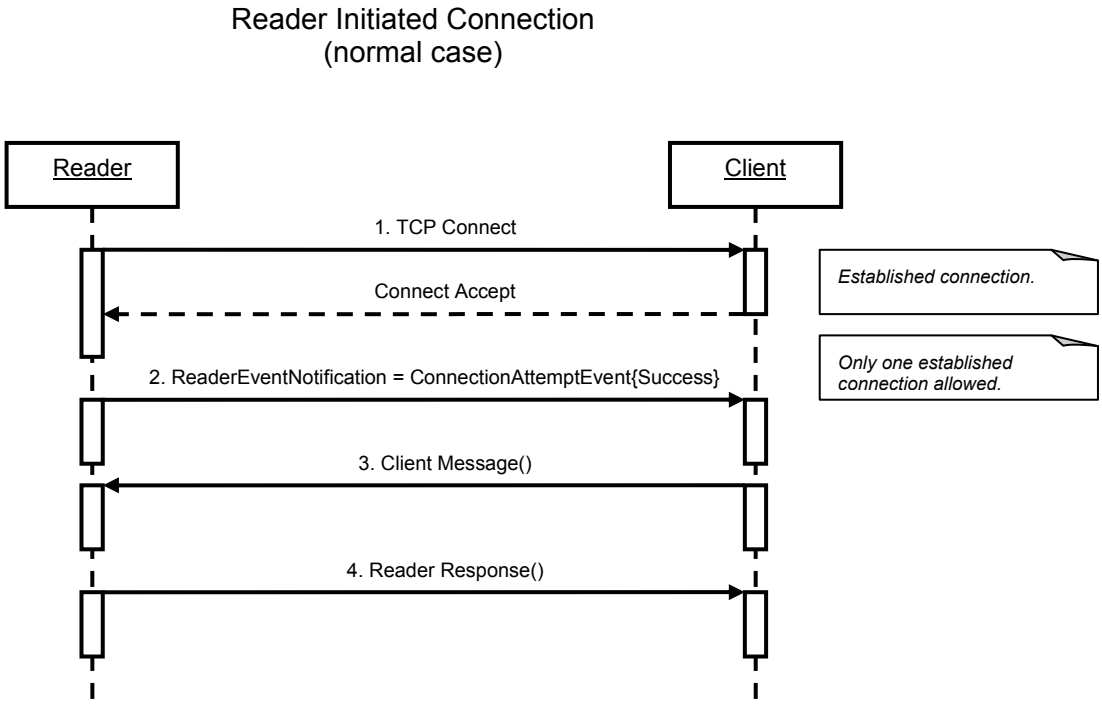
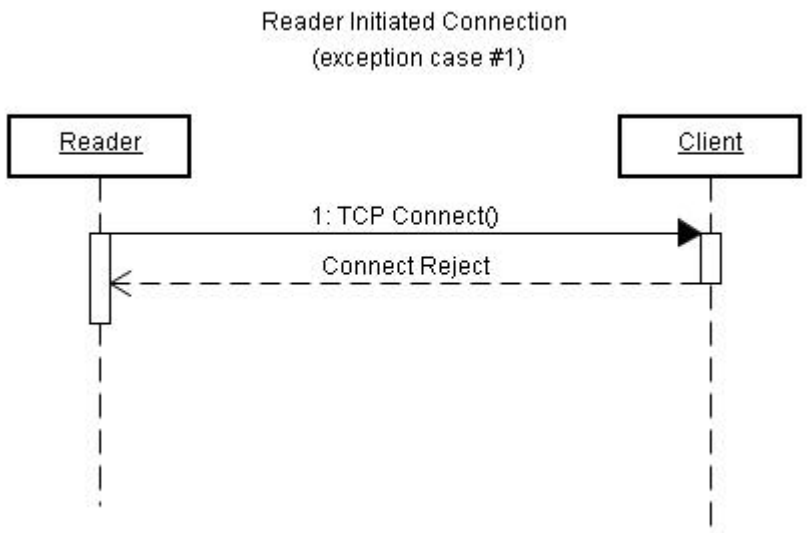


Figure 14: Reader Initiated Connection (Normal)



3535

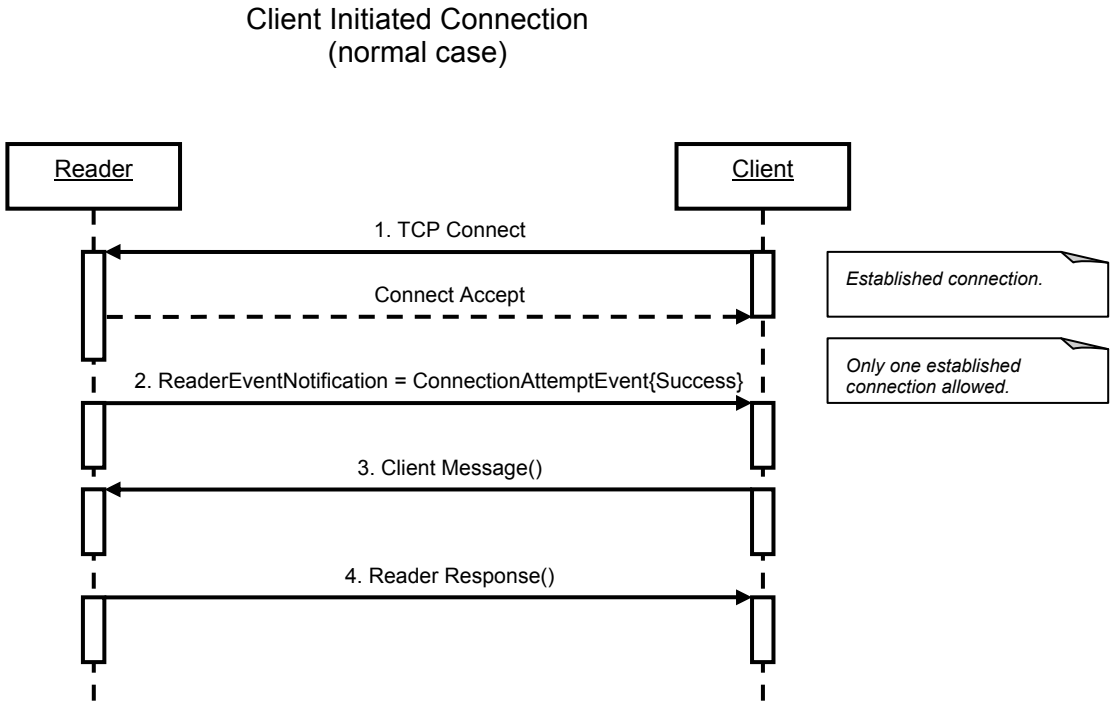
3536 **Figure 15: Reader Initiated Connection (Exception)**

3537

3538

3539

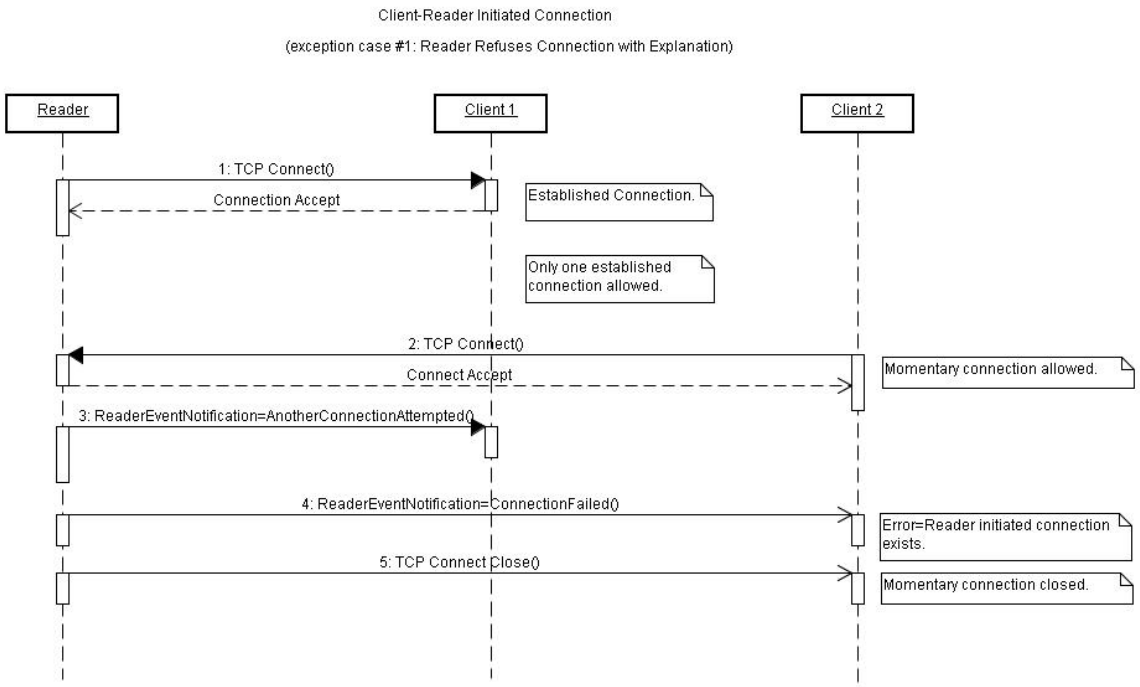
3540



3541

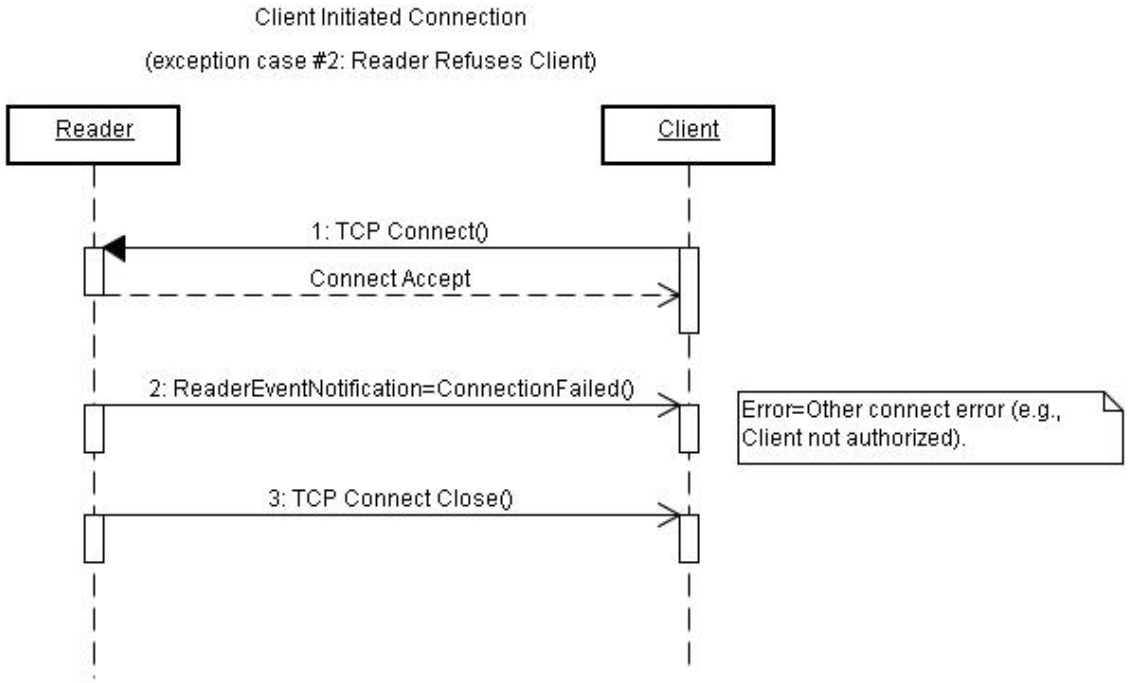
3542 **Figure 16: Client Initiated Connection (Normal)**

3543



3544

3545 **Figure 17: Client Initiated Connection (Exception #1)**



3546

3547 **Figure 18: Client Initiated Connection (exception #2)**

3548

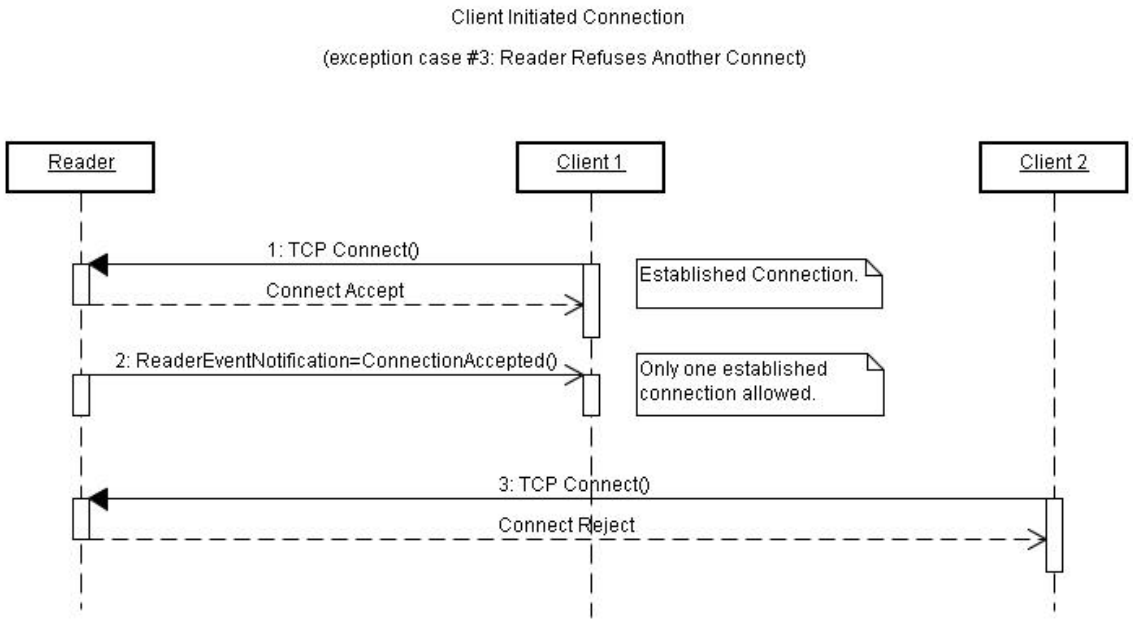


Figure 19: Client Initiated Connection (exception #3)

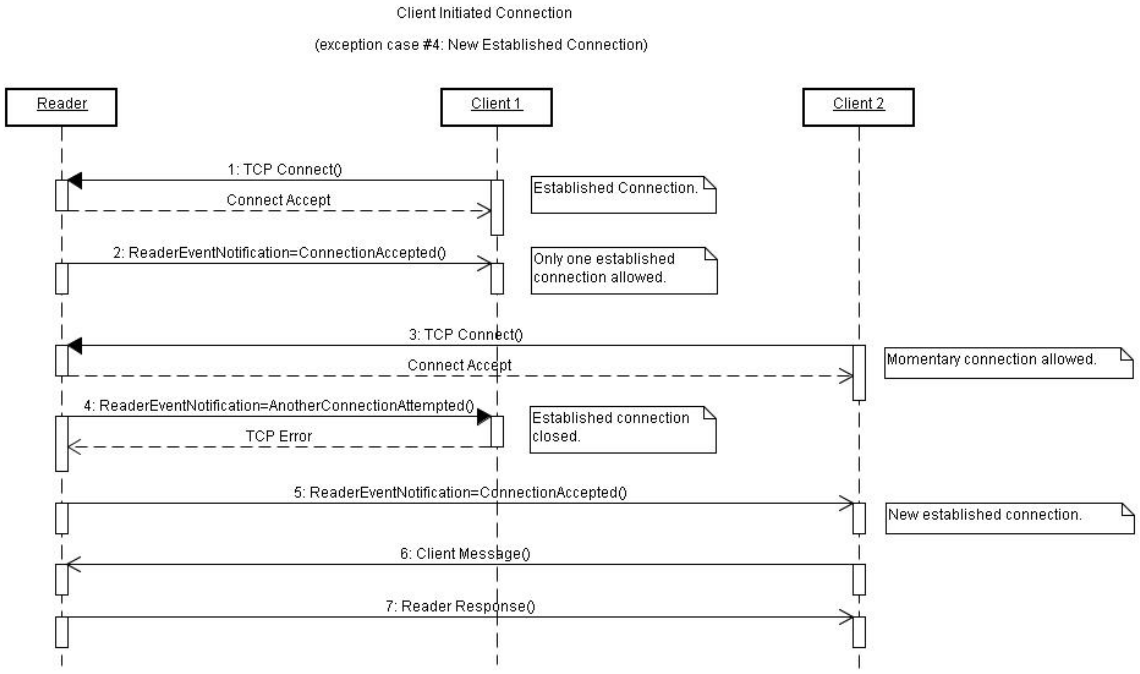


Figure 20: Client Initiated Connection (exception #4)

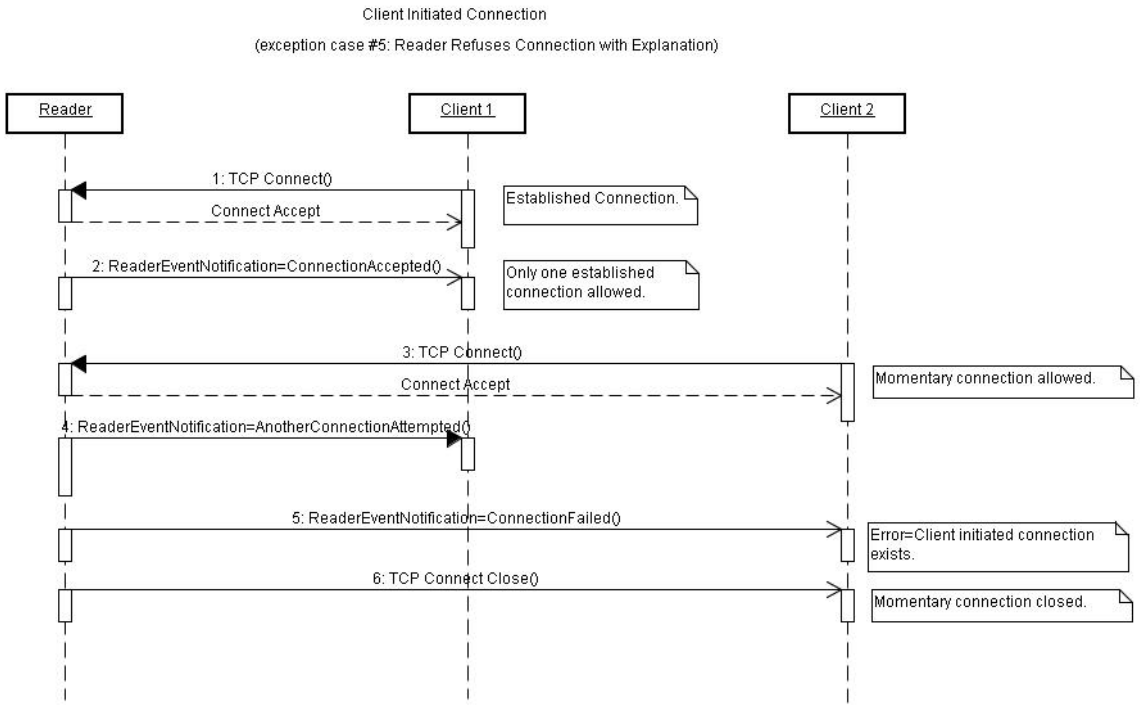


Figure 21: Client Initiated Connection (exception #5)

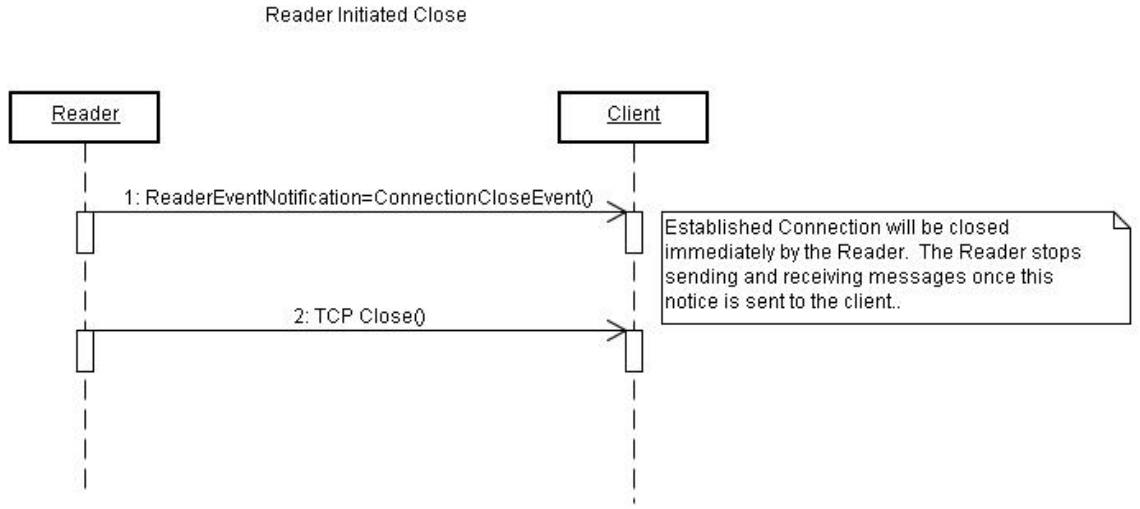
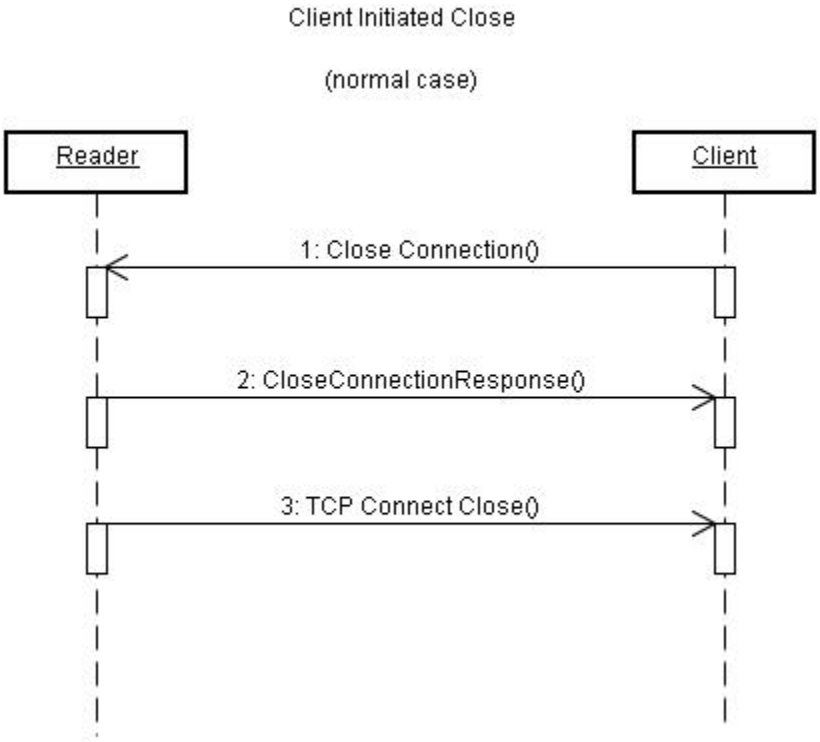


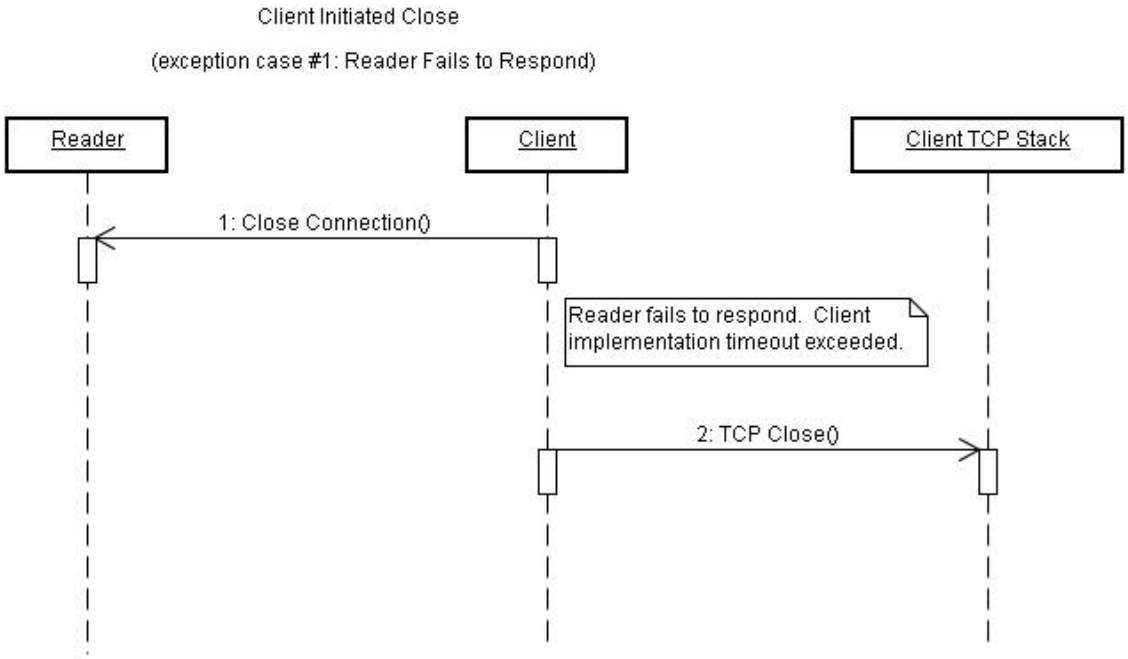
Figure 22: Reader Initiated Close



3563

3564 **Figure 23: Client Initiated Close (Normal)**

3565



3566

3567 **Figure 24: Client Initiated Close (Exception)**

18.2 Security in TCP Transport

This section describes the security aspects for LLRP connections running over a TCP transport binding. Refer to the previous section for any TCP connection related requirements.

18.2.1 Normative Section

The LLRP Client and LLRP Reader MAY implement TLS. The LLRP Client and LLRP Reader MAY use a different port for TLS LLRP connections and non-TLS LLRP connections.

The LLRP Client MAY be capable of operating in a mixed deployment, where it communicates using TLS with a set of Readers and just plain TCP with a different set of Readers. In such mixed deployments, the LLRP Client MAY use different ports for TLS and non-TLS LLRP connections. The default port for TLS-LLRP connections is 5085, as established by IANA (see http://www.iana.org/assignments/port-numbers), but other ports can be used.

The LLRP endpoint that initiates the TLS connection MAY be the same LLRP endpoint that initiated the underlying TCP connection.

The LLRP endpoints SHALL use at least TLS1.0 [TLS10] and are recommended to use TLS1.1 [TLS11].

If the Reader or Client uses X.509 certificates[X509] for authentication, the certificates SHALL be compliant with the EPCGlobal Security2 working group specification [SEC2].

18.2.2 Informative Section

18.2.2.1 Overview of TLS

The TLS protocol provides privacy and data integrity between two authenticated communicating applications. TLS is a light weight transport protocol and has been proven to be reliable and secure by the use of millions of real users for many years. The strength of TLS can be chosen by the cipher suite negotiated by the two communicating parties through a flexible mechanism during the handshaking.

TLS is particularly useful for TCP based applications. First, a TLS client initiates a connection with the TLS server. After a TLS connection is established, the applications can use the transport connection like an ordinary TCP connection, while having the added value that the data is protected and that both parties are mutually authenticated.

For interoperability, a TLS client and server have to implement at least one common cipher suite. The credentials required for mutual authentication depend on the suite negotiated. For example, if the negotiated suite is using RSA for key exchange, then the server must own a server certificate (with private key) for RSA encryption purposes while the client must have a client certificate (with private key) for RSA signing purposes. Further, each side must have the root Certificate Authority (CA) certificates to

verify the certificates presented by the peers. TLS also requires each party to present the CA certificates (except the root) that directly and indirectly issue the certificate.

18.2.2.2 Threat Analysis for LLRP

With TLS being used for Reader and Client communication, the following protections are provided, assuming that the credentials for the TLS client and server are not stolen:

- Readers only talk to authorized LLRP Clients;
- LLRP Clients only talk to authorized Readers;
- No other party can read the LLRP messages (privacy protection) or inject/modify messages without being detected (integrity protection).

Note that the strength of protection depends on the negotiated cipher suite.

18.2.2.3 Configuration Elements for TLS

In order to use TLS for LLRP, the following information has to be configured and/or provisioned at each entity (Reader or Client):

- **TLS enabled:** Yes or no. If TLS is not enabled, the rest of the information need not be configured and the LLRP endpoint (Reader or Client) SHALL use TCP directly.
- **TLS role:** Whether the LLRP endpoint is playing the TLS client or the TLS server role. A TLS client initiates a TCP connection to jump start TLS handshaking. A TLS server passively listens on the TCP server port.
- **Preferred list of cipher suites**: A TLS client proposes the list of cipher suites to the TLS server during TLS handshaking. The TLS server will pick one suite from the proposed list if it is also in the preferred list maintained by the server. In TLS, the order of suites in the proposed list has no significance. Also, it is up to the server's local policy to select when there are multiple choices.
- **Certificates and private keys**: A TLS server needs a server certificate (with private key) for TLS server authentication. A TLS client needs a client certificate (with private key) for TLS client authentication. In each case, all the CA certificates (except the root) in the chain have to be available.
- **Root CA certificates**: A TLS server needs to maintain the root CA certificate of the client certificate. This is used for verifying client certificates. A TLS client needs to maintain the root CA certificate of the server certificate. This is used for verifying server certificates.
- **List of authorized devices:** Each TLS server MAY have a list of authorized TLS clients that can connect to it. Likewise, each TLS client MAY have a list of authorized TLS servers that it can connect to.

The configuration and/or provisioning of a LLRP endpoint is out of the scope of TLS and LLRP. Provisioning is important but does not affect the interoperability of LLRP. Vendors should have the flexibility to choose the most cost-effective ways (for provisioning and protecting provisioned credentials) based on designs, available technologies, potential threats, security requirements, and so on. This is a topic that should be addressed in DCI.

18.2.2.4 Why different TLS server port?

It is recommended that the TLS server should listen to a TCP port different from that for non-TLS mode for the following reasons:

- If one of the endpoints has to be deployed behind firewalls, IT managers are more willing to open a port they know only TLS traffic can pass through.
- Without using a different port, a non-TLS server may be confused by the TLS Client-Hello handshaking message.
- Without using a different port, a TLS server may be confused by the LLRP application message (non-TLS handshaking message).
- Without using a different port, for each new TCP connection, a server in a mixed environment (TLS and non-TLS) may have to wait a few moments to see if a Client-Hello message ever arrives from the client before it can conclude whether it is a TLS connection or not.
- Without using a different port, it is potentially harder to implement a hybrid server if the server relies on third-party libraries for handling TLS. This is because the server application has to read the first message from the client to know if it is a TLS connection. It may be difficult for the TLS library to take over a connection after the TLS Client-Hello message has been consumed.

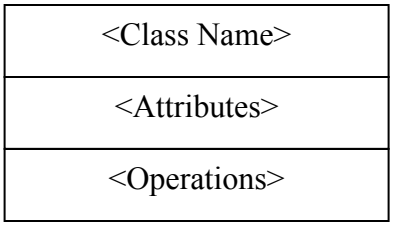
However, if a deployment in totality is only TLS or only non-TLS, the LLRP endpoint can be configured only as a TLS server or non-TLS server exclusively, then there should be no problem using the same port, as long as a non-TLS server can ignore TLS handshaking messages from a TLS client and as long as a TLS server can ignore non-TLS handshaking messages from a non-TLS client.

19 (Informative) Object Model

The Object Model (OM) presented in this section illustrates the data structures inherent in the LLRP specification and further described in section 5. These OM diagrams are based upon Unified Modeling Language (UML) notation (see www.uml.org). There are two kinds of LLRP data structures: 1) *messages* and 2) *data parameters*. Messages can be composed of data parameters. Data parameters can be further composed of other data parameters. A simple data element (i.e., a data element with no subcomponents) is called a *data field*.

In the OM, both kinds of data structures are represented by UML class diagrams. Data fields are represented as class attributes.

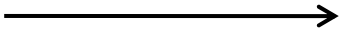
A UML class is defined as a collection of objects with common structure, common relationships, etc. A UML class is illustrated as a rectangle partitioned into three compartments as follows:



The OM is used only to describe structure and therefore the *Operations* compartment is left empty for all OM classes.

There are three class relationship notations used in the OM:

- Association with one-way navigation.



0..1

This notation represents that one class includes a reference to another class (the arrowhead side). LLRP data structures reference each other via an identifier (e.g., ROSpecID).

A number or a range of numbers (e.g., 0..1) can appear on either side of the line. This is the multiplicity of the relationship (e.g., the number of instances of one class related to one instance of the other class). If no number appears on a side of the line, then a one is implied.

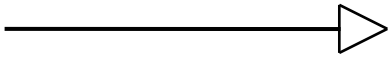
- Aggregation.

0..1

This notation represents that one class (the diamond side) includes another class embedded within it.

A number or a range of numbers (e.g., 0..1) can appear on either side of the line. This is the multiplicity of the relationship (e.g., the number of instances of one class related to one instance of the other class). If no number appears on a side of the line, then a one is implied.

- Inheritance.



This notation represents that one class is a superclass of another class known as the base class (the arrowhead side). A superclass includes all attributes and relationships of the base class plus additional features.

19.1 Capabilities

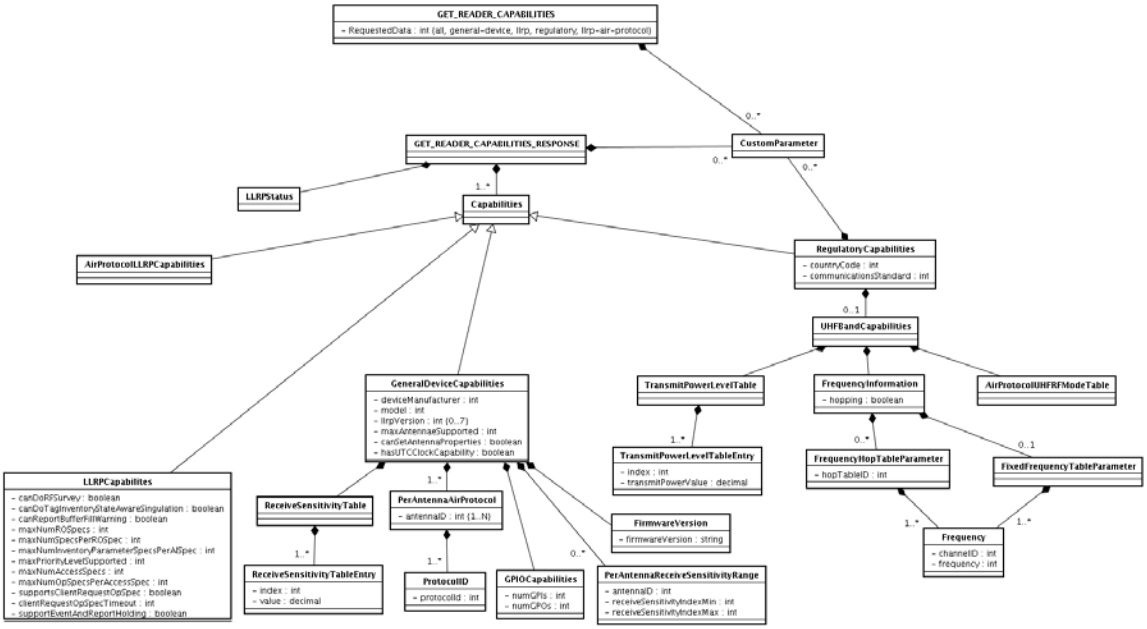


Figure 25: Capabilities

19.2 Configuration

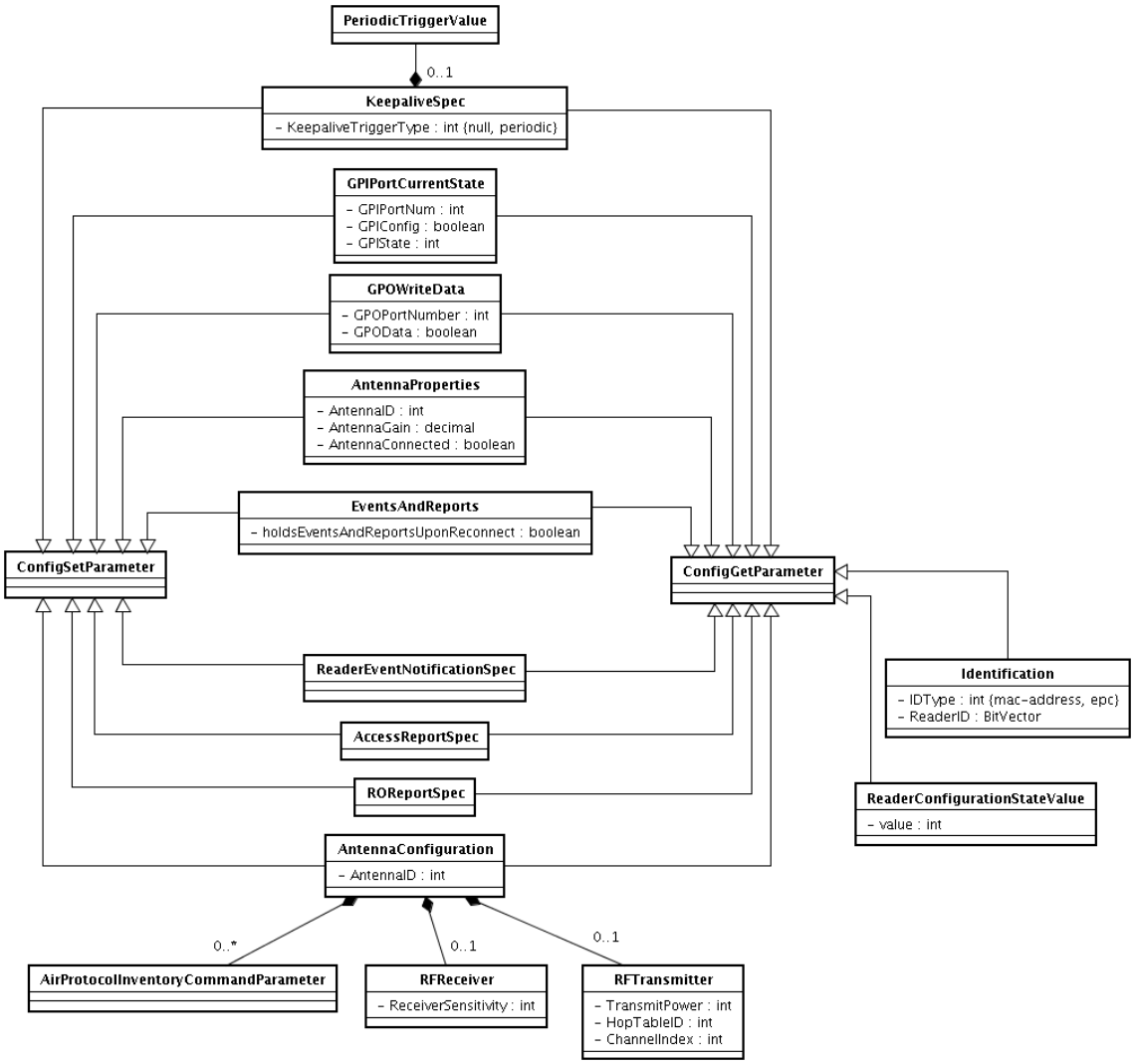


Figure 26: Configuration

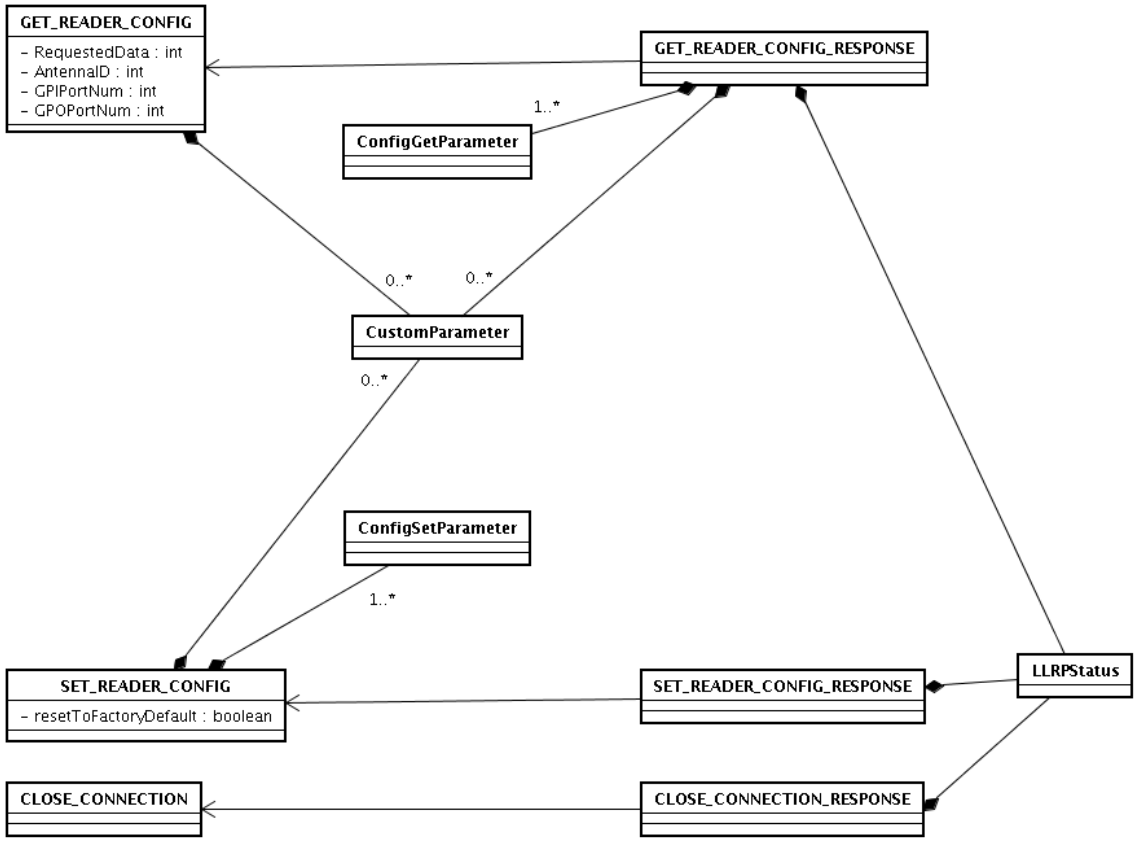


Figure 27: Configuration Commands

19.3 ROSpec

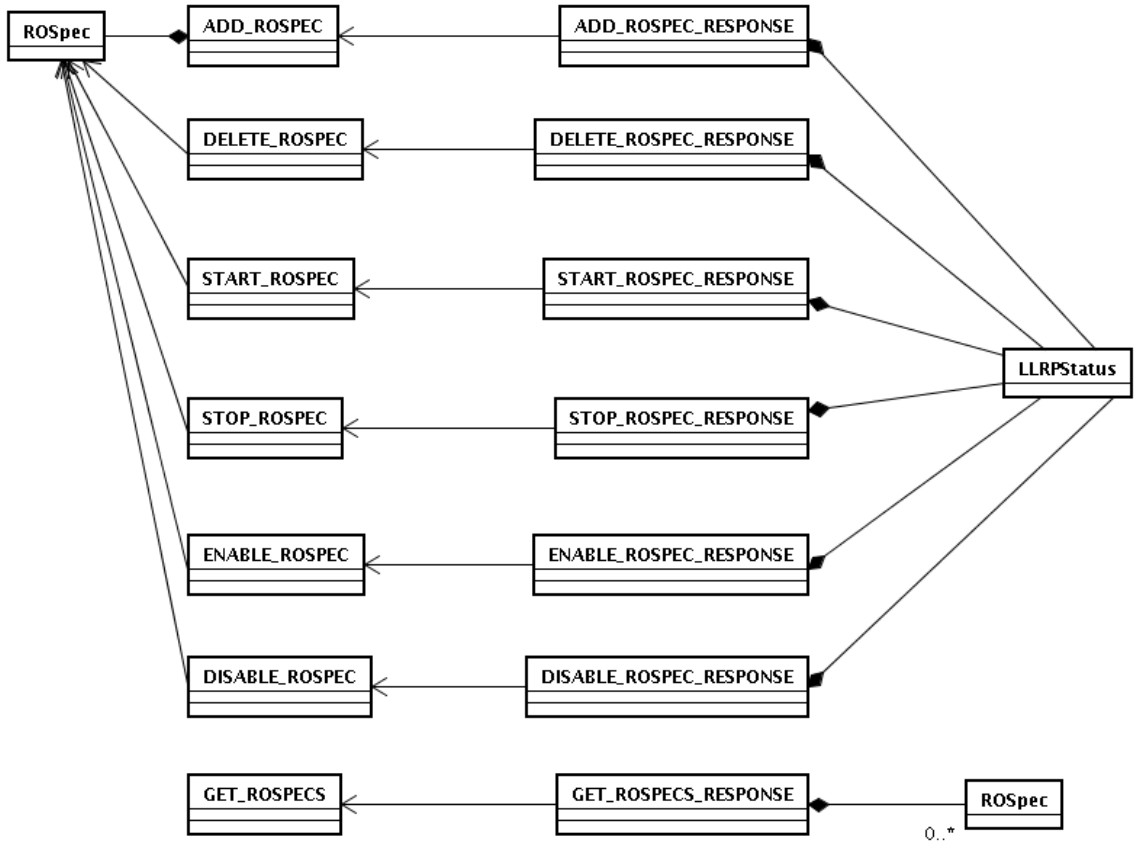


Figure 28: RO Commands

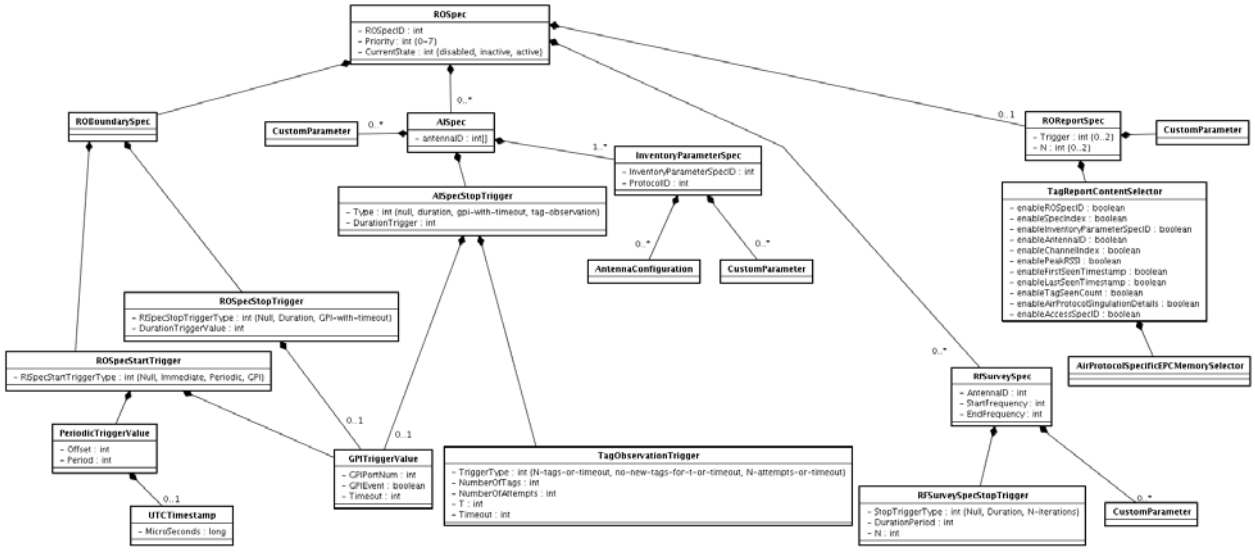


Figure 29: ROSpec

19.4 AccessSpec

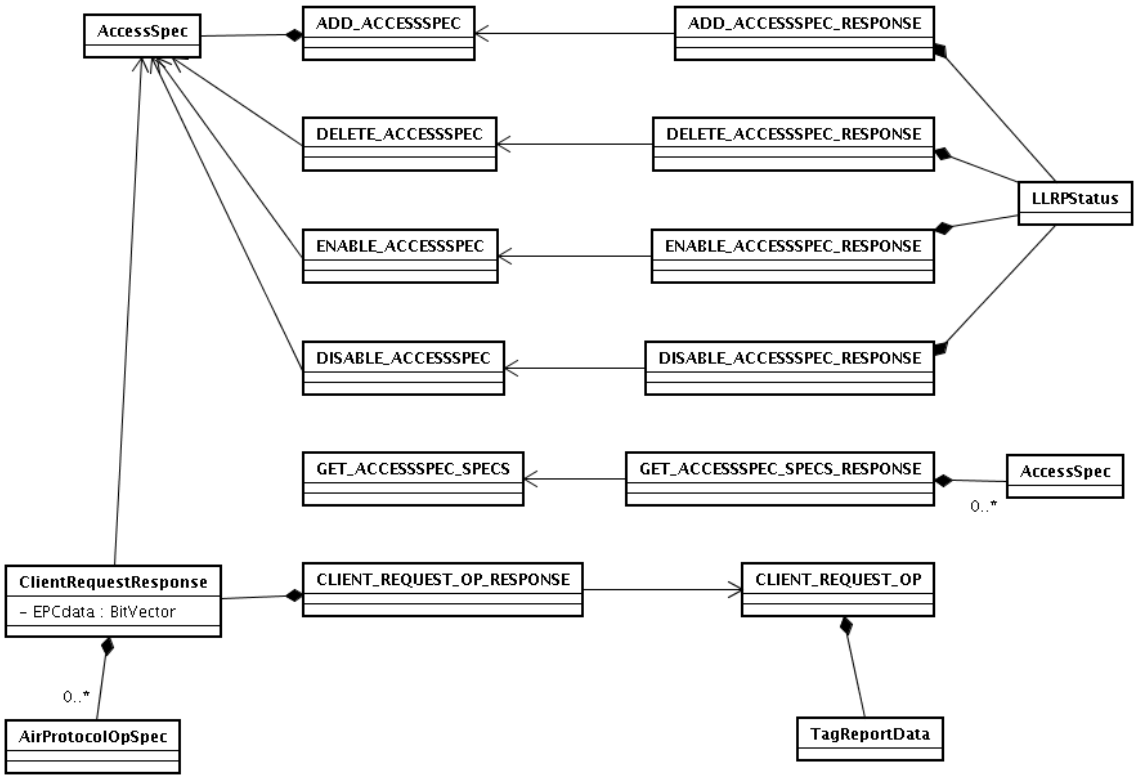


Figure 30: Access Commands

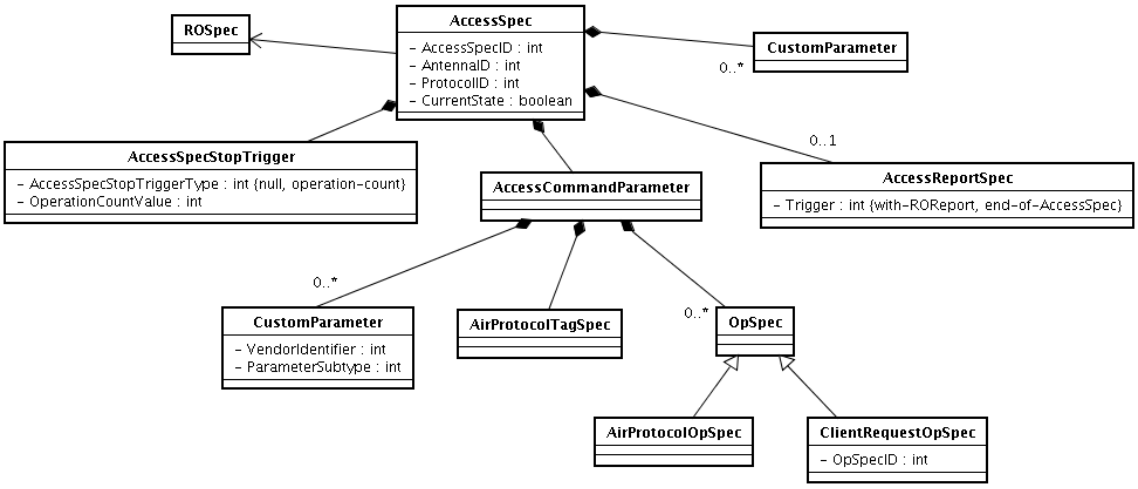


Figure 31: AccessSpec

19.5 C1G2 Parameters

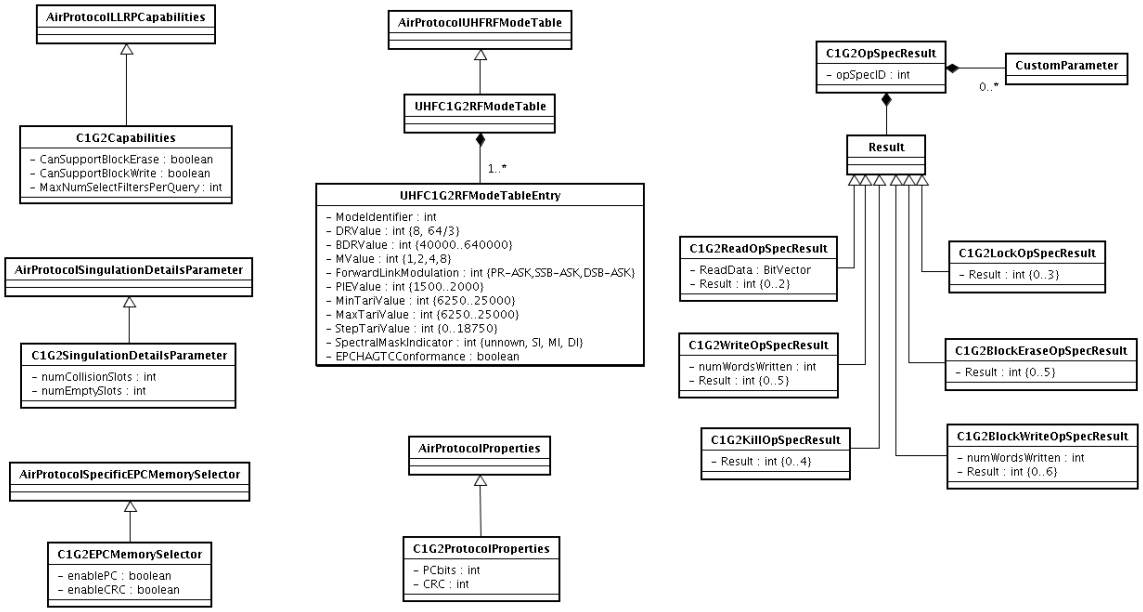


Figure 32: C1G2 Parameters

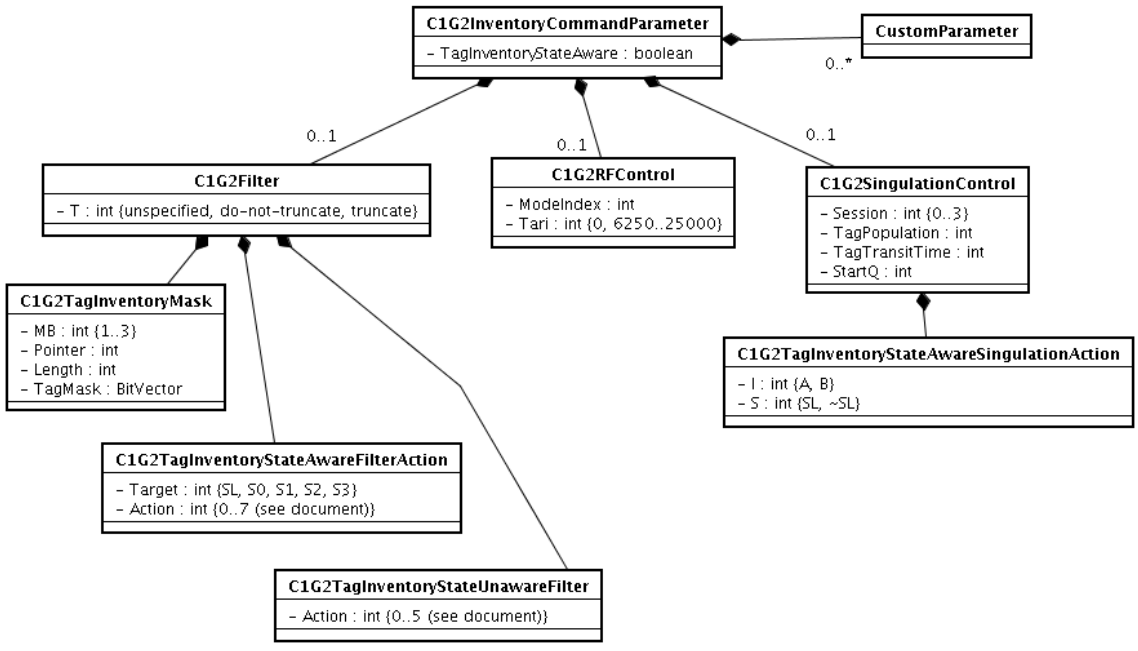


Figure 33: C1G2 Inventory Command

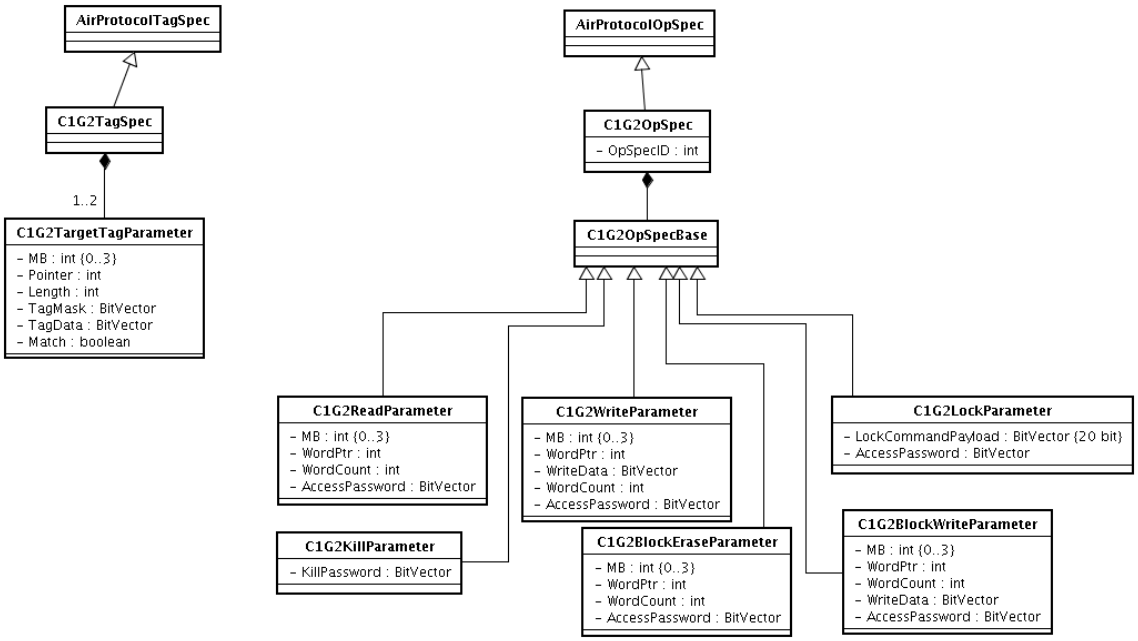


Figure 34: C1G2 AccessSpec

19.6 Reporting and Notification

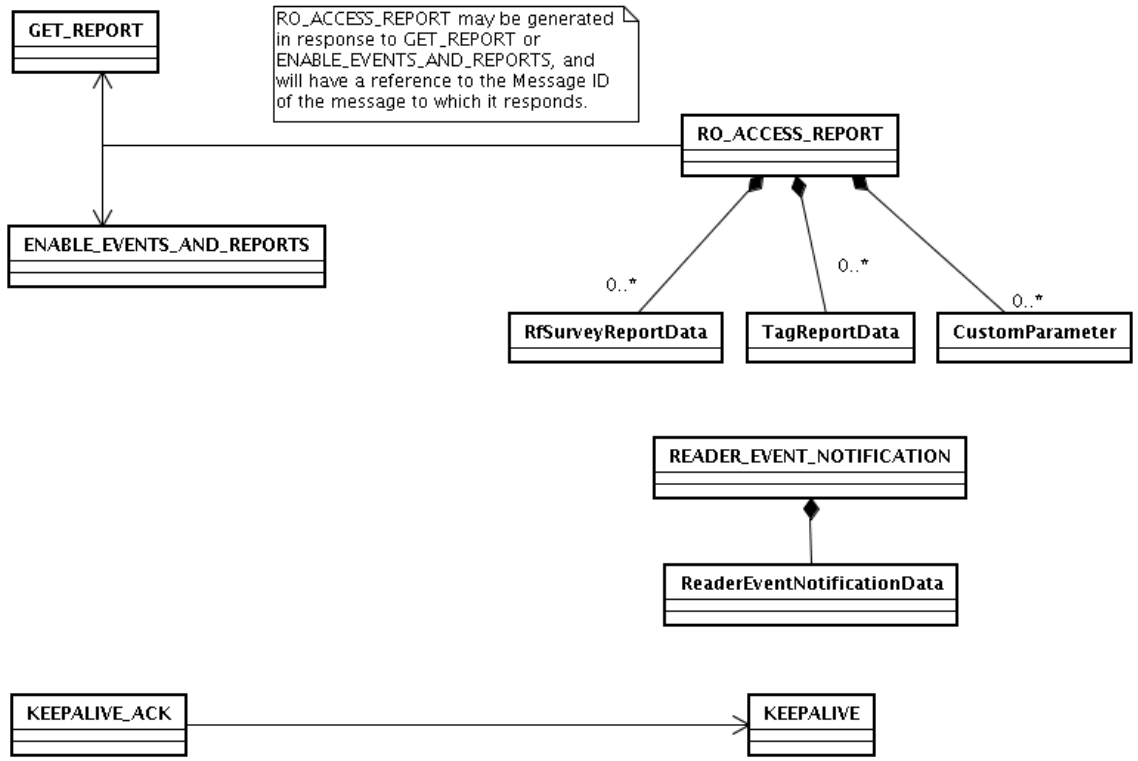


Figure 35: Reporting and Notification

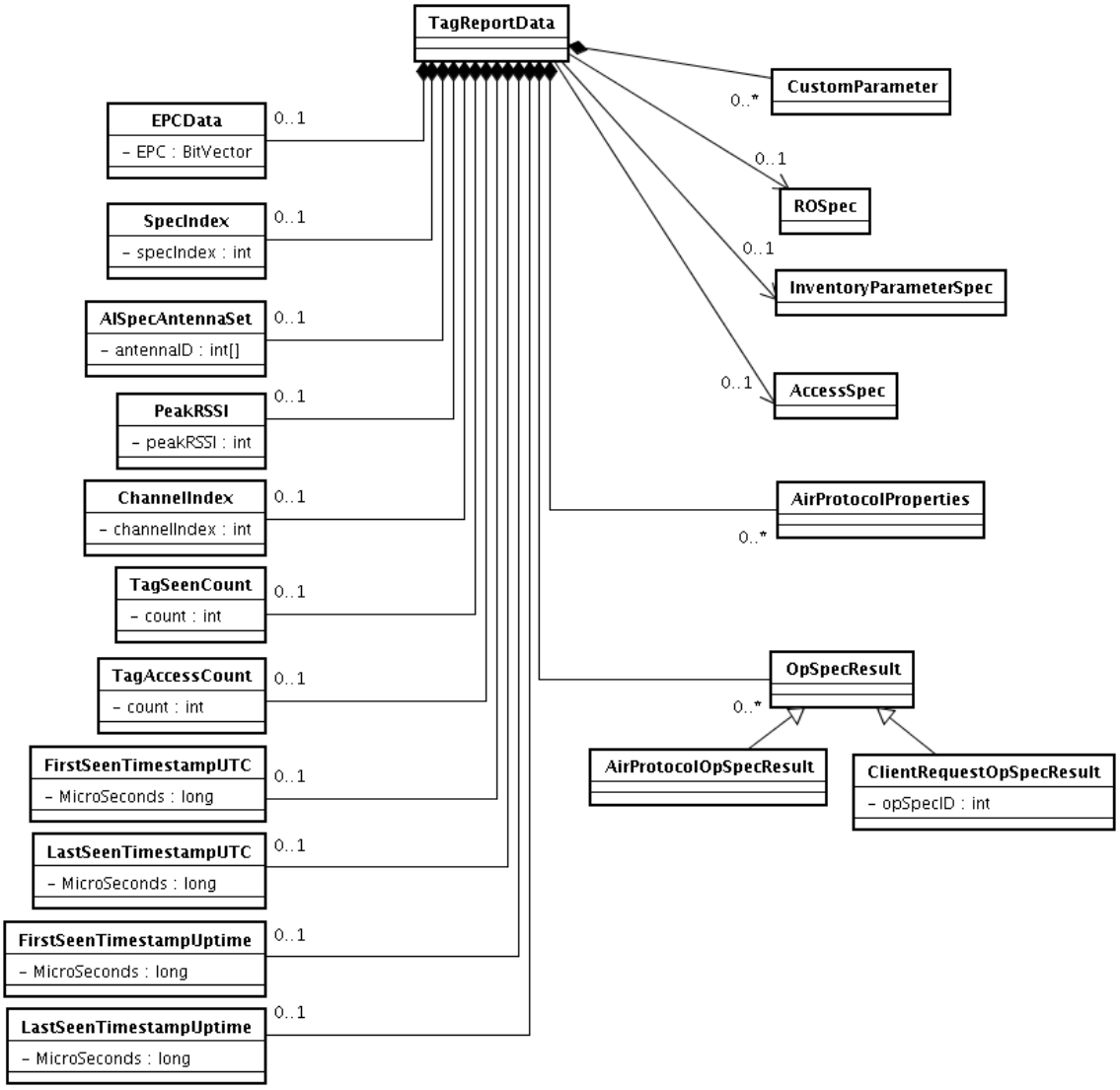
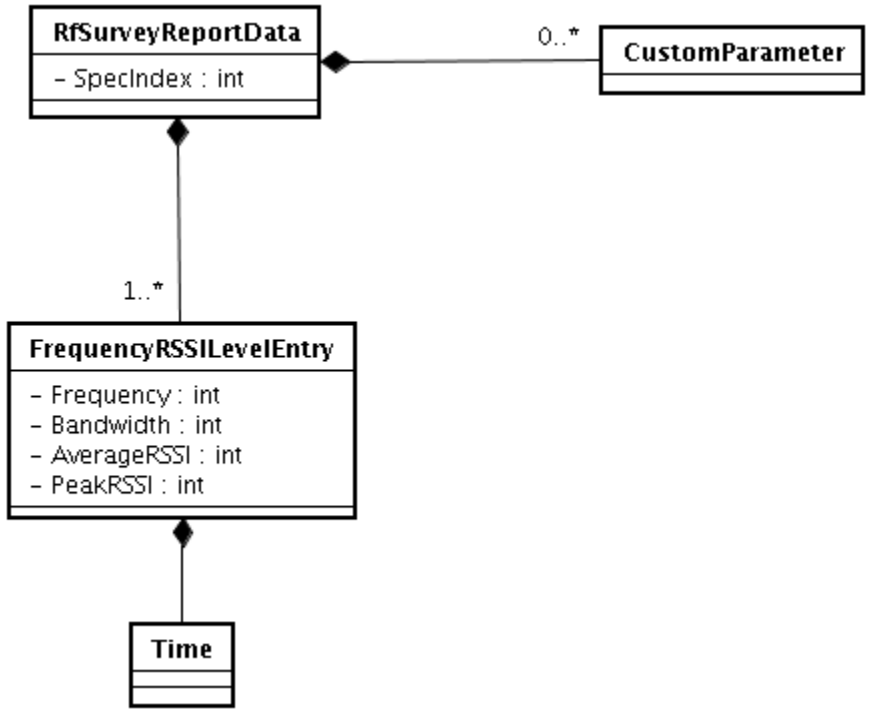
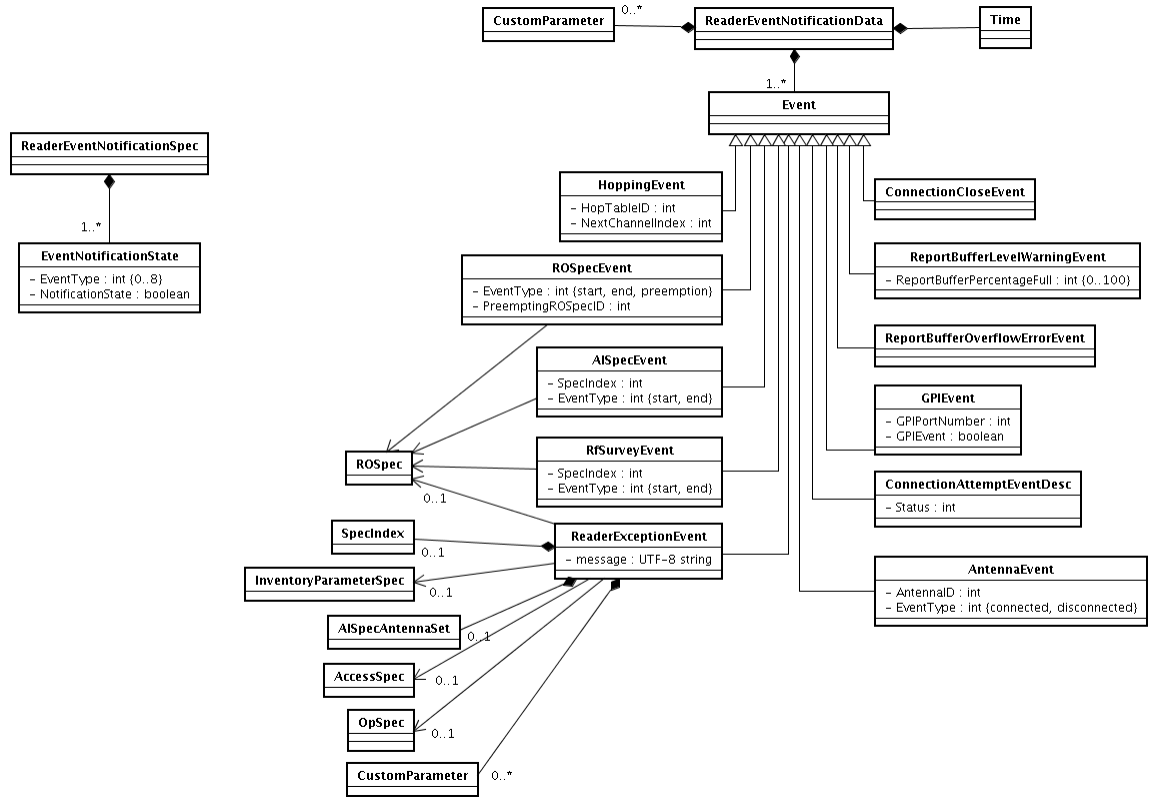


Figure 36: TagReportData



3744

3745 **Figure 37: RFSurveyReportData**



3746

3747 **Figure 38: Reader Event Notification Data**

3748

19.7 General

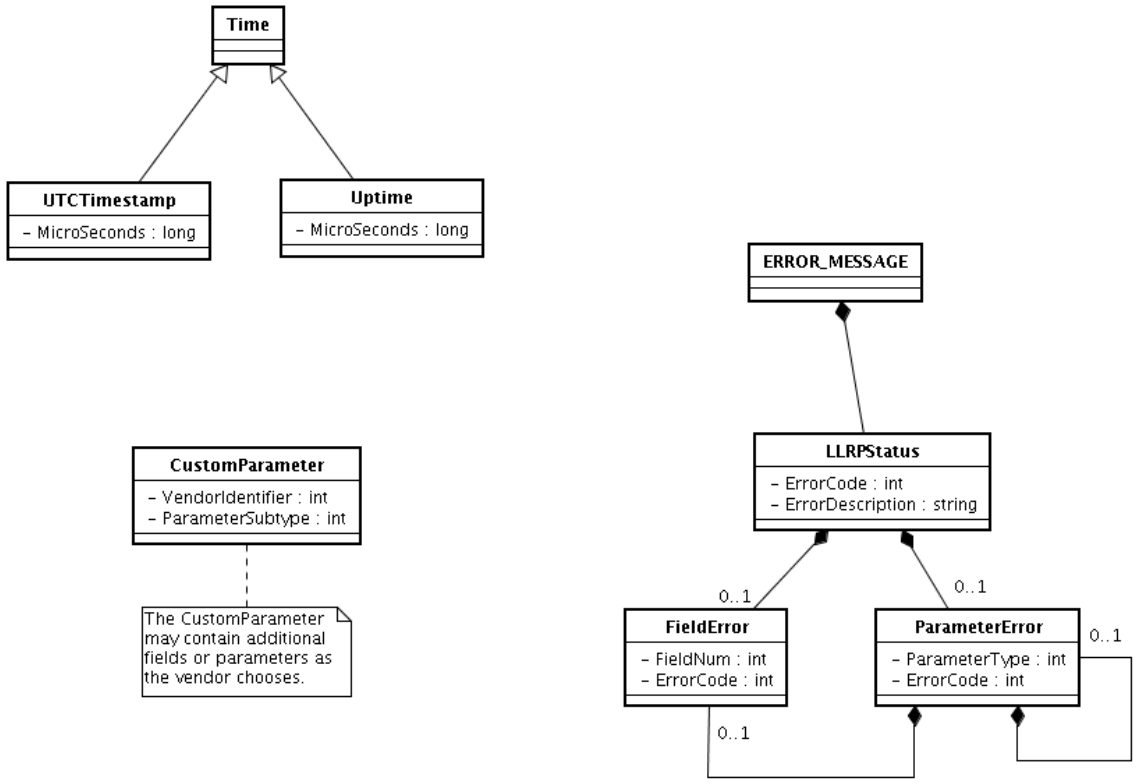


Figure 39: General Data

20 (Informative) TCP Keepalives

The TCP specification doesn't specify any specific handling of idle connections, where there is no data being transmitted by either end for a prolonged period of time. However, in some TCP implementations, there is an option called TCP-keepalive which may be turned on. If turned on, TCP-keepalive packets are sent only during periods of inactivity, on a configurable interval. If the connection is still valid, the other end responds with a segment containing an ack. If the connection is not valid the other end will reply with a connection reset (RST) and the connection is closed by this end.

Due to events like network failures, or Client failures, half connections may remain at the Reader because the TCP connection was not cleanly terminated. If the Reader doesn't implement TCP-keepalive, the only way to recover (i.e., reconnect to the Reader) may be to reboot the Reader.

However, there are Readers for which intermittent connectivity may be a normal mode of operation – e.g., mobile Readers, handheld Readers. When connectivity is lost for these devices, the use of TCP-keepalive acts negatively and closes the TCP session prematurely before the TCP session would have timed out. If keepalives were not used, the mobile Reader would just start sending LLRP messages as soon as the link layer is re-established without requiring a re-establishment of the TCP session as long as the TCP session did not timeout.

21 (Informative) References

[ISODir2] ISO, "Rules for the structure and drafting of International Standards (ISO/IEC Directives, Part 2, 2001, 4th edition)," July 2002.

[C1G2] Class 1 Generation 2 UHF Air Interface Protocol Standard Version 1.0.9

http://www.epcglobalinc.org/standards_technology/EPCglobal2UHFRFIDProtocolV109122005.pdf

[ALE 1.0] EPCglobal Application Level Events (ALE) 1.0 Specification

http://www.epcglobalinc.org/standards_technology/EPCglobal_ApplicationALE_Specification_v112-2005.pdf

[Class0] 900 MHz Class 0 Radio Frequency (RF) Identification Tag Specification,

http://www.epcglobalinc.org/standards_technology/Secure/v1.0/UHF-class0.pdf

[Class1] 860MHz -- 930 MHz Class 1 Radio Frequency (RF) Identification Tag Radio Frequency & Logical Communication Interface Specification.,

http://www.epcglobalinc.org/standards_technology/Secure/v1.0/UHF-class1.pdf

[ARC] EPCglobal Architecture Framework 1.0

http://www.epcglobalinc.org/standards_technology/Final-epcglobal-arch-20050701.pdf

[**ISO3166**] ISO, "Codes for the Representation of Names of Countries".

http://www.iso.org/iso/en/prods-services/iso3166ma/index.html

[**UTC**] IETF RFC 3339, "Date and Time on the Internet: Timestamps", July 2002.

http://www.ietf.org/rfc/rfc3339.txt

[**EUI64**] "Guidelines For 64-bit Global Identifier (EUI-64)", http://standards.ieee.org/db/oui/tutorials/EUI64.html

[**TLS11**] IETF RFC 4346, "The Transport Layer Security (TLS) Protocol Version 1.1". http://www.ietf.org/rfc/rfc4346.txt

[**TLS10**] IETF RFC 2246, "The TLS Protocol Version 1.0", http://www.ietf.org/rfc/rfc2246.txt

[**X509**] ITU-T Recommendation X.509 (1997 E): Information Technology - Open Systems Interconnection - "The Directory Authentication Framework". 1988.

[**SEC2**] EPCGlobal Certificate Profile, http://www.epcglobalinc.org/standards_technology/SAG%20Security%20Cert%20Profile%20March%208%202006.pdf

[**UTF8**] IETF RFC 3629, "UTF-8, a transformation format of ISO 10646", November 2003. See also Annex D of ISO 10646-1:2000. http://www.ietf.org/rfc/rfc3629.txt

[**HK**] OFTA 1049,

http://www.ofta.gov.hk/en/standards/hktaspec/hkta1049.pdf#search=%22OFTA%201049%22

[**TW**] DGT LP0002,

http://www.dgt.gov.tw/English/Type-approval/8.4/LP0002/LP0002-940324.pdf

[**JPN**] ARIB STD T89, http://www.arib.or.jp/english/html/overview/st_j.html

[**KOR**] MIC Article 5-2, (Radio Equipment for RFID/USN): Technical Requirements for the radio equipment for passive RFID using the frequency range of 908.5~914MHz.

22 Acknowledgement of Contributors and Companies Opt'd-in during the Creation of this Standard (Informative)

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Below is a list of more active participants and contributors in the development of LLRP 1.0. This list does not acknowledge those who only monitored the process or those who chose not to have their name listed here. Active participants status was granted to those who generated emails, attended face-to-face meetings and conference calls that were associated with the development of this Standard.

First Name	Last Name	Company	Notable Role
Dave	Husak	Reva Systems	Co-Chair
Rob	Buck	Intermec	Co-Chair
Pattabhiraman	Krishna	Reva Systems	Editor
Mark	Frey	EPCglobal Inc.	Facilitator for WG
Software Team at Impinj		Impinj	Minutes Recorder
Marc	Horowitz	BEA Systems	
Suresh	Bhaskaran	Intelleflex	
Daniel	Paley	Tagent Corp.	
Bud	Biswas	Polaris Networks	
Bob	O'Hara	Cisco	
Daniel	Bowman	Kimberly-Clark Corp	
Margaret	Wasserman	ThingMagic, LLC	
Arthur	Howarth	Cisco	
Richard	Bach	GlobeRanger	
Rick	Schuessler	Symbol Tech./Motorola	

Howard	Kapustein	Manhattan Associates	
David	Missimer	Sirit	
Darrel	Pinson	Symbol Technologies, Inc.	
Matt	Poduska	Intermec	
Steve	Lockhart	Sirit	
David	Lavin	IBM	
Lynn	Hingst	Intermec	
John	Walter	Intermec	
Soumya	Roy chowdhury	Polaris Networks	
Martin	Jackson	Wal-Mart	
Steve	Lin	Sirit	
Bryan	Tracey	GlobeRanger	
Scott	de Deug	IBM	
Ted	Osinski	MET Labs	
Scott	Barvick	Reva Systems	
Manpreet	Singh	Symbol Technologies, Inc.	
Heena	Nandu	Intelleflex	
Gerhard	Gangl	7iD (formerly EOSS GmbH)	
Bill	Bares	Intelleflex	
Jim	Sykes	Savi Networks	
Sudhir	Hasbe	Sirit	
Albert	Lin	WJ Co.	
Shigeya	Suzuki	Auto-ID Labs - Japan	
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Matthew	Harmon	Q.E.D. Systems	
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Mark	Richardson	ThingMagic, LLC	
David	Nesbitt	Vue Technology	
Roger	Stewart	Applied Wireless (AWID)	
Yukiko	Yumoto	Auto Id Lab Japan	
Abel	Sanchez	Auto-ID Labs - MIT	
John	Williams	Auto-ID Labs - MIT	

Mark	Sompel	AWID	
Ken	Traub	BEA Systems	
Matt	Robshaw	France Telecom	
Wayne	Liu	Impinj	
Tareef	Al-Mahdawi	Intelleflex	
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John	Boulas	KCC	
John	Anderla	KCC	
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Chang Yeol	Lee	Metarights	
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Satoshi	Kinoshita	NEC Corporation	
Hiroki	Tagato	NEC Corporation	
Sergio	Lobo	NXP Semiconductors	
Gregory	Grisco	Oracle Corporation	
Jahangir	Nakra	Procter & Gamble	
Trong	Le	Psion Teklogix Inc.	
Craig	Harmon	Q.E.D. Systems	
Peter	Spreadborough	Reva Systems	
Sudhir	Hasbe	Samsys	
Stephan	Haller	SAP	
Steve	Winkler	SAP	
Sengu	Elango	Savi	
Neal	Herman	Savi	
Don	Ahn	Savi Technology	
L. Julia	Zhu	Savi Technology	
Pankaj	Shukla	Symbol	
Jong	Park	Tibco	
Keith	Rider	Tyco / ADT	
Bob	Sawdye	Tyco / ADT	
David	Harty	VeriSign	
Richard	Campero	Vue Technology	

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3833

3834 The following list in corporate alphabetical order contains all companies that were
3835 opt'd-in to the Reader Operations Working Group and have signed the
3836 EPCglobal IP Policy.

3837

Company
(ETRI) Electronics and Telecommunications Research Institute
7iD (formerly EOSS GmbH)
Accenture
Acer Cybercenter Service Inc.
Altria Group, Inc./Kraft Foods
Applied Wireless (AWID)
Ark Tech Ltd
Auto-ID Labs - Cambridge
Auto-ID Labs - Japan
Auto-ID Labs - MIT
BEA Systems
Blackbay Ltd.
CAEN
Cisco
Convergence Sys Ltd
Dai Nippon Printing
Denso Wave Inc
ECO, Inc.
EPCglobal Inc.
FEIG Electronic
France Telecom
Fujitsu Ltd
GlobeRanger
GS1 Australia EAN
GS1 Germany (CCG)
GS1 Hong Kong
GS1 Japan
GS1 South Korea
GS1 Taiwan (EAN)

GS1 US
IBM
Impinj
Infineon Technologies NA Corp
Institute for Information Industry
Intelleflex
Intermec
Internet Initiative Japan, Inc.
Johnson & Johnson
Kimberly-Clark Corp
KL-NET
Korea Computer Servs, Ltd
LIT (Research Ctr for Logistics Info Tech)
Loftware, Inc.
Manhattan Associates
MET Labs
Metarights
Metro
Microelectronics Technology, Inc.
Mstar Semiconductor
NCR
NEC Corporation
NXP Semiconductors
OatSystems
ODIN Technologies
Omron
Oracle Corporation
Panda Int'l Transp Ltd
Pango Networks, Inc.
Paxar
PepsiCo
Polaris Networks
Procter & Gamble
Psion Teklogix Inc.
Q.E.D. Systems

Raining Data Corporation
RetailTech
Reva Systems
RFIP Ltd. (formerly Radio Freq Ident Ctr)
RFXCEL Corp
SAP
Savi Technology
Sirit
SOFTBANK TELECOM Corp. (Japan)
Supply Insight, Inc.
SyGade Solutions
Symbol Technologies, Inc.
T3C Incorporated
Tagent Corporation
TagSys
TEGO, Inc.
ThingMagic, LLC
Tibco
Toppan Printing Co
Toray International, Inc.
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