MQTT for Sensor Networks (MQTT-SN) Version 2.0

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Related work:
This specification is related to:

- *MQTT Version 5.0*. Edited by Andrew Banks, Ed Briggs, Ken Borgendale, and Rahul Gupta. OASIS Standard. Latest version: https://docs.oasis-open.org/mqtt/mqtt/v5.0/mqtt-v5.0.html.
- *MQTT Version 3.1.1*. Edited by Andrew Banks and Rahul Gupta. OASIS Standard. Latest version: http://docs.oasis-open.org/mqtt/mqtt/v3.1.1/mqtt-v3.1.1.html.
- *MQTT-SN Version 1.2* by Andy Stanford-Clark and Hong Linh Truong. Link: https://www.oasis-open.org/committees/download.php/66091/MQTT-SN_spec_v1.2.pdf.

Abstract:
This specification defines the MQTT for Sensor Networks protocol (MQTT-SN). It is closely related to the MQTT v3.1.1 and MQTT v5.0 standards. MQTT-SN is optimized for implementation on low-cost, battery-operated devices with limited processing and storage resources. It is designed so that it will work over a variety of networking technologies and bridge to an MQTT network.

Status:
This document was last revised or approved by the OASIS Message Queuing Telemetry Transport (MQTT) TC on the above date. The level of approval is also listed above. Check the "Latest stage" location noted above for possible later revisions of this document. Any other numbered Versions and other technical work produced by the Technical Committee (TC) are listed at https://www.oasis-open.org/committees/tc_home.php?wg_abbrev=mqtt#technical .

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The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] and [RFC8174] when, and only when, they appear in all capitals, as shown here.

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Notices

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1 Introduction

[All text is normative unless otherwise labeled]

1.1 MQTT For Sensor Networks (MQTT-SN)

Sensor Networks are simple, low cost and easy to deploy, they are typically used to provide, event detection, monitoring, automation, process control and more. Sensor Networks often comprise of many battery-powered sensors and actuators, each containing a limited amount of storage and processing capability. They usually communicate wirelessly.

Sensor Networks are self-forming, continually change, and do not have any central control. The wireless network connections and processing nodes will fail, and the batteries will run out. The nodes will be replaced, added or removed in an unplanned way. The identities of the devices are usually created when they are manufactured, this avoids the need for specialist configuration when they are deployed. Applications running outside the Sensor Network do not need to know the details of the devices in it. The applications consume information from the sensors and send instructions to actuators based only on labels created by the application designers. The labels are called Topic Names in the MQTT and MQTT-SN protocols. The MQTT-SN implementation carries the information between a set of applications and the correct set of devices based on its knowledge of the network and the applications designer's choice of Topic Names.

Consider an example of a medicine tracking application. The application needs to know the location and temperature of the medicine, but it does not want to concern itself with the network details of the devices providing the data. It may be that the number and types of the devices changes over time. There may also be other applications using the same sensor data for other purposes. The model is that the devices and applications produce and consume data to and from the Topics rather than the other devices and applications.

This MQTT-SN specification is a variant of the MQTT version 5 specification. It is adapted to exploit low power and low bandwidth wireless networks. Low power wireless radio links have higher numbers of transmission errors compared to more powerful networks because they are more susceptible to interference and fading of the radio signals. They also have lower transmission rates.

For example, wireless networks based on the IEEE 802.15.4 standard used by Zigbee have a maximum bandwidth of 250 kbit/s in the 2.4 GHz band. To reduce transmission errors the packets are kept short. The maximum packet length at the physical layer is 128 bytes and half of these may be used for Media Access Control and security.

The MQTT-SN protocol is optimized for implementation on low-cost, battery-operated devices with limited processing and storage resources. The capabilities are kept simple and the specification allows partial implementations.

1.1.1 MQTT-SN and MQTT Differences

MQTT and MQTT-SN specifications are similar in many ways and meant to interoperate with each other, but the two specifications are independent of each other.

MQTT-SN can work isolated from other networks or in conjunction with MQTT. The main differences between MQTT-SN and MQTT are:

1 MQTT-SN uses separate packets to transfer the Will Topic and Will Payload if they are used. The Will Topic and Will Payload can be modified during the lifetime of a Session.

2 In addition to Topic Alias and long Topic Names MQTT-SN allows predefined and short two-byte Topic Names.

3 If the network supports multicastbroadcast, Gateway discovery can be implemented, otherwise the Gateway addresses must be configured in the nodes.

4 The Will message is part of the Session State and is discarded as part of Clean Start processing.

5 Support for sleeping clients allows battery operated devices to enter a low power mode. In this state, messages for the client are buffered by the Gateway and delivered when the client wakes.

6 A new Quality of Service level (OUT OF BAND) is introduced in MQTT-SN, allowing devices to publish without a GW session having been established.

7 MQTT-SN doesn't have any requirement on the underlying transport and it can use connectionless network transports such as User Datagram Protocol (UDP).

8 MQTT-SN introduced the Protection packet for message-based security based on symmetric cryptography.

1.2 Changes from earlier Versions

[Optional section.]

This section provides a description of significant differences from previously published, differently numbered Versions of this specification, if any. (Detailed revision history of this numbered Version should be tracked in an Appendix.)

1.2.1 MQTT-SN v1.2

Text describing the changes/differences

1.3 Organization of the MQTT-SN specification

The specification is split into seven chapters:

- Chapter 1 – Introduction
- Chapter 2 – MQTT-SN Control Packet format
- Chapter 3 – MQTT-SN Control Packet listing
- Chapter 4 – Operational Behavior
- Chapter 5 – Conformance

1.4 Glossary

Application Message:

The data carried by the MQTT-SN protocol across the network for the application. When an Application Message is transported by MQTT-SN it contains payload data, a Quality of Service (QoS) and a Topic Name.

Client:

A program or device that uses MQTT-SN. A Client:

- Optionally Connects to the Gateway
- publishes Application Messages to topics.

- subscribes to request Application Messages that it is interested in receiving.
- unsubscribes to remove a request for Application Messages.
- Issues a DISCONNECT to the Gateway.

Gateway (abbrev. GW):

A program or device accepting MQTT-SN protocol packets from Clients. A Gateway:

- accepts CONNECT packets from Clients and initializes Sessions.
- accepts Application Messages published by Clients and sends them to the Server.
- processes Subscribe and Unsubscribe requests from Clients.
- forwards Application Messages from the Server to Clients.
- maintains a Gateway “Session” for each Client on the GW.
- maintains a dictionary of topic alias’s for each Client.

Server or Broker:

A program or device accepting MQTT protocol connections from the Gateways. A Server or Broker:

- accepts Network Connections from Gateways.
- Ultimately accepts Application Messages published by Clients.
- processes Subscribe and Unsubscribe requests from Clients.
- forwards Application Messages that match Client Subscriptions to the Gateways.
- closes the Network Connection from the Gateway.

Session:

A session is the shared state between client and gateway.

Unicast:

Multicast:

Virtual Connection:

Carries the MQTT-SN data between a Client and a Gateway, or a broadcast to all Gateways and all clients.

Refer to section 3.2 Networks & Transport Layers for informative examples.

Subscription:

A Subscription comprises a Topic Filter and a maximum QoS. A Subscription is associated with a single Session. A Session can contain more than one Subscription. Each Subscription within a Session has a different Topic Filter.

Topic Alias:

A topic alias is a 16-bit unsigned integer assigned by the Gateway during a session or pre-assigned by the application which represents and replaces a topic name or topic filter in the protocol packets.

Topic Name:

The label attached to an Application Message which is matched against the Subscriptions known to the Gateway / Server.

Topic Filter:

An expression contained in a Subscription to indicate an interest in one or more topics. A Topic Filter can include wildcard characters.

Wildcard Subscription:

A Wildcard Subscription is a Subscription with a Topic Filter containing one or more wildcard characters. This allows the subscription to match more than one Topic Name.

Control Packet:

A packet of information that is sent across the Virtual Connection. The MQTT-SN specification defines 31 (twenty nine) different types of MQTT-SN Control Packet, for example the PUBLISH packet is used to convey Application Messages.

Wireless Sensor Networks (abbrev. WSN):

Networks of spatially dispersed and dedicated sensors that monitor and record the physical conditions of the environment and forward the collected data to a central location.

8.1

1.4 Data representation

1.4.1 Bits (Byte)

Bits in a byte are labeled 7 to 0. Bit number 7 is the most significant bit, the least significant bit is assigned bit number 0.

1.4.2 Two Byte Integer

Two Byte Integer data values are 16-bit unsigned integers in big-endian order: the high order byte precedes the lower order byte. This means that a 16-bit word is presented on the network as Most Significant Byte (MSB), followed by Least Significant Byte (LSB).

1.4.3 Four Byte Integer

Four Byte Integer data values are 32-bit unsigned integers in big-endian order: the high order byte precedes the successively lower order bytes. This means that a 32-bit word is presented on the network as Most Significant Byte (MSB), followed by the next most Significant Byte (MSB), followed by the next most Significant Byte (MSB), followed by Least Significant Byte (LSB).

1.4.4 UTF-8 Encoded String

Text fields within the MQTT-SN Control Packets are encoded as fixed length UTF-8 strings.
UTF-8 [RFC3629] is an efficient encoding of Unicode [Unicode] characters that optimizes the encoding of ASCII characters in support of text-based communications.

Unless stated otherwise all variable length UTF-8 encoded strings can have any length in the range 0 to 65,535 bytes.

Bit	7	6	5	4	3	2	1	0
byte 1 ….	UTF-8 encoded character data, if length > 0.							

Table 1: Structure of UTF-8 Encoded Strings

The character data in a UTF-8 Encoded String MUST be well-formed UTF-8 as defined by the Unicode specification [Unicode] and restated in RFC 3629 [RFC3629]. In particular, the character data MUST NOT include encodings of code points between U+D800 and U+DFFF. If the Client or Server receives an MQTT Control Packet containing ill-formed UTF-8 it is a Malformed Packet

A UTF-8 Encoded String MUST NOT include an encoding of the null character U+0000. If a receiver (Server or Client) receives an MQTT-SN Control Packet containing U+0000 it is a Malformed Packet.

The data SHOULD NOT include encodings of the Unicode [Unicode] code points listed below. If a receiver (Server or Client) receives an MQTT-SN Control Packet containing any of them it MAY treat it as a Malformed Packet. These are the Disallowed Unicode code points.

- U+0001..U+001F control characters
- U+007F..U+009F control characters
- Code points defined in the Unicode specification [Unicode] to be non-characters (for example U+0FFFF)

A UTF-8 encoded sequence 0xEF 0xBB 0xBF is always interpreted as U+FEFF ("ZERO WIDTH NO-BREAK SPACE") wherever it appears in a string and MUST NOT be skipped over or stripped off by a packet receiver.

Informative example

For example, the string A𪛔 which is LATIN CAPITAL Letter A followed by the code point U+2A6D4 (which represents a CJK IDEOGRAPH EXTENSION B character) is encoded as follows:

Bit	7	6	5	4	3	2	1	0
byte 1	‘A’ (0x41)							
	0	1	0	0	0	0	0	1
byte 2	(0xF0)							
	1	1	1	1	0	0	0	0
byte 3	(0xAA)							
	1	0	1	0	1	0	1	0
byte 4	(0x9B)							
	1	0	0	1	1	0	1	1
byte 5	(0x94)							

	1	0	0	1	0	1	0	0

Table 2: Fixed Length UTF-8 Encoded String informative example

2 MQTT-SN Control Packet format

2.1 Structure of an MQTT-SN Control Packet

The MQTT-SN protocol operates by exchanging a series of MQTT-SN Control Packets in a defined way. This section describes the format of these packets.

An MQTT-SN Control Packet consists of up to two parts, always in the following order as shown below.

Control Packet Header, present in all MQTT-SN Control Packets
Control Packet Variable Part, present in some MQTT-SN Control Packets

Table 3: Structure of an MQTT-SN Control Packet

2.1.1 Packet Header

Each MQTT-SN Control Packet contains a Header of format 1 or format 2 as shown below.

Byte	Use
1	Length
2	MQTT-SN Control Packet Type

Table 4: Packet Header Format 1

Byte	Use
1	Length 0x01
2	Length MSB
3	Length LSB
4	MQTT-SN Control Packet Type

Table 5: Packet Header Format 2

2.1.2 Length

The *Length* field is either 1-byte or 3-byte integer and specifies the total number of bytes contained in the packet (including the *Length* field itself).

If the first byte of the *Length* field is coded “0x01” then the *Length* field is 3-bytes long; in this case, the two following bytes specify the total number of bytes of the packet (most-significant byte first). Otherwise, the *Length* field is only 1-byte long and specifies itself the total number of bytes contained in the packet.

The 3-byte format allows the encoding of packet lengths up to 65,535 bytes. Packets with lengths up to and including 255 bytes MUST use the shorter byte format.

Informative comment

MQTT-SN does not support packet fragmentation and reassembly, the maximum packet length that could be used in a network is governed by the maximum packet size that is supported by that network, and not by the maximum length that could be encoded by MQTT-SN.

2.1.3 MQTT-SN Control Packet Type

The MQTT-SN Control Packet Type field is 1-byte long and specifies the MQTT-SN Control Packet type which is one of the values shown below.

Name	Value	Direction of flow	Description
ADVERTISE	0x00	Gateway broadcast	Advertise the gateway presence
SEARCHGW	0x01	Client broadcast	Client GWINFO request
GWINFO	0x02	Gateway to Client	Response to a SEARCHGW
AUTH	0x03	Client to Gateway or Gateway to Client	Authentication handshake
CONNECT	0x04	Client to Gateway	Virtual Connection request
CONNACK	0x05	Gateway to Client	Virtual Connection acknowledgement
WILLTOPICREQ	0x06	Gateway to Client	Request the will topic name
WILLTOPIC	0x07	Client to Gateway	Supply the will topic name
WILLMSGREQ	0x08	Gateway to Client	Request the will message
WILLMSG	0x09	Client to Gateway	Supply the will message
REGISTER	0x0A	Client to Gateway	Request topic alias
REGACK	0x0B	Gateway to Client	Supply topic alias
PUBLISH	0x0C	Client to Gateway or Gateway to Client	Publish packet
PUBACK	0x0D	Client to Gateway or Gateway to Client	Publish acknowledgment (QoS 1) or Publish error (Any QoS).
PUBCOMP	0x0E	Client to Gateway or Gateway to Client	Publish complete (QoS 2 delivery part 3)
PUBREC	0x0F	Client to Gateway or Gateway to Client	Publish received (QoS 2 delivery part 1)

PUBREL	0x10	Client to Gateway or Gateway to Client	Publish release (QoS 2 delivery part 2)
PUBLISH-OUT-OF BAND	0x11	Client to Gateway	Publish packet for out of band messages which need have no session on the gateway or broker
SUBSCRIBE	0x12	Client to Gateway	Subscribe request
SUBACK	0x13	Gateway to Client	Subscribe acknowledgment
UNSUBSCRIBE	0x14	Client to Gateway	Unsubscribe request
UNSUBACK	0x15	Gateway to Client	Unsubscribe acknowledgment
PINGREQ	0x16	Client to Gateway	PING request
PINGRESP	0x17	Gateway to Client	PING response
DISCONNECT	0x18	Client to Gateway or Gateway to Client	Disconnect notification
- Reserved -	0x19		Forbidden
WILLTOPICUPD	0x1A	Client to Gateway	Modify the will topic name
WILLTOPICRESP	0x1B	Gateway to Client	Acknowledge the will topic name modification
WILLMSGUPD	0x1C	Client to Gateway	Modify the will message
WILLMSGRESP	0x1D	Gateway to Client	Acknowledge the will message modification
- Reserved -	0x1E-0xFD		Forbidden
FORWARDERENCAPSULATION	0xFE	Forwarder to Client or Forwarder to Gateway	Encapsulated MQTT-SN packet
PROTECTION	0xFF	Client to Gateway or Gateway to Client	A protection envelope that can encapsulate any MQTT-SN packet with the exception of Forwarder-Encapsulation packet (0xFE)

Table 6: Packet type listing

2.2 Packet Identifier

The Variable Header component of many of the MQTT-SN Control Packet types includes a Two Byte Integer Packet Identifier field. MQTT-SN Control Packets that require a Packet Identifier are shown below:

MQTT-SN Control Packet	Packet Identifier field
CONNECT	NO
CONNACK	NO

PUBLISH	YES (If QoS > 0)
PUBLISHOOB	NO
PUBACK	YES
PUBREC	YES
PUBREL	YES
PUBCOMP	YES
SUBSCRIBE	YES
SUBACK	YES
UNSUBSCRIBE	YES
UNSUBACK	YES
PINGREQ	NO
PINGRESP	NO
DISCONNECT	NO
AUTH	NO
ADVERTISE	NO
SEARCHGW	NO
GWINFO	NO
WILLTOPICREQ	NO
WILLTOPIC	NO
WILLMGSREQ	NO
WILLMSG	NO
REGISTER	YES
REGACK	YES
WILLTOPICUPD	NO
WILLTOPICRESP	NO
WILLMSGUPD	NO
WILLMSGRESP	NO
Encapsulated Packet	NO
PROTECTION	NO

Table 8 Packets with Packet Identifier

A PUBLISH packet MUST NOT contain a Packet Identifier if its QoS value is set to 0.

A PUBLISH packet MUST NOT contain a Packet Identifier if its QoS value is set to -1.

Each time a Client sends a new SUBSCRIBE, UNSUBSCRIBE,or PUBLISH (where QoS > 0 and it is not OUT OF BAND) MQTT Control Packet it MUST assign it a non-zero Packet Identifier that is currently unused.

Each time a Gateway sends a new PUBLISH (with QoS > 0) MQTT-SN Control Packet it MUST assign it a non zero Packet Identifier that is currently unused.

The Packet Identifier becomes available for reuse after the sender has processed the corresponding acknowledgement packet, defined as follows. In the case of a QoS 1 PUBLISH, this is the corresponding PUBACK; in the case of QoS 2 PUBLISH it is PUBCOMP or a PUBREC with a Reason Code of 128 or greater. For SUBSCRIBE or UNSUBSCRIBE it is the corresponding SUBACK or UNSUBACK.

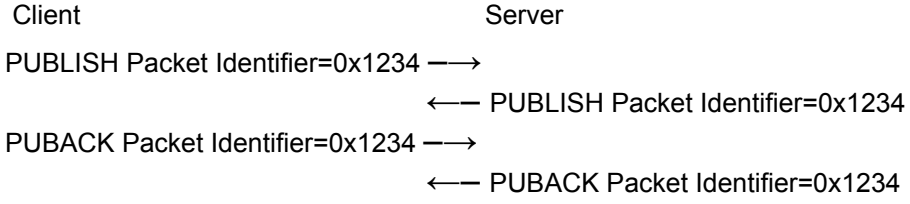
Packet Identifiers used with PUBLISH, SUBSCRIBE and UNSUBSCRIBE packets form a single, unified set of identifiers separately for the Client and the Gateway in a Session. A Packet Identifier cannot be used by more than one command at any time.

A PUBACK, PUBREC , PUBREL, or PUBCOMP packet MUST contain the same Packet Identifier as the PUBLISH packet that was originally sent. A SUBACK and UNSUBACK MUST contain the Packet Identifier that was used in the corresponding SUBSCRIBE and UNSUBSCRIBE packet respectively.

The Client and Gateway assign Packet Identifiers independently of each other. As a result, Client-Server pairs can participate in concurrent message exchanges using the same Packet Identifiers.

Informative comment

It is possible for a Client to send a PUBLISH packet with Packet Identifier 0x1234 and then receive a different PUBLISH packet with Packet Identifier 0x1234 from its Server before it receives a PUBACK for the PUBLISH packet that it sent.



2.3 MQTT-SN Packet Fields

2.3.1 Protocol Id

The *Protocol Id* is 1-byte long. It is only present in a CONNECT packet and corresponds to the MQTT ‘protocol name’ and ‘protocol version’.

It is coded 0x02. 0x01 was used for MQTT-SN 1.2. All other values are reserved.

2.3.2 Radius

The *Radius* field is 1-byte long and indicates the value of the broadcast radius. The value 0x00 means “broadcast to all nodes in the network”.

2.3.3 Reason Code

A Reason Code is a one-byte long value that indicates the result of an operation. Reason Codes share a common set of values across the various Control Packet types.

Each value and meaning of each *Reason Code* field is shown below.

Identifier		Description	Packet
Dec	Hex		
0	0x00	Success	CONNACK, SUBACK, UNSUBACK, REGACK, PUBACK, WILLTOPICRESP, WILLPACKETRESP, DISCONNECT
1	0x01	Congestion	CONNACK, SUBACK, UNSUBACK, REGACK, PUBACK, WILLTOPICRESP, WILLPACKETRESP
2	0x02	Invalid topic alias	SUBACK, UNSUBACK, REGACK, PUBACK, WILLTOPICRESP, WILLMSGRESP
3	0x03	Not supported	CONNACK, SUBACK, UNSUBACK, REGACK, PUBACK, WILLTOPICRESP, WILLMSGRESP
5	0x05	No session	DISCONNECT
140	0x8C	Bad authentication method	AUTH
135	0x87	Not authorized	AUTH
132	0x84	Unsupported protocol version	CONNACK
149	0x95	Packet too large	DISCONNECT
151	0x97	Quota exceeded	REGACK, SUBACK
153	0x99	Payload format invalid	DISCONNECT

Table 9: Reason Code Values

2.3.4 Topic Alias Type

The *Topic Alias Type* field is 2-byte long and contains the value of the topic alias. The values “0x0000” and “0xFFFF” are reserved and therefore should not be used.

2.3.5 Topic Name

The *Topic Name* field has a variable length and contains an UTF8-encoded string that specifies the topic name.

2.3.6 Will Packet

The *Will Packet* field has a variable length and contains the Will packet.

2.3.7 Will Topic

The *Will Topic* field has a variable length and contains the Will topic name.

2.4 Topic Alias Types

Several packets will refer to a topic alias type in their flags. This is a 2-bit field which determines the format of the topic Id value.

The allowable values are as follows:

	Topic Alias Type Value	Name	Description
0	0b00	Normal Topic Alias	A normal topic alias is negotiated between the gateway and client within the scope of a gateway session.
1	0b01	Predefined Topic Alias	A predefined alias is known statically by both the gateway and the client outside the scope of a gateway session. No negotiation is required since both entities have knowledge of the topic alias mapping.
2	0b10	Short Topic Name	A 2-byte topic name which requires no negotiation.
3	0b11	Long Topic Name	A full topic, which requires no session negotiation.

Table 10: Topic alias types and their description

Please refer to operational behavior for detailed descriptions of topic types and aliases.

3 MQTT-SN Control Packets

3.1 Format of Individual Packets

This section specifies the format of the individual MQTT-SN packets.

3.1.1 ADVERTISE

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type							
Byte 3	GwId							
Byte 4	Duration MSB							
Byte 5	Duration LSB							

Table 11: ADVERTISE Packet

The ADVERTISE packet is sent periodically by the gateway to advertise its presence. The time interval until the next transmission is indicated by the *Duration* field.

Informative comment

If UDP is used as transport protocol, the ADVERTISE packet is generally sent using the broadcast address as destination.

3.1.1.1 Length & Packet Type

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 1.8.2 for a detailed description.

3.1.1.2 GwId

The *GwId* field is at least 1-byte identifier and uniquely identifies a gateway which is advertising itself in the network.

The MQTT-SN protocol itself doesn't guarantee the uniqueness of the *GwId* field.

Informative comment

If the Gateway has a MAC address, it can be used as *GwId*.

3.1.1.3 Duration

The *Duration* field is a 2-byte integer. It specifies the time interval in seconds until the next ADVERTISE packet is broadcasted by this gateway period.

The maximum value that can be encoded is approximately 18 hours.

3.1.2 SEARCHGW

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type							
Byte 3	Radius							

Table 12: SEARCHGW packet

The SEARCHGW packet is sent by a client when it searches for a Gateway. The transmission radius of the SEARCHGW is limited and depends on the density of the clients deployment, e.g. only 1-hop transmission in case of a very dense network in which every MQTT-SN client is reachable from each other within 1-hop transmission.

3.1.2.1 Length & Packet Type

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 1.8.2 for a detailed description.

3.1.2.2 Radius

The transmission radius is also indicated to the underlying network layer when MQTT-SN gives this packet for transmission.

A Client or a Gateway MUST NOT forward the SEARCHGW received if the Radius value is 0.

If a Client or a Gateway forwards the SEARCHGW received, it MUST reduce the Radius value by 1.

3.1.3 GWINFO

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type							
Byte 3	GwId							
Byte 4 … N	GwAddress *(optional)*							

Table 13: GWINFO packet

The GWINFO packet is sent as response to a SEARCHGW packet using the broadcast service of the underlying layer, with the radius as indicated in the SEARCHGW packet. If sent by a Gateway, it contains only the id of the sending Gateway; otherwise, if sent by a client, it also includes the address of the Gateway.

3.1.3.1 Length & Packet Type

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 1.8.2 for a detailed description.

3.1.3.2 GwId

The *GwId* field is 1-byte long and uniquely identifies a Gateway in the network.

3.1.3.3 GwAdd

The *GwAdd* field has a variable length and contains the address of a Gateway. Its length depends on the type of network over which MQTT-SN operates and is specified by the Length byte. Optional, only included if the packet is sent by a client.

3.1.4 CONNECT

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type							
	CONNECT FLAGS							
	Reserved	Default Awake Messages				Authentication	Will	Clean Start
Byte 3	*0*	*X*	*X*	*X*		*X*	*X*	*X*
	WILL FLAGS (OPTIONAL)							
	Reserved			Will Retained	Will QoS	Will Topic Alias Type		
Byte (3 + 1)	0	0	0	0	X	X	X	X
Byte 4	Protocol Version							
Byte 5	Keep Alive MSB							
Byte 6	Keep Alive LSB							
Byte 7	Session Expiry Interval MSB							
Byte 8	Session Expiry Interval							
Byte 9	Session Expiry Interval							
Byte 10	Session Expiry Interval LSB							
Byte 11	Max Packet Size MSB							
Byte 12	Max Packet Size LSB							
Byte (12 + 1)	Will Topic Alias MSB **OR** Will Topic Length MSB (TL)							
Byte (12 + 2)	Will Topic Alias LSB Will Topic Length LSB (TL)							
Byte (12 + 3)	Full Will Topic Name + Will Data							
Byte 13 … N	Client Identifier							

Table 14: CONNECT packet

The CONNECT packet is sent from the Client to the Gateway to set up a session.

3.1.4.1 Length & Packet Type

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 1.8.2 for a detailed description.

3.1.4.2 Connect Flags

The Connect Flags is 1 byte field which contains several parameters specifying the behavior of the MQTT-SN Virtual Connection.

The Connect *Flags* field includes the following flags:

- **Clean Start:** Stored in Bit 0 and specifies whether the Virtual Connection starts a new Session or is a continuation of an existing Session

- **Will**: Stored in Bit 1 and if set to 1 it indicates that client is asking for Will topic and Will message prompting
- **Authentication**: Stored in Bit 2 and indicates the authentication exchange to follow
- **Default Awake Messages**: A value between 0-15 to indicate the maximum number of messages a client shall receive during an AWAKE session. Specifying 0 will mean it is up to the gateway to determine how many messages it will send, which may be unbounded.

The Gateway MUST validate that the reserved flags in the CONNECT packet are set to 0. If any of the reserved flags is not 0 it is a Malformed Packet.

3.1.4.3 Protocol Version

The one-byte unsigned value that represents the revision level of the protocol used by the Client.

Protocol Version	Value
Version 1.2	0x01
Version 2.0	**0x02**
Reserved for future versions	0x03 – 0xFF

Table 15: Protocol version values

The value of the Protocol Version field for MQTT-SN version 2.0 MUST be 2 (0x02).

A Gateway which supports multiple versions of the MQTT-SN protocol uses the Protocol Version to determine which version of MQTT-SN the Client is using. If the Protocol Version is valid but it is not the latest one available (for instance 0x02) and the Gateway does not want to accept the CONNECT packet, the Server MAY send a CONNACK packet with Reason Code 0x84 (Unsupported Protocol Version) and consider the session closed.

3.1.4.4 Keep Alive Timer

The Keep Alive is a Two Byte Integer greater than 0 (1 - 65,535), which is a time interval measured in seconds. It is the maximum time interval that is permitted to elapse between the point at which the Client finishes transmitting one MQTT-SN Control Packet and the point it starts sending the next. It is the responsibility of the Client to ensure that the interval between MQTT Control Packets being sent does not exceed the Keep Alive value. In the absence of sending any other MQTT-SN Control Packets, the Client MUST send a PINGREQ packet.

> **Informative comment**
>
> The Client can send PINGREQ at any time, irrespective of the Keep Alive value, and check for a corresponding PINGRESP to determine that the network and the Gateway are available.

If the Gateway does not receive an MQTT-SN Control Packet from the Client within one and a half times the Keep Alive time period, it MUST consider the session ‘LOST’ (see state description in table 3.6).

If a Client does not receive a PINGRESP packet within a T_{retry} amount of time after it has sent a PINGREQ, it SHOULD retry the transmission according to B4 up to the max attempts. If a PINGRESP is still not received it MUST close the Session to the Gateway by way of a DISCONNECT, with the understanding that the GW may no longer be reachable.

A Keep Alive must have a value greater than 0. It is considered a protocol error If a Keep Alive value of 0 is set.

Informative comment
The Gateway may have other reasons to disconnect the Client, for instance because it is shutting down. Setting Keep Alive does not guarantee that the Client will remain connected.

Informative comment

The actual value of the Keep Alive is application specific; typically, this is a few minutes. The maximum value of 65,535 is 18 hours 12 minutes and 15 seconds.

3.1.4.5 Session Expiry Interval

The Session Expiry Interval is a four-byte integer time interval measured in seconds. If the Session Expiry Interval is set to 0, the Session ends (and state deleted) when a (non SLEEPING) DISCONNECT packet is sent from either the client or gateway.

If the Session Expiry Interval is 0xFFFFFFFF (UINT_MAX), the Session does not expire.

The Client and Gateway MUST store the Session State after a DISCONNECT is issued if the Session Expiry Interval is greater than 0.

Informative comment

The clock in the Client or Gateway may not be running for part of the time interval, for instance because the Client or Gateway are not running. This might cause the deletion of the state to be delayed.

Informative comment

The client and gateway between them should negotiate a reasonable and practical session expiry interval according to the network and infrastructure environment in which they are deployed. For example, it would not be practical to set a session – expiry – interval of many months on a gateway whose hardware is only capable of storing a few client sessions.

3.1.4.6 Max Packet Size

A Two Byte (16-bit) Integer representing the Maximum Packet Size the Client is willing to accept. If the Maximum Packet Size is set to 0, no limit on the packet size is imposed beyond the limitations in the protocol as a result of the remaining length encoding and the protocol header sizes.

Informative comment

It is the responsibility of the application to select a suitable Maximum Packet Size value if it chooses to restrict the Maximum Packet Size.

The packet size is the total number of bytes in an MQTT Control Packet, as defined in section 3.1. The Client uses the Maximum Packet Size to inform the Server that it will not process packets exceeding this limit.

The Gateway MUST NOT send packets exceeding Maximum Packet Size to the Client. If a Client receives a packet whose size exceeds this limit, this is a Protocol Error, the Client uses DISCONNECT with Reason Code 0x95 (Packet too large).

Where a Packet is too large to send, the Gateway MUST discard it without sending it and then behave as if it had completed sending that Application Message.

Informative comment

Where a packet is discarded without being sent, the Gateway could place the discarded packet on a 'dead letter queue' or perform other diagnostic action. Such actions are outside the scope of this specification.

3.1.4.7 Client Identifier

The Client Identifier (ClientID) identifies the Client to the Gateway. Each Client connecting to the Gateway has a unique ClientID. The ClientID MUST be used by Clients and by Gateway to identify the state that they hold relating to this MQTT-SN Session between the Client and the Gateway.

Informative comment

A Client Identifier can be between 0 - 65,521 bytes. We advise for practicality, ClientID's are restricted to a reasonable size (less than 243 bytes to fit within a small CONNECT packet).

When the clientID is present (greater than 0 bytes), the Gateway MUST allow values which are between 1 and 23 UTF-8 encoded bytes in length, and that contain only the characters "0123456789abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ".

The Gateway may choose to allow more than 23 bytes.

The Client Identifier MUST be a UTF-8 Encoded String.

3.1.5 CONNACK

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type							
Byte 3	Reason Code							
	CONNECT FLAGS							
	Reserved							SessionPresent
Byte 4	0	0	0	0	0	0	0	X
Byte 5	Session Expiry Interval MSB							
Byte 6	Session Expiry Interval							
Byte 7	Session Expiry Interval							

Byte 8	Session Expiry Interval LSB
Byte 9 … N	Assigned Client Identifier (optional)

Table 16: CONNACK packet

The CONNACK packet is sent by the Gateway in response to a Virtual Connection request from a client.

3.1.5.1 Length & Packet Type

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 1.8.2 for a detailed description.

3.1.5.2 Reason Code

Byte 3 in the CONNACK header contains the Connect Reason Code. If a CONNECT packet is received by the Server, the Server will send a CONNACK packet containing the appropriate Reason code from the table below.

Value	Hex	Reason Code name	Description
0	0x00	Success	The Virtual Connection is Accepted
128	0x80	Unspecified error	The Server does not wish to reveal the reason for the failure, or none of the other Reason Codes apply.
129	0x81	Malformed Packet	Data within the CONNECT packet could not be correctly parsed.
130	0x82	Protocol Error	Data in the CONNECT packet does not conform to this specification.
131	0x83	Implementation specific error	The CONNECT is valid but is not accepted by this Server.
132	0x84	Unsupported Protocol Version	The Server does not support the version of the MQTT protocol requested by the Client.
133	0x85	Client Identifier not valid	The Client Identifier is a valid string but is not allowed by the Server.
134	0x86	Bad User Name or Password	The Server does not accept the User Name or Password specified by the Client
135	0x87	Not authorized	The Client is not authorized to connect.

136	0x88	Server unavailable	The MQTT Server is not available.
137	0x89	Server busy	The Server is busy. Try again later.
138	0x8A	Banned	This Client has been banned by administrative action. Contact the server administrator.
140	0x8C	Bad authentication method	The authentication method is not supported or does not match the authentication method currently in use.
144	0x90	Topic Name invalid	The Will Topic Name is not malformed, but is not accepted by this Server.
149	0x95	Packet too large	The CONNECT packet exceeded the maximum permissible size.
151	0x97	Quota exceeded	An implementation or administrative imposed limit has been exceeded.
155	0x9B	QoS not supported	The Server does not support the QoS set in Will QoS.
159	0x9F	Virtual Connection rate exceeded	The Virtual Connection rate limit has been exceeded.

Table 17: CONNACK Reason Codes values

3.1.5.3 Connack Flags

The Connack Flags is 1 byte field located at byte 4 which contains parameters specifying the behavior of the MQTT-SN Virtual Connection on the gateway.

The Connack *Flags* field includes the following flags:

- **Session Present:** Stored in Bit 0 and specifies whether an existing session was present on the gateway for the given client identifier

The Client MUST validate that the reserved flags in the CONNACK packet are set to 0. If any of the reserved flags is not 0 it is a Malformed Packet.

3.1.5.4 Session Expiry Interval

If the Session Expiry Interval is 0, the value of Session Expiry Interval in the CONNECT Packet is used. *The server uses this property to inform the Client that it is using a value other than that sent by the Client in the CONNECT*.

3.1.5.5 Assigned Client Identifier

The Client Identifier assigned by the gateway when the associated CONNECT packet contained no Client Identifier. If the Client connects using a zero length Client Identifier, the Server MUST respond with a

CONNACK containing an Assigned Client Identifier. The Assigned Client Identifier MUST be a new Client Identifier not used by any other Session currently in the Gateway.

The Assigned Client Identifier MUST be a UTF-8 Encoded String.

Informative comment

Assigned Client Identifiers SHOULD BE be less than 247 bytes so they can be accommodated in a small packet version. This is also to cater for devices which may not support larger Client Identifiers.

Informative comment

Where a transparent gateway obtains an Assigned Client Identifier which is deemed too large for a device, it should maintain a registry to map shorter gateway generated Client Identifiers with their versions returned from the broker.

3.1.6 WILLTOPICREQ

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type							

Table 18: WILLTOPICREQ packet

The WILLTOPICREQ packet is sent by the GW to request a client for sending the Will topic name.

3.1.7 WILLMSGREQ

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type							

Table 19: WILLMSGREQ packet

The WILLMSGREQ packet is sent by the GW to request a client for sending the Will packet.

3.1.8 WILLTOPIC

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type							
	WILL TOPIC FLAGS							

	Reserved	*Will QoS*		*Retain*	*Reserved*	*Reserved*	*Reserved*	*Reserved*
Byte 3	*0*	*X*	*X*	*X*	*0*	*0*	*0*	*0*
Byte 4.. N	Will Topic							

Table 20: WILLTOPIC packet

The WILLTOPIC packet is sent by a client as response to the WILLTOPICREQ packet for transferring its Will topic name to the GW.

3.1.8.1 Length & Packet Type

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 1.8.2 for a detailed description.

3.1.8.2 WILLTOPIC Flags

The WillTopic Flags is 1 byte field containing several parameters specifying the properties of the WillTopic.

The WillTopic Flags field includes the following flags:

- **Retain:** Stored in Bit 4, this bit specifies if the Will Message is to be retained.
- **Will QoS**: Stored in Bit 5 and 6, these two bits specify the QoS level to be used.

3.1.8.3 Will Topic

Contains a Fixed Length UTF-8 Encoded String containing the Will Topic Name.

An empty WILLTOPIC packet is a WILLTOPIC packet without Flags and Will Topic field (i.e. it is exactly 2 bytes long). It is used by a client to delete the Will topic and the Will packet stored in the gateway.

3.1.9 WILLMSG

Bit	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Byte 1	Length							
Byte 2	Packet Type							
Byte 3 .. N	Will Message							

Table 21: WILLMSG packet

The WILLPACKET packet is sent by a client as response to a WILLMSGREQ for transferring its Will packet to the GW.

3.1.9.1 Length & Packet Type

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 1.8.2 for a detailed description.

3.1.9.2 Will Message

Contains the Will Message which is published by after the Virtual Connection is closed

3.1.10 AUTH

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type							
Byte 3	Auth Reason Code							
Byte 4	Auth Method Length (K)							
Byte 5:5+K	Auth Method							
Byte 6+K:N	Auth Data (N)							

Table 22: AUTH packet

The AUTH message is first sent by the client as part of an authentication exchange. The server responds with another AUTH message and so on until the authentication is complete. The server then responds with a CONNACK message.

3.1.10.1 Length & Packet Type

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 1.8.2 for a detailed description.

3.1.10.2 Reason Code

Byte 3 in the Auth packet holds the Authentication Reason Code. The values for the 1 byte unsigned Authentication Reason Code field are shown below.

The sender of the AUTH Packet MUST use one of the Authenticate Reason Codes.

Dec	Hex	Reason Code Name	Sent by	Description
0	0x00	Success	Gateway	Authentication is successful
24	0x18	Continue authentication	Client or Server	Continue the authentication with another step
25	0x19	Re-authenticate	Client	Initiate another authentication

Table 23: AUTH Reason Code

3.1.10.3 Auth Method Length

The length of the auth method string.

3.1.10.4 Auth Method

A UTF-8 Encoded String containing the name of the authentication method.

3.1.10.5 Auth Data

Binary Data containing authentication data. The contents of this data are defined by the authentication method.

Informative comment

For a simple cleartext password is analogous to MQTT user name and password, the SASL PLAIN method can be used.

3.1.11 REGISTER

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type							
Byte 3	Topic Alias MSB							
Byte 4	Topic Alias LSB							
Byte 5	Packet Id MSB							
Byte 6	Packet Id LSB							
Byte 7 … N	Topic Name							

Table 24: REGISTER packet

The REGISTER packet is sent by a client to a GW for requesting a topic alias value for the included topic name. It is also sent by a GW to inform a client about the topic alias value it has assigned to the included topic name.

3.1.11.1 Length & Packet Type

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 1.8.2 for a detailed description.

3.1.11.2 Topic Alias

If sent by a client, it is coded 0x0000 and is not relevant; if sent by a GW, it contains the topic alias value assigned to the topic name included in the Topic Name field.

3.1.11.3 Packet Id

Should be coded such that it can be used to identify the corresponding REGACK packet.

3.1.11.4 Topic Name

Fixed Length UTF-8 Encoded String Contains the fully qualified topic name.

3.1.12 REGACK

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							

Byte 2	Packet Type							
	REGACK FLAGS							
	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Topic Alias Type	
Byte 3	0	0	0	0	0	0	X	X
Byte 4	Topic Alias MSB							
Byte 5	Topic Alias LSB							
Byte 6	Packet Id MSB							
Byte 7	Packet Id LSB							
Byte 8	Reason Code							

Table 25: REGACK packet

The REGACK packet is sent by a client or by a GW as an acknowledgment to the receipt and processing of a REGISTER packet.

3.1.12.1 Length & Packet Type

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 1.8.2 for a detailed description.

3.1.12.2 REGACK Flags

The REGACK Flags is 1 byte field in Byte position 3 of the REGACK packet.

The REGACK Flags field includes the following flag:

- **Topic Alias Type**. This is a 2-bit field in Bit 0 and 1 which determines the format of the topic Id value. Refer to Table 10 for the definition of the various topic types.

3.1.12.3 Topic Alias

A Topic Alias is an integer value that is used to identify the Topic instead of the Topic Name. This numeric value is used as the Topic Alias.

3.1.12.4 Packet Id

The same value as the one contained in the corresponding REGISTER packet.

3.1.12.5 Reason Code

Byte 8 in the REGACK packet holds the Register Reason Code.

Dec	Hex	Reason Code Name	Description
0	0x00	Success	Request for the topic alias value for the included topic name is successful

1	0x01	Congestion	The gateway/server notification that it is experiencing congestion
2	0x02	Invalid Topic Alias	The Client or GW has received a REGISTER packet containing a Topic Alias which has a value that is not recognized.
3	0x03	Not supported	Topic Alias are not supported by the Client or gateway

Table 26: REGACK Reason Code

3.1.13 Publish Variants

MQTT-SN is designed to be optimized for packet size. For this reason, the PUBLISH packet has been split into 3 variants; Variant 1 catering for Quality of Service -1 where a protocol version field is required, Variant 2 catering for Quality of Service 0 where no response ACK is required and thus no packet identifier is required and Quality of Service 1 and 2 where a response is expected, Variant 3 catering for Out Of Band messages where minimal overhead is required. Due to the fundamental structural difference of QoS -1 and OOB, a respective new packet type has been introduced. The table below breaks down the different versions of the PUBLISH packet and their respective type identifiers.

Packet Type	Type	Description
Publish	0x0C	A PUBLISH packet corresponding to Quality of Service (QoS) 0, 1 or 2
Publish Minus 1	0x0C	A second variant of the PUBLISH packet corresponding to Quality of Service minus 1 – This represents the PUBLISH Minus One from the original specification and is included for purposes of backward compatibility. This packet has been superseded by Publish OOB (0x11)
Publish Out Of Band (OOB)	0x11	A PUBLISH message that need have no session present on the GW or broker

3.1.14 PUBLISH MINUS -1 (Reference from 1.2)

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type (0x0C)							

	PUBLISH-M1 FLAGS							
	DUP	*QoS*		*Retain*	*Reserved*	*Reserved*	*Topic Alias Type*	
Byte 3	*X*	*X*	*X*	*X*	*0*	*0*	*X*	*X*
Byte 4	Topic Alias MSB							
Byte 5	Topic Alias LSB							
Byte 6	0x00 – Fixed Field Value							
Byte 7	0x00 – Fixed Field Value							
Byte 8 .. N	Data							

Table 27: PUBLISH packet

This packet is used by both clients and gateways to publish data for a certain topic.

3.1.14.1 Length & Packet Type

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 1.8.2 for a detailed description.

3.1.14.2 PUBLISH Flags

The PUBLISH Flags field is 1-byte located in Byte 3 position of the PUBLISH control packet.

The PUBLISH Flags includes the following flags:

- **Topic Alias Type**. This is a 2-bit field in Bit 0 and 1 which determines the format of the topic Id value. Refer to Table 10 for the definition of the various topic alias types.
- **QoS**: This is a 2-bit field stored in Bit 5 and 6. QoS has the same meaning as with MQTT indicating the Quality of Service. Set to “0b00” for QoS 0, “0b01” for QoS 1, “0b10” for QoS 2, and “0b11” for QoS -1. For a detailed description of the various Quality Of Service levels please refer to the operational behavior section.
- **DUP**: 1 bit field stored in Bit 7 and has the same meaning as with MQTT. It notes the duplicate delivery of packets. If the DUP flag is set to “0”, it signifies that the packet is sent for the first time. If the DUP flag is set to “1”, it signifies that the packet was retransmitted.
- **Retain**: 1 bit field stored in Bit 4 and has the same meaning as with MQTT. The field signifies whether the existing retained message for this topic is replaced or kept.

3.1.14.3 Topic Alias or Topic Length

In the case of Topic Alias Type being b11 this field will refer to the length of data assigned to the “Full Topic Name”, in all other cases, this will be the value used as the topic alias or short topic name.

3.1.14.4 Data

In the case of Topic Alias Type b11 the data section will be prefixed with a “Full Topic Name” encoded with a UTF-8 encoded string value of length determined by the previously defined length field. Thereafter,

the *Data* field corresponds to payload of an MQTT PUBLISH packet. It has a variable length and contains the application data that is being published.

3.1.15 PUBLISH OUT OF BAND

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type (0x11)							
	PUBLISH OUT OF BAND (OOB)							
	Reserved	*Reserved*		*Retain*	*Reserved*	*Reserved*	*Topic Alias Type*	
Byte 3	*0*	*0*	*0*	*X*	*0*	*0*	*X*	*X*
Byte 4	Topic Alias MSB				**OR**		Topic Length MSB (TL)	
Byte 5	Topic Alias LSB						Topic Length LSB (TL)	
Byte (6 + TL) .. N	Data Or (Full Topic Name + Data)							

Table 28: PUBLISH packet

This packet is used by both clients and gateways to publish data for a certain topic.

3.1.15.1 Length & Packet Type

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 1.8.2 for a detailed description.

3.1.15.2 PUBLISH Flags

The PUBLISH Flags field is 1-byte located in the Byte 3 position of the PUBLISH control packet.

The PUBLISH Flags includes the following flags:

- **Topic Alias Type**. This is a 2-bit field in Bit 0 and 1 which determines the format of the topic Id value. Refer to Table 10 for the definition of the various topic alias types.
- **Retain**: 1 bit field stored in Bit 4 and has the same meaning as with MQTT. The field signifies whether the existing retained message for this topic is replaced or kept.

3.1.15.3 Topic Alias or Topic Length

In the case of Topic Alias Type being b11 this field will refer to the length of data assigned to the “Full Topic Name”, in all other cases, this will be the value used as the topic alias or short topic name.

3.1.15.4 Data

In the case of Topic Alias Type b11 the data section will be prefixed with a “Full Topic Name” encoded with a UTF-8 encoded string value of length determined by the previously defined length field. Thereafter, the *Data* field corresponds to the payload of an MQTT PUBLISH packet. It has a variable length and contains the application data that is being published.

3.1.16 PUBLISH (used for QoS 0)

<table>
<tr><th>Bit</th><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th>0</th></tr>
<tr><td>Byte 1</td><td colspan="8">Length</td></tr>
<tr><td>Byte 2</td><td colspan="8">Packet Type (0x0C)</td></tr>
<tr><td rowspan="2"></td><td colspan="8">PUBLISH QoS 0 FLAGS</td></tr>
<tr><td>DUP</td><td colspan="2">QoS</td><td>Retain</td><td>Reserved</td><td>Reserved</td><td colspan="2">Topic Alias Type</td></tr>
<tr><td>Byte 3</td><td>X</td><td>X</td><td>X</td><td>X</td><td>0</td><td>0</td><td>X</td><td>X</td></tr>
<tr><td>Byte 4</td><td colspan="3" rowspan="2">Topic Alias MSB
Topic Alias LSB</td><td colspan="2" rowspan="2">OR</td><td colspan="3" rowspan="2">Topic Length MSB (TL)
Topic Length LSB (TL)</td></tr>
<tr><td>Byte 5</td></tr>
<tr><td>Byte (6 + TL) .. N</td><td colspan="8">Data Or (Full Topic Name + Data)</td></tr>
</table>

Table 29: PUBLISH packet

This packet is used by both clients and gateways to publish data for a certain topic.

3.1.16.1 Length & Packet Type

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 1.8.2 for a detailed description.

3.1.16.2 PUBLISH Flags

The PUBLISH Flags field is 1-byte located in Byte 3 position of the PUBLISH control packet.

The PUBLISH Flags includes the following flags:

- **Topic Alias Type**. This is a 2-bit field in Bit 0 and 1 which determines the format of the topic Id value. Refer to Table 10 for the definition of the various topic alias types.
- **QoS**: This is a 2-bit field stored in Bit 5 and 6. QoS has the same meaning as with MQTT indicating the Quality of Service. Set to “0b00” for QoS 0, “0b01” for QoS 1, “0b10” for QoS 2, and “0b11” for QoS -1. For a detailed description of the various Quality Of Service levels please refer to the operational behavior section.
- **DUP**: 1 bit field stored in Bit 7 and has the same meaning as with MQTT. It notes the duplicate delivery of packet. If the DUP flag is, set to “0”, it signifies that the packet is sent for the first time. If the DUP flag is set to “1”, it signifies that the packet was retransmitted.
- **Retain**: 1 bit field stored in Bit 4 and has the same meaning as with MQTT. The field signifies whether the existing retained message for this topic is replaced or kept.

3.1.16.3 Topic Alias or Topic Length

In the case of Topic Alias Type being b11 this field will refer to the length of data assigned to the “Full Topic Name”, in all other cases, this will be the value used as the topic alias or short topic name.

3.1.16.4 Data

In the case of Topic Alias Type b11 the data section will be prefixed with a “Full Topic Name” encoded with a UTF-8 encoded string value of length determined by the previously defined length field. Thereafter, the *Data* field corresponds to the payload of an MQTT PUBLISH packet. It has a variable length and contains the application data that is being published.

3.1.17 PUBLISH (used for QoS 1 & 2)

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type (0x0C)							
	PUBLISH QoS 1&2 FLAGS							
	DUP	*QoS*		*Retain*	*Reserved*	*Reserved*	*Topic Alias Type*	
Byte 3	*X*	*X*	*X*	*X*	*0*	*0*	*X*	*X*
Byte 4	Packet Id MSB							
Byte 5	Packet Id LSB							
Byte 6	Topic Alias MSB				**OR**		Topic Length MSB (TL)	
Byte 7	Topic Alias LSB						Topic Length LSB (TL)	
Byte (8 + TL) .. N	Data Or (Full Topic Name + Data)							

Table 30: PUBLISH packet

This packet is used by both clients and gateways to publish data for a certain topic.

3.1.17.1 Length & Packet Type

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 1.8.2 for a detailed description.

3.1.17.2 PUBLISH Flags

The PUBLISH Flags field is 1-byte located in Byte 3 position of the PUBLISH control packet.

The PUBLISH Flags includes the following flags:

- **Topic Alias Type**. This is a 2-bit field in Bit 0 and 1 which determines the format of the topic Id value. Refer to Table 10 for the definition of the various topic alias types.
- **QoS**: This is a 2-bit field stored in Bit 5 and 6. QoS has the same meaning as with MQTT indicating the Quality of Service. Set to “0b00” for QoS 0, “0b01” for QoS 1, “0b10” for QoS 2, and “0b11” for QoS -1. For a detailed description of the various Quality Of Service levels please refer to the operational behavior section.
- **DUP**: 1 bit field stored in Bit 7 and has the same meaning as with MQTT. It notes the duplicate delivery of packets. If the DUP flag is set to “0”, it signifies that the packet is sent for the first time. If the DUP flag is set to “1”, it signifies that the packet was retransmitted.
- **Retain**: 1 bit field stored in Bit 4 and has the same meaning as with MQTT. The field signifies whether the existing retained message for this topic is replaced or kept.

3.1.17.3 Topic Length

Contains the length of the topic value. This will be either 2 bytes when using a standard alias (0b00, 0b01 or 0b10) or the length of the full topic name when the topic type is 0b11.

3.1.17.4 Packet Id

Same meaning as the MQTT “Packet ID”; only relevant in case of QoS levels 1 and 2, otherwise coded 0x0000.

3.1.17.5 Topic Alias or Topic Name

Contains topic name encoded as a Fixed Length UTF-8 Encoded String, topic alias, or short topic name as indicated in the *Topic Alias Type* field in flags.

3.1.17.6 Data

The *Data* field corresponds to the payload of an MQTT PUBLISH packet. It has a variable length and contains the application data that is being published.

3.1.18 PUBACK – Publish Acknowledgement

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type							
Byte 3	Packet Id MSB							
Byte 4	Packet Id LSB							
Byte 5	Reason Code							

Table 31: PUBACK packet

A PUBACK packet is the response to a PUBLISH packet with QoS 1. It can also be sent as response to a PUBLISH packet of any QoS (*with the exception of QoS -1, or Publish Out Of Band*) in case of an error; the error reason is then indicated in the *Reason Code* field.

3.1.18.1 Length & Packet Type

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 1.8.2 for a detailed description.

3.1.18.2 Packet Id

Same value as the one contained in the corresponding PUBLISH packet.

3.1.18.3 Reason Code

Byte 5 in the PUBACK packet holds the Reason code in response to the PUBLISH packet. The Client or Server sending the PUBACK packet MUST use one of the PUBACK Reason Codes

Dec	Hex	Reason Code Name	Description

0	0x00	Success	Publish to gateway/server was successful
1	0x01	Congestion	The gateway/server notification that it is experiencing congestion
2	0x02	Invalid Topic Alias	The gateway/server has received a PUBLISH packet containing a Topic Alias which has a value that is not recognized.
3	0x03	Not supported	The client/server does not accept or support the QoS or other properties of the PUBLISH.

Table 32: PUBACK Reason Code

3.1.19 PUBREC (QoS 2 delivery part 1)

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type							
Byte 3	Packet Id MSB							
Byte 4	Packet Id LSB							

Table 33: PUBREC packet

A PUBREC packet is the response to a PUBLISH packet with QoS 2. It is the second packet of the QoS 2 protocol exchange.

3.1.19.1 Length & Packet Type

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 2.1 for a detailed description.

3.1.19.2 Packet Id

Same value as the one contained in the corresponding PUBLISH packet.

3.1.20 PUBREL (QoS 2 delivery part 2)

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type							
Byte 3	Packet Id MSB							
Byte 4	Packet Id LSB							

Table 34: PUBREL packet

A PUBREL packet is the response to a PUBREC packet. It is the third packet of the QoS 2 protocol exchange.

3.1.20.1 Length & Packet Type

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 2.1 for a detailed description.

3.1.20.2 Packet Id

Same value as the one contained in the corresponding PUBLISH packet.

3.1.21 PUBCOMP (QoS 2 delivery part 3)

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type							
Byte 3	Packet Id MSB							
Byte 4	Packet Id LSB							

Table 35: PUBCOMP packet

The PUBCOMP packet is the response to a PUBREL packet. It is the fourth and final packet of the QoS 2 protocol exchange.

3.1.21.1 Length & Packet Type

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 1.8.2 for a detailed description.

3.1.21.2 Packet Identifier

Same value as the one contained in the corresponding PUBLISH packet.

3.1.22 SUBSCRIBE

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type							
	SUBSCRIBE FLAGS							
	No Local	*QoS*		*Retain as published*	*Retain Handling*		*Topic Alias Type*	
Byte 3	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*
Byte 4	Packet Id MSB							
Byte 5	Packet Id LSB							
Byte 6	Topic Alias MSB			**OR**			Topic Filter Byte 6 … N	
Byte 7	Topic Alias LSB							

Table 36: SUBSCRIBE packet

The SUBSCRIBE packet is used by a client to subscribe to a certain topic name.

3.1.22.1 Length & Packet Type

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 1.8.2 for a detailed description.

3.1.22.2 SUBSCRIBE Flags

The SUBSCRIBE Flags field is 1-byte and contains the following flags:

- **QoS**: maximum QoS. This gives the maximum QoS level at which the Server can send Application Messages to the Client. It is a Protocol Error if the Maximum QoS field has the value 3.
- **No Local**: if the value is 1, Application Messages MUST NOT be forwarded to a Virtual Connection with a ClientID equal to the ClientID of the publishing Virtual Connection
- **Retain as published**: If 1, Application Messages forwarded using this subscription keep the RETAIN flag they were published with. If 0, Application Messages forwarded using this subscription have the RETAIN flag set to 0. Retained messages sent when the subscription is established have the RETAIN flag set to 1.
- **Retain handling**: This option specifies whether retained messages are sent when the subscription is established. This does not affect the sending of retained messages at any point after the subscribe. If there are no retained messages matching the Topic Filter, all these values act the same. The values are:
    - 0: Send retained messages at the time of the subscribe
    - 1: Send retained messages at subscribe only if the subscription does not currently exist
    - 2: Do not send retained messages at the time of the subscribe.

  It is a Protocol Error to send a Retain Handling value of 3.
- **Topic Alias Type**: indicates the type of Topic Alias or Topic Filter included in this packet. Refer to Table 10 for the definition of the various types.

3.1.22.3 Packet Id

Should be coded such that it can be used to identify the corresponding SUBACK packet.

3.1.22.4 Topic Alias or Topic Filter

Contains Fixed Length UTF-8 Encoded String topic filter, topic alias, or short topic name as indicated in the *Topic Alias Type* field in flags. Determines the topic names which this subscription is interested in.

3.1.23 SUBACK

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type							
	SUBACK FLAGS							
	Reserved	*Granted QoS*		*Reserved*	*Reserved*	*Reserved*	*Topic Alias Type*	
Byte 3	*0*	*X*	*X*	*0*	*0*	*0*	*X*	*X*
Byte 4	Topic Alias MSB							
Byte 5	Topic Alias LSB							
Byte 6	Packet Id MSB							
Byte 7	Packet Id LSB							
Byte 8	Reason Code							

Table 37: SUBACK packet

The SUBACK packet is sent by a gateway to a client as an acknowledgment to the receipt and processing of a SUBSCRIBE packet.

3.1.23.1 Length & Packet Type

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 1.8.2 for a detailed description.

3.1.23.2 Flags

The SUBACK Flags field is 1-byte located in Byte 3 position of the SUBACK control packet. The SUBACK Flags includes the following flags:

- **Topic Alias Type**. This is a 2-bit field in Bit 0 and 1 which determines the format of the topic Id value. Refer to Table 10 for the definition of the various topic types.
- **Granted QoS**: This is a 2-bit field in Bit 5 and 6 which notes the Quality of Service that was granted for the Subscription

3.1.23.3 Topic Alias

In case of “accepted” the value that will be used as topic alias by the gateway when sending PUBLISH packets to the client (not relevant in case of subscriptions to a short topic name or to a topic name which contains wildcard characters)

3.1.23.4 Packet Identifier

Same value as the one contained in the corresponding SUBSCRIBE packet.

3.1.23.5 Reason Code

Byte 8 in the SUBACK packet holds the Reason code in response to SUBSCRIBE packet. The Client or Server sending the SUBACK packet MUST use one of the SUBACK Reason Codes

Dec	Hex	Reason Code Name	Description
0	0x00	Success	SUBSCRIBE to gateway/server was successful
1	0x01	Congestion	The gateway/server notification that it is experiencing congestion
2	0x02	Invalid Topic Alias	The gateway/server has received a SUBSCRIBE packet containing a Topic Alias which has a value that is not recognized.
3	0x03	Not supported	The client/server does not accept or support the properties provided with SUBSCRIBE packet.

Table 38: SUBACK Reason Code

3.1.24 UNSUBSCRIBE

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type							
	UNSUBSCRIBE FLAGS							
	Reserved	*Reserved*		*Reserved*	*Reserved*	*Reserved*	*Topic Alias Type*	
Byte 3	*0*	*0*	*0*	*0*	*0*	*0*	*X*	*X*
Byte 4	Packet Identifier MSB							
Byte 5	Packet Identifier LSB							
Byte 6	Topic Alias MSB				**OR**	Topic Filter		
Byte 7	Topic Alias LSB					Byte 6 … N		

Table 39: UNSUBSCRIBE packet

An UNSUBSCRIBE packet is sent by the client to the GW to unsubscribe from named topics.

3.1.24.1 Length & Packet Type

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 1.8.2 for a detailed description.

3.1.24.2 UNSUBSCRIBE Flags

For The UNSUBSCRIBE Flags is 1 byte field in Byte position 3 of the UNSUBSCRIBE packet.

The UNSUBSCRIBE Flags field includes the following flag:

- **Topic Type.** This is a 2-bit field in Bit 0 and 1 which determines the format of the topic Id value. Refer to Table 10 for the definition of the various topic types.

3.1.24.3 Packet Identifier

Should be coded such that it can be used to identify the corresponding SUBACK packet.

3.1.24.4 Topic Alias or Topic Filter

Contains Fixed Length UTF-8 Encoded String topic filter, topic alias, or short topic name as indicated in the *Topic Alias Type* field.

3.1.25 UNSUBACK

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type							
Byte 3	Packet Id MSB							
Byte 4	Packet Id LSB							
Byte 5	Reason Code							

Table 40: UNSUBACK packet

An UNSUBACK packet is sent by a GW to acknowledge the receipt and processing of an UNSUBSCRIBE packet.

3.1.25.1 Length & Packet Type

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 1.8.2 for a detailed description.

3.1.25.2 Packet Identifier

Same value as the one contained in the corresponding UNSUBSCRIBE packet.

3.1.25.3 Reason Code

Byte 5 in the UNSUBACK packet holds the Reason code in response to UNSUBCRIBE packet. The gateway/server sending the UNSUBACK packet MUST use one of the UNSUBACK Reason Codes

Dec	Hex	Reason Code Name	Description

0	0x00	Success	Processing of UNSUBSCRIBE was to gateway/server was successful
1	0x01	Congestion	The gateway/server notification that it is experiencing congestion
2	0x02	Invalid Topic Alias	The gateway/server has received an UNSUBSCRIBE packet containing a Topic Alias which is has a value that is not considered valid

Table 41: UNSUBACK Reason Code

3.1.26 PINGREQ

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type							
Byte 3 … N	Client Identifier (optional)							

Table 42: PINGREQ packet

As with MQTT, the PINGREQ packet is an ”are you alive” packet that is sent from or received by a connected client.

3.1.26.1 Length & Packet Type

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 1.8.2 for a detailed description.

3.1.26.2 Client Identifier (optional)

Contains the client identifier (client id); this field is optional and is included by a “sleeping” client when it goes to the “awake” state and is waiting for packets sent by the server/gateway.

The Client Identifier MUST be a Fixed Length UTF-8 Encoded String.

3.1.27 PINGRESP

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type							
Byte 3	Messages Remaining (optional)							

Table 43: PINGRESP packet

As with MQTT, a PINGRESP packet is the response to a PINGREQ packet and means ”yes I am alive”. Keep Alive packets flow in either direction, sent either by a connected client or the gateway. it has only a header and no variable part.

Moreover, a PINGRESP packet is sent by a gateway to inform a sleeping client that it has no more buffered packets for that client.

3.1.27.1 Length & Packet Type

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 1.8.2 for a detailed description.

3.1.27.2 Messages Remaining

The number of messages left when a client is sent back to sleep. Optional – for use at the end of a client's awake period. Values can be:

Allowed Values	Description
0	No messages remain in the queue
1 – 254 (incl.)	The number of messages remaining in the queue
255 (0xFF)	An unspecified positive number of messages remain in the queue greater than 0.

Table 44: Allowed PINGRESP continuation values

3.1.28 DISCONNECT

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type							
	DISCONNECT FLAGS							
	Reserved				*Reason Code Present*	*Session Expiry Interval Present*	*Reason String Present*	Retain Registrations
Byte 3	0	0	0	0	X	X	X	X
Byte 4	Reason Code (optional)							
Byte 5	Session Expiry Interval MSB (optional)							
Byte 6	Session Expiry Interval (optional)							
Byte 7	Session Expiry Interval (optional)							
Byte 8	Session Expiry Interval LSB (optional)							
Byte 9 … N	Reason String (optional)							

Table 45: DISCONNECT packet

As with MQTT, the DISCONNECT packet is sent by a client to indicate that it wants to close the Virtual connection. The gateway will acknowledge the receipt of that packet by returning a DISCONNECT to the client. A server or gateway may also send a DISCONNECT to a client, e.g. in case a gateway, due to an error, cannot map a received packet to a client. Upon receiving such a DISCONNECT packet, a client should try to setup the Virtual Connection again by sending a CONNECT packet to the gateway or server.

A DISCONNECT packet with a *Session Expiry Interval* field is sent by a client when it wants to go to the "asleep" state. The receipt of this packet is also acknowledged by the gateway by means of a DISCONNECT packet.

3.1.28.1 Length & Packet Type

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 1.8.2 for a detailed description.

3.1.28.2 Disconnect Flags

The Disconnect Flags is 1 byte field located at byte 3 which contains parameters specifying the behavior of the MQTT-SN sleep on the gateway.

The Disconnect *Flags* field includes the following flags:

- **Reason Code Present:** Stored in Bit 3 Does the reason code exist on the packet
- **Session Expiry Interval Present:** Stored in Bit 2, Does the session expiry interval field exist.
- **Reason String Present:** Stored in Bit 1, Does the reason string field exist
- **Retain Registrations:** Stored in Bit 0 and specifies whether registrations should be retained by the gateway during the sleep state. "0" indicates registrations should be removed during the sleeping period and renegotiated when AWAKE or ACTIVE. "1" indicates registrations should be retained during the SLEEP period, and therefore not renegotiated when AWAKE or ACTIVE.

The Gateway MUST validate that the reserved flags in the DISCONNECT packet are set to 0. If any of the reserved flags is not 0 it is a Malformed Packet.

3.1.28.3 Reason Code

The Reason Code for the DISCONNECT control packet is optional. If provided, Byte 3 in the DISCONNECT control packet holds the Reason Code of the disconnection.

Dec	Hex	Reason Code Name	Description
0	0x00	Success	The normal disconnection was made; Disconnect request processed successfully.
5	0x05	No Virtual Connection	There is no active Virtual Connection for disconnection
149	0x95	Packet too large	Packet sent whose size exceeds the maximum packet size
153	0x99	Payload format invalid	Payload is not of the format indicated.

Table 46: DISCONNECT Reason Code

3.1.28.4 Session Expiry Interval

The Session Expiry Interval is a four-byte integer time interval measured in seconds. If the Session Expiry Interval is set to 0 or omitted, the Session is transitioned to the "***disconnected***" state. When the value of this field is greater than zero, it is deemed to be sent by a client that wants to transition to the "***asleep***" state, see Section 3.19 for further details. At this point the keep alive timer becomes obsolete until the device issues a new CONNECT.

3.1.28.5 Reason String

Fixed Length UTF-8 Encoded String representing a clear text description of disconnection.

3.1.29 WILLTOPICUPD

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type							
	WILLTOPICUPD FLAGS							
	Reserved	*Will QoS*		*Retain*	*Reserved*	*Reserved*	*Reserved*	*Reserved*
Byte 3	*0*	*X*	*X*	*X*	*0*	*0*	*0*	*0*
Byte 4.. N	Will Topic							

Table 47: WILLTOPICUPD packet

The WILLTOPICUPD packet is sent by a client to update its Will topic name stored in the GW/server.

3.1.29.1 Length & Packet Type

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 1.8.2 for a detailed description.

3.1.29.2 Flags

The WILLTOPICUPD Flags is 1 byte field in Byte 3 position of the packet specifying the properties of the WILLTOPICUPD.

The WILLTOPICUPD Flags field includes the following flags:

- **Will QoS**: Stored in Bit 5 and 6, these two bits specify the QoS level to be used.

3.1.29.3 Will Topic

Contains the Will topic name.An empty WILLTOPICUPD packet is a WILLTOPICUPD packet without Flags and WillTopic field (i.e. it is exactly 2 bytes long). It is used by a client to delete its Will topic and Will message stored in the GW/server.

3.1.30 WILLMSGUPD

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							

Byte 2	Packet Type
Byte 3 .. N	Will Message

Table 48: WILLMSGUPD packet

The WILLMSGUPD packet is sent by a client to update its Will packet stored in the GW/server.

3.1.30.1 Length & Packet Type

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 1.8.2 for a detailed description.

3.1.30.2 Will Message

Contains the Will message.

3.1.31 WILLTOPICRESP

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type							
Byte 3	Reason Code							

Table 49: WILLTOPICRESP packet

The WILLTOPICRESP packet is sent by a GW to acknowledge the receipt and processing of an WILLTOPICUPD packet.

3.1.31.1 Length & Packet Type

Uses packet header format 1. Please refer to section 2.1 for a detailed description.

3.1.31.2 Reason Code

Byte 3 in the WILLTOPICRESP control packet contains the Reason Code returned from the processing of the WILLTOPICUPD packet.

Dec	Hex	Reason Code name	Description
0	0x00	Success	The Will Topic update request was received successfully.
1	0x01	Congestion	There is network or server congestion in receiving Will Topic response
2	0x02	Invalid topic alias	The Topic name alias is not accepted by the Server.

3	0x03	Not supported	The server does not accept or support the properties provided with the WILLTOPICRESP packet.

Table 50: WILLTOPICRESP Reason Code

3.1.32 WILLMSGRESP

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type							
Byte 3	Reason Code							

Table 51: WILLMSGRESP

The WILLMSGRESP packet is sent by a GW to acknowledge the receipt and processing of an WILLMSGUPD packet.

3.1.32.1 Length & Packet Type

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 1.8.2 for a detailed description.

3.1.32.2 Reason Code

Byte 3 in the WILLMSGRESP control packet contains the Reason Code returned from processing of the WILLMSGUPD control packet.

Dec	Hex	Reason Code name	Description
0	0x00	Success	The Will Message update was accepted and processed successfully.
1	0x01	Congestion	There is network or server congestion in receiving the Will Message update packet.
2	0x02	Invalid topic alias	The Will Topic name alias is not accepted by the Server
3	0x03	Not supported	The Server does not accept or support the properties provided with WILLMSGUPD packet.

Table 52: WILLMSGRESP Reason Code

3.1.33 Forwarder Encapsulation

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type							
Byte 3	Ctrl							
Byte 4 .. N	Wireless Node Id							
Byte (N + 1 ,,, M)	MQTT SN packet							

Table 53: Format of an encapsulated MQTT-SN frame

As detailed in Section 4, MQTT-SN clients can also access a GW via a forwarder in case the GW is not directly attached to their WSNs. The forwarder simply encapsulates the MQTT-SN frames it receives on the wireless side and forwards them unchanged to the GW; in the opposite direction, it decapsulates the frames it receives from the gateway and sends them to the clients, unchanged too.

3.1.33.1 Length

1-byte long, specifies the number of bytes up to the end of the “Wireless Node Id” field (incl. the Length byte itself)

3.1.33.2 Packet Type

Coded “0xFE”, see Table 6

3.1.33.3 Ctrl

The Ctrl byte contains control information exchanged between the GW and the forwarder.

Bit	7	6	5	4	3	2	1	0
	Reserved						*Radius*	
	0	0	0	0	0	0	X	X

Table 54: Format of the ctrl byte

3.1.33.4 Radius

Broadcast radius (only relevant in direction GW to forwarder)

3.1.33.5 Wireless Node Id

Identifies the wireless node which has sent or should receive the encapsulated MQTT-SN packet. The mapping between this Id and the address of the wireless node is implemented by the forwarder, if needed.

3.1.33.6 MQTT SN Packet

The MQTT-SN packet, encoded according to the packet type.

3.1.34 PROTECTION

Bit	7	6	5	4	3	2	1	0
Byte 1	Length							
Byte 2	Packet Type							
	PROTECTION FLAGS							
	Auth Tag Length				*Crypto Material Length*		*Monotonic Counter Length*	
Byte 3	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*
Byte 4	Protection Scheme							
Byte 5 - 12	Sender Id							
Byte 13 - 16	Random							
Byte 17 - P	Crypto Material (Optional)							
Byte Q - R	Monotonic Counter (Optional)							
Byte S - T	Protected MQTT-SN Packet							
Byte U - N	Authentication Tag							

Table 53: Format of the protection packet

The PROTECTION packet provides a secure envelope for any other MQTT-SN packet (with the exception of the Forward Encapsulation packet). The fields provided on the protection packet provide a means by which the sender can be identified and the packet can be protected, using a number of prescribed protection schemes.

The sender is the originator of the “Protected MQTT-SN Packet” and responsible for its protection. This responsibility can’t be delegated to a third entity like a Forwarder.

The sender identification is required as the sender and the receiver of the PROTECTION packet must have access to the same shared key to be used directly or after derivation. The authentication of the sender and the receiver, their authorizations and the provisioning of the shared keys used to protect integrity and optionally confidentiality of the PROTECTION packet content are out of scope for this technical proposal.

A PROTECTION packet, like any other one, can be the payload of a Forward Encapsulation packet.

//TODO - Break out the conformance aspects of this paragraph from recommendations.

When the PROTECTION packet is handled by a GW, it is mandatory to use it to protect all MQTT-SN packets exchanged with a Client for which a shared key (indexed by its Sender Id) is available.

If the client is not enrolled to the GW (so the GW has no access to a key shared with it on the basis of its Sender Id) and the Client and GW are not in a private network, it is recommended for the GW to process only MQTT-SN packets received over a DTLS session initiated with mutual authentication by the client.

When the PROTECTION packet is handled by a Client, it is mandatory to use it to protect all MQTT-SN packets exchanged with a GW for which a shared key (indexed by its GwId) is available.

If the GW is not enrolled to the Client (so the Client has no access to a key shared with it on the basis of its GwId) and the Client and GW are not in a private network, it is recommended for the Client to open a DTLS session and process only MQTT-SN packets received over it.

3.1.34.1 Length

The first 2 or 4 bytes of the packet are encoded according to the variable length packet header format. Please refer to section 1.8.2 for a detailed description.

3.1.34.2 Packet Type

Coded "0x1E", see Table 63

3.1.34.3 Protection Flags

The PROTECTION Flags is 1 byte field in Byte position 3 of the packet, specifying the properties of the PROTECTION.

The PROTECTION Flags field includes the following flags:

- **(Auth)entication tag length -** (4 bits) should represent the number of 16 bits groups forming the authentication tag in big-endian order.
    - Only 14 of the 16 possible values are allowed:
        - If 0x00, the authentication tag length is provider defined
        - the values from 0x1 to 0x2 are Reserved;
        - any other value 0xZ, so between 0x3 and 0xF, is allowed and the authentication tag length will be (0xZ+1)*16 bits; for example
            - if the value is 0xF, the Authentication tag length will be (0xF+1)*16=256 bits;
            - if the value is 0x3, the Authentication tag length will be (0x3+1)*16=64 bits;
    - If a truncation of the output of the authentication algorithm is required, it has to be taken in most significant bits first order (leftmost bits).
    - If an extension of the output of the authentication algorithm is required, 0s are appended until the Authentication tag length is reached.
    - Some values are not allowed for some protection schemes. For instance the values 0x03, 0x04, 0x05, 0x06 are not allowed for AES-CCM-128-128, AES-CCM-128-192, AES-CCM-128-256, AES-GCM-128-128, AES-GCM-128-192, AES-GCM-128-256 and ChaCha20/Poly1305 as for those protection schemes the 128-bit authentication tag can't be truncated.

- **Crypto material length -** (2 bits) should represent the number of 16 bits groups forming the crypto material in big-endian order. Below the meaning of each possible value:
    - if 0x3, a crypto material field of 96 bits (12 bytes) is present
    - if 0x2, a crypto material field of 32 bits (4 bytes) is present
    - if 0x1, a crypto material field of 16 bits (2 bytes) is present
    - if 0x0, the crypto material field is not present.

- **Monotonic counter length -** (2 bits) should represent the number of bytes forming the monotonic counter in big-endian order. Only 3 of the 4 possible values are allowed:
    - the value 0x3 is Reserved;
    - if 0x2, a monotonic counter field of 32 bits (4 bytes) is present;
    - if 0x1, a monotonic counter field of 16 bits (2 bytes) is present;
    - if 0x0, the monotonic counter field is not present.

3.1.34.4 Protection Scheme

A (1 byte) field located at byte 4 should contain one of the not Reserved indexes in the following table. In general two types of protection scheme are considered: **Authentication only** (like HMAC or CMAC) and **AEAD** (Authenticated Encryption with Associated Data, like GCM, CCM or ChaCha20/Poly1305).

Index	Name	Auth Only	Key size	Tag size
0x00	HMAC-SHA256 (Note 1)	Yes	Any size (Note 2)	256 bits
0x01	HMAC-SHA3_256 (Note 1)	Yes	Any size (Note 2)	256 bits
0x02	CMAC-128 (Note 3)	Yes	128 bits	128 bits
0x03	CMAC-192 (Note 3)	Yes	192 bits	128 bits
0x04	CMAC-256 (Note 3)	Yes	256 bits	128 bits
0x05-0x3B	RESERVED			
0x3C-0x3F	Provider defined	Yes	Provider defined	Provider defined
0x40	AES-CCM-64-128 (Notes 4,5)	No	128 bits	64 bits
0x41	AES-CCM-64-192 (Notes 4,5)	No	192 bits	64 bits
0x42	AES-CCM-64-256 (Notes 4,5)	No	256 bits	64 bits
0x43	AES-CCM-128-128 (Notes 4,5)	No	128 bits	128 bits
0x44	AES-CCM-128-192 (Notes 4,5)	No	192 bits	128 bits
0x45	AES-CCM-128-256 (Notes 4,5)	No	256 bits	128 bits
0x46	AES-GCM-128-128 (Notes 6,7)	No	128 bits	128 bits
0x47	AES-GCM-128-192 (Notes 6,7)	No	192 bits	128 bits
0x48	AES-GCM-128-256 (Notes 6,7)	No	256 bits	128 bits
0x49	ChaCha20/Poly1305 (Notes 8,9)	No	256 bits	128 bits
0x4A-0xEF	RESERVED			
0xF0-0xFF	Provider defined	No	Provider defined	Provider defined

Note(s):

1. Reference https://www.rfc-editor.org/rfc/rfc2104
2. Reference https://nvlpubs.nist.gov/nistpubs/FIPS/NIST.FIPS.198-1.pdf
3. Reference https://www.rfc-editor.org/rfc/rfc4493 and https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-38b.pdf and https://csrc.nist.gov/CSRC/media/Projects/Cryptographic-Standards-and-Guidelines/documents/examples/AES_CMAC.pdf
4. Reference https://www.rfc-editor.org/rfc/rfc3610 and security considerations on https://www.rfc-editor.org/rfc/rfc8152#section-10.2.1
5. AES CCM requires a 13 bytes nonce as indicated in https://www.rfc-editor.org/rfc/rfc8152#section-10.2 and the nonce is obtained by performing

SHA256, truncated to the leftmost 104 bits, of the sequence Byte 1 to Byte R (all packet fields until Protected MQTT-SN Packet)

6. Reference https://nvlpubs.nist.gov/nistpubs/Legacy/SP/nistspecialpublication800-38d.pdf and security considerations on https://www.rfc-editor.org/rfc/rfc8152#section-10.1.1
7. AES GCM requires a 12 bytes IV as indicated in https://www.rfc-editor.org/rfc/rfc8152#section-10.1 and the IV is obtained by performing SHA256, truncated to the leftmost 96 bits, of the sequence Byte 1 to Byte R (all packet fields until Protected MQTT-SN Packet)
8. Reference: https://www.rfc-editor.org/rfc/rfc7539 and security considerations on https://www.rfc-editor.org/rfc/rfc8152#section-10.3.1
9. ChaCha20/Poly1305 requires a 12 bytes nonce as indicated in https://www.rfc-editor.org/rfc/rfc8152#section-10.3 obtained by performing SHA256 truncated to 96 bit of the sequence Byte 1 to Byte R (all packet fields until Protected MQTT-SN Packet)

3.1.34.5 Sender Id

Located at Bytes 5 - 12 the Sender Id field (8 bytes) should contain:

If the message is originated by the ***Gateway***:

- The SHA256 of the GwId truncated to the leftmost 64 bits (8 bytes);

If the message is originated by the ***Client***:

- **If a session is available**: the SHA256 of the [Client Identifier] truncated to the leftmost 64 bits (8 bytes);
- **If a session is not available**: a unique value per sender over 8 bytes (like a MAC address, or other identifying characteristics). The methods to guarantee the uniqueness of the Sender Id in this case are out of scope for this technical proposal.

Informative

8 bytes for the "Sender Id" field seems enough as it is calculated with a cryptographic hash, so the probability of collision is 1/2^64=5.42x10^{-20}.

Client Behavior
In order to create a whitelist of authorized senders, the Client should store a map of GwId and SHA256(GwId) *truncated to the leftmost 64 bits. GwId can be obtained from pre-configuration, from an ADVERTISE packet or from a GWINFO packet*.

Gateway Behavior
In order to create a whitelist of authorized senders, the MQTT-SN Gateway should store a map of ClientID and SHA256(ClientID) truncated to the leftmost 64 bits (8 bytes for each registered ClientID) for the clients having an active session and store a list of authorized Sender Ids for the clients not capable to establish sessions.

3.1.34.6 Random

Located at Byte 13 - 16 , the "**Random**" field (4 bytes) should contain a random number (not guessable) generated at the PROTECTION packet creation .

Informative

In case of CCM, in the worst case scenario where the "Crypto Material" and the "Monotonic Counter" optional fields are not present, the recommended nonce on 13 bytes will be calculated as SHA256 truncated to 104 bits of the sequence Byte 1 to Byte 16 (all packet fields until Protected MQTT-SN Packet). So considering the same Sender Id, the same nonce can be generated with a probability of 1/2^32=2.33x10^{-10}. With a shorter Random field of 2 bytes, the

same nonce would be calculated with a probability of only 1/2^16=1.53x10^{-5}. As CCM is a derivation of CTR (see https://en.wikipedia.org/wiki/CCM_mode), the nonce should never be reused for the same key so the probability to generate two identical nonces should be kept as low as possible. Same for GCM and ChaCha20/Poly1305, the security depends on choosing a unique IV of 12 bytes for every encryption performed with the same key (https://en.wikipedia.org/wiki/Galois/Counter_Mode).

3.1.34.7 Crypto Material

Located at Byte (17 - P), the optional field "**Crypto Material**" contains 0, 2, 4 or 12 bytes of crypto material that when defined it can be used to derive, from a shared master secret, the same keys on the two endpoints and/or, when filled partially or totally with a random value, to further reduce the probability of IV/nonce reuse for CCM or GCM or ChaCha20/Poly1305. For instance when the Crypto material length is set to 0x03, the Crypto Material field can be partially filled with a random value of 9 bytes (the remaining 3 bytes can be set to 0 if not used) in order to reach the 13 bytes used only once recommended for the nonce used by CCM or it can be partially filled with a random value of 8 bytes in order to reach the 12 bytes used only once recommended for the IV/nonce used by GCM or ChaCha20/Poly1305 .

3.1.34.8 Monotonic Counter

Located at Byte Byte (Q - R), the optional field "**Monotonic Counter**" contains 0, 2 or 4 byte number that when defined, is increased by the Client or GW for every packet sent. The counters should be considered independent of session or destination. E.g. The UE will keep a counter independently from the GW.

3.1.34.9 Protected MQTT-SN Packet

Located at Byte (S - T), the field "**Protected MQTT-SN Packet**" contains the MQTT-SN packet that is being secured, encoded as per its packet type.
The "Protected MQTT-SN Packet" should not be a "Forwarder-Encapsulation packet" as the shared key used directly or after derivation for the protection must belong to the originator of the content and not to a Forwarder that, in general, is not able to securely identify the originator.

3.1.34.10 Authentication Tag

Located at Byte (U - N), the field "**Authentication tag**" field has a length depending on the "Authentication tag length" flag and it is calculated, on the basis of the "Protection scheme" selected in Byte 4, on ALL the preceding fields.

4 Operational behavior

An important design point of MQTT-SN is to be as close as possible to MQTT. Therefore, all protocol semantics should remain, as far as possible, the same as those defined by MQTT. In the following we will focus on those points that either are new to or deviate from MQTT.

4.1 MQTT-SN Architecture

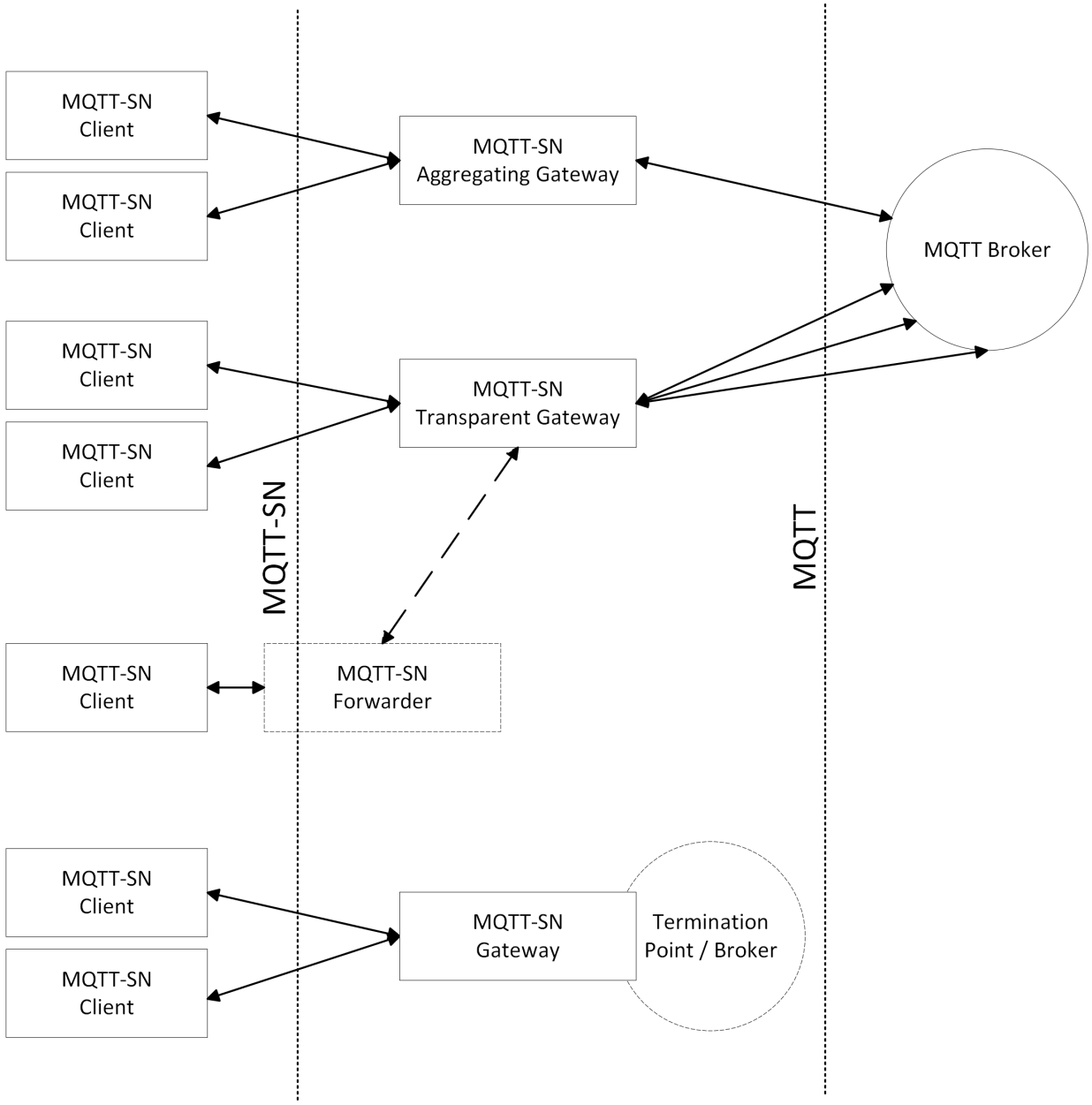


Figure 1: MQTT-SN Architecture

The architecture of MQTT-SN is shown in figure 1. There are three kinds of MQTT-SN components, MQTT-SN *clients*, MQTT-SN *gateways*, and MQTT-SN *forwarders*. MQTT-SN clients connect themselves to an MQTT server/broker via an MQTT-SN Gateway using the MQTT-SN protocol. An MQTT-SN

Gateway may or may not be integrated with a MQTT server. Where an MQTT broker is involved, the MQTT protocol is used between the MQTT broker and the MQTT-SN Gateway. Its main function is the translation between MQTT and MQTT-SN.

MQTT-SN clients can also access a Gateway via a forwarder in case the Gateway is not directly attached to their network. The forwarder simply encapsulates the MQTT-SN frames it receives on the wireless side and forwards them unchanged to the Gateway; in the opposite direction, it decapsulates the frames it receives from the gateway and sends them to the clients, unchanged too.

We can differentiate between two types of Gateway, namely *transparent* and *aggregating* Gateways, see Fig. 2. They are explained in the following sections.

4.1.1 Transparent Gateway

For each connected MQTT-SN client a transparent Gateway will set up and maintain a MQTT connection to the MQTT server. This MQTT connection is reserved exclusively for the end-to-end and almost transparent packet exchange between the client and the server. There will be as many MQTT connections between the Gateway and the server as MQTT-SN clients connected to the Gateway. The transparent Gateway will perform a “syntax” translation between the two protocols. Since all packet exchanges are end-to-end between the MQTT-SN client and the MQTT Server, all functions and features that are implemented by the server can be offered to the client.

Although the implementation of the transparent Gateway is simpler when compared to the one of an aggregating Gateway, it requires the MQTT server to support a separate connection for each active client. Some MQTT server implementations might impose a limitation on the number of concurrent connections that they support.

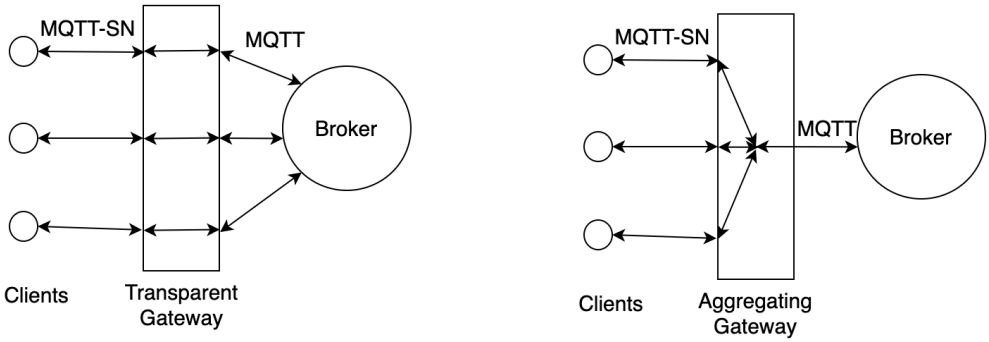


Figure 2: Transparent and Aggregating Gateways

4.1.2 Aggregating Gateway

Instead of having a MQTT connection for each connected client, an aggregating Gateway will have only one MQTT connection to the Server. All packet exchanges between a MQTT-SN client and an aggregating Gateway end at the Gateway. The Gateway then decides which information will be given further to the Server. Although its implementation is more complex than the one of a transparent Gateway, an aggregating Gateway may be helpful in case of WSNs with very large number of SAs because it reduces the number of MQTT connections that the Gateway must support concurrently.

4.2 Networks & Transport Layers

The MQTT-SN V2.0 protocol requires an underlying transport to create a Virtual Connection, this carries datagrams from a Client to a Gateway and a Gateway to a Client.
The underlying transport may also broadcast datagrams from a Client to all Gateways and from a Gateway to all Clients.
The datagrams carry the MQTT-SN V2.0 Packets which must be received unaltered and complete.

- The underlying transport does not need to be reliable, it is expected that datagrams will be lost or delivered out of order.
- If the network might deliver a datagram more than once, then it is highly recommended that the PROTECTION packet Monotonic Counter is used to eliminate the duplicates.
- The MQTT-SN V2.0 protocol will tolerate out of order Packets and it will retransmit lost Packets.
- The MQTT-SN V2.0 does not perform error correction. If a corrupted or partial Packets is received it will cause a protocol error.
- The MQTT-SN V2.0 implementation may use either the origin network address or the sender identifier in the PROTECTION Packet to determine the identity of the Virtual Connection.
- The underlying network does not need to provide low latency transmission.
- The networks may be connectionless, the Virtual Connections do not need to have an event that signals when they begin or end.
- The networks may be radio networks.

Informative comment

UDP as defined in [RFC0768] can be used for MQTT-SN v2.0 if the Maximum Transmission Unit is configured to be more than the MQTT-SN Packet size used and no datagram fragmentation occurs. Depending on the network configuration, UDP can duplicate datagrams. If this can happen, the PROTECTION Packet monotonic counter should be used.

Examples of possible consequences of not removing duplicates datagrams are:
– DISCONNECT Packet applied to the wrong Virtual Connection
– SUBSCRIBE and UNSUBSCRIBE Packets applied to the wrong Virtual Connection
– PUBLISH QOS=2 published more than once

The following transport protocols are also suitable but if not capable of multicast/broadcast the implementation of the optional ADVERTISE, SEARCHGW, GWINFO packets may not be possible and also the multicast/broadcast of the PUBLISH MINUS -1 packets may not be possible:

- DTLS v1.2 [RFC6347]
- DTLS v1.3 [RFC9147]
- QUIC [RFC9000]
- Non-IP protocolsTCP/IP [RFC0793]
- TLS [RFC5246]
- WebSocket [RFC6455].

Informative comment

TCP ports 8883 and 1883 are registered with IANA for MQTT TLS and non-TLS communication respectively.

4.3 Gateway Advertisement and Discovery

A gateway may announce its presence by broadcasting periodically an ADVERTISE packet to all devices that are currently parts of the network. A gateway should only advertise its presence if it is connected to a server (or is itself a server).

Multiple gateways may be active at the same time in the same network. In this case they will have different ids. It is up to the client to decide to which gateway it wants to connect. At any point in time a client is allowed to be connected to only one gateway.

A client should maintain a list of active gateways together with their network addresses. This list is populated by means of the ADVERTISE and GWINFO packets received.

The time duration T_{ADV} until the gateway sends the next ADVERTISE packet is indicated in the *Duration* field of the ADVERTISE packets. A client may use this information to monitor the availability of a gateway. For example, if it does not receive ADVERTISE packets from a gateway for N_{ADV} consecutive times, it may assume that the gateway is down and removes it from its list of active gateways. Similarly, gateways in stand-by mode will become active (i.e. start sending ADVERTISE packets) if they miss successively a couple of times advertisements from a certain gateway.

Since the ADVERTISE packets are broadcasted into the whole wireless network, the time interval T_{ADV} between two ADVERTISE packets sent by a gateway should be large enough (e.g. greater than 15 min) to avoid bandwidth congestion in the network.

The large value of T_{ADV} will lead to a long waiting time for new clients which are looking for a gateway. To shorten this waiting time a client may broadcast a SEARCHGW packet. To prevent broadcast storms when multiple clients start searching for GW almost at the same time, the sending of the SEARCHGW packet is delayed by a random time between 0 and $T_{SEARCHGW}$. A client will cancel its transmission of the SEARCHGW packet if it receives during this delay time a SEARCHGW packet sent by another client and identical to the one it wants to send, and behaves as if the SEARCHGW packet was sent by itself.

The broadcast radius R_b of the SEARCHGW packet is limited, e.g. to a single hop in case of a dense deployment of MQTT-SN clients.

Upon receiving a SEARCHGW packet a gateway replies with a GWINFO packet containing its id. Similarly, a client answers with a GWINFO packet if it has at least one active gateway in its list of active gateways. If the client has multiple GWs in its list, it selects one GW out of its list and includes that information into the GWINFO packet.

Like the SEARCHGW packet, the GWINFO packet is broadcast with the same radius R_b, which is indicated in the SEARCHGW packet. The radius R_b is also given to the underlying layer when these two packets are passed down for transmission.

To give priority to the gateways a client will delay its sending of the GWINFO packet for a random time T_{GWINFO}. If during this delay time the client receives a GWINFO packet it will cancel the transmission of its GWINFO packet.

In case of no response the SEARCHGW packet may be retransmitted. In this case the time intervals between consecutive SEARCHGW packets should be increased by the exponential backoff algorithm described in the appendix.

4.4 Session Establishment

As with MQTT, an MQTT-SN client needs to set up a session on the GW, unless it is publishing ONLY using OUT OF BAND packets. The procedure for setting up a session with a GW is illustrated in Fig. 3.

The CONNECT packet contains flags to communicate to the gateway that will or auth or both interactions should take place.

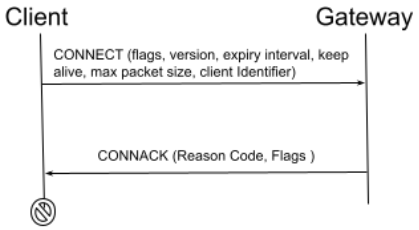


Figure 3a: Connect procedure (without will flag set)

If the Will flag is set, the client then sends these two pieces of information to the GW upon receiving the corresponding request packets WILLTOPICREQ and WILLMSQREQ. The procedure is terminated with the CONNACK packet sent by the GW.

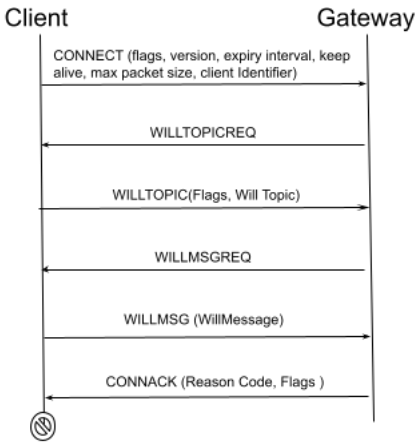


Figure 3b: Connect procedure (with will flag set)

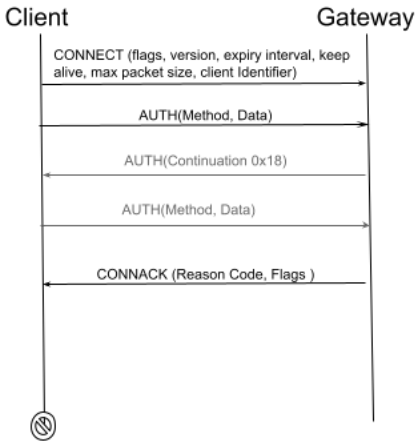


Figure 3c: Connect procedure (with auth flag set)

In case the gateway could not accept the CONNECT request (e.g. because of congestion or it does not support a feature indicated in the CONNECT packet), the gateway returns a CONNACK packet with the rejection reason.

In the case where the client provides no client identifier, the Server MUST respond with a CONNACK containing an Assigned Client Identifier.

The Assigned Client Identifier MUST be a new Client Identifier not used by any other Session currently in the gateway.

4.5 Quality of Service levels and protocol flows

MQTT delivers Application Messages according to the Quality of Service (QoS) levels defined in the following sections. The delivery protocol is symmetric, in the description below the Client and Server & Gateway can each take the role of either sender or receiver. The delivery protocol is concerned solely with the delivery of an application message from a single sender to a single receiver. When the Gateway is delivering an Application Message to more than one Client, each Client is treated independently. The QoS level used to deliver an Application Message outbound to the Client could differ from that of the inbound Application Message.

4.5.1 QoS 0: At most once delivery

The message is delivered according to the capabilities of the underlying network. No response is sent by the receiver and no retry is performed by the sender. The message arrives at the receiver either once or not at all.

In the QoS 0 delivery protocol, the sender

- MUST send a PUBLISH packet with QoS 0 and DUP flag set to 0.

In the QoS 0 delivery protocol, the receiver

- Accepts ownership of the message when it receives the PUBLISH packet.

Sender Action	Control Packet	Receiver Action
PUBLISH QoS 0, DUP=0		
	---------->	
		Deliver Application Message to appropriate onward recipient(s)

4.5.2 QoS 1: At least once delivery

This Quality of Service level ensures that the message arrives at the receiver at least once. A QoS 1 PUBLISH packet has a Packet Identifier in its Variable Header and is acknowledged by a PUBACK packet.

In the QoS 1 delivery protocol, the sender

- MUST assign an unused Packet Identifier each time it has a new Application Message to publish
- MUST send a PUBLISH packet containing this Packet Identifier with QoS 1 and DUP flag set to 0
- MUST treat the PUBLISH packet as “unacknowledged” until it has received the corresponding PUBACK packet from the receiver.

The Packet Identifier becomes available for reuse once the sender has received the PUBACK packet.

In a difference to MQTT 5, the sender is NOT permitted to send further PUBLISH packets with different Packet Identifiers while it is waiting to receive acknowledgements. At any given time a sender my ONLY have 1 outstanding application message inflight.

In the QoS 1 delivery protocol, the receiver

- MUST respond with a PUBACK packet containing the Packet Identifier from the incoming PUBLISH packet, having accepted ownership of the Application Message
- After it has sent a PUBACK packet the receiver MUST treat any incoming PUBLISH packet that contains the same Packet Identifier as being a new Application Message, irrespective of the setting of its DUP flag

Figure 4.2 – QoS 1 protocol flow diagram, Informative example

Sender Action	MQTT Control Packet	Receiver action
Store message		
Send PUBLISH QoS 1, DUP=0, <Packet Identifier>	---------->	
		Initiate onward delivery of the Application Message[1]
	<----------	Send PUBACK <Packet Identifier>
Discard message		

[1] The receiver does not need to complete delivery of the Application Message before sending the PUBACK. When its original sender receives the PUBACK packet, ownership of the Application Message is transferred to the receiver.

4.5.3 QoS 2: Exactly once delivery

This is the highest Quality of Service level, for use when neither loss nor duplication of messages are acceptable. There is an increased overhead associated with QoS 2.

In the QoS 2 delivery protocol, the sender:

- MUST assign an unused Packet Identifier when it has a new Application Message to publish
- MUST send a PUBLISH packet containing this Packet Identifier with QoS 2 and DUP flag set to 0
- MUST treat the PUBLISH packet as “unacknowledged” until it has received the corresponding PUBREC packet from the receiver
- MUST send a PUBREL packet when it receives a PUBREC packet from the receiver with a Reason Code value less than 0x80. This PUBREL packet MUST contain the same Packet Identifier as the original PUBLISH packet
- MUST treat the PUBREL packet as “unacknowledged” until it has received the corresponding PUBCOMP packet from the receiver
- MUST NOT re-send the PUBLISH once it has sent the corresponding PUBREL packet
- MUST NOT apply Message expiry if a PUBLISH packet has been sent

The Packet Identifier becomes available for reuse once the sender has received the PUBCOMP packet or a PUBREC with a Reason Code of 0x80 or greater.

In a difference to MQTT 5, the sender is NOT permitted to send further PUBLISH packets with different Packet Identifiers while it is waiting to receive acknowledgements. At any given time a sender my ONLY have 1 outstanding application message inflight.

In the QoS 2 delivery protocol, the receiver:

- MUST respond with a PUBREC containing the Packet Identifier from the incoming PUBLISH packet, having accepted ownership of the Application Message
- If it has sent a PUBREC with a Reason Code of 0x80 or greater, the receiver MUST treat any subsequent PUBLISH packet that contains that Packet Identifier as being a new Application Message
- Until it has received the corresponding PUBREL packet, the receiver MUST acknowledge any subsequent PUBLISH packet with the same Packet Identifier by sending a PUBREC. It MUST NOT cause duplicate messages to be delivered to any onward recipients in this case
- MUST respond to a PUBREL packet by sending a PUBCOMP packet containing the same Packet Identifier as the PUBREL
- After it has sent a PUBCOMP, the receiver MUST treat any subsequent PUBLISH packet that contains that Packet Identifier as being a new Application Message

4.5.4 QoS -1: Constrained client delivery

This feature is defined for very simple client implementations which only support a limited sub-set of features. There is no requirement to setup nor tear down a Virtual Connection, no registration nor subscription. The sender just sends its PUBLISH packets to it’s counterpart (whose address is known

a-priori) and forgets them. It does not care whether the address is correct, whether the counterpart is alive, or whether the packets arrive. Only the following parameter values are allowed for a PUBLISH packet with QoS level -1:

- QoS flag: set to “0b11”
- Topic Alias Type flag: either “0b01” for pre-defined topic alias, “0b10” for short topic name, “0b11” for full topic names.
- Topic Alias or Topic Name field: value of the pre-defined topic alias or of the short topic or of the full topic name
- Data field: the data to be published.

Whilst no Virtual Connection is mandated for QoS -1 delivery, a constrained client who has previously connected and established a session may wish to PUBLISH at QoS -1 during any of the lifecycle states. If the GW can determine the origin of a QoS -1 packet, it should not impact/change any existing session except for resetting the keep-alive timer.

4.5.5 OUT OF BAND: Constrained client delivery

This feature is defined for very simple client implementations which only support a limited sub-set of features. There is no requirement to setup nor tear down a Virtual Connection, no registration nor subscription. The sender just sends its PUBLISH packets to it’s counterpart (whose address is known a-priori) and forgets them. It does not care whether the address is correct, whether the counterpart is alive, or whether the packets arrive. Only the following parameter values are allowed for a PUBLISH OUT OF BAND packet:

- Topic Alias Type flag: either “0b01” for pre-defined topic alias, “0b10” for short topic name, “0b11” for full topic names.
- Topic Alias or Topic Name field: value of the pre-defined topic alias or of the short topic or of the full topic name
- Data field: the data to be published.

Whilst no Virtual Connection is mandated for OUT OF BAND delivery, a constrained client who has previously connected and established a session may wish to PUBLISH OUT OF BAND during any of the lifecycle states. If the GW can determine the origin of a OUT OF BAND packet, it should not impact/change any existing session except for resetting the keep-alive timer.

4.6 Client states

At any given point in time, a client may be in one of **5 different states**. Transition through these states is governed by a strictly coordinated sequence of packets between client and server/gateway and further mediated by timers resident on the gateway. A client is in the *active* state when the server/gateway receives a CONNECT packet from that client. This state is supervised by the server/gateway with the “keep alive” timer. If the server/gateway does not receive any packet from the client for a period longer than the keep alive duration (indicated in the CONNECT packet), the gateway will consider that client as *lost* and activates for example the Will feature for that client. A client goes to the *disconnected* state when the server/gateway receives a DISCONNECT without a *session expiry interval* field. This state is not time-supervised by the server/gateway. A client moves into the asleep state by issuing a DISCONNECT with a *session expiry interval* field. For more information on the sleep state, please refer to the “Sleeping clients” section.

State	State Description	Possible Transitions
DISCONNECTED	The client is considered offline. The GW may or may not have a previous session state for this client. From here a client may transition ONLY to the **ACTIVE** state.	**ACTIVE**

ACTIVE	The client is actively engaged in the session. It should be able to send and receive packets. Its state is supervised by the GW with the associated “keep alive” timers. From here the client may transition to **ASLEEP** (by way of DISCONNECT with a session expiry interval > 0), **DISCONNECTED** (by way of DISCONNECT with a session expiry of 0) or LOST (by way of supervised gateway timers).	**ASLEEP** **DISCONNECTED** **LOST**
ASLEEP	The client is engaged in an ongoing session. It cannot receive packets; it can send packets. The GW should not expect a response from the client in this state until further packets are received from the client. From here the client may transition to **AWAKE** (by way of PINGREQ), **ACTIVE** by way of CONNECT, **DISCONNECTED** (by way of DISCONNECT with a session expiry of 0) or **LOST** (by way of supervised gateway timers).	**AWAKE** **ACTIVE** **DISCONNECTED** **LOST**
AWAKE	The client is partially engaged in an ongoing session; it is obliged to not send ANY packets other than those involved in the receipt of PUBLISH packets (PUBACK, PUBREC, PUBCOMP, REGACK) or a DISCONNECT to transition to **DISCONNECTED**. The client transitions back to the **ASLEEP** state on receipt of a PINGRESP packet or **LOST** (by way of supervised gateway timers).	**ASLEEP** **DISCONNECTED** **LOST**
LOST	The client is considered offline and not able to receive packets until it has re-established a session with the GW by way of a CONNECT. The GW **must not** attempt to send packets to a client in the **LOST** state**.** Any packets received from a client whose state is **LOST** should not be processed and a DISCONNECT with error should be sent in response, unless the packets received are PUBLISH OUT OF BAND or PUBLISH -1. Session state may exist on the GW for a client in the **LOST** state.	**ACTIVE**

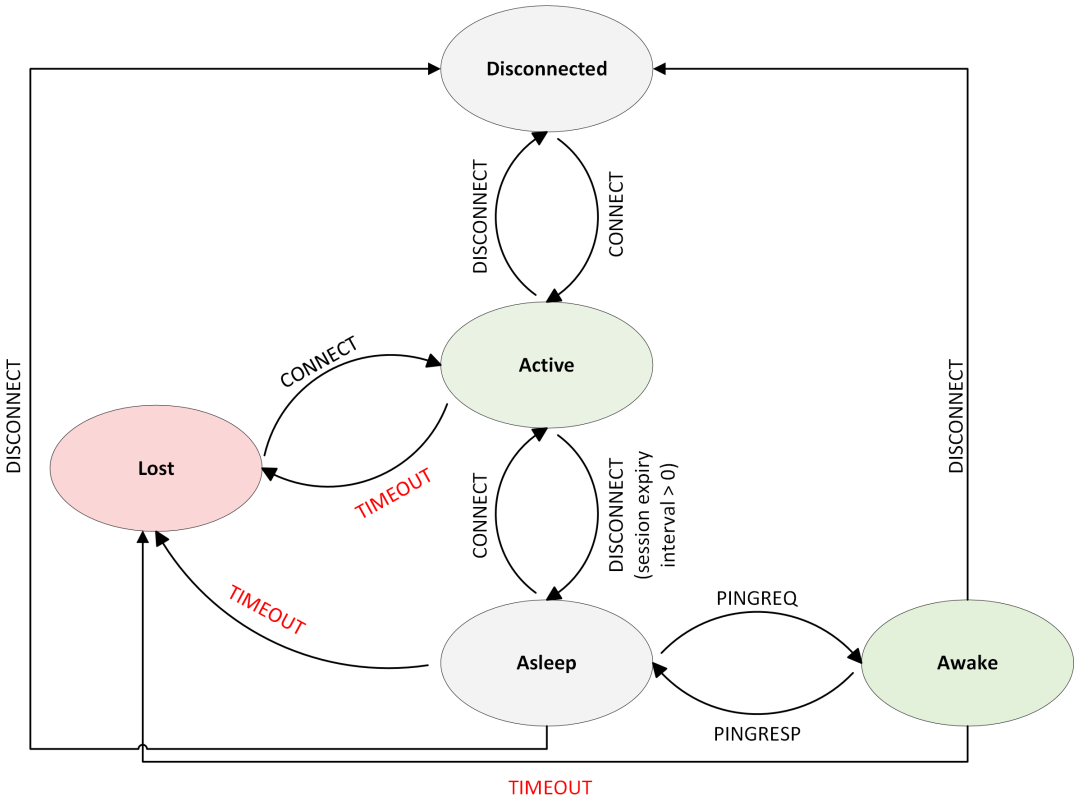


Figure 4: Client's state transition diagram

4.7 Session state

Sessions are maintained by both the Client and a Gateway. Sessions typically include (but are not limited to):

- Client Identifier
- Last packet received timestamp
- Keep Alive value
- Session Expiry Interval value
- Outbound unconfirmed application messages
- Inbound unconfirmed application messages
- Buffered messages from the broker
- Registered topic alias dictionary (normal topic alias's)
- Confirmed subscriptions with their granted QoS
- Network address of Gateway (in the case of clients).
- Network address of Client (in the case of gateways).
- Next outbound packet identifier

4.8 Clean start

With MQTT, when a client disconnects, its subscriptions are retained for a period of time. They are persistent and valid for new Virtual Connections, until either they are explicitly un-subscribed by the client, or the client establishes a new Virtual Connection with the "clean start" flag set or their idle time exceeds the session expiry interval associated with the session.

In MQTT-SN the meaning of a “clean start” is extended to the Will feature, i.e. not only the subscriptions are persistent, but also the Will topic and the Will packet. The two flags “CleanStart” and “Will” in the CONNECT have then the following meanings:

- CleanStart=true, Will=true: The GW will delete all subscriptions and Will data related to the client, and starts prompting for new Will topic and Will packet.
- CleanStart=true, Will=false: The GW will delete all subscriptions and Will data related to the client, and returns CONNACK (no prompting for Will topic and Will packet).
- CleanStart=false, Will=true: The GW keeps all stored client’s data, but prompts for new Will topic and Will packet. The newly received Will data will overwrite the stored Will data.
- CleanStart=false, Will=false: The GW keeps all stored client’s data and returns CONNACK (no prompting for Will topic and Will packet).

Note that if a client wants to delete only its Will data at Virtual Connection setup, it could send a CONNECT packet with “CleanStart=false” and “Will=true”, and sends an empty WILLTOPIC packet to the GW when prompted to do so. It could also send a CONNECT packet with “CleanStart=false” and “Will=false” and use the will update PACKETS to modify the Will data.

4.9 Procedure for updating the Will data

At any time during a Virtual Connection a client could update its Will data stored in the gateway by sending a WILLTOPICUPD or a WILLMSGUPD packet. The information contained in these two packets will overwrite the corresponding ones stored in the gateway. Both packets are acknowledged by the gateway. Both packets can be used independently from each other.

Note that an empty WILLTOPICUPD packet will delete both the Will topic and Will packet stored at the gateway.

4.10 Topic Name and Topic Filter Registration Procedure

Because of the limited bandwidth and the small packet payload in wireless sensor networks, data is not published together with its topic name as in MQTT. A registration procedure is introduced which allows both a client and a GW to inform its peer about the short topic alias and its corresponding topic name before it can start sending PUBLISH packets using the short topic alias.

A topic alias is a two-byte long replacement of the string-based topic name. A client needs to use the REGISTER procedure to inform the gateway about the topic name it wants to employ and gets from the gateway the corresponding topic alias. It then will use this topic alias in the PUBLISH packets it sends to the gateway. In the opposite direction, the PUBLISH packets also contain a 2-byte topic alias (instead of the string-based topic name). The client is informed about the relation between topic alias and topic name by means of either a former SUBSCRIBE procedure, or a REGISTER procedure started by the gateway.

To register a topic name a client sends a REGISTER packet to the GW. If the registration could be accepted, the gateway assigns a *topic alias* to the received topic name and returns it with a REGACK packet to the client.

If the client initiates a REGISTER against a topic which is known by the gateway to have a predefined topic alias associated with it, it is an error case, but one which should not be terminal to the session since firmware updates could lead to this scenario. The gateway will specify its topic alias type to be predefined

and set the topic alias value to match that defined on the gateway in the REGACK, it will also set an ERROR reason code on the REGACK to indicate the issue. The client can then choose to update its registry of predefined topic alias' if it so wishes.

Predefined topicId values CANNOT be used interchangeably with the NORMAL alias type. This is considered a protocol violation.

If there are no predefined topic alias', the gateway will pass back a NORMAL topic alias type. If the registration could not be accepted, a REGACK is also returned to the client with the failure reason encoded in the *ReasonCode* field.

After having received the REGACK packet with *ReasonCode =“accepted”*, the client shall use the assigned *topicId* to publish data of the corresponding topic name. If, however the REGACK contains a rejection code, the client may try to register later again. If the Reason Code was *“Congestion”*, the client should wait for a time T_{WAIT} before restarting the registration procedure.

At any point in time a client may have only one REGISTER packet outstanding, i.e., it must wait for a REGACK packet before it can register another topic name.

A GW sends a REGISTER packet to a client if it wants to inform that client about the topic name and the assigned topic alias that it will use later when sending PUBLISH packets of the corresponding topic name. This happens for example when no prior registrations exists, or when the client has DISCONNECTED with retail registration false, or the client re-connects without having set the “CleanStart” flag or the client has subscribed to topic names that contain wildcard characters such as # or +.

Informative comment

The gateway should attempt to make the best effort to reuse the same topic alias' mappings that existed during any initial associated ACTIVE states.

4.11 Topic Name and Topic Filter Mapping and Aliasing

On the gateway the mapping table between registered topic ids and topic names MUST be implemented per client (and not by a single shared pool between all clients), to reduce the risk of an incorrect topic id from a client matching another client's valid topic.

For performance and efficiency reasons the broker may choose to align topic alias' for registered normal topic aliases between multiple clients. The mapping table of predefined topic aliases is separate from normal registered aliases. It is global and shared between all clients and gateways and may overlap with registered aliases, since it is in a different pool.

4.12 Pre-defined topic alias' and short topic names

A “pre-defined” topic alias is a topic alias who's mapping to a topic name is known in advance by both the client's application and the gateway. This is indicated in the *Flags* field of the packet. When using pre-defined topic alias', both sides can start immediately with the sending of PUBLISH packets; there is no need for the REGISTER procedure as in the case of ”normal” topic alias'. When receiving a PUBLISH packet with a pre-defined topic alias, of which the mapping to a topic name is unknown, the receiver should return a PUBACK with the *ReasonCode= “Rejection: invalid topic* alias*”*.

The presence of a pre-defined topic alias does not imply any other meaning onto the topic name / topic filter itself. All lifecycle operations, for example SUBSCRIBE / UNSUBSCRIBE may still be used in the use of these aliases except for REGISTER.

A “short” topic name is a topic name that has a fixed length of two bytes. It could be carried together with the data within a PUBLISH packet, thus no REGISTER procedure is needed for a short topic name. Otherwise, all rules that apply to normal topic names also apply to short topic names. Note however that it does not make sense to do wildcarding in subscriptions to short topic names, because it is not possible to define a meaningful name hierarchy with only two characters.

4.13 Client’s Topic Subscribe/Unsubscribe Procedure

To subscribe to a topic name, a client sends a SUBSCRIBE packet to the gateway with the topic name included in that packet. If the gateway is able accept the subscription, it assigns a topic alias to the received topic name and returns it within a SUBACK packet to the client. If the subscription cannot be accepted, then a SUBACK packet is also returned to the client with the rejection cause encoded in the *ReasonCode* field. If the rejection cause is *“Congestion”*, the client should wait for the time T_{WAIT} before resending the SUBSCRIBE packet to the gateway.

If the client subscribes to a topic name which contains a wildcard character, the returning SUBACK packet will contain the topic alias value 0x0000. The GW will the use the registration procedure to inform the client about the to-be-used topic alias value when it has the first PUBLISH packet with a matching topic name to be sent to the client.

Similar to the client’s PUBLISH procedure, topic alias’ may also be pre-defined for certain topic names. Short topic names may be used as well. In those two cases the client still needs to subscribe to those pre-defined topic alias’ or short topic names.

To unsubscribe, a client sends an UNSUBSCRIBE packet to the gateway, which will then be answered by means of an UNSUBACK packet.

As for the REGISTER procedure, a client may have only one SUBSCRIBE or one UNSUBSCRIBE transaction open at a time.

4.14 Client’s Publish Procedure

After having registered successfully a topic name with the gateway, the client can start publishing data relating to the registered topic name by sending PUBLISH packets to the gateway. The PUBLISH packets contain the assigned topic alias.

All three QoS levels and their corresponding packet flows are supported as defined in MQTT. The only difference is the use of topic alias’ instead of topic names in the PUBLISH packets.

Regardless of the requested QoS level the client may receive in response to its PUBLISH a PUBACK packet which contains either:

- The *ReasonCode*= *“Rejection: invalid topic* alias*”*: in this case the client needs to register the topic name again before it can publish data related to that topic name; or
- The *ReasonCode*= *“Congestion”*: in this the client shall stop publishing toward the gateway for at least the time T_{WAIT}.

-

At any point in time a client may have only one QoS level 1 or 2 PUBLISH packet outstanding in each direction; i.e. it has to wait for the termination of this PUBLISH packet exchange before it could start a new level 1 or 2 transaction

4.15 Gateway's Publish Procedure

Like the client's PUBLISH procedure described in Section 3.14, the gateway sends PUBLISH packets with the topic alias value that was returned in the SUBACK packet to the client.

Preceding the PUBLISH packet the GW may send a REGISTER packet to inform the client about the topic name and its assigned topic alias value. This will happen for example when the client re-connects without clean start or has subscribed to topic names with wildcard characters. Upon receiving a REGISTER packet the client replies with a REGACK packet. The GW will wait for the REGACK packet before it sends the PUBLISH packet to the client.

The client could reject the REGISTER packet with a REGACK packet indicating the rejection reason; this corresponds to an unsubscribe to the topic name indicated in the REGISTER packet. Note that unsubscribe to a topic name with wildcard characters can only be done with the unsubscribe procedure and not with the rejection of a REGISTER packet, since a REGISTER packet never contains a topic name with wildcard characters.

If the client receives a PUBLISH packet with an unknown topic alias value, it shall respond with a PUBACK packet with the *ReasonCode="Rejected: invalid topic alias"*. This will trigger the gateway to delete or correct the wrong topic alias assignment.

Note that in case either the topic name or the data is too long to fit into a REGISTER or a PUBLISH packet, the gateway silently aborts the publish procedure, i.e. no warning is sent to the affected subscribers.

4.16 Keep Alive and PING Procedure

As with MQTT, the value of the Keep Alive timer is indicated in the CONNECT packet. The client should send a PINGREQ packet within each Keep Alive time period, which the GW acknowledges with a PINGRESP packet.

Similarly, a client shall answer with a PINGRESP packet when it receives a PINGREQ packet from the GW to which it is connected. Otherwise, the received PINGREQ packet is ignored.

Clients should use this procedure to supervise the liveliness of the gateway to which they are connected. If a client does not receive a PINGRESP from the gateway even after multiple retransmissions of the PINGREQ packet, it should first try to connect to another gateway before trying to reconnect to this gateway. Note that because the clients' keep-alive timers are not synchronized with each other, in case of a gateway failure there is practically no danger for a storm of CONNECT packets sent almost at the same time by all affected clients towards a new gateway.

4.17 Client's Disconnect Procedure

A client sends a DISCONNECT packet to the GW to indicate that it is about to close its Virtual Connection. After this point, the client is then required to establish a new Virtual Connection with the GW before it can exchange information with that GW again. Like MQTT, sending the DISCONNECT packet does not affect existing subscriptions and Will data. They are persistent until they are either expired or

explicitly un-subscribed, or deleted, or modified by the client, or if the client establishes a new Virtual Connection with the CleanStart flag set. The gateway acknowledges the receipt of the DISCONNECT packet by returning a DISCONNECT to the client.

A client may also receive an unsolicited DISCONNECT sent by the gateway. This may happen for example when the gateway, due to an error, cannot identify the client to which a received packet belongs. Upon receiving such a DISCONNECT packet a client should retry to setup the Virtual Connection again by sending a CONNECT packet to the gateway.

4.18 Client's Retransmission Procedure

All packets that are "unicasted" to the GW (i.e. sent using the GW's unicast address and not broadcasted) and for which a GW's reply is expected are supervised by a retry timer T_{retry} and a retry counter N_{retry}. The retry timer T_{retry} is started by the client when the packet is sent and stopped when the expected GW's reply is received. If T_{retry} times out and the expected GW's reply is not received, the client retransmits the packet. After N_{retry} retransmissions, the client aborts the procedure and assumes that the MQTT-SN gateway is no longer available. It should then try to connect to another gateway.

4.19 Sleeping clients

Sleeping clients are clients residing on (battery-operated) devices that want to save as much energy as possible. These devices need to enter a sleep mode whenever they are not active and will wake up whenever they have data to send or to receive. The server/gateway needs to be aware of the sleeping state of these clients and will buffer messages destined to them for later delivery when they wake up.

If a client wants to sleep, it sends a DISCONNECT packet which contains a sleep session expiry interval. The server/gateway acknowledges that packet with a DISCONNECT packet and considers the client for being in *asleep* state. The *asleep* state is supervised by the server/gateway with the indicated sleep session expiry interval. If the server/gateway does not receive any packet from the client for a period longer than the sleep session expiry interval, the server/gateway will consider that client as *lost* and - as with the keep alive procedure - activates for example the Will feature.

During the *asleep* state, packets that need to be sent to the client are buffered at the server/gateway. The gateway MUST buffer application messages of quality-of-service 1 & 2.

Informative comment

The gateway may *choose* to buffer messages of Quality-of-Service 0, whilst the client is sleeping and is within its session expiry interval.

The sleep timer is stopped when the server/gateway receives a PINGREQ from the client. Like the CONNECT packet, this PINGREQ packet contains the *Client Id*. The identified client is then in the *awake* state. If the server/gateway has buffered packets for the client, it will send these packets to the client, acknowledging the max-receive value sent in the PINGREQ packet. If the number of messages buffered on the gateway queue exceeds the value specified by the client in the max-receive field, the gateway shall send only the max-receive value number of messages, and cut short the AWAKE cycle, responding with a PINGRESP with a messages-left value of either the number of messages remaining in the gateway buffer or 0xFFFF (meaning undetermined number of messages greater than 0 remaining).

During the AWAKE state, for each packet the gateway sends to the client, the application messages' quality of service shall be honored, and a full packet interaction shall take place including all normative phases of acknowledgement, including any associated retransmission logic. If, during the delivery of

application messages from the gateway to the client, the gateway detects a timeout in the delivery, it should transition the client state to LOST and a DISCONNECT packet with error sent to the device.

The transfer of packets to the client is closed by the server/gateway by means of a PINGRESP packet, i.e. the server/gateway will consider the client as *asleep* and restart the sleep timer again after having sent the PINGRESP packet. If the server/gateway does not have any packets buffered for the client, it answers immediately with a PINGRESP packet, returns the client back to the *asleep* state, and restarts the sleep timer for that client.

After having sent the PINGREQ to the server/gateway, the client uses the “retransmission procedure” of section 3.18 to supervise the arrival of packets sent by the server/gateway, i.e. it restarts timer Tretry when it receives a packet other than a PINGRESP, and stops it when it receives a PINGRESP. The PINGREQ packet is retransmitted, and timer Tretry restarted when timer Tretry times out. To avoid a flattening of its battery due to excessive retransmission of the PINGREQ packet (e.g. if it loses the gateway), the client should limit the retransmission of the PINGREQ packet (e.g. by a retry counter) and go back to sleep when the limit is reached and it still does not receive a PINGRESP packet.

From the *asleep* or *awake* state, a client can return either to the *active* state by sending a CONNECT packet or to the *disconnected* state by sending a normal DISCONNECT packet (i.e. without session expiry interval field). The client can also modify its sleep configuration by sending a DISCONNECT packet with a new value of the session expiry interval.

Note that a sleeping client should go the *awake* state only if it just wants to check whether the server/gateway has any messages buffered for it and return as soon as possible to the *asleep* state without sending any packets to the server/gateway. Otherwise, it should return to the *active* state by sending a CONNECT packet to the server/gateway.

Topic Alias mappings exist only while a client is active and last for the entire session expiry interval of the active state. Therefore, the gateway must re-register any topic alias’s during the AWAKE state, which will last until the last PINGRESP is issued.

> **Informative comment**
>
> The gateway should attempt to make the best effort to reuse the same topic alias’ mappings that existed during any initial associated ACTIVE states.

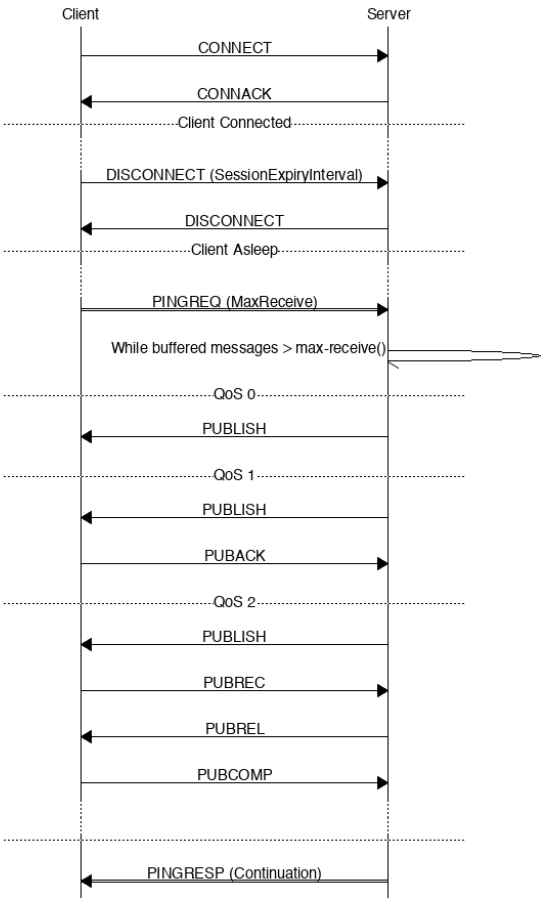


Figure 5: Awake ping packet flush

4.20 Authentication

Authentication involves the exchange of AUTH packets between the Client and the Server after the CONNECT and before the CONNACK packets.

To begin an authentication exchange, the Client sets the AUTH flag in the CONNECT packet. It then sends an AUTH packet with an Authentication Method. This specifies the authentication method to use. If the Server does not support the Authentication Method supplied by the Client, it MAY send a CONNACK with a Reason Code of 0x8C (Bad authentication method) or 0x87 (Not Authorized) and MUST close the Connection.

The Authentication Method is an agreement between the Client and Server about the meaning of the data sent in the Authentication Data and any of the other fields in CONNECT, and the exchanges and processing needed by the Client and Server to complete the authentication.

Informative comment

The Authentication Method is commonly a SASL mechanism, using such a registered name aids interchange. However, the Authentication Method is not constrained to using registered SASL mechanisms.

If the Authentication Method selected by the Client specifies that the Client sends data first, the Client SHOULD include an Authentication Data property in the AUTH packet. This property can be used to provide data as specified by the Authentication Method. The contents of the Authentication Data are defined by the authentication method.

If the Gateway requires additional information to complete the authentication, it can send an AUTH packet to the Client. This packet MUST contain a Reason Code of 0x18 (Continue

authentication). If the authentication method requires the Gateway to send authentication data to the Client, it is sent in the Authentication Data.

The Client responds to an AUTH packet from the Gateway by sending a further AUTH packet. This packet MUST contain a Reason Code of 0x18 (Continue authentication). If the authentication method requires the Client to send authentication data for the Gateway, it is sent in the Authentication Data.

The Client and Server exchange AUTH packets as needed until the Gateway accepts the authentication by sending a CONNACK with a Reason Code of 0. If the acceptance of the authentication requires data to be sent to the Client, it is sent in the Authentication Data.

The Client can close the Virtual Connection at any point in this process by sending a DISCONNECT packet. The Server can reject the authentication at any point in this process by sending a CONNACK with a Reason Code of 0x80 or above as described in section 4.13.

The implementation of authentication is OPTIONAL for both Clients and Gateways. If the Client does not include an Authentication Method in the CONNECT, the Gateway MUST NOT send an AUTH packet. If the Client does not set the Authentication Flag in the CONNECT, the Client MUST NOT send an AUTH packet to the Server.

If the Client does not set the Authentication Flag in the CONNECT packet, the Server SHOULD authenticate using some or all of the information in the CONNECT packet in conjunction with the underlying transport layer.

Informative example showing a user name and password authentication:

· Client to Gateway: CONNECT Authentication Flag=1 Authentication Data=client-first-data

· Client to Gateway: AUTH rc=0x01 Authentication Method="PLAIN" Authentication Data=client-first-data

· Gateway to Gateway CONNACK rc=0

Where client-first data is the content of the SASL PLAIN message as described in RFC 4616:

The mechanism consists of a single message, a string of [UTF-8] encoded [Unicode] characters, from the client to the server. The[UTF-8] client presents the authorization identity (identity to act as), followed by a NUL (U+0000) character, followed by the authentication identity (identity whose password will be used), followed by a NUL (U+0000) character, followed by the clear-text password. As with other SASL mechanisms, the client does not provide an authorization identity when it wishes the server to derive an identity from the credentials and use that as the authorization identity.

4.21 Retained Packets

If the RETAIN flag is set to 1 in a PUBLISH packet sent by a Client to a Server, the Server MUST replace any existing retained packet for this topic and store the Publish Data, so that it can be delivered to future subscribers whose subscriptions match its Topic Name. If the Publish Data contains zero bytes it is processed normally by the Server but any retained packet with the same topic name MUST be removed and any future subscribers for the topic will not receive a retained packet. A retained packet with Publish Data containing zero bytes MUST NOT be stored as a retained packet on the Server.

4.22 Optional Features

The ADVERTISE, SEARCHGW and GWINFO packet type support is optional. For instance, it is not required if the MQTT-SN Gateway is an Internet node reachable via a public IP address.

The Forwarder Encapsulation packet type support is optional. For instance, it is not required if the MQTT-SN Clients are able to reach directly a MQTT-SN Gateway.

The PROTECTION packet type support is optional. For instance, it is not required if the MQTT-SN Gateway and the MQTT-SN Clients interact over a secure communication channel, like DTLS or any communication channel assuring the authenticity and optionally the confidentiality protection.

5 Conformance

(**Note**: The OASIS TC Process requires that a specification approved by the TC at the Committee Specification Public Review Draft, Committee Specification or OASIS Standard level must include a separate section, listing a set of numbered conformance clauses, to which any implementation of the specification must adhere in order to claim conformance to the specification (or any optional portion thereof). This is done by listing the conformance clauses here.

For the definition of "conformance clause," see OASIS Defined Terms.

See "Guidelines to Writing Conformance Clauses": https://docs.oasis-open.org/templates/TCHandbook/ConformanceGuidelines.html.

Remove this note before submitting for publication.)

Appendix A. References

[Required section.]

This appendix contains the normative and informative references that are used in this document.

While any hyperlinks included in this appendix were valid at the time of publication, OASIS cannot guarantee their long-term validity.

Note: Any normative work cited in the body of the text as needed to implement the work product must be listed in the Normative References section below. Each reference to a separate document or artifact in this work must be listed here and must be identified as either a Normative or an Informative Reference.

For all References – Normative and Informative:

Recommended approach: Set up **[Reference]** label elements as "Bookmarks", then create hyperlinks to them within the document at locations from which the references are cited. Citations in the body of the text should be hyperlinked to the appropriate Reference entry, not directly to targets which are not a part of this Work Product.

The proper format for citation of technical work produced by an OASIS TC (whether Standards Track or Non-Standards Track) is:

[Citation Label]

Work Product title (italicized). Edited by Albert Alston, Bob Ballston, and Calvin Carlson. Approval date (DD Month YYYY). OASIS Stage Identifier and Revision Number (e.g., OASIS Committee Specification Draft 01). Principal URI (stage-specific URI, e.g., with stage component: somespec-v1.0-csd01.html). Latest stage: (static URI, without stage identifiers, used as a symbolic link to most recently published stage of this Version).

For example:

[OpenDoc-1.2]

Open Document Format for Office Applications (OpenDocument) Version 1.2. Edited by Patrick Durusau and Michael Brauer. 19 January 2011. OASIS Committee Specification Draft 07. https://docs.oasis-open.org/office/v1.2/csd07/OpenDocument-v1.2-csd07.html. Latest stage: https://docs.oasis-open.org/office/v1.2/OpenDocument-v1.2.html.

Reference sources:

For references to IETF RFCs, use the approved citation formats at:
https://docs.oasis-open.org/templates/ietf-rfc-list/ietf-rfc-list.html.
The most recent IETF RFC references are listed by the IETF at
https://www.rfc-editor.org/in-notes/rfc-ref.txt.
For references to W3C Recommendations, use the approved citation formats at:
https://docs.oasis-open.org/templates/w3c-recommendations-list/w3c-recommendations-list.html.
Remove this note before submitting for publication.

A.1 Normative References

The following documents are referenced in such a way that some or all of their content constitutes requirements of this document.

[RFC2119]
Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <https://www.rfc-editor.org/info/rfc2119>.

[RFC8174]
Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <https://www.rfc-editor.org/info/rfc8174>.

[Reference]
[Full reference citation]

[RFC2119]

Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997,

http://www.rfc-editor.org/info/rfc2119

[RFC3629]

Yergeau, F., "UTF-8, a transformation format of ISO 10646", STD 63, RFC 3629, DOI 10.17487/RFC3629, November 2003,

http://www.rfc-editor.org/info/rfc3629

[RFC6455]

Fette, I. and A. Melnikov, "The WebSocket Protocol", RFC 6455, DOI 10.17487/RFC6455, December 2011,

http://www.rfc-editor.org/info/rfc6455

[Unicode]

The Unicode Consortium. The Unicode Standard,

http://www.unicode.org/versions/latest/

A.2 Informative References

The following referenced documents are not required for the application of this document but may assist the reader with regard to a particular subject area.

[RFC3552]
Rescorla, E. and B. Korver, "Guidelines for Writing RFC Text on Security Considerations", BCP 72, RFC 3552, DOI 10.17487/RFC3552, July 2003, <https://www.rfc-editor.org/info/rfc3552>.

[Reference]
[Full reference citation]

Appendix B. Security and Privacy Considerations

[Optional section.]

Note: OASIS strongly recommends that Technical Committees consider issues that might affect safety, security, privacy, and/or data protection in implementations of their work products and document these for implementers and adopters. For some purposes, you may find it required, e.g. if you apply for IANA registration.

While it may not be immediately obvious how your work product might make systems vulnerable to attack, most work products, because they involve communications between systems, message formats, or system settings, open potential channels for exploit. For example, IETF [RFC3552] lists “eavesdropping, replay, message insertion, deletion, modification, and man-in-the-middle” as well as potential denial of service attacks as threats that must be considered and, if appropriate, addressed in IETF RFCs.

In addition to considering and describing foreseeable risks, this section should include guidance on how implementers and adopters can protect against these risks.

We encourage editors and TC members concerned with this subject to read Guidelines for Writing RFC Text on Security Considerations, IETF [RFC3552], for more information.

The MQTT SN protocol is optimized for implementation on low-cost, battery-powered devices with limited processing and storage resources. The capabilities are kept simple and the specification allows for partial implementations. Device identities are typically created at manufacturing, eliminating the need for special configuration at deployment. MQTT-SN can work in isolation from other networks or in conjunction with MQTT.

MQTT-SN Client and Gateway/Server implementations SHOULD offer Authentication and Authorization options. Furthermore, the confidentiality and authenticity of the MQTT-SN messages can be provided by the underlying transport or can be obtained by encapsulating the MQTT-SN messages into the PROTECTION packet.

Applications concerned with critical infrastructure, personally identifiable information, or other personal or sensitive information are strongly advised to use these security capabilities.

Industry specific security profiles

It is anticipated that the MQTT protocol will be designed into industry specific application profiles, each defining a threat model and the specific security mechanisms to be used to address these threats. Recommendations for specific security mechanisms will often be taken from existing works including:

[NISTCSF] NIST Cyber Security Framework

[NIST7628] NISTIR 7628 Guidelines for Smart Grid Cyber Security

[FIPS1402] Security Requirements for Cryptographic Modules (FIPS PUB 140-2)

[PCIDSS] PCI-DSS Payment Card Industry Data Security Standard

[NSAB] NSA Suite B Cryptography

Appendix C. Acknowledgments

[Required section.]

Note: A Work Product approved by the TC must include a list of people who participated in the development of the Work Product. This is generally done by collecting the list of names in this appendix. This list shall be initially compiled by the Chair, and any Member of the TC may add or remove their names from the list by request.

Remove these yellow notes before submitting for publication.

C.1 Special Thanks

Note: This is an optional subsection to call out contributions from TC members. If a TC wants to thank non-TC members then they should avoid using the term "contribution" and instead thank them for their "expertise" or "assistance".

Substantial contributions to this document from the following individuals are gratefully acknowledged:

[Participant Name, Affiliation | Individual Member]

C.2 Participants

Note: A TC can determine who they list here, however, Observers must not be listed. It is common practice for TCs to list everyone that was part of the TC during the creation of the document, but this is ultimately a TC decision on who they want to list and not list.

The following individuals were members of this Technical Committee during the creation of this document and their contributions are gratefully acknowledged:

[Participant Name, Affiliation | Individual Member]

Appendix D. Revision History

[Optional section.]

Revisions made since the initial stage of this numbered Version of this document may be tracked here.

Note: If revision tracking is handled in another system like github, provide a link to it instead of using this table, if desired. Remove this note before submitting for publication.

Revision	Date	Editor	Changes Made
WD-01	[27th February 2020]	[Andrew Banks]	[Merge Initial Document and Input Specification]
WD-02	[4th April 2020]	[Andrew Banks] [Rahul Gupta]	[Terminology, DataTypes, CONNECT packet] [Specification Diagrams]
WD-05	[21st February 2021]	[Simon Johnson]	[Packet Diagrams, Bit Tables, Field Definitions]
WD-06	[10th March 2021]	[Simon Johnson]	[Sleeping client operational behavior, Terminology changes, 13 JIRA resolutions added to specification, Section numbering changes]
WD-07	[15th March 2021]	[Simon Johnson]	[Added 4 byte (32 bit) integer description]
WD-08	[26th March 2021]	[Simon Johnson]	[Added max packet size to CONNECT, Added Session Expiry Interval to CONNACK, Removed ZigBee references, Removed capabilities flag from CONNECT, AUTH packet added along with Authentication operational behavior. Standardized page margins]
WD-09	[05th May 2021]	[Simon Johnson]	[Added long topic type to topicIdTypes, updated PUBLISH to accommodate new topic type, added topic type matrix]
WD-10	[October 2021]	[Simon Johnson]	[Document format aligned with core specification, removal of introduction, addition of packet ID table, adding error code]
WD-11	[October 2021]	[Simon Johnson]	[MQTT-SN Architecture moved into operational behavior, removal of variable integer definition, addition of session state section, normative comments added to sleeping client operational behaviour]
WD-12	[November 2021]	[Andrew Banks]	Rework 1.5 Background
WD-13	[November 2021]	[Simon Johnson]	[Move Authentication and Retained messages into operational behavior, rationalized tables and figures, separated packet definitions of similar structures into distinct sections.]

WD-14	[Decmeber 2021]	[Simon Johnson]	[First implementation attempt, Fixed table references, Fixed PingResp packet]
WD-15	[December 2021]	[Simon Johnson]	[Tara added as editor, return code additions]
WD-15	[February 2022]	[Tara Walker]	Changed Return Code nomenclature to be more consistent w/5.0. Added Reason Codes to each control packet type
WD-16	March 2022	[Tara Walker]	Updated WILL*Types to correct Packet Type. Added Global Flags Table to Section 2. Updated each Control Packet Flags in Section 3 adding missing Flag Sections. Formatting: Auto update of Table numbering, Auto update of WD Revision numbering for footer.
WD-17	April 2022	[Simon Johnson]	Updated use of topic name and topic filter to be aligned with MQTT 5. Topic alias becomes topic alias type. Added quality of service protocol flow as it differed to MQTT 5 (inflight). Conformance references removed as these will need to be wholly owned OR externally referenced.
WD-18	June 2022	[Tara E. Walker]	Updated items based upon the feedback from Alex Kritikos.
WD-19	August 2022	[Simon Johnson]	Remove change tracking as document was becoming unworkable.
WD-20	September 2022	[Simon Johnson]	Integrate feedback from committee meeting relating to the work by Miroslav Prymek. Added resolution of CONNACK session present per MQTT 585
WD-21	October 2022	[Simon Johnson]	Client States section added to describe the 5 states. Updated the state transition diagram to accommodate new disconnect field and new transitions between Awake -> Lost and Asleep -> Disconnected. Security section added. Figure 2 – MQTT-SN Architecture diagram updated. Font updated to Arial from bespoke font. QoS -1 – Section added to the QoS chapter (NOTE: updated text to allow for bi-directional -1 PUBLISHING). Introduction of Exponential backoff algorithm. Applied issue issue 587 (max messages set in CONNECT flags).
WD-22	November 2022	[Simon Johnson]	Integrate MQTT 591 (sleep behavior)

			Replace instances of “return code” to “reason code” PINGREQ timeout aligned with Tretry (15 seconds) from the ill defined “reasonable amount of time” Exponential Algo fix (using the factor n assuming it was the product!) Client Identifier size clarification. Publish variants added; distinguish variant based on QoS field to save 2 bytes for single flight PUBLISH packets. Incorporated B4. Into retry timer.
WD-23	December 2022	[Simon Johnson]	CONNECT Client Identifier Informative and Normative définition update. CONNACK Client Identifier Informative and Normative définition update. CONNACK reason codes updated. KeepAlive boundary specified removing 0 as an option per the committee call. Added Session Expiry “reasonable” setting statement. Added sequence diagrams for CONNECT, CONNECT with WILL, CONNECT with AUTH. Network Connection Section (IANA Omitted but we need to add this to agenda)
WD-24	December 2022	[Simon Johnson, Davide Lenzarini, Ian Craggs]	Removal of Network Connection references. Modified PUBLISH -1 & 0 tables to remove topic length field Modified PUBLISH 1 & 2 tables to remove topic length field Changed Data field description on the above Updated sleeping device section Ensured the references to the Packet Length and type section was consistent in all packet types.
WD-25	January 2023	[Simon Johnson]	Broken out PUBLISH -1 into its own packet type Disconnect flags field moved and added existence flags for optional fields Introduction titles changed to better sign post where the inforlmation resides in the document
WD-26	May 2023	[Simon Johnson,	Backwards compatible PUBLISH -1, new OOB Publish message to repace it. Removal of security section to allow to rewrite.

		Davide Lenzarini]	
WD-27	November 2023	[Simon Johnson, Davide Lenzarini]	Network&Trasport Layer chapter updated to define the impact of lower layers features on the MQTT-SN protocol. Replaced the term MQTT-SN “connection” with the term “Virtual Connection”.

Appendix E. Implementation Notes

E.1 Support of QoS Level -1 and OUT OF BAND

Because PUBLISH packets with QoS level -1 and OUT OF BAND could be sent at any time by clients (even with no Virtual Connection setup) a transparent GW needs to maintain for those packets a dedicated MQTT connection with the server. An aggregating or hybrid GW may use any aggregating MQTT connection to forward those packets to the server.

E.2 “Best practice” values for timers and counters

Table 30 shows the “best practice” values for the timers and counters defined in this specification.

Timer/Counter	Recommended value
T_{ADV}	greater than 15 minutes
N_{ADV}	2 -3
$T_{SEARCHGW}$	5 seconds
T_{GWINFO}	5 seconds
T_{WAIT}	greater than 5 minutes
T_{retry}	Implement B4 with a starting value of 1 second after an initial wait period of 5 seconds. So first retry will be ~6 seconds.
N_{retry}	3 – 5

Table 30: “Best practice” values for timers and counters

The “tolerance” of the sleep and keep-alive timers at the server/gateway depends on the values indicated by the clients. For example, the timer values should be 10% higher than the indicated values for periods larger than 1 minute, and 50% higher if less.

E.3 Mapping of Topic Alias to Topic Names and Topic Filters

It is strongly recommended that in the gateway the mapping table between topic alias and topic names is implemented per client (and not by a single shared pool between all clients), to reduce the risk of an incorrect topic alias from a client matching another client’s valid topic, and thus causing a publication to the wrong topic, which could potentially have disastrous consequences.

E.4 Exponential Backoff

The following error handling strategy should be used for networked devices to avoid overwhelming recipient network entities whilst providing for efficient reestablishment handling. The client shall periodically retry a failed packet with increasing delays between attempts, constrained by a max retry time and interleaved with a suitable seed of randomness.

Algorithm:

An exponential backoff algorithm retries requests exponentially, increasing the waiting time between retries up to a maximum backoff time. For example:

1. Initial packet sent.

2. If the operation fails, wait 1000 + (random number) milliseconds (ran) and retry the operation.
3. If the operation fails, wait 2000 + (random number) milliseconds (ran) and retry the operation.
4. If the operation fails, wait 4000 + (random number) milliseconds (ran) and retry the operation.
5. Continued, up to a maximum backoff (max) time.
6. Continue waiting and retrying up to some maximum number of retries, but do not increase the wait period between retries.

The wait time is min(((2^n * sf) + ran), max) with n incremented by 1 for each iteration (or operation) and the scaling factor (sf) being set to some reasonable value (suggested 1000 as in the example above).

The random number helps to avoid cases where many clients are synchronized by some situation, and all retry at once. The value of random number ran is recalculated after each retry. The random number (ran) should be no larger than the scaling factor (sf).

Appendix F. Notices

[Required section. Do not change.]

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