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Related work:

This specification is related to:

- *MQTT and the NIST Cybersecurity Framework Version 1.0*. Edited by Geoff Brown and Louis-Philippe Lamoureux. Latest version: <http://docs.oasis-open.org/mqtt/mqtt-nist-cybersecurity/v1.0/mqtt-nist-cybersecurity-v1.0.html>.

Abstract:

MQTT is a Client Server publish/subscribe messaging transport protocol. It is light weight, open, simple, and designed so as to be easy to implement. These characteristics make it ideal for use in many situations, including constrained environments such as for communication in Machine to Machine (M2M) and Internet of Things (IoT) contexts where a small code footprint is required and/or network bandwidth is at a premium.

The protocol runs over TCP/IP, or over other network protocols that provide ordered, lossless, bi-directional connections. Its features include:

- Use of the publish/subscribe message pattern which provides one-to-many message distribution and decoupling of applications.
- A messaging transport that is agnostic to the content of the payload.
- Three qualities of service for message delivery:

- "At most once", where messages are delivered according to the best efforts of the operating environment. Message loss can occur. This level could be used, for example, with ambient sensor data where it does not matter if an individual reading is lost as the next one will be published soon after.
- "At least once", where messages are assured to arrive but duplicates can occur.
- "Exactly once", where message are assured to arrive exactly once. This level could be used, for example, with billing systems where duplicate or lost messages could lead to incorrect charges being applied.
- A small transport overhead and protocol exchanges minimized to reduce network traffic.
- A mechanism to notify interested parties when an abnormal disconnection occurs.

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1 Introduction

1.1 Organization of MQTT

This specification is split into seven chapters:

- [Chapter 1 - Introduction](#)
- [Chapter 2 - MQTT Control Packet format](#)
- [Chapter 3 - MQTT Control Packets](#)
- [Chapter 4 - Operational behavior](#)
- [Chapter 5 - Security](#)
- [Chapter 6 - Using WebSocket as a network transport](#)
- [Chapter 7 - Conformance Targets](#)

1.2 Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this specification are to be interpreted as described in IETF RFC 2119 [[RFC2119](#)].

Network Connection:

A construct provided by the underlying transport protocol that is being used by MQTT.

- It connects the Client to the Server.
- It provides the means to send an ordered, lossless, stream of bytes in both directions.

For examples see Section 4.2.

Application Message:

The data carried by the MQTT protocol across the network for the application. When Application Messages are transported by MQTT they have an associated Quality of Service and a Topic Name.

Client:

A program or device that uses MQTT. A Client always establishes the Network Connection to the Server. It can

- Publish Application Messages that other Clients might be interested in.
- Subscribe to request Application Messages that it is interested in receiving.
- Unsubscribe to remove a request for Application Messages.
- Disconnect from the Server.

Server:

A program or device that acts as an intermediary between Clients which publish Application Messages and Clients which have made Subscriptions. A Server

- Accepts Network Connections from Clients.
- Accepts Application Messages published by Clients.

- 35 • Processes Subscribe and Unsubscribe requests from Clients.
36 • Forwards Application Messages that match Client Subscriptions.

37 **Subscription:**

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

41 **Topic Name:**

42 The label attached to an Application Message which is matched against the Subscriptions known to the
43 Server. The Server sends a copy of the Application Message to each Client that has a matching
44 Subscription.

45 **Topic Filter:**

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

48 **Session:**

49 A stateful interaction between a Client and a Server. Some Sessions last only as long as the Network
50 Connection, others can span multiple consecutive Network Connections between a Client and a Server.

51 **MQTT Control Packet:**

52 A packet of information that is sent across the Network Connection. The MQTT specification defines
53 fourteen different types of Control Packet, one of which (the PUBLISH packet) is used to convey
54 Application Messages.

55 **1.3 Normative references**

56 **[RFC2119]**

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58 *1997.*

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66 *Dierks, T. and E. Rescorla, "The Transport Layer Security (TLS) Protocol Version 1.2", RFC 5246, August*
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77 **1.4 Non normative references**

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94 **[IEEE 802.1AR]**

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100 *1: General*

101 http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=56425

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103 **[MQTT NIST]**

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105 *Cybersecurity*

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108 **[MQTTV31]**

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111

112 **[NISTCSF]**

113 *Improving Critical Infrastructure Cybersecurity Executive Order 13636*

114 <http://www.nist.gov/itl/upload/preliminary-cybersecurity-framework.pdf>

115

116 **[NIST7628]**

117 *NISTIR 7628 Guidelines for Smart Grid Cyber Security*
118 http://www.nist.gov/smartgrid/upload/nistir-7628_total.pdf

119

120 **[NSAB]**

121 *NSA Suite B Cryptography*
122 http://www.nsa.gov/ia/programs/suiteb_cryptography/

123

124 **[PCIDSS]**

125 *PCI-DSS Payment Card Industry Data Security Standard*
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155 <http://www.ietf.org/rfc/rfc6749.txt>

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157 [RFC6960]

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159 *Key Infrastructure Online Certificate Status Protocol - OCSP", RFC 6960, June 2013.*

160 <http://www.ietf.org/rfc/rfc6960.txt>

161

162 [SARBANES]

163 *Sarbanes-Oxley Act of 2002.*

164 <http://www.gpo.gov/fdsys/pkg/PLAW-107publ204/html/PLAW-107publ204.htm>

165

166 [USEUSAFEHARB]

167 *U.S.-EU Safe Harbor*

168 http://export.gov/safeharbor/eu/eg_main_018365.asp

169 1.5 Data representations

170 1.5.1 Bits

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

173 1.5.2 Integer data values

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

177 1.5.3 UTF-8 encoded strings

178 Text fields in the Control Packets described later are encoded as UTF-8 strings. UTF-8 [RFC3629] is an
179 efficient encoding of Unicode [Unicode] characters that optimizes the encoding of ASCII characters in
180 support of text-based communications.

181

182 Each of these strings is prefixed with a two byte length field that gives the number of bytes in a UTF-8
183 encoded string itself, as illustrated in Figure 1.1 Structure of UTF-8 encoded strings below. Consequently
184 there is a limit on the size of a string that can be passed in one of these UTF-8 encoded string
185 components; you cannot use a string that would encode to more than 65535 bytes.

186

187 Unless stated otherwise all UTF-8 encoded strings can have any length in the range 0 to 65535 bytes.

188 Figure 1.1 Structure of UTF-8 encoded strings

Bit	7	6	5	4	3	2	1	0
byte 1	String length MSB							
byte 2	String length LSB							
byte 3	UTF-8 Encoded Character Data, if length > 0.							

189
 190 The character data in a UTF-8 encoded string MUST be well-formed UTF-8 as defined by the Unicode
 191 specification [Unicode] and restated in RFC 3629 [RFC3629]. In particular this data MUST NOT include
 192 encodings of code points between U+D800 and U+DFFF. If a Server or Client receives a Control Packet
 193 containing ill-formed UTF-8 it MUST close the Network Connection [MQTT-1.5.3-1].

194
 195 A UTF-8 encoded string MUST NOT include an encoding of the null character U+0000. If a receiver
 196 (Server or Client) receives a Control Packet containing U+0000 it MUST close the Network
 197 Connection [MQTT-1.5.3-2].
 198

199 The data SHOULD NOT include encodings of the Unicode [Unicode] code points listed below. If a
 200 receiver (Server or Client) receives a Control Packet containing any of them it MAY close the Network
 201 Connection:

- 202
- 203 U+0001..U+001F control characters
- 204 U+007F..U+009F control characters

205 Code points defined in the Unicode specification [Unicode] to be non-characters (for example U+0FFFF)

206
 207 A UTF-8 encoded sequence 0xEF 0xBB 0xBF is always to be interpreted to mean U+FEFF ("ZERO
 208 WIDTH NO-BREAK SPACE") wherever it appears in a string and MUST NOT be skipped over or stripped
 209 off by a packet receiver [MQTT-1.5.3-3].

210

211 1.5.3.1 Non normative example

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

215

216 **Figure 1.2 UTF-8 encoded string non normative example**

Bit	7	6	5	4	3	2	1	0
byte 1	String Length MSB (0x00)							
	0	0	0	0	0	0	0	0
byte 2	String Length LSB (0x05)							
	0	0	0	0	0	1	0	1
byte 3	'A' (0x41)							
	0	1	0	0	0	0	0	1
byte 4	(0xF0)							
	1	1	1	1	0	0	0	0
byte 5	(0xAA)							
	1	0	1	0	1	0	1	0
byte 6	(0x9B)							
	1	0	0	1	1	0	1	1

byte 7	(0x94)							
	1	0	0	1	0	1	0	0

217

218 **1.6 Editing conventions**

219 Text highlighted in **Yellow** within this specification identifies conformance statements. Each conformance
 220 statement has been assigned a reference in the format **[MQTT-x.x.x-y]**.

2 MQTT Control Packet format

2.1 Structure of an MQTT Control Packet

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

An MQTT Control Packet consists of up to three parts, always in the following order as illustrated in [Figure 2.1 - Structure of an MQTT Control Packet](#).

Figure 2.1 – Structure of an MQTT Control Packet

Fixed header, present in all MQTT Control Packets
Variable header, present in some MQTT Control Packets
Payload, present in some MQTT Control Packets

2.2 Fixed header

Each MQTT Control Packet contains a fixed header. [Figure 2.2 - Fixed header format](#) illustrates the fixed header format.

Figure 2.2 - Fixed header format

Bit	7	6	5	4	3	2	1	0
byte 1	MQTT Control Packet type				Flags specific to each MQTT Control Packet type			
byte 2...	Remaining Length							

2.2.1 MQTT Control Packet type

Position: byte 1, bits 7-4.

Represented as a 4-bit unsigned value, the values are listed in [Table 2.1 - Control packet types](#).

Table 2.1 - Control packet types

Name	Value	Direction of flow	Description
Reserved	0	Forbidden	Reserved
CONNECT	1	Client to Server	Client request to connect to Server
CONNACK	2	Server to Client	Connect acknowledgment
PUBLISH	3	Client to Server or	Publish message

		Server to Client	
PUBACK	4	Client to Server or Server to Client	Publish acknowledgment
PUBREC	5	Client to Server or Server to Client	Publish received (assured delivery part 1)
PUBREL	6	Client to Server or Server to Client	Publish release (assured delivery part 2)
PUBCOMP	7	Client to Server or Server to Client	Publish complete (assured delivery part 3)
SUBSCRIBE	8	Client to Server	Client subscribe request
SUBACK	9	Server to Client	Subscribe acknowledgment
UNSUBSCRIBE	10	Client to Server	Unsubscribe request
UNSUBACK	11	Server to Client	Unsubscribe acknowledgment
PINGREQ	12	Client to Server	PING request
PINGRESP	13	Server to Client	PING response
DISCONNECT	14	Client to Server	Client is disconnecting
Reserved	15	Forbidden	Reserved

240

241 2.2.2 Flags

242 The remaining bits [3-0] of byte 1 in the fixed header contain flags specific to each MQTT Control Packet
 243 type as listed in the [Table 2.2 - Flag Bits](#) below. Where a flag bit is marked as “Reserved” in [Table 2.2 -](#)
 244 [Flag Bits](#), it is reserved for future use and MUST be set to the value listed in that table [\[MQTT-2.2.2-1\]](#). If
 245 invalid flags are received, the receiver MUST close the Network Connection [\[MQTT-2.2.2-2\]](#). See Section
 246 4.8 for details about handling errors.

247

248 **Table 2.2 - Flag Bits**

Control Packet	Fixed header flags	Bit 3	Bit 2	Bit 1	Bit 0
CONNECT	Reserved	0	0	0	0
CONNACK	Reserved	0	0	0	0
PUBLISH	Used in MQTT 3.1.1	DUP ¹	QoS ²	QoS ²	RETAIN ³
PUBACK	Reserved	0	0	0	0
PUBREC	Reserved	0	0	0	0

PUBREL	Reserved	0	0	1	0
PUBCOMP	Reserved	0	0	0	0
SUBSCRIBE	Reserved	0	0	1	0
SUBACK	Reserved	0	0	0	0
UNSUBSCRIBE	Reserved	0	0	1	0
UNSUBACK	Reserved	0	0	0	0
PINGREQ	Reserved	0	0	0	0
PINGRESP	Reserved	0	0	0	0
DISCONNECT	Reserved	0	0	0	0

249

250 DUP¹ = Duplicate delivery of a PUBLISH Control Packet

251 QoS² = PUBLISH Quality of Service

252 RETAIN³ = PUBLISH Retain flag

253 See Section 3.3.1 for a description of the DUP, QoS, and RETAIN flags in the PUBLISH Control Packet.

254 2.2.3 Remaining Length

255 **Position:** starts at byte 2.

256

257 The Remaining Length is the number of bytes remaining within the current packet, including data in the
 258 variable header and the payload. The Remaining Length does not include the bytes used to encode the
 259 Remaining Length.

260

261 The Remaining Length is encoded using a variable length encoding scheme which uses a single byte for
 262 values up to 127. Larger values are handled as follows. The least significant seven bits of each byte
 263 encode the data, and the most significant bit is used to indicate that there are following bytes in the
 264 representation. Thus each byte encodes 128 values and a "continuation bit". The maximum number of
 265 bytes in the Remaining Length field is four.

266

267 **Non normative comment**

268 For example, the number 64 decimal is encoded as a single byte, decimal value 64, hexadecimal
 269 0x40. The number 321 decimal (= 65 + 2*128) is encoded as two bytes, least significant first. The
 270 first byte is 65+128 = 193. Note that the top bit is set to indicate at least one following byte. The
 271 second byte is 2.

272

273 **Non normative comment**

274 This allows applications to send Control Packets of size up to 268,435,455 (256 MB). The
 275 representation of this number on the wire is: 0xFF, 0xFF, 0xFF, 0x7F.

276 [Table 2.4](#) shows the Remaining Length values represented by increasing numbers of bytes.

277

278 **Table 2.4 Size of Remaining Length field**

Digits	From	To
--------	------	----

1	0 (0x00)	127 (0x7F)
2	128 (0x80, 0x01)	16 383 (0xFF, 0x7F)
3	16 384 (0x80, 0x80, 0x01)	2 097 151 (0xFF, 0xFF, 0x7F)
4	2 097 152 (0x80, 0x80, 0x80, 0x01)	268 435 455 (0xFF, 0xFF, 0xFF, 0x7F)

279

280

Non normative comment

281 The algorithm for encoding a non negative integer (X) into the variable length encoding scheme is
282 as follows:

```
283     do
284         encodedByte = X MOD 128
285         X = X DIV 128
286         // if there are more data to encode, set the top bit of this byte
287         if ( X > 0 )
288             encodedByte = encodedByte OR 128
289         endif
290         'output' encodedByte
291     while ( X > 0 )
```

292

293 Where MOD is the modulo operator (% in C), DIV is integer division (/ in C), and OR is bit-wise or
294 (| in C).

295

Non normative comment

297 The algorithm for decoding the Remaining Length field is as follows:

298

```
299     multiplier = 1
300     value = 0
301     do
302         encodedByte = 'next byte from stream'
303         value += (encodedByte AND 127) * multiplier
304         multiplier *= 128
305         if (multiplier > 128*128*128)
306             throw Error(Malformed Remaining Length)
307     while ((encodedByte AND 128) != 0)
```

308

309 where AND is the bit-wise and operator (& in C).

310

311 When this algorithm terminates, value contains the Remaining Length value.

312 2.3 Variable header

313 Some types of MQTT Control Packets contain a variable header component. It resides between the fixed
314 header and the payload. The content of the variable header varies depending on the Packet type. The
315 Packet Identifier field of variable header is common in several packet types.

316 **2.3.1 Packet Identifier**

317 **Figure 2.3 - Packet Identifier bytes**

Bit	7	6	5	4	3	2	1	0
byte 1	Packet Identifier MSB							
byte 2	Packet Identifier LSB							

318

319 The variable header component of many of the Control Packet types includes a 2 byte Packet Identifier
 320 field. These Control Packets are PUBLISH (where QoS > 0), PUBACK, PUBREC, PUBREL, PUBCOMP,
 321 SUBSCRIBE, SUBACK, UNSUBSCRIBE, UNSUBACK.

322

323 SUBSCRIBE, UNSUBSCRIBE, and PUBLISH (in cases where QoS > 0) Control Packets MUST contain a
 324 non-zero 16-bit Packet Identifier [MQTT-2.3.1-1]. Each time a Client sends a new packet of one of these
 325 types it MUST assign it a currently unused Packet Identifier [MQTT-2.3.1-2]. If a Client re-sends a
 326 particular Control Packet, then it MUST use the same Packet Identifier in subsequent re-sends of that
 327 packet. The Packet Identifier becomes available for reuse after the Client has processed the
 328 corresponding acknowledgement packet. In the case of a QoS 1 PUBLISH this is the corresponding
 329 PUBACK; in the case of QoS 2 it is PUBCOMP. For SUBSCRIBE or UNSUBSCRIBE it is the
 330 corresponding SUBACK or UNSUBACK [MQTT-2.3.1-3]. The same conditions apply to a Server when it
 331 sends a PUBLISH with QoS > 0 [MQTT-2.3.1-4].

332

333 A PUBLISH Packet MUST NOT contain a Packet Identifier if its QoS value is set to 0 [MQTT-2.3.1-5].

334

335 A PUBACK, PUBREC or PUBREL Packet MUST contain the same Packet Identifier as the PUBLISH
 336 Packet that was originally sent [MQTT-2.3.1-6]. Similarly SUBACK and UNSUBACK MUST contain the
 337 Packet Identifier that was used in the corresponding SUBSCRIBE and UNSUBSCRIBE Packet
 338 respectively [MQTT-2.3.1-7].

339

340 Control Packets that require a Packet Identifier are listed in [Table 2.5 - Control Packets that contain a](#)
 341 [Packet Identifier](#).

342 **Table 2.5 - Control Packets that contain a Packet Identifier**

Control Packet	Packet Identifier field
CONNECT	NO
CONNACK	NO
PUBLISH	YES (If QoS > 0)
PUBACK	YES
PUBREC	YES
PUBREL	YES
PUBCOMP	YES
SUBSCRIBE	YES
SUBACK	YES

UNSUBSCRIBE	YES
UNSUBACK	YES
PINGREQ	NO
PINGRESP	NO
DISCONNECT	NO

343

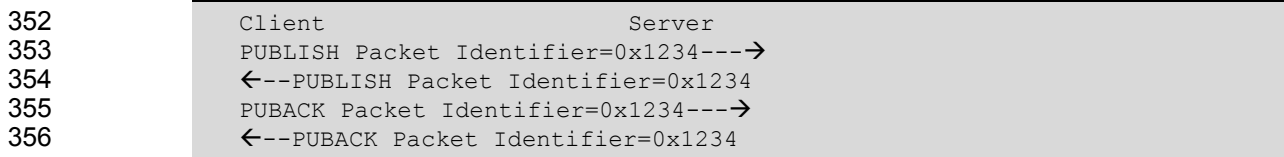
344 The Client and Server assign Packet Identifiers independently of each other. As a result, Client Server
 345 pairs can participate in concurrent message exchanges using the same Packet Identifiers.

346

347 **Non normative comment**

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

351



357 **2.4 Payload**

358 Some MQTT Control Packets contain a payload as the final part of the packet, as described in Chapter 3.
 359 In the case of the PUBLISH packet this is the Application Message. [Table 2.6 - Control Packets that
 360 contain a Payload](#) lists the Control Packets that require a Payload.

361 **Table 2.6 - Control Packets that contain a Payload**

Control Packet	Payload
CONNECT	Required
CONNACK	None
PUBLISH	Optional
PUBACK	None
PUBREC	None
PUBREL	None
PUBCOMP	None
SUBSCRIBE	Required
SUBACK	Required
UNSUBSCRIBE	Required
UNSUBACK	None
PINGREQ	None

PINGRESP	None
DISCONNECT	None

362

3 MQTT Control Packets

3.1 CONNECT – Client requests a connection to a Server

After a Network Connection is established by a Client to a Server, the first Packet sent from the Client to the Server MUST be a CONNECT Packet [MQTT-3.1.0-1].

A Client can only send the CONNECT Packet once over a Network Connection. The Server MUST process a second CONNECT Packet sent from a Client as a protocol violation and disconnect the Client [MQTT-3.1.0-2]. See section 4.8 for information about handling errors.

The payload contains one or more encoded fields. They specify a unique Client identifier for the Client, a Will topic, Will Message, User Name and Password. All but the Client identifier are optional and their presence is determined based on flags in the variable header.

3.1.1 Fixed header

Figure 3.1 – CONNECT Packet fixed header

Bit	7	6	5	4	3	2	1	0
byte 1	MQTT Control Packet type (1)				Reserved			
	0	0	0	1	0	0	0	0
byte 2...	Remaining Length							

Remaining Length field
Remaining Length is the length of the variable header (10 bytes) plus the length of the Payload. It is encoded in the manner described in section 2.2.3.

3.1.2 Variable header

The variable header for the CONNECT Packet consists of four fields in the following order: Protocol Name, Protocol Level, Connect Flags, and Keep Alive.

3.1.2.1 Protocol Name

Figure 3.2 - Protocol Name bytes

	Description	7	6	5	4	3	2	1	0
Protocol Name									
byte 1	Length MSB (0)	0	0	0	0	0	0	0	0
byte 2	Length LSB (4)	0	0	0	0	0	1	0	0
byte 3	'M'	0	1	0	0	1	1	0	1
byte 4	'Q'	0	1	0	1	0	0	0	1
byte 5	'T'	0	1	0	1	0	1	0	0

byte 6	'T'	0	1	0	1	0	1	0	0
--------	-----	---	---	---	---	---	---	---	---

386

387 The Protocol Name is a UTF-8 encoded string that represents the protocol name "MQTT", capitalized as
 388 shown. The string, its offset and length will not be changed by future versions of the MQTT specification.

389

390 If the protocol name is incorrect the Server MAY disconnect the Client, or it MAY continue processing the
 391 CONNECT packet in accordance with some other specification. In the latter case, the Server MUST NOT
 392 continue to process the CONNECT packet in line with this specification [MQTT-3.1.2-1].

393

Non normative comment

394

395 Packet inspectors, such as firewalls, could use the Protocol Name to identify MQTT traffic.

396

3.1.2.2 Protocol Level

396

Figure 3.3 - Protocol Level byte

397

	Description	7	6	5	4	3	2	1	0
Protocol Level									
byte 7	Level(4)	0	0	0	0	0	1	0	0

398

399 The 8 bit unsigned value that represents the revision level of the protocol used by the Client. The value of
 400 the Protocol Level field for the version 3.1.1 of the protocol is 4 (0x04). The Server MUST respond to the
 401 CONNECT Packet with a CONNACK return code 0x01 (unacceptable protocol level) and then disconnect
 402 the Client if the Protocol Level is not supported by the Server [MQTT-3.1.2-2].

3.1.2.3 Connect Flags

403

404 The Connect Flags byte contains a number of parameters specifying the behavior of the MQTT
 405 connection. It also indicates the presence or absence of fields in the payload.

404
405

Figure 3.4 - Connect Flag bits

406

Bit	7	6	5	4	3	2	1	0
	User Name Flag	Password Flag	Will Retain	Will QoS		Will Flag	Clean Session	Reserved
byte 8	X	X	X	X	X	X	X	0

407 The Server MUST validate that the reserved flag in the CONNECT Control Packet is set to zero and
 408 disconnect the Client if it is not zero [MQTT-3.1.2-3].

3.1.2.4 Clean Session

409

Position: bit 1 of the Connect Flags byte.

410

411 This bit specifies the handling of the Session state.

411

412

413 The Client and Server can store Session state to enable reliable messaging to continue across a
 414 sequence of Network Connections. This bit is used to control the lifetime of the Session state.

414

415

416

417 If CleanSession is set to 0, the Server MUST resume communications with the Client based on state from
418 the current Session (as identified by the Client identifier). If there is no Session associated with the Client
419 identifier the Server MUST create a new Session. The Client and Server MUST store the Session after
420 the Client and Server are disconnected [MQTT-3.1.2-4]. After the disconnection of a Session that had
421 CleanSession set to 0, the Server MUST store further QoS 1 and QoS 2 messages that match any
422 subscriptions that the client had at the time of disconnection as part of the Session state [MQTT-3.1.2-5].
423 It MAY also store QoS 0 messages that meet the same criteria.

424
425 If CleanSession is set to 1, the Client and Server MUST discard any previous Session and start a new
426 one. This Session lasts as long as the Network Connection. State data associated with this Session
427 MUST NOT be reused in any subsequent Session [MQTT-3.1.2-6].

428
429 The Session state in the Client consists of:

- 430 • QoS 1 and QoS 2 messages which have been sent to the Server, but have not been completely
431 acknowledged.
- 432 • QoS 2 messages which have been received from the Server, but have not been completely
433 acknowledged.

434
435 The Session state in the Server consists of:

- 436 • The existence of a Session, even if the rest of the Session state is empty.
- 437 • The Client's subscriptions.
- 438 • QoS 1 and QoS 2 messages which have been sent to the Client, but have not been completely
439 acknowledged.
- 440 • QoS 1 and QoS 2 messages pending transmission to the Client.
- 441 • QoS 2 messages which have been received from the Client, but have not been completely
442 acknowledged.
- 443 • Optionally, QoS 0 messages pending transmission to the Client.

444
445 Retained messages do not form part of the Session state in the Server, they MUST NOT be deleted when
446 the Session ends [MQTT-3.1.2.7].

447
448 See Section 4.1 for details and limitations of stored state.

449
450 When CleanSession is set to 1 the Client and Server need not process the deletion of state atomically.

451
452 **Non normative comment**

453 To ensure consistent state in the event of a failure, the Client should repeat its attempts to
454 connect with CleanSession set to 1, until it connects successfully.

455
456 **Non normative comment**

457 Typically, a Client will always connect using CleanSession set to 0 or CleanSession set to 1 and
458 not swap between the two values. The choice will depend on the application. A Client using
459 CleanSession set to 1 will not receive old Application Messages and has to subscribe afresh to
460 any topics that it is interested in each time it connects. A Client using CleanSession set to 0 will
461 receive all QoS 1 or QoS 2 messages that were published while it was disconnected. Hence, to
462 ensure that you do not lose messages while disconnected, use QoS 1 or QoS 2 with
463 CleanSession set to 0.

464
465
466
467
468
469
470

Non normative comment

When a Client connects with CleanSession set to 0, it is requesting that the Server maintain its MQTT session state after it disconnects. Clients should only connect with CleanSession set to 0, if they intend to reconnect to the Server at some later point in time. When a Client has determined that it has no further use for the session it should do a final connect with CleanSession set to 1 and then disconnect.

471 3.1.2.5 Will Flag

472 **Position:** bit 2 of the Connect Flags.

473
474 If the Will Flag is set to 1 this indicates that, if the Connect request is accepted, a Will Message MUST be
475 stored on the Server and associated with the Network Connection. The Will Message MUST be published
476 when the Network Connection is subsequently closed unless the Will Message has been deleted by the
477 Server on receipt of a DISCONNECT Packet [MQTT-3.1.2-8].

478 Situations in which the Will Message is published include, but are not limited to:

- 479 • An I/O error or network failure detected by the Server.
- 480 • The Client fails to communicate within the Keep Alive time.
- 481 • The Client closes the Network Connection without first sending a DISCONNECT Packet.
- 482 • The Server closes the Network Connection because of a protocol error.

483
484 If the Will Flag is set to 1, the Will QoS and Will Retain fields in the Connect Flags will be used by the
485 Server, and the Will Topic and Will Message fields MUST be present in the payload [MQTT-3.1.2-9].

486 The Will Message MUST be removed from the stored Session state in the Server once it has been
487 published or the Server has received a DISCONNECT packet from the Client [MQTT-3.1.2-10].

488 If the Will Flag is set to 0 the Will QoS and Will Retain fields in the Connect Flags MUST be set to zero
489 and the Will Topic and Will Message fields MUST NOT be present in the payload [MQTT-3.1.2-11].

490 If the Will Flag is set to 0, a Will Message MUST NOT be published when this Network Connection ends
491 [MQTT-3.1.2-12].

492
493 The Server SHOULD publish Will Messages promptly. In the case of a Server shutdown or failure the
494 server MAY defer publication of Will Messages until a subsequent restart. If this happens there might be a
495 delay between the time the server experienced failure and a Will Message being published.

496 3.1.2.6 Will QoS

497 **Position:** bits 4 and 3 of the Connect Flags.

498
499 These two bits specify the QoS level to be used when publishing the Will Message.

500
501 If the Will Flag is set to 0, then the Will QoS MUST be set to 0 (0x00) [MQTT-3.1.2-13].

502 If the Will Flag is set to 1, the value of Will QoS can be 0 (0x00), 1 (0x01), or 2 (0x02). It MUST NOT be 3
503 (0x03) [MQTT-3.1.2-14].

504 3.1.2.7 Will Retain

505 **Position:** bit 5 of the Connect Flags.

506
507 This bit specifies if the Will Message is to be Retained when it is published.

508

509 If the Will Flag is set to 0, then the Will Retain Flag MUST be set to 0 [MQTT-3.1.2-15].

510 If the Will Flag is set to 1:

- 511 • If Will Retain is set to 0, the Server MUST publish the Will Message as a non-retained message [MQTT-3.1.2-16].
- 512
- 513 • If Will Retain is set to 1, the Server MUST publish the Will Message as a retained message [MQTT-3.1.2-17].
- 514

515 3.1.2.8 User Name Flag

516 **Position:** bit 7 of the Connect Flags.

517

518 If the User Name Flag is set to 0, a user name MUST NOT be present in the payload [MQTT-3.1.2-18].

519 If the User Name Flag is set to 1, a user name MUST be present in the payload [MQTT-3.1.2-19].

520 3.1.2.9 Password Flag

521 **Position:** bit 6 of the Connect Flags byte.

522

523 If the Password Flag is set to 0, a password MUST NOT be present in the payload [MQTT-3.1.2-20].

524 If the Password Flag is set to 1, a password MUST be present in the payload [MQTT-3.1.2-21].

525 If the User Name Flag is set to 0, the Password Flag MUST be set to 0 [MQTT-3.1.2-22].

526 3.1.2.10 Keep Alive

527 **Figure 3.5 Keep Alive bytes**

Bit	7	6	5	4	3	2	1	0
byte 9	Keep Alive MSB							
byte 10	Keep Alive LSB							

528

529 The Keep Alive is a time interval measured in seconds. Expressed as a 16-bit word, it is the maximum
530 time interval that is permitted to elapse between the point at which the Client finishes transmitting one
531 Control Packet and the point it starts sending the next. It is the responsibility of the Client to ensure that
532 the interval between Control Packets being sent does not exceed the Keep Alive value. In the absence of
533 sending any other Control Packets, the Client MUST send a PINGREQ Packet [MQTT-3.1.2-23].

534

535 The Client can send PINGREQ at any time, irrespective of the Keep Alive value, and use the PINGRESP
536 to determine that the network and the Server are working.

537

538 If the Keep Alive value is non-zero and the Server does not receive a Control Packet from the Client
539 within one and a half times the Keep Alive time period, it MUST disconnect the Network Connection to the
540 Client as if the network had failed [MQTT-3.1.2-24].

541

542 If a Client does not receive a PINGRESP Packet within a reasonable amount of time after it has sent a
543 PINGREQ, it SHOULD close the Network Connection to the Server.

544

545 A Keep Alive value of zero (0) has the effect of turning off the keep alive mechanism. This means that, in
546 this case, the Server is not required to disconnect the Client on the grounds of inactivity.

547 Note that a Server is permitted to disconnect a Client that it determines to be inactive or non-responsive
 548 at any time, regardless of the Keep Alive value provided by that Client.

549

550 **Non normative comment**

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

553 **3.1.2.11 Variable header non normative example**

554 **Figure 3.6 - Variable header non normative example**

	Description	7	6	5	4	3	2	1	0
Protocol Name									
byte 1	Length MSB (0)	0	0	0	0	0	0	0	0
byte 2	Length LSB (4)	0	0	0	0	0	1	0	0
byte 3	'M'	0	1	0	0	1	1	0	1
byte 4	'Q'	0	1	0	1	0	0	0	1
byte 5	'T'	0	1	0	1	0	1	0	0
byte 6	'T'	0	1	0	1	0	1	0	0
Protocol Level									
	Description	7	6	5	4	3	2	1	0
byte 7	Level (4)	0	0	0	0	0	1	0	0
Connect Flags									
byte 8	User Name Flag (1)								
	Password Flag (1)								
	Will Retain (0)								
	Will QoS (01)	1	1	0	0	1	1	1	0
	Will Flag (1)								
	Clean Session (1)								
	Reserved (0)								
Keep Alive									
byte 9	Keep Alive MSB (0)	0	0	0	0	0	0	0	0
byte 10	Keep Alive LSB (10)	0	0	0	0	1	0	1	0

555

556 3.1.3 Payload

557 The payload of the CONNECT Packet contains one or more length-prefixed fields, whose presence is
558 determined by the flags in the variable header. These fields, if present, MUST appear in the order Client
559 Identifier, Will Topic, Will Message, User Name, Password [MQTT-3.1.3-1].

560 3.1.3.1 Client Identifier

561 The Client Identifier (ClientId) identifies the Client to the Server. Each Client connecting to the Server has
562 a unique ClientId. The ClientId MUST be used by Clients and by Servers to identify state that they hold
563 relating to this MQTT Session between the Client and the Server [MQTT-3.1.3-2].

564
565 The Client Identifier (ClientId) MUST be present and MUST be the first field in the CONNECT packet
566 payload [MQTT-3.1.3-3].

567

568 The ClientId MUST be a UTF-8 encoded string as defined in Section 1.5.3 [MQTT-3.1.3-4].

569

570 The Server MUST allow ClientIds which are between 1 and 23 UTF-8 encoded bytes in length, and that
571 contain only the characters

572 "0123456789abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ" [MQTT-3.1.3-5].

573

574 The Server MAY allow ClientId's that contain more than 23 encoded bytes. The Server MAY allow
575 ClientId's that contain characters not included in the list given above.

576

577 A Server MAY allow a Client to supply a ClientId that has a length of zero bytes, however if it does so the
578 Server MUST treat this as a special case and assign a unique ClientId to that Client. It MUST then
579 process the CONNECT packet as if the Client had provided that unique ClientId [MQTT-3.1.3-6].

580

581 If the Client supplies a zero-byte ClientId, the Client MUST also set CleanSession to 1 [MQTT-3.1.3-7].

582

583 If the Client supplies a zero-byte ClientId with CleanSession set to 0, the Server MUST respond to the
584 CONNECT Packet with a CONNACK return code 0x02 (Identifier rejected) and then close the Network
585 Connection [MQTT-3.1.3-8].

586

587 If the Server rejects the ClientId it MUST respond to the CONNECT Packet with a CONNACK return code
588 0x02 (Identifier rejected) and then close the Network Connection [MQTT-3.1.3-9].

589

590 Non normative comment

591 A Client implementation could provide a convenience method to generate a random ClientId. Use
592 of such a method should be actively discouraged when the CleanSession is set to 0.

593 3.1.3.2 Will Topic

594 If the Will Flag is set to 1, the Will Topic is the next field in the payload. The Will Topic MUST be a UTF-8
595 encoded string as defined in Section 1.5.3 [MQTT-3.1.3-10].

596 3.1.3.3 Will Message

597 If the Will Flag is set to 1 the Will Message is the next field in the payload. The Will Message defines the
598 Application Message that is to be published to the Will Topic as described in Section 3.1.2.5. This field
599 consists of a two byte length followed by the payload for the Will Message expressed as a sequence of
600 zero or more bytes. The length gives the number of bytes in the data that follows and does not include the
601 2 bytes taken up by the length itself.

602

603 When the Will Message is published to the Will Topic its payload consists only of the data portion of this
604 field, not the first two length bytes.

605 3.1.3.4 User Name

606 If the User Name Flag is set to 1, this is the next field in the payload. **The User Name MUST be a UTF-8**
607 **encoded string as defined in Section 1.5.3 [MQTT-3.1.3-11]**. It can be used by the Server for
608 authentication and authorization.

609 3.1.3.5 Password

610 If the Password Flag is set to 1, this is the next field in the payload. The Password field contains 0 to
611 65535 bytes of binary data prefixed with a two byte length field which indicates the number of bytes used
612 by the binary data (it does not include the two bytes taken up by the length field itself).

613 **Figure 3.7 - Password bytes**

Bit	7	6	5	4	3	2	1	0
byte 1	Data length MSB							
byte 2	Data length LSB							
byte 3	Data, if length > 0.							

614

615 3.1.4 Response

616 Note that a Server MAY support multiple protocols (including earlier versions of this protocol) on the same
617 TCP port or other network endpoint. If the Server determines that the protocol is MQTT 3.1.1 then it
618 validates the connection attempt as follows.

619

- 620 1. If the Server does not receive a CONNECT Packet within a reasonable amount of time after the
621 Network Connection is established, the Server SHOULD close the connection.
622
- 623 2. **The Server MUST validate that the CONNECT Packet conforms to section 3.1 and close the**
624 **Network Connection without sending a CONNACK if it does not conform [MQTT-3.1.4-1].**
625
- 626 3. The Server MAY check that the contents of the CONNECT Packet meet any further restrictions
627 and MAY perform authentication and authorization checks. If any of these checks fail, it SHOULD
628 send an appropriate CONNACK response with a non-zero return code as described in section 3.2
629 and it MUST close the Network Connection.

630

631 If validation is successful the Server performs the following steps.

632

- 633 1. **If the ClientId represents a Client already connected to the Server then the Server MUST**
634 **disconnect the existing Client [MQTT-3.1.4-2].**
- 635
- 636 2. **The Server MUST perform the processing of CleanSession that is described in section 3.1.2.4**
637 **[MQTT-3.1.4-3].**
- 638
- 639 3. **The Server MUST acknowledge the CONNECT Packet with a CONNACK Packet containing a**
640 **zero return code [MQTT-3.1.4-4].**

641
 642 4. Start message delivery and keep alive monitoring.

643
 644 Clients are allowed to send further Control Packets immediately after sending a CONNECT Packet;
 645 Clients need not wait for a CONNACK Packet to arrive from the Server. If the Server rejects the
 646 CONNECT, it MUST NOT process any data sent by the Client after the CONNECT Packet [MQTT-3.1.4-
 647 5].
 648

649 **Non normative comment**

650 Clients typically wait for a CONNACK Packet, However, if the Client exploits its freedom to send
 651 Control Packets before it receives a CONNACK, it might simplify the Client implementation as it
 652 does not have to police the connected state. The Client accepts that any data that it sends before it
 653 receives a CONNACK packet from the Server will not be processed if the Server rejects the
 654 connection.

655 **3.2 CONNACK – Acknowledge connection request**

656 The CONNACK Packet is the packet sent by the Server in response to a CONNECT Packet received
 657 from a Client. The first packet sent from the Server to the Client MUST be a CONNACK Packet [MQTT-
 658 3.2.0-1].

659
 660 If the Client does not receive a CONNACK Packet from the Server within a reasonable amount of time,
 661 the Client SHOULD close the Network Connection. A "reasonable" amount of time depends on the type of
 662 application and the communications infrastructure.

663 **3.2.1 Fixed header**

664 The fixed header format is illustrated in [Figure 3.8 – CONNACK Packet fixed header](#).

665 **Figure 3.8 – CONNACK Packet fixed header**

Bit	7	6	5	4	3	2	1	0
byte 1	MQTT Control Packet Type (2)				Reserved			
	0	0	1	0	0	0	0	0
byte 2	Remaining Length (2)							
	0	0	0	0	0	0	1	0

666
 667 **Remaining Length field**

668 This is the length of the variable header. For the CONNACK Packet this has the value 2.

669 **3.2.2 Variable header**

670 The variable header format is illustrated in [Figure 3.9 – CONNACK Packet variable header](#).

671 **Figure 3.9 – CONNACK Packet variable header**

	Description	7	6	5	4	3	2	1	0
Connect Acknowledge Flags		Reserved							SP ¹
byte 1		0	0	0	0	0	0	0	X

Connect Return code									
byte 2		X	X	X	X	X	X	X	X

672 **3.2.2.1 Connect Acknowledge Flags**

673 Byte 1 is the "Connect Acknowledge Flags". Bits 7-1 are reserved and MUST be set to 0.

674

675 Bit 0 (SP¹) is the Session Present Flag.

676 **3.2.2.2 Session Present**

677 Position: bit 0 of the Connect Acknowledge Flags.

678

679 If the Server accepts a connection with CleanSession set to 1, the Server MUST set Session Present to 0
680 in the CONNACK packet in addition to setting a zero return code in the CONNACK packet [MQTT-3.2.2-
681 1].

682

683 If the Server accepts a connection with CleanSession set to 0, the value set in Session Present depends
684 on whether the Server already has stored Session state for the supplied client ID. If the Server has stored
685 Session state, it MUST set Session Present to 1 in the CONNACK packet [MQTT-3.2.2-2]. If the Server
686 does not have stored Session state, it MUST set Session Present to 0 in the CONNACK packet. This is in
687 addition to setting a zero return code in the CONNACK packet [MQTT-3.2.2-3].

688

689 The Session Present flag enables a Client to establish whether the Client and Server have a consistent
690 view about whether there is already stored Session state.

691

692 Once the initial setup of a Session is complete, a Client with stored Session state will expect the Server to
693 maintain its stored Session state. In the event that the value of Session Present received by the Client
694 from the Server is not as expected, the Client can choose whether to proceed with the Session or to
695 disconnect. The Client can discard the Session state on both Client and Server by disconnecting,
696 connecting with Clean Session set to 1 and then disconnecting again.

697

698 If a server sends a CONNACK packet containing a non-zero return code it MUST set Session Present to
699 0 [MQTT-3.2.2-4].

700

701 **3.2.2.3 Connect Return code**

702 Byte 2 in the Variable header.

703

704 The values for the one byte unsigned Connect Return code field are listed in Table 3.1 – Connect Return
705 code values. If a well formed CONNECT Packet is received by the Server, but the Server is unable to
706 process it for some reason, then the Server SHOULD attempt to send a CONNACK packet containing the
707 appropriate non-zero Connect return code from this table. If a server sends a CONNACK packet
708 containing a non-zero return code it MUST then close the Network Connection [MQTT-3.2.2-5].

709 **Table 3.1 – Connect Return code values**

Value	Return Code Response	Description
0	0x00 Connection Accepted	Connection accepted
1	0x01 Connection Refused, unacceptable protocol version	The Server does not support the level of the MQTT protocol requested by the Client
2	0x02 Connection Refused, identifier rejected	The Client identifier is correct UTF-8 but not

		allowed by the Server
3	0x03 Connection Refused, Server unavailable	The Network Connection has been made but the MQTT service is unavailable
4	0x04 Connection Refused, bad user name or password	The data in the user name or password is malformed
5	0x05 Connection Refused, not authorized	The Client is not authorized to connect
6-255		Reserved for future use

710

711 If none of the return codes listed in Table 3.1 – Connect Return code values are deemed applicable, then
 712 the Server MUST close the Network Connection without sending a CONNACK [MQTT-3.2.2-6].

713 3.2.3 Payload

714 The CONNACK Packet has no payload.

715 3.3 PUBLISH – Publish message

716 A PUBLISH Control Packet is sent from a Client to a Server or from Server to a Client to transport an
 717 Application Message.

718 3.3.1 Fixed header

719 Figure 3.10 – PUBLISH Packet fixed header illustrates the fixed header format:

720 **Figure 3.10 – PUBLISH Packet fixed header**

Bit	7	6	5	4	3	2	1	0
byte 1	MQTT Control Packet type (3)			DUP flag		QoS level		RETAIN
	0	0	1	1	X	X	X	X
byte 2	Remaining Length							

721

722 3.3.1.1 DUP

723 **Position:** byte 1, bit 3.

724 If the DUP flag is set to 0, it indicates that this is the first occasion that the Client or Server has attempted
 725 to send this MQTT PUBLISH Packet. If the DUP flag is set to 1, it indicates that this might be re-delivery
 726 of an earlier attempt to send the Packet.

727

728 The DUP flag MUST be set to 1 by the Client or Server when it attempts to re-deliver a PUBLISH Packet
 729 [MQTT-3.3.1.-1]. The DUP flag MUST be set to 0 for all QoS 0 messages [MQTT-3.3.1-2].

730

731 The value of the DUP flag from an incoming PUBLISH packet is not propagated when the PUBLISH
 732 Packet is sent to subscribers by the Server. The DUP flag in the outgoing PUBLISH packet is set
 733 independently to the incoming PUBLISH packet, its value MUST be determined solely by whether the
 734 outgoing PUBLISH packet is a retransmission [MQTT-3.3.1-3].

735

736 Non normative comment

737 The recipient of a Control Packet that contains the DUP flag set to 1 cannot assume that it has
738 seen an earlier copy of this packet.

739

740 **Non normative comment**

741 It is important to note that the DUP flag refers to the Control Packet itself and not to the
742 Application Message that it contains. When using QoS 1, it is possible for a Client to receive a
743 PUBLISH Packet with DUP flag set to 0 that contains a repetition of an Application Message that
744 it received earlier, but with a different Packet Identifier. Section 2.3.1 provides more information
745 about Packet Identifiers.

746 **3.3.1.2 QoS**

747 **Position:** byte 1, bits 2-1.

748 This field indicates the level of assurance for delivery of an Application Message. The QoS levels are
749 listed in the [Table 3.2 - QoS definitions](#), below.

750

751 **Table 3.2 - QoS definitions**

QoS value	Bit 2	bit 1	Description
0	0	0	At most once delivery
1	0	1	At least once delivery
2	1	0	Exactly once delivery
-	1	1	Reserved – must not be used

752 A PUBLISH Packet MUST NOT have both QoS bits set to 1. If a Server or Client receives a PUBLISH
753 Packet which has both QoS bits set to 1 it MUST close the Network Connection [\[MQTT-3.3.1-4\]](#).

754 **3.3.1.3 RETAIN**

755 **Position:** byte 1, bit 0.

756

757 If the RETAIN flag is set to 1, in a PUBLISH Packet sent by a Client to a Server, the Server MUST store
758 the Application Message and its QoS, so that it can be delivered to future subscribers whose
759 subscriptions match its topic name [\[MQTT-3.3.1-5\]](#). When a new subscription is established, the last
760 retained message, if any, on each matching topic name MUST be sent to the subscriber [\[MQTT-3.3.1-6\]](#).
761 If the Server receives a QoS 0 message with the RETAIN flag set to 1 it MUST discard any message
762 previously retained for that topic. It SHOULD store the new QoS 0 message as the new retained
763 message for that topic, but MAY choose to discard it at any time - if this happens there will be no retained
764 message for that topic [\[MQTT-3.3.1-7\]](#). See Section 4.1 for more information on storing state.

765

766 When sending a PUBLISH Packet to a Client the Server MUST set the RETAIN flag to 1 if a message is
767 sent as a result of a new subscription being made by a Client [\[MQTT-3.3.1-8\]](#). It MUST set the RETAIN
768 flag to 0 when a PUBLISH Packet is sent to a Client because it matches an established subscription
769 regardless of how the flag was set in the message it received [\[MQTT-3.3.1-9\]](#).

770

771 A PUBLISH Packet with a RETAIN flag set to 1 and a payload containing zero bytes will be processed as
772 normal by the Server and sent to Clients with a subscription matching the topic name. Additionally any
773 existing retained message with the same topic name MUST be removed and any future subscribers for
774 the topic will not receive a retained message [\[MQTT-3.3.1-10\]](#). “As normal” means that the RETAIN flag is

775 not set in the message received by existing Clients. A zero byte retained message MUST NOT be stored
776 as a retained message on the Server [MQTT-3.3.1-11].

777
778 If the RETAIN flag is 0, in a PUBLISH Packet sent by a Client to a Server, the Server MUST NOT store
779 the message and MUST NOT remove or replace any existing retained message [MQTT-3.3.1-12].

780
781 **Non normative comment**

782 Retained messages are useful where publishers send state messages on an irregular basis. A
783 new subscriber will receive the most recent state.

784
785 **Remaining Length field**

786 This is the length of variable header plus the length of the payload.

787 **3.3.2 Variable header**

788 The variable header contains the following fields in the order: Topic Name, Packet Identifier.

789 **3.3.2.1 Topic Name**

790 The Topic Name identifies the information channel to which payload data is published.

791
792 The Topic Name MUST be present as the first field in the PUBLISH Packet Variable header. It MUST be
793 a UTF-8 encoded string [MQTT-3.3.2-1] as defined in section 1.5.3.

794 The Topic Name in the PUBLISH Packet MUST NOT contain wildcard characters [MQTT-3.3.2-2].

795 The Topic Name in a PUBLISH Packet sent by a Server to a subscribing Client MUST match the
796 Subscription's Topic Filter according to the matching process defined in Section 4.7 [MQTT-3.3.2-3].
797 However, since the Server is permitted to override the Topic Name, it might not be the same as the Topic
798 Name in the original PUBLISH Packet.

799 **3.3.2.2 Packet Identifier**

800 The Packet Identifier field is only present in PUBLISH Packets where the QoS level is 1 or 2. Section
801 2.3.1 provides more information about Packet Identifiers.

802 **3.3.2.3 Variable header non normative example**

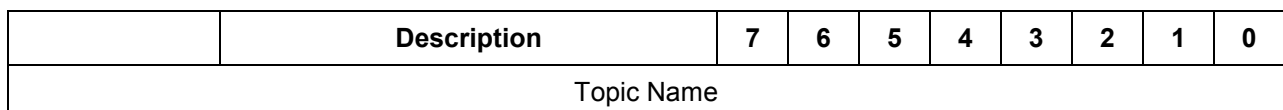
803 Figure 3.11 - Publish Packet variable header non normative example illustrates an example variable
804 header for the PUBLISH Packet briefly described in Table 3.3 - Publish Packet non normative example.

805 **Table 3.3 - Publish Packet non normative example**

Field	Value
Topic Name	a/b
Packet Identifier	10

806

807 **Figure 3.11 - Publish Packet variable header non normative example**



byte 1	Length MSB (0)	0	0	0	0	0	0	0	0
byte 2	Length LSB (3)	0	0	0	0	0	0	1	1
byte 3	'a' (0x61)	0	1	1	0	0	0	0	1
byte 4	'/' (0x2F)	0	0	1	0	1	1	1	1
byte 5	'b' (0x62)	0	1	1	0	0	0	1	0
Packet Identifier									
byte 6	Packet Identifier MSB (0)	0	0	0	0	0	0	0	0
byte 7	Packet Identifier LSB (10)	0	0	0	0	1	0	1	0

808

809 3.3.3 Payload

810 The Payload contains the Application Message that is being published. The content and format of the
811 data is application specific. The length of the payload can be calculated by subtracting the length of the
812 variable header from the Remaining Length field that is in the Fixed Header. It is valid for a PUBLISH
813 Packet to contain a zero length payload.

814 3.3.4 Response

815 The receiver of a PUBLISH Packet MUST respond according to Table 3.4 - Expected Publish Packet
816 response as determined by the QoS in the PUBLISH Packet [MQTT-3.3.4-1].

817 **Table 3.4 - Expected Publish Packet response**

QoS Level	Expected Response
QoS 0	None
QoS 1	PUBACK Packet
QoS 2	PUBREC Packet

818

819 3.3.5 Actions

820 The Client uses a PUBLISH Packet to send an Application Message to the Server, for distribution to
821 Clients with matching subscriptions.

822

823 The Server uses a PUBLISH Packet to send an Application Message to each Client which has a
824 matching subscription.

825

826 When Clients make subscriptions with Topic Filters that include wildcards, it is possible for a Client's
827 subscriptions to overlap so that a published message might match multiple filters. In this case the Server
828 MUST deliver the message to the Client respecting the maximum QoS of all the matching subscriptions
829 [MQTT-3.3.5-1]. In addition, the Server MAY deliver further copies of the message, one for each
830 additional matching subscription and respecting the subscription's QoS in each case.

831

832 The action of the recipient when it receives a PUBLISH Packet depends on the QoS level as described in
833 Section 4.3.

834
 835 If a Server implementation does not authorize a PUBLISH to be performed by a Client; it has no way of
 836 informing that Client. It MUST either make a positive acknowledgement, according to the normal QoS
 837 rules, or close the Network Connection [MQTT-3.3.5-2].

838 **3.4 PUBACK – Publish acknowledgement**

839 A PUBACK Packet is the response to a PUBLISH Packet with QoS level 1.

840 **3.4.1 Fixed header**

841 **Figure 3.12 - PUBACK Packet fixed header**

Bit	7	6	5	4	3	2	1	0
byte 1	MQTT Control Packet type (4)				Reserved			
	0	1	0	0	0	0	0	0
byte 2	Remaining Length (2)							
	0	0	0	0	0	0	1	0

842
 843 **Remaining Length field**
 844 This is the length of the variable header. For the PUBACK Packet this has the value 2.

845 **3.4.2 Variable header**

846 This contains the Packet Identifier from the PUBLISH Packet that is being acknowledged.

847 **Figure 3.13 – PUBACK Packet variable header**

Bit	7	6	5	4	3	2	1	0
byte 1	Packet Identifier MSB							
byte 2	Packet Identifier LSB							

848
 849 **3.4.3 Payload**
 850 The PUBACK Packet has no payload.

851 **3.4.4 Actions**

852 This is fully described in Section 4.3.2.

853 **3.5 PUBREC – Publish received (QoS 2 publish received, part 1)**

854 A PUBREC Packet is the response to a PUBLISH Packet with QoS 2. It is the second packet of the QoS
 855 2 protocol exchange.

856 **3.5.1 Fixed header**

857 **Figure 3.14 – PUBREC Packet fixed header**

Bit	7	6	5	4	3	2	1	0
byte 1	MQTT Control Packet type (5)				Reserved			
	0	1	0	1	0	0	0	0
byte 2	Remaining Length (2)							
	0	0	0	0	0	0	1	0

858
859 **Remaining Length field**

860 This is the length of the variable header. For the PUBREC Packet this has the value 2.

861 **3.5.2 Variable header**

862 The variable header contains the Packet Identifier from the PUBLISH Packet that is being acknowledged.

863 **Figure 3.15 – PUBREC Packet variable header**

Bit	7	6	5	4	3	2	1	0
byte 1	Packet Identifier MSB							
byte 2	Packet Identifier LSB							

864
865 **3.5.3 Payload**

866 The PUBREC Packet has no payload.

867 **3.5.4 Actions**

868 This is fully described in Section 4.3.3.

869 **3.6 PUBREL – Publish release (QoS 2 publish received, part 2)**

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

872 **3.6.1 Fixed header**

873 **Figure 3.16 – PUBREL Packet fixed header**

Bit	7	6	5	4	3	2	1	0
byte 1	MQTT Control Packet type (6)				Reserved			
	0	1	1	0	0	0	1	0
byte 2	Remaining Length (2)							
	0	0	0	0	0	0	1	0

875 Bits 3,2,1 and 0 of the fixed header in the PUBREL Control Packet are reserved and MUST be set to
 876 0,0,1 and 0 respectively. The Server MUST treat any other value as malformed and close the Network
 877 Connection [MQTT-3.6.1-1].

878

879 **Remaining Length field**

880 This is the length of the variable header. For the PUBREL Packet this has the value 2.

881 **3.6.2 Variable header**

882 The variable header contains the same Packet Identifier as the PUBREC Packet that is being
 883 acknowledged.

884 **Figure 3.17 – PUBREL Packet variable header**

Bit	7	6	5	4	3	2	1	0	
byte 1	Packet Identifier MSB								
byte 2	Packet Identifier LSB								

885

886 **3.6.3 Payload**

887 The PUBREL Packet has no payload.

888 **3.6.4 Actions**

889 This is fully described in Section 4.3.3.

890 **3.7 PUBCOMP – Publish complete (QoS 2 publish received, part 3)**

891

892 The PUBCOMP Packet is the response to a PUBREL Packet. It is the fourth and final packet of the QoS
 893 2 protocol exchange.

894 **3.7.1 Fixed header**

895 **Figure 3.18 – PUBCOMP Packet fixed header**

Bit	7	6	5	4	3	2	1	0	
byte 1	MQTT Control Packet type (7)				Reserved				
	0	1	1	1	0	0	0	0	
byte 2	Remaining Length (2)								
	0	0	0	0	0	0	1	0	

896

897 **Remaining Length field**

898 This is the length of the variable header. For the PUBCOMP Packet this has the value 2.

899 **3.7.2 Variable header**

900 The variable header contains the same Packet Identifier as the PUBREL Packet that is being
901 acknowledged.

902 **Figure 3.19 – PUBCOMP Packet variable header**

Bit	7	6	5	4	3	2	1	0
byte 1	Packet Identifier MSB							
byte 2	Packet Identifier LSB							

903

904 **3.7.3 Payload**

905 The PUBCOMP Packet has no payload.

906 **3.7.4 Actions**

907 This is fully described in Section 4.3.3.

908 **3.8 SUBSCRIBE - Subscribe to topics**

909 The SUBSCRIBE Packet is sent from the Client to the Server to create one or more Subscriptions. Each
910 Subscription registers a Client's interest in one or more Topics. The Server sends PUBLISH Packets to
911 the Client in order to forward Application Messages that were published to Topics that match these
912 Subscriptions. The SUBSCRIBE Packet also specifies (for each Subscription) the maximum QoS with
913 which the Server can send Application Messages to the Client.

914 **3.8.1 Fixed header**

915 **Figure 3.20 – SUBSCRIBE Packet fixed header**

Bit	7	6	5	4	3	2	1	0
byte 1	MQTT Control Packet type (8)				Reserved			
	1	0	0	0	0	0	1	0
byte 2	Remaining Length							

916

917 Bits 3,2,1 and 0 of the fixed header of the SUBSCRIBE Control Packet are reserved and MUST be set to
918 0,0,1 and 0 respectively. The Server MUST treat any other value as malformed and close the Network
919 Connection [MQTT-3.8.1-1].

920

921 **Remaining Length field**

922 This is the length of variable header (2 bytes) plus the length of the payload.

923 **3.8.2 Variable header**

924 The variable header contains a Packet Identifier. Section 2.3.1 provides more information about Packet
925 Identifiers.

926 **3.8.2.1 Variable header non normative example**

927 Figure 3.21 shows a variable header with Packet Identifier set to 10.

928 **Figure 3.21 - Variable header with a Packet Identifier of 10, Non normative example**

	Description	7	6	5	4	3	2	1	0
Packet Identifier									
byte 1	Packet Identifier MSB (0)	0	0	0	0	0	0	0	0
byte 2	Packet Identifier LSB (10)	0	0	0	0	1	0	1	0

929

930 **3.8.3 Payload**

931 The payload of a SUBSCRIBE Packet contains a list of Topic Filters indicating the Topics to which the
 932 Client wants to subscribe. The Topic Filters in a SUBSCRIBE packet payload MUST be UTF-8 encoded
 933 strings as defined in Section 1.5.3 [MQTT-3.8.3-1]. A Server SHOULD support Topic filters that contain
 934 the wildcard characters defined in Section 4.7.1. If it chooses not to support topic filters that contain
 935 wildcard characters it MUST reject any Subscription request whose filter contains them [MQTT-3.8.3-2].
 936 Each filter is followed by a byte called the Requested QoS. This gives the maximum QoS level at which
 937 the Server can send Application Messages to the Client.

938

939 The payload of a SUBSCRIBE packet MUST contain at least one Topic Filter / QoS pair. A SUBSCRIBE
 940 packet with no payload is a protocol violation [MQTT-3.8.3-3]. See section 4.8 for information about
 941 handling errors.

942

943 The requested maximum QoS field is encoded in the byte following each UTF-8 encoded topic name, and
 944 these Topic Filter / QoS pairs are packed contiguously.

945

946 **Figure 3.22 – SUBSCRIBE Packet payload format**

Description	7	6	5	4	3	2	1	0
Topic Filter								
byte 1	Length MSB							
byte 2	Length LSB							
bytes 3..N	Topic Filter							
Requested QoS								
	Reserved						QoS	
byte N+1	0	0	0	0	0	0	X	X

947

948 The upper 6 bits of the Requested QoS byte are not used in the current version of the protocol. They are
 949 reserved for future use. The Server MUST treat a SUBSCRIBE packet as malformed and close the
 950 Network Connection if any of Reserved bits in the payload are non-zero, or QoS is not 0,1 or 2 [MQTT-3-
 951 8.3-4].

952 **3.8.3.1 Payload non normative example**

953 [Figure 3.23 - Payload byte format non normative example](#) shows the payload for the SUBSCRIBE
 954 Packet briefly described in [Table 3.5 - Payload non normative example](#).

955

956 **Table 3.5 - Payload non normative example**

Topic Name	“a/b”
Requested QoS	0x01
Topic Name	“c/d”
Requested QoS	0x02

957 **Figure 3.23 - Payload byte format non normative example**

	Description	7	6	5	4	3	2	1	0
Topic Filter									
byte 1	Length MSB (0)	0	0	0	0	0	0	0	0
byte 2	Length LSB (3)	0	0	0	0	0	0	1	1
byte 3	'a' (0x61)	0	1	1	0	0	0	0	1
byte 4	'/' (0x2F)	0	0	1	0	1	1	1	1
byte 5	'b' (0x62)	0	1	1	0	0	0	1	0
Requested QoS									
byte 6	Requested QoS(1)	0	0	0	0	0	0	0	1
Topic Filter									
byte 7	Length MSB (0)	0	0	0	0	0	0	0	0
byte 8	Length LSB (3)	0	0	0	0	0	0	1	1
byte 9	'c' (0x63)	0	1	1	0	0	0	1	1
byte 10	'/' (0x2F)	0	0	1	0	1	1	1	1
byte 11	'd' (0x64)	0	1	1	0	0	1	0	0
Requested QoS									
byte 12	Requested QoS(2)	0	0	0	0	0	0	1	0

958

959 **3.8.4 Response**

960 When the Server receives a SUBSCRIBE Packet from a Client, the Server MUST respond with a
 961 SUBACK Packet [\[MQTT-3.8.4-1\]](#). The SUBACK Packet MUST have the same Packet Identifier as the
 962 SUBSCRIBE Packet that it is acknowledging [\[MQTT-3.8.4-2\]](#).

963

964 The Server is permitted to start sending PUBLISH packets matching the Subscription before the Server
965 sends the SUBACK Packet.

966

967 If a Server receives a SUBSCRIBE Packet containing a Topic Filter that is identical to an existing
968 Subscription's Topic Filter then it MUST completely replace that existing Subscription with a new
969 Subscription. The Topic Filter in the new Subscription will be identical to that in the previous Subscription,
970 although its maximum QoS value could be different. Any existing retained messages matching the Topic
971 Filter MUST be re-sent, but the flow of publications MUST NOT be interrupted [MQTT-3.8.4-3].

972

973 Where the Topic Filter is not identical to any existing Subscription's filter, a new Subscription is created
974 and all matching retained messages are sent.

975

976 If a Server receives a SUBSCRIBE packet that contains multiple Topic Filters it MUST handle that packet
977 as if it had received a sequence of multiple SUBSCRIBE packets, except that it combines their responses
978 into a single SUBACK response [MQTT-3.8.4-4].

979

980 The SUBACK Packet sent by the Server to the Client MUST contain a return code for each Topic
981 Filter/QoS pair. This return code MUST either show the maximum QoS that was granted for that
982 Subscription or indicate that the subscription failed [MQTT-3.8.4-5]. The Server might grant a lower
983 maximum QoS than the subscriber requested. The QoS of Payload Messages sent in response to a
984 Subscription MUST be the minimum of the QoS of the originally published message and the maximum
985 QoS granted by the Server. The server is permitted to send duplicate copies of a message to a
986 subscriber in the case where the original message was published with QoS 1 and the maximum QoS
987 granted was QoS 0 [MQTT-3.8.4-6].

988

989 **Non normative examples**

990

991 If a subscribing Client has been granted maximum QoS 1 for a particular Topic Filter, then a QoS
992 0 Application Message matching the filter is delivered to the Client at QoS 0. This means that at
993 most one copy of the message is received by the Client. On the other hand a QoS 2 Message
994 published to the same topic is downgraded by the Server to QoS 1 for delivery to the Client, so
995 that Client might receive duplicate copies of the Message.

996

997 If the subscribing Client has been granted maximum QoS 0, then an Application Message
998 originally published as QoS 2 might get lost on the hop to the Client, but the Server should never
999 send a duplicate of that Message. A QoS 1 Message published to the same topic might either get
1000 lost or duplicated on its transmission to that Client.

1001

1002 **Non normative comment**

1003 Subscribing to a Topic Filter at QoS 2 is equivalent to saying "I would like to receive Messages
1004 matching this filter at the QoS with which they were published". This means a publisher is
1005 responsible for determining the maximum QoS a Message can be delivered at, but a subscriber is
1006 able to require that the Server downgrades the QoS to one more suitable for its usage.

1007 **3.9 SUBACK – Subscribe acknowledgement**

1008 A SUBACK Packet is sent by the Server to the Client to confirm receipt and processing of a SUBSCRIBE
1009 Packet.

1010

1011 A SUBACK Packet contains a list of return codes, that specify the maximum QoS level that was granted
1012 in each Subscription that was requested by the SUBSCRIBE.

1013 **3.9.1 Fixed header**

1014 **Figure 3.24 – SUBACK Packet fixed header**

Bit	7	6	5	4	3	2	1	0
byte 1	MQTT Control Packet type (9)				Reserved			
	1	0	0	1	0	0	0	0
byte 2	Remaining Length							

1015

1016 **Remaining Length field**

1017 This is the length of variable header (2 bytes) plus the length of the payload.

1018 **3.9.2 Variable header**

1019 The variable header contains the Packet Identifier from the SUBSCRIBE Packet that is being
 1020 acknowledged. [Figure 3.25 - variable header format](#) below illustrates the format of the variable header.

1021 **Figure 3.25 – SUBACK Packet variable header**

Bit	7	6	5	4	3	2	1	0
byte 1	Packet Identifier MSB							
byte 2	Packet Identifier LSB							

1022 **3.9.3 Payload**

1023 The payload contains a list of return codes. Each return code corresponds to a Topic Filter in the
 1024 SUBSCRIBE Packet being acknowledged. **The order of return codes in the SUBACK Packet MUST**
 1025 **match the order of Topic Filters in the SUBSCRIBE Packet** [MQTT-3.9.3-1].

1026

1027 [Figure 3.26 - Payload format](#) below illustrates the Return Code field encoded in a byte in the Payload.

1028 **Figure 3.26 – SUBACK Packet payload format**

Bit	7	6	5	4	3	2	1	0
	Return Code							
byte 1	X	0	0	0	0	0	X	X

1029

1030 Allowed return codes:

- 1031 0x00 - Success - Maximum QoS 0
- 1032 0x01 - Success - Maximum QoS 1
- 1033 0x02 - Success - Maximum QoS 2
- 1034 0x80 - Failure

1035

1036 **SUBACK return codes other than 0x00, 0x01, 0x02 and 0x80 are reserved and MUST NOT be**
 1037 **used** [MQTT-3.9.3-2].

1038 **3.9.3.1 Payload non normative example**

1039 [Figure 3.27 - Payload byte format non normative example](#) shows the payload for the SUBACK
 1040 Packet briefly described in [Table 3.6 - Payload non normative example](#).

1041 **Table 3.6 - Payload non normative example**

Success - Maximum QoS 0	0
Success - Maximum QoS 2	2
Failure	128

1042 **Figure 3.27 - Payload byte format non normative example**

	Description	7	6	5	4	3	2	1	0
byte 1	Success - Maximum QoS 0	0	0	0	0	0	0	0	0
byte 2	Success - Maximum QoS 2	0	0	0	0	0	0	1	0
byte 3	Failure	1	0	0	0	0	0	0	0

1043

1044 **3.10 UNSUBSCRIBE – Unsubscribe from topics**

1045 An UNSUBSCRIBE Packet is sent by the Client to the Server, to unsubscribe from topics.

1046 **3.10.1 Fixed header**

1047 **Figure 3.28 – UNSUBSCRIBE Packet Fixed header**

Bit	7	6	5	4	3	2	1	0
byte 1	MQTT Control Packet type (10)				Reserved			
	1	0	1	0	0	0	1	0
byte 2	Remaining Length							

1048

1049 Bits 3,2,1 and 0 of the fixed header of the UNSUBSCRIBE Control Packet are reserved and MUST be set
 1050 to 0,0,1 and 0 respectively. The Server MUST treat any other value as malformed and close the Network
 1051 Connection [\[MQTT-3.10.1-1\]](#).

1052

1053 **Remaining Length field**

1054 This is the length of variable header (2 bytes) plus the length of the payload.

1055 **3.10.2 Variable header**

1056 The variable header contains a Packet Identifier. Section 2.3.1 provides more information about Packet
 1057 Identifiers.

1058 **Figure 3.29 – UNSUBSCRIBE Packet variable header**

Bit	7	6	5	4	3	2	1	0
-----	---	---	---	---	---	---	---	---

byte 1	Packet Identifier MSB
byte 2	Packet Identifier LSB

1059

1060 3.10.3 Payload

1061 The payload for the UNSUBSCRIBE Packet contains the list of Topic Filters that the Client wishes to
 1062 unsubscribe from. The Topic Filters in an UNSUBSCRIBE packet MUST be UTF-8 encoded strings as
 1063 defined in Section 1.5.3, packed contiguously [MQTT-3.10.3-1].

1064 The Payload of an UNSUBSCRIBE packet MUST contain at least one Topic Filter. An UNSUBSCRIBE
 1065 packet with no payload is a protocol violation [MQTT-3.10.3-2]. See section 4.8 for information about
 1066 handling errors.

1067

1068 3.10.3.1 Payload non normative example

1069 Figure 3.30 - Payload byte format non normative example show the payload for the
 1070 UNSUBSCRIBE Packet briefly described in Table3.7 - Payload non normative example.

1071 Table3.7 - Payload non normative example

Topic Filter	"a/b"
Topic Filter	"c/d"

1072 Figure 3.30 - Payload byte format non normative example

	Description	7	6	5	4	3	2	1	0
Topic Filter									
byte 1	Length MSB (0)	0	0	0	0	0	0	0	0
byte 2	Length LSB (3)	0	0	0	0	0	0	1	1
byte 3	'a' (0x61)	0	1	1	0	0	0	0	1
byte 4	'/' (0x2F)	0	0	1	0	1	1	1	1
byte 5	'b' (0x62)	0	1	1	0	0	0	1	0
Topic Filter									
byte 6	Length MSB (0)	0	0	0	0	0	0	0	0
byte 7	Length LSB (3)	0	0	0	0	0	0	1	1
byte 8	'c' (0x63)	0	1	1	0	0	0	1	1
byte 9	'/' (0x2F)	0	0	1	0	1	1	1	1
byte 10	'd' (0x64)	0	1	1	0	0	1	0	0

1073 3.10.4 Response

1074 The Topic Filters (whether they contain wildcards or not) supplied in an UNSUBSCRIBE packet MUST be
 1075 compared character-by-character with the current set of Topic Filters held by the Server for the Client. If
 1076 any filter matches exactly then its owning Subscription is deleted, otherwise no additional processing

1077 occurs [MQTT-3.10.4-1].

1078

1079 If a Server deletes a Subscription:

- 1080 • It MUST stop adding any new messages for delivery to the Client [MQTT-3.10.4-2].
- 1081 • It MUST complete the delivery of any QoS 1 or QoS 2 messages which it has started to send to
1082 the Client [MQTT-3.10.4-3].
- 1083 • It MAY continue to deliver any existing messages buffered for delivery to the Client.

1084

1085 The Server MUST respond to an UNSUBSCRIBE request by sending an UNSUBACK packet. The
1086 UNSUBACK Packet MUST have the same Packet Identifier as the UNSUBSCRIBE Packet [MQTT-
1087 3.10.4-4]. Even where no Topic Subscriptions are deleted, the Server MUST respond with an
1088 UNSUBACK [MQTT-3.10.4-5].

1089

1090 If a Server receives an UNSUBSCRIBE packet that contains multiple Topic Filters it MUST handle that
1091 packet as if it had received a sequence of multiple UNSUBSCRIBE packets, except that it sends just one
1092 UNSUBACK response [MQTT-3.10.4-6].

1093 3.11 UNSUBACK – Unsubscribe acknowledgement

1094

1095 The UNSUBACK Packet is sent by the Server to the Client to confirm receipt of an UNSUBSCRIBE
1096 Packet.

1097 3.11.1 Fixed header

1098 Figure 3.31 – UNSUBACK Packet fixed header

Bit	7	6	5	4	3	2	1	0
byte 1	MQTT Control Packet type (11)				Reserved			
	1	0	1	1	0	0	0	0
byte 2	Remaining Length (2)							
	0	0	0	0	0	0	1	0

1099 Remaining Length field

1100 This is the length of the variable header. For the UNSUBACK Packet this has the value 2.

1101 3.11.2 Variable header

1102 The variable header contains the Packet Identifier of the UNSUBSCRIBE Packet that is being
1103 acknowledged.

1104 Figure 3.32 – UNSUBACK Packet variable header

Bit	7	6	5	4	3	2	1	0
byte 1	Packet Identifier MSB							
byte 2	Packet Identifier LSB							

1105

1106 **3.11.3 Payload**

1107 The UNSUBACK Packet has no payload.

1108

1109 **3.12 PINGREQ – PING request**

1110 The PINGREQ Packet is sent from a Client to the Server. It can be used to:

- 1111 1. Indicate to the Server that the Client is alive in the absence of any other Control Packets being sent from the Client to the Server.
- 1112
- 1113 2. Request that the Server responds to confirm that it is alive.
- 1114 3. Exercise the network to indicate that the Network Connection is active.
- 1115

1116 This Packet is used in Keep Alive processing, see Section 3.1.2.10 for more details.

1117 **3.12.1 Fixed header**

1118 **Figure 3.33 – PINGREQ Packet fixed header**

Bit	7	6	5	4	3	2	1	0
byte 1	MQTT Control Packet type (12)				Reserved			
	1	1	0	0	0	0	0	0
byte 2	Remaining Length (0)							
	0	0	0	0	0	0	0	0

1119

1120 **3.12.2 Variable header**

1121 The PINGREQ Packet has no variable header.

1122 **3.12.3 Payload**

1123 The PINGREQ Packet has no payload.

1124 **3.12.4 Response**

1125 The Server MUST send a PINGRESP Packet in response to a PINGREQ Packet [MQTT-3.12.4-1].

1126 **3.13 PINGRESP – PING response**

1127 A PINGRESP Packet is sent by the Server to the Client in response to a PINGREQ Packet. It indicates that the Server is alive.

1128

1129 This Packet is used in Keep Alive processing, see Section 3.1.2.10 for more details.

1131 **3.13.1 Fixed header**

1132 **Figure 3.34 – PINGRESP Packet fixed header**

Bit	7	6	5	4	3	2	1	0

byte 1	MQTT Control Packet type (13)				Reserved			
	1	1	0	1	0	0	0	0
byte 2	Remaining Length (0)							
	0	0	0	0	0	0	0	0

1133

1134 3.13.2 Variable header

1135 The PINGRESP Packet has no variable header.

1136 3.13.3 Payload

1137 The PINGRESP Packet has no payload.

1138 3.14 DISCONNECT – Disconnect notification

1139 The DISCONNECT Packet is the final Control Packet sent from the Client to the Server. It indicates that
1140 the Client is disconnecting cleanly.

1141 3.14.1 Fixed header

1142 **Figure 3.35 – DISCONNECT Packet fixed header**

Bit	7	6	5	4	3	2	1	0
byte 1	MQTT Control Packet type (14)				Reserved			
	1	1	1	0	0	0	0	0
byte 2	Remaining Length (0)							
	0	0	0	0	0	0	0	0

1143 The Server MUST validate that reserved bits are set to zero and disconnect the Client if they are not zero
1144 [MQTT-3.14.1-1].

1145 3.14.2 Variable header

1146 The DISCONNECT Packet has no variable header.

1147 3.14.3 Payload

1148 The DISCONNECT Packet has no payload.

1149 3.14.4 Response

1150 After sending a DISCONNECT Packet the Client:

- 1151 • MUST close the Network Connection [MQTT-3.14.4-1].
- 1152 • MUST NOT send any more Control Packets on that Network Connection [MQTT-3.14.4-2].

1153

1154 On receipt of DISCONNECT the Server:

- 1155 • MUST discard any Will Message associated with the current connection without publishing it, as
1156 described in Section 3.1.2.5 [MQTT-3.14.4-3].

1157

- SHOULD close the Network Connection if the Client has not already done so.

1158 4 Operational behavior

1159 4.1 Storing state

1160 It is necessary for the Client and Server to store Session state in order to provide Quality of Service
1161 guarantees. The Client and Server MUST store Session state for the entire duration of the Session
1162 [MQTT-4.1.0-1]. A Session MUST last at least as long it has an active Network Connection [MQTT-4.1.0-
1163 2].

1164
1165 Retained messages do not form part of the Session state in the Server. The Server SHOULD retain such
1166 messages until deleted by a Client.

1167
1168 **Non normative comment**

1169 The storage capabilities of Client and Server implementations will of course have limits in terms
1170 of capacity and may be subject to administrative policies such as the maximum time that Session
1171 state is stored between Network Connections. Stored Session state can be discarded as a result
1172 of an administrator action, including an automated response to defined conditions. This has the
1173 effect of terminating the Session. These actions might be prompted by resource constraints or for
1174 other operational reasons. It is prudent to evaluate the storage capabilities of the Client and
1175 Server to ensure that they are sufficient.

1176
1177 **Non normative comment**

1178 It is possible that hardware or software failures may result in loss or corruption of Session state
1179 stored by the Client or Server.

1180
1181 **Non normative comment**

1182 Normal operation of the Client of Server could mean that stored state is lost or corrupted because
1183 of administrator action, hardware failure or software failure. An administrator action could be an
1184 automated response to defined conditions. These actions might be prompted by resource
1185 constraints or for other operational reasons. For example the server might determine that based
1186 on external knowledge, a message or messages can no longer be delivered to any current or
1187 future client.

1188
1189 **Non normative comment**

1190 An MQTT user should evaluate the storage capabilities of the MQTT Client and Server
1191 implementations to ensure that they are sufficient for their needs.

1192 1193 4.1.1 Non normative example

1194 For example, a user wishing to gather electricity meter readings may decide that they need to use QoS 1
1195 messages because they need to protect the readings against loss over the network, however they may
1196 have determined that the power supply is sufficiently reliable that the data in the Client and Server can be
1197 stored in volatile memory without too much risk of its loss.

1198 Conversely a parking meter payment application provider might decide that there are no circumstances
1199 where a payment message can be lost so they require that all data are force written to non-volatile
1200 memory before it is transmitted across the network.

1201 **4.2 Network Connections**

1202 The MQTT protocol requires an underlying transport that provides an ordered, lossless, stream of bytes
1203 from the Client to Server and Server to Client.

1204
1205 **Non normative comment**

1206 The transport protocol used to carry MQTT 3.1 was TCP/IP as defined in [\[RFC793\]](#). TCP/IP can
1207 be used for MQTT 3.1.1. The following are also suitable:

- 1208 • TLS [\[RFC5246\]](#)
- 1209 • WebSocket [\[RFC6455\]](#)

1210 **Non normative comment**

1211 TCP ports 8883 and 1883 are registered with IANA for MQTT TLS and non TLS communication
1212 respectively.

1213
1214 Connectionless network transports such as User Datagram Protocol (UDP) are not suitable on their own
1215 because they might lose or reorder data.

1216 **4.3 Quality of Service levels and protocol flows**

1217 MQTT delivers Application Messages according to the Quality of Service (QoS) levels defined here. The
1218 delivery protocol is symmetric, in the description below the Client and Server can each take the role of
1219 either Sender or Receiver. The delivery protocol is concerned solely with the delivery of an application
1220 message from a single Sender to a single Receiver. When the Server is delivering an Application
1221 Message to more than one Client, each Client is treated independently. The QoS level used to deliver an
1222 Application Message outbound to the Client could differ from that of the inbound Application Message.

1223 The non-normative flow diagrams in the following sections are intended to show possible implementation
1224 approaches.

1225 **4.3.1 QoS 0: At most once delivery**

1226 The message is delivered according to the capabilities of the underlying network. No response is sent by
1227 the receiver and no retry is performed by the sender. The message arrives at the receiver either once or
1228 not at all.

1229
1230 In the QoS 0 delivery protocol, the Sender

- 1231 • **MUST send a PUBLISH packet with QoS=0, DUP=0** [\[MQTT-4.3.1-1\]](#).

1232
1233 In the QoS 0 delivery protocol, the Receiver

- 1234 • Accepts ownership of the message when it receives the PUBLISH packet.

1235 **Figure 4.1 – QoS 0 protocol flow diagram, non normative example**

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

1236 **4.3.2 QoS 1: At least once delivery**

1237 This quality of service ensures that the message arrives at the receiver at least once. A QoS 1 PUBLISH
 1238 Packet has a Packet Identifier in its variable header and is acknowledged by a PUBACK Packet. Section
 1239 2.3.1 provides more information about Packet Identifiers.

1240

1241 In the QoS 1 delivery protocol, the Sender

- 1242 • MUST assign an unused Packet Identifier each time it has a new Application Message to
 1243 publish.
- 1244 • MUST send a PUBLISH Packet containing this Packet Identifier with QoS=1, DUP=0.
- 1245 • MUST treat the PUBLISH Packet as “unacknowledged” until it has received the corresponding
 1246 PUBACK packet from the receiver. See Section 4.4 for a discussion of unacknowledged
 1247 messages.

1248 [MQTT-4.3.2-1].

1249 The Packet Identifier becomes available for reuse once the Sender has received the PUBACK Packet.

1250

1251 Note that a Sender is permitted to send further PUBLISH Packets with different Packet Identifiers while it
 1252 is waiting to receive acknowledgements.

1253

1254 In the QoS 1 delivery protocol, the Receiver

- 1255 • MUST respond with a PUBACK Packet containing the Packet Identifier from the incoming
 1256 PUBLISH Packet, having accepted ownership of the Application Message
- 1257 • After it has sent a PUBACK Packet the Receiver MUST treat any incoming PUBLISH packet that
 1258 contains the same Packet Identifier as being a new publication, irrespective of the setting of its
 1259 DUP flag.

1260 [MQTT-4.3.2-2].

1261

1262 **Figure 4.2 – QoS 1 protocol flow diagram, non normative example**

Sender Action	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		

1263

1264 ¹ The receiver is not required to complete delivery of the Application Message before sending the
 1265 PUBACK. When its original sender receives the PUBACK packet, ownership of the Application
 1266 Message is transferred to the receiver.

1267

1268 **4.3.3 QoS 2: Exactly once delivery**

1269 This is the highest quality of service, for use when neither loss nor duplication of messages are
 1270 acceptable. There is an increased overhead associated with this quality of service.

1271
 1272 A QoS 2 message has a Packet Identifier in its variable header. Section 2.3.1 provides more information
 1273 about Packet Identifiers. The receiver of a QoS 2 PUBLISH Packet acknowledges receipt with a two-step
 1274 acknowledgement process.

1275
 1276 **In the QoS 2 delivery protocol, the Sender**

- 1277 • MUST assign an unused Packet Identifier when it has a new Application Message to publish.
- 1278 • MUST send a PUBLISH packet containing this Packet Identifier with QoS=2, DUP=0.
- 1279 • MUST treat the PUBLISH packet as “unacknowledged” until it has received the corresponding
 1280 PUBREC packet from the receiver. See Section 4.4 for a discussion of unacknowledged
 1281 messages.
- 1282 • MUST send a PUBREL packet when it receives a PUBREC packet from the receiver. This
 1283 PUBREL packet MUST contain the same Packet Identifier as the original PUBLISH packet.
- 1284 • MUST treat the PUBREL packet as “unacknowledged” until it has received the corresponding
 1285 PUBCOMP packet from the receiver.
- 1286 • MUST NOT re-send the PUBLISH once it has sent the corresponding PUBREL packet.

1287 **[MQTT-4.3.3-1].**

1288 The Packet Identifier becomes available for reuse once the Sender has received the PUBCOMP Packet.

1289
 1290 Note that a Sender is permitted to send further PUBLISH Packets with different Packet Identifiers while it
 1291 is waiting to receive acknowledgements.

1292
 1293 **In the QoS 2 delivery protocol, the Receiver**

- 1294 • MUST respond with a PUBREC containing the Packet Identifier from the incoming PUBLISH
 1295 Packet, having accepted ownership of the Application Message.
- 1296 • Until it has received the corresponding PUBREL packet, the Receiver MUST acknowledge any
 1297 subsequent PUBLISH packet with the same Packet Identifier by sending a PUBREC. It MUST
 1298 NOT cause duplicate messages to be delivered to any onward recipients in this case.
- 1299 • MUST respond to a PUBREL packet by sending a PUBCOMP packet containing the same
 1300 Packet Identifier as the PUBREL.
- 1301 • After it has sent a PUBCOMP, the receiver MUST treat any subsequent PUBLISH packet that
 1302 contains that Packet Identifier as being a new publication.

1303 **[MQTT-4.3.3-2].**

1304
 1305 **Figure 4.3 – QoS 2 protocol flow diagram, non normative example**

Sender Action	Control Packet	Receiver Action
Store message		
PUBLISH QoS 2, DUP 0 <Packet Identifier>		
	----->	

		Method A, Store message or Method B, Store <Packet Identifier> then Initiate onward delivery of the Application Message ¹
		PUBREC <Packet Identifier>
	<-----	
Discard message, Store PUBREC received <Packet Identifier>		
PUBREL <Packet Identifier>		
	----->	
		Method A, Initiate onward delivery of the Application Message ¹ then discard message or Method B, Discard <Packet Identifier>
		Send PUBCOMP <Packet Identifier>
	<-----	
Discard stored state		

1306
1307
1308
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1310
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1313
1314

¹ The receiver is not required to complete delivery of the Application Message before sending the PUBREC or PUBCOMP. When its original sender receives the PUBREC packet, ownership of the Application Message is transferred to the receiver.

Figure 4.3 shows that there are two methods by which QoS 2 can be handled by the receiver. They differ in the point within the flow at which the message is made available for onward delivery. The choice of Method A or Method B is implementation specific. As long as an implementation chooses exactly one of these approaches, this does not affect the guarantees of a QoS 2 flow.

1315 4.4 Message delivery retry

1316 When a Client reconnects with CleanSession set to 0, both the Client and Server MUST re-send any
1317 unacknowledged PUBLISH Packets (where QoS > 0) and PUBREL Packets using their original Packet
1318 Identifiers [MQTT-4.4.0-1]. This is the only circumstance where a Client or Server is REQUIRED to
1319 redeliver messages.

1320
1321
1322
1323
1324

Non normative comment

Historically retransmission of Control Packets was required to overcome data loss on some older TCP networks. This might remain a concern where MQTT 3.1.1 implementations are to be deployed in such environments.

1325 4.5 Message receipt

1326 When a Server takes ownership of an incoming Application Message it MUST add it to the Session state
1327 of those clients that have matching Subscriptions. Matching rules are defined in Section 4.7 [MQTT-4.5.0-
1328 1].

1329 Under normal circumstances Clients receive messages in response to Subscriptions they have created. A
1330 Client could also receive messages that do not match any of its explicit Subscriptions. This can happen if
1331 the Server automatically assigned a subscription to the Client. A Client could also receive messages
1332 while an UNSUBSCRIBE operation is in progress. The Client MUST acknowledge any Publish Packet it
1333 receives according to the applicable QoS rules regardless of whether it elects to process the Application
1334 Message that it contains [MQTT-4.5.0-2].

1335 4.6 Message ordering

1336 A Client MUST follow these rules when implementing the protocol flows defined elsewhere in this chapter:

- 1337 • When it re-sends any PUBLISH packets, it MUST re-send them in the order in which the original
1338 PUBLISH packets were sent (this applies to QoS 1 and QoS 2 messages) [MQTT-4.6.0-1]
- 1339 • It MUST send PUBACK packets in the order in which the corresponding PUBLISH packets were
1340 received (QoS 1 messages) [MQTT-4.6.0-2]
- 1341 • It MUST send PUBREC packets in the order in which the corresponding PUBLISH packets were
1342 received (QoS 2 messages) [MQTT-4.6.0-3]
- 1343 • It MUST send PUBREL packets in the order in which the corresponding PUBREC packets were
1344 received (QoS 2 messages) [MQTT-4.6.0-4]

1345

1346 A Server MUST by default treat each Topic as an "Ordered Topic". It MAY provide an administrative or
1347 other mechanism to allow one or more Topics to be treated as an "Unordered Topic" [MQTT-4.6.0-5].

1348

1349 When a Server processes a message that has been published to an Ordered Topic, it MUST follow the
1350 rules listed above when delivering messages to each of its subscribers. In addition it MUST send
1351 PUBLISH packets to consumers (for the same Topic and QoS) in the order that they were received from
1352 any given Client [MQTT-4.6.0-6].

1353

1354

Non normative comment

1355 The rules listed above ensure that when a stream of messages is published and subscribed to
1356 with QoS 1, the final copy of each message received by the subscribers will be in the order that
1357 they were originally published in, but the possibility of message duplication could result in a re-
1358 send of an earlier message being received after one of its successor messages. For example a
1359 publisher might send messages in the order 1,2,3,4 and the subscriber might receive them in the
1360 order 1,2,3,2,3,4.

1361

1362 If both Client and Server make sure that no more than one message is "in-flight" at any one time
1363 (by not sending a message until its predecessor has been acknowledged), then no QoS 1
1364 message will be received after any later one - for example a subscriber might receive them in the
1365 order 1,2,3,3,4 but not 1,2,3,2,3,4. Setting an in-flight window of 1 also means that order will be
1366 preserved even if the publisher sends a sequence of messages with different QoS levels on the
1367 same topic.

1368 4.7 Topic Names and Topic Filters

1369 4.7.1 Topic wildcards

1370 The topic level separator is used to introduce structure into the Topic Name. If present, it divides the
1371 Topic Name into multiple “topic levels”.

1372 A subscription’s Topic Filter can contain special wildcard characters, which allow you to subscribe to
1373 multiple topics at once.

1374 **The wildcard characters can be used in Topic Filters, but MUST NOT be used within a Topic Name**
1375 **[MQTT-4.7.1-1].**

1376 4.7.1.1 Topic level separator

1377 The forward slash (‘/’ U+002F) is used to separate each level within a topic tree and provide a hierarchical
1378 structure to the Topic Names. The use of the topic level separator is significant when either of the two
1379 wildcard characters is encountered in Topic Filters specified by subscribing Clients. Topic level separators
1380 can appear anywhere in a Topic Filter or Topic Name. Adjacent Topic level separators indicate a zero
1381 length topic level.

1382 4.7.1.2 Multi-level wildcard

1383 The number sign (‘#’ U+0023) is a wildcard character that matches any number of levels within a topic.
1384 The multi-level wildcard represents the parent and any number of child levels. **The multi-level wildcard**
1385 **character MUST be specified either on its own or following a topic level separator. In either case it MUST**
1386 **be the last character specified in the Topic Filter [MQTT-4.7.1-2].**

1387

1388 **Non normative comment**

1389 For example, if a Client subscribes to “sport/tennis/player1/#”, it would receive messages
1390 published using these topic names:

- 1391 • “sport/tennis/player1”
- 1392 • “sport/tennis/player1/ranking”
- 1393 • “sport/tennis/player1/score/wimbledon”

1394

1395 **Non normative comment**

- 1396 • “sport/#” also matches the singular “sport”, since # includes the parent level.
- 1397 • “#” is valid and will receive every Application Message
- 1398 • “sport/tennis/#” is valid
- 1399 • “sport/tennis#” is not valid
- 1400 • “sport/tennis/#/ranking” is not valid

1401 4.7.1.3 Single level wildcard

1402 The plus sign (‘+’ U+002B) is a wildcard character that matches only one topic level.

1403

1404 **The single-level wildcard can be used at any level in the Topic Filter, including first and last levels. Where**
1405 **it is used it MUST occupy an entire level of the filter [MQTT-4.7.1-3].** It can be used at more than one
1406 level in the Topic Filter and can be used in conjunction with the multilevel wildcard.

1407

1408 **Non normative comment**

1409 For example, “sport/tennis/+” matches “sport/tennis/player1” and “sport/tennis/player2”, but not
1410 “sport/tennis/player1/ranking”. Also, because the single-level wildcard matches only a single level,
1411 “sport/+” does not match “sport” but it does match “sport/”.

1412

1413 **Non normative comment**

- 1414 • “+” is valid
- 1415 • “+/tennis/#” is valid
- 1416 • “sport+” is not valid
- 1417 • “sport+/player1” is valid
- 1418 • “/finance” matches “+/+” and “/+”, but not “+”

1419 **4.7.2 Topics beginning with \$**

1420 The Server MUST NOT match Topic Filters starting with a wildcard character (# or +) with Topic Names
1421 beginning with a \$ character [MQTT-4.7.2-1]. The Server SHOULD prevent Clients from using such Topic
1422 Names to exchange messages with other Clients. Server implementations MAY use Topic Names that
1423 start with a leading \$ character for other purposes.

1424

1425 **Non normative comment**

- 1426 • \$SYS/ has been widely adopted as a prefix to topics that contain Server-specific
1427 information or control APIs
- 1428 • Applications cannot use a topic with a leading \$ character for their own purposes

1429

1430 **Non normative comment**

- 1431 • A subscription to “#” will not receive any messages published to a topic beginning with a
1432 \$
- 1433 • A subscription to “+/monitor/Clients” will not receive any messages published to
1434 “\$SYS/monitor/Clients”
- 1435 • A subscription to “\$SYS/#” will receive messages published to topics beginning with
1436 “\$SYS/”
- 1437 • A subscription to “\$SYS/monitor/+” will receive messages published to
1438 “\$SYS/monitor/Clients”
- 1439 • For a Client to receive messages from topics that begin with \$SYS/ and from topics that
1440 don’t begin with a \$, it has to subscribe to both “#” and “\$SYS/#”

1441 **4.7.3 Topic semantic and usage**

1442 The following rules apply to Topic Names and Topic Filters:

- 1443 • All Topic Names and Topic Filters MUST be at least one character long [MQTT-4.7.3-1]
- 1444 • Topic Names and Topic Filters are case sensitive
- 1445 • Topic Names and Topic Filters can include the space character
- 1446 • A leading or trailing ‘/’ creates a distinct Topic Name or Topic Filter
- 1447 • A Topic Name or Topic Filter consisting only of the ‘/’ character is valid
- 1448 • Topic Names and Topic Filters MUST NOT include the null character (Unicode U+0000)
1449 [Unicode] [MQTT-4.7.3-2]
- 1450 • Topic Names and Topic Filters are UTF-8 encoded strings, they MUST NOT encode to more than
1451 65535 bytes [MQTT-4.7.3-3]. See Section 1.5.3

1452 There is no limit to the number of levels in a Topic Name or Topic Filter, other than that imposed by the
1453 overall length of a UTF-8 encoded string.

1454 When it performs subscription matching the Server MUST NOT perform any normalization of Topic
1455 Names or Topic Filters, or any modification or substitution of unrecognized characters [MQTT-4.7.3-4].
1456 Each non-wildcarded level in the Topic Filter has to match the corresponding level in the Topic Name
1457 character for character for the match to succeed.
1458

1459 **Non normative comment**

1460 The UTF-8 encoding rules mean that the comparison of Topic Filter and Topic Name could be
1461 performed either by comparing the encoded UTF-8 bytes, or by comparing decoded Unicode
1462 characters

1463

1464 **Non normative comment**

- 1465
- “ACCOUNTS” and “Accounts” are two different topic names
 - “Accounts payable” is a valid topic name
 - “/finance” is different from “finance”
- 1466
1467
1468

1469 An Application Message is sent to each Client Subscription whose Topic Filter matches the Topic Name
1470 attached to an Application Message. The topic resource MAY be either predefined in the Server by an
1471 administrator or it MAY be dynamically created by the Server when it receives the first subscription or an
1472 Application Message with that Topic Name. The Server MAY also use a security component to selectively
1473 authorize actions on the topic resource for a given Client.

1474 4.8 Handling errors

1475

1476 Unless stated otherwise, if either the Server or Client encounters a protocol violation, it MUST close the
1477 Network Connection on which it received that Control Packet which caused the protocol violation [MQTT-
1478 4.8.0-1].

1479 A Client or Server implementation might encounter a Transient Error (for example an internal buffer full
1480 condition) that prevents successful processing of an MQTT packet.

1481 If the Client or Server encounters a Transient Error while processing an inbound Control Packet it MUST
1482 close the Network Connection on which it received that Control Packet [MQTT-4.8.0-2]. If a Server
1483 detects a Transient Error it SHOULD NOT disconnect or have any other effect on its interactions with any
1484 other Client.

1485 5 Security

1486 5.1 Introduction

1487 This Chapter is provided for guidance only and is **Non Normative**. However, it is strongly recommended
1488 that Server implementations that offer TLS [\[RFC5246\]](#) SHOULD use TCP port 8883 (IANA service name:
1489 secure-mqtt).

1490

1491 There are a number of threats that solution providers should consider. For example:

- 1492 • Devices could be compromised
- 1493 • Data at rest in Clients and Servers might be accessible
- 1494 • Protocol behaviors could have side effects (e.g. “timing attacks”)
- 1495 • Denial of Service (DoS) attacks
- 1496 • Communications could be intercepted, altered, re-routed or disclosed
- 1497 • Injection of spoofed Control Packets

1498

1499 MQTT solutions are often deployed in hostile communication environments. In such cases,
1500 implementations will often need to provide mechanisms for:

- 1501 • Authentication of users and devices
- 1502 • Authorization of access to Server resources
- 1503 • Integrity of MQTT Control Packets and application data contained therein
- 1504 • Privacy of MQTT Control Packets and application data contained therein

1505

1506 As a transport protocol, MQTT is concerned only with message transmission and it is the implementer's
1507 responsibility to provide appropriate security features. This is commonly achieved by using TLS
1508 [\[RFC5246\]](#).

1509

1510 In addition to technical security issues there could also be geographic (e.g. U.S.-EU SafeHarbor
1511 [\[USEUSAFEHARB\]](#)), industry specific (e.g. PCI DSS [\[PCIDSS\]](#)) and regulatory considerations (e.g.
1512 Sarbanes-Oxley [\[SARBANES\]](#)).

1513 5.2 MQTT solutions: security and certification

1514 An implementation might want to provide conformance with specific industry security standards such as
1515 NIST Cyber Security Framework [\[NISTCSF\]](#), PCI-DSS [\[PCIDSS\]](#)), FIPS-140-2 [\[FIPS1402\]](#) and NSA Suite
1516 B [\[NSAB\]](#).

1517 Guidance on using MQTT within the NIST Cyber Security Framework [\[NISTCSF\]](#) can be found in the
1518 MQTT supplemental publication, MQTT and the NIST Framework for Improving Critical Infrastructure
1519 Cybersecurity [\[MQTT NIST\]](#). The use of industry proven, independently verified and certified technologies
1520 will help meet compliance requirements.

1521 **5.3 Lightweight cryptography and constrained devices**

1522 Advanced Encryption Standard [\[AES\]](#) and Data Encryption Standard [\[DES\]](#) are widely adopted.

1523

1524 ISO 29192 [\[ISO29192\]](#) makes recommendations for cryptographic primitives specifically tuned to perform
1525 on constrained “low end” devices.

1526 **5.4 Implementation notes**

1527 There are many security concerns to consider when implementing or using MQTT. The following section
1528 should not be considered a “check list”.

1529

1530 An implementation might want to achieve some, or all, of the following:

1531 **5.4.1 Authentication of Clients by the Server**

1532 The CONNECT Packet contains Username and Password fields. Implementations can choose how to
1533 make use of the content of these fields. They may provide their own authentication mechanism, use an
1534 external authentication system such as LDAP [\[RFC4511\]](#) or OAuth [\[RFC6749\]](#) tokens, or leverage
1535 operating system authentication mechanisms.

1536

1537 Implementations passing authentication data in clear text, obfuscating such data elements or requiring no
1538 authentication data should be aware this can give rise to Man-in-the-Middle and replay attacks. Section
1539 5.4.5 introduces approaches to ensure data privacy.

1540

1541 A Virtual Private Network (VPN) between the Clients and Servers can provide confidence that data is only
1542 being received from authorized Clients.

1543

1544 Where TLS [\[RFC5246\]](#) is used, SSL Certificates sent from the Client can be used by the Server to
1545 authenticate the Client.

1546

1547 An implementation might allow for authentication where the credentials are sent in an Application
1548 Message from the Client to the Server.

1549 **5.4.2 Authorization of Clients by the Server**

1550 An implementation may restrict access to Server resources based on information provided by the Client
1551 such as User Name, Client Identifier, the hostname/IP address of the Client, or the outcome of
1552 authentication mechanisms.

1553 **5.4.3 Authentication of the Server by the Client**

1554 The MQTT protocol is not trust symmetrical: it provides no mechanism for the Client to authenticate the
1555 Server.

1556

1557 Where TLS [\[RFC5246\]](#) is used, SSL Certificates sent from the Server can be used by the Client to
1558 authenticate the Server. Implementations providing MQTT service for multiple hostnames from a single IP
1559 address should be aware of the Server Name Indication extension to TLS defined in section 3 of RFC

1560 6066 [RFC6066]. This allows a Client to tell the Server the hostname of the Server it is trying to connect
1561 to.

1562

1563 An implementation might allow for authentication where the credentials are sent in an Application
1564 Message from the Server to the Client.

1565

1566 A VPN between Clients and Servers can provide confidence that Clients are connecting to the intended
1567 Server.

1568 **5.4.4 Integrity of Application Messages and Control Packets**

1569 Applications can independently include hash values in their Application Messages. This can provide
1570 integrity of the contents of Publish Control Packets across the network and at rest.

1571

1572 TLS [RFC5246] provides hash algorithms to verify the integrity of data sent over the network.

1573

1574 The use of VPNs to connect Clients and Servers can provide integrity of data across the section of the
1575 network covered by a VPN.

1576 **5.4.5 Privacy of Application Messages and Control Packets**

1577 TLS [RFC5246] can provide encryption of data sent over the network. There are valid TLS cipher suites
1578 that include a NULL encryption algorithm that does not encrypt data. To ensure privacy Clients and
1579 Servers should avoid these cipher suites.

1580

1581 An application might independently encrypt the contents of its Application Messages. This could provide
1582 privacy of the Application Message both over the network and at rest. This would not provide privacy for
1583 other properties of the Application Message such as Topic Name.

1584

1585 Client and Server implementations can provide encrypted storage for data at rest such as Application
1586 Messages stored as part of a Session.

1587

1588 The use of VPNs to connect Clients and Servers can provide privacy of data across the section of the
1589 network covered by a VPN.

1590 **5.4.6 Non-repudiation of message transmission**

1591 Application designers might need to consider appropriate strategies to achieve end to end non-
1592 repudiation.

1593 **5.4.7 Detecting compromise of Clients and Servers**

1594 Client and Server implementations using TLS [RFC5246] should provide capabilities to ensure that any
1595 SSL certificates provided when initiating a TLS [RFC5246] connection are associated with the hostname
1596 of the Client connecting or Server being connected to.

1597

1598 Client and Server implementations using TLS [\[RFC5246\]](#) can choose to provide capabilities to check
1599 Certificate Revocation Lists (CRLs [\[RFC5280\]](#)) and Online Certificate Status Protocol (OCSP) [\[RFC6960\]](#)
1600 to prevent revoked certificates from being used.

1601
1602 Physical deployments might combine tamper-proof hardware with the transmission of specific data in
1603 Application Messages. For example a meter might have an embedded GPS to ensure it is not used in an
1604 unauthorized location. [\[IEEE 802.1AR\]](#) is a standard for implementing mechanisms to authenticate a
1605 device's identity using a cryptographically bound identifier.

1606 **5.4.8 Detecting abnormal behaviors**

1607 Server implementations might monitor Client behavior to detect potential security incidents. For example:

- 1608 • Repeated connection attempts
- 1609 • Repeated authentication attempts
- 1610 • Abnormal termination of connections
- 1611 • Topic scanning (attempts to send or subscribe to many topics)
- 1612 • Sending undeliverable messages (no subscribers to the topics)
- 1613 • Clients that connect but do not send data

1614
1615 Server implementations might disconnect Clients that breach its security rules.

1616
1617 Server implementations detecting unwelcome behavior might implement a dynamic block list based on
1618 identifiers such as IP address or Client Identifier.

1619
1620 Deployments might use network level controls (where available) to implement rate limiting or blocking
1621 based on IP address or other information.

1622 **5.4.9 Other security considerations**

1623 If Client or Server SSL certificates are lost or it is considered that they might be compromised they should
1624 be revoked (utilizing CRLs [\[RFC5280\]](#) and/or OSCP [\[RFC6960\]](#)).

1625
1626 Client or Server authentication credentials, such as User Name and Password, that are lost or considered
1627 compromised should be revoked and/or reissued.

1628
1629 In the case of long lasting connections:

- 1630 • Client and Server implementations using TLS [\[RFC5246\]](#) should allow for session renegotiation
1631 to establish new cryptographic parameters (replace session keys, change cipher suites, change
1632 authentication credentials).
- 1633 • Servers may disconnect Clients and require them to re-authenticate with new credentials.

1634
1635 Constrained devices and Clients on constrained networks can make use of TLS session resumption
1636 [\[RFC5077\]](#), in order to reduce the costs of reconnecting TLS [\[RFC5246\]](#) sessions.

1637

1638 Clients connected to a Server have a transitive trust relationship with other Clients connected to the same
1639 Server and who have authority to publish data on the same topics.

1640 **5.4.10 Use of SOCKS**

1641 Implementations of Clients should be aware that some environments will require the use of SOCKSv5
1642 [\[RFC1928\]](#) proxies to make outbound Network Connections. Some MQTT implementations could make
1643 use of alternative secured tunnels (e.g. SSH) through the use of SOCKS. Where implementations choose
1644 to use SOCKS, they should support both anonymous and user-name password authenticating SOCKS
1645 proxies. In the latter case, implementations should be aware that SOCKS authentication might occur in
1646 plain-text and so should avoid using the same credentials for connection to a MQTT Server.

1647 **5.4.11 Security profiles**

1648 Implementers and solution designers might wish to consider security as a set of profiles which can be
1649 applied to the MQTT protocol. An example of a layered security hierarchy is presented below.

1650 **5.4.11.1 Clear communication profile**

1651 When using the clear communication profile, the MQTT protocol runs over an open network with no
1652 additional secure communication mechanisms in place.

1653 **5.4.11.2 Secured network communication profile**

1654 When using the secured network communication profile, the MQTT protocol runs over a physical or virtual
1655 network which has security controls e.g., VPNs or physically secure network.

1656 **5.4.11.3 Secured transport profile**

1657 When using the secured transport profile, the MQTT protocol runs over a physical or virtual network and
1658 using TLS [\[RFC5246\]](#) which provides authentication, integrity and privacy.

1659

1660 TLS [\[RFC5246\]](#) Client authentication can be used in addition to – or in place of – MQTT Client
1661 authentication as provided by the Username and Password fields.

1662 **5.4.11.4 Industry specific security profiles**

1663 It is anticipated that the MQTT protocol will be designed into industry specific application profiles, each
1664 defining a threat model and the specific security mechanisms to be used to address these threats.
1665 Recommendations for specific security mechanisms will often be taken from existing works including:

1666

1667 [\[NISTCSF\]](#) NIST Cyber Security Framework

1668 [\[NIST7628\]](#) NISTIR 7628 Guidelines for Smart Grid Cyber Security

1669 [\[FIPS1402\]](#) Security Requirements for Cryptographic Modules (FIPS PUB 140-2)

1670 [\[PCIDSS\]](#) PCI-DSS Payment Card Industry Data Security Standard

1671 [\[NSAB\]](#) NSA Suite B Cryptography

6 Using WebSocket as a network transport

1672

1673 If MQTT is transported over a WebSocket [RFC6455] connection, the following conditions apply:

- 1674 • MQTT Control Packets MUST be sent in WebSocket binary data frames. If any other type of
1675 data frame is received the recipient MUST close the Network Connection [MQTT-6.0.0-1].
- 1676 • A single WebSocket data frame can contain multiple or partial MQTT Control Packets. The
1677 receiver MUST NOT assume that MQTT Control Packets are aligned on WebSocket frame
1678 boundaries [MQTT-6.0.0-2].
- 1679 • The client MUST include “mqtt” in the list of WebSocket Sub Protocols it offers [MQTT-6.0.0-3].
- 1680 • The WebSocket Sub Protocol name selected and returned by the server MUST be “mqtt”
1681 [MQTT-6.0.0-4].
- 1682 • The WebSocket URI used to connect the client and server has no impact on the MQTT protocol.

6.1 IANA Considerations

1683

1684 This specification requests IANA to register the WebSocket MQTT sub-protocol under the “WebSocket
1685 Subprotocol Name” registry with the following data:

1686

1687 **Figure 6.1 - IANA WebSocket Identifier**

Subprotocol Identifier	mqtt
Subprotocol Common Name	mqtt
Subprotocol Definition	http://docs.oasis-open.org/mqtt/mqtt/v3.1.1/mqtt-v3.1.1.html

1688

1689 7 Conformance

1690 The MQTT specification defines conformance for MQTT Client implementations and MQTT Server
1691 implementations.

1692

1693 An MQTT implementation MAY conform as both an MQTT Client and MQTT Server implementation. A
1694 Server that both accepts inbound connections and establishes outbound connections to other Servers
1695 MUST conform as both an MQTT Client and MQTT Server [MQTT-7.0.0-1].

1696

1697 Conformant implementations MUST NOT require the use of any extensions defined outside of this
1698 specification in order to interoperate with any other conformant implementation [MQTT-7.0.0-2].

1699 7.1 Conformance Targets

1700 7.1.1 MQTT Server

1701 An MQTT Server conforms to this specification only if it satisfies all the statements below:

1702 1. The format of all Control Packets that the Server sends matches the format described in Chapter 2 and
1703 Chapter 3.

1704 2. It follows the Topic matching rules described in Section 4.7.

1705 3. It satisfies all of the MUST level requirements in the following chapters that are identified except for
1706 those that only apply to the Client:

1707 - Chapter 1 - Introduction

1708 - Chapter 2 - MQTT Control Packet format

1709 - Chapter 3 - MQTT Control Packets

1710 - Chapter 4 - Operational behavior

1711 - Chapter 6 - (if MQTT is transported over a WebSocket connection)

1712 - Chapter 7 - Conformance Targets

1713

1714 A conformant Server MUST support the use of one or more underlying transport protocols that provide an
1715 ordered, lossless, stream of bytes from the Client to Server and Server to Client [MQTT-7.1.1-1]. However
1716 conformance does not depend on it supporting any specific transport protocols. A Server MAY support
1717 any of the transport protocols listed in Section 4.2, or any other transport protocol that meets the
1718 requirements of [MQTT-7.1.1-1].

1719 7.1.2 MQTT Client

1720 An MQTT Client conforms to this specification only if it satisfies all the statements below:

1721 1. The format of all Control Packets that the Client sends matches the format described in Chapter 2 and
1722 Chapter 3.

1723 2. It satisfies all of the MUST level requirements in the following chapters that are identified except for
1724 those that only apply to the Server:

1725 - Chapter 1 - Introduction

1726 - Chapter 2 - MQTT Control Packet format

1727 - Chapter 3 - MQTT Control Packets

1728 - Chapter 4 - Operational behavior

1729 - Chapter 6 - (if MQTT is transported over a WebSocket connection)

1730 - Chapter 7 - Conformance Targets

1731

1732 A conformant Client MUST support the use of one or more underlying transport protocols that provide an
1733 ordered, lossless, stream of bytes from the Client to Server and Server to Client [MQTT-7.1.2-1]. However
1734 conformance does not depend on it supporting any specific transport protocols. A Client MAY support any
1735 of the transport protocols listed in Section 4.2, or any other transport protocol that meets the requirements
1736 of [MQTT-7.1.2-1].

1737

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1740

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Appendix B. Mandatory normative statements (non normative)

1801 This Appendix is non-normative and is provided as a convenient summary of the numbered conformance
1802 statements found in the main body of this document. See Chapter 7 for a definitive list of conformance
1803 requirements.

Normative Statement Number	Normative Statement
[MQTT-1.5.3-1]	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 this data MUST NOT include encodings of code points between U+D800 and U+DFFF. If a Server or Client receives a Control Packet containing ill-formed UTF-8 it MUST close the Network Connection.
[MQTT-1.5.3-2]	A UTF-8 encoded string MUST NOT include an encoding of the null character U+0000. If a receiver (Server or Client) receives a Control Packet containing U+0000 it MUST close the Network Connection.
[MQTT-1.5.3-3]	A UTF-8 encoded sequence 0xEF 0xBB 0xBF is always to be interpreted to mean 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.
[MQTT-2.2.2-1]	Where a flag bit is marked as "Reserved" in Table 2.2 - Flag Bits, it is reserved for future use and MUST be set to the value listed in that table.
[MQTT-2.2.2-2]	If invalid flags are received, the receiver MUST close the Network Connection.
[MQTT-2.3.1-1]	SUBSCRIBE, UNSUBSCRIBE, and PUBLISH (in cases where QoS > 0) Control Packets MUST contain a non-zero 16-bit Packet Identifier.
[MQTT-2.3.1-2]	Each time a Client sends a new packet of one of these types it MUST assign it a currently unused Packet Identifier.
[MQTT-2.3.1-3]	If a Client re-sends a particular Control Packet, then it MUST use the same Packet Identifier in subsequent re-sends of that packet. The Packet Identifier becomes available for reuse after the Client has processed the corresponding acknowledgement packet. In the case of a QoS 1 PUBLISH this is the corresponding PUBACK; in the case of QoS 2 it is PUBCOMP. For SUBSCRIBE or UNSUBSCRIBE it is the corresponding SUBACK or UNSUBACK.
[MQTT-2.3.1-4]	The same conditions [MQTT-2.3.1-3] apply to a Server when it sends a PUBLISH with QoS >0.
[MQTT-2.3.1-5]	A PUBLISH Packet MUST NOT contain a Packet Identifier if its QoS value is set to 0.
[MQTT-2.3.1-6]	A PUBACK, PUBREC or PUBREL Packet MUST contain the same Packet Identifier as the PUBLISH Packet that was originally sent.
[MQTT-2.3.1-7]	Similarly to [MQTT-2.3.1-6], SUBACK and UNSUBACK MUST contain the Packet Identifier that was used in the corresponding SUBSCRIBE and UNSUBSCRIBE Packet respectively.
[MQTT-3.1.0-1]	After a Network Connection is established by a Client to a Server, the first Packet sent from the Client to the Server MUST be a CONNECT Packet.

[MQTT-3.1.0-2]	The Server MUST process a second CONNECT Packet sent from a Client as a protocol violation and disconnect the Client.
[MQTT-3.1.2-1]	If the protocol name is incorrect the Server MAY disconnect the Client, or it MAY continue processing the CONNECT packet in accordance with some other specification. In the latter case, the Server MUST NOT continue to process the CONNECT packet in line with this specification.
[MQTT-3.1.2-2]	The Server MUST respond to the CONNECT Packet with a CONNACK return code 0x01 (unacceptable protocol level) and then disconnect the Client if the Protocol Level is not supported by the Server.
[MQTT-3.1.2-3]	The Server MUST validate that the reserved flag in the CONNECT Control Packet is set to zero and disconnect the Client if it is not zero.
[MQTT-3.1.2-4]	If CleanSession is set to 0, the Server MUST resume communications with the Client based on state from the current Session (as identified by the Client identifier). If there is no Session associated with the Client identifier the Server MUST create a new Session. The Client and Server MUST store the Session after the Client and Server are disconnected.
[MQTT-3.1.2-5]	After the disconnection of a Session that had CleanSession set to 0, the Server MUST store further QoS 1 and QoS 2 messages that match any subscriptions that the client had at the time of disconnection as part of the Session state.
[MQTT-3.1.2-6]	If CleanSession is set to 1, the Client and Server MUST discard any previous Session and start a new one. This Session lasts as long as the Network Connection. State data associated with this Session MUST NOT be reused in any subsequent Session.
[MQTT-3.1.2.7]	Retained messages do not form part of the Session state in the Server, they MUST NOT be deleted when the Session ends.
[MQTT-3.1.2-8]	If the Will Flag is set to 1 this indicates that, if the Connect request is accepted, a Will Message MUST be stored on the Server and associated with the Network Connection. The Will Message MUST be published when the Network Connection is subsequently closed unless the Will Message has been deleted by the Server on receipt of a DISCONNECT Packet.
[MQTT-3.1.2-9]	If the Will Flag is set to 1, the Will QoS and Will Retain fields in the Connect Flags will be used by the Server, and the Will Topic and Will Message fields MUST be present in the payload.
[MQTT-3.1.2-10]	The Will Message MUST be removed from the stored Session state in the Server once it has been published or the Server has received a DISCONNECT packet from the Client.
[MQTT-3.1.2-11]	If the Will Flag is set to 0 the Will QoS and Will Retain fields in the Connect Flags MUST be set to zero and the Will Topic and Will Message fields MUST NOT be present in the payload.
[MQTT-3.1.2-12]	If the Will Flag is set to 0, a Will Message MUST NOT be published when this Network Connection ends.
[MQTT-3.1.2-13]	If the Will Flag is set to 0, then the Will QoS MUST be set to 0 (0x00).
[MQTT-3.1.2-14]	If the Will Flag is set to 1, the value of Will QoS can be 0 (0x00), 1 (0x01), or 2 (0x02). It MUST NOT be 3 (0x03).
[MQTT-3.1.2-15]	If the Will Flag is set to 0, then the Will Retain Flag MUST be set to 0.

[MQTT-3.1.2-16]	If the Will Flag is set to 1 and If Will Retain is set to 0, the Server MUST publish the Will Message as a non-retained message.
[MQTT-3.1.2-17]	If the Will Flag is set to 1 and If Will Retain is set to 1, the Server MUST publish the Will Message as a retained message.
[MQTT-3.1.2-18]	If the User Name Flag is set to 0, a user name MUST NOT be present in the payload.
[MQTT-3.1.2-19]	If the User Name Flag is set to 1, a user name MUST be present in the payload.
[MQTT-3.1.2-20]	If the Password Flag is set to 0, a password MUST NOT be present in the payload.
[MQTT-3.1.2-21]	If the Password Flag is set to 1, a password MUST be present in the payload.
[MQTT-3.1.2-22]	If the User Name Flag is set to 0, the Password Flag MUST be set to 0.
[MQTT-3.1.2-23]	It is the responsibility of the Client to ensure that the interval between Control Packets being sent does not exceed the Keep Alive value. In the absence of sending any other Control Packets, the Client MUST send a PINGREQ Packet.
[MQTT-3.1.2-24]	If the Keep Alive value is non-zero and the Server does not receive a Control Packet from the Client within one and a half times the Keep Alive time period, it MUST disconnect the Network Connection to the Client as if the network had failed.
[MQTT-3.1.3-1]	These fields, if present, MUST appear in the order Client Identifier, Will Topic, Will Message, User Name, Password.
[MQTT-3.1.3-2]	Each Client connecting to the Server has a unique ClientId. The ClientId MUST be used by Clients and by Servers to identify state that they hold relating to this MQTT Session between the Client and the Server.
[MQTT-3.1.3-3]	The Client Identifier (ClientId) MUST be present and MUST be the first field in the CONNECT packet payload.
[MQTT-3.1.3-4]	The ClientId MUST be a UTF-8 encoded string as defined in Section 1.5.3.
[MQTT-3.1.3-5]	The Server MUST allow ClientIds which are between 1 and 23 UTF-8 encoded bytes in length, and that contain only the characters "0123456789abcdefghijklmnopqrstuvwxyzaBCDEFGHIJKLMNOPQRSTUVWXYZ".
[MQTT-3.1.3-6]	A Server MAY allow a Client to supply a ClientId that has a length of zero bytes. However if it does so the Server MUST treat this as a special case and assign a unique ClientId to that Client. It MUST then process the CONNECT packet as if the Client had provided that unique ClientId.
[MQTT-3.1.3-7]	If the Client supplies a zero-byte ClientId, the Client MUST also set CleanSession to 1.
[MQTT-3.1.3-8]	If the Client supplies a zero-byte ClientId with CleanSession set to 0, the Server MUST respond to the CONNECT Packet with a CONNACK return code 0x02 (Identifier rejected) and then close the Network Connection.
[MQTT-3.1.3-9]	If the Server rejects the ClientId it MUST respond to the CONNECT Packet with a CONNACK return code 0x02 (Identifier rejected) and then close the Network Connection.

[MQTT-3.1.3-10]	The Will Topic MUST be a UTF-8 encoded string as defined in Section 1.5.3.
[MQTT-3.1.3-11]	The User Name MUST be a UTF-8 encoded string as defined in Section 1.5.3.
[MQTT-3.1.4-1]	The Server MUST validate that the CONNECT Packet conforms to section 3.1 and close the Network Connection without sending a CONNACK if it does not conform.
[MQTT-3.1.4-2]	If the ClientId represents a Client already connected to the Server then the Server MUST disconnect the existing Client.
[MQTT-3.1.4-3]	If CONNECT validation is successful the Server MUST perform the processing of CleanSession that is described in section 3.1.2.4.
[MQTT-3.1.4-4]	If CONNECT validation is successful the Server MUST acknowledge the CONNECT Packet with a CONNACK Packet containing a zero return code.
[MQTT-3.1.4-5]	If the Server rejects the CONNECT, it MUST NOT process any data sent by the Client after the CONNECT Packet.
[MQTT-3.2.0-1]	The first packet sent from the Server to the Client MUST be a CONNACK Packet.
[MQTT-3.2.2-1]	If the Server accepts a connection with CleanSession set to 1, the Server MUST set Session Present to 0 in the CONNACK packet in addition to setting a zero return code in the CONNACK packet.
[MQTT-3.2.2-2]	If the Server accepts a connection with CleanSession set to 0, the value set in Session Present depends on whether the Server already has stored Session state for the supplied client ID. If the Server has stored Session state, it MUST set Session Present to 1 in the CONNACK packet.
[MQTT-3.2.2-3]	If the Server does not have stored Session state, it MUST set Session Present to 0 in the CONNACK packet. This is in addition to setting a zero return code in the CONNACK packet.
[MQTT-3.2.2-4]	If a server sends a CONNACK packet containing a non-zero return code it MUST set Session Present to 0.
[MQTT-3.2.2-5]	If a server sends a CONNACK packet containing a non-zero return code it MUST then close the Network Connection.
[MQTT-3.2.2-6]	If none of the return codes listed in Table 3.1 – Connect Return code values are deemed applicable, then the Server MUST close the Network Connection without sending a CONNACK.
[MQTT-3.3.1-1]	The DUP flag MUST be set to 1 by the Client or Server when it attempts to re-deliver a PUBLISH Packet.
[MQTT-3.3.1-2]	The DUP flag MUST be set to 0 for all QoS 0 messages.
[MQTT-3.3.1-3]	The value of the DUP flag from an incoming PUBLISH packet is not propagated when the PUBLISH Packet is sent to subscribers by the Server. The DUP flag in the outgoing PUBLISH packet is set independently to the incoming PUBLISH packet, its value MUST be determined solely by whether the outgoing PUBLISH packet is a retransmission.
[MQTT-3.3.1-4]	A PUBLISH Packet MUST NOT have both QoS bits set to 1. If a Server or Client receives a PUBLISH Packet which has both QoS bits set to 1 it MUST close the Network Connection.

[MQTT-3.3.1-5]	If the RETAIN flag is set to 1, in a PUBLISH Packet sent by a Client to a Server, the Server MUST store the Application Message and its QoS, so that it can be delivered to future subscribers whose subscriptions match its topic name.
[MQTT-3.3.1-6]	When a new subscription is established, the last retained message, if any, on each matching topic name MUST be sent to the subscriber.
[MQTT-3.3.1-7]	If the Server receives a QoS 0 message with the RETAIN flag set to 1 it MUST discard any message previously retained for that topic. It SHOULD store the new QoS 0 message as the new retained message for that topic, but MAY choose to discard it at any time - if this happens there will be no retained message for that topic.
[MQTT-3.3.1-8]	When sending a PUBLISH Packet to a Client the Server MUST set the RETAIN flag to 1 if a message is sent as a result of a new subscription being made by a Client.
[MQTT-3.3.1-9]	It MUST set the RETAIN flag to 0 when a PUBLISH Packet is sent to a Client because it matches an established subscription regardless of how the flag was set in the message it received.
[MQTT-3.3.1-10]	A PUBLISH Packet with a RETAIN flag set to 1 and a payload containing zero bytes will be processed as normal by the Server and sent to Clients with a subscription matching the topic name. Additionally any existing retained message with the same topic name MUST be removed and any future subscribers for the topic will not receive a retained message.
[MQTT-3.3.1-11]	A zero byte retained message MUST NOT be stored as a retained message on the Server.
[MQTT-3.3.1-12]	If the RETAIN flag is 0, in a PUBLISH Packet sent by a Client to a Server, the Server MUST NOT store the message and MUST NOT remove or replace any existing retained message.
[MQTT-3.3.2-1]	The Topic Name MUST be present as the first field in the PUBLISH Packet Variable header. It MUST be a UTF-8 encoded string.
[MQTT-3.3.2-2]	The Topic Name in the PUBLISH Packet MUST NOT contain wildcard characters.
[MQTT-3.3.2-3]	The Topic Name in a PUBLISH Packet sent by a Server to a subscribing Client MUST match the Subscription's Topic Filter according to the matching process defined in Section 4.7.
[MQTT-3.3.4-1]	The receiver of a PUBLISH Packet MUST respond according to Table 3.4 - Expected Publish Packet response as determined by the QoS in the PUBLISH Packet.
[MQTT-3.3.5-1]	The Server MUST deliver the message to the Client respecting the maximum QoS of all the matching subscriptions.
[MQTT-3.3.5-2]	If a Server implementation does not authorize a PUBLISH to be performed by a Client; it has no way of informing that Client. It MUST either make a positive acknowledgement, according to the normal QoS rules, or close the Network Connection.
[MQTT-3.6.1-1]	Bits 3,2,1 and 0 of the fixed header in the PUBREL Control Packet are reserved and MUST be set to 0,0,1 and 0 respectively. The Server MUST treat any other value as malformed and close the Network Connection.

[MQTT-3.8.1-1]	Bits 3,2,1 and 0 of the fixed header of the SUBSCRIBE Control Packet are reserved and MUST be set to 0,0,1 and 0 respectively. The Server MUST treat any other value as malformed and close the Network Connection.
[MQTT-3.8.3-1]	The Topic Filters in a SUBSCRIBE packet payload MUST be UTF-8 encoded strings as defined in Section 1.5.3.
[MQTT-3.8.3-2]	If the Server chooses not to support topic filters that contain wildcard characters it MUST reject any Subscription request whose filter contains them.
[MQTT-3.8.3-3]	The payload of a SUBSCRIBE packet MUST contain at least one Topic Filter / QoS pair. A SUBSCRIBE packet with no payload is a protocol violation.
[MQTT-3.8.3-4]	The Server MUST treat a SUBSCRIBE packet as malformed and close the Network Connection if any of Reserved bits in the payload are non-zero, or QoS is not 0,1 or 2.
[MQTT-3.8.4-1]	When the Server receives a SUBSCRIBE Packet from a Client, the Server MUST respond with a SUBACK Packet.
[MQTT-3.8.4-2]	The SUBACK Packet MUST have the same Packet Identifier as the SUBSCRIBE Packet that it is acknowledging.
[MQTT-3.8.4-3]	If a Server receives a SUBSCRIBE Packet containing a Topic Filter that is identical to an existing Subscription's Topic Filter then it MUST completely replace that existing Subscription with a new Subscription. The Topic Filter in the new Subscription will be identical to that in the previous Subscription, although its maximum QoS value could be different. Any existing retained messages matching the Topic Filter MUST be re-sent, but the flow of publications MUST NOT be interrupted.
[MQTT-3.8.4-4]	If a Server receives a SUBSCRIBE packet that contains multiple Topic Filters it MUST handle that packet as if it had received a sequence of multiple SUBSCRIBE packets, except that it combines their responses into a single SUBACK response.
[MQTT-3.8.4-5]	The SUBACK Packet sent by the Server to the Client MUST contain a return code for each Topic Filter/QoS pair. This return code MUST either show the maximum QoS that was granted for that Subscription or indicate that the subscription failed.
[MQTT-3.8.4-6]	The Server might grant a lower maximum QoS than the subscriber requested. The QoS of Payload Messages sent in response to a Subscription MUST be the minimum of the QoS of the originally published message and the maximum QoS granted by the Server. The server is permitted to send duplicate copies of a message to a subscriber in the case where the original message was published with QoS 1 and the maximum QoS granted was QoS 0.
[MQTT-3.9.3-1]	The order of return codes in the SUBACK Packet MUST match the order of Topic Filters in the SUBSCRIBE Packet.
[MQTT-3.9.3-2]	SUBACK return codes other than 0x00, 0x01, 0x02 and 0x80 are reserved and MUST NOT be used.
[MQTT-3.10.1-1]	Bits 3,2,1 and 0 of the fixed header of the UNSUBSCRIBE Control Packet are reserved and MUST be set to 0,0,1 and 0 respectively. The Server MUST treat any other value as malformed and close the Network Connection.
[MQTT-3.10.3-1]	The Topic Filters in an UNSUBSCRIBE packet MUST be UTF-8 encoded strings as defined in Section 1.5.3, packed contiguously.

[MQTT-3.10.3-2]	The Payload of an UNSUBSCRIBE packet MUST contain at least one Topic Filter. An UNSUBSCRIBE packet with no payload is a protocol violation.
[MQTT-3.10.4-1]	The Topic Filters (whether they contain wildcards or not) supplied in an UNSUBSCRIBE packet MUST be compared character-by-character with the current set of Topic Filters held by the Server for the Client. If any filter matches exactly then its owning Subscription is deleted, otherwise no additional processing occurs.
[MQTT-3.10.4-2]	If a Server deletes a Subscription It MUST stop adding any new messages for delivery to the Client.
[MQTT-3.10.4-3]	If a Server deletes a Subscription It MUST complete the delivery of any QoS 1 or QoS 2 messages which it has started to send to the Client.
[MQTT-3.10.4-4]	The Server MUST respond to an UNSUBSCRIBE request by sending an UNSUBACK packet. The UNSUBACK Packet MUST have the same Packet Identifier as the UNSUBSCRIBE Packet.
[MQTT-3.10.4-5]	Even where no Topic Subscriptions are deleted, the Server MUST respond with an UNSUBACK.
[MQTT-3.10.4-6]	If a Server receives an UNSUBSCRIBE packet that contains multiple Topic Filters it MUST handle that packet as if it had received a sequence of multiple UNSUBSCRIBE packets, except that it sends just one UNSUBACK response.
[MQTT-3.12.4-1]	The Server MUST send a PINGRESP Packet in response to a PINGREQ packet.
[MQTT-3.14.1-1]	The Server MUST validate that reserved bits are set to zero and disconnect the Client if they are not zero.
[MQTT-3.14.4-1]	After sending a DISCONNECT Packet the Client MUST close the Network Connection.
[MQTT-3.14.4-2]	After sending a DISCONNECT Packet the Client MUST NOT send any more Control Packets on that Network Connection.
[MQTT-3.14.4-3]	On receipt of DISCONNECT the Server MUST discard any Will Message associated with the current connection without publishing it, as described in Section 3.1.2.5.
[MQTT-4.1.0-1]	The Client and Server MUST store Session state for the entire duration of the Session.
[MQTT-4.1.0-2]	A Session MUST last at least as long it has an active Network Connection.
[MQTT-4.3.1-1]	In the QoS 0 delivery protocol, the Sender <ul style="list-style-type: none"> • MUST send a PUBLISH packet with QoS=0, DUP=0.
[MQTT-4.3.2-1]	In the QoS 1 delivery protocol, the Sender <ul style="list-style-type: none"> • 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, DUP=0. • MUST treat the PUBLISH Packet as "unacknowledged" until it has received the corresponding PUBACK packet from the receiver. See Section 4.4 for a discussion of unacknowledged messages.
[MQTT-4.3.2-2]	In the QoS 1 delivery protocol, the Receiver

	<ul style="list-style-type: none"> • 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 publication, irrespective of the setting of its DUP flag.
[MQTT-4.3.3-1]	<p>In the QoS 2 delivery protocol, the Sender</p> <ul style="list-style-type: none"> • 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, DUP=0. • MUST treat the PUBLISH packet as "unacknowledged" until it has received the corresponding PUBREC packet from the receiver. See Section 4.4 for a discussion of unacknowledged messages. • MUST send a PUBREL packet when it receives a PUBREC packet from the receiver. 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.
[MQTT-4.3.3-2]	<p>In the QoS 2 delivery protocol, the Receiver</p> <ul style="list-style-type: none"> • MUST respond with a PUBREC containing the Packet Identifier from the incoming PUBLISH Packet, having accepted ownership of the 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 publication.
[MQTT-4.4.0-1]	<p>When a Client reconnects with CleanSession set to 0, both the Client and Server MUST re-send any unacknowledged PUBLISH Packets (where QoS > 0) and PUBREL Packets using their original Packet Identifiers.</p>
[MQTT-4.5.0-1]	<p>When a Server takes ownership of an incoming Application Message it MUST add it to the Session state of those clients that have matching Subscriptions. Matching rules are defined in Section 4.7.</p>
[MQTT-4.5.0-2]	<p>The Client MUST acknowledge any Publish Packet it receives according to the applicable QoS rules regardless of whether it elects to process the Application Message that it contains.</p>
[MQTT-4.6.0-1]	<p>When it re-sends any PUBLISH packets, it MUST re-send them in the order in which the original PUBLISH packets were sent (this applies to QoS 1 and QoS 2 messages).</p>
[MQTT-4.6.0-2]	<p>Client MUST send PUBACK packets in the order in which the corresponding</p>

	PUBLISH packets were received (QoS 1 messages).
[MQTT-4.6.0-3]	Client MUST send PUBREC packets in the order in which the corresponding PUBLISH packets were received (QoS 2 messages).
[MQTT-4.6.0-4]	Client MUST send PUBREL packets in the order in which the corresponding PUBREC packets were received (QoS 2 messages).
[MQTT-4.6.0-5]	A Server MUST by default treat each Topic as an "Ordered Topic". It MAY provide an administrative or other mechanism to allow one or more Topics to be treated as an "Unordered Topic".
[MQTT-4.6.0-6]	When a Server processes a message that has been published to an Ordered Topic, it MUST follow the rules listed above when delivering messages to each of its subscribers. In addition it MUST send PUBLISH packets to consumers (for the same Topic and QoS) in the order that they were received from any given Client.
[MQTT-4.7.1-1]	The wildcard characters can be used in Topic Filters, but MUST NOT be used within a Topic Name.
[MQTT-4.7.1-2]	The multi-level wildcard character MUST be specified either on its own or following a topic level separator. In either case it MUST be the last character specified in the Topic Filter.
[MQTT-4.7.1-3]	The single-level wildcard can be used at any level in the Topic Filter, including first and last levels. Where it is used it MUST occupy an entire level of the filter.
[MQTT-4.7.2-1]	The Server MUST NOT match Topic Filters starting with a wildcard character (# or +) with Topic Names beginning with a \$ character.
[MQTT-4.7.3-1]	All Topic Names and Topic Filters MUST be at least one character long.
[MQTT-4.7.3-2]	Topic Names and Topic Filters MUST NOT include the null character (Unicode U+0000).
[MQTT-4.7.3-3]	Topic Names and Topic Filters are UTF-8 encoded strings, they MUST NOT encode to more than 65535 bytes.
[MQTT-4.7.3-4]	When it performs subscription matching the Server MUST NOT perform any normalization of Topic Names or Topic Filters, or any modification or substitution of unrecognized characters.
[MQTT-4.8.0-1]	Unless stated otherwise, if either the Server or Client encounters a protocol violation, it MUST close the Network Connection on which it received that Control Packet which caused the protocol violation.
[MQTT-4.8.0-2]	If the Client or Server encounters a Transient Error while processing an inbound Control Packet it MUST close the Network Connection on which it received that Control Packet.
[MQTT-6.0.0-1]	MQTT Control Packets MUST be sent in WebSocket binary data frames. If any other type of data frame is received the recipient MUST close the Network Connection.
[MQTT-6.0.0-2]	A single WebSocket data frame can contain multiple or partial MQTT Control Packets. The receiver MUST NOT assume that MQTT Control Packets are aligned on WebSocket frame boundaries.
[MQTT-6.0.0-3]	The client MUST include "mqtt" in the list of WebSocket Sub Protocols it offers.
[MQTT-6.0.0-4]	The WebSocket Sub Protocol name selected and returned by the server MUST

	be "mqtt".
[MQTT-7.0.0-1]	A Server that both accepts inbound connections and establishes outbound connections to other Servers MUST conform as both an MQTT Client and MQTT Server.
[MQTT-7.0.0-2]	Conformant implementations MUST NOT require the use of any extensions defined outside of this specification in order to interoperate with any other conformant implementation.
[MQTT-7.1.1-1]	A conformant Server MUST support the use of one or more underlying transport protocols that provide an ordered, lossless, stream of bytes from the Client to Server and Server to Client.
[MQTT-7.1.2-1]	A conformant Client MUST support the use of one or more underlying transport protocols that provide an ordered, lossless, stream of bytes from the Client to Server and Server to Client.

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Appendix C. Revision history (non normative)

1806

Revision	Date	Editor	Changes Made
[02]	[29 April 2013]	[A Banks]	[Tighten up language for Connect packet]
[03]	[09 May 2013]	[A Banks]	[Tighten up language in Section 02 Command Message Format]
[04]	[20 May 2013]	[Rahul Gupta]	Tighten up language for PUBLISH message
[05]	[5th June 2013]	[A Banks] [Rahul Gupta]	[Issues -5,9,13] [Formatting and language tighten up in PUBACK, PUBREC, PUBREL, PUBCOMP message]
[06]	[20 th June 2013]	[Rahul Gupta]	[Issue – 17, 2, 28, 33] [Formatting and language tighten up in SUBSCRIBE, SUBACK, UNSUBSCRIBE, UNSUBACK, PINGREQ, PINGRESP, DISCONNECT Control Packets] Terms Command message change to Control Packet Term “message” is generically used, replaced this word accordingly with packet, publication, subscription.
[06]	[21 June 2013]	[A Banks] [Rahul Gupta]	Resolved Issues – 12,20,15, 3, 35, 34, 23, 5, 21 Resolved Issues – 32,39, 41
[07]	[03 July 2013]	[A Banks] [Rahul Gupta]	Resolved Issues – 18,11,4 Resolved Issues – 26,31,36,37
[08]	[19 July 2013]	[A Banks] [Rahul Gupta]	Resolved Issues – 6, 29, 45 Resolved Issues – 36, 25, 24 Added table for fixed header and payload
[09]	[01 August 2013]	[A Banks]	Resolved Issues – 49, 53, 46, 67, 29, 66, 62, 45, 69, 40, 61, 30
[10]	[10 August 2013]	[A Banks] [Rahul Gupta]	Resolved Issues – 19, 63, 57, 65, 72 Conformance section added
[11]	[10 September 2013]	[A Banks] [N O’Leary & Rahul Gupta]	Resolved Issues – 56 Updated Conformance section
[12]	[18 September 2013]	[Rahul Gupta] [A Banks]	Resolved Issues – 22, 42, 81, 84, 85, 7, 8, 14, 16, Security section is added Resolved Issue -1

[13]	[27 September 2013]	[A Banks]	Resolved Issues – 64, 68, 76, 86, 27, 60, 82, 55, 78, 51, 83, 80
[14]	[10 October 2013]	[A Banks] [Rahul Gupta]	Resolved Issues – 58, 59, 10, 89, 90, 88, 77 Resolved Issues – 94, 96, 93, 92, 95, 87, 74, 71
[15]	[24 October 2013]	[A Banks] [Rahul Gupta]	Resolved Issues – 52, 97, 98, 101 Resolved Issues – 100 Added normative statement numbering and Appendix A
[16]	[21 November 2013]	[A Banks]	Resolved Issues -103, 104, 44
[17]	[05 December 2013]	[A Banks] [Rahul Gupta]	Resolved Issues – 105, 70, 102, 106, 107, 108, 109, 110 Updated normative statement numbering and Appendix A
[CSD04]	[28 January 2014]	[Rahul Gupta]	Resolved Issues – 112, 114, 115, 120, 117, 134, 132, 133, 130, 131, 129
[18]	[20 February 2014]	[A Banks] [Rahul Gupta]	Resolved Issues – 175, 139, 176, 166, 149, 164, 140, 154, 178, 188, 181, 155, 170, 196, 173, 157, 195, 191, 150, 179, 185, 174, 163 Resolved Issues – 135, 136, 147, 161, 169, 180, 182, 184, 189, 187
[19]	[28 February 2014]	[A Banks] [Rahul Gupta]	Resolved Issues – 167, 192, 141, 138, 137, 198, 165 Resolved Issues – 199, 144, 159,
[20]	[07 March 2014]	[A Banks] [Rahul Gupta]	Resolved Issues – 113, 162, 158, 146 Resolved Issues – 172, 190, 202, 201
[21]	[17 March 2014]	[A Banks] [Rahul Gupta]	Resolved Issues – 151, 194, 160, 168 Resolved Issues – 205,
[22]	[27 March 2014]	[Rahul Gupta] [A Banks]	Resolved Issues – 145, 186, 142 Resolved Issues – 152, 193
[23]	[28 March 2014]	[A Banks]	Resolved Issues – 204, 148, 210, 208, 209, 171, 183, 117, 212
[24]	[7 April 2014]	[Rahul Gupta] [A Banks]	Added Table of figures Corrected Issue 209
[25]	[8 May 2014]	[Rahul Gupta]	Resolved Issues – 213, 214
[25]	[3 September 2014]	[A Banks]	Resolved Issues – 240, 242, 246
[26]	[17 September 2014]	[Rahul Gupta]	Resolved Issues – 247