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OASIS Message Queuing Telemetry Transport (MQTT) TC

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Related work:

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- *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.

Status:

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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.
- Processes Subscribe and Unsubscribe requests from Clients.
- 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]**

57 *Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March*
58 *1997.*

59 <http://www.ietf.org/rfc/rfc2119.txt>

60

61 **[RFC3629]**

62 *Yergeau, F., "UTF-8, a transformation format of ISO 10646", STD 63, RFC 3629, November 2003*

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64

65 **[RFC5246]**

66 *Dierks, T. and E. Rescorla, "The Transport Layer Security (TLS) Protocol Version 1.2", RFC 5246, August*
67 *2008.*

68 <http://www.ietf.org/rfc/rfc5246.txt>

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70 **[RFC6455]**

71 *Fette, I. and A. Melnikov, "The WebSocket Protocol", RFC 6455, December 2011.*

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74 **[Unicode]**

75 *The Unicode Consortium. The Unicode Standard.*

76 <http://www.unicode.org/versions/latest/>

77 **1.4 Non normative references**

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79 *Postel, J. Transmission Control Protocol. STD 7, IETF RFC 793, September 1981.*
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81
82 **[AES]**
83 *Advanced Encryption Standard (AES) (FIPS PUB 197).*
84 <http://csrc.nist.gov/publications/fips/fips197/fips-197.pdf>
85
86 **[DES]**
87 *Data Encryption Standard (DES).*
88 <http://csrc.nist.gov/publications/fips/fips46-3/fips46-3.pdf>
89
90 **[FIPS1402]**
91 *Security Requirements for Cryptographic Modules (FIPS PUB 140-2)*
92 <http://csrc.nist.gov/publications/fips/fips140-2/fips1402.pdf>
93
94 **[IEEE 802.1AR]**
95 *IEEE Standard for Local and metropolitan area networks - Secure Device Identity*
96 <http://standards.ieee.org/findstds/standard/802.1AR-2009.html>
97
98 **[ISO29192]**
99 *ISO/IEC 29192-1:2012 Information technology -- Security techniques -- Lightweight cryptography -- Part*
100 *1: General*
101 http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=56425
102
103 **[MQTT NIST]**
104 *MQTT supplemental publication, MQTT and the NIST Framework for Improving Critical Infrastructure*
105 *Cybersecurity*
106 <http://docs.oasis-open.org/mqtt/mqtt-nist-cybersecurity/v1.0/mqtt-nist-cybersecurity-v1.0.html>
107
108 **[MQTTV31]**
109 *MQTT V3.1 Protocol Specification.*
110 <http://public.dhe.ibm.com/software/dw/webservices/ws-mqtt/mqtt-v3r1.html>
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*

126 https://www.pcisecuritystandards.org/security_standards/
127
128 **[RFC1928]**
129 *Leech, M., Ganis, M., Lee, Y., Kuris, R., Koblas, D., and L. Jones, "SOCKS Protocol Version 5", RFC*
130 *1928, March 1996.*
131 <http://www.ietf.org/rfc/rfc1928.txt>
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135 *2006.*
136 <http://www.ietf.org/rfc/rfc4511.txt>
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138 **[RFC5077]**
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140 *Resumption without Server-Side State", RFC 5077, January 2008.*
141 <http://www.ietf.org/rfc/rfc5077.txt>
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143 **[RFC5280]**
144 *Cooper, D., Santesson, S., Farrell, S., Boeyen, S., Housley, R., and W. Polk, "Internet X.509 Public Key*
145 *Infrastructure Certificate and Certificate Revocation List (CRL) Profile", RFC 5280, May 2008.*
146 <http://www.ietf.org/rfc/rfc5280.txt>
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148 **[RFC6066]**
149 *Eastlake 3rd, D., "Transport Layer Security (TLS) Extensions: Extension Definitions", RFC 6066, January*
150 *2011.*
151 <http://www.ietf.org/rfc/rfc6066.txt>
152
153 **[RFC6749]**
154 *Hardt, D., Ed., "The OAuth 2.0 Authorization Framework", RFC 6749, October 2012.*
155 <http://www.ietf.org/rfc/rfc6749.txt>
156
157 **[RFC6960]**
158 *Santesson, S., Myers, M., Ankney, R., Malpani, A., Galperin, S., and C. Adams, "X.509 Internet Public*
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 U+0001..U+001F control characters
- 203 U+007F..U+009F control characters
- 204 Code points defined in the Unicode specification [Unicode] to be non-characters (for example U+0FFFF)

205
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𠵼 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 **2 MQTT Control Packet format**

218 **2.1 Structure of an MQTT Control Packet**

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

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

223

224 **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

225 **2.2 Fixed header**

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

228

229 **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							

230

231 **2.2.1 MQTT Control Packet type**

232 **Position:** byte 1, bits 7-4.

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

234

235 **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	Publish message

		or 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

236

237 2.2.2 Flags

238 The remaining bits [3-0] of byte 1 in the fixed header contain flags specific to each MQTT Control Packet
 239 type as listed in the [Table 2.2 - Flag Bits](#) below. Where a flag bit is marked as “Reserved” in [Table 2.2 -](#)
 240 [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
 241 invalid flags are received, the receiver MUST close the Network Connection [MQTT-2.2.2-2]. See Section
 242 4.8 for details about handling errors.

243

244 **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

245

246 DUP¹ = Duplicate delivery of a PUBLISH Control Packet

247 QoS² = PUBLISH Quality of Service

248 RETAIN³ = PUBLISH Retain flag

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

250 2.2.3 Remaining Length

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

252

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

256

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

262

263 **Non normative comment**

264 For example, the number 64 decimal is encoded as a single byte, decimal value 64, hexadecimal
 265 0x40. The number 321 decimal (= 65 + 2*128) is encoded as two bytes, least significant first. The
 266 first byte is 65+128 = 193. Note that the top bit is set to indicate at least one following byte. The
 267 second byte is 2.

268

269 **Non normative comment**

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

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

273

274 **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)

275

276

Non normative comment

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

```

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

```

288

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

291

292 **Non normative comment**

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

294

```

295     multiplier = 1
296     value = 0
297     do
298         encodedByte = 'next byte from stream'
299         value += (encodedByte AND 127) * multiplier
300         multiplier *= 128
301         if (multiplier > 128*128*128)
302             throw Error(Malformed Remaining Length)
303         while ((encodedByte AND 128) != 0)

```

304

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

306

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

308 **2.3 Variable header**

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

312 **2.3.1 Packet Identifier**

313 **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							

314

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

318

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

328

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

330

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

335

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

338 **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

339

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

342

343 **Non normative comment**

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

347

```

348 Client                               Server
349 PUBLISH Packet Identifier=0x1234--->
350 <--PUBLISH Packet Identifier=0x1234
351 PUBACK Packet Identifier=0x1234--->
352 <--PUBACK Packet Identifier=0x1234

```

353 **2.4 Payload**

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

357 **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

358

359 **3 MQTT Control Packets**

360 **3.1 CONNECT – Client requests a connection to a Server**

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

363
 364 A Client can only send the CONNECT Packet once over a Network Connection. The Server MUST
 365 process a second CONNECT Packet sent from a Client as a protocol violation and disconnect the Client
 366 [MQTT-3.1.0-2]. See section 4.8 for information about handling errors.

367
 368 The payload contains one or more encoded fields. They specify a unique Client identifier for the Client, a
 369 Will topic, Will Message, User Name and Password. All but the Client identifier are optional and their
 370 presence is determined based on flags in the variable header.

371 **3.1.1 Fixed header**

372 **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							

373
 374 **Remaining Length field**
 375 Remaining Length is the length of the variable header (10 bytes) plus the length of the Payload. It is
 376 encoded in the manner described in section 2.2.3.

377 **3.1.2 Variable header**

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

380 **3.1.2.1 Protocol Name**

381 **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
--------	-----	---	---	---	---	---	---	---	---

382

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

385

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

389

Non normative comment

390

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

391

3.1.2.2 Protocol Level

392

Figure 3.3 - Protocol Level byte

393

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

394

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

3.1.2.3 Connect Flags

399

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

Figure 3.4 - Connect Flag bits

402

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

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

3.1.2.4 Clean Session

405

406 **Position:** bit 1 of the Connect Flags byte.

406

407 This bit specifies the handling of the Session state.

407

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

408

409

410

411

412

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

420

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

424

425 The Session state in the Client consists of:

- 426 • QoS 1 and QoS 2 messages which have been sent to the Server, but have not been completely
427 acknowledged.
- 428 • QoS 2 messages which have been received from the Server, but have not been completely
429 acknowledged.

430

431 The Session state in the Server consists of:

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

440

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

443

444 See Section 4.1 for details and limitations of stored state.

445

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

447

448 **Non normative comment**

449 Consequently, in the event of a failure to connect the Client should repeat its attempts to connect
450 with CleanSession set to 1, until it connects successfully.

451

452 **Non normative comment**

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

460
461
462
463
464
465
466

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.

3.1.2.5 Will Flag

467
468 **Position:** bit 2 of the Connect Flags.

469
470 If the Will Flag is set to 1 this indicates that, if the Connect request is accepted, a Will Message MUST be
471 stored on the Server and associated with the Network Connection. The Will Message MUST be published
472 when the Network Connection is subsequently closed unless the Will Message has been deleted by the
473 Server on receipt of a DISCONNECT Packet [MQTT-3.1.2-8].

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

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

479

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

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

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

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

488

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

3.1.2.6 Will QoS

492
493 **Position:** bits 4 and 3 of the Connect Flags.

494

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

496

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

498 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
499 (0x03) [MQTT-3.1.2-14].

3.1.2.7 Will Retain

500
501 **Position:** bit 5 of the Connect Flags.

502

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

504
 505 If the Will Flag is set to 0, then the Will Retain Flag MUST be set to 0 [MQTT-3.1.2-15].
 506 If the Will Flag is set to 1:

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

511 **3.1.2.8 User Name Flag**

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

513
 514 If the User Name Flag is set to 0, a user name MUST NOT be present in the payload [MQTT-3.1.2-18].
 515 If the User Name Flag is set to 1, a user name MUST be present in the payload [MQTT-3.1.2-19].

516 **3.1.2.9 Password Flag**

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

518
 519 If the Password Flag is set to 0, a password MUST NOT be present in the payload [MQTT-3.1.2-20].
 520 If the Password Flag is set to 1, a password MUST be present in the payload [MQTT-3.1.2-21].
 521 If the User Name Flag is set to 0, the Password Flag MUST be set to 0 [MQTT-3.1.2-22].

522 **3.1.2.10 Keep Alive**

523 **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							

524
 525 The Keep Alive is a time interval measured in seconds. Expressed as a 16-bit word, it is the maximum
 526 time interval that is permitted to elapse between the point at which the Client finishes transmitting one
 527 Control Packet and the point it starts sending the next. It is the responsibility of the Client to ensure that
 528 the interval between Control Packets being sent does not exceed the Keep Alive value. In the absence of
 529 sending any other Control Packets, the Client MUST send a PINGREQ Packet [MQTT-3.1.2-23].

530
 531 The Client can send PINGREQ at any time, irrespective of the Keep Alive value, and use the PINGRESP
 532 to determine that the network and the Server are working.

533
 534 If the Keep Alive value is non-zero and the Server does not receive a Control Packet from the Client
 535 within one and a half times the Keep Alive time period, it MUST disconnect the Network Connection to the
 536 Client as if the network had failed [MQTT-3.1.2-24].

537
 538 If a Client does not receive a PINGRESP Packet within a reasonable amount of time after it has sent a
 539 PINGREQ, it SHOULD close the Network Connection to the Server.

540
 541 A Keep Alive value of zero (0) has the effect of turning off the keep alive mechanism. This means that, in
 542 this case, the Server is not required to disconnect the Client on the grounds of inactivity.

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

545

546 **Non normative comment**

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

549 **3.1.2.11 Variable header non normative example**

550 **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

551

552 3.1.3 Payload

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

556 3.1.3.1 Client Identifier

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

560

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

563

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

565

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

568 "0123456789abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ" [MQTT-3.1.3-5].

569

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

572

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

576

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

578

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

582

583 If the Server rejects the ClientId it MUST respond to the CONNECT Packet with a CONNACK return code
584 0x02 (Identifier rejected) and then close the Network Connection [MQTT-3.1.3-9].

585

586 Non normative comment

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

589 3.1.3.2 Will Topic

590 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
591 encoded string as defined in Section 1.5.3 [MQTT-3.1.3-10].

592 3.1.3.3 Will Message

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

598

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

601 3.1.3.4 User Name

602 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**
603 **encoded string as defined in Section 1.5.3 [MQTT-3.1.3-11]**. It can be used by the Server for
604 authentication and authorization.

605 3.1.3.5 Password

606 If the Password Flag is set to 1, this is the next field in the payload. The Password field contains 0 to
607 65535 bytes of binary data prefixed with a two byte length field which indicates the number of bytes used
608 by the binary data (it does not include the two bytes taken up by the length field itself).

609 **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.							

610

611 3.1.4 Response

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

615

- 616 1. If the Server does not receive a CONNECT Packet within a reasonable amount of time after the
617 Network Connection is established, the Server SHOULD close the connection.
618
- 619 2. **The Server MUST validate that the CONNECT Packet conforms to section 3.1 and close the**
620 **Network Connection without sending a CONNACK if it does not conform [MQTT-3.1.4-1]**.
621
- 622 3. The Server MAY check that the contents of the CONNECT Packet meet any further restrictions
623 and MAY perform authentication and authorization checks. If any of these checks fail, it SHOULD
624 send an appropriate CONNACK response with a non-zero return code as described in section 3.2
625 and it MUST close the Network Connection.

626

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

628

- 629 1. **If the ClientId represents a Client already connected to the Server then the Server MUST**
630 **disconnect the existing Client [MQTT-3.1.4-2]**.
631
- 632 2. **The Server MUST perform the processing of CleanSession that is described in section 3.1.2.4**
633 **[MQTT-3.1.4-3]**.
634
- 635 3. **The Server MUST acknowledge the CONNECT Packet with a CONNACK Packet containing a**
636 **zero return code [MQTT-3.1.4-4]**.

637
 638 4. Start message delivery and keep alive monitoring.
 639

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

645 **Non normative comment**

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

651 **3.2 CONNACK – Acknowledge connection request**

652 The CONNACK Packet is the packet sent by the Server in response to a CONNECT Packet received
 653 from a Client. **The first packet sent from the Server to the Client MUST be a CONNACK Packet [MQTT-**
 654 **3.2.0-1].**
 655

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

659 **3.2.1 Fixed header**

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

661 **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

662
 663 **Remaining Length field**

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

665 **3.2.2 Variable header**

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

667 **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

668 **3.2.2.1 Connect Acknowledge Flags**

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

670
671 Bit 0 (SP¹) is the Session Present Flag.

672 **3.2.2.2 Session Present**

673 Position: bit 0 of the Connect Acknowledge Flags.

674
675 If the Server accepts a connection with CleanSession set to 1, the Server MUST set Session Present to 0
676 in the CONNACK packet in addition to setting a zero return code in the CONNACK packet [MQTT-3.2.2-
677 1].

678
679 If the Server accepts a connection with CleanSession set to 0, the value set in Session Present depends
680 on whether the Server already has stored Session state for the supplied client ID. If the Server has stored
681 Session state, it MUST set Session Present to 1 in the CONNACK packet [MQTT-3.2.2-2]. If the Server
682 does not have stored Session state, it MUST set Session Present to 0 in the CONNACK packet. This is in
683 addition to setting a zero return code in the CONNACK packet [MQTT-3.2.2-3].

684
685 The Session Present flag enables a Client to establish whether the Client and Server have a consistent
686 view about whether there is already stored Session state.

687
688 Once the initial setup of a Session is complete, a Client with stored Session state will expect the Server to
689 maintain its stored Session state. In the event that the value of Session Present received by the Client
690 from the Server is not as expected, the Client can choose whether to proceed with the Session or to
691 disconnect. The Client can discard the Session state on both Client and Server by disconnecting,
692 connecting with Clean Session set to 1 and then disconnecting again.

693
694 If a server sends a CONNACK packet containing a non-zero return code it MUST set Session Present to
695 0 [MQTT-3.2.2-4].

696

697 **3.2.2.3 Connect Return code**

698 Byte 2 in the Variable header.

699

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

705 **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

706

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

709 3.2.3 Payload

710 The CONNACK Packet has no payload.

711 3.3 PUBLISH – Publish message

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

714 3.3.1 Fixed header

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

716 **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							

717

718 3.3.1.1 DUP

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

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

723

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

726

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

731

732 Non normative comment

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

735

736 **Non normative comment**

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

742 **3.3.1.2 QoS**

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

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

746

747 **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

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

750 **3.3.1.3 RETAIN**

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

752

753 This flag is only used on the PUBLISH Packet.

754

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

763

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

768

769 A PUBLISH Packet with a RETAIN flag set to 1 and a payload containing zero bytes will be processed as
770 normal by the Server and sent to Clients with a subscription matching the topic name. Additionally any

771 existing retained message with the same topic name MUST be removed and any future subscribers for
 772 the topic will not receive a retained message [MQTT-3.3.1-10]. “As normal” means that the RETAIN flag is
 773 not set in the message received by existing Clients. A zero byte retained message MUST NOT be stored
 774 as a retained message on the Server [MQTT-3.3.1-11].

775
 776 If the RETAIN flag is 0, in a PUBLISH Packet sent by a Client to a Server, the Server MUST NOT store
 777 the message and MUST NOT remove or replace any existing retained message [MQTT-3.3.1-12].

778
 779 **Non normative comment**
 780 Retained messages are useful where publishers send state messages on an irregular basis. A
 781 new subscriber will receive the most recent state.

782
 783 **Remaining Length field**

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

785 **3.3.2 Variable header**

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

787 **3.3.2.1 Topic Name**

788 The Topic Name identifies the information channel to which payload data is published.
 789
 790 The Topic Name MUST be present as the first field in the PUBLISH Packet Variable header. It MUST be
 791 a UTF-8 encoded string [MQTT-3.3.2-1] as defined in section 1.5.3.
 792 The Topic Name in the PUBLISH Packet MUST NOT contain wildcard characters [MQTT-3.3.2-2].
 793 The Topic Name in a PUBLISH Packet sent by a Server to a subscribing Client MUST match the
 794 Subscription’s Topic Filter according to the matching process defined in Section 4.7 [MQTT-3.3.2-3].
 795 However, since the Server is permitted to override the Topic Name, it might not be the same as the Topic
 796 Name in the original PUBLISH Packet.

797 **3.3.2.2 Packet Identifier**

798 The Packet Identifier field is only present in PUBLISH Packets where the QoS level is 1 or 2. Section
 799 2.3.1 provides more information about Packet Identifiers.

800 **3.3.2.3 Variable header non normative example**

801 [Figure 3.11 - Publish Packet variable header non normative example](#) illustrates an example variable
 802 header for the PUBLISH Packet briefly described in [Table 3.3 - Publish Packet non normative example](#).

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

Field	Value
Topic Name	a/b
Packet Identifier	10

804
 805 **Figure 3.11 - Publish Packet variable header non normative example**

	Description	7	6	5	4	3	2	1	0

Topic Name									
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

806

807 3.3.3 Payload

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

812 3.3.4 Response

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

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

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

816

817 3.3.5 Actions

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

820

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

823

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

829

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

832

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

836 3.4 PUBACK – Publish acknowledgement

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

838 3.4.1 Fixed header

839 **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

840

841 Remaining Length field

842 This is the length of the variable header. For the PUBACK Packet this has the value 2.

843 3.4.2 Variable header

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

845 **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							

846

847 3.4.3 Payload

848 The PUBACK Packet has no payload.

849 3.4.4 Actions

850 This is fully described in Section 4.3.2.

851 3.5 PUBREC – Publish received (QoS 2 publish received, part 1)

852 A PUBREC Packet is the response to a PUBLISH Packet with QoS 2. It is the second packet of the QoS
853 2 protocol exchange.

854 **3.5.1 Fixed header**

855 **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

856

857 **Remaining Length field**

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

859 **3.5.2 Variable header**

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

861 **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							

862

863 **3.5.3 Payload**

864 The PUBREC Packet has no payload.

865 **3.5.4 Actions**

866 This is fully described in Section 4.3.3.

867 **3.6 PUBREL – Publish release (QoS 2 publish received, part 2)**

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

870 **3.6.1 Fixed header**

871 **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

872

873 Bits 3,2,1 and 0 of the fixed header in the PUBREL Control Packet are reserved and MUST be set to
 874 0,0,1 and 0 respectively. The Server MUST treat any other value as malformed and close the Network
 875 Connection [MQTT-3.6.1-1].

876

877 **Remaining Length field**

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

879 **3.6.2 Variable header**

880 The variable header contains the same Packet Identifier as the PUBREC Packet that is being
 881 acknowledged.

882 **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							

883

884 **3.6.3 Payload**

885 The PUBREL Packet has no payload.

886 **3.6.4 Actions**

887 This is fully described in Section 4.3.3.

888 **3.7 PUBCOMP – Publish complete (QoS 2 publish received, part 3)**

889

890 The PUBCOMP Packet is the response to a PUBREL Packet. It is the fourth and final packet of the QoS
 891 2 protocol exchange.

892 **3.7.1 Fixed header**

893 **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

894

895 **Remaining Length field**

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

897 **3.7.2 Variable header**

898 The variable header contains the same Packet Identifier as the PUBREL Packet that is being
899 acknowledged.

900 **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							

901

902 **3.7.3 Payload**

903 The PUBCOMP Packet has no payload.

904 **3.7.4 Actions**

905 This is fully described in Section 4.3.3.

906 **3.8 SUBSCRIBE - Subscribe to topics**

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

912 **3.8.1 Fixed header**

913 **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							

914

915 Bits 3,2,1 and 0 of the fixed header of the SUBSCRIBE Control Packet are reserved and MUST be set to
916 0,0,1 and 0 respectively. The Server MUST treat any other value as malformed and close the Network
917 Connection [MQTT-3.8.1-1].

918

919 **Remaining Length field**

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

921 **3.8.2 Variable header**

922 The variable header contains a Packet Identifier. Section 2.3.1 provides more information about Packet
923 Identifiers.

924 **3.8.2.1 Variable header non normative example**

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

926 **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

927

928 **3.8.3 Payload**

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

936

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

940

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

943

944 **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

945

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

950 **3.8.3.1 Payload non normative example**

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

953

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

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

955 **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

956

957 **3.8.4 Response**

958 **When the Server receives a SUBSCRIBE Packet from a Client, the Server MUST respond with a**
 959 **SUBACK Packet [MQTT-3.8.4-1]. The SUBACK Packet MUST have the same Packet Identifier as the**
 960 **SUBSCRIBE Packet that it is acknowledging [MQTT-3.8.4-2].**

961

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

964

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

970

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

973

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

977

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

986

987 **Non normative examples**

988

989 If a subscribing Client has been granted maximum QoS 1 for a particular Topic Filter, then a QoS
990 0 Application Message matching the filter is delivered to the Client at QoS 0. This means that at
991 most one copy of the message is received by the Client. On the other hand a QoS 2 Message
992 published to the same topic is downgraded by the Server to QoS 1 for delivery to the Client, so
993 that Client might receive duplicate copies of the Message.

994

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

999

1000 **Non normative comment**

1001 Subscribing to a Topic Filter at QoS 2 is equivalent to saying "I would like to receive Messages
1002 matching this filter at the QoS with which they were published". This means a publisher is
1003 responsible for determining the maximum QoS a Message can be delivered at, but a subscriber is
1004 able to require that the Server downgrades the QoS to one more suitable for its usage.

1005 **3.9 SUBACK – Subscribe acknowledgement**

1006 A SUBACK Packet is sent by the Server to the Client to confirm receipt and processing of a SUBSCRIBE
1007 Packet.

1008

1009 A SUBACK Packet contains a list of return codes, that specify the maximum QoS level that was granted
1010 in each Subscription that was requested by the SUBSCRIBE.

1011 **3.9.1 Fixed header**

1012 **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							

1013

1014 **Remaining Length field**

1015 This is the length of variable header (2 bytes) plus the length of the payload.

1016 **3.9.2 Variable header**

1017 The variable header contains the Packet Identifier from the SUBSCRIBE Packet that is being
 1018 acknowledged. [Figure 3.25 - variable header format](#) below illustrates the format of the variable header.

1019 **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							

1020 **3.9.3 Payload**

1021 The payload contains a list of return codes. Each return code corresponds to a Topic Filter in the
 1022 SUBSCRIBE Packet being acknowledged. **The order of return codes in the SUBACK Packet MUST**
 1023 **match the order of Topic Filters in the SUBSCRIBE Packet [MQTT-3.9.3-1].**

1024

1025 [Figure 3.26 - Payload format](#) below illustrates the Return Code field encoded in a byte in the Payload.

1026 **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

1027

1028 Allowed return codes:

1029 0x00 - Success - Maximum QoS 0

1030 0x01 - Success - Maximum QoS 1

1031 0x02 - Success - Maximum QoS 2

1032 0x80 - Failure

1033

1034 **SUBACK return codes other than 0x00, 0x01, 0x02 and 0x80 are reserved and MUST NOT be**
 1035 **used [MQTT-3.9.3-2].**

1036 **3.9.3.1 Payload non normative example**

1037 Figure 3.27 - Payload byte format non normative example shows the payload for the SUBACK
 1038 Packet briefly described in Table 3.6 - Payload non normative example.

1039 **Table 3.6 - Payload non normative example**

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

1040 **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

1041

1042 **3.10 UNSUBSCRIBE – Unsubscribe from topics**

1043 An UNSUBSCRIBE Packet is sent by the Client to the Server, to unsubscribe from topics.

1044 **3.10.1 Fixed header**

1045 **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							

1046

1047 Bits 3,2,1 and 0 of the fixed header of the UNSUBSCRIBE Control Packet are reserved and MUST be set
 1048 to 0,0,1 and 0 respectively. The Server MUST treat any other value as malformed and close the Network
 1049 Connection [MQTT-3.10.1-1].

1050

1051 **Remaining Length field**

1052 This is the length of variable header (2 bytes) plus the length of the payload.

1053 **3.10.2 Variable header**

1054 The variable header contains a Packet Identifier. Section 2.3.1 provides more information about Packet
 1055 Identifiers.

1056 **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

1057

1058 3.10.3 Payload

1059 The payload for the UNSUBSCRIBE Packet contains the list of Topic Filters that the Client wishes to
 1060 unsubscribe from. The Topic Filters in an UNSUBSCRIBE packet MUST be UTF-8 encoded strings as
 1061 defined in Section 1.5.3, packed contiguously [MQTT-3.10.3-1].

1062 The Payload of an UNSUBSCRIBE packet MUST contain at least one Topic Filter. An UNSUBSCRIBE
 1063 packet with no payload is a protocol violation [MQTT-3.10.3-2]. See section 4.8 for information about
 1064 handling errors.

1065

1066 3.10.3.1 Payload non normative example

1067 Figure 3.30 - Payload byte format non normative example show the payload for the
 1068 UNSUBSCRIBE Packet briefly described in Table3.7 - Payload non normative example.

1069 Table3.7 - Payload non normative example

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

1070 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

1071 3.10.4 Response

1072 The Topic Filters (whether they contain wildcards or not) supplied in an UNSUBSCRIBE packet MUST be
 1073 compared character-by-character with the current set of Topic Filters held by the Server for the Client. If
 1074 any filter matches exactly then its owning Subscription is deleted, otherwise no additional processing

1075 occurs [MQTT-3.10.4-1].

1076

1077 If a Server deletes a Subscription:

- 1078 • It MUST stop adding any new messages for delivery to the Client [MQTT-3.10.4-2].
- 1079 • It MUST complete the delivery of any QoS 1 or QoS 2 messages which it has started to send to
1080 the Client [MQTT-3.10.4-3].
- 1081 • It MAY continue to deliver any existing messages buffered for delivery to the Client.

1082

1083 The Server MUST respond to an UNSUBSCRIBE request by sending an UNSUBACK packet. The
1084 UNSUBACK Packet MUST have the same Packet Identifier as the UNSUBSCRIBE Packet [MQTT-
1085 3.10.4-4]. Even where no Topic Subscriptions are deleted, the Server MUST respond with an
1086 UNSUBACK [MQTT-3.10.4-5].

1087

1088 If a Server receives an UNSUBSCRIBE packet that contains multiple Topic Filters it MUST handle that
1089 packet as if it had received a sequence of multiple UNSUBSCRIBE packets, except that it sends just one
1090 UNSUBACK response [MQTT-3.10.4-6].

1091 3.11 UNSUBACK – Unsubscribe acknowledgement

1092

1093 The UNSUBACK Packet is sent by the Server to the Client to confirm receipt of an UNSUBSCRIBE
1094 Packet.

1095 3.11.1 Fixed header

1096 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

1097 Remaining Length field

1098 This is the length of the variable header. For the UNSUBACK Packet this has the value 2.

1099 3.11.2 Variable header

1100 The variable header contains the Packet Identifier of the UNSUBSCRIBE Packet that is being
1101 acknowledged.

1102 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							

1103

1104 **3.11.3 Payload**

1105 The UNSUBACK Packet has no payload.

1106

1107 **3.12 PINGREQ – PING request**

1108 The PINGREQ Packet is sent from a Client to the Server. It can be used to:

- 1109 1. Indicate to the Server that the Client is alive in the absence of any other Control Packets being
- 1110 sent from the Client to the Server.
- 1111 2. Request that the Server responds to confirm that it is alive.
- 1112 3. Exercise the network to indicate that the Network Connection is active.

1113

1114 This Packet is used in Keep Alive processing, see Section 3.1.2.10 for more details.

1115 **3.12.1 Fixed header**

1116 **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

1117

1118 **3.12.2 Variable header**

1119 The PINGREQ Packet has no variable header.

1120 **3.12.3 Payload**

1121 The PINGREQ Packet has no payload.

1122 **3.12.4 Response**

1123 The Server MUST send a PINGRESP Packet in response to a PINGREQ Packet [MQTT-3.12.4-1].

1124 **3.13 PINGRESP – PING response**

1125 A PINGRESP Packet is sent by the Server to the Client in response to a PINGREQ Packet. It indicates
1126 that the Server is alive.

1127

1128 This Packet is used in Keep Alive processing, see Section 3.1.2.10 for more details.

1129 **3.13.1 Fixed header**

1130 **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

1131

1132 3.13.2 Variable header

1133 The PINGRESP Packet has no variable header.

1134 3.13.3 Payload

1135 The PINGRESP Packet has no payload.

1136 3.14 DISCONNECT – Disconnect notification

1137 The DISCONNECT Packet is the final Control Packet sent from the Client to the Server. It indicates that
1138 the Client is disconnecting cleanly.

1139 3.14.1 Fixed header

1140 **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

1141 The Server MUST validate that reserved bits are set to zero and disconnect the Client if they are not zero
1142 [MQTT-3.14.1-1].

1143 3.14.2 Variable header

1144 The DISCONNECT Packet has no variable header.

1145 3.14.3 Payload

1146 The DISCONNECT Packet has no payload.

1147 3.14.4 Response

1148 **After sending a DISCONNECT Packet the Client:**

- 1149 • MUST close the Network Connection [MQTT-3.14.4-1].
- 1150 • MUST NOT send any more Control Packets on that Network Connection [MQTT-3.14.4-2].

1151

1152 **On receipt of DISCONNECT the Server:**

- 1153 • MUST discard any Will Message associated with the current connection without publishing it, as
1154 described in Section 3.1.2.5 [MQTT-3.14.4-3].

- 1155
- SHOULD close the Network Connection if the Client has not already done so.

1156 4 Operational behavior

1157 4.1 Storing state

1158 It is necessary for the Client and Server to store Session state in order to provide Quality of Service
1159 guarantees. The Client and Server MUST store Session state for the entire duration of the Session
1160 [MQTT-4.1.0-1]. A Session MUST last at least as long it has an active Network Connection [MQTT-4.1.0-
1161 2].

1162
1163 Retained messages do not form part of the Session state in the Server. The Server SHOULD retain such
1164 messages until deleted by a Client.

1165

1166 Non normative comment

1167 The storage capabilities of Client and Server implementations will of course have limits in terms
1168 of capacity and may be subject to administrative policies such as the maximum time that Session
1169 state is stored between Network Connections. Stored Session state can be discarded as a result
1170 of an administrator action, including an automated response to defined conditions. This has the
1171 effect of terminating the Session. These actions might be prompted by resource constraints or for
1172 other operational reasons. It is prudent to evaluate the storage capabilities of the Client and
1173 Server to ensure that they are sufficient.

1174

1175 Non normative comment

1176 It is possible that hardware or software failures may result in loss or corruption of Session state
1177 stored by the Client or Server.

1178

1179 Non normative comment

1180 Normal operation of the Client or Server could mean that stored state is lost or corrupted because
1181 of administrator action, hardware failure or software failure. An administrator action could be an
1182 automated response to defined conditions. These actions might be prompted by resource
1183 constraints or for other operational reasons. For example the server might determine that based
1184 on external knowledge, a message or messages can no longer be delivered to any current or
1185 future client.

1186

1187 Non normative comment

1188 An MQTT user should evaluate the storage capabilities of the MQTT Client and Server
1189 implementations to ensure that they are sufficient for their needs.

1190

1191 4.1.1 Non normative example

1192 For example, a user wishing to gather electricity meter readings may decide that they need to use QoS 1
1193 messages because they need to protect the readings against loss over the network, however they may
1194 have determined that the power supply is sufficiently reliable that the data in the Client and Server can be
1195 stored in volatile memory without too much risk of its loss.

1196 Conversely a parking meter payment application provider might decide that there are no circumstances
1197 where a payment message can be lost so they require that all data are force written to non-volatile
1198 memory before it is transmitted across the network.

1199 **4.2 Network Connections**

1200 The MQTT protocol requires an underlying transport that provides an ordered, lossless, stream of bytes
 1201 from the Client to Server and Server to Client.

1202
 1203 **Non normative comment**

1204 The transport protocol used to carry MQTT 3.1 was TCP/IP as defined in [RFC793]. TCP/IP can
 1205 be used for MQTT 3.1.1. The following are also suitable:

- 1206 • TLS [RFC5246]
- 1207 • WebSocket [RFC6455]

1208
 1209 Connectionless network transports such as User Datagram Protocol (UDP) are not suitable on their own
 1210 because they might lose or reorder data.

1211 **4.3 Quality of Service levels and protocol flows**

1212 MQTT delivers Application Messages according to the Quality of Service (QoS) levels defined here. The
 1213 delivery protocol is symmetric, in the description below the Client and Server can each take the role of
 1214 either Sender or Receiver. The delivery protocol is concerned solely with the delivery of an application
 1215 message from a single Sender to a single Receiver. When the Server is delivering an Application
 1216 Message to more than one Client, each Client is treated independently. The QoS level used to deliver an
 1217 Application Message outbound to the Client could differ from that of the inbound Application Message.

1218 The non-normative flow diagrams in the following sections are intended to show possible implementation
 1219 approaches.

1220 **4.3.1 QoS 0: At most once delivery**

1221 The message is delivered according to the capabilities of the underlying network. No response is sent by
 1222 the receiver and no retry is performed by the sender. The message arrives at the receiver either once or
 1223 not at all.

1224
 1225 In the QoS 0 delivery protocol, the Sender

- 1226 • MUST send a PUBLISH packet with QoS=0, DUP=0 [MQTT-4.3.1-1].

1227
 1228 In the QoS 0 delivery protocol, the Receiver

- 1229 • Accepts ownership of the message when it receives the PUBLISH packet.

1230 **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)

1231 **4.3.2 QoS 1: At least once delivery**

1232 This quality of service ensures that the message arrives at the receiver at least once. A QoS 1 PUBLISH
 1233 Packet has a Packet Identifier in its variable header and is acknowledged by a PUBACK Packet. Section
 1234 2.3.1 provides more information about Packet Identifiers.

1235

1236 **In the QoS 1 delivery protocol, the Sender**

- 1237 • MUST assign an unused Packet Identifier each time it has a new Application Message to
 1238 publish.
- 1239 • MUST send a PUBLISH Packet containing this Packet Identifier with QoS=1, DUP=0.
- 1240 • MUST treat the PUBLISH Packet as “unacknowledged” until it has received the corresponding
 1241 PUBACK packet from the receiver. See Section 4.4 for a discussion of unacknowledged
 1242 messages.

1243 [MQTT-4.3.2-1].

1244 The Packet Identifier becomes available for reuse once the Sender has received the PUBACK Packet.

1245

1246 Note that a Sender is permitted to send further PUBLISH Packets with different Packet Identifiers while it
 1247 is waiting to receive acknowledgements.

1248

1249 **In the QoS 1 delivery protocol, the Receiver**

- 1250 • MUST respond with a PUBACK Packet containing the Packet Identifier from the incoming
 1251 PUBLISH Packet, having accepted ownership of the Application Message
- 1252 • After it has sent a PUBACK Packet the Receiver MUST treat any incoming PUBLISH packet that
 1253 contains the same Packet Identifier as being a new publication, irrespective of the setting of its
 1254 DUP flag.

1255 [MQTT-4.3.2-2].

1256

1257 **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		

1258

1259 ¹ The receiver is not required to complete delivery of the Application Message before sending the
 1260 PUBACK. When its original sender receives the PUBACK packet, ownership of the Application
 1261 Message is transferred to the receiver.

1262

1263 **4.3.3 QoS 2: Exactly once delivery**

1264 This is the highest quality of service, for use when neither loss nor duplication of messages are
 1265 acceptable. There is an increased overhead associated with this quality of service.

1266
 1267 A QoS 2 message has a Packet Identifier in its variable header. Section 2.3.1 provides more information
 1268 about Packet Identifiers. The receiver of a QoS 2 PUBLISH Packet acknowledges receipt with a two-step
 1269 acknowledgement process.

1270
 1271 **In the QoS 2 delivery protocol, the Sender**

- 1272 • MUST assign an unused Packet Identifier when it has a new Application Message to publish.
- 1273 • MUST send a PUBLISH packet containing this Packet Identifier with QoS=2, DUP=0.
- 1274 • MUST treat the PUBLISH packet as “unacknowledged” until it has received the corresponding
 1275 PUBREC packet from the receiver. See Section 4.4 for a discussion of unacknowledged
 1276 messages.
- 1277 • MUST send a PUBREL packet when it receives a PUBREC packet from the receiver. This
 1278 PUBREL packet MUST contain the same Packet Identifier as the original PUBLISH packet.
- 1279 • MUST treat the PUBREL packet as “unacknowledged” until it has received the corresponding
 1280 PUBCOMP packet from the receiver.
- 1281 • MUST NOT re-send the PUBLISH once it has sent the corresponding PUBREL packet.

1282 [MQTT-4.3.3-1].

1283 The Packet Identifier becomes available for reuse once the Sender has received the PUBCOMP Packet.

1284
 1285 Note that a Sender is permitted to send further PUBLISH Packets with different Packet Identifiers while it
 1286 is waiting to receive acknowledgements.

1287
 1288 **In the QoS 2 delivery protocol, the Receiver**

- 1289 • MUST respond with a PUBREC containing the Packet Identifier from the incoming PUBLISH
 1290 Packet, having accepted ownership of the Application Message.
- 1291 • Until it has received the corresponding PUBREL packet, the Receiver MUST acknowledge any
 1292 subsequent PUBLISH packet with the same Packet Identifier by sending a PUBREC. It MUST
 1293 NOT cause duplicate messages to be delivered to any onward recipients in this case.
- 1294 • MUST respond to a PUBREL packet by sending a PUBCOMP packet containing the same
 1295 Packet Identifier as the PUBREL.
- 1296 • After it has sent a PUBCOMP, the receiver MUST treat any subsequent PUBLISH packet that
 1297 contains that Packet Identifier as being a new publication.

1298 [MQTT-4.3.3-2].

1299

1300 **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		

1301
1302 ¹ The receiver is not required to complete delivery of the Application Message before sending the
1303 PUBREC or PUBCOMP. When its original sender receives the PUBREC packet, ownership of the
1304 Application Message is transferred to the receiver.

1305 **Figure 4.3** shows that there are two methods by which QoS 2 can be handled by the receiver. They
1306 differ in the point within the flow at which the message is made available for onward delivery. The
1307 choice of Method A or Method B is implementation specific. As long as an implementation chooses
1308 exactly one of these approaches, this does not affect the guarantees of a QoS 2 flow.

1309

1310 4.4 Message delivery retry

1311 When a Client reconnects with CleanSession set to 0, both the Client and Server MUST re-send any
1312 unacknowledged PUBLISH Packets (where QoS > 0) and PUBREL Packets using their original Packet
1313 Identifiers [MQTT-4.4.0-1]. This is the only circumstance where a Client or Server is REQUIRED to
1314 redeliver messages.

1315

1316 Non normative comment

1317 Historically retransmission of Control Packets was required to overcome data loss on some older
1318 TCP networks. This might remain a concern where MQTT 3.1.1 implementations are to be
1319 deployed in such environments.

1320 4.5 Message receipt

1321 When a Server takes ownership of an incoming Application Message it MUST add it to the Session state
1322 of those clients that have matching Subscriptions. Matching rules are defined in Section 4.7 [MQTT-4.5.0-
1323 1].

1324 Under normal circumstances Clients receive messages in response to Subscriptions they have created. A
1325 Client could also receive messages that do not match any of its explicit Subscriptions. This can happen if
1326 the Server automatically assigned a subscription to the Client. A Client could also receive messages
1327 while an UNSUBSCRIBE operation is in progress. The Client MUST acknowledge any Publish Packet it
1328 receives according to the applicable QoS rules regardless of whether it elects to process the Application
1329 Message that it contains [MQTT-4.5.0-2].

1330 4.6 Message ordering

1331 A Client MUST follow these rules when implementing the protocol flows defined elsewhere in this chapter:

- 1332 • When it re-sends any PUBLISH packets, it MUST re-send them in the order in which the original
1333 PUBLISH packets were sent (this applies to QoS 1 and QoS 2 messages) [MQTT-4.6.0-1]
- 1334 • It MUST send PUBACK packets in the order in which the corresponding PUBLISH packets were
1335 received (QoS 1 messages) [MQTT-4.6.0-2]
- 1336 • It MUST send PUBREC packets in the order in which the corresponding PUBLISH packets were
1337 received (QoS 2 messages) [MQTT-4.6.0-3]
- 1338 • It MUST send PUBREL packets in the order in which the corresponding PUBREC packets were
1339 received (QoS 2 messages) [MQTT-4.6.0-4]

1340

1341 A Server MUST by default treat each Topic as an "Ordered Topic". It MAY provide an administrative or
1342 other mechanism to allow one or more Topics to be treated as an "Unordered Topic" [MQTT-4.6.0-5].

1343

1344 When a Server processes a message that has been published to an Ordered Topic, it MUST follow the
1345 rules listed above when delivering messages to each of its subscribers. In addition it MUST send
1346 PUBLISH packets to consumers (for the same Topic and QoS) in the order that they were received from
1347 any given Client [MQTT-4.6.0-6].

1348

1349 Non normative comment

1350 The rules listed above ensure that when a stream of messages is published and subscribed to
1351 with QoS 1, the final copy of each message received by the subscribers will be in the order that
1352 they were originally published in, but the possibility of message duplication could result in a re-
1353 send of an earlier message being received after one of its successor messages. For example a
1354 publisher might send messages in the order 1,2,3,4 and the subscriber might receive them in the
1355 order 1,2,3,2,3,4.

1356

1357 If both Client and Server make sure that no more than one message is "in-flight" at any one time
1358 (by not sending a message until its predecessor has been acknowledged), then no QoS 1
1359 message will be received after any later one - for example a subscriber might receive them in the
1360 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
1361 preserved even if the publisher sends a sequence of messages with different QoS levels on the
1362 same topic.

1363 4.7 Topic Names and Topic Filters

1364 4.7.1 Topic wildcards

1365 The topic level separator is used to introduce structure into the Topic Name. If present, it divides the
1366 Topic Name into multiple “topic levels”.

1367 A subscription’s Topic Filter can contain special wildcard characters, which allow you to subscribe to
1368 multiple topics at once.

1369 **The wildcard characters can be used in Topic Filters, but MUST NOT be used within a Topic Name**
1370 **[MQTT-4.7.1-1].**

1371 4.7.1.1 Topic level separator

1372 The forward slash (‘/’ U+002F) is used to separate each level within a topic tree and provide a hierarchical
1373 structure to the Topic Names. The use of the topic level separator is significant when either of the two
1374 wildcard characters is encountered in Topic Filters specified by subscribing Clients. Topic level separators
1375 can appear anywhere in a Topic Filter or Topic Name. Adjacent Topic level separators indicate a zero
1376 length topic level.

1377 4.7.1.2 Multi-level wildcard

1378 The number sign (‘#’ U+0023) is a wildcard character that matches any number of levels within a topic.
1379 The multi-level wildcard represents the parent and any number of child levels. **The multi-level wildcard**
1380 **character MUST be specified either on its own or following a topic level separator. In either case it MUST**
1381 **be the last character specified in the Topic Filter [MQTT-4.7.1-2].**

1382

1383 **Non normative comment**

1384 For example, if a Client subscribes to “sport/tennis/player1/#”, it would receive messages
1385 published using these topic names:

- 1386 • “sport/tennis/player1”
- 1387 • “sport/tennis/player1/ranking”
- 1388 • “sport/tennis/player1/score/wimbledon”

1389

1390 **Non normative comment**

- 1391 • “sport/#” also matches the singular “sport”, since # includes the parent level.
- 1392 • “#” is valid and will receive every Application Message
- 1393 • “sport/tennis/#” is valid
- 1394 • “sport/tennis#” is not valid
- 1395 • “sport/tennis#/ranking” is not valid

1396 4.7.1.3 Single level wildcard

1397 The plus sign (‘+’ U+002B) is a wildcard character that matches only one topic level.

1398

1399 **The single-level wildcard can be used at any level in the Topic Filter, including first and last levels. Where**
1400 **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
1401 level in the Topic Filter and can be used in conjunction with the multilevel wildcard.

1402

1403 **Non normative comment**

1404 For example, "sport/tennis/+" matches "sport/tennis/player1" and "sport/tennis/player2", but not
1405 "sport/tennis/player1/ranking". Also, because the single-level wildcard matches only a single level,
1406 "sport/+" does not match "sport" but it does match "sport/".

1407

1408 **Non normative comment**

- 1409 • "+" is valid
- 1410 • "+/tennis/#" is valid
- 1411 • "sport+" is not valid
- 1412 • "sport+/player1" is valid
- 1413 • "/finance" matches "+/+" and "/+", but not "+"

1414 4.7.2 Topics beginning with \$

1415 The Server MUST NOT match Topic Filters starting with a wildcard character (# or +) with Topic Names
1416 beginning with a \$ character [MQTT-4.7.2-1]. The Server SHOULD prevent Clients from using such Topic
1417 Names to exchange messages with other Clients. Server implementations MAY use Topic Names that
1418 start with a leading \$ character for other purposes.

1419

1420 **Non normative comment**

- 1421 • \$SYS/ has been widely adopted as a prefix to topics that contain Server-specific
1422 information or control APIs
- 1423 • Applications cannot use a topic with a leading \$ character for their own purposes

1424

1425 **Non normative comment**

- 1426 • A subscription to "#" will not receive any messages published to a topic beginning with a
1427 \$
- 1428 • A subscription to "+/monitor/Clients" will not receive any messages published to
1429 "\$SYS/monitor/Clients"
- 1430 • A subscription to "\$SYS/#" will receive messages published to topics beginning with
1431 "\$SYS/"
- 1432 • A subscription to "\$SYS/monitor/+" will receive messages published to
1433 "\$SYS/monitor/Clients"
- 1434 • For a Client to receive messages from topics that begin with \$SYS/ and from topics that
1435 don't begin with a \$, it has to subscribe to both "#" and "\$SYS/#"

1436 4.7.3 Topic semantic and usage

1437 The following rules apply to Topic Names and Topic Filters:

- 1438 • All Topic Names and Topic Filters MUST be at least one character long [MQTT-4.7.3-1]
- 1439 • Topic Names and Topic Filters are case sensitive
- 1440 • Topic Names and Topic Filters can include the space character
- 1441 • A leading or trailing '/' creates a distinct Topic Name or Topic Filter
- 1442 • A Topic Name or Topic Filter consisting only of the '/' character is valid
- 1443 • Topic Names and Topic Filters MUST NOT include the null character (Unicode U+0000)
1444 [Unicode] [MQTT-4.7.3-2]
- 1445 • Topic Names and Topic Filters are UTF-8 encoded strings, they MUST NOT encode to more than
1446 65535 bytes [MQTT-4.7.3-3]. See Section 1.5.3

1447 There is no limit to the number of levels in a Topic Name or Topic Filter, other than that imposed by the
1448 overall length of a UTF-8 encoded string.

1449 **When it performs subscription matching the Server MUST NOT perform any normalization of Topic**
1450 **Names or Topic Filters, or any modification or substitution of unrecognized characters [MQTT-4.7.3-4].**

1451 Each non-wildcarded level in the Topic Filter has to match the corresponding level in the Topic Name
1452 character for character for the match to succeed.

1453

1454 **Non normative comment**

1455 The UTF-8 encoding rules mean that the comparison of Topic Filter and Topic Name could be
1456 performed either by comparing the encoded UTF-8 bytes, or by comparing decoded Unicode
1457 characters

1458

1459 **Non normative comment**

1460

- “ACCOUNTS” and “Accounts” are two different topic names

1461

- “Accounts payable” is a valid topic name

1462

- “/finance” is different from “finance”

1463

1464 An Application Message is sent to each Client Subscription whose Topic Filter matches the Topic Name
1465 attached to an Application Message. The topic resource MAY be either predefined in the Server by an
1466 administrator or it MAY be dynamically created by the Server when it receives the first subscription or an
1467 Application Message with that Topic Name. The Server MAY also use a security component to selectively
1468 authorize actions on the topic resource for a given Client.

1469 **4.8 Handling errors**

1470

1471 **Unless stated otherwise, if either the Server or Client encounters a protocol violation, it MUST close the**
1472 **Network Connection on which it received that Control Packet which caused the protocol violation [MQTT-**
1473 **4.8.0-1].**

1474 A Client or Server implementation might encounter a Transient Error (for example an internal buffer full
1475 condition) that prevents successful processing of an MQTT packet.

1476 **If the Client or Server encounters a Transient Error while processing an inbound Control Packet it MUST**
1477 **close the Network Connection on which it received that Control Packet [MQTT-4.8.0-2].** If a Server
1478 detects a Transient Error it SHOULD NOT disconnect or have any other effect on its interactions with any
1479 other Client.

1480 5 Security

1481 5.1 Introduction

1482 This Chapter is provided for guidance only and is **Non Normative**. However, it is strongly recommended
1483 that Server implementations that offer TLS [\[RFC5246\]](#) SHOULD use TCP port 8883 (IANA service name:
1484 secure-mqtt).

1485
1486 There are a number of threats that solution providers should consider. For example:

- 1487 • Devices could be compromised
- 1488 • Data at rest in Clients and Servers might be accessible
- 1489 • Protocol behaviors could have side effects (e.g. “timing attacks”)
- 1490 • Denial of Service (DoS) attacks
- 1491 • Communications could be intercepted, altered, re-routed or disclosed
- 1492 • Injection of spoofed Control Packets

1493
1494 MQTT solutions are often deployed in hostile communication environments. In such cases,
1495 implementations will often need to provide mechanisms for:

- 1496 • Authentication of users and devices
- 1497 • Authorization of access to Server resources
- 1498 • Integrity of MQTT Control Packets and application data contained therein
- 1499 • Privacy of MQTT Control Packets and application data contained therein

1500
1501 As a transport protocol, MQTT is concerned only with message transmission and it is the implementer’s
1502 responsibility to provide appropriate security features. This is commonly achieved by using TLS
1503 [\[RFC5246\]](#).

1504
1505 In addition to technical security issues there could also be geographic (e.g. U.S.-EU SafeHarbor
1506 [\[USEUSAFEHARB\]](#)), industry specific (e.g. PCI DSS [\[PCIDSS\]](#)) and regulatory considerations (e.g.
1507 Sarbanes-Oxley [\[SARBANES\]](#)).

1508 5.2 MQTT solutions: security and certification

1509 An implementation might want to provide conformance with specific industry security standards such as
1510 NIST Cyber Security Framework [\[NISTCSF\]](#), PCI-DSS [\[PCIDSS\]](#), FIPS-140-2 [\[FIPS1402\]](#) and NSA Suite
1511 B [\[NSAB\]](#).

1512 Guidance on using MQTT within the NIST Cyber Security Framework [\[NISTCSF\]](#) can be found in the
1513 MQTT supplemental publication, MQTT and the NIST Framework for Improving Critical Infrastructure
1514 Cybersecurity [\[MQTT NIST\]](#). The use of industry proven, independently verified and certified technologies
1515 will help meet compliance requirements.

1516 5.3 Lightweight cryptography and constrained devices

1517 Advanced Encryption Standard [\[AES\]](#) and Data Encryption Standard [\[DES\]](#) are widely adopted.

1518

1519 ISO 29192 [ISO29192] makes recommendations for cryptographic primitives specifically tuned to perform
1520 on constrained “low end” devices.

1521 **5.4 Implementation notes**

1522 There are many security concerns to consider when implementing or using MQTT. The following section
1523 should not be considered a “check list”.

1524

1525 An implementation might want to achieve some, or all, of the following:

1526 **5.4.1 Authentication of Clients by the Server**

1527 The CONNECT Packet contains Username and Password fields. Implementations can choose how to
1528 make use of the content of these fields. They may provide their own authentication mechanism, use an
1529 external authentication system such as LDAP [RFC4511] or OAuth [RFC6749] tokens, or leverage
1530 operating system authentication mechanisms.

1531

1532 Implementations passing authentication data in clear text, obfuscating such data elements or requiring no
1533 authentication data should be aware this can give rise to Man-in-the-Middle and replay attacks. Section
1534 5.4.5 introduces approaches to ensure data privacy.

1535

1536 A Virtual Private Network (VPN) between the Clients and Servers can provide confidence that data is only
1537 being received from authorized Clients.

1538

1539 Where TLS [RFC5246] is used, SSL Certificates sent from the Client can be used by the Server to
1540 authenticate the Client.

1541

1542 An implementation might allow for authentication where the credentials are sent in an Application
1543 Message from the Client to the Server.

1544 **5.4.2 Authorization of Clients by the Server**

1545 An implementation may restrict access to Server resources based on information provided by the Client
1546 such as User Name, Client Identifier, the hostname/IP address of the Client, or the outcome of
1547 authentication mechanisms.

1548 **5.4.3 Authentication of the Server by the Client**

1549 The MQTT protocol is not trust symmetrical: it provides no mechanism for the Client to authenticate the
1550 Server.

1551

1552 Where TLS [RFC5246] is used, SSL Certificates sent from the Server can be used by the Client to
1553 authenticate the Server. Implementations providing MQTT service for multiple hostnames from a single IP
1554 address should be aware of the Server Name Indication extension to TLS defined in section 3 of RFC
1555 6066 [RFC6066]. This allows a Client to tell the Server the hostname of the Server it is trying to connect
1556 to.

1557

1558 An implementation might allow for authentication where the credentials are sent in an Application
1559 Message from the Server to the Client.

1560

1561 A VPN between Clients and Servers can provide confidence that Clients are connecting to the intended
1562 Server.

1563 **5.4.4 Integrity of Application Messages and Control Packets**

1564 Applications can independently include hash values in their Application Messages. This can provide
1565 integrity of the contents of Publish Control Packets across the network and at rest.

1566
1567 TLS [\[RFC5246\]](#) provides hash algorithms to verify the integrity of data sent over the network.

1568
1569 The use of VPNs to connect Clients and Servers can provide integrity of data across the section of the
1570 network covered by a VPN.

1571 **5.4.5 Privacy of Application Messages and Control Packets**

1572 TLS [\[RFC5246\]](#) can provide encryption of data sent over the network. There are valid TLS cipher suites
1573 that include a NULL encryption algorithm that does not encrypt data. To ensure privacy Clients and
1574 Servers should avoid these cipher suites.

1575
1576 An application might independently encrypt the contents of its Application Messages. This could provide
1577 privacy of the Application Message both over the network and at rest. This would not provide privacy for
1578 other properties of the Application Message such as Topic Name.

1579
1580 Client and Server implementations can provide encrypted storage for data at rest such as Application
1581 Messages stored as part of a Session.

1582
1583 The use of VPNs to connect Clients and Servers can provide privacy of data across the section of the
1584 network covered by a VPN.

1585 **5.4.6 Non-repudiation of message transmission**

1586 Application designers might need to consider appropriate strategies to achieve end to end non-
1587 repudiation.

1588 **5.4.7 Detecting compromise of Clients and Servers**

1589 Client and Server implementations using TLS [\[RFC5246\]](#) should provide capabilities to ensure that any
1590 SSL certificates provided when initiating a TLS [\[RFC5246\]](#) connection are associated with the hostname
1591 of the Client connecting or Server being connected to.

1592
1593 Client and Server implementations using TLS [\[RFC5246\]](#) can choose to provide capabilities to check
1594 Certificate Revocation Lists (CRLs [\[RFC5280\]](#)) and Online Certificate Status Protocol (OSCP) [\[RFC6960\]](#)
1595 to prevent revoked certificates from being used.

1596
1597 Physical deployments might combine tamper-proof hardware with the transmission of specific data in
1598 Application Messages. For example a meter might have an embedded GPS to ensure it is not used in an
1599 unauthorized location. [\[IEEE 802.1AR\]](#) is a standard for implementing mechanisms to authenticate a
1600 device's identity using a cryptographically bound identifier.

1601 **5.4.8 Detecting abnormal behaviors**

1602 Server implementations might monitor Client behavior to detect potential security incidents. For example:

- 1603
- Repeated connection attempts
 - Repeated authentication attempts
 - Abnormal termination of connections
- 1604
1605

- 1606
- Topic scanning (attempts to send or subscribe to many topics)
- 1607
- Sending undeliverable messages (no subscribers to the topics)
- 1608
- Clients that connect but do not send data

1609

1610 Server implementations might disconnect Clients that breach its security rules.

1611

1612 Server implementations detecting unwelcome behavior might implement a dynamic block list based on
1613 identifiers such as IP address or Client Identifier.

1614

1615 Deployments might use network level controls (where available) to implement rate limiting or blocking
1616 based on IP address or other information.

1617 **5.4.9 Other security considerations**

1618 If Client or Server SSL certificates are lost or it is considered that they might be compromised they should
1619 be revoked (utilizing CRLs [\[RFC5280\]](#) and/or OSCP [\[RFC6960\]](#)).

1620

1621 Client or Server authentication credentials, such as User Name and Password, that are lost or considered
1622 compromised should be revoked and/or reissued.

1623

1624 In the case of long lasting connections:

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

1629

1630 Constrained devices and Clients on constrained networks can make use of TLS session resumption
1631 [\[RFC5077\]](#), in order to reduce the costs of reconnecting TLS [\[RFC5246\]](#) sessions.

1632

1633 Clients connected to a Server have a transitive trust relationship with other Clients connected to the same
1634 Server and who have authority to publish data on the same topics.

1635 **5.4.10 Use of SOCKS**

1636 Implementations of Clients should be aware that some environments will require the use of SOCKSv5
1637 [\[RFC1928\]](#) proxies to make outbound Network Connections. Some MQTT implementations could make
1638 use of alternative secured tunnels (e.g. SSH) through the use of SOCKS. Where implementations choose
1639 to use SOCKS, they should support both anonymous and user-name password authenticating SOCKS
1640 proxies. In the latter case, implementations should be aware that SOCKS authentication might occur in
1641 plain-text and so should avoid using the same credentials for connection to a MQTT Server.

1642 **5.4.11 Security profiles**

1643 Implementers and solution designers might wish to consider security as a set of profiles which can be
1644 applied to the MQTT protocol. An example of a layered security hierarchy is presented below.

1645 **5.4.11.1 Clear communication profile**

1646 When using the clear communication profile, the MQTT protocol runs over an open network with no
1647 additional secure communication mechanisms in place.

1648 **5.4.11.2 Secured network communication profile**

1649 When using the secured network communication profile, the MQTT protocol runs over a physical or virtual
1650 network which has security controls e.g., VPNs or physically secure network.

1651 **5.4.11.3 Secured transport profile**

1652 When using the secured transport profile, the MQTT protocol runs over a physical or virtual network and
1653 using TLS [\[RFC5246\]](#) which provides authentication, integrity and privacy.

1654

1655 TLS [\[RFC5246\]](#) Client authentication can be used in addition to – or in place of – MQTT Client
1656 authentication as provided by the Username and Password fields.

1657 **5.4.11.4 Industry specific security profiles**

1658 It is anticipated that the MQTT protocol will be designed into industry specific application profiles, each
1659 defining a threat model and the specific security mechanisms to be used to address these threats.

1660 Recommendations for specific security mechanisms will often be taken from existing works including:

1661

1662 [\[NISTCSF\]](#) NIST Cyber Security Framework

1663 [\[NIST7628\]](#) NISTIR 7628 Guidelines for Smart Grid Cyber Security

1664 [\[FIPS1402\]](#) Security Requirements for Cryptographic Modules (FIPS PUB 140-2)

1665 [\[PCIDSS\]](#) PCI-DSS Payment Card Industry Data Security Standard

1666 [\[NSAB\]](#) NSA Suite B Cryptography

6 Using WebSocket as a network transport

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

- 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-6.0.0-1].
- 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-6.0.0-2].
- The client MUST include “mqtt” in the list of WebSocket Sub Protocols it offers [MQTT-6.0.0-3].
- The WebSocket Sub Protocol name selected and returned by the server MUST be “mqtt” [MQTT-6.0.0-4].
- The WebSocket URI used to connect the client and server has no impact on the MQTT protocol.

6.1 IANA Considerations

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

Figure 6.1 - IANA WebSocket Identifier

Subprotocol Identifier	Mqtt
Subprotocol Common Name	Mqtt
Subprotocol Definition	http://docs.oasis-open.org/mqtt/mqtt/v4.0/mqtt-v4.0.html

1684 7 Conformance

1685 The MQTT specification defines conformance for MQTT Client implementations and MQTT Server
1686 implementations.

1687

1688 An MQTT implementation MAY conform as both an MQTT Client and MQTT Server implementation. A
1689 Server that both accepts inbound connections and establishes outbound connections to other Servers
1690 MUST conform as both an MQTT Client and MQTT Server [MQTT-7.0.0-1].

1691

1692 Conformant implementations MUST NOT require the use of any extensions defined outside of this
1693 specification in order to interoperate with any other conformant implementation [MQTT-7.0.0-2].

1694 7.1 Conformance Targets

1695 7.1.1 MQTT Server

1696 An MQTT Server conforms to this specification only if it satisfies all the statements below:

1697 1. The format of all Control Packets that the Server sends matches the format described in Chapter 2 and
1698 Chapter 3.

1699 2. It follows the Topic matching rules described in Section 4.7.

1700 3. It satisfies all of the MUST level requirements in the following chapters that are identified except for
1701 those that only apply to the Client:

1702 - Chapter 1 - Introduction

1703 - Chapter 2 - MQTT Control Packet format

1704 - Chapter 3 - MQTT Control Packets

1705 - Chapter 4 - Operational behavior

1706 - Chapter 6 - (if MQTT is transported over a WebSocket connection)

1707 - Chapter 7 - Conformance Targets

1708

1709 A conformant Server MUST support the use of one or more underlying transport protocols that provide an
1710 ordered, lossless, stream of bytes from the Client to Server and Server to Client [MQTT-7.1.1-1]. However
1711 conformance does not depend on it supporting any specific transport protocols. A Server MAY support
1712 any of the transport protocols listed in Section 4.2, or any other transport protocol that meets the
1713 requirements of [MQTT-7.1.1-1].

1714 7.1.2 MQTT Client

1715 An MQTT Client conforms to this specification only if it satisfies all the statements below:

1716 1. The format of all Control Packets that the Client sends matches the format described in Chapter 2 and
1717 Chapter 3.

1718 2. It satisfies all of the MUST level requirements in the following chapters that are identified except for
1719 those that only apply to the Server:

1720 - Chapter 1 - Introduction

1721 - Chapter 2 - MQTT Control Packet format

1722 - Chapter 3 - MQTT Control Packets

1723 - Chapter 4 - Operational behavior

1724 - Chapter 6 - (if MQTT is transported over a WebSocket connection)

1725 - Chapter 7 - Conformance Targets

1726

1727 A conformant Client MUST support the use of one or more underlying transport protocols that provide an
1728 ordered, lossless, stream of bytes from the Client to Server and Server to Client [MQTT-7.1.2-1]. However
1729 conformance does not depend on it supporting any specific transport protocols. A Client MAY support any
1730 of the transport protocols listed in Section 4.2, or any other transport protocol that meets the requirements
1731 of [MQTT-7.1.2-1].

1732

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1735

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1792

1793

1794

Appendix B. Mandatory normative statements (non normative)

1795

1796 This Appendix is non-normative and is provided as a convenient summary of the numbered conformance
 1797 statements found in the main body of this document. See Chapter 7 for a definitive list of conformance
 1798 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)

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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
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