MQTT Protocol

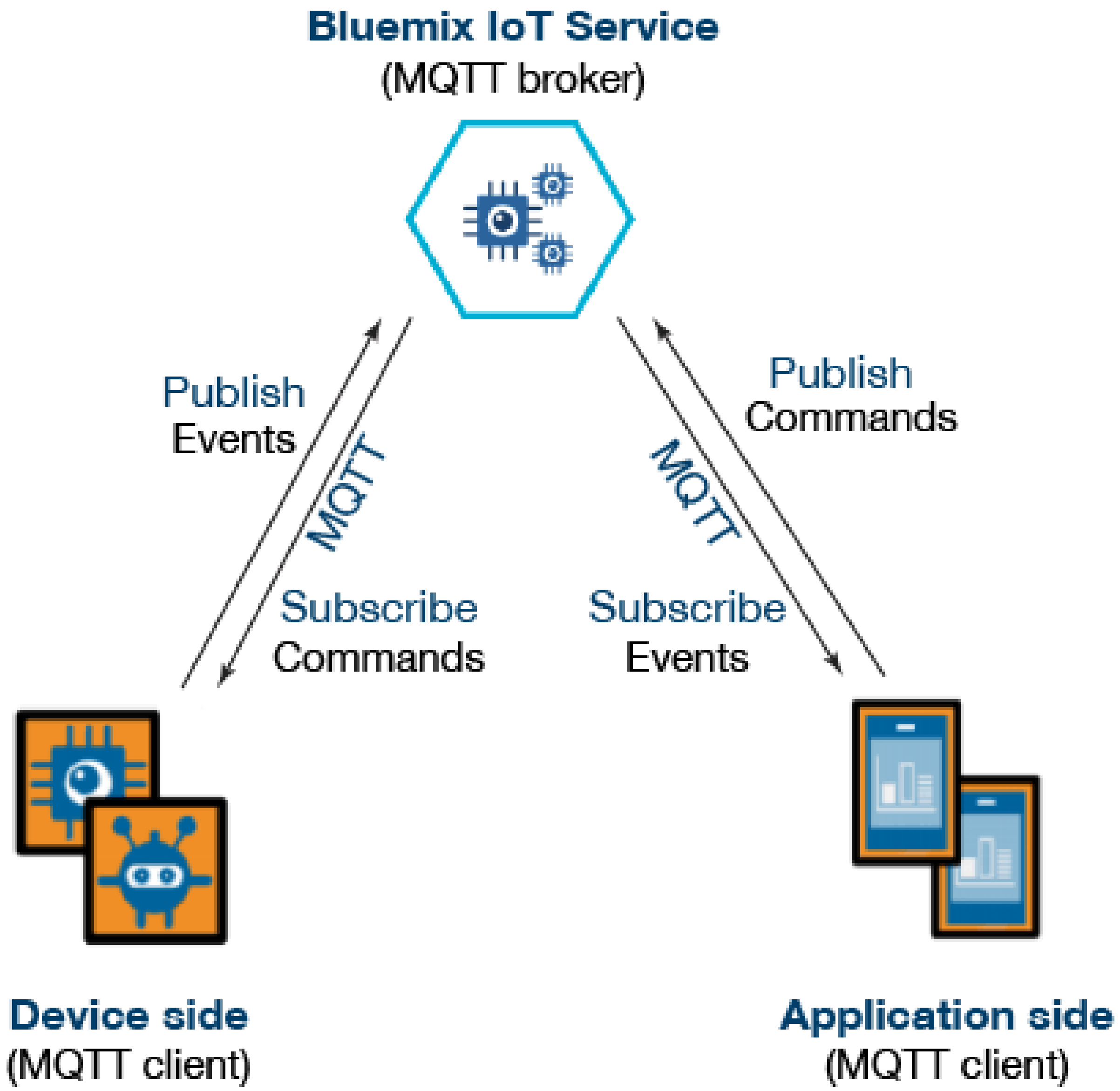
Internet-of-Things (IoT)

COCSC20

MQTT

- Message Queuing Telemetry Transport
- A lightweight publish/subscribe protocol with predictable bi-directional message delivery.
- It is M2M/IoT connectivity protocol.
- MQTT is an Event based IoT middleware (one to many)
- In a nutshell, MQTT consist of three parts:
  - Broker
  - Subscribers
  - Publishers

MQTT



Bluemix IoT Service
(MQTT broker)

Publish
Events

MQTT

Subscribe
Commands

Publish
Commands

MQTT

Subscribe
Events

Device side
(MQTT client)

Application side
(MQTT client)

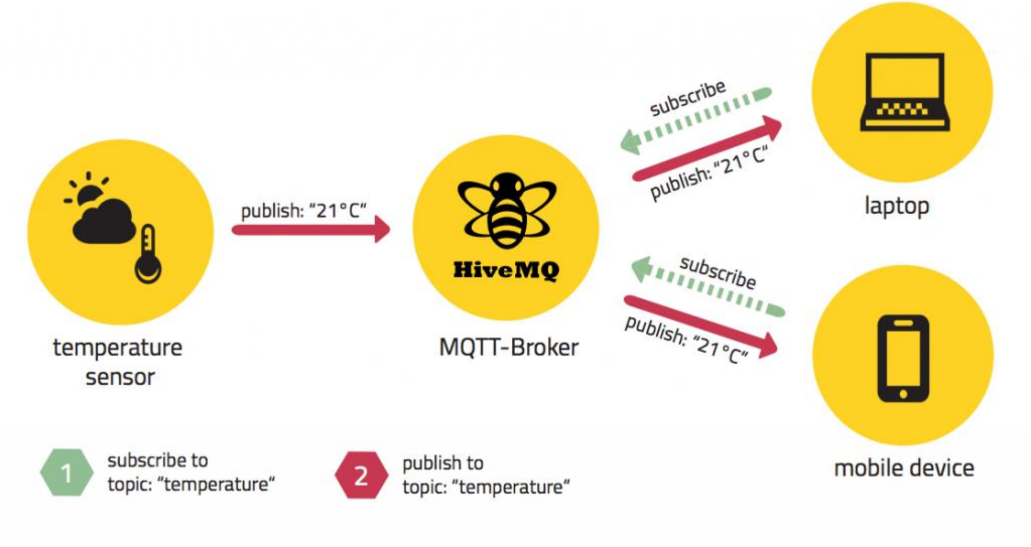
MQTT

- MQTT was invented by Andy Stanford-Clark (IBM) and Arlen Nipper back in 1999, where their use case was to create a protocol for **minimal battery loss** and **minimal bandwidth** connecting oil pipelines over satellite connections. They specified the following goals, which the future protocol should have:
  - Simple to implement
  - Provide a Quality of Service Data Delivery
  - Lightweight and Bandwidth Efficient
  - Data Agnostic
  - Continuous Session Awareness

MQTT

- Built for **proprietary embedded systems**; now shifting to IoT.
- You can send **anything as a message**; up to 256 MB.
- Built for **unreliable** networks.
- Enterprise scale implementations down to **hobby projects**
- Decouples readers and writers.
- Message have a topic, quality of service, and retain status associated with them.

Publish/Subscribe Concept



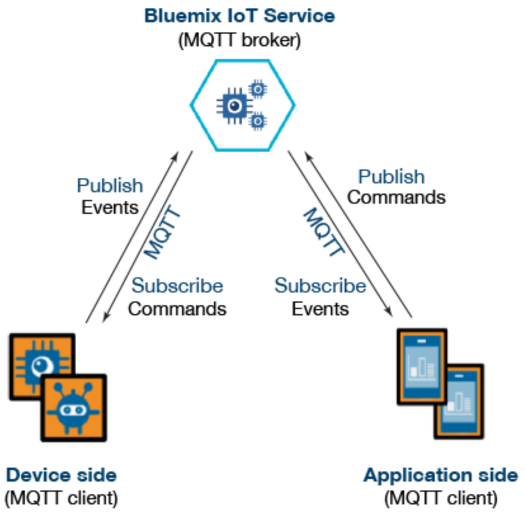
Decoupled in space and time:
The clients do not need each others IP address and port (space) and they do not need to be running at the same time (time).

The **broker's IP and port** must be known by clients.

Namespace hierarchy used for topic filtering.

It may be the case that a published message is never consumed by any Subscriber.

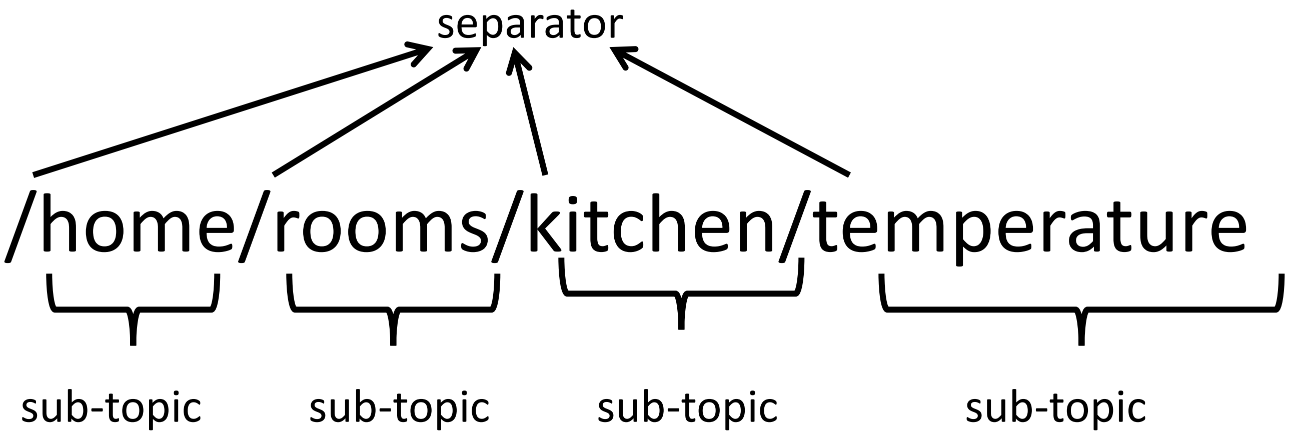
MQTT: Example



- Clients **connect** to a "Broker"
- Clients **subscribe** to topics e.g.,
  - client.subscribe('toggleLight/1')
  - client.subscribe('toggleLight/2')
  - client.subscribe('toggleLight/3')
- Clients can **publish** messages to topics:
  - client.publish('toggleLight/1', 'toggle');
  - client.publish('toggleLight/2', 'toggle');
- All clients receive all messages published to topics they subscribe to
- **Messages can be anything**
  - Text
  - Images
  - etc.

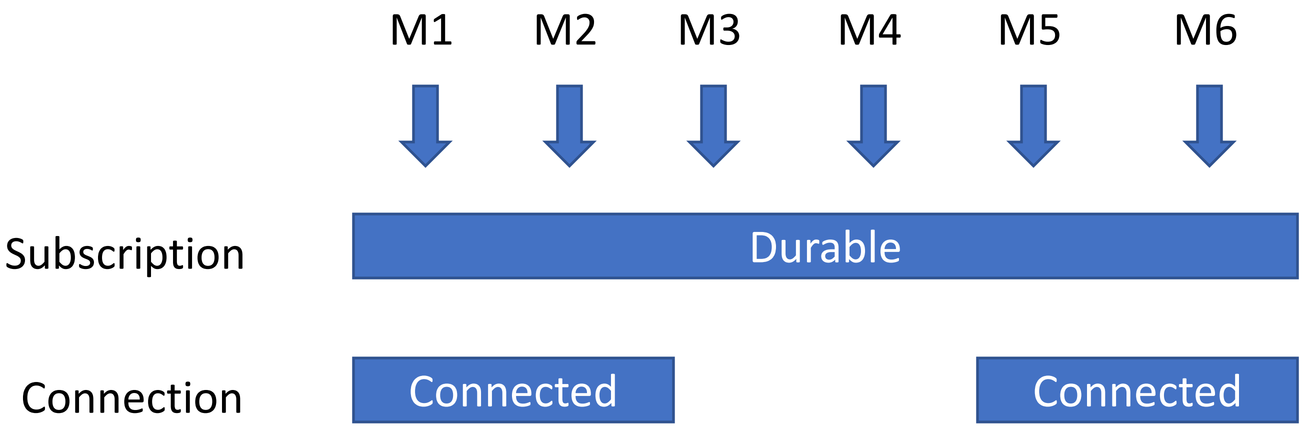
Topics

- Each published data specifies a topic
- Each subscriber subscribed to that topic will receive it.
- Topic format:



Durable/Transient Subscriptions

- Subscriptions
  - Durable
    - If the subscriber disconnect, messages are buffered at the broker and delivered upon reconnection
  - Non-durable
    - Connection lifetime gives subscription lifetime



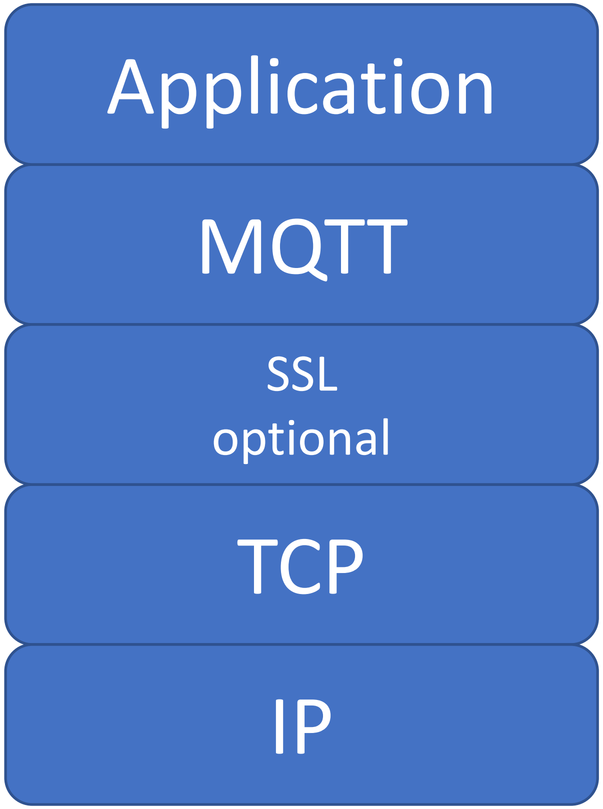
State Retention

- Publications
  - Retained (“persistent” message)
    - The subscriber upon first connection receives the last good publication (i.e., does not have to wait for new publication).
  - One flag set both in the publish packet to the broker and subscribers
    - Only the most recent persistent message is stored and distributed

Session Aware

- Last Will and Testament (LWT) – topic published upon disconnecting a connection.
- Any client can register an LWT.
- Anybody subscribing to the LWT topic will know when a certain device (that registered a LWT) disconnected.

Protocol Stack



Application

MQTT

SSL
optional

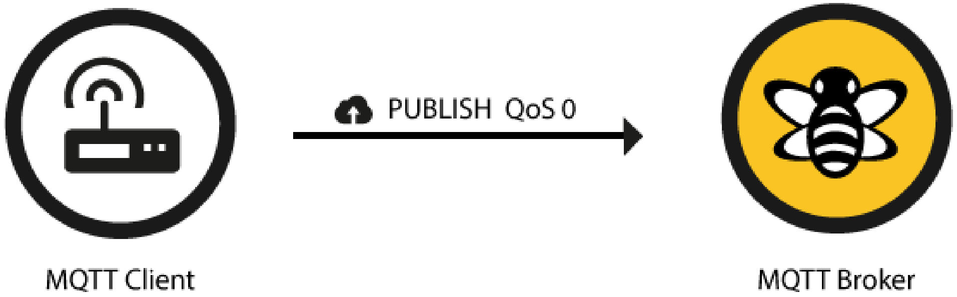
TCP

IP

TCP/IP Port: 1883
When running over SSL, TCP/IP port 8883
SSL: Secure Socket Layer (encryption)

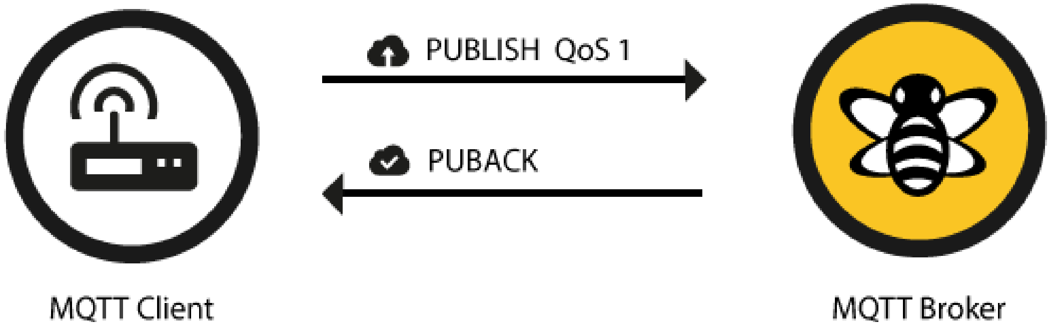
Publishing “QoS” (Reliability)

- 0 – unreliable (aka “at most once”)
  - OK for continuous streams, least overhead (1 message)
  - “Fire and forget”
  - TCP will still provide reliability



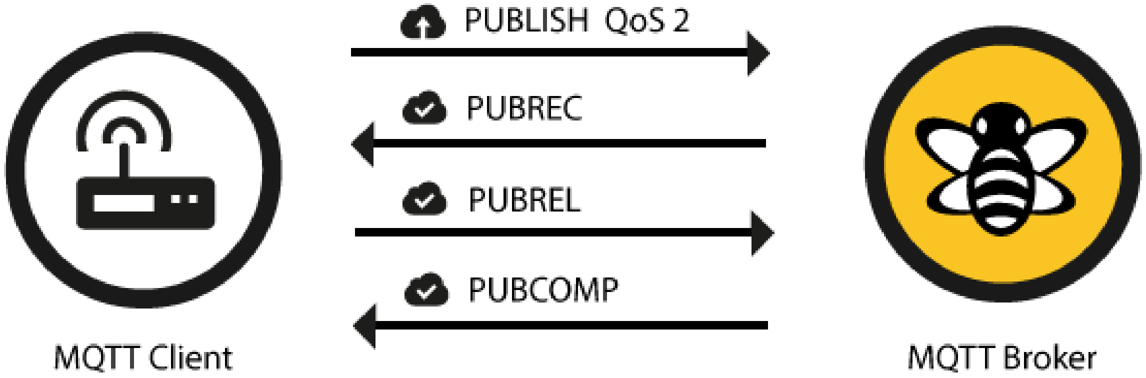
Publishing "QoS" (Reliability)

- 1 – delivery "at least once" (duplicates possible)
  - Used for alarms – more overhead (2 messages)
  - Contains message ID (to match with ACKed message)



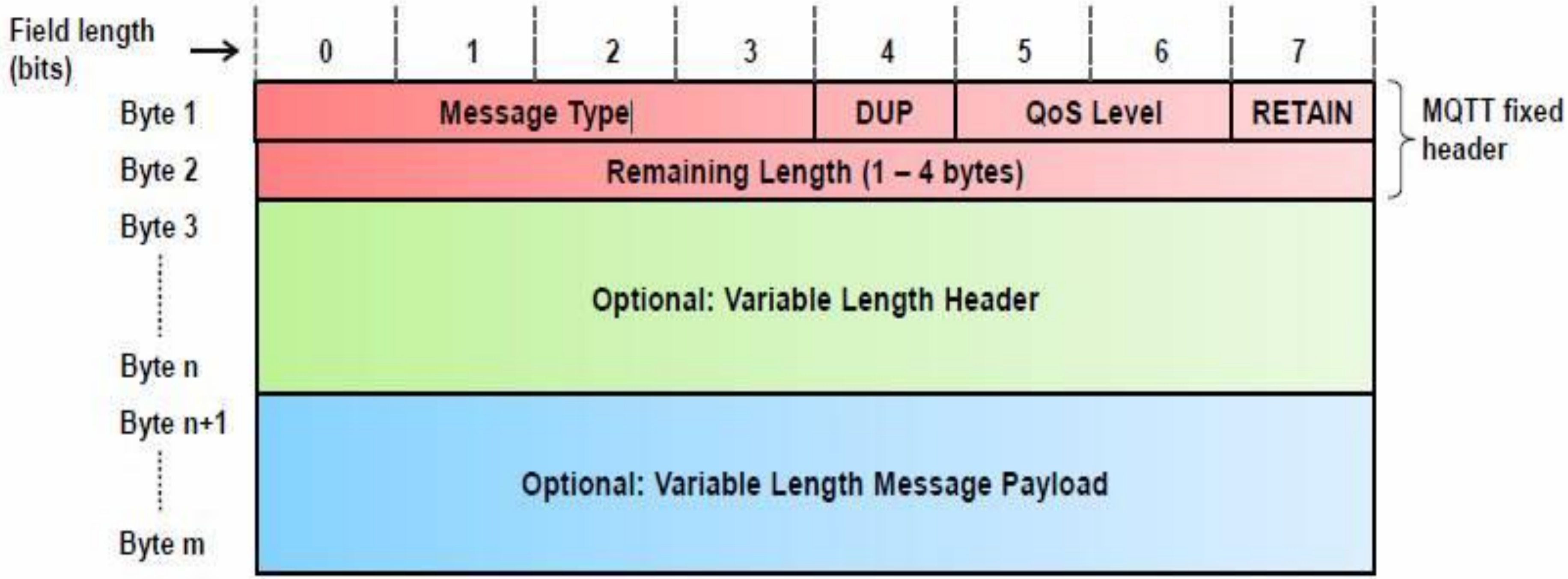
Publishing “QoS” (Reliability)

- 2 – delivery “exactly once”
  - Utmost reliability is important – most overhead (4 messages) and slowest



MQTT Message Format

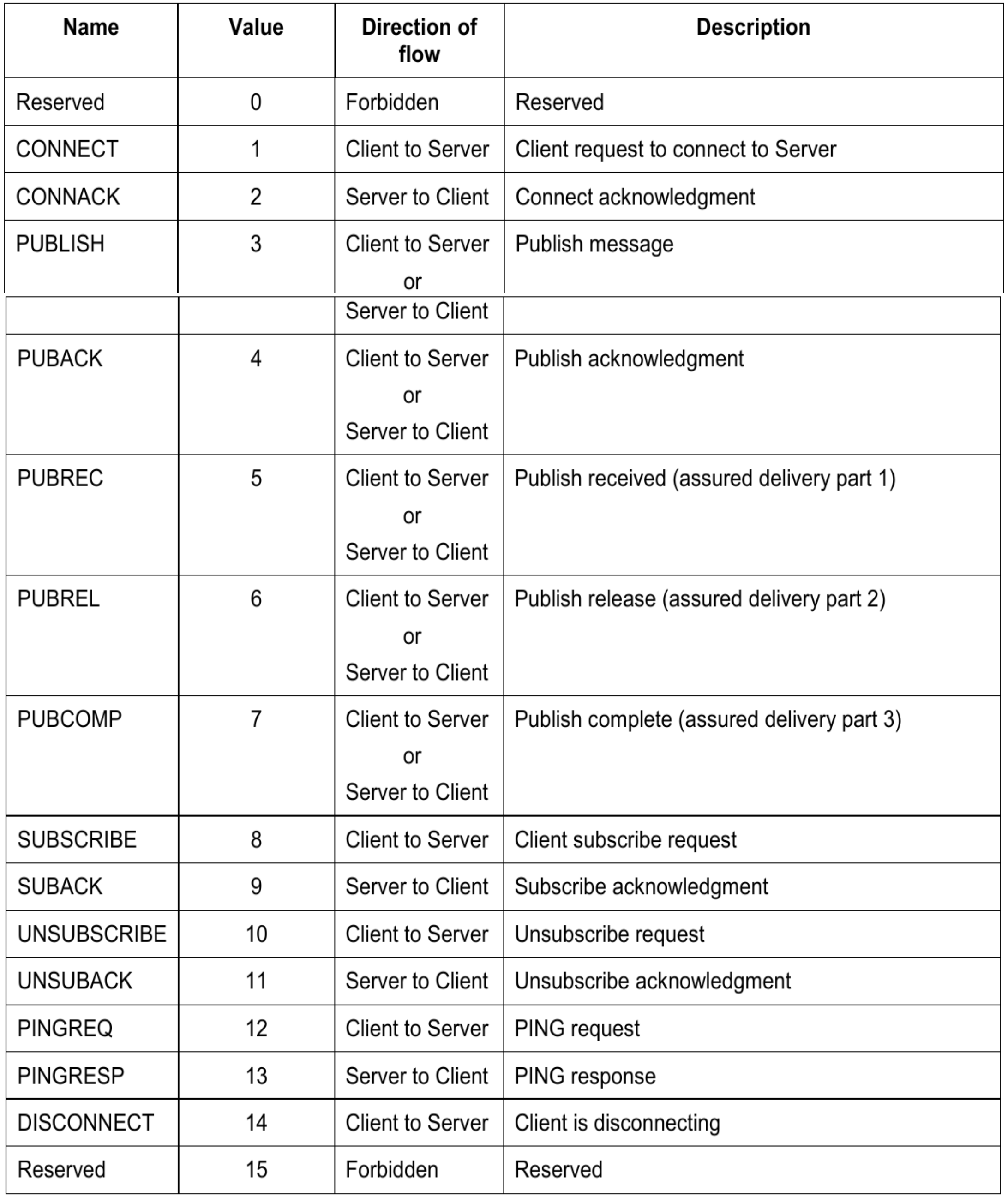
Shortest Message is Two Bytes



Field length (bits) →	0	1	2	3	4	5	6	7
Byte 1	Message Type				DUP	QoS Level		RETAIN
Byte 2	Remaining Length (1 – 4 bytes)							
Byte 3 ⋮ Byte n	Optional: Variable Length Header							
Byte n+1 ⋮ Byte m	Optional: Variable Length Message Payload							

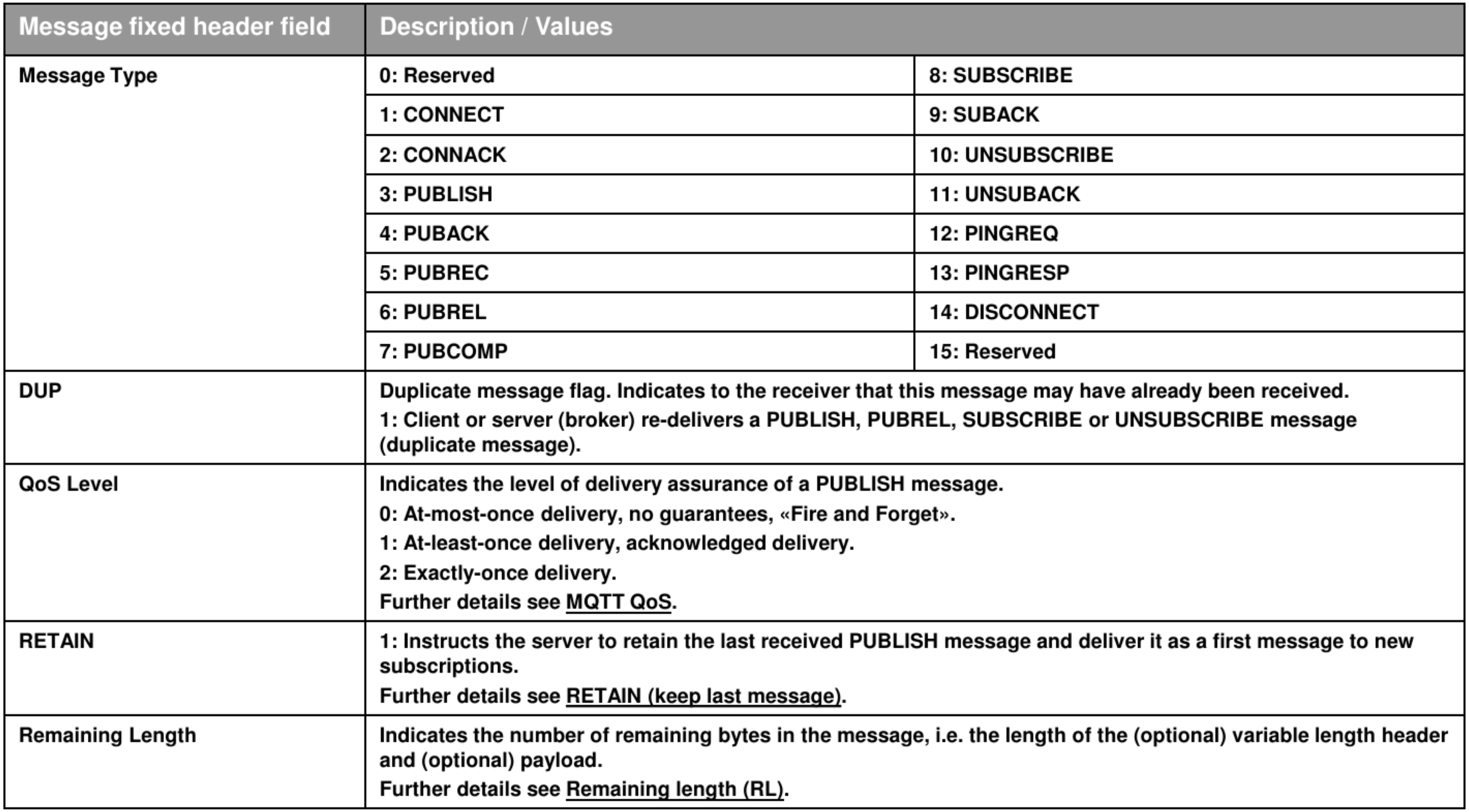
MQTT fixed header

Message Types



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

MQTT Fixed Header



Message fixed header field	Description / Values	
Message Type	0: Reserved	8: SUBSCRIBE
	1: CONNECT	9: SUBACK
	2: CONNACK	10: UNSUBSCRIBE
	3: PUBLISH	11: UNSUBACK
	4: PUBACK	12: PINGREQ
	5: PUBREC	13: PINGRESP
	6: PUBREL	14: DISCONNECT
	7: PUBCOMP	15: Reserved
DUP	Duplicate message flag. Indicates to the receiver that this message may have already been received. 1: Client or server (broker) re-delivers a PUBLISH, PUBREL, SUBSCRIBE or UNSUBSCRIBE message (duplicate message).	
QoS Level	Indicates the level of delivery assurance of a PUBLISH message. 0: At-most-once delivery, no guarantees, «Fire and Forget». 1: At-least-once delivery, acknowledged delivery. 2: Exactly-once delivery. Further details see MQTT QoS.	
RETAIN	1: Instructs the server to retain the last received PUBLISH message and deliver it as a first message to new subscriptions. Further details see RETAIN (keep last message).	
Remaining Length	Indicates the number of remaining bytes in the message, i.e. the length of the (optional) variable length header and (optional) payload. Further details see Remaining length (RL).	

Thank You

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Comparison CoAP & MQTT

Both used in IoT

- CoAP:
  - one-to-one communication
  - UDP/IP
  - unreliable
  - lightweight and easy to implement

- MQTT:
  - many-to-many communication
  - TCP/IP
  - focus on message delivery; reliable
  - higher overheads (protocol data, processing costs)