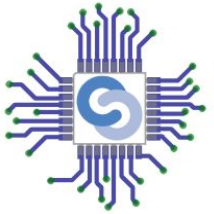


Embedded Systems Laboratory

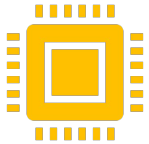
Internet of Things

Lecture 3 - Communication Protocols

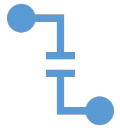
Internet of Things (IoT)

Internet-connected devices such as sensors, appliances, RFID devices, actuators, instruments etc.

Mainly works with IPv6 instead on IPv4



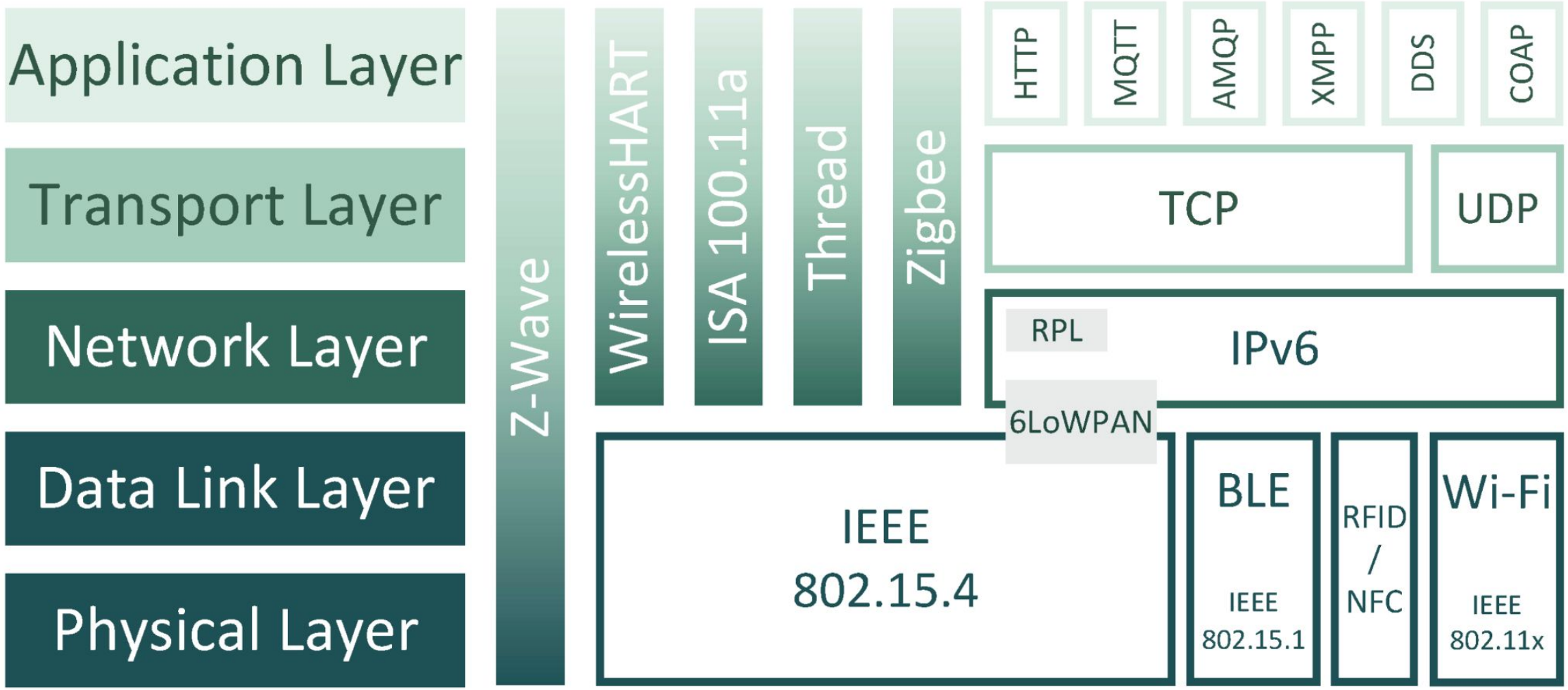
Powered mainly by sensors nodes (motes) which are low-cost, small-size and power-efficient



Every node has an address that can be accessed from (theoretically) anywhere

Real-time guarantee

IoT Network Stack



Source: https://www.mdpi.com/2079-9292/9/1/111/htm

Physical / Data Link Layer

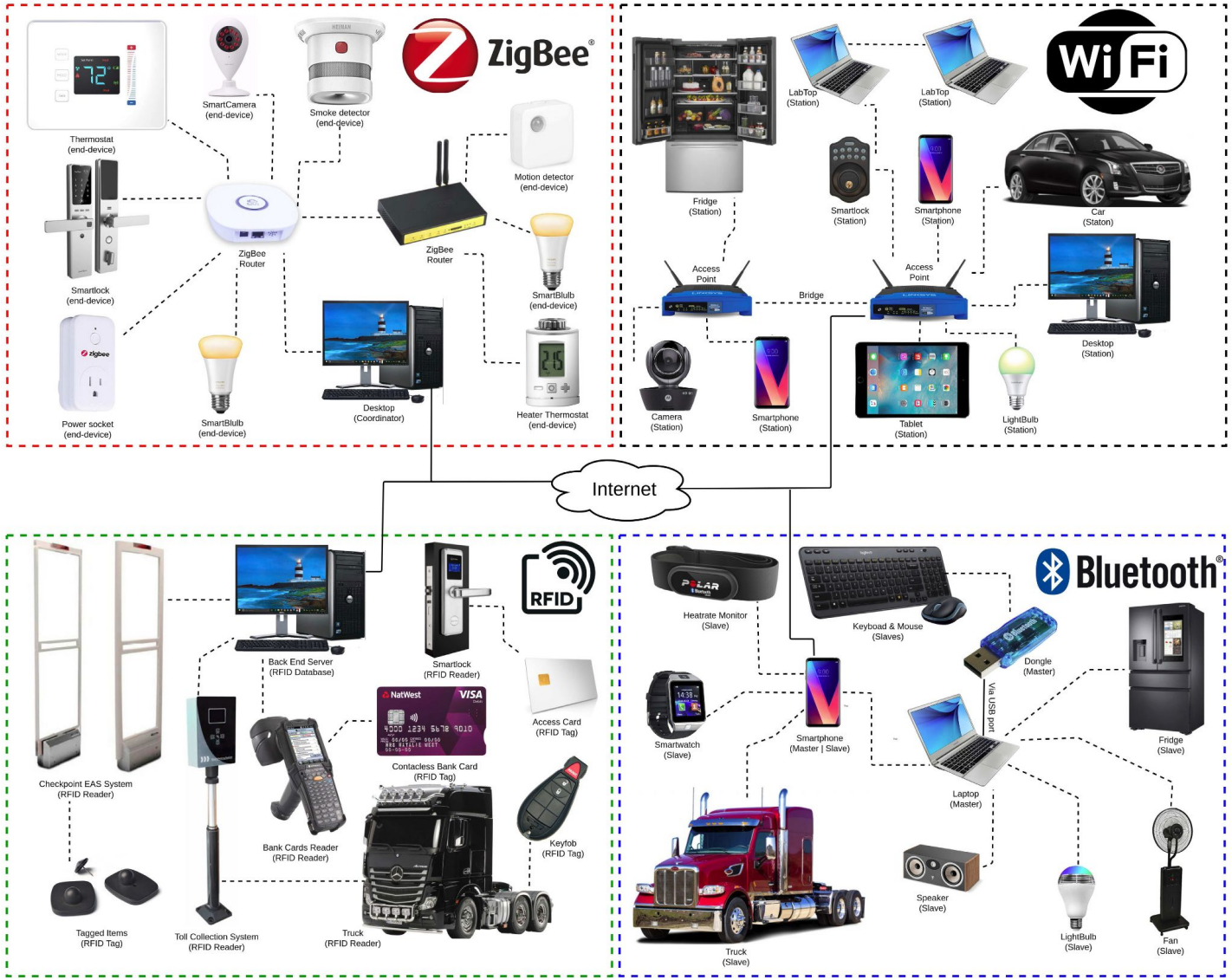
802.11 - Wi-Fi

BLE

802.15.4 – Low Data Rate WPAN

RFID

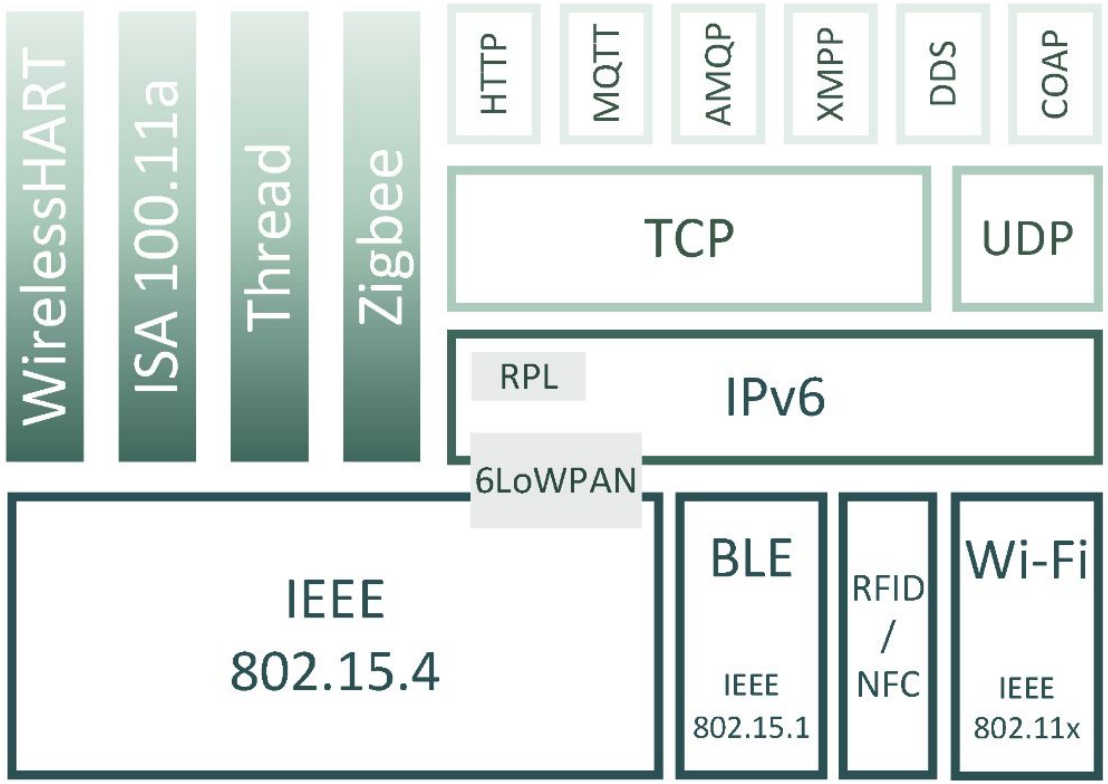
Physical / Data Link Layer



Source: K. Lounis, M. Zulkernine: Attacks and Defenses in Short-Range Wireless Technologies for IoT

IEEE 802.15.4

- Standard for low power IoT networks
- Physical & data link layers
- Base for ZigBee, Thread, WirelessHART
- 6LoWPAN relies on it
- Support for multiple topologies (star, mesh)
- 64-bit MAC addresses, 16-bit short addresses



IEEE 802.15.4

- Small packet size – 128 bytes including MAC, 103 bytes payload
- Data rates between 20kbps and 250kbps
- Range:
  - Usually between 10m and 30m
  - Some strong transceivers
    - Hundreds of meters / km
    - Line of sight
    - ZigBee Pro

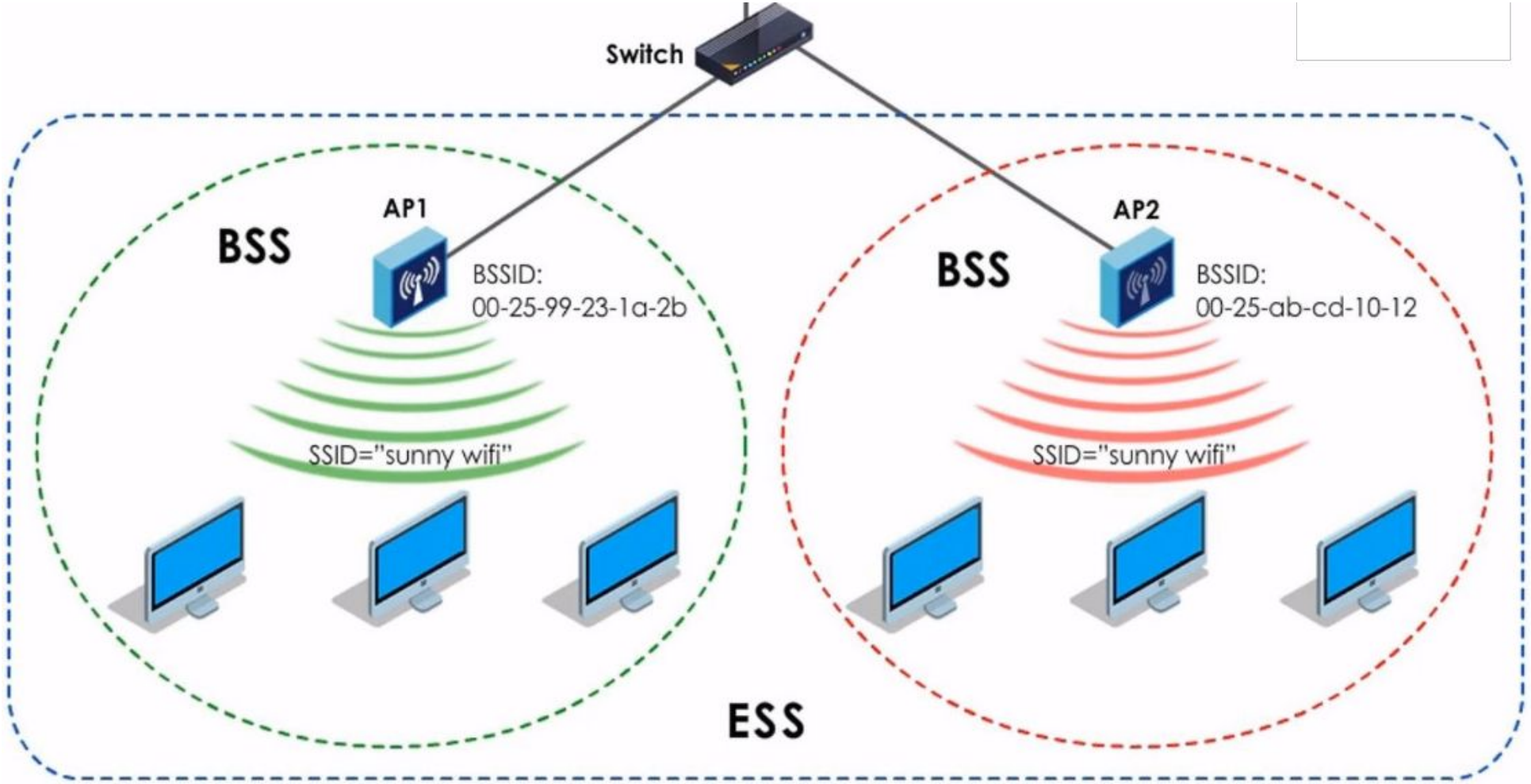
IEEE 802.11 Wi-Fi

- 2.4GHz and 5GHz unlicensed radio bands
- 802.11ax - data rate 9.6Gbps
- CSMA/CA
  - Avoid collisions
  - Binary exponential back-off algorithm
- Configurations: Infrastructure, Ad Hoc, Bridge, Repeater
- Bridge & Repeater extends range

IEEE 802.11 Wi-Fi

- Infrastructure:
  - AP is coordinator
  - Clients are associated & authenticated
  - BSSID = AP MAC address
  - SSID = network name
  - ESS, ESSID
- Ad Hoc
  - Flexible network infrastructure (mesh)
  - Any device can be station or coordinator
  - IBSS, SSID

IEEE 802.11 Wi-Fi - Infrastructure



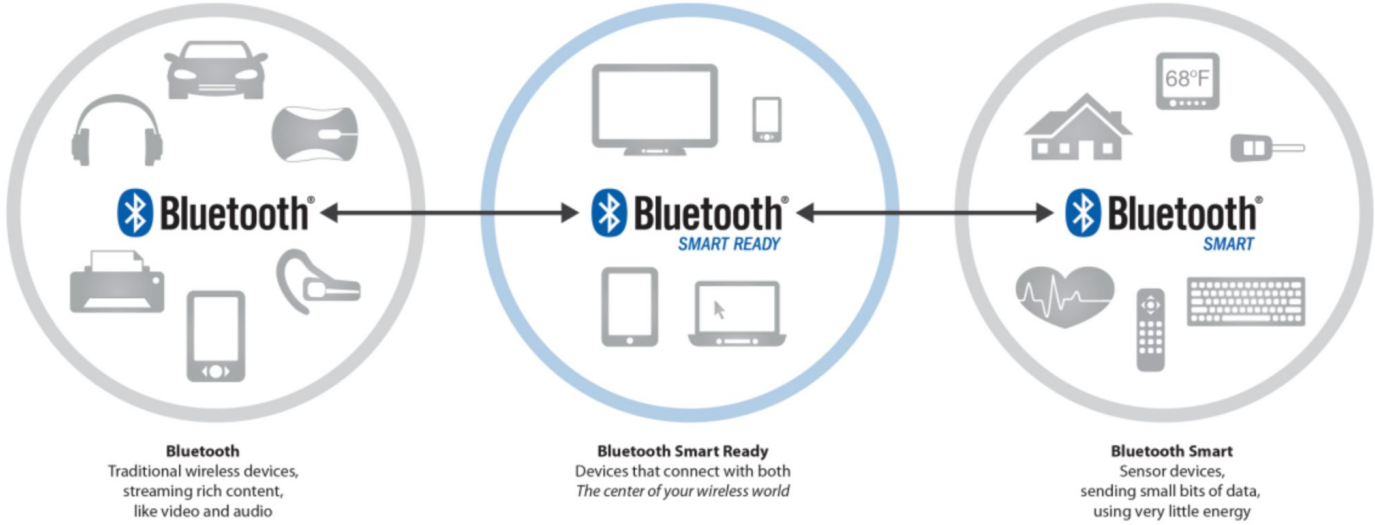
Source: https://layerlogix.com/wireless-lan-terms-explained/

Bluetooth

- Based on IEEE 802.15.1 standard
- Short range
- 2.4GHz unlicensed radio band
- FHSS to reduce interference
- Bluetooth 5.2 in 2019
- Pairing mechanism
  - Authentication
  - Master & slave
- Piconet
- 48-bit device address

BLE

- In 2010 - Bluetooth 4.0 => BLE
- Bluetooth Smart (BLE single mode)
  - Only the BT smart stack
  - Not compatible with classic BT
- Bluetooth Smart Ready (BLE dual mode)
  - Both classic and smart stacks
  - Compatible with classic BT



Source: https://embeddedcentric.com/introduction-to-bluetooth-low-energy-bluetooth-5/

Network Layer Protocols

IPv4	IPv6	6LoWPAN
Exhausted in 2011 32-bit address	128-bit addresses	Adaptation layer Header compression Fragmentation

Why IPv6?

- Pros
  - More suitable for high density
  - Stateless mandated
  - No NAT necessary
  - Location aware addressing
- Cons
  - Larger address width
  - Complying with IPv6 node requirements (IPSec is mandated)

IPv6 over IEEE 802.15.4

- IPv6
  - MTU is 1280 bytes
  - Reflects technology advancement
- 802.15.4
  - Maximum bandwidth 250 Kpbs
  - Frame size is 127 bytes
  - MAC addresses on 64 bits or 16 bits
  - Minimize header overhead, minimize memory consumption

IPv6 over IEEE 802.15.4

- Main challenges for using IPv6 over 802.15.4
  - IPv6 has minimum MTU 10 times larger
  - IPv6 has 40 bytes headers
  - Low power and lossy networks
- Solutions:
  - Fragmentation & header compression
  - Adaptive and responsive network layer

6LoWPAN - IETF RFC 6282

- 6LoWPAN Working Group from IETF => RFC 6282
- Encapsulation of IPv6 packet into 802.15.4 frame
- Header compression
  - The elimination of header fields that can be derived from other headers
  - Stateless and context-based compression
- Fragmentation
- Stateless auto-configuration

RPL

- Routing Protocol for Low power and lossy networks
- defined by IETF in RFC 6550
- IETF ROLL working group
- IP smart object networks / Low-power and lossy networks
- Distance-vector & source routing protocol
- “route-over” protocol
- Communication:
  - multipoint-to-point
  - point-to-multipoint
  - point-to-point

Transport Layer Protocols

TCP

- Error Control, Flow Control and Congestion Control
- Every packet needs an acknowledgement
- Reliable Protocol

UDP

- No Acknowledgement is needed
- Stateless Protocol
- Simple to implement
- Usually Multimedia Data is sent over UDP
- IoT-friendly

Application Layer Protocol

HTTP

HTTP Methods and Their Meaning

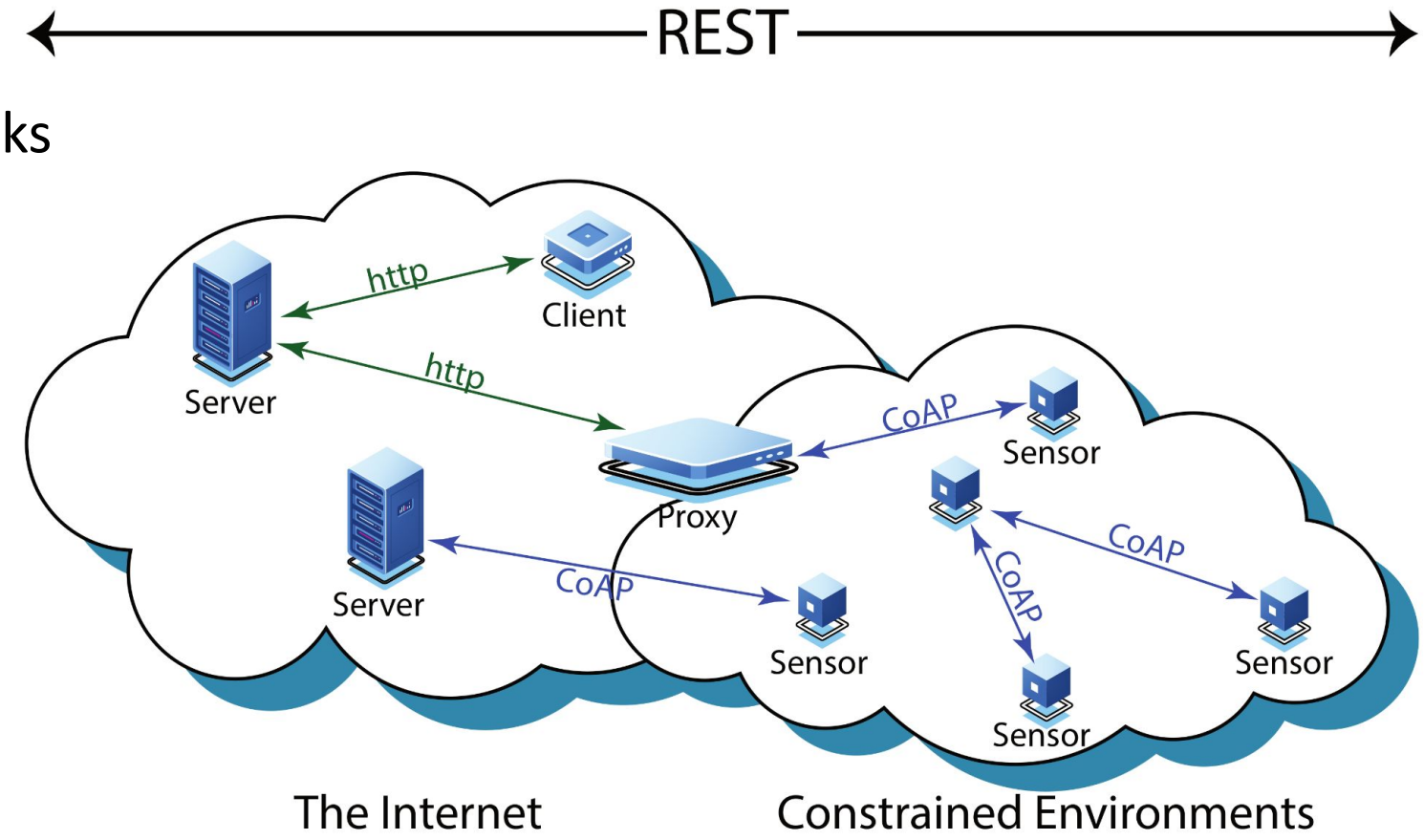
Method	Meaning
GET	Read data
POST	Insert data
PUT or PATCH	Update data, or insert if a new id
DELETE	Delete data

lynda.com

- GET, PUT, POST, DELETE, HEAD, TRACE, OPTIONS commands
- Stateless – each request is different than others
- HTTP client can be a browser or application
- MIME

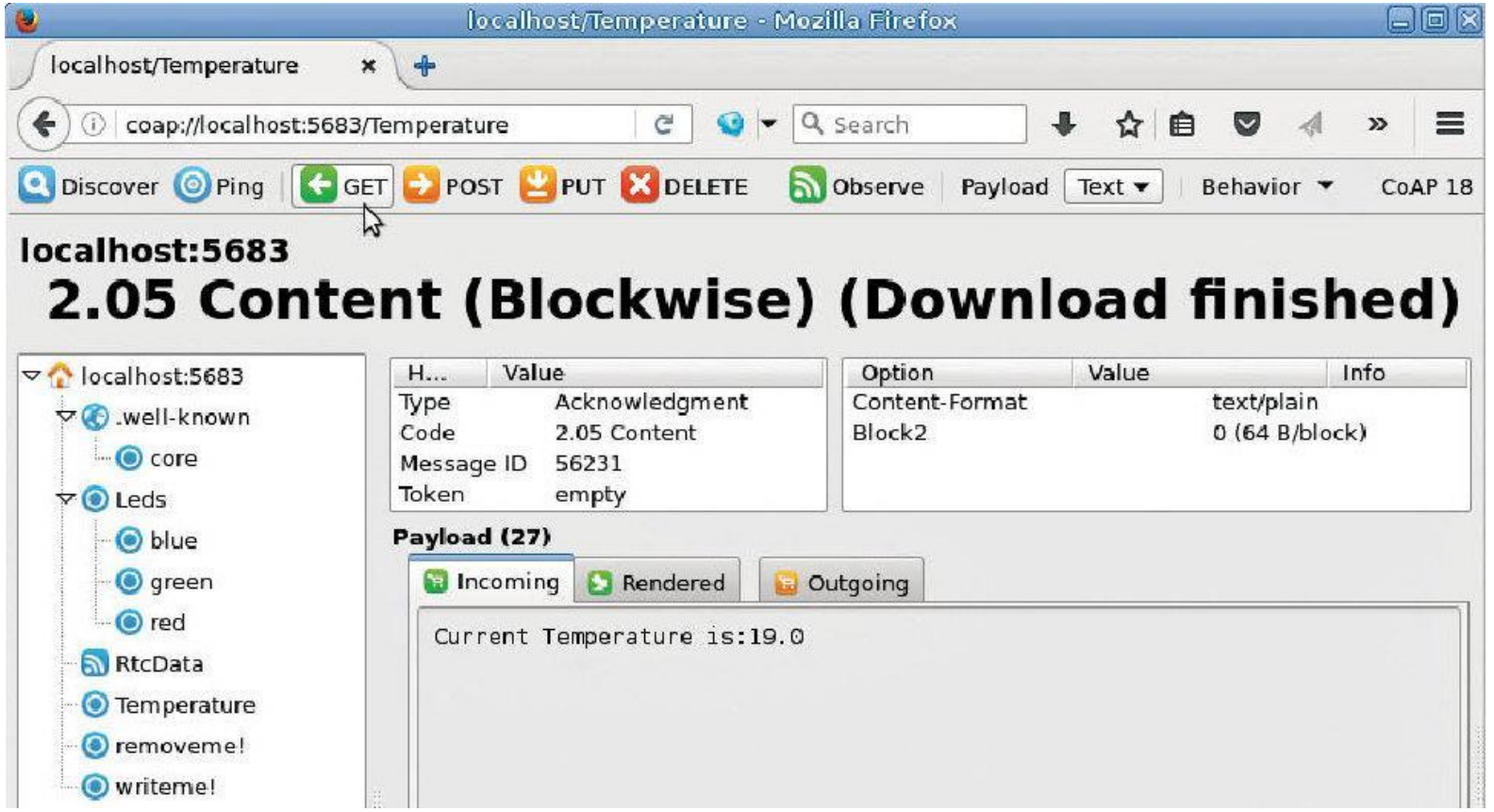
CoAP - Constrained Application Protocol

- For low power and lossy networks
- Machine-to-Machine (M2M)
- Request-response model
- CoAP <-> HTTP
- Multicast, low overhead
- Runs over UDP instead of TCP
- GET, PUT, POST, DELETE
- Resource discovery



Source: Tariq, M.A.; Khan, M.; Raza Khan, M.T.; Kim, D. Enhancements and Challenges in CoAP—A Survey. *Sensors* **2020**, *20*, 6391.

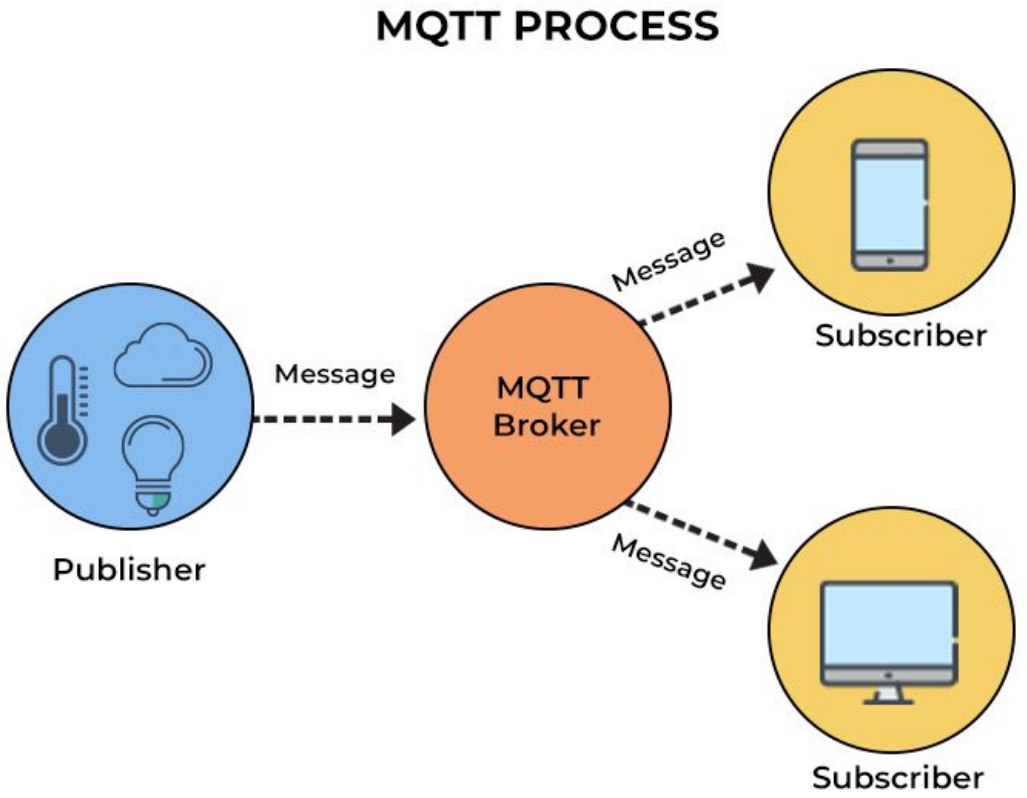
CoAP - Constrained Application Protocol



Source: https://www.opensourceforu.com/2016/09/coap-get-started-with-iot-protocols/

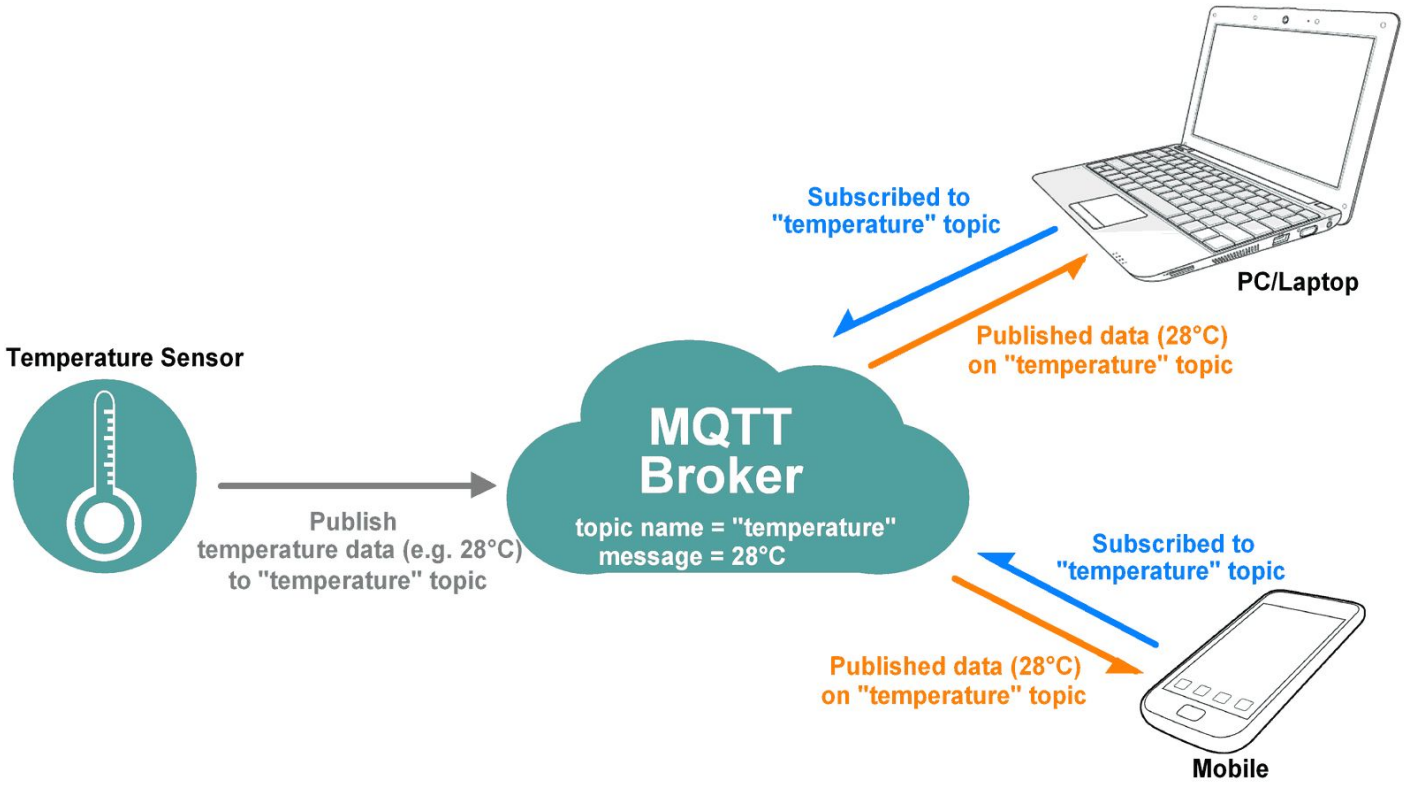
MQTT - Message Queue Telemetry Transport

- Based on a publisher-subscriber model
- Uses MQTT broker as a server
- Nodes publish data to the broker
- Other devices subscribe to the broker to receive the data
- Resource constrained devices



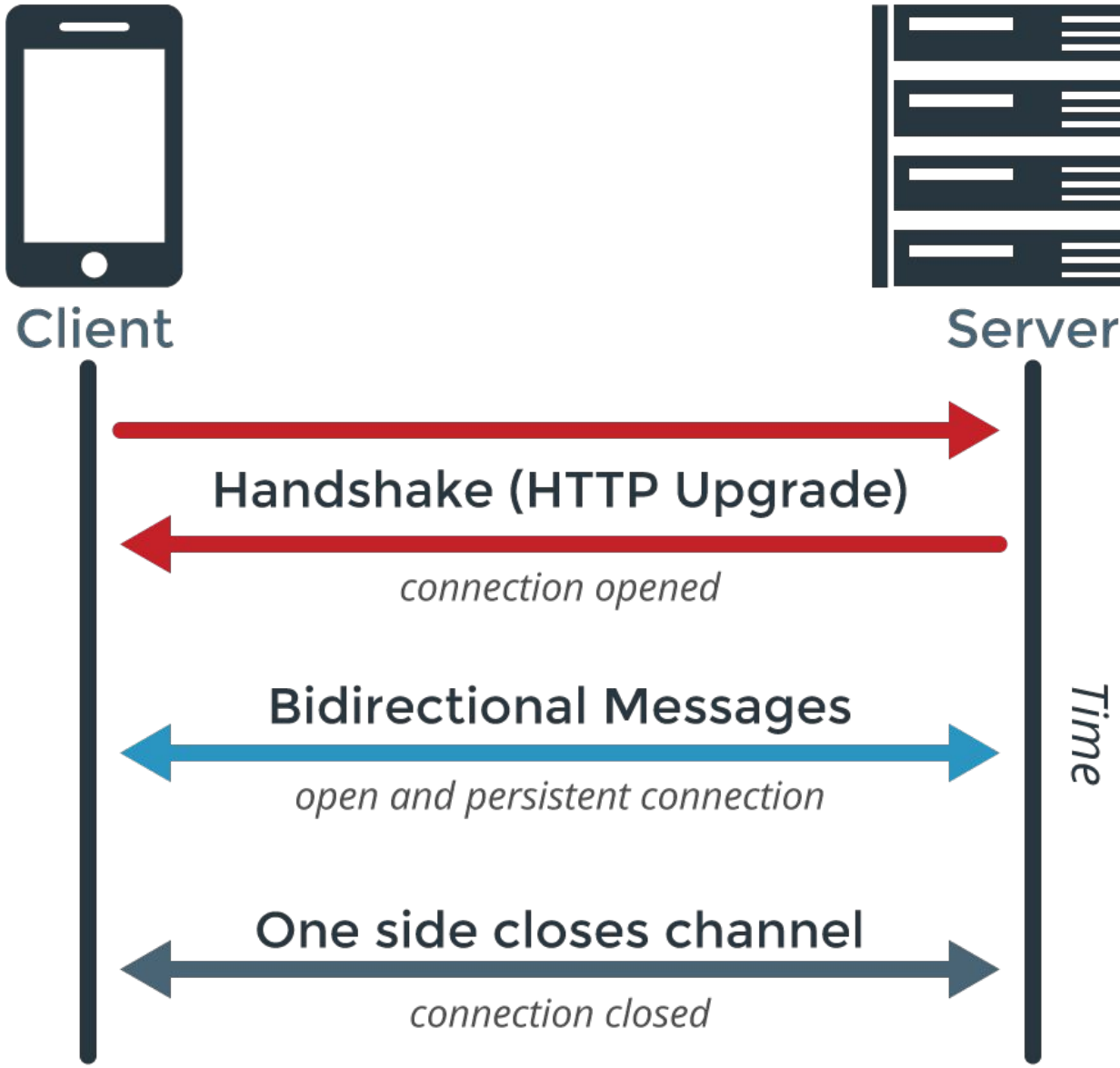
MQTT - Message Queue Telemetry Transport

- Communication models:
  - One-to-many
  - Many-to-one
  - Many-to-many



Source: https://www.electronicwings.com/nodemcu/nodemcu-mqtt-client-with-arduino-ide

Web Sockets

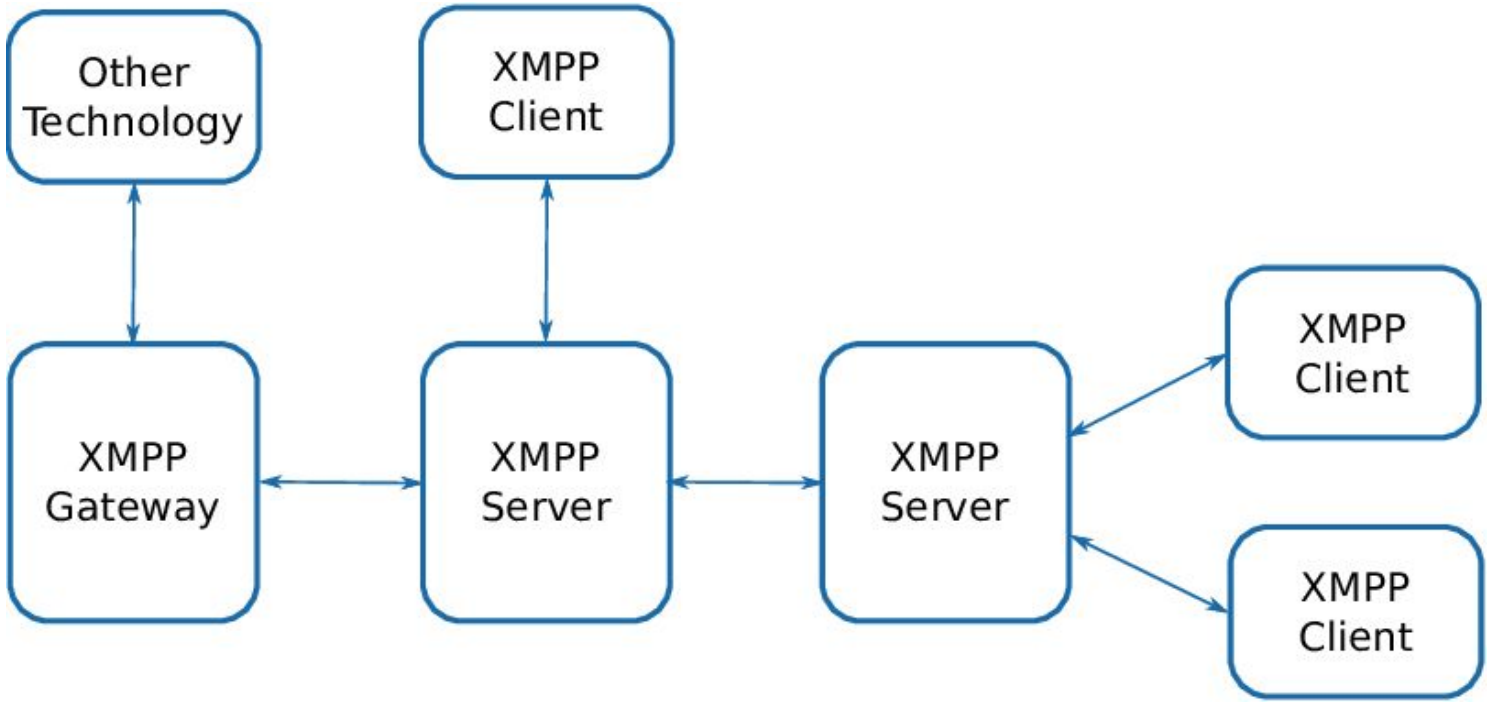


- Full duplex communication over single socket for sending messages between client and server
- Handshake
- TCP-based
- Client can be a browser, IoT device, mobile application etc.

Source: https://www.pubnub.com/learn/glossary/what-is-websocket/

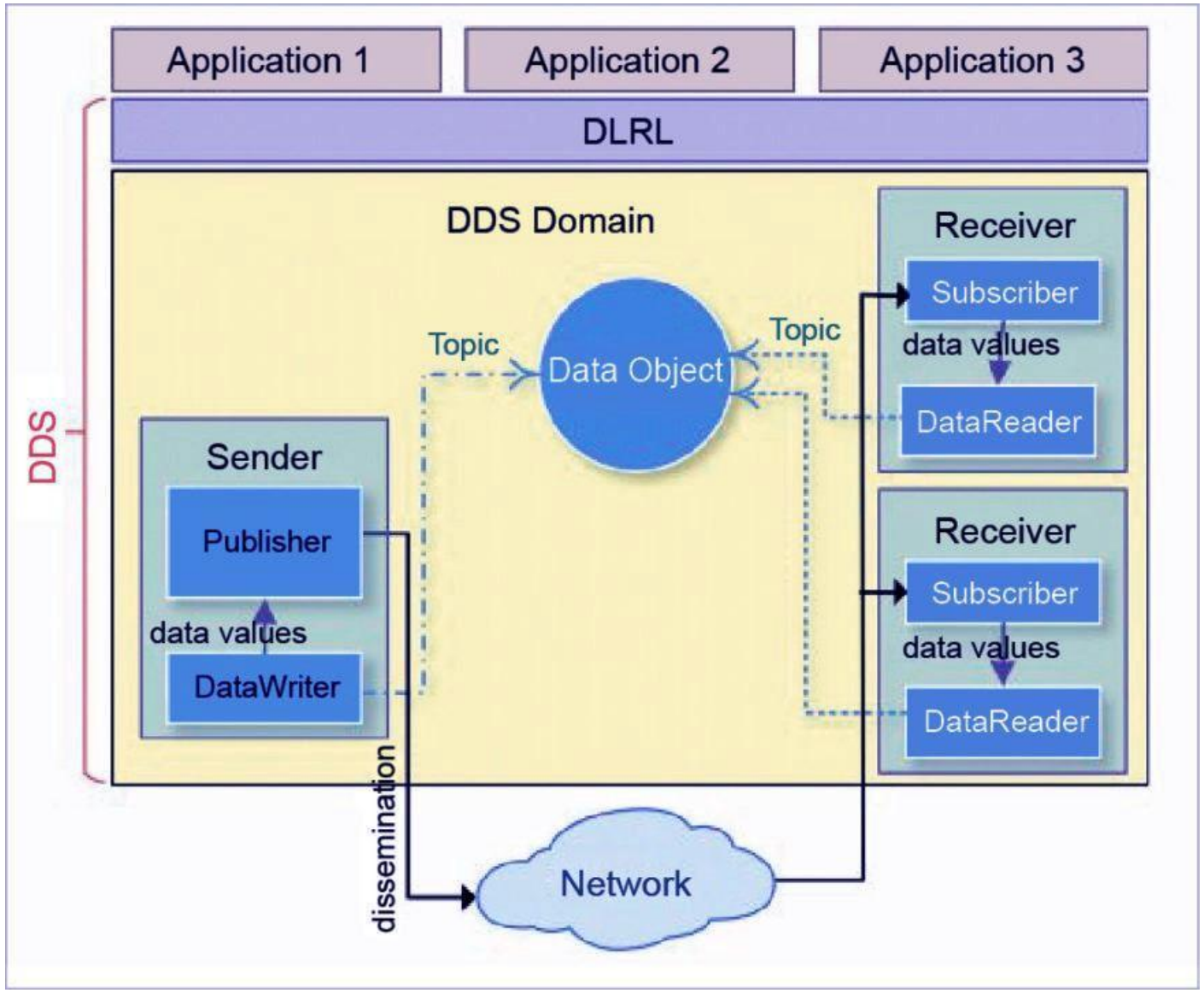
XMPP – eXtensible Messaging and Presence Protocol

- Real-time communication and streaming of XML data between network elements
- Suitable for audio, video, messaging, gaming
- Based on client-server as well as server-server architecture



Source: Alvear, Oscar & Calafate, Carlos & Cano, Juan-Carlos & Manzoni, Pietro. (2018). Crowdsensing in Smart Cities: Overview, Platforms, and Environment Sensing Issues. Sensors. 18. 460. 10.3390/s18020460.

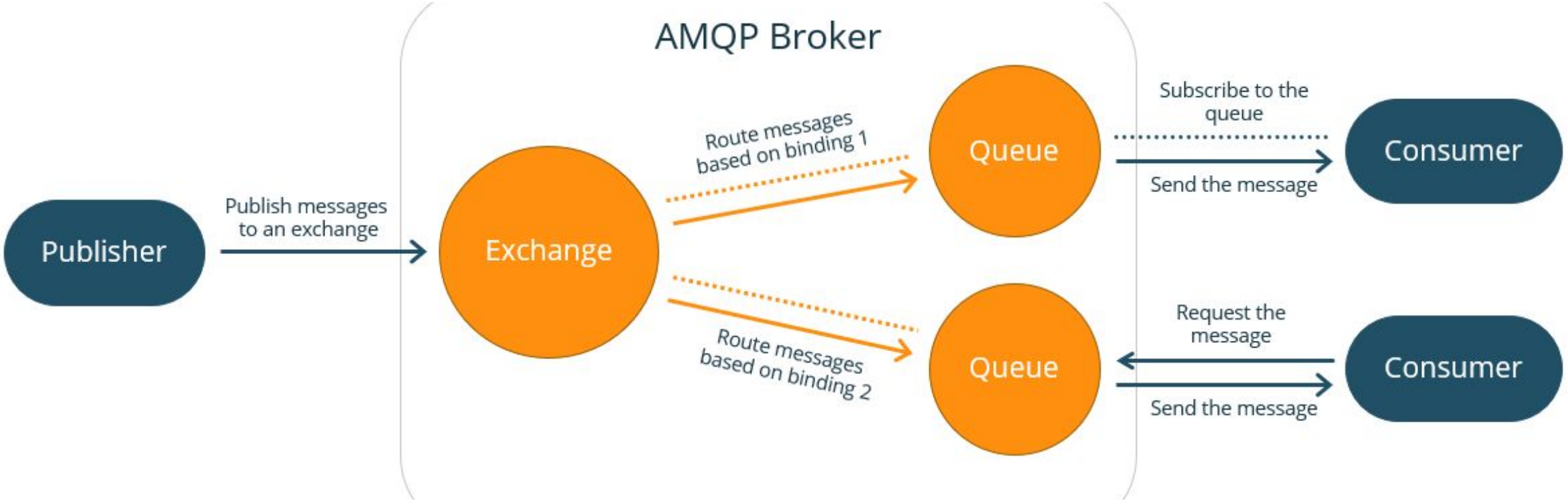
DDS – Data Distribution Service



- Middleware for M2M
- Publisher-subscriber model
- Multiple publishers
- Multiple subscribers
- QoS and configurable reliability

Source:
https://medium.com/@rinu.gour123/4-major-iot-protocols-mqtt-coap-amqp-dds-46016897c3e9

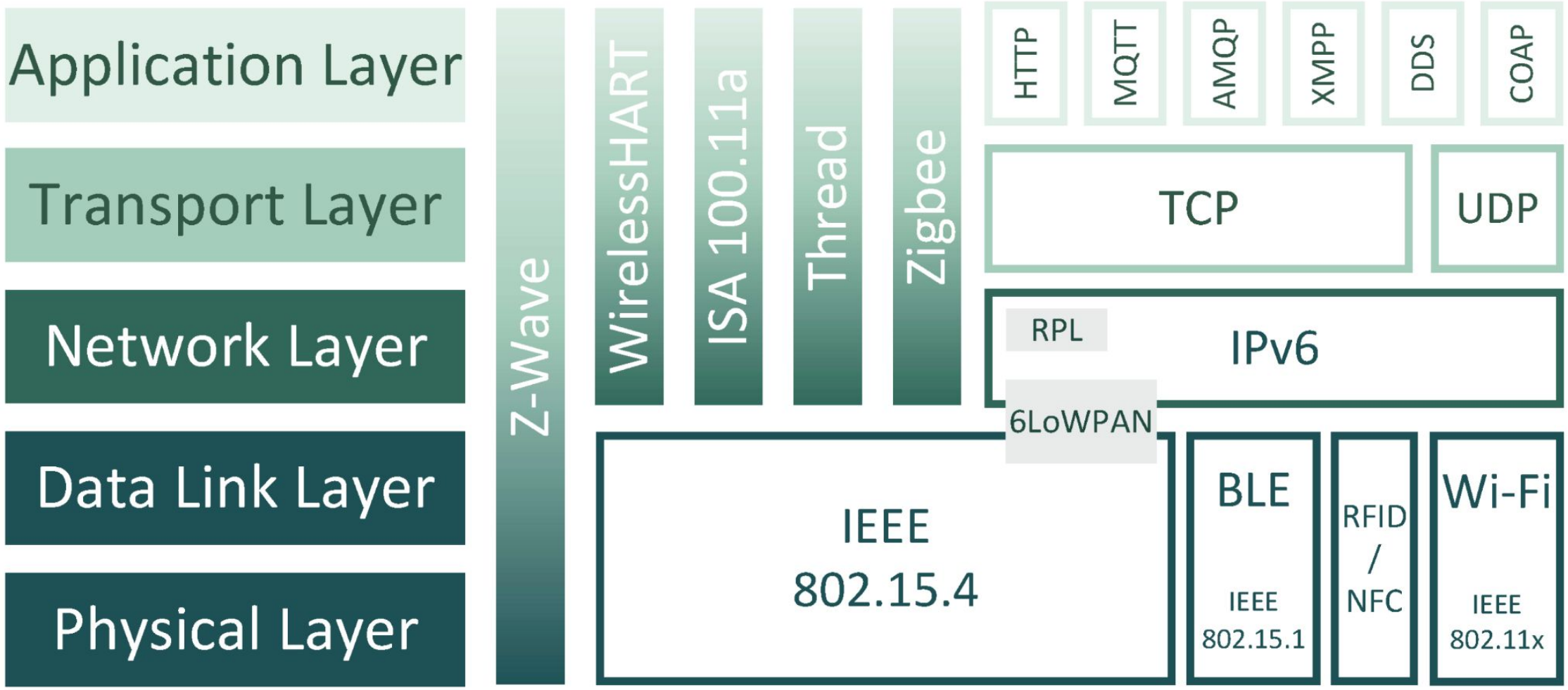
AMQP – Advanced Message Queuing Protocol



Source: https://support.smartbear.com/readyapi/docs/testing/amqp.html

- Point-to-point, pub-sub and routing/queuing
- AMQP brokers
- Messages pushed by brokers or pulled by consumers

The End


Application Layer
Transport Layer
Network Layer
Data Link Layer
Physical Layer
Z-Wave
WirelessHART
ISA 100.11a
Thread
Zigbee
HTTP
MQTT
AMQP
XMPP
DDS
COAP
TCP
UDP
RPL
IPv6
6LoWPAN
IEEE
802.15.4
BLE
IEEE
802.15.1
RFID
/
NFC
Wi-Fi
IEEE
802.11x