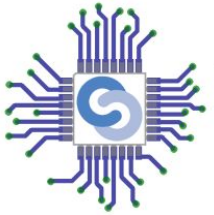


Embedded Systems Laboratory

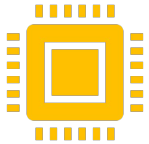
Internet of Things

Lecture 3 - Communication Protocols

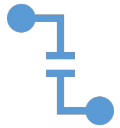
Internet of Things (IoT)

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

Mainly works with IPv6 instead on IPv4



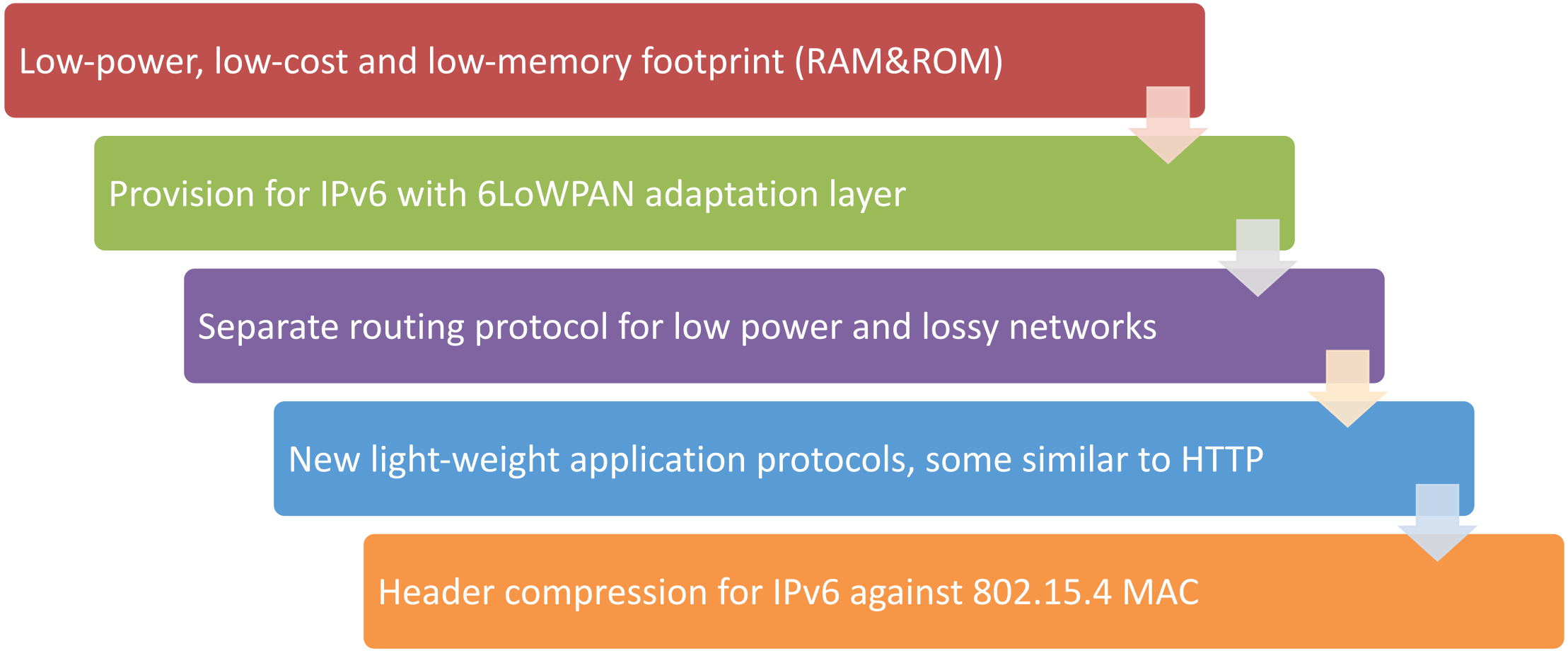
Powered mainly by sensors nodes (motes) which are low-cost, small-size and power-efficient



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

Real-time guarantee

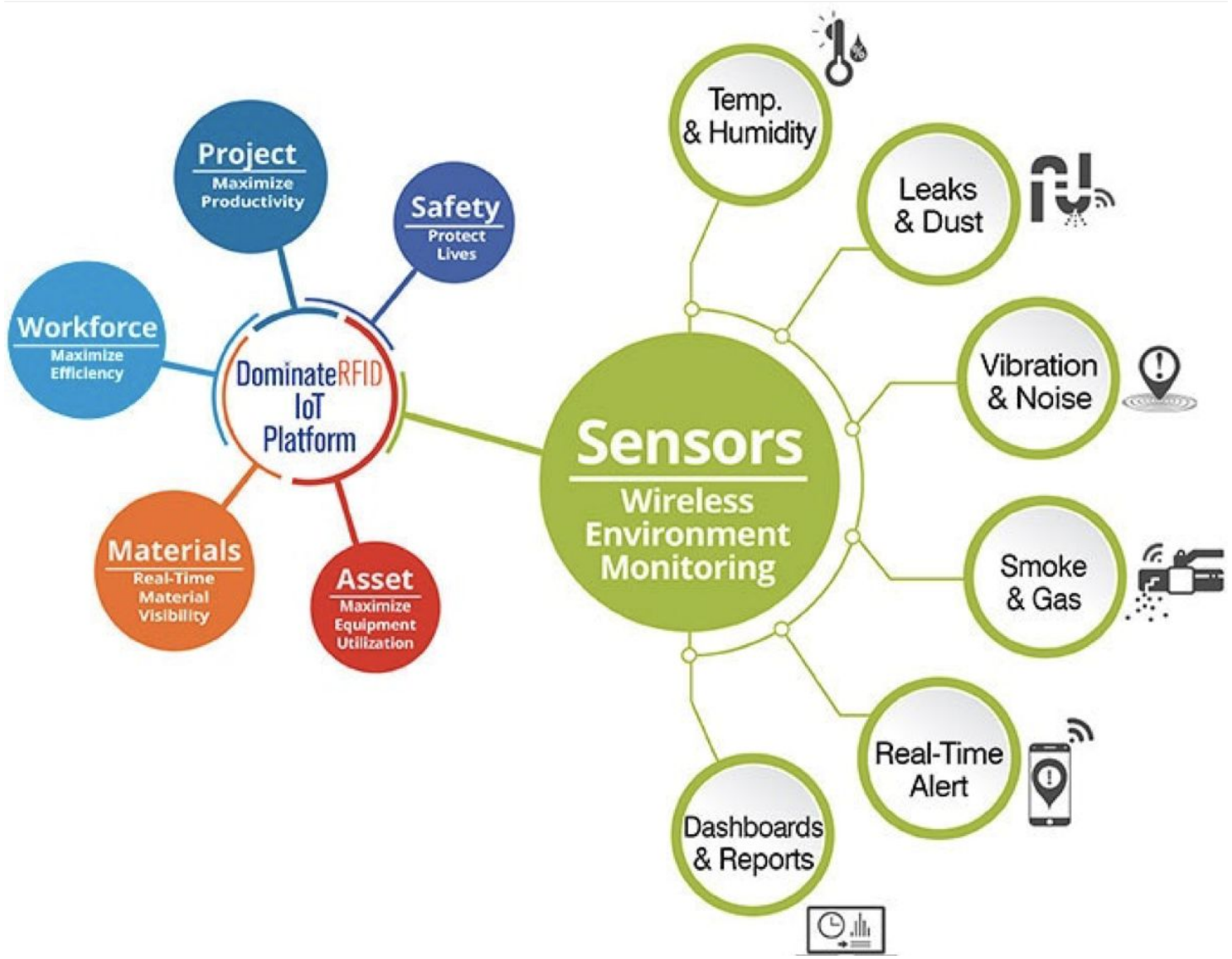
IoT Demands


Low-power, low-cost and low-memory footprint (RAM&ROM)
Provision for IPv6 with 6LoWPAN adaptation layer
Separate routing protocol for low power and lossy networks
New light-weight application protocols, some similar to HTTP
Header compression for IPv6 against 802.15.4 MAC

Smart City

Image source: https://internetofbusiness.com/global-smart-city-platform-market/

Environment Monitoring



Energy Distribution

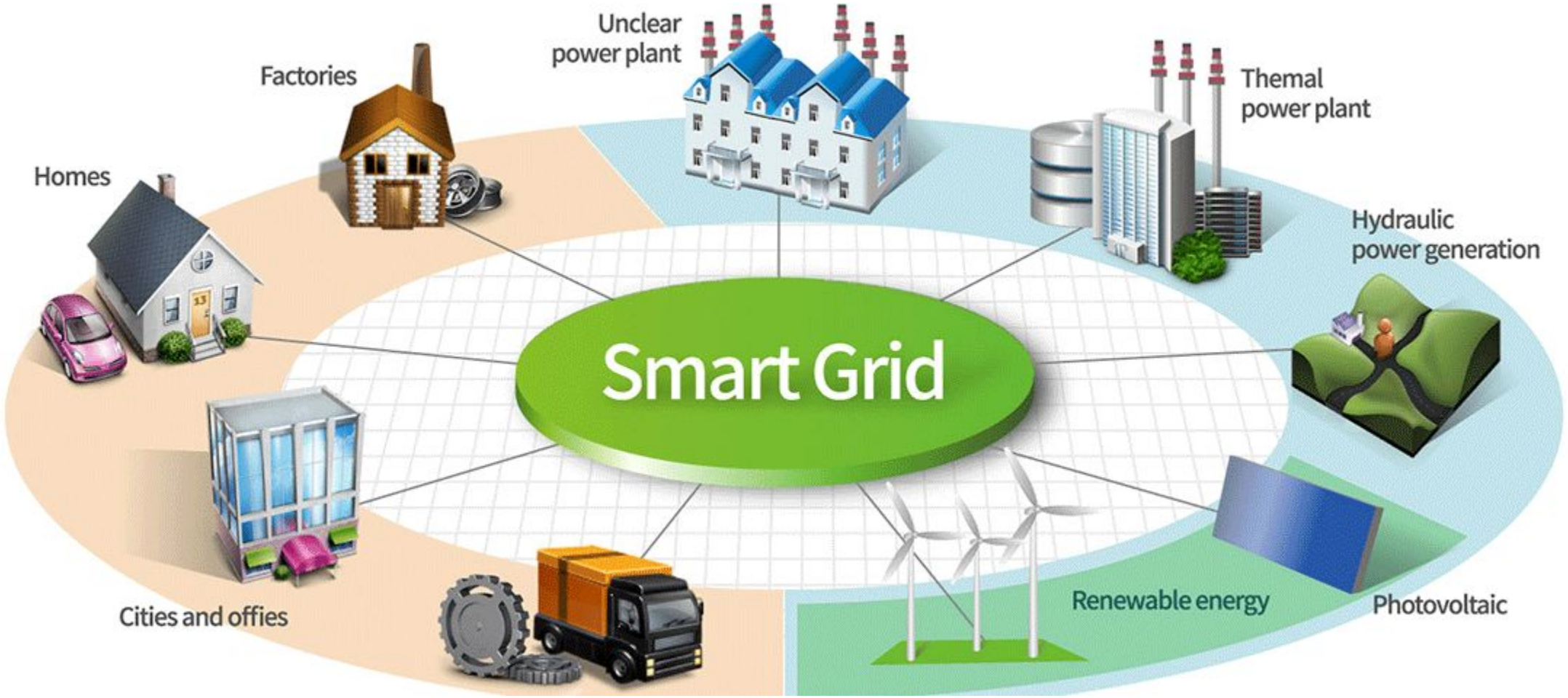


Image source: https://internetofbusiness.com/global-smart-city-platform-market/

Real-time Supply Chain

Image source: https://www.onthemosway.eu/how-the-internet-of-things-re-write-the-supply-chains-rules/

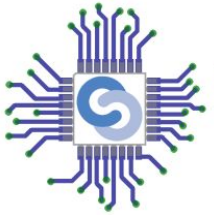
Industrial IoT

Image source: https://www.tibco.com/reference-center/what-is-iiot

Networking

- Networking is key component (Different layers)
- Addressing schemes (IPv4 vs. IPv6)
- Data transmission (ZigBee, WiFi, 5G, LTE etc.)
- Transfer speed (kbps, Mbps, Gbps)
- Medium control (MAC layer and Data Link Layer)
- Cross-geography (CoAP, MQTT etc.)

OSI Layers vs. IoT Layers



HTTP, SSH etc.	CoAP, MQTT etc.
TCP, UDP, ICMP	UDP, ICMPv6
BGP, SPF, OLSR	IPv6, RPL
IPv4, IPv6	6LoWPAN
802.3, 802.11 MAC	802.15.4 MAC
802.3, 802.11 PHY	802.15.4 PHY

Characteristics

Small packet size

Low bandwidth (10s-100s kbps)

Star and mesh topology

Low power, battery operated

Low cost

Ad-hoc network, device has limited accessibility

Unreliable wireless medium

Issues

- Adaptation layer (6LoWPAN)
- No method exists to run IP over 802.15.4 networks
  - IPv6 MTU is 1280 bytes
- Not all ad-hoc protocols may be immediately suitable for 6LoWPAN
- Security for multi-hop networks needs to be considered

IEEE 802.15.4

- Small packet size – 128 bytes including MAC, 103 bytes payload
- Uses 64-bit MAC addresses, has provision for 16-bit short addresses
- Support for multiple topologies
- Data rates between 20kbps and 250kbps
- Range between 10m and 30m

Why IPv6?

- Pros
  - More suitable for high density
  - Stateless mandated
  - No NAT necessary
  - Possibility of adding innovative techniques such as location aware addressing
- Cons
  - Larger address width
  - Complying with IPv6 node requirements (IPSec is mandated)

Considerations

- Cost of deployment
- Time to market
- Complexity in deploying
- Hazards due to human error
- Scalability

IoT Communication Protocols

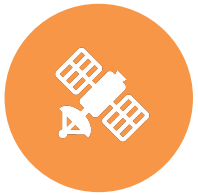
Link-layer Protocols

802.3 – Ethernet

802.11 – WiFi

802.16 – WiMax

802.15.4 – Low Data Rate WPAN



2G/3G/4G/5G – Mobile Communication

Network Layer Protocols

IPv4	IPv6	6LoWPAN
Exhausted in 2011 32-bit address	128-bit addresses	Limited processing capability Shows compression mechanism with IPv6 over 802.15.4

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

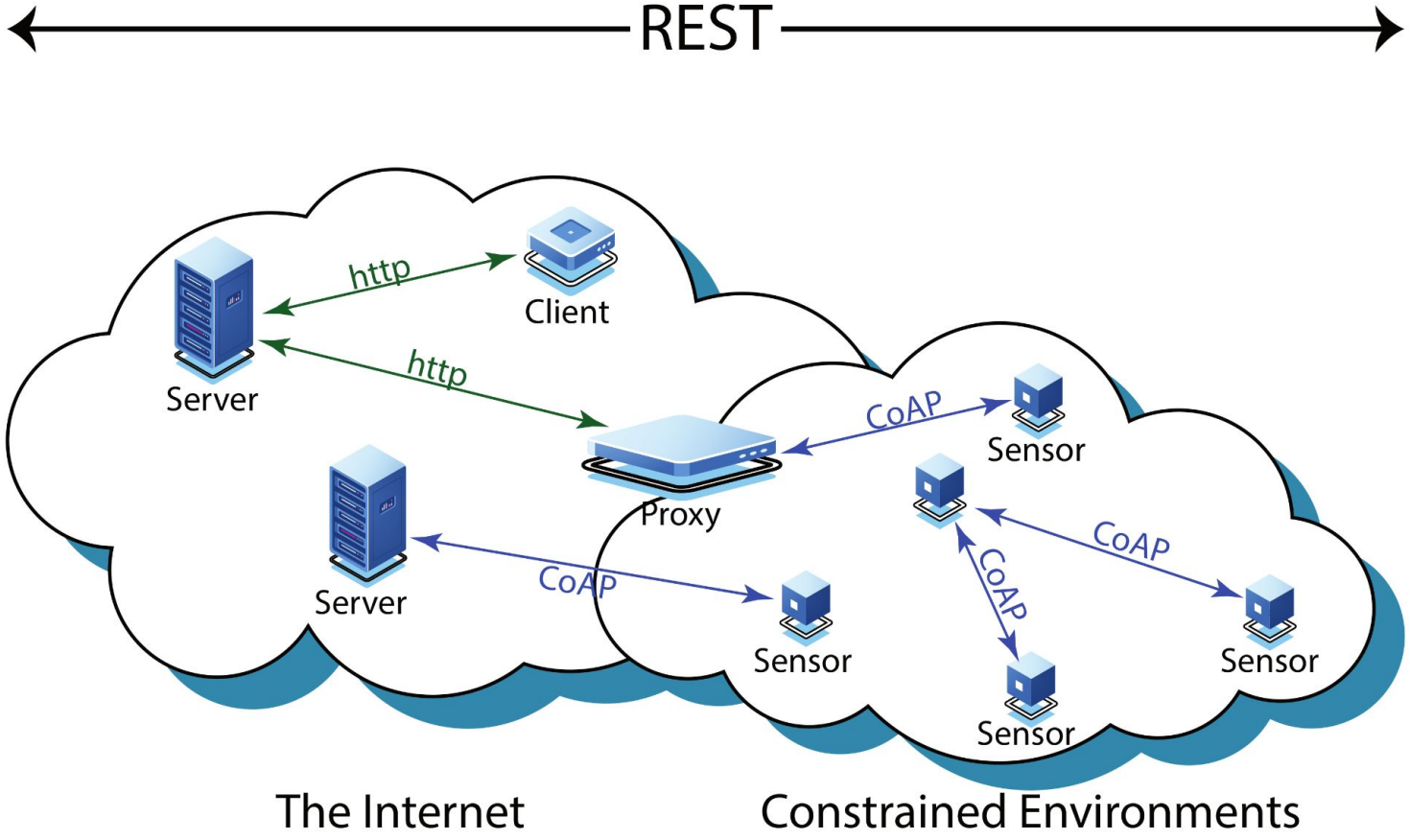
HTTP Methods and Their Meaning

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, etc. commands
- Stateless – each request is different than others
- HTTP client can be a browser or application
- Multiple headers (Multi-purpose Internet Mail Extensions - MIME)

CoAP - Constrained Application Protocol



- Machine-to-Machine (M2M)
- Request-response model
- Runs on UDP instead of TCP
- GET, PUT, POST, DELETE, etc.

Image 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

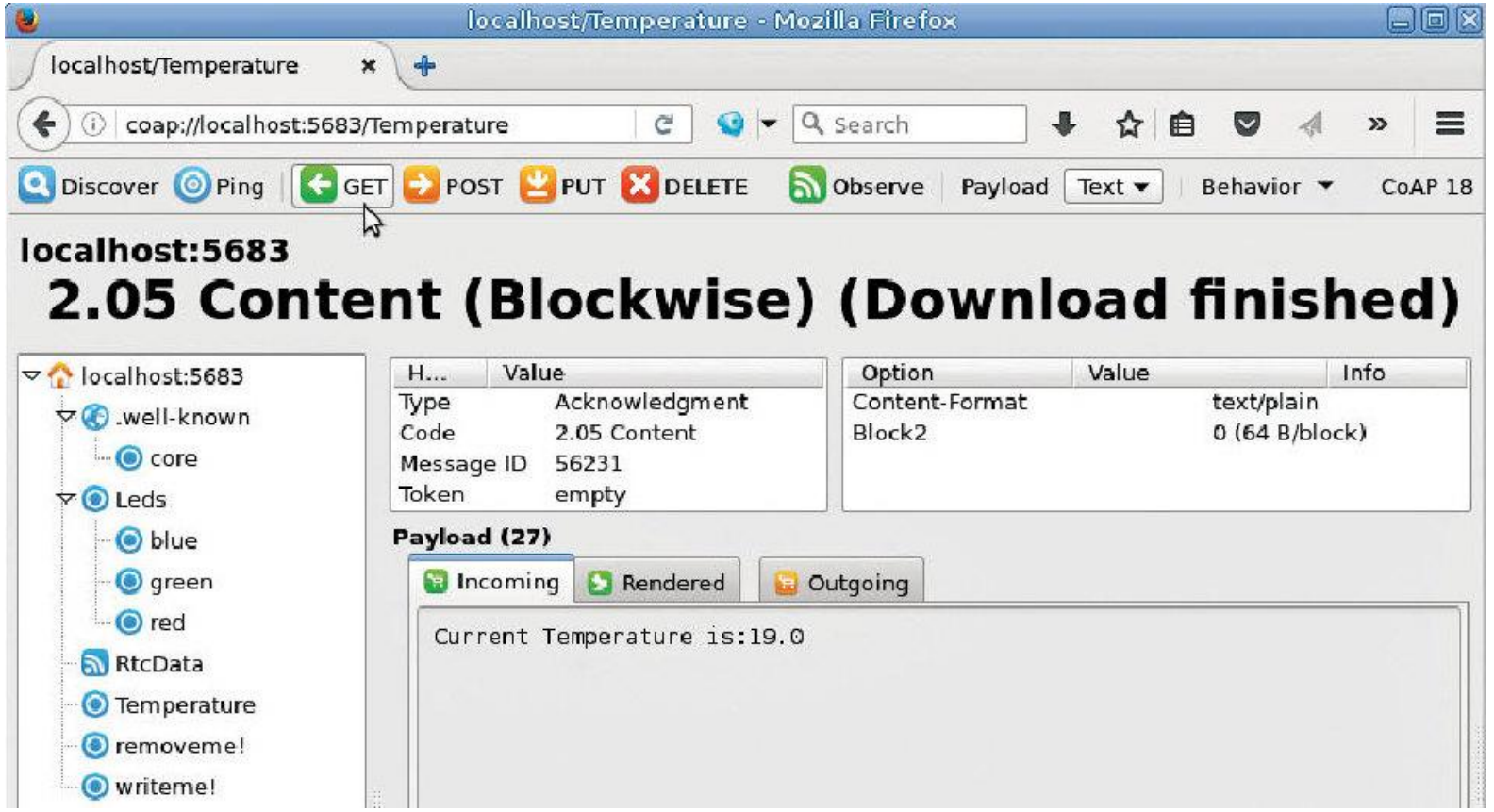


Image source: https://www.opensourceforu.com/2016/09/coap-get-started-with-iot-protocols/

MQTT - Message Queue Telemetry Transport

- Based on a pub-sub model
- Uses MQTT broker as a server
- Useful for applications where memory and resources are heavily constrained
- Used in Automotive (IoV)

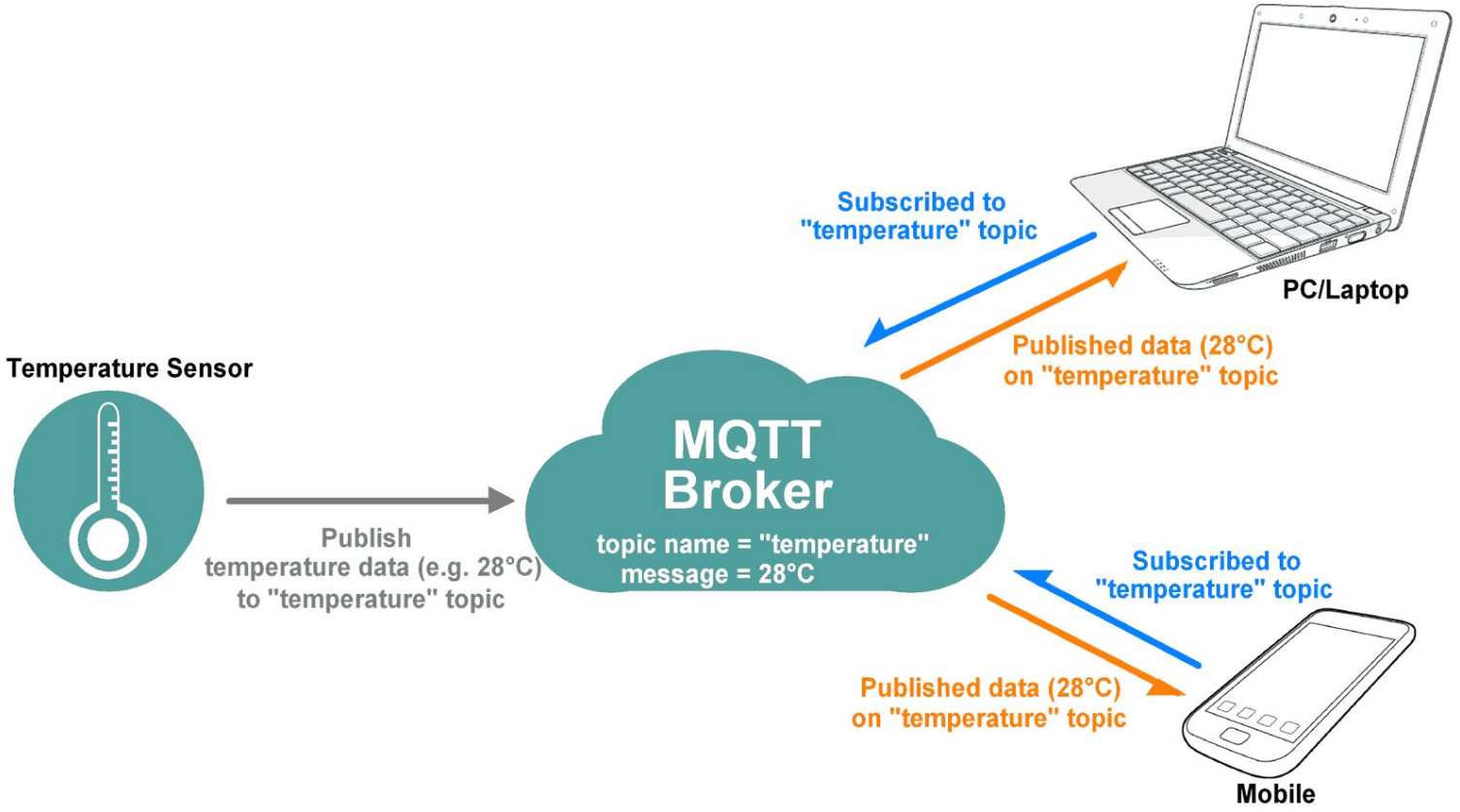
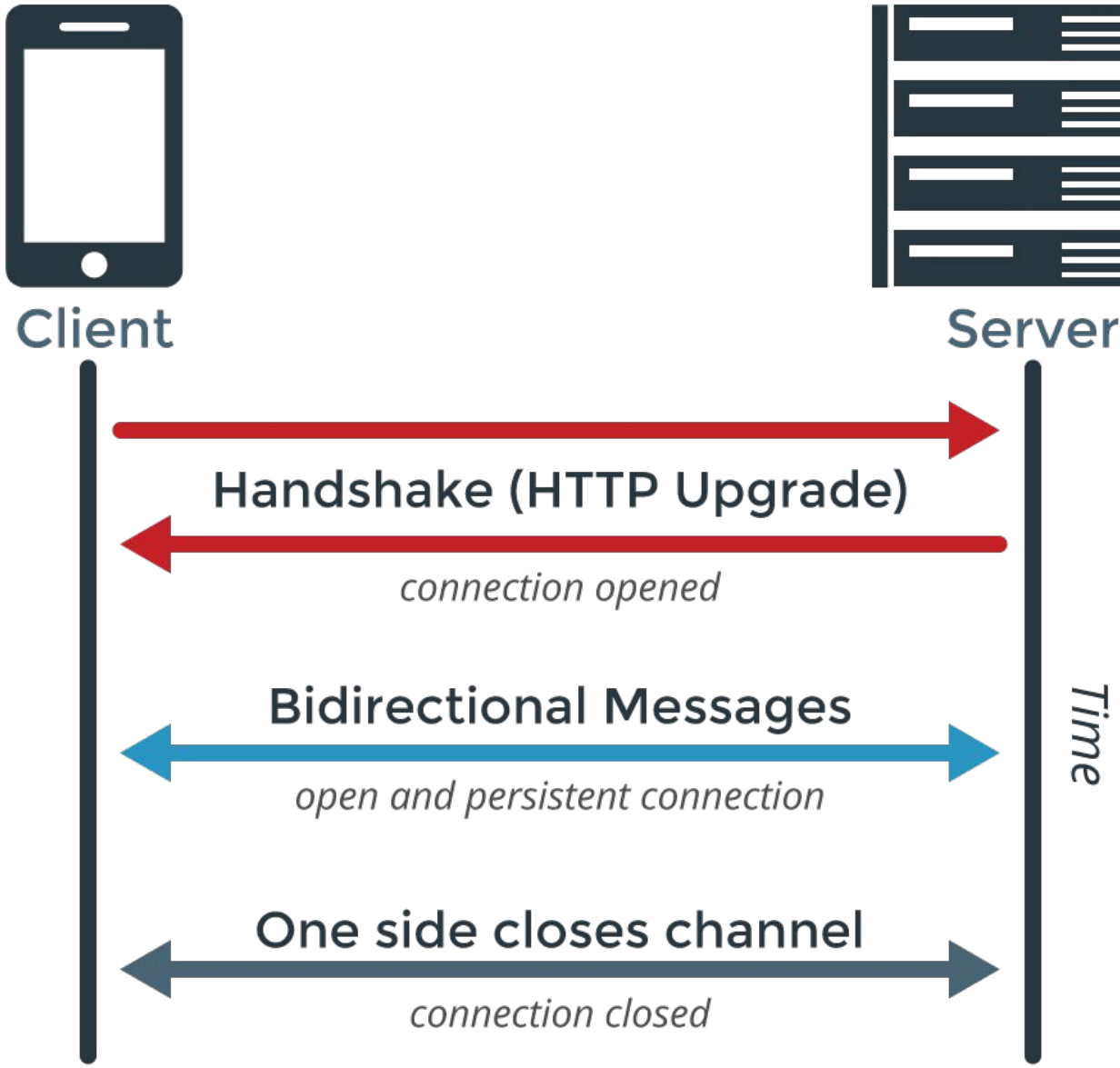


Image source: https://www.electronicwings.com/nodemcu/nodemcu-mqtt-client-with-arduino-ide

Web Sockets



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

Image 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 Voice/Video chats, messaging, data syndication, gaming, multi party chat
- Based on client-server as well as server-server architecture

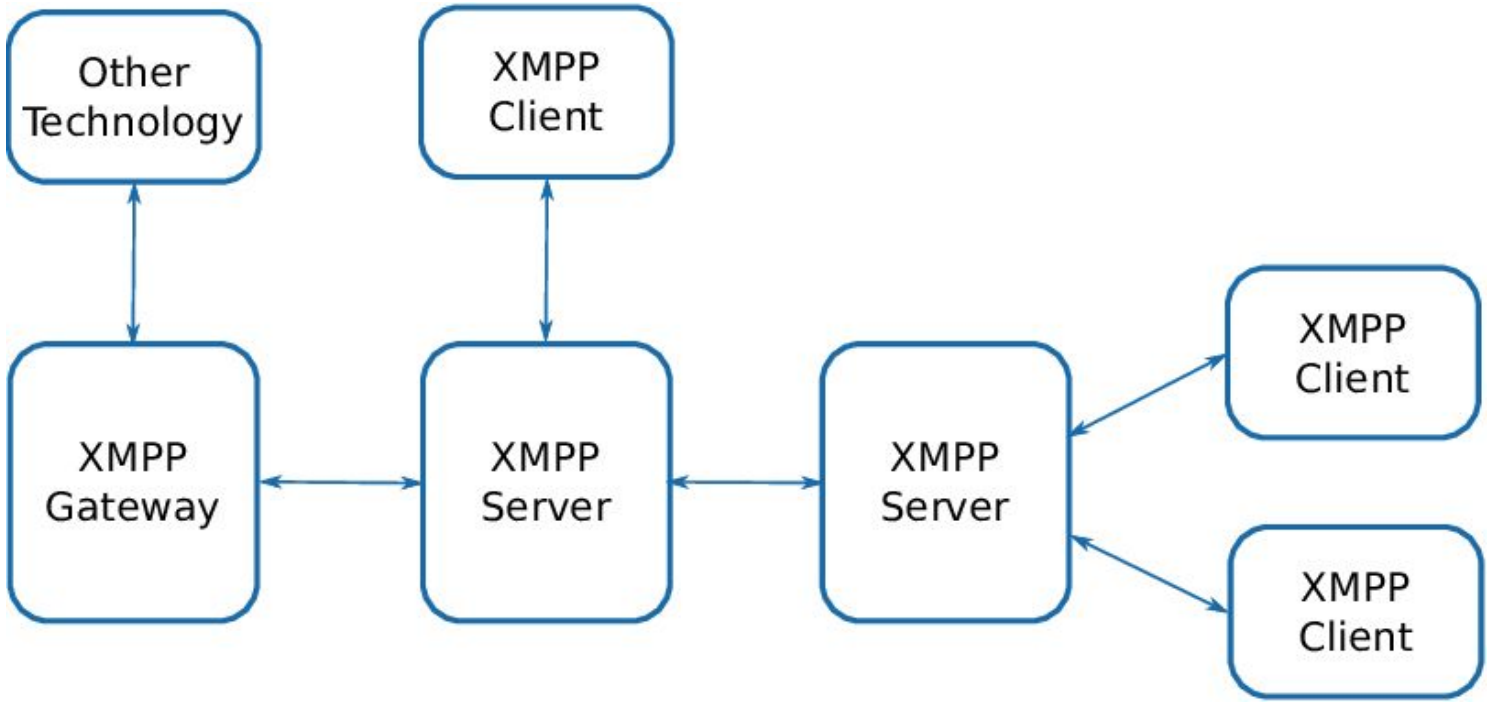
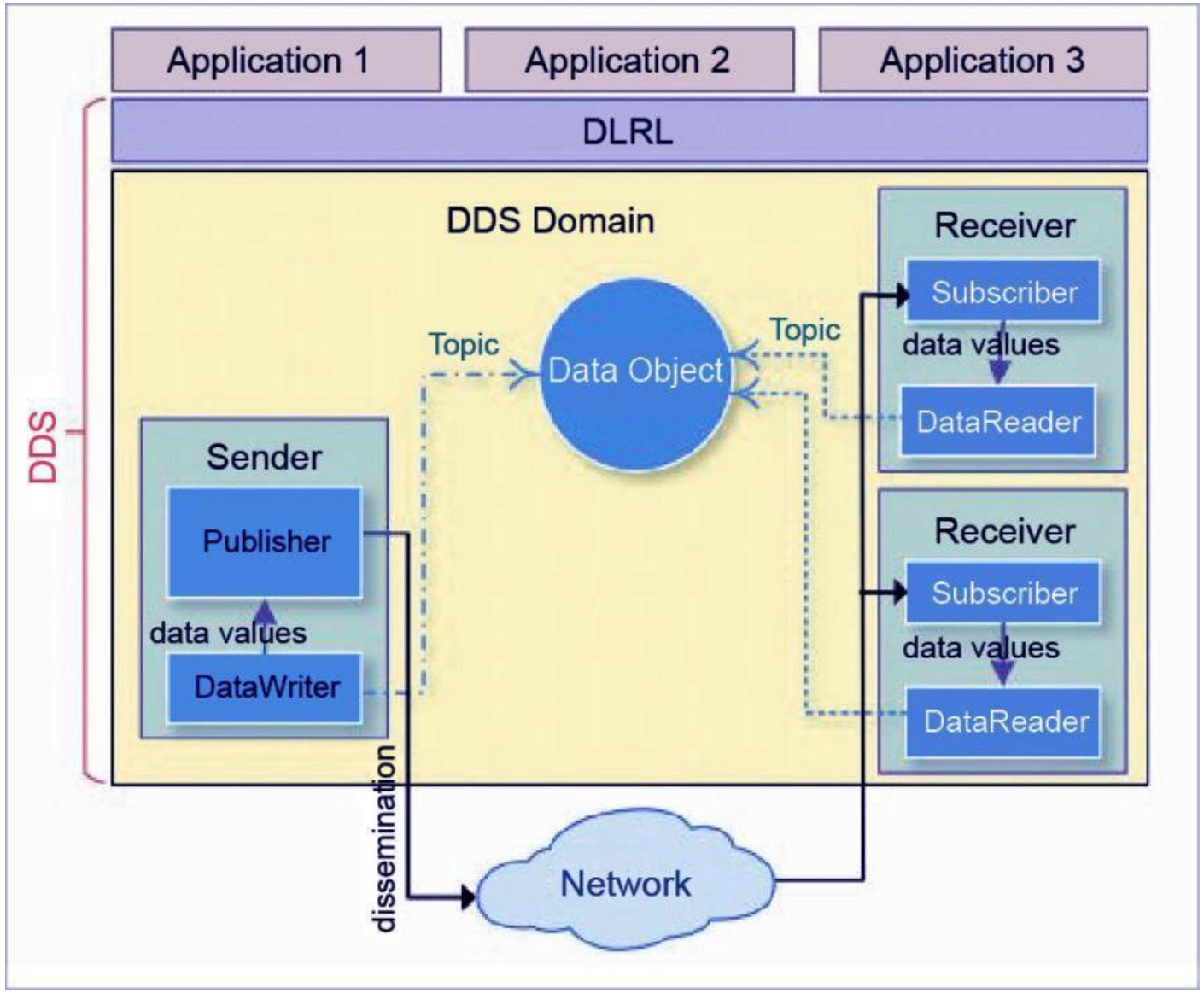


Image source: Alvear, Oscar & Calafate, Carlos & Cano, Juan-Carlos & Manzoni, Pietro. (2018). Crowdsensing in Smart Cities: Overview, Platforms, and Environment Sensing Issues. Sensors. 18. 460. 10.3390/s18020460.

DDS – Data Distribution Service



- Middleware for M2M
- Pub-sub model
- Multiple publishers
- Multiple subscribers
- QoS and configurable reliability

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

AMQP – Advanced Message Queuing Protocol

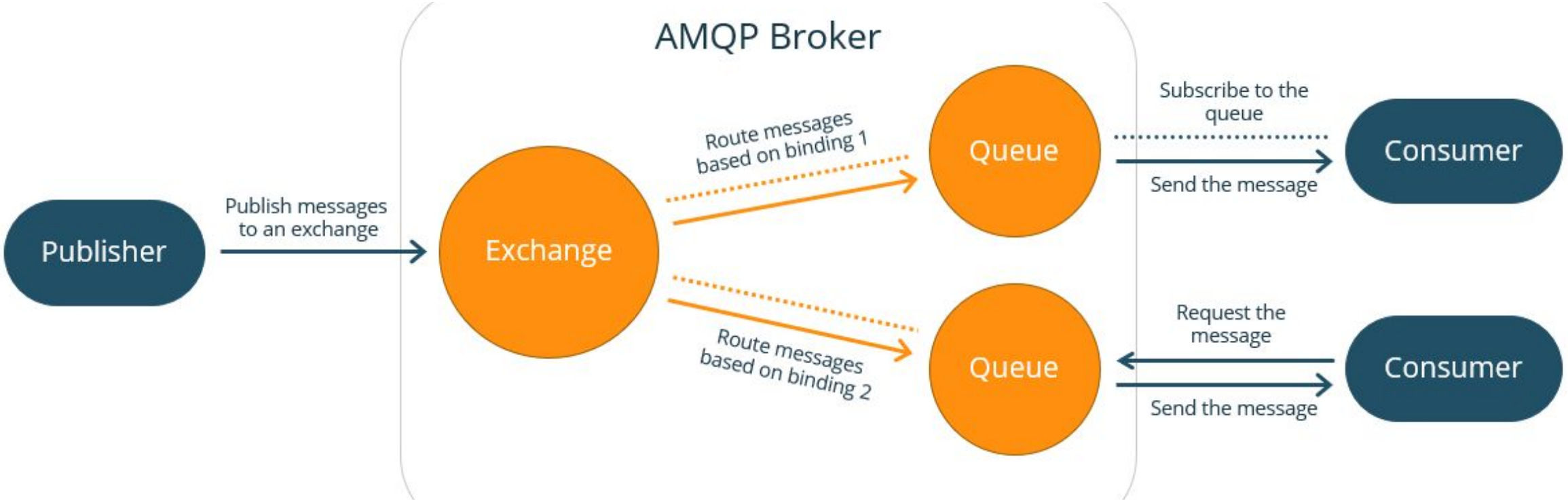
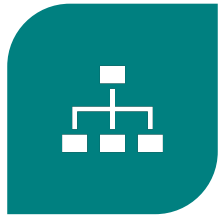


Image source: https://support.smartbear.com/readyapi/docs/testing/amqp.html

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

IoT Functional Blocks

APPLICATION



MANAGEMENT

SECURITY

DEVICES

SERVICES

COMMUNICATION