Service Oriented Middleware for IoT

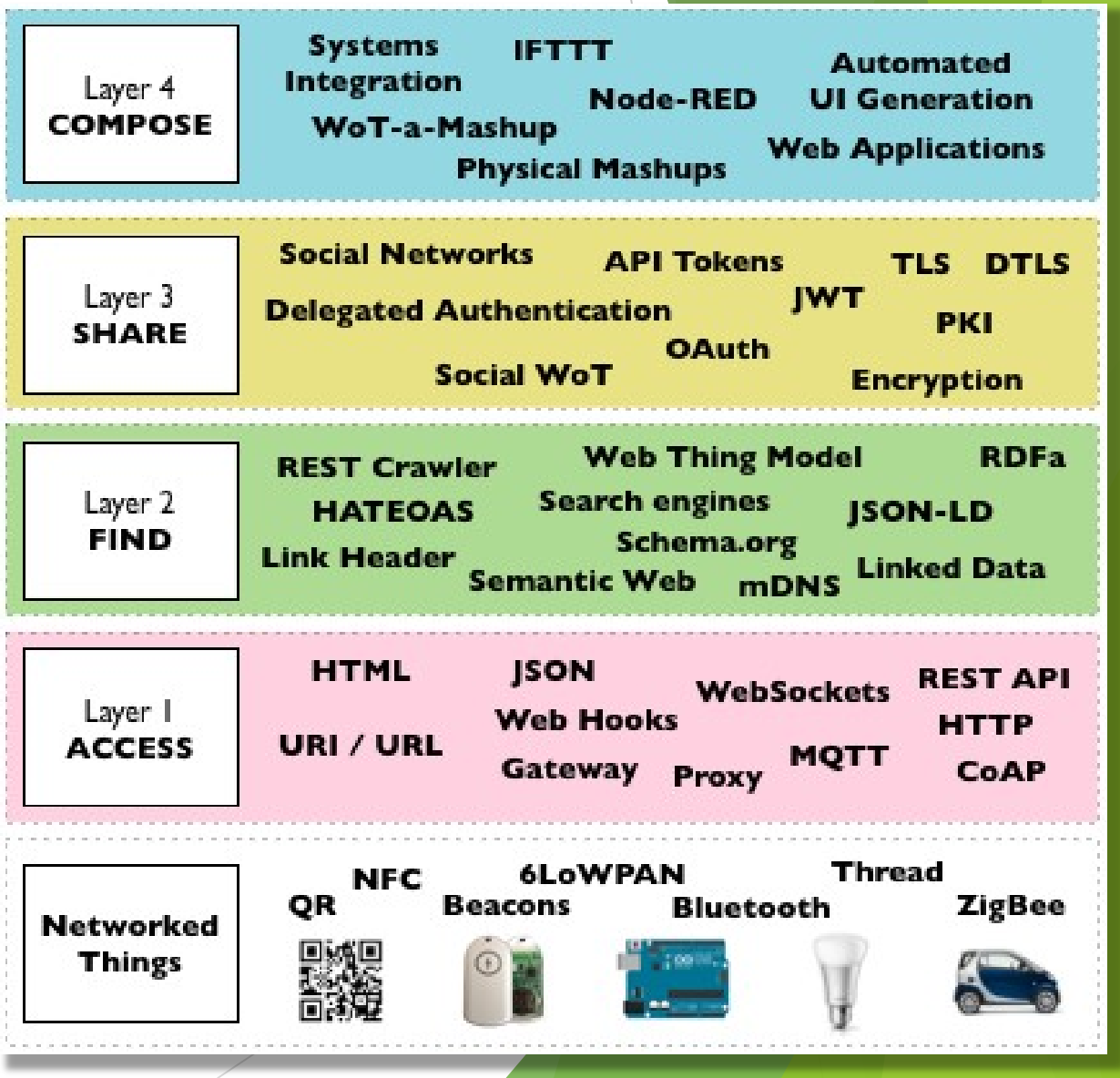
SOM, based on ROA or SOA Approaches

Reference : Service-oriented middleware: A survey Jameela Al-Jaroodi, Nader Mohamed, Journal of Network and Computer Applications, Volume 35, Issue 1, January 2012, Pages 211–220, Collaborative Computing and Applications

Web Service for an “Access” layer for IoT

- Provides a way to **access** services (devices) through the Web
  - Using Web standard protocols
  - Using dedicated protocols specific to IoT
  - etc…

- Different kind of **architectures**



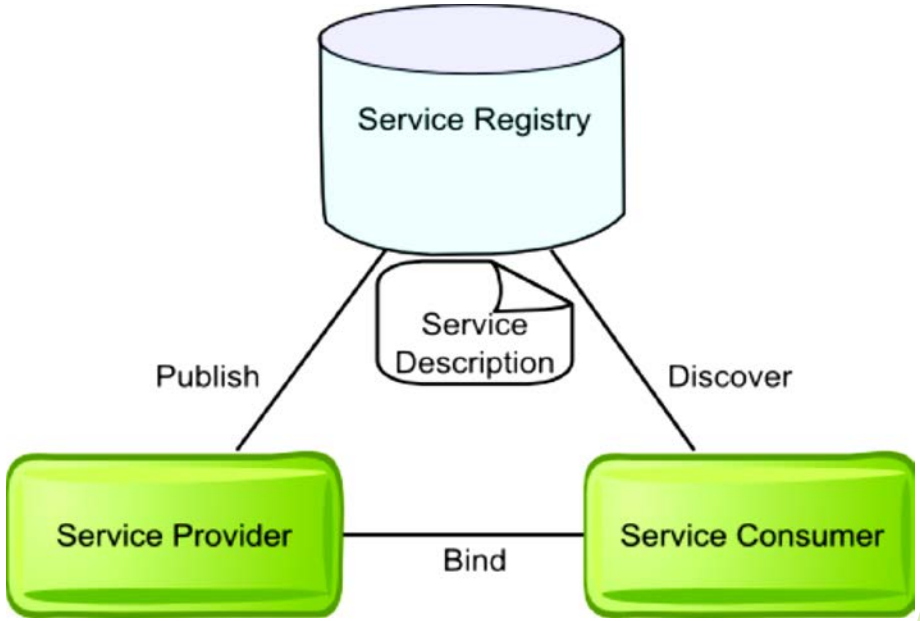
Middleware and Service Oriented Concepts

- Service-Oriented Middleware* is a kind of middleware based on the Service Oriented Architecture (SOA) paradigm that supports the development of distributed software systems in terms of loosely coupled networked services.
- In SOA, networked resources are made available as autonomous software services that can be accessed without knowledge of their underlying technologies.
- Key feature of SOA is that services are independent entities, with well-defined interfaces, which can be invoked in a standard way, without requiring the client to have knowledge about how the service actually performs its tasks.

(*) A Perspective on the Future of Middleware-based Software Engineering, Valérie Issarny, Mauro Caporuscio, Nikolaos Georgantas, Workshop on the Future of Software Engineering : FOSE 2007, 2007, Minneapolis, United States. pp.244-258, 2007, https://hal.inria.fr/inria-00415919

Middleware and Service Oriented Concepts

- The SOA style is structured around three key architectural components: (i) service provider, (ii) service consumer, and (iii) service registry
- In SOA-based environments, the Service-Oriented Middleware (SOM) is in charge of enabling the deployment of services and coordination among the three key conceptual elements that characterize the SOA style.
- Popularity of service oriented computing is mainly due to its **Web Service** instantiation.



Trends Web of Things or Web Service for Device

- Two kind of approaches based on Service Oriented Architectures :
  - ROA (DAO) : Resource or data oriented
    - Communication pattern between service consumer and provider is based on shared URL
    - Principle : Resources as URL like hyperlinks in a classical Web approach
  - SOA : Service oriented
    - Communication pattern between service consumer and provider is RPC
    - Principle : RPC using SOAP protocol over HTTP

Resource Oriented Architecture

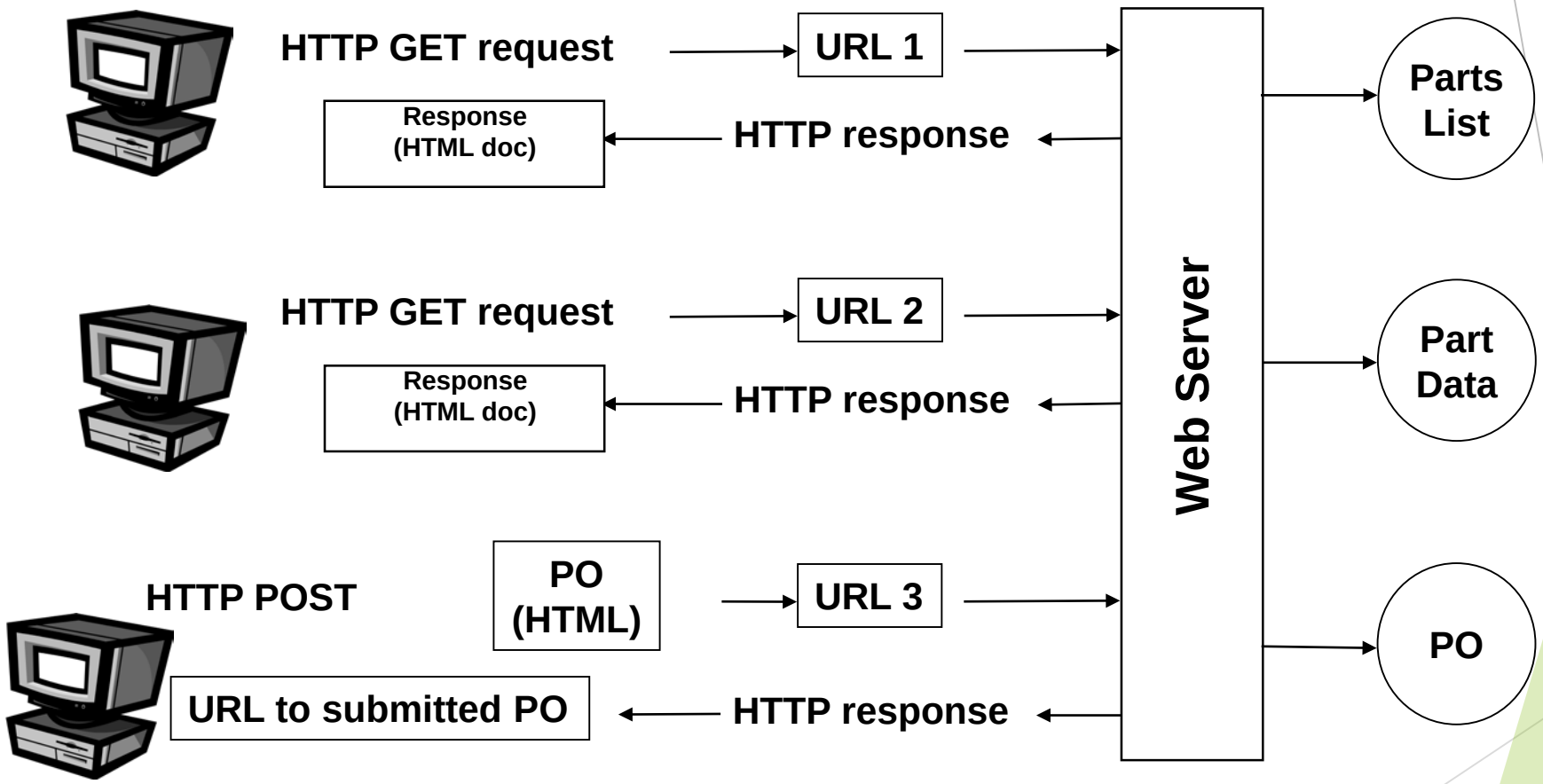
RESTful Web Services

- REpresentational State Transfer
  - Architecture inherent in all web based system since 1994, not explicitly described as an architecture until later
  - An architecture - not a set of standard
    - Web Services is both an architecture and a set of standards
- Goal: To leverage web based standards to allow inter-application communication as simply as possible
  - Matches the ‘standard’ web interaction model
  - Resources as URL like hyperlinks in a classical Web approach

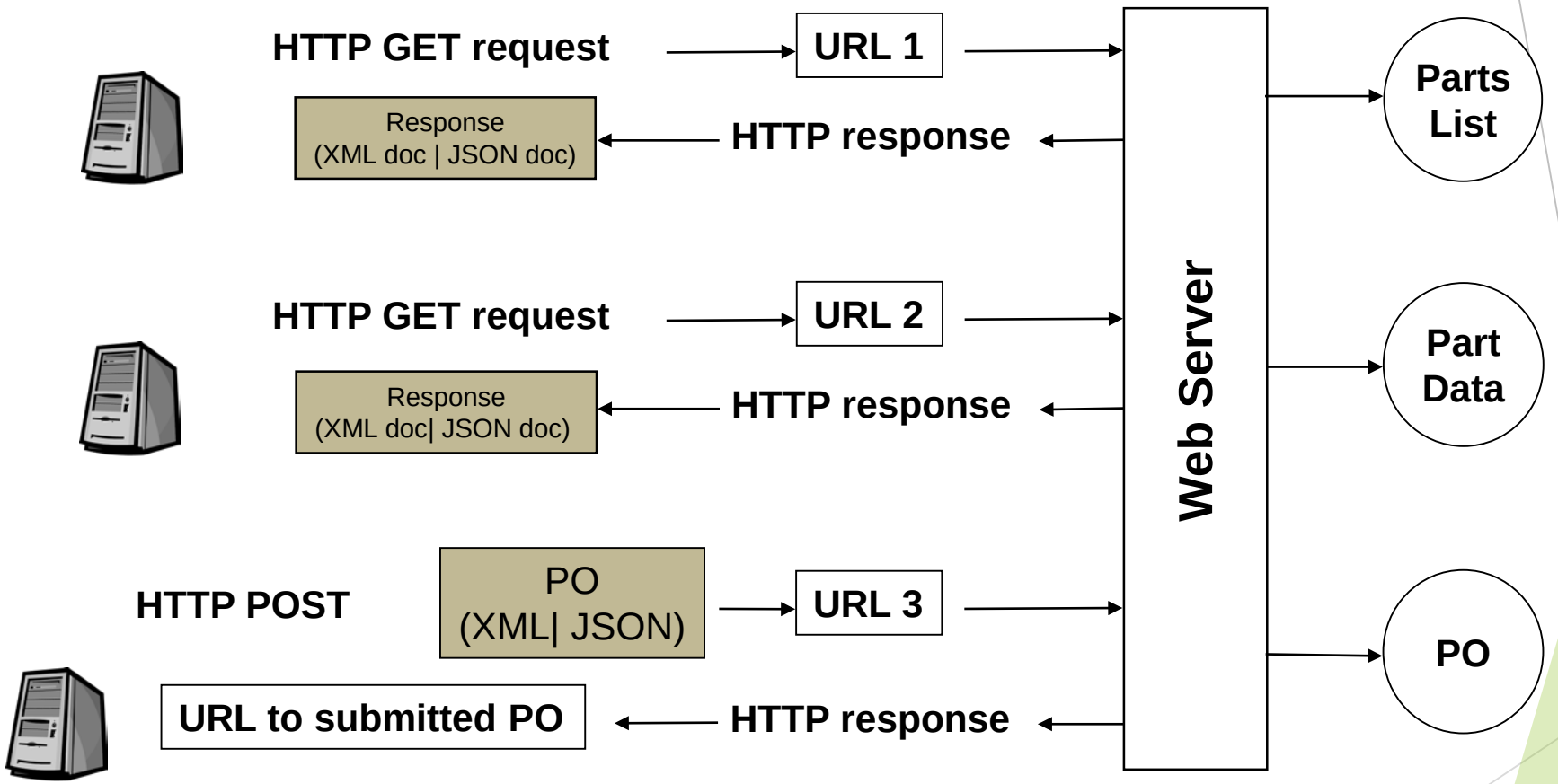
REST architecture

- Uses HTTP operations (CRUD, the four basic functions of persistent storage):
  - POST = "here's some new info" (Create)
  - GET = "give me some info" (Read/Retrieve)
  - PUT = "here's some update info" (Update/Modify)
  - DELETE = "delete some info" (Delete/Destroy)
- Typically exchanges XML documents
  - But supports a wide range of other internet media types
- Example of client side REST request: GET /shoppingcart/5873
  - Server must be able to correctly interpret the client request as there is no explicitly defined equivalent to an interface definition

The standard Web architecture



The RESTful architecture



REST Architecture

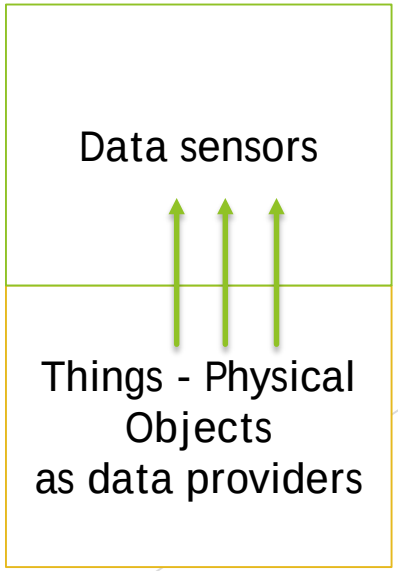
- Servers are stateless and messages can be interpreted without examining history
  - Messages are self-contained
- There is no such thing as a “service”.
  - There are just resources which are accessed through URI
    - URI = generalization of URL
- Clients navigate through a series of steps towards a goal by following hypertext links (GET) and submitting representations (POST).

ROA and Mashup

- Mashups is “A way to create new Web applications by combining existing Web resources utilizing data and Web APIs” [Benslimane et al., 2008]

- ROA is Well-adapted for Mashups (Composite Web Applications)
- Well-adapted for Web Sensors Network (WSN)

- But lacks for non sensor device … like actuators …



REST – strong versus weak

- Pure REST should use ‘pure’ URI only
  - E.g. GET /shoppingcart/5873
- Many REST implementations also allow parameter passing
  - E.g. GET /shoppingcart/5873?sessionID=123
- Allowing parameter passing makes REST a lot more usable but blurs the architectural principle of statelessness
- Indeed Data can be specific command like instruction code …
  - But is it the purpose ?
  - Is this not another way to rebuild a SOA stack ?

Service Oriented Architecture (SOAP-WS)

SOA : Service oriented Architecture

- A service provides business functions to its consumer and in ISO 19119 [ISO/TC-211] it is defined as
  - “ Distinct part of the functionality that is provided by an entity through interfaces ”
- Also called WS-* (for * recommendations, Cf. https://www.w3.org/2002/ws/)

- SOAP based Web Service, the alternative
- RPC using SOAP protocol over HTTP

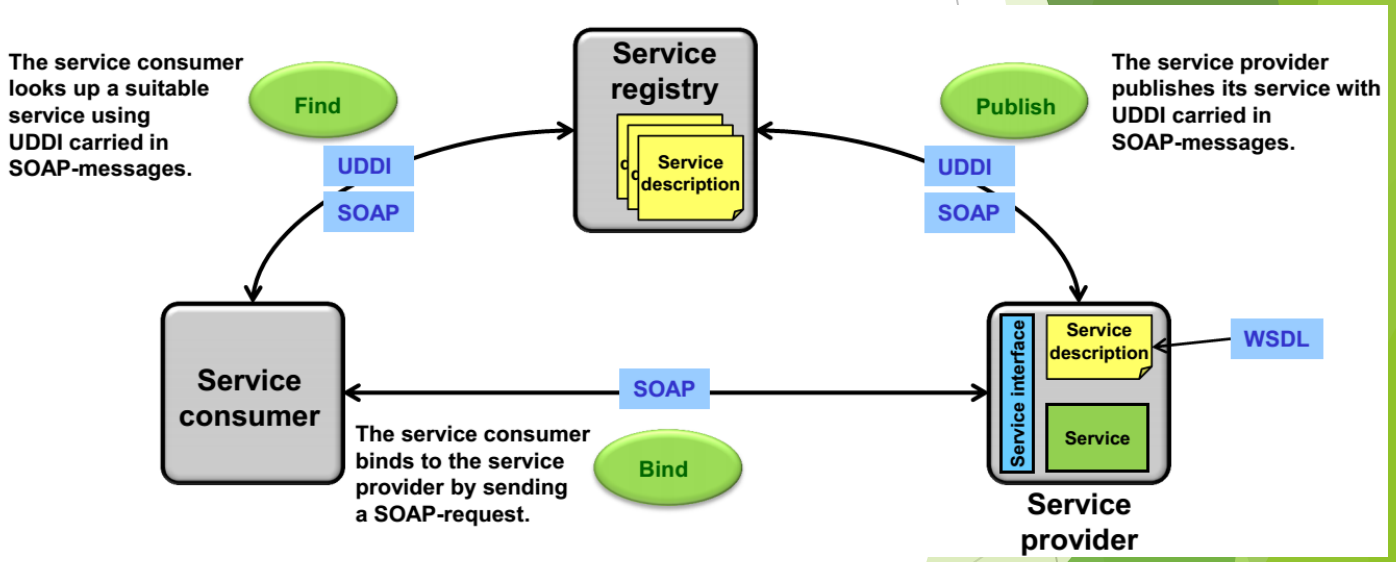
Sample SOAP RPC Message

- <Envelope> is the root node
- <Header>, <Body> et <Fault> are children nodes :

```
<?xml version="1.0" encoding="UTF-8" standalone="no" ?>
<soap:Envelope xmlns:soap="http://schemas.xmlsoap.org/soap/envelope/"
soap:encodingStyle="http://schemas.xmlsoap.org/soap/encoding/">
  <soap:Header>
    ... Header information...
  </soap:Header>
  <soap:Body>
    ... Body information...
    <soap:Fault>    ...Fault information...
    </soap:Fault>
  </soap:Body>
</soap:Envelope>
```

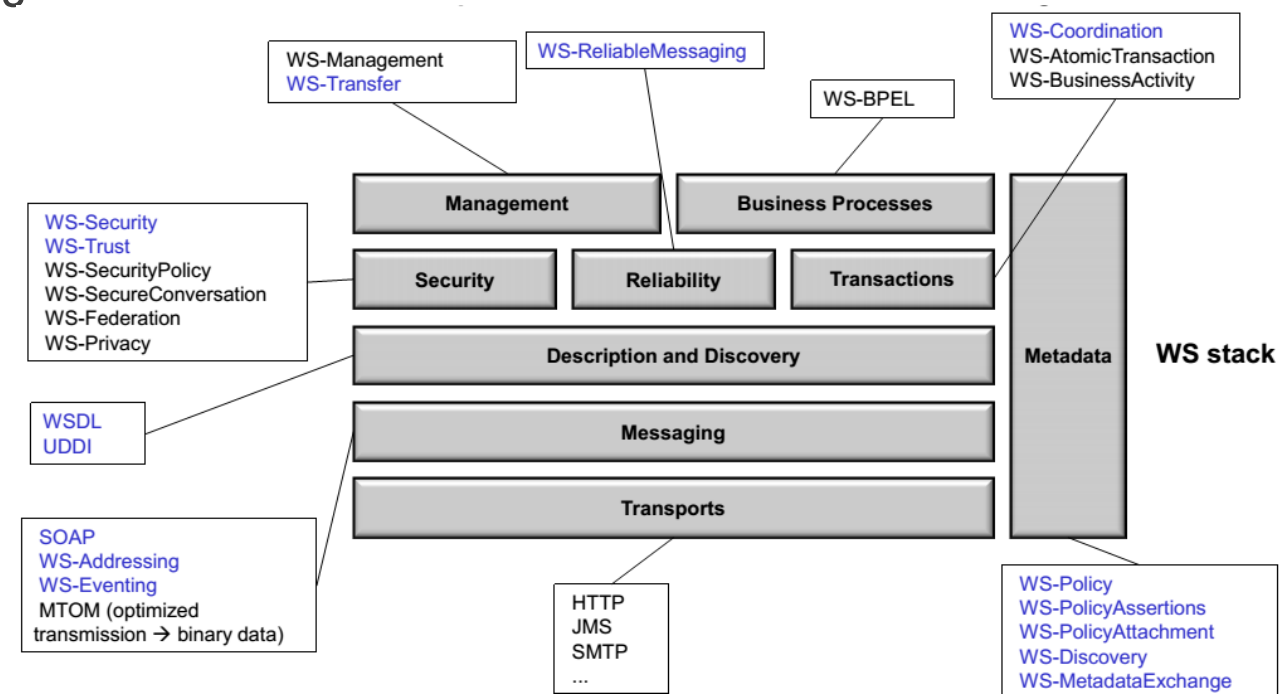
WS-*architecture more than ROA

- SOAP+WSDL+UDDI defines a general model for a web service architecture.
  - SOAP: Simple Object Access Protocol
  - WSDL: Web Service Description Language
  - UDDI: Universal Description and Discovery Protocol
  - Service consumer: User of a service
  - Service provider: Entity that implements a service (=server)
  - Service registry : Central place where available services are listed and advertised for lookup



WS-* Models

- Stack of WS-standards
- The W3C and OASIS WS-stack provide a framework / toolbox for constructing web service architectures



Disadvantages of Web Services

- Low-level abstraction
  - leaves a lot to be implemented
- Interaction patterns have to be built
  - one-to-one and request-reply provided
  - one-to-many?
- No location transparency

CoAP : Constrained Application Protocol

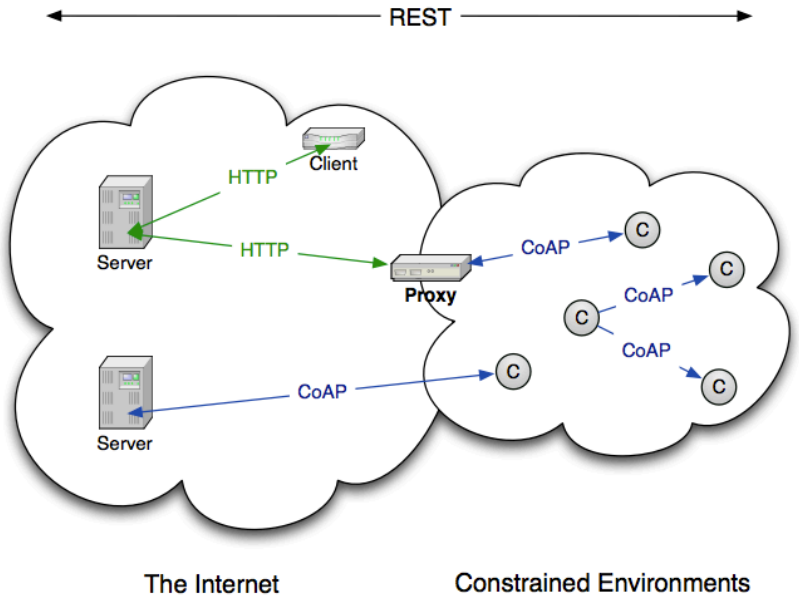
LightWeight RESTFUL protocol for IoT and M2M …

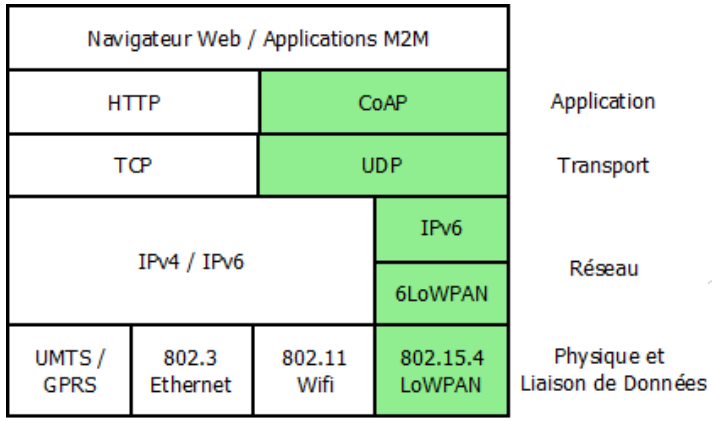
Over UDP

RFC 7252 (IETF 06-2014)

What CoAP is (and is not)

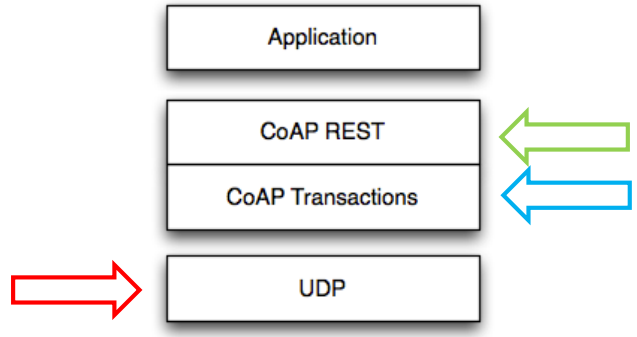
- CoAP is
  - A RESTful protocol
  - Both synchronous and asynchronous
  - For constrained devices (small mem, slow proc) and networks
  - Specialized for M2M applications
  - Easy to proxy to/from HTTP
- CoAP is not
  - A replacement for HTTP
  - General HTTP compression
  - Separate from the web





CoAP/protocol

- Endpoint
  - IP addr, UDP port
- CoAP Transactions
- CoAP Message Format
  - 4 byte header
  - Options
  - Payload
    - uint (unsigned integer)
    - string
    - …

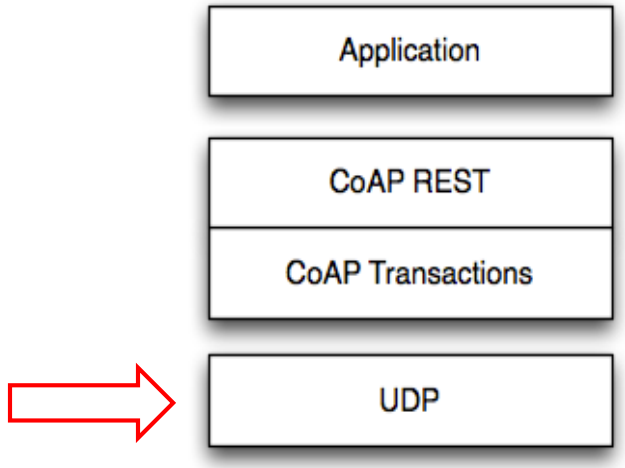



```
Client                Server
     |                   |
     |   CON tid=48      |
     |  GET http://n..   |
     +----------------->|
     |                   |
     |   ACK tid=48      |
     |<-----------------+
```

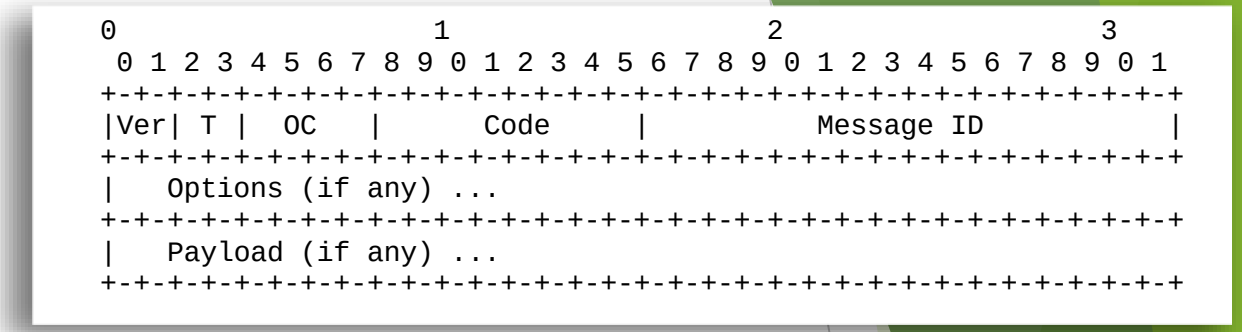
```
0       1       2       3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Ver| T |  OC   |    Code     |          Message ID           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Options (if any) ...
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Payload (if any) ...
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

CoAP / transport and Endpoint

- Endpoint
  - IP addr, UDP port
- Transport Protocol
  - Default UDP but not required
  - SMS, TCP and SCTP also possible
- Ports
  - UDP Port 5683 (mandatory)
  - UDP Ports 61616-61631 compressed 6lowPAN

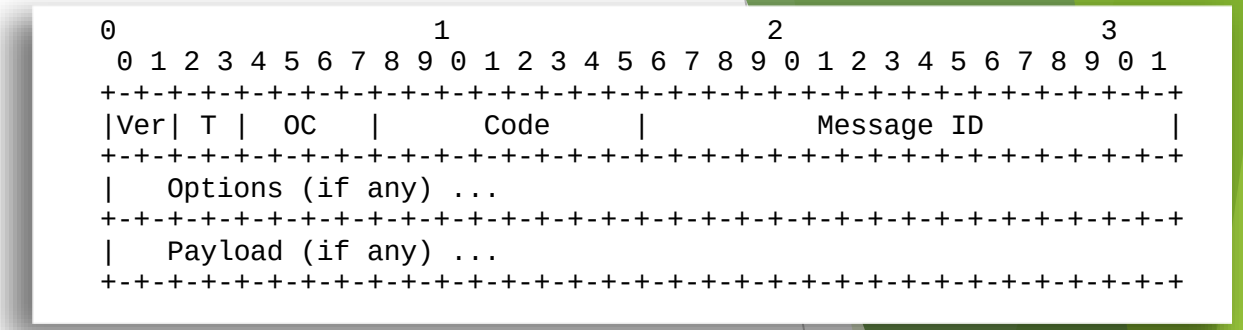


CoAP/protocol



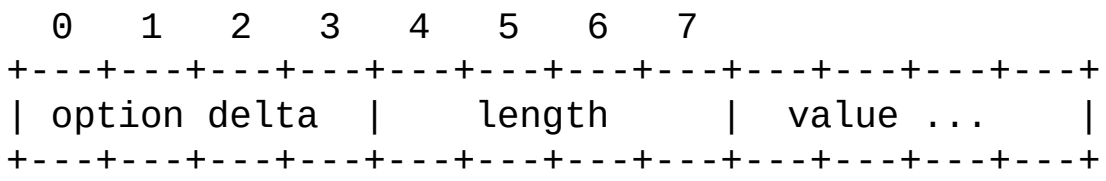
- The first 4 bytes that are mandatory contain the following pieces of information:
- A. Byte 0
  - a. 2-bit version: The first two bits indicate the CoAP version number. As of now, only version 1 is supported.
  - b. 2-bit type code: The next two bits indicate the message type. This can take one of 4 values – CON, NON, ACK, RST
  - c. 4-bit token length: The next 4 bits indicate the length of the token value in bytes. As explained before, the token is used to correlate messages. The length of token can be between 0-8 bytes. Other values are reserved.
- B. Byte 1 – This contains the message code.
  - The message code values can be GET, PUT, POST, NOT FOUND etc. I will talk about other possible message codes later on in this book.
- C. Byte 2,3 – The next two bytes together make up a 16-bit number.
  - This is where the message ID is carried. This is an unsigned number.

CoAP/protocol Options

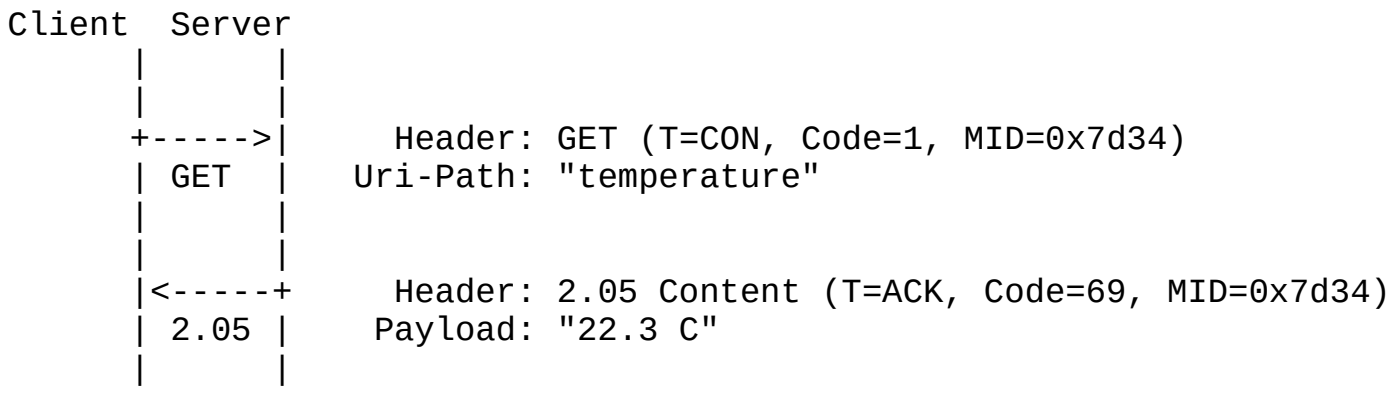


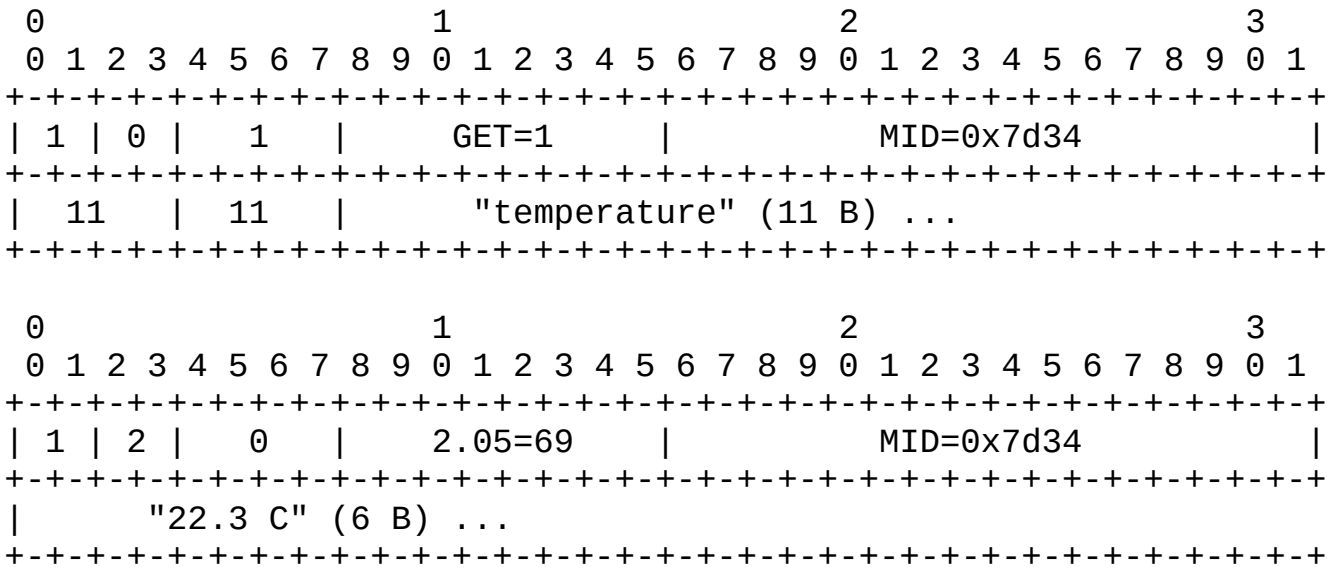
- After the first 4 bytes, based on the context, the message may contain additional bytes

Typical Option:



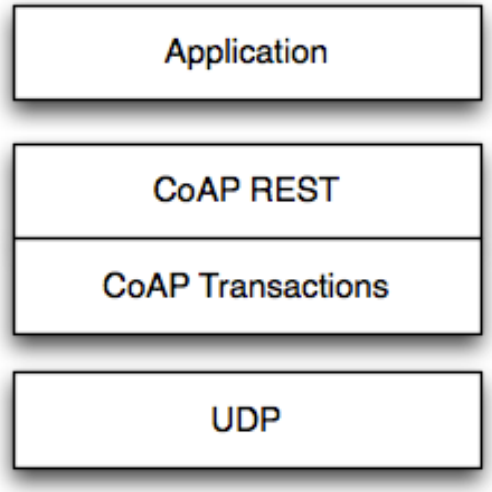
CoAP / example





The Transaction Model

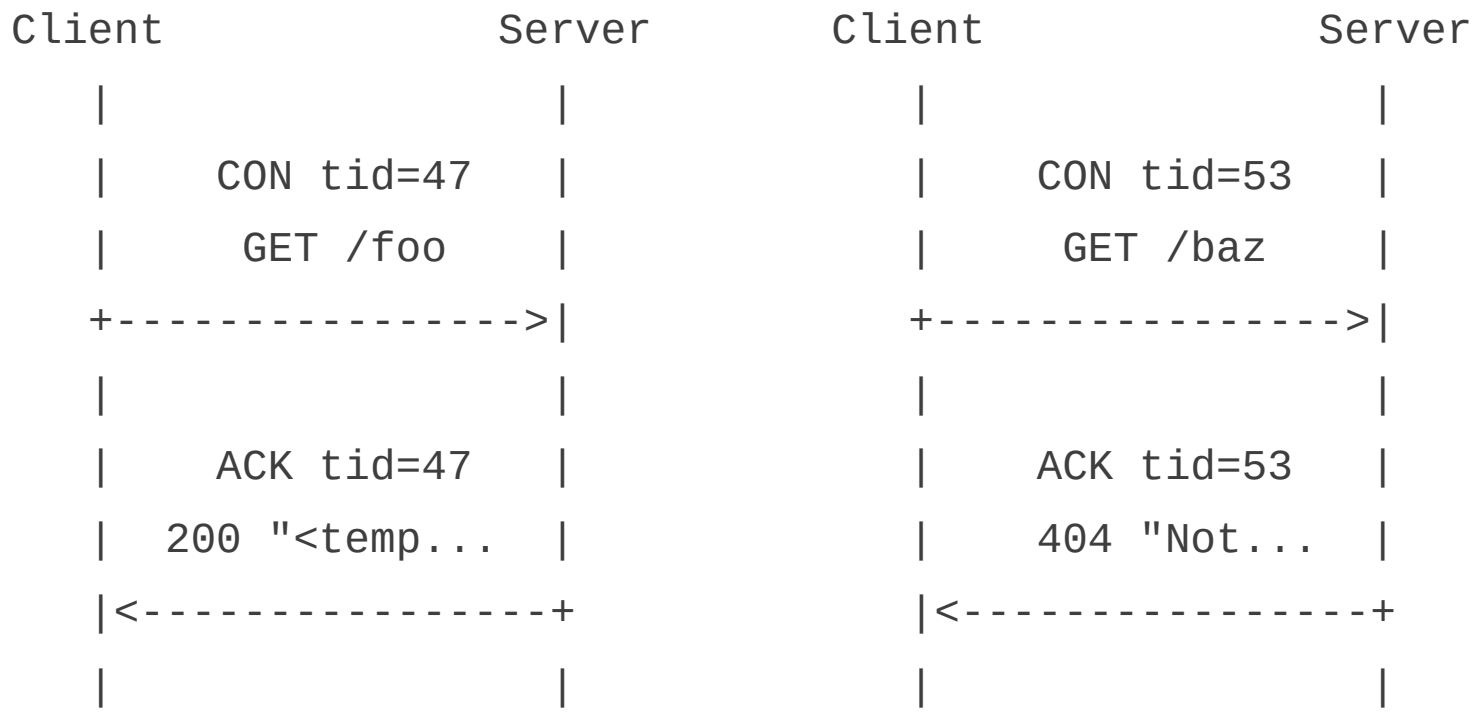
- Transport
  - CoAP is defined for UDP
- Transaction
  - Single message exchange between end-points
  - CON, NON, ACK, RST
- REST
  - Piggybacked on transaction messages
  - Method, Response Code and Options (URI, content-type etc.)



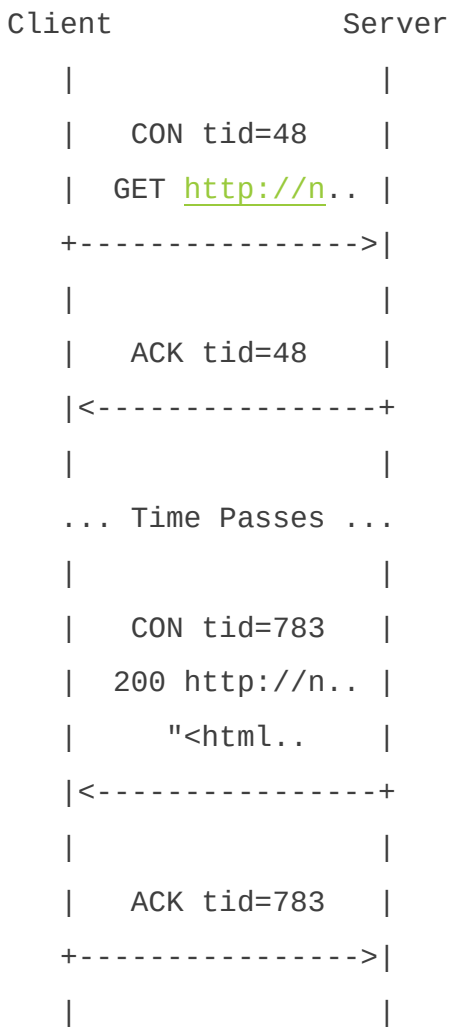
CoAP/message types

- Confirmable message
- Non-confirmable message
- Ack message
- Reset message

Synchronous Transaction

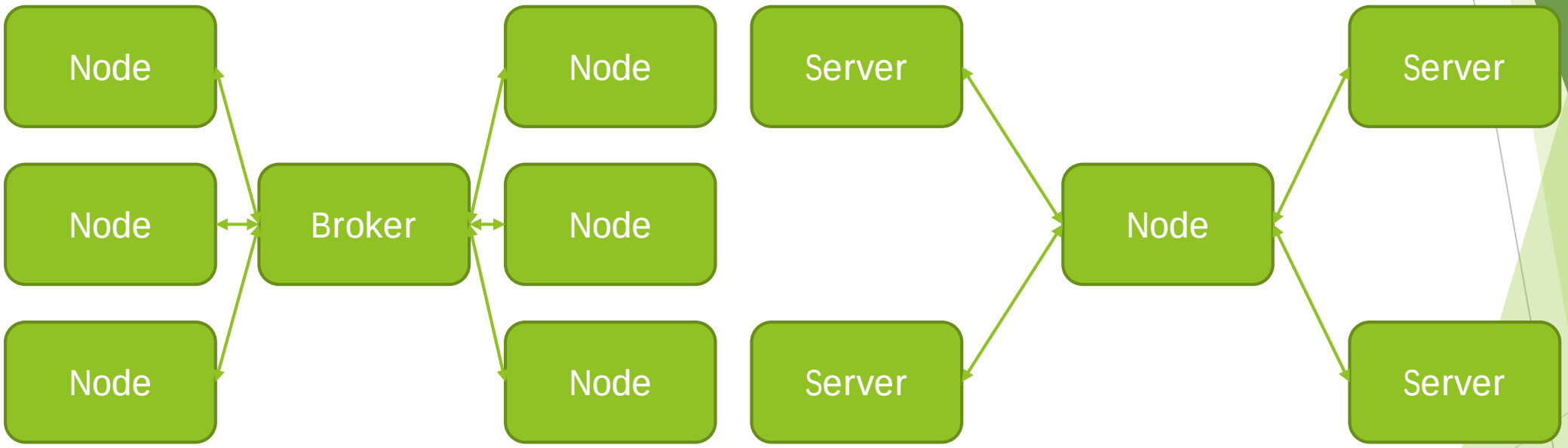


Asynchronous Transaction



CoAP vs MQTT

- MQTT
- CoAP



CoAP vs MQTT

- MQTT
  - Publish/Subscribe
  - Non RESTful
  - QoS
  - Store and Forward
  - Good for transferring data/commands over unstable connections
- CoAP
  - Web Service
  - RESTful
  - No QoS in protocol
  - Goof for client/server concepts over stable connections. Nodes only execute “commands”
- Both
  - Well suited for low volumes networks and low power devices (IoT)
  - Can use secure connections (CoAP uses DTLS as preferred cryptographic method)

And...

What do we need now?

Web Service for a “Find” layer for IoT

- Provides a way to **find** and **locate** relevant services (devices) on the Web
  - Search engines,
  - Crawlers,
  - etc…
- Some standard provides some protocols for
  - Dynamic discovery
  - Availability Management
  - Ex. UPnP and DPWS
  - We’ll see that in the next course