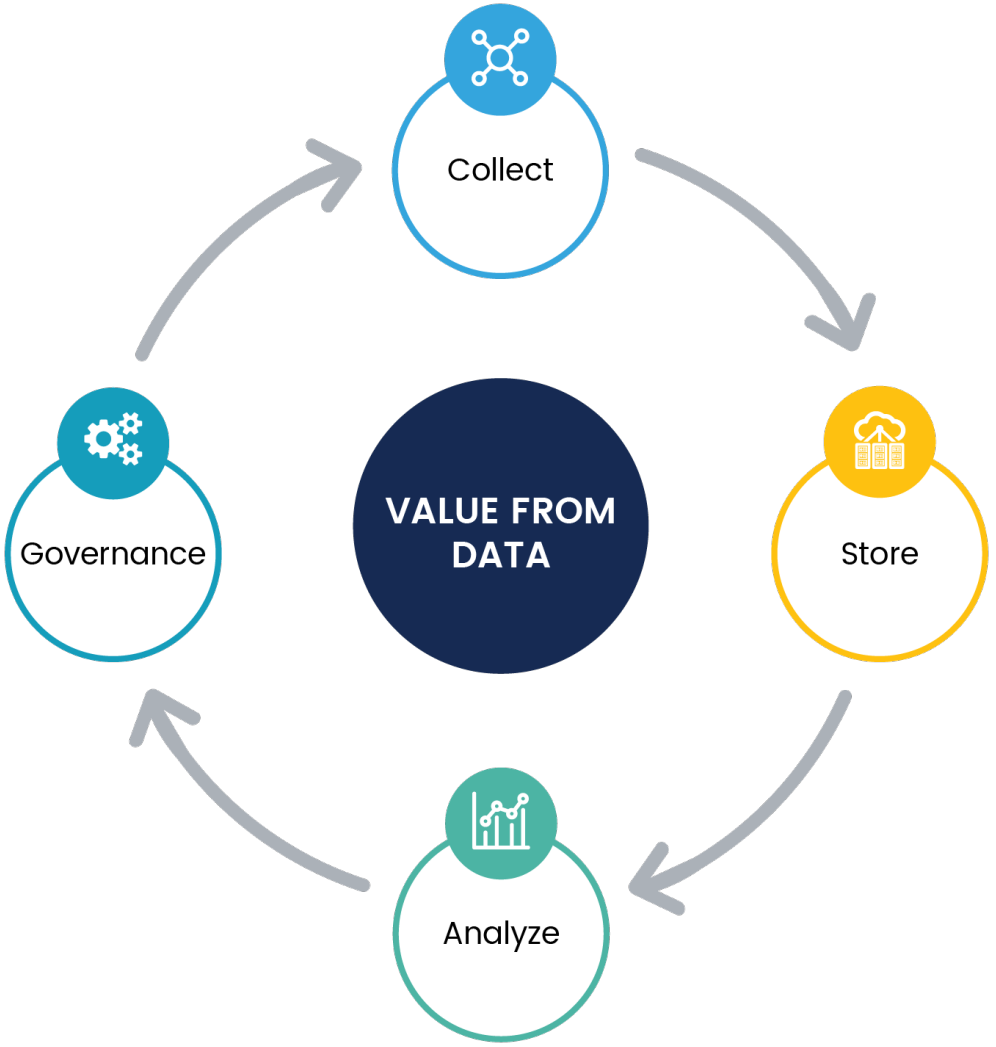
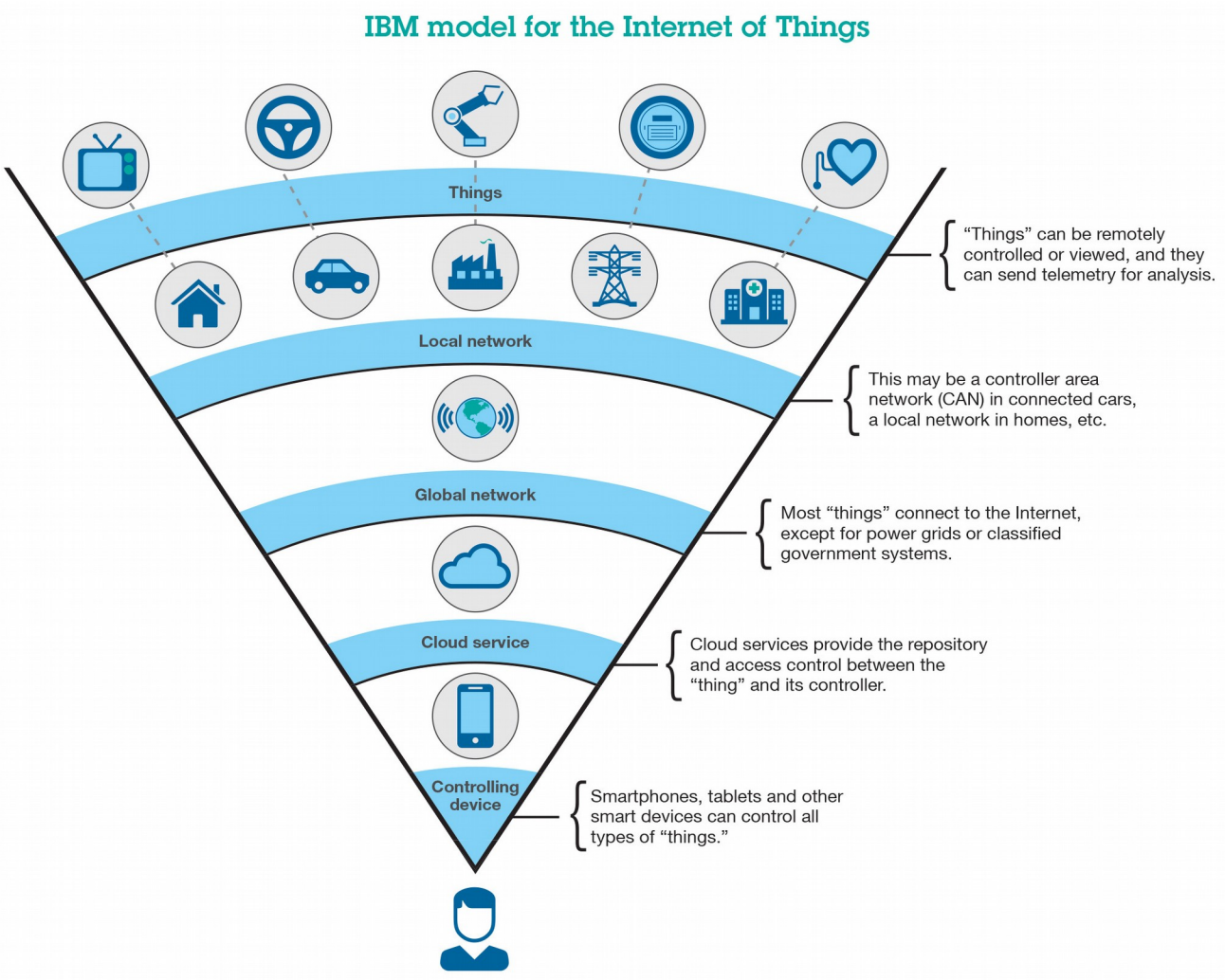
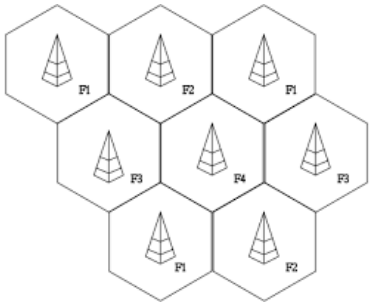

Collect
Store
Analyze
Governance
VALUE FROM DATA

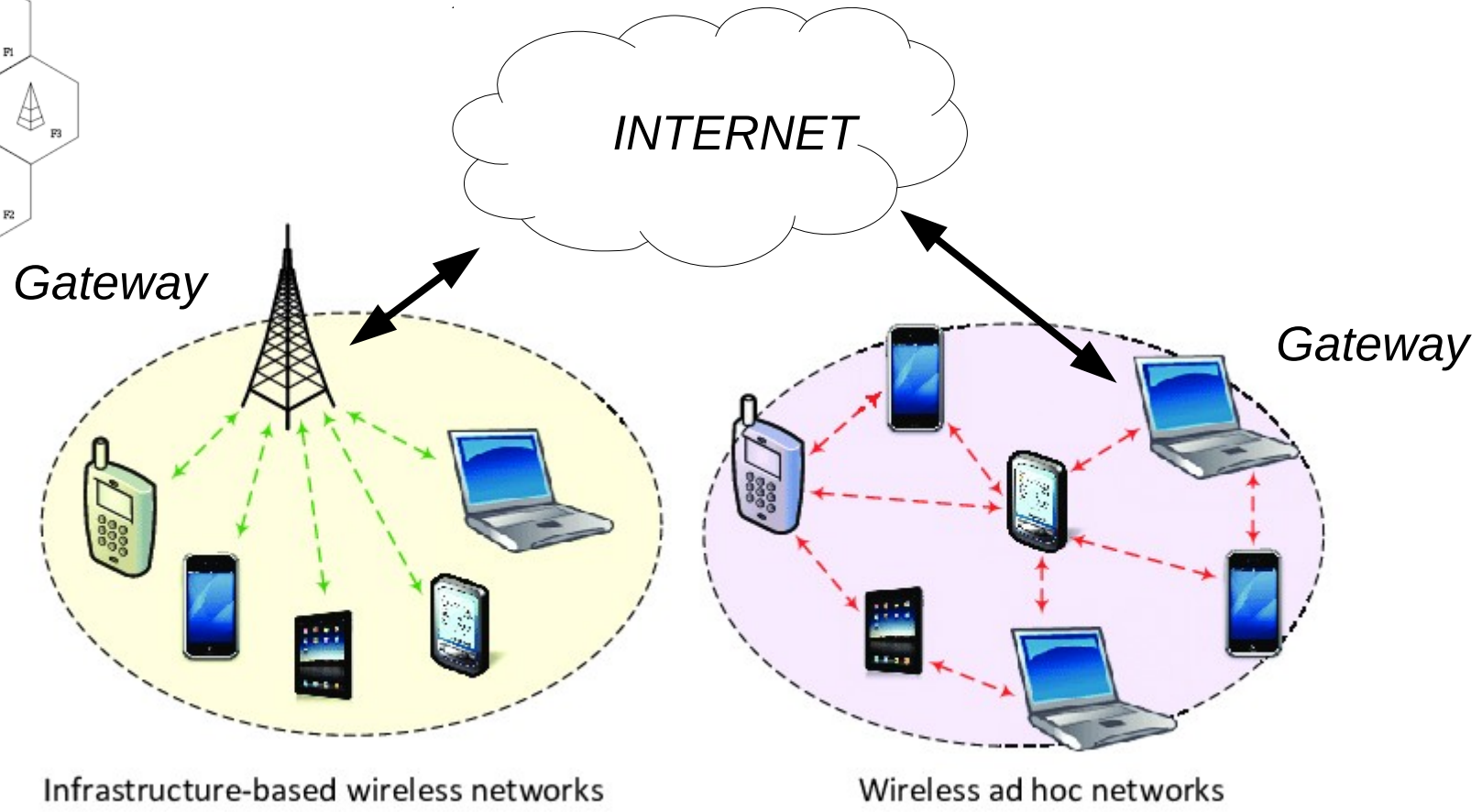


Graphic 1. IBM model for the Internet of Things

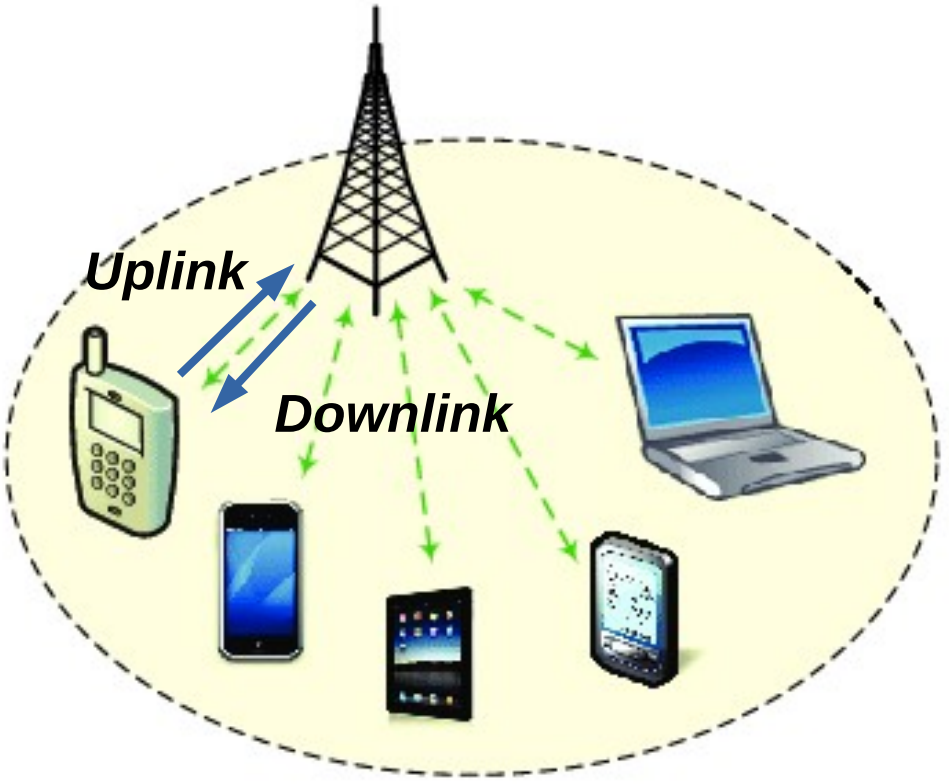
Source: IBM X-Force® Research and Development

Source: https://en.wikipedia.org/wiki/Cellular_network

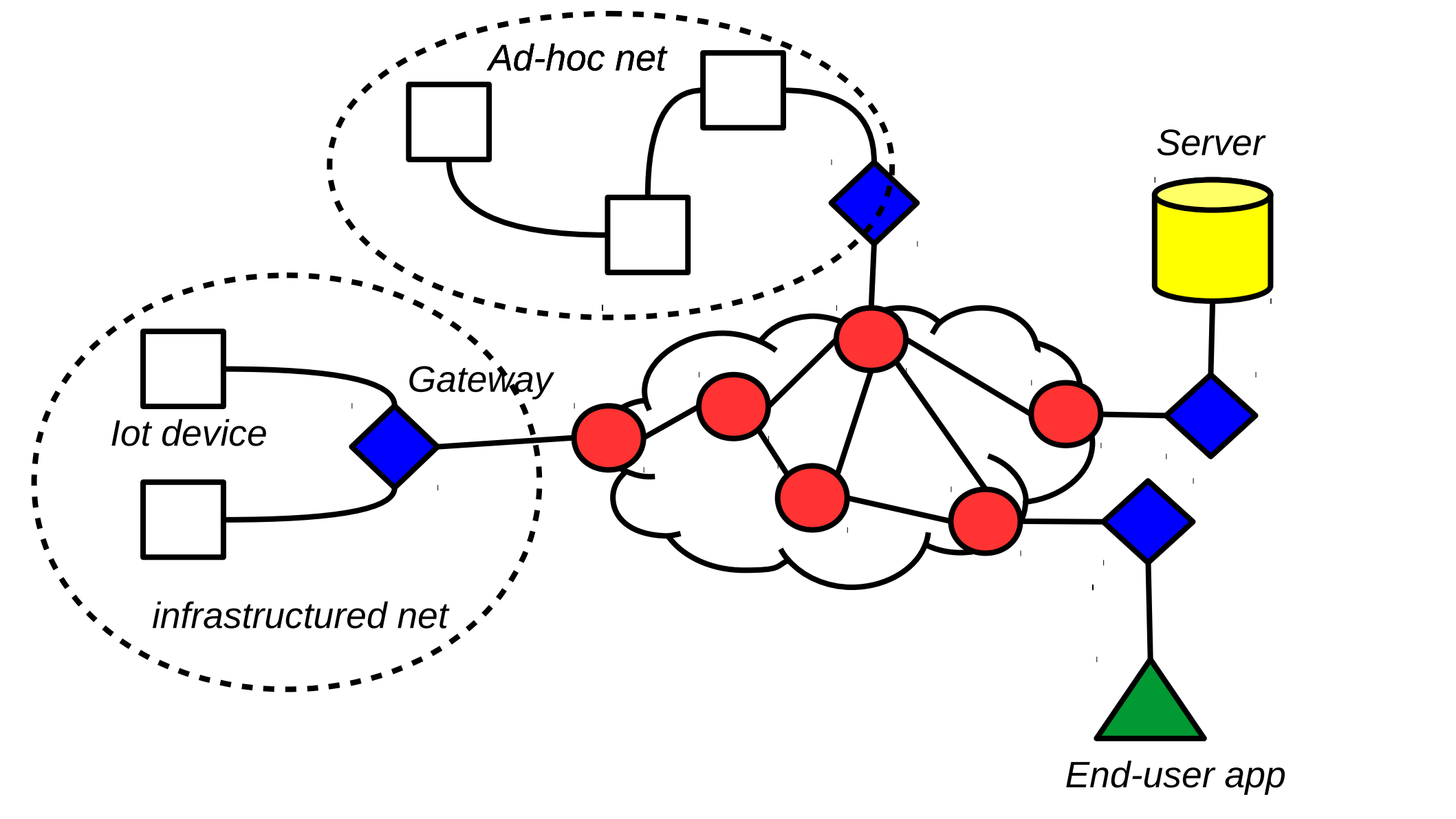


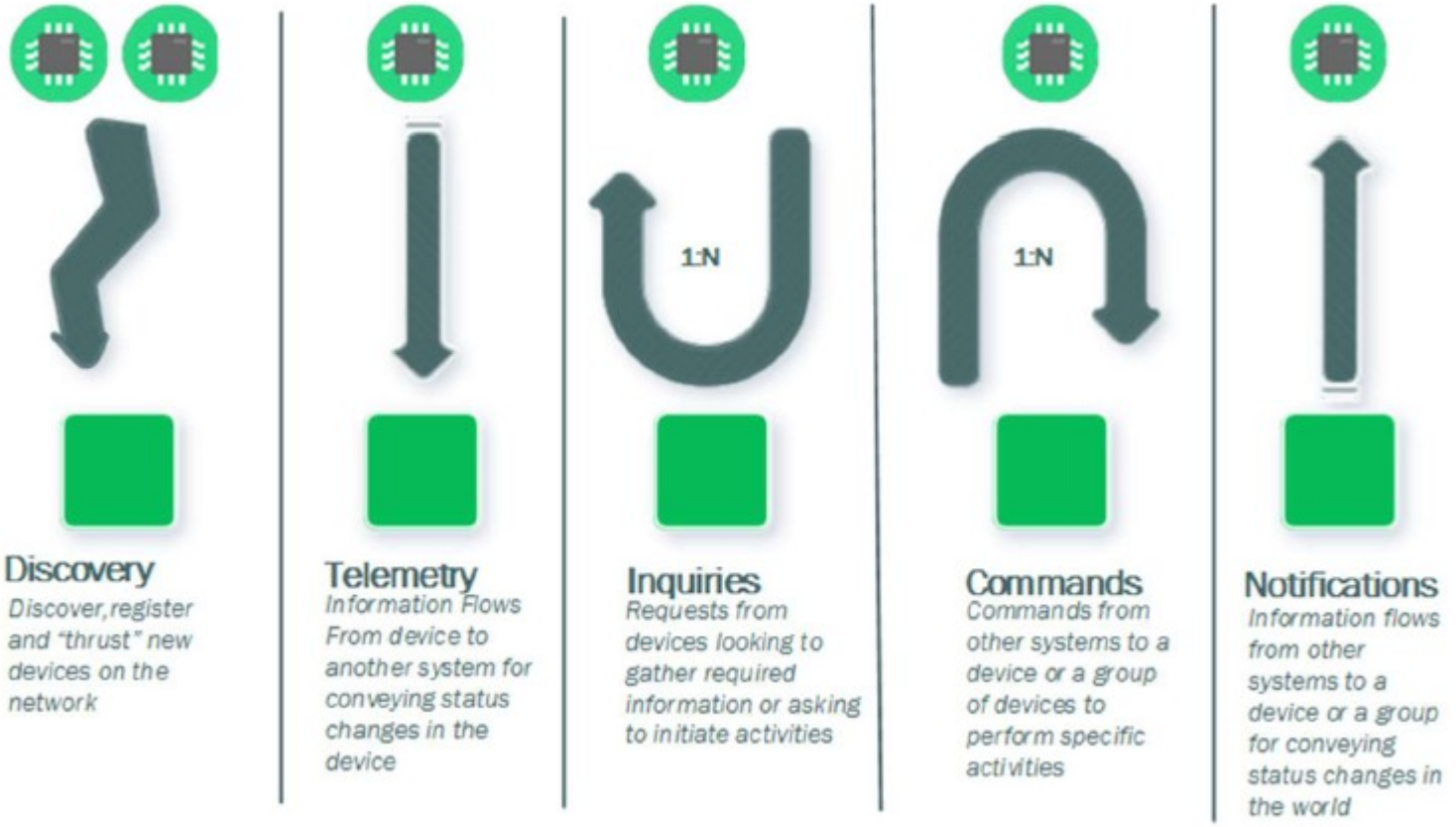


Source: https://www.researchgate.net/figure/Comparison-between-infrastructure-networks-cellular-network-and-WLAN-and-wireless-ad_fig3_278412748



Infrastructure-based wireless networks


Ad-hoc net
Server
Gateway
Iot device
infrastructured net
End-user app

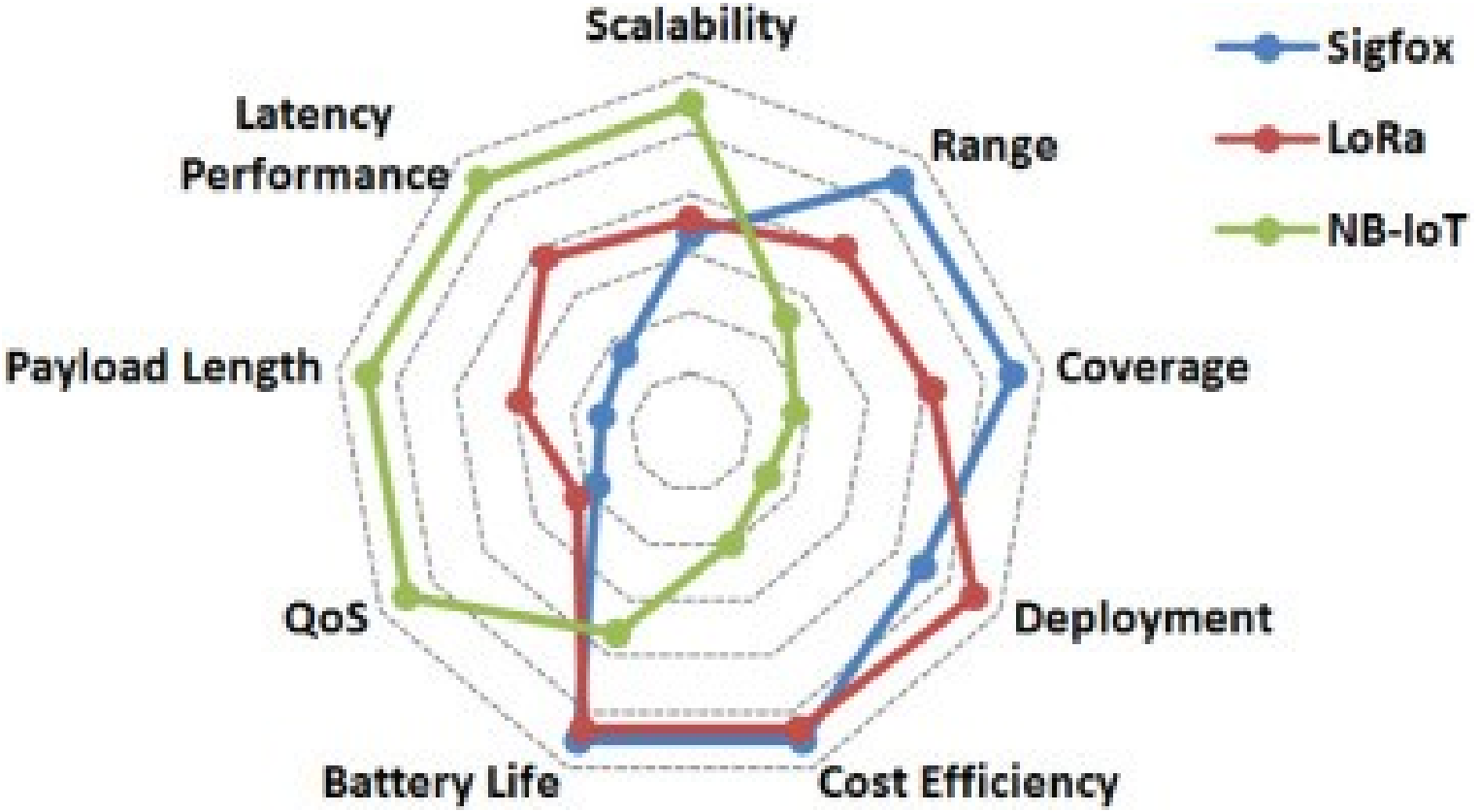


https://www.snap4city.org/drupal/node/68

4 C

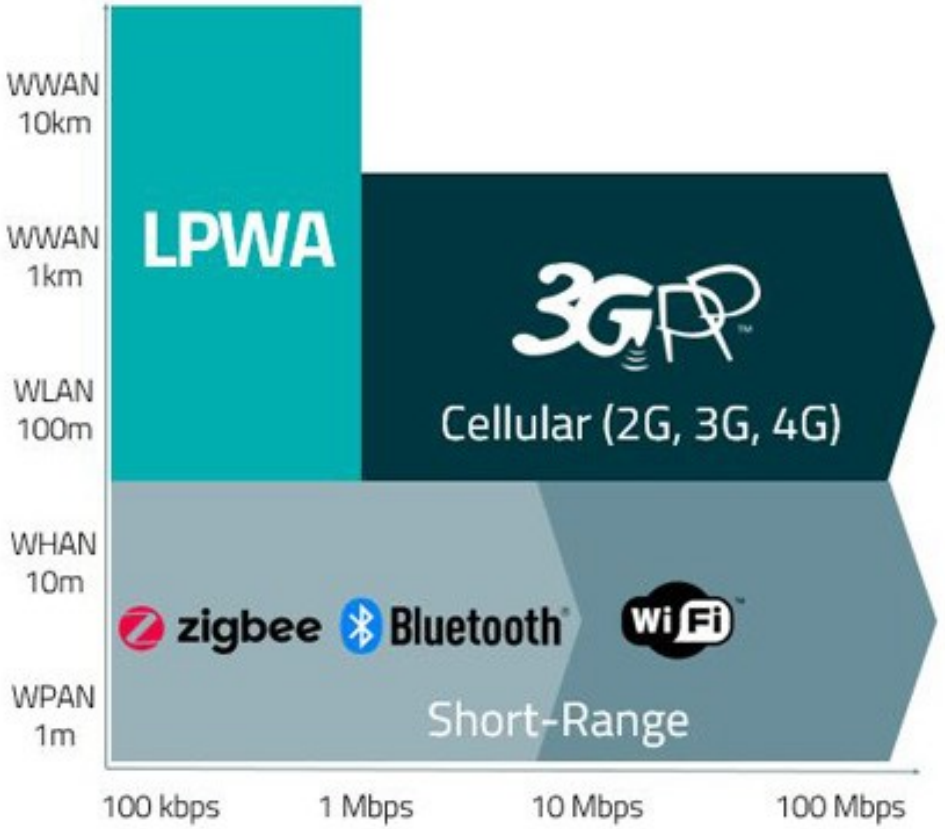
- Cost (devices and services costs)
- Current (battery life)
- Coverage (reach)
- Capacity (network)

https://www.sierrawireless.com/iot-blog/iot-blog/2016/07/what_is_lpwa_for_the_internet_of_things_part-1_the_thre_-cs_of_iot/



https://www.itu.int/en/ITU-D/Regional-Presence/AsiaPacific/SiteAssets/Pages/Events/2018/CoESmartcityoct2018/IOT_SmartCity/IoT%20Spectrum%20Needs.pdf

Wireless Technology comparison



	LPWA	Cellular 2G, 3G, 4G	Short-Range PAN | WLAN
Agriculture	●	○	○
Asset Tracking	●	●	○
Appliances	●	○	●
Automotive	○	●	●
Consumer	●	○	●
Energy	●	●	●
Enterprise	○	●	●
Healthcare	●	○	●
Industrial	●	○	●
Smart City	●	●	○
Smart Home	○	○	●
Transportation	○	●	●

https://www.sierrawireless.com/iot-blog/iot-blog/2016/07/what_is_lpwa_for_the_internet_of_things_part-1_the_thre_-cs_of_iot/

LPWA

SIGFOX
One network A billion dreams

Objects

Uplink payload: 0 to 12 bytes
Downlink payload: 0 to 8 bytes

0 to 140 messages per day per device

Sigfox Stations

Over 1 million messages can be processed per base station per day

Sigfox Cloud™

Web interface

API

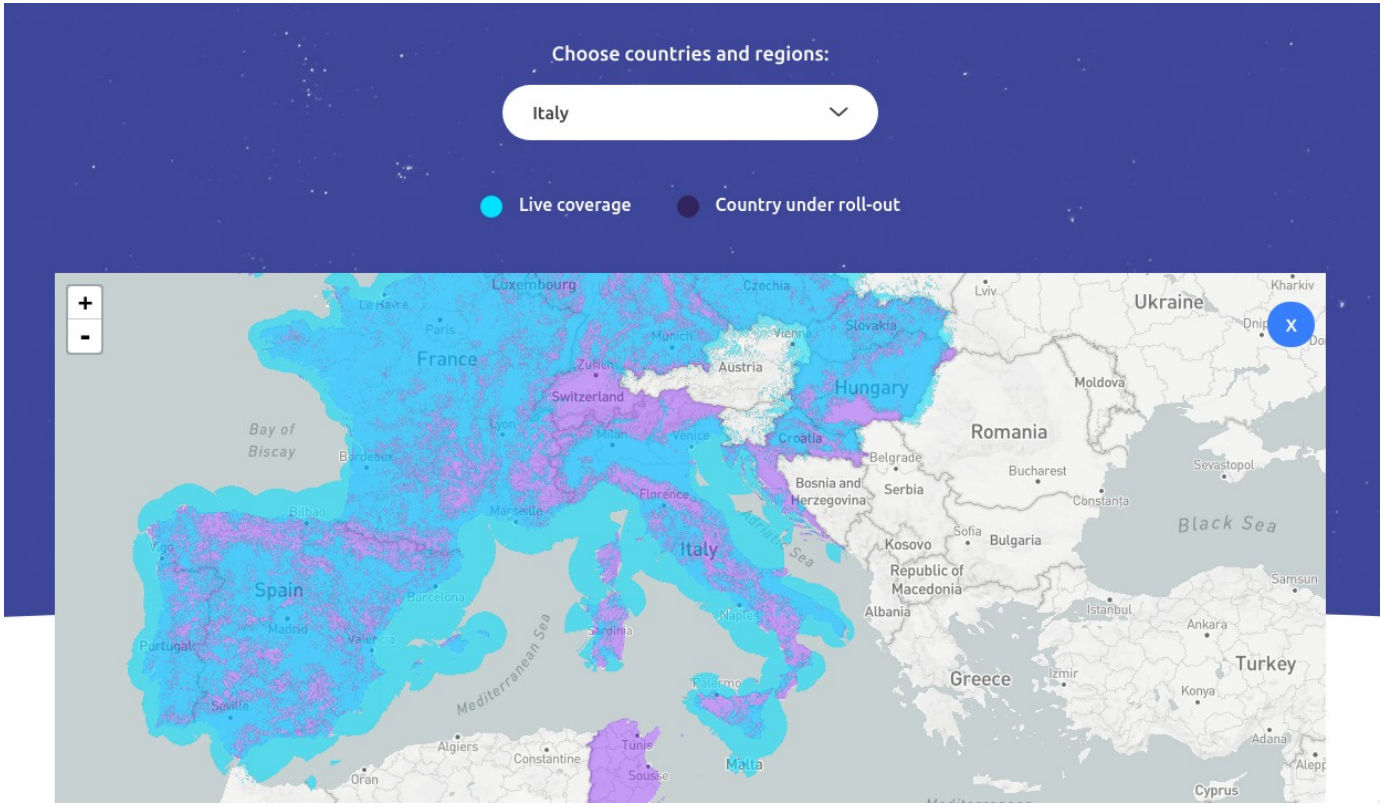
Callbacks

Customer IT

https://aprendiendoarduino.wordpress.com/category/sigfox/

SIGFOX

One network A billion dreams



https://www.sigfox.com/en/coverage

Business

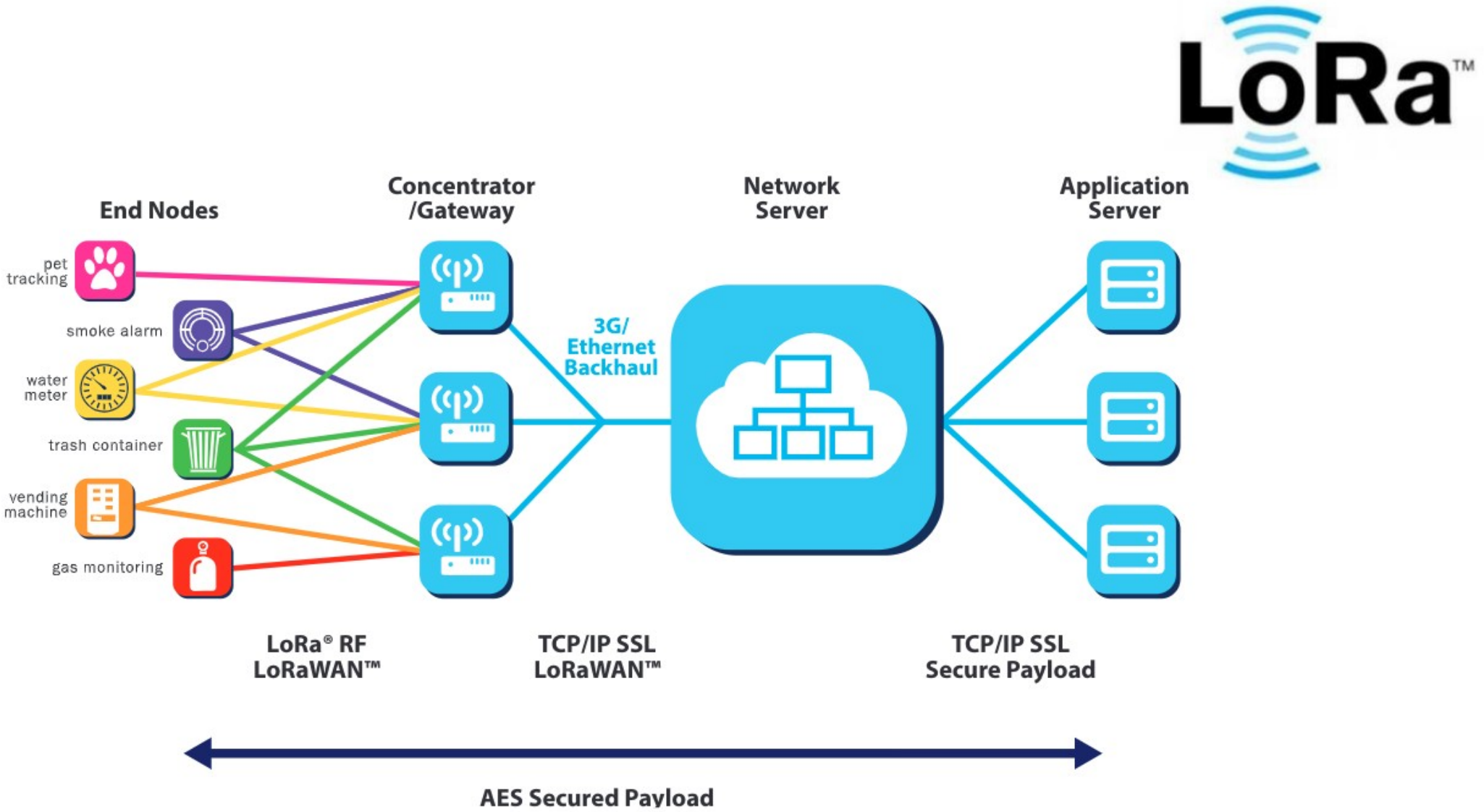
- “Dear Martin. SIGFOX pricing depends on the devices volume, the level of subscription required and the level of commitment. In order to give you a first idea, you can consider a range from 1 EUR per device per month to 1 EUR per device per year. If you have a specific project/use case to address we could help you identify the right price and plan that will best match your connectivity requirements.”

https://ask.sigfox.com/questions/574/subscription-price.html

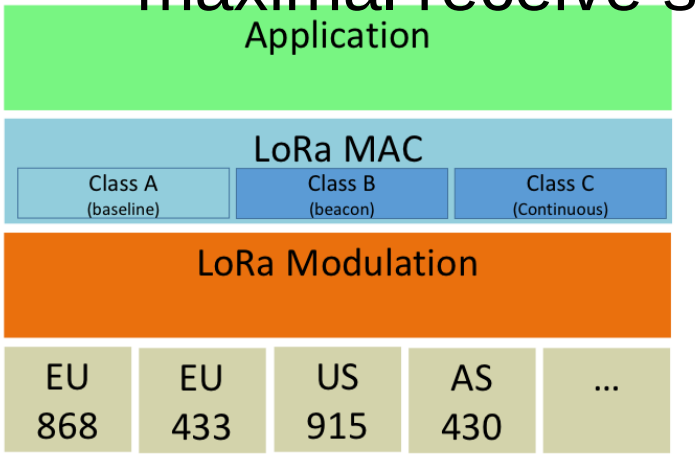
A simple example: Arduino MKRFOX1200

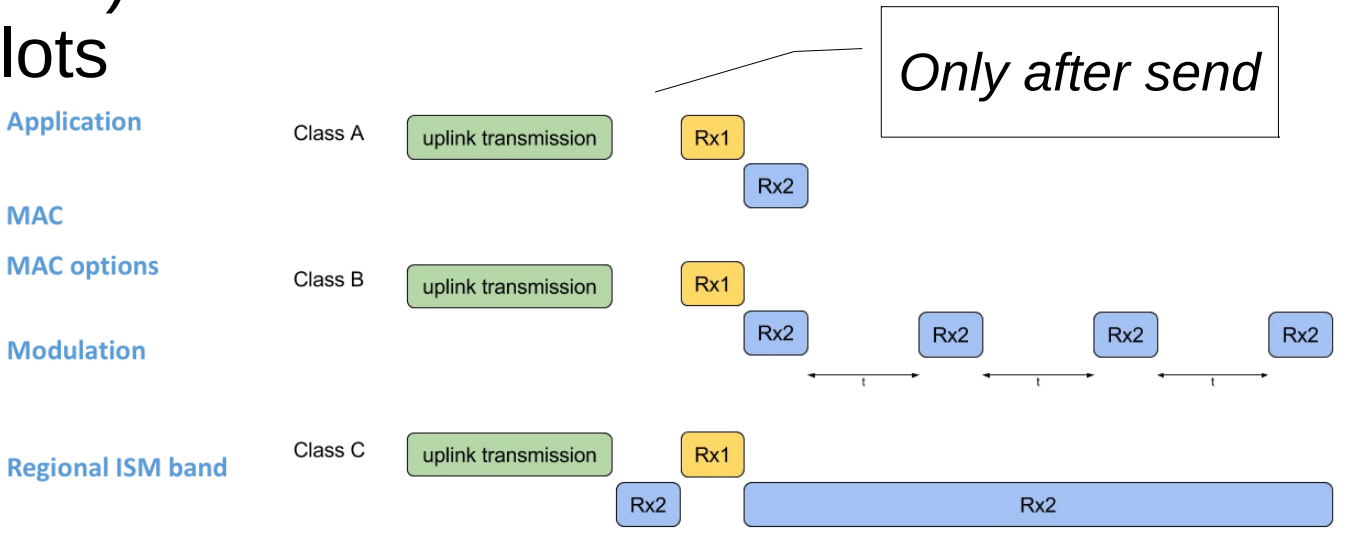
- https://www.arduino.cc/en/Reference/SigFox

ARDUINO™


LoRa™
End Nodes
Concentrator /Gateway
Network Server
Application Server
pet tracking
smoke alarm
water meter
trash container
vending machine
gas monitoring
3G/ Ethernet Backhaul
LoRa® RF LoRaWAN™
TCP/IP SSL LoRaWAN™
TCP/IP SSL Secure Payload
AES Secured Payload

- LoRa Alliance https://lora-alliance.org/
- 3 classes of devices LoRAWan:
  - Classe A: Bi-directional end-devices
  - Classe B (beacons): Bi-directional end-devices with scheduled receive slots
  - Classe C (continuous): Bi-directional end-devices with maximal receive slots





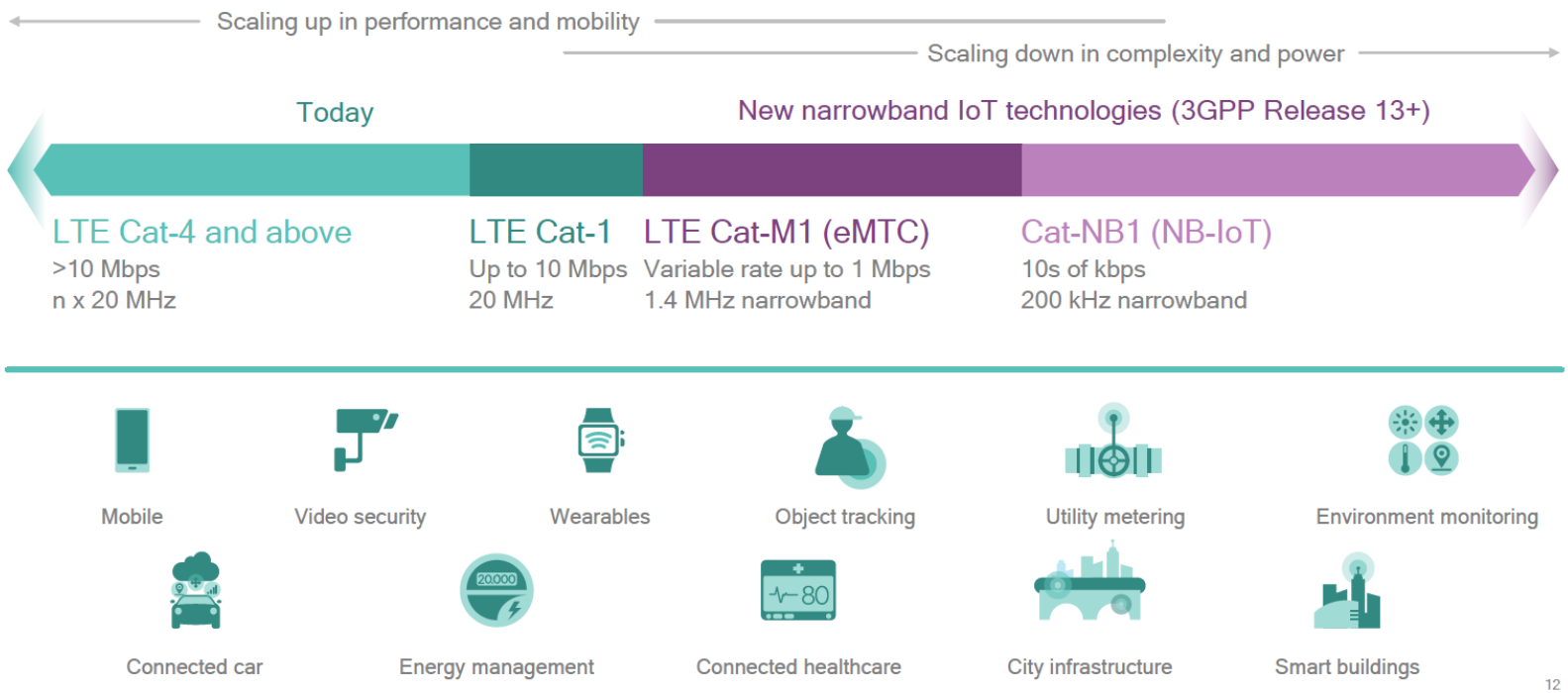
A simple example: Arduino MKRFOX1300

- https://www.arduino.cc/en/Tutorial/MKRWANLoraSendAndReceive

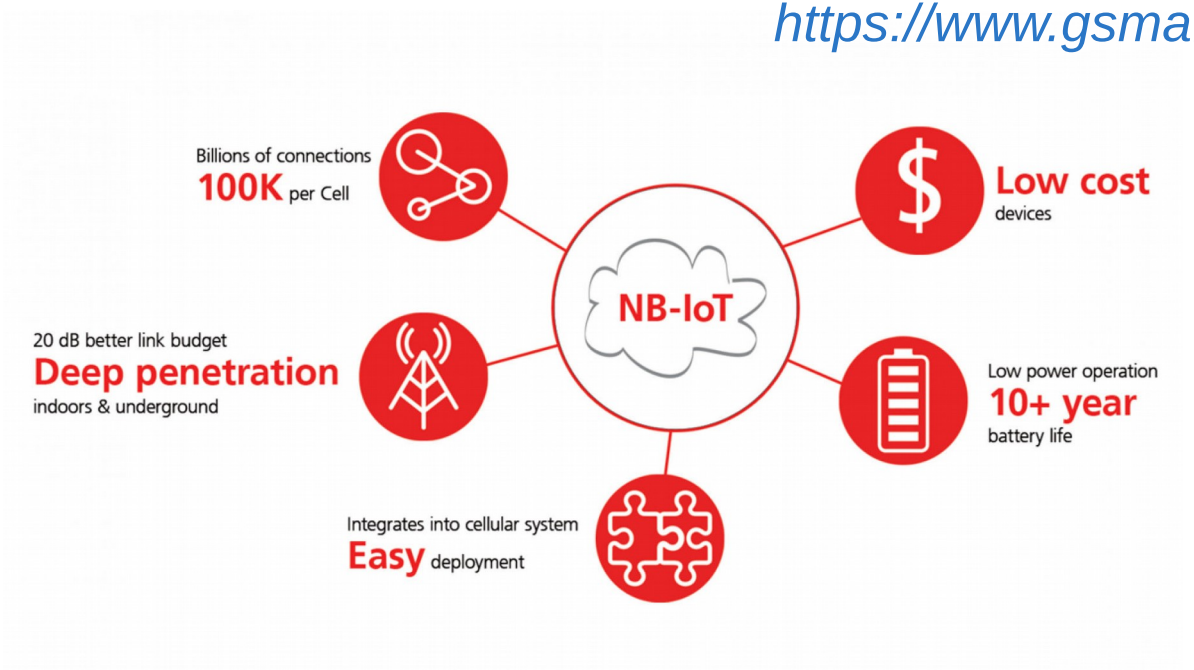
THE THINGS NETWORK

ARDUINO™

https://tutorial.cytron.io/2017/09/15/lesson-1-build-simple-arduino-lora-node-10-mi


Scaling up in performance and mobility
Scaling down in complexity and power
Today
New narrowband IoT technologies (3GPP Release 13+)
LTE Cat-4 and above
>10 Mbps
n x 20 MHz
LTE Cat-1
Up to 10 Mbps
20 MHz
LTE Cat-M1 (eMTC)
Variable rate up to 1 Mbps
1.4 MHz narrowband
Cat-NB1 (NB-IoT)
10s of kbps
200 kHz narrowband
Mobile
Video security
Wearables
Object tracking
Utility metering
Environment monitoring
Connected car
Energy management
Connected healthcare
City infrastructure
Smart buildings

https://www.gsma.com/iot/mobile-iot-commercial-launc



Operator	Country/Region	Technology
3	Hong Kong	NB-IoT
AIS	Thailand	LTE-M
AIS	Thailand	NB-IoT
APTG	Taiwan	LTE-M
APTG	Taiwan	NB-IoT
AT&T	North America	LTE-M
AT&T	Mexico	LTE-M
China Mobile	Hong Kong	NB-IoT
China Mobile	China	NB-IoT
China Telecom	China	NB-IoT
China Unicom	China	NB-IoT
Chunghwa Telecom	Taiwan	NB-IoT
Dialog Ataxia	Sri Lanka	LTE-M
DNA	Finland	NB-IoT
Dialog Ataxia	Sri Lanka	NB-IoT

Mobile operators and network equipment vendors generally set up Open IoT

TIM vodafone

A simple example!

https://wiki.dragino.com/index.php?title=NB-IoT_Shield

ARDUINO™

Star

Mesh

Cluster Tree

ZigBee Coordinator

ZigBee Routers

ZigBee Devices

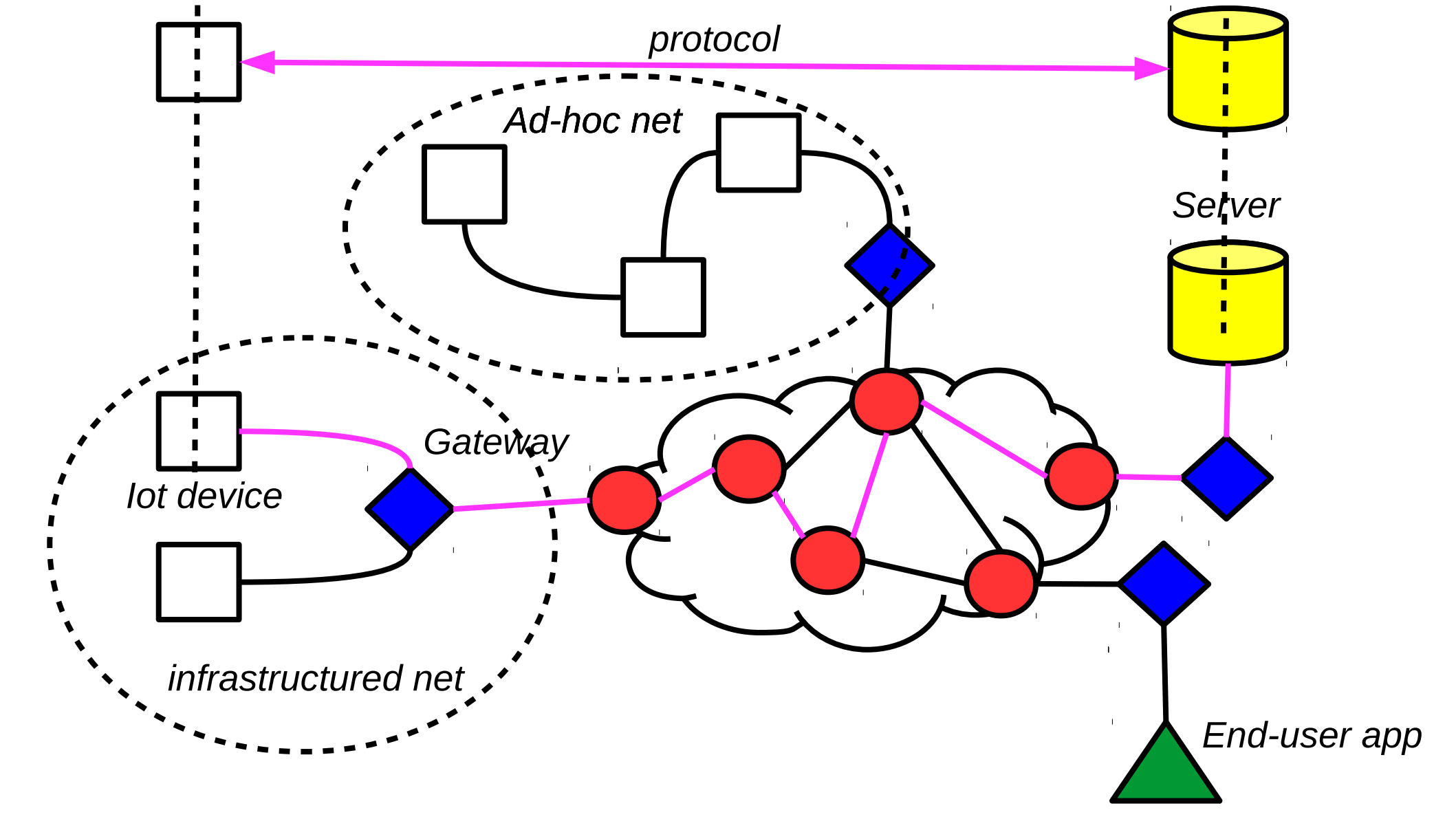
A simple example!

https://spin.atomicobject.com/2016/07/18/xbee-tutorial/

ARDUINO™

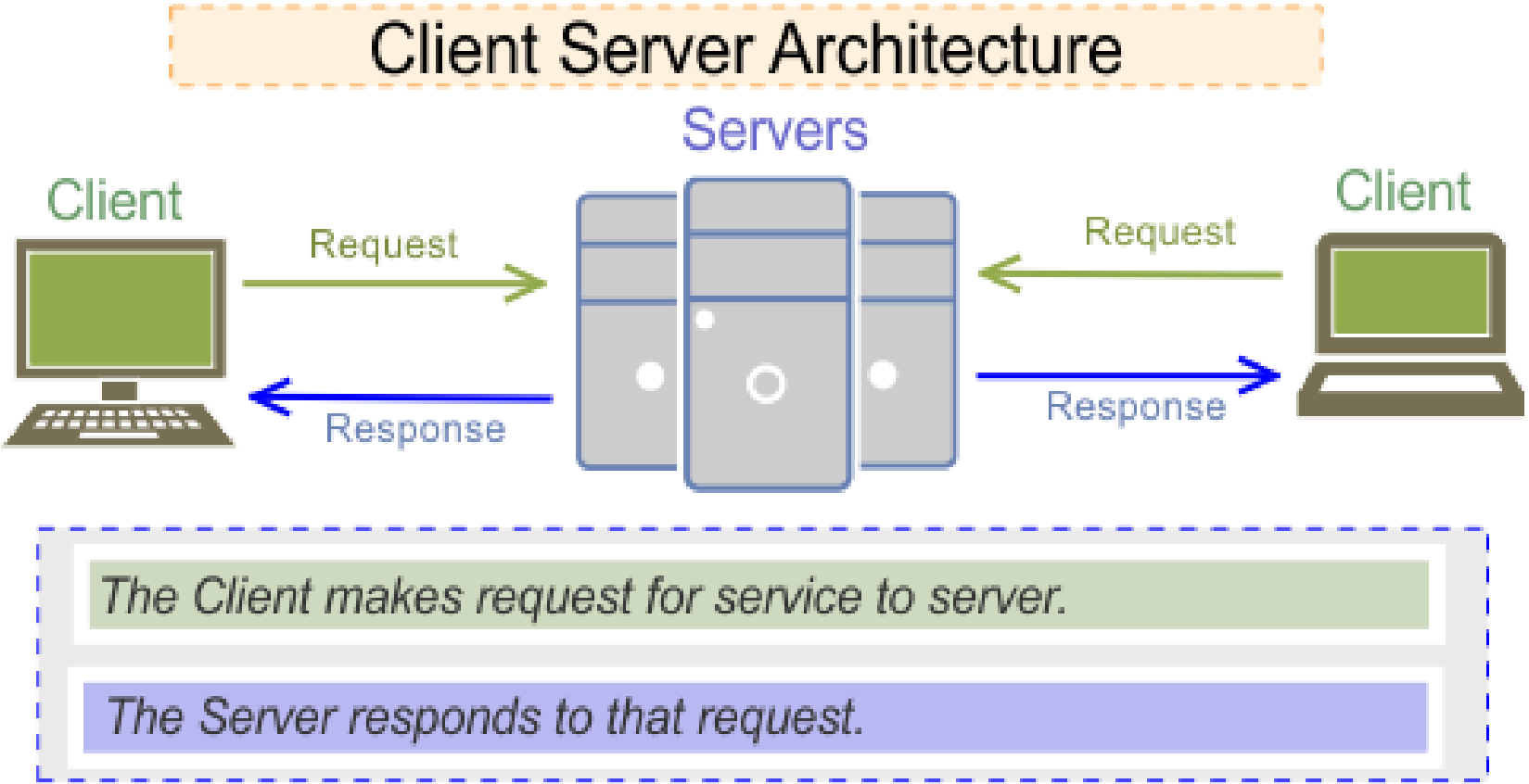
WIRELESS TECHNOLOGIES AT A GLANCE					
Technology	Frequency	Data rate	Range	Power	Cost
2G/3G	Cellular bands	10 Mb/s	Several km	High	High
802.15.4	2.4 GHz	250 kb/s	100 m	Low	Low
Bluetooth	2.4 GHz	1, 2.1, 3 Mb/s	100 m	Low	Low
LoRa	< 1 GHz	<50 kb/s	2-5 km	Low	Medium
LTE Cat 0/1	Cellular bands	1-10 Mb/s	Several km	Medium	High
NB-IoT	Cellular bands	0.1-1 Mb/s	Several km	Medium	High
SIGFOX	<1 GHz	Very low	Several km	Low	Medium
Weightless	<1 GHz	0.1-24 Mb/s	Several km	Low	Low
Wi-Fi (11f/h)	2.4, 5, <1 GHz	0.1-1 Mb/s	Several km	Medium	Low
WirelessHART	2.4 GHz	250 kb/s	100 m	Medium	Medium
ZigBee	2.4 GHz	250 kb/s	100 m	Low	Medium
Z-Wave	908.42 MHz	40 kb/s	30 m	Low	Medium

https://www.electronicdesign.com/iot/12-wireless-options-iotm2m-diversity-or-dilemma


protocol
Ad-hoc net
Server
Gateway
Iot device
infrastructured net
End-user app

A network protocol is a set of established rules that dictates how to format, transmit and receive data so computer network devices -- from servers and routers to endpoints -- can communicate regardless of the differences in their underlying infrastructures, designs or standards.

HTTP: Hypertext Transfer Protocol



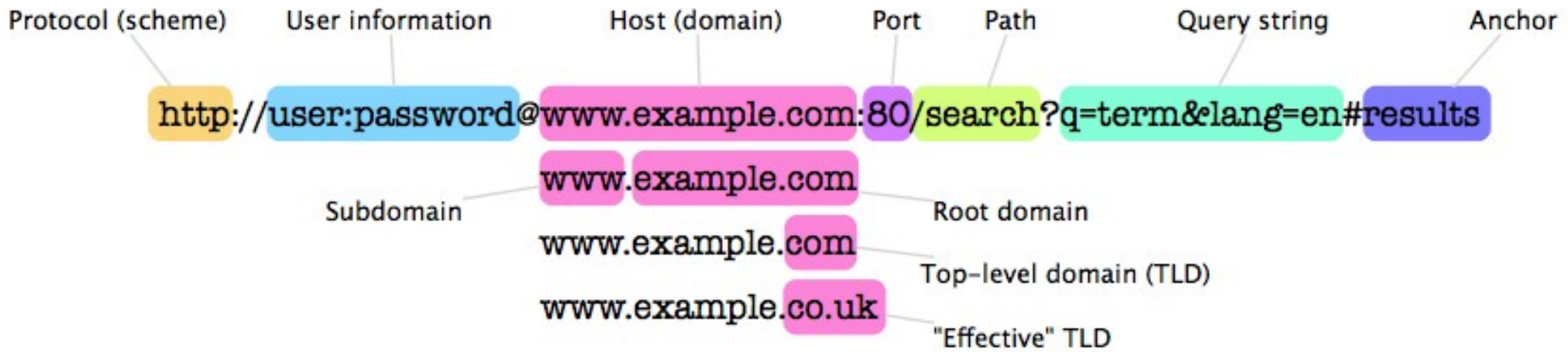
http://www.dailywebsolutions.com/what-is-client-server-architecture

HTTP should be, Resource Transfer Protocol

A resource is a chunk of data identified by a URL Unified Resource Locator

- Static: A file
- Dynamic: The output of a script/function/program

Know Your Uniform Resource Locator



https://stackoverflow.com/questions/406192/get-current-url-with-jquery

Web of things

- http://mynetwork/thing1/temperature1
- http://mynetwork/thing2/actuator?switch=on

Resources in the Web of Things are the data generated by the sensors or to control the actuators

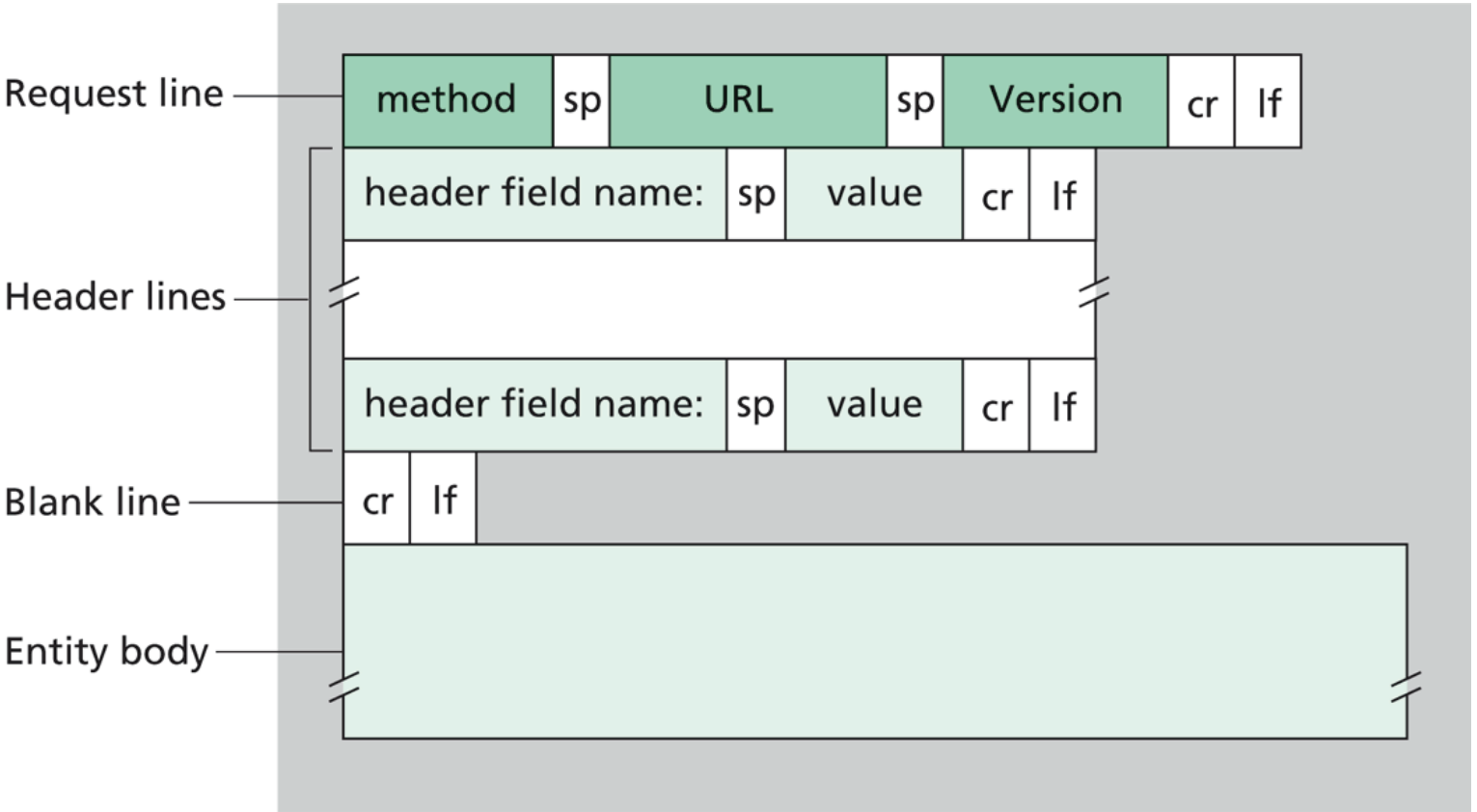
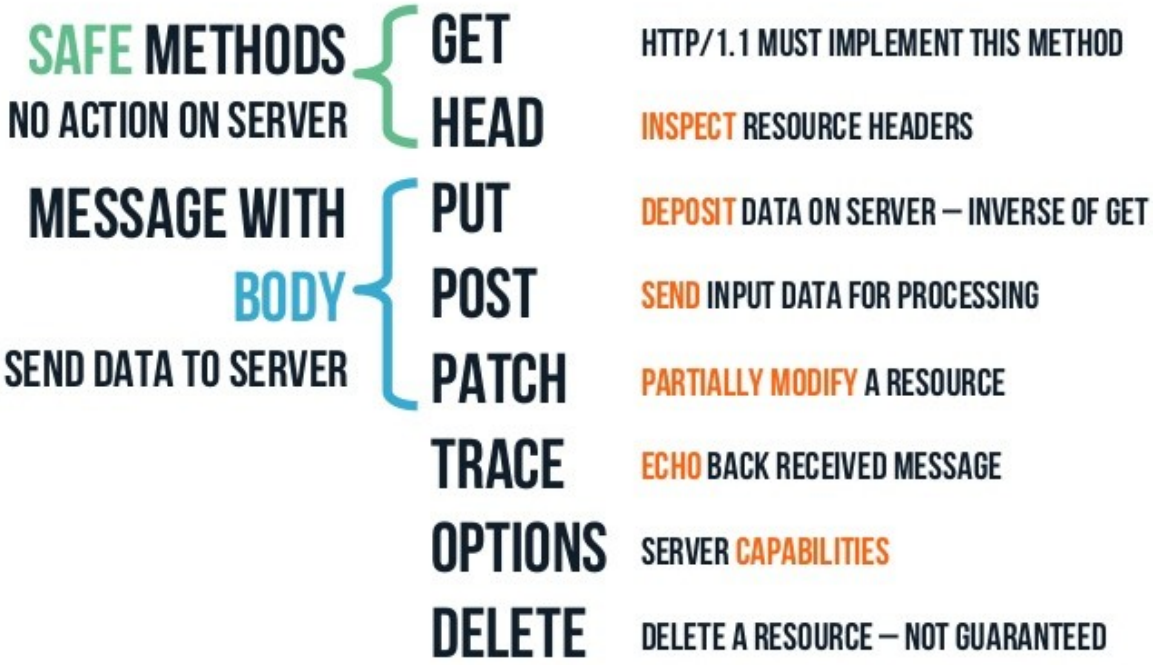


Figure 2.8 ♦ General format of a request message



http://www.aliencoders.org/content/automated-bash-script-to-test-http-header-response/

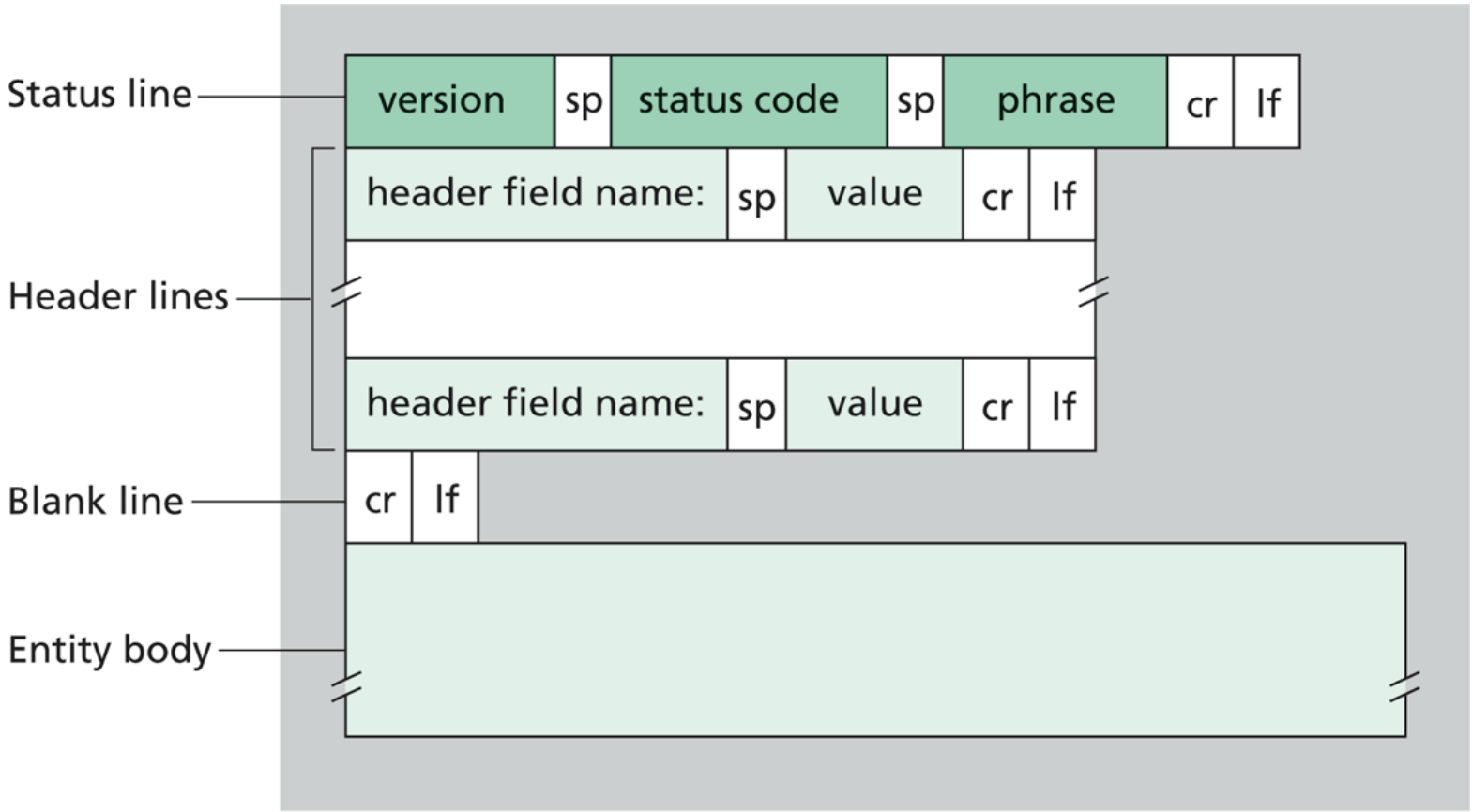


Figure 2.9 ♦ General format of a response message

https://www.cheatography.com/kstep/cheat-sheets/http-status-codes/

Cheatography

HTTP Status Codes Cheat Sheet

by kstep via cheatography.com/424/cs/199/

1xx: HTTP Informational Codes

100	Continue
101	Switching Protocols
102	Processing WebDAV
103	Checkpoint draft POST PUT
122	Request-URI too long IE7

2xx: HTTP Successful Codes

200	OK
201	Created
202	Accepted
203	Non-Authoritative Information 1.1
204	No Content
205	Reset Content
206	Partial Content
207	Multi-Status WebDAV 4918
208	Already Reported WebDAV 5842
226	IM Used 3229 GET

3xx: HTTP Redirection Codes

300	Multiple Choices
301	Moved Permanently
302	Found
303	See Other 1.1
304	Not Modified
305	Use Proxy 1.1
306	Switch Proxy unused
307	Temporary Redirect 1.1
308	Permanent Redirect 7538

4xx: HTTP Client Error Code

400	Bad Request
401	Unauthorized
402	Payment Required res
403	Forbidden
404	Not Found
405	Method Not Allowed
406	Not Acceptable
407	Proxy Authentication Required
408	Request Timeout
409	Conflict
410	Gone
411	Length Required
412	Precondition Failed
413	Request Entity Too Large
414	Request-URI Too Long
415	Unsupported Media Type
416	Requested Range Not Satisfiable
417	Expectation Failed
418	I'm a teapot 2324
422	Unprocessable Entity WebDAV 4918
423	Locked WebDAV 4918
424	Failed Dependency WebDAV 4918
425	Unordered Collection 3648
426	Upgrade Required 2817
428	Precondition Required draft
429	Too Many Requests draft
431	Request Header Fields Too Large draft

5xx: HTTP Server Error Codes

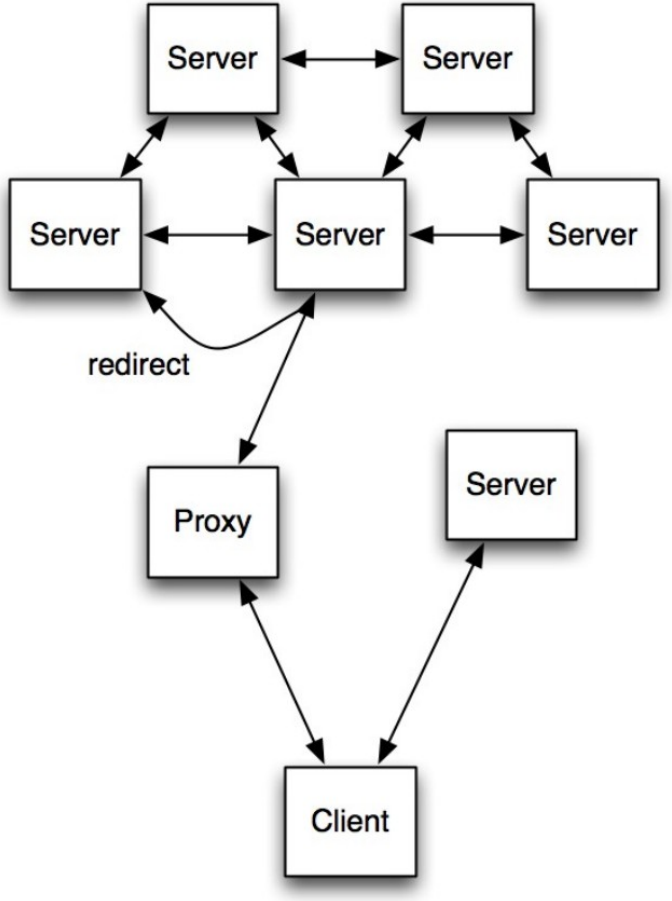
500	Internal Server Error
501	Not Implemented
502	Bad Gateway
503	Service Unavailable
504	Gateway Timeout
505	HTTP Version Not Supported
506	Variant Also Negotiates 2295
507	Insufficient Storage WebDAV 4918
508	Loop Detected WebDAV 5842
509	Bandwidth Limit Exceeded nostd
510	Not Extended 2774
511	Network Authentication Required draft
598	Network read timeout error nostd
599	Network connect timeout error nostd

HTTP Code Comments

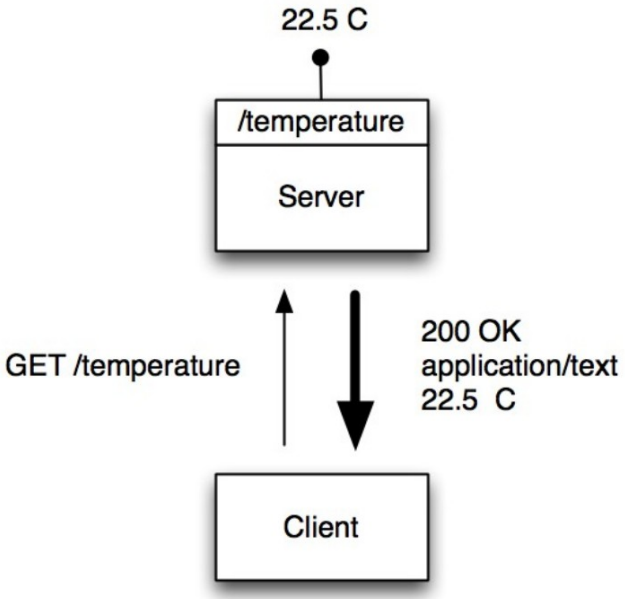
WebDAV	WebDAV extension
1.1	HTTP/1.1
GET, POST, PUT, POST	For these methods only
IE	IE extension
MS	MS extension
nginx	nginx extension
2518, 2817, 2295, 2774, 3229, 4918, 5842	RFC number
draft	Proposed draft
nostd	Non standard extension

REST

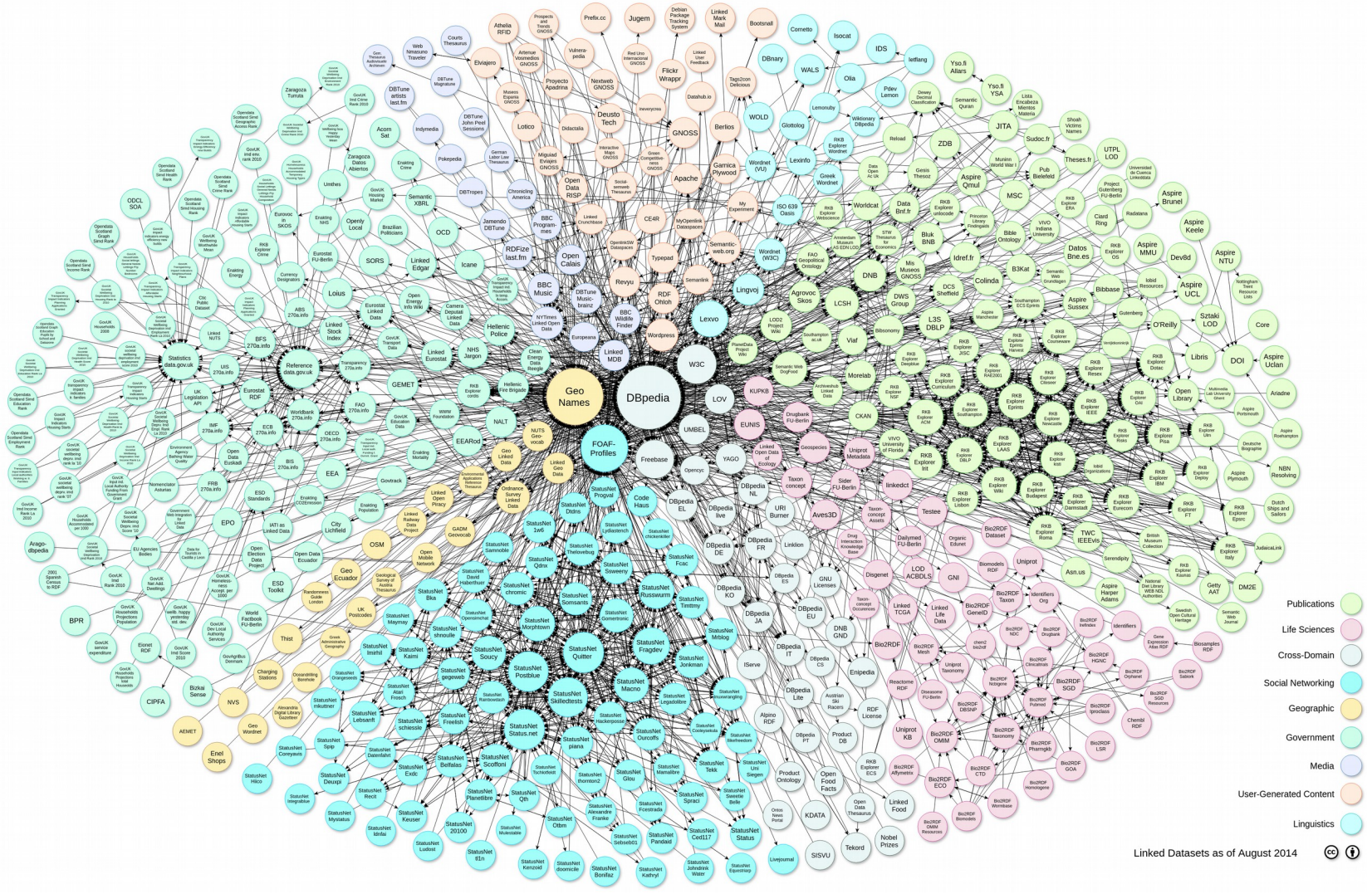
- Architectural Style (not a standard)
- Idea: a network of web resources where the client progresses through an application by traversing links to access new resources, namely to access there source state (i.e. the resorce representation state)
- Uses existing standards such as HTTP (not only HTTP!!!)



CRUD	REST	
CREATE	POST	Create a sub resource
READ	GET	Retrieve the *current state* of the resource
UPDATE	PUT	Initialize or update the state of a resource at the given URI
DELETE	DELETE	Clear a resource, after the URI is no longer valid

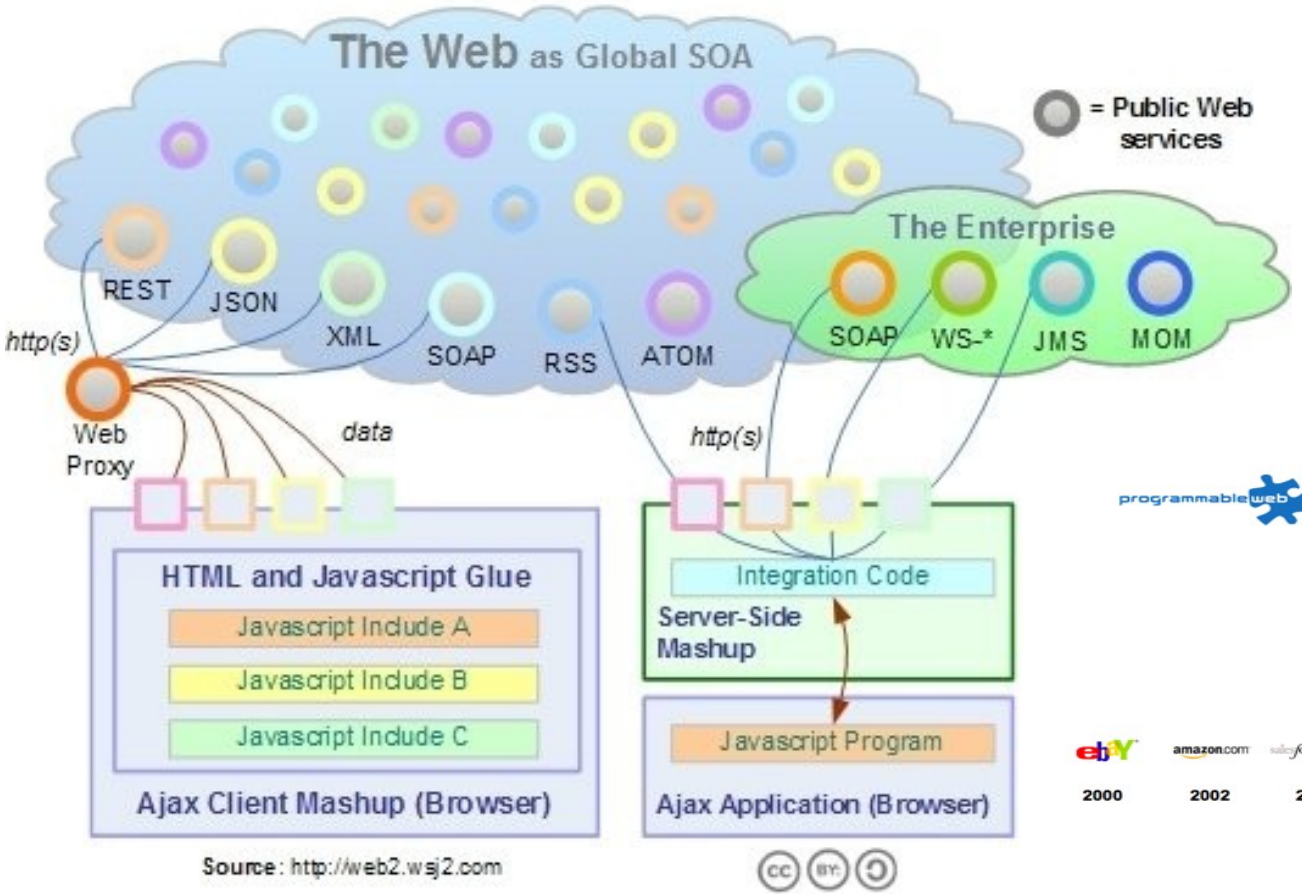


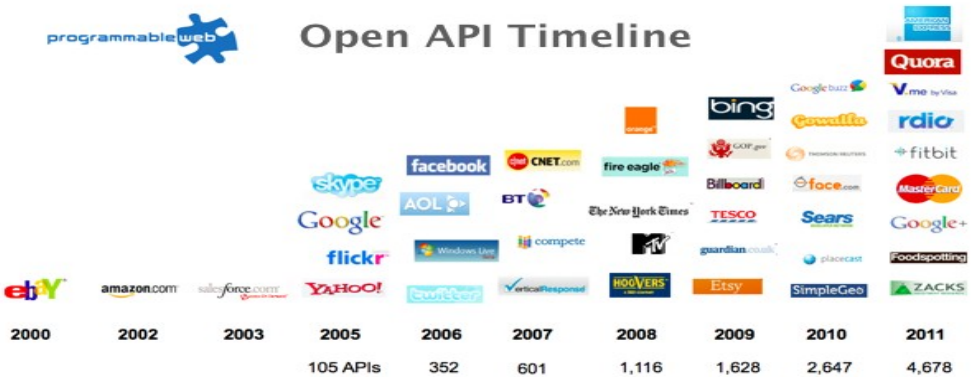
https://www.slideshare.net/cesare.pautasso/some-rest-design-patterns-and-antipatterns



https://upload.wikimedia.org/wikipedia/commons/a/a9/LOD_Cloud_2014-08.svg

Mashup (web application hybrid)

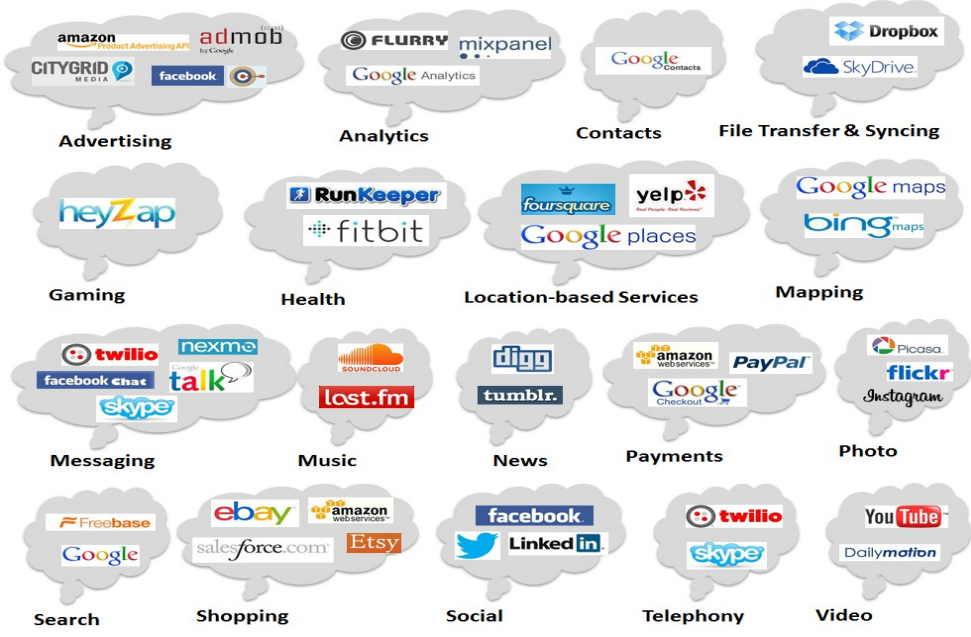


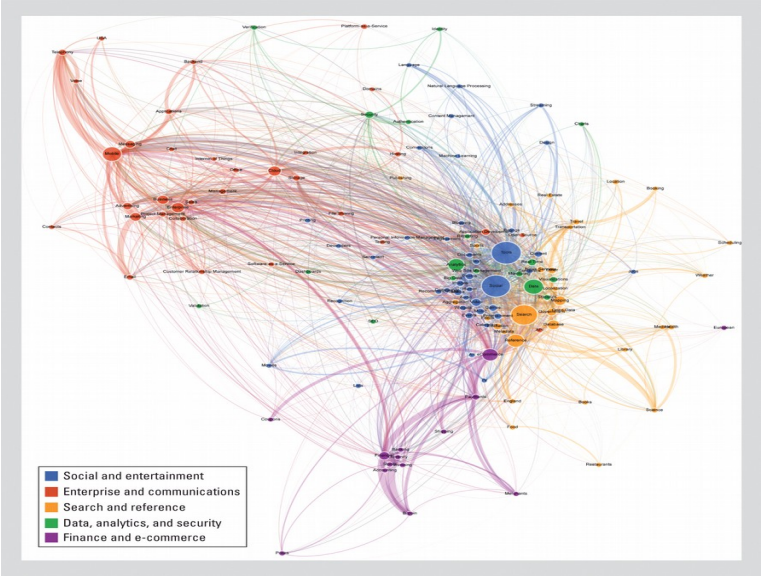


https://www.researchgate.net/figure/Mashups-on-the-Web-and-in-the-Enterprise_fig1_329644655,
https://www.slideshare.net/jmusser/open-api-ecosystem-overview-december-2010

ProgrammableWeb

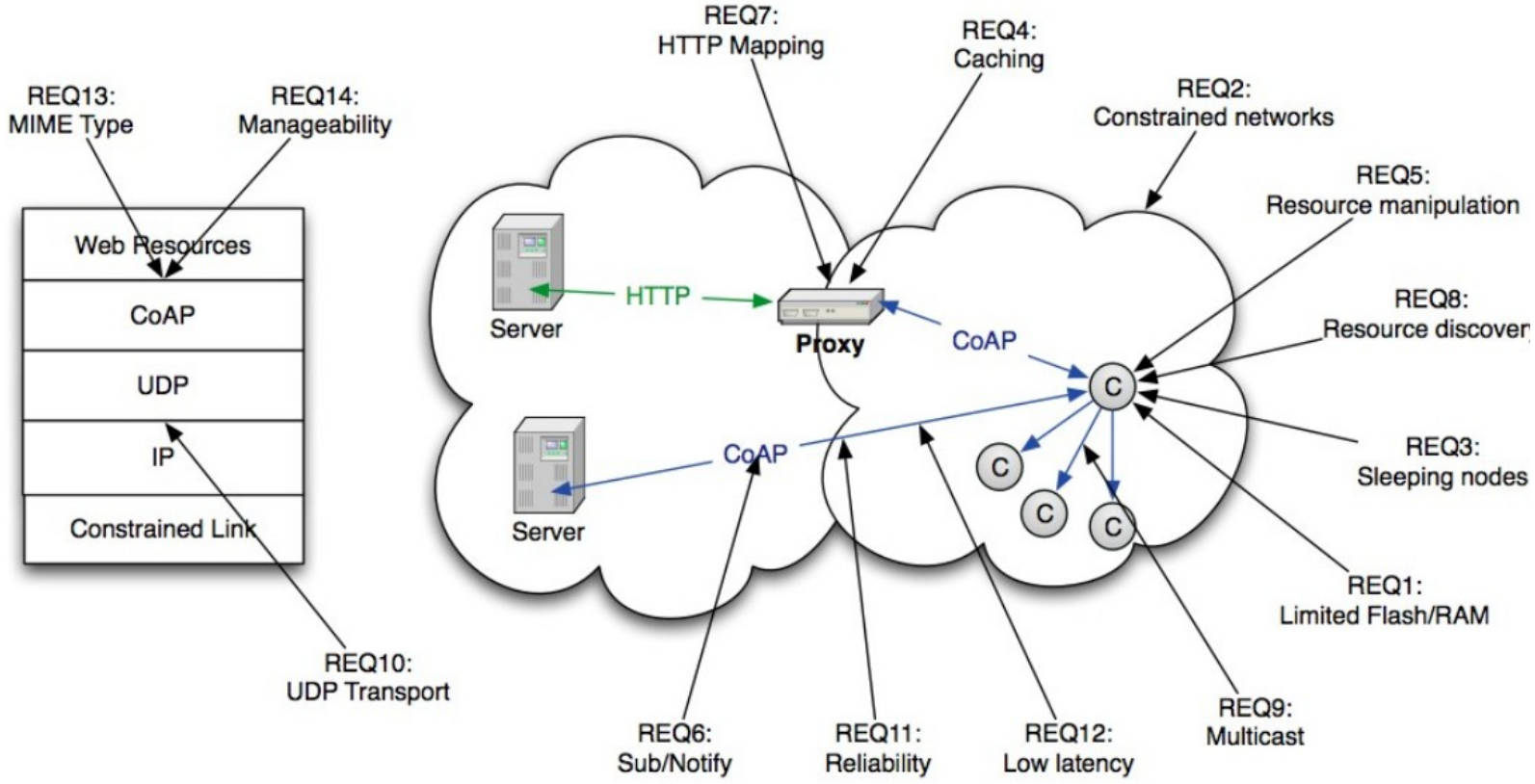
https://www.programmableweb.com/





IS HTTP SUITABLE FOR IOT?

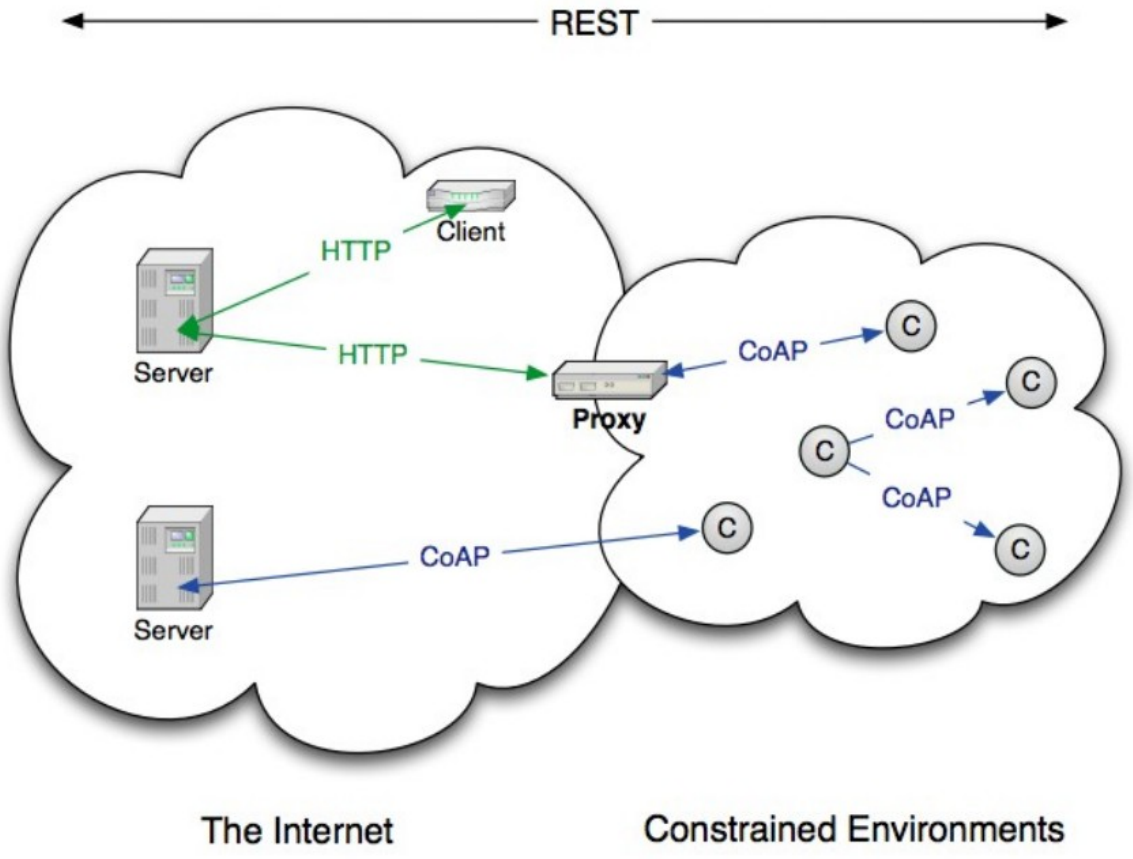
COAP Constrained Application Protocol



See draft-shelby-core-coap-req

http://bit.ly/ARMcoap

COAP Architecture



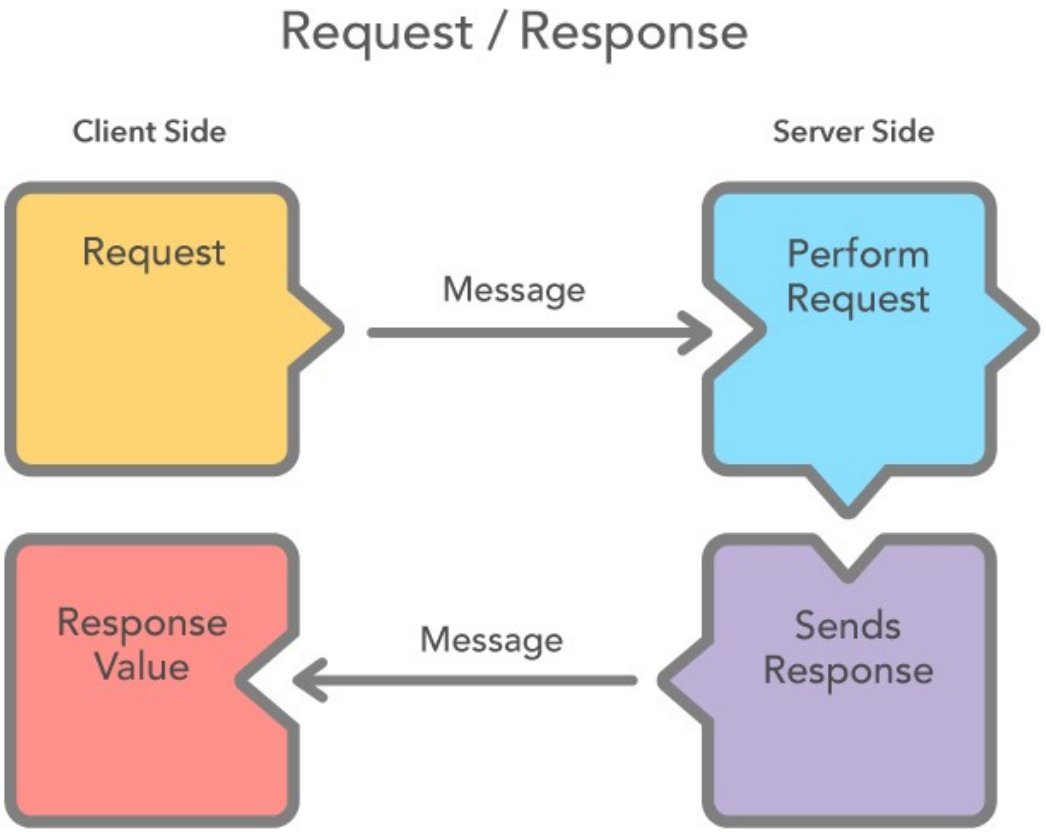
CoAP is

- *A very efficient RESTful protocol*
- *Ideal for constrained devices and networks*
- *Specialized for M2M applications*
- *Easy to proxy to/from HTTP*

Main features

- Embedded web transfer protocol (coap://)
- Asynchronous transaction model
- UDP binding with reliability and multicast support
- GET, POST, PUT, DELETE methods
- URI support
- Small, simple 4 byte header
- DTLS based PSK, RPK and Certificate security
- Subset of MIME types and HTTP response codes
- Built-in discovery
- Optional observation and block transfer

Up to now

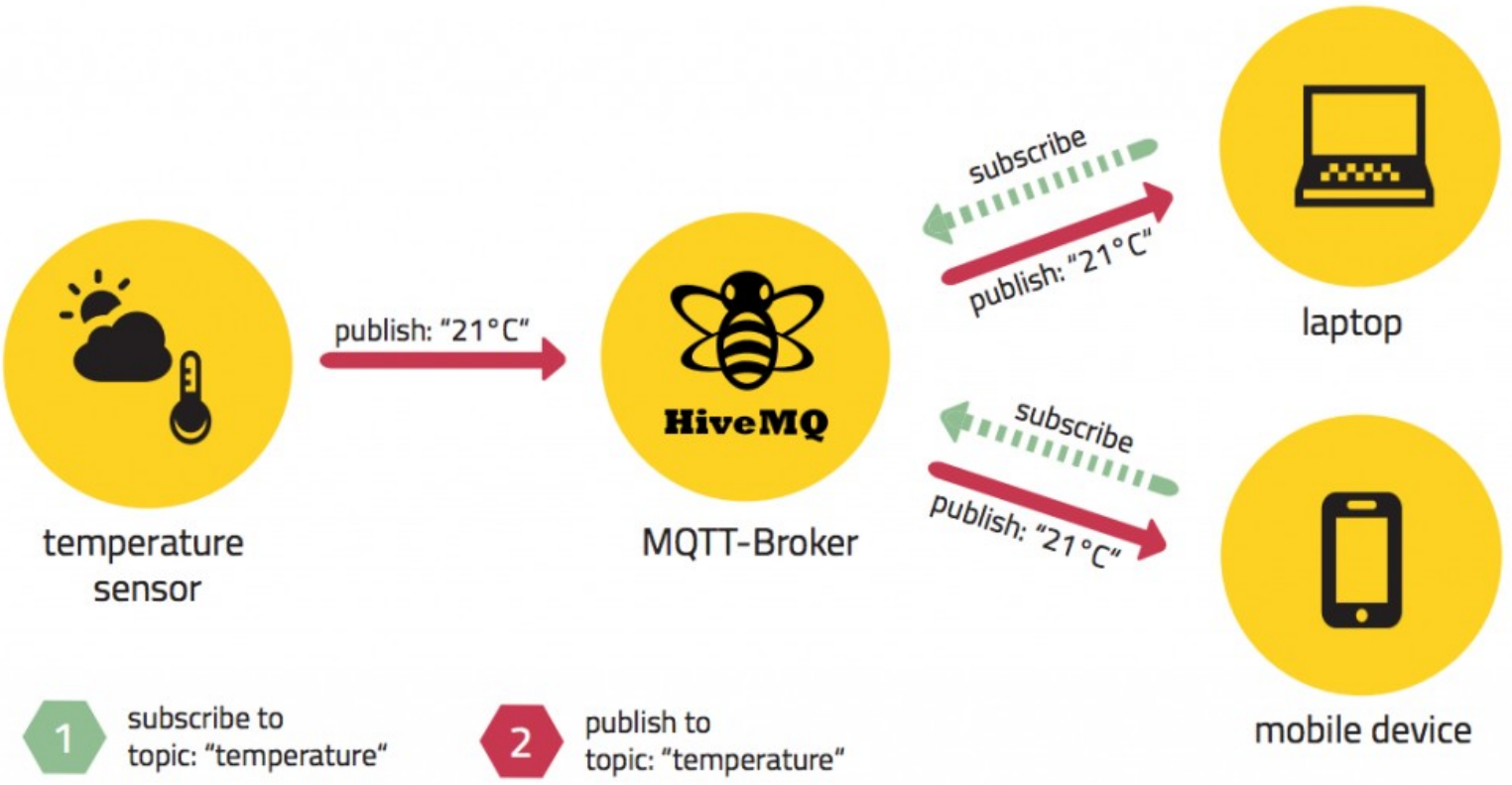


https://vanilla-java.github.io/2016/05/17/Modelling-Microservice-Patterns-in-Code.html

How to know when something interesting happens?

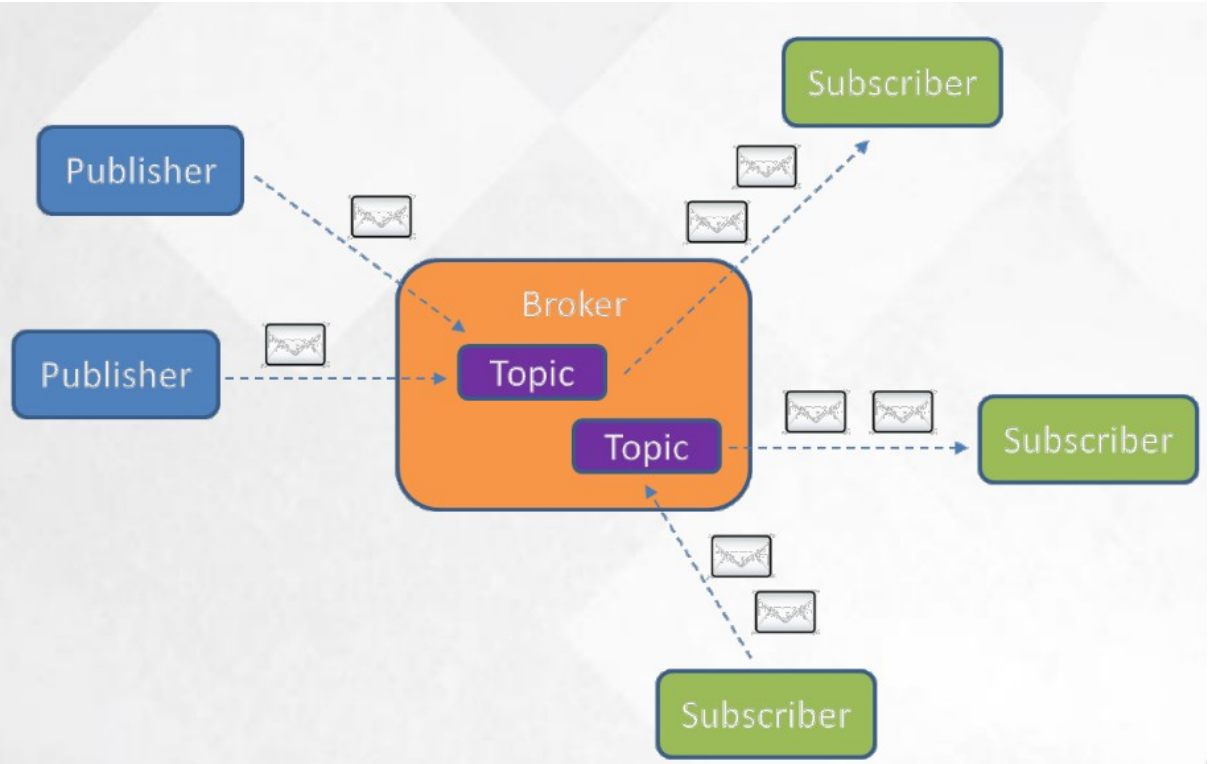
- You cannot know in advance!
- Request at regular intervals → polling
- Very inefficient
- We need a different paradigm

Publish/Subscribe



https://iotraspi2.wordpress.com/2016/02/21/mqtt/

Publish/Subscribe



- Broker receives subscription from clients on topics
- Broker receives messages and forward them to the subscribers
- Clients subscribe/publishes on topics

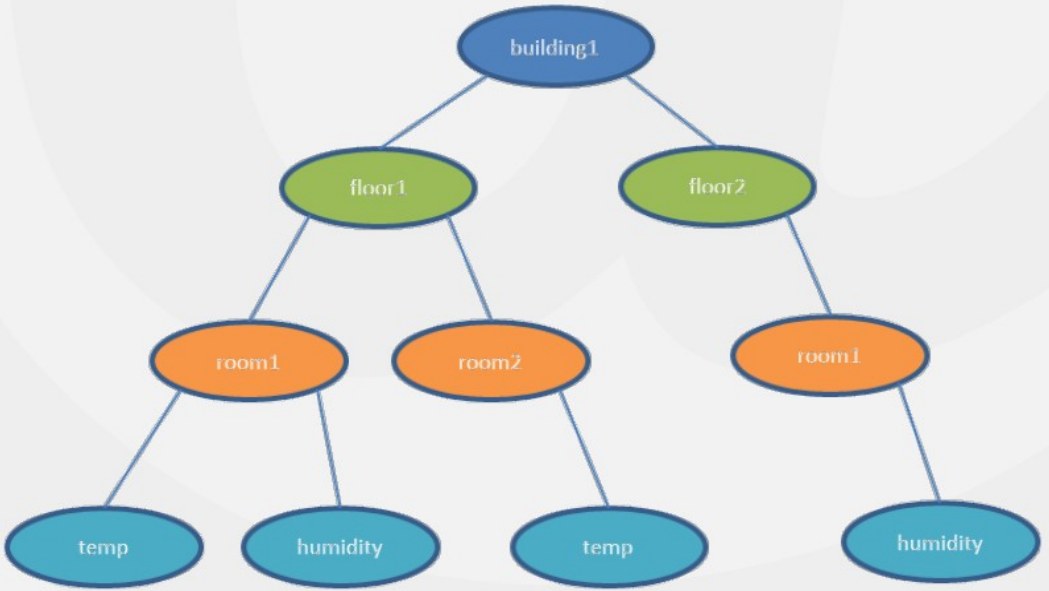
https://www.slideshare.net/paolopat/mqtt-iot-protocols-comparison

MQTT (Message Queue Telemetry Transport)

- Lightweight : smallest packet size 2 bytes (header),
- Reduced clients footprint (C# M2Mqtt library 30 KB)
- Reliable : three QoS and patterns to avoid packet loss on client disconnection
- Simple :
  - TCP based
  - **Asynchronous**
  - **Publish/Subscribe**
  - Few verbs
  - Payload agnostic

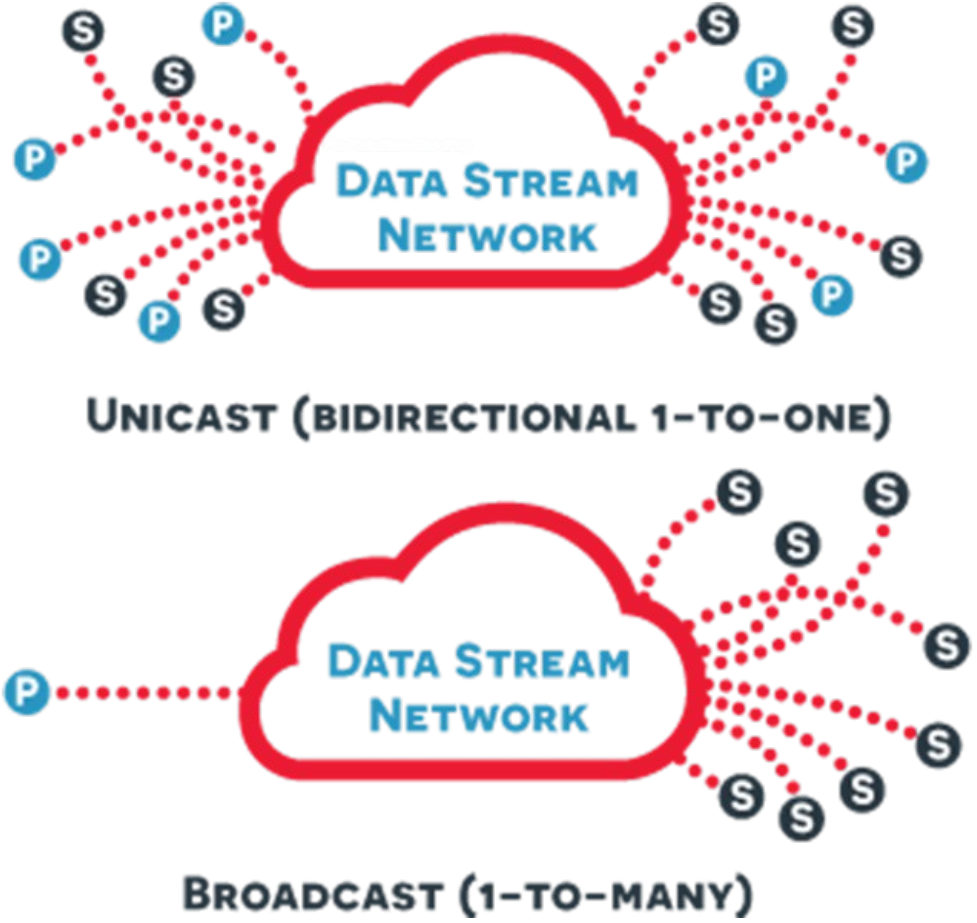
Topics for publish and subscribe

- hierarchical
- wildcards (# and +)
  - ex. building1/+/room1, building1/floor1/room1/#



https://www.slideshare.net/paolopat/mqtt-iot-protocols-comparison

P/S paradigms



https://www.pubnub.com/blog/2015-01-12-what-is-publishsubscribe-and-realtime-data-streams/

Google Trends