Network Architectures and Topologies for IoT

COMP5047 – Lecture 05

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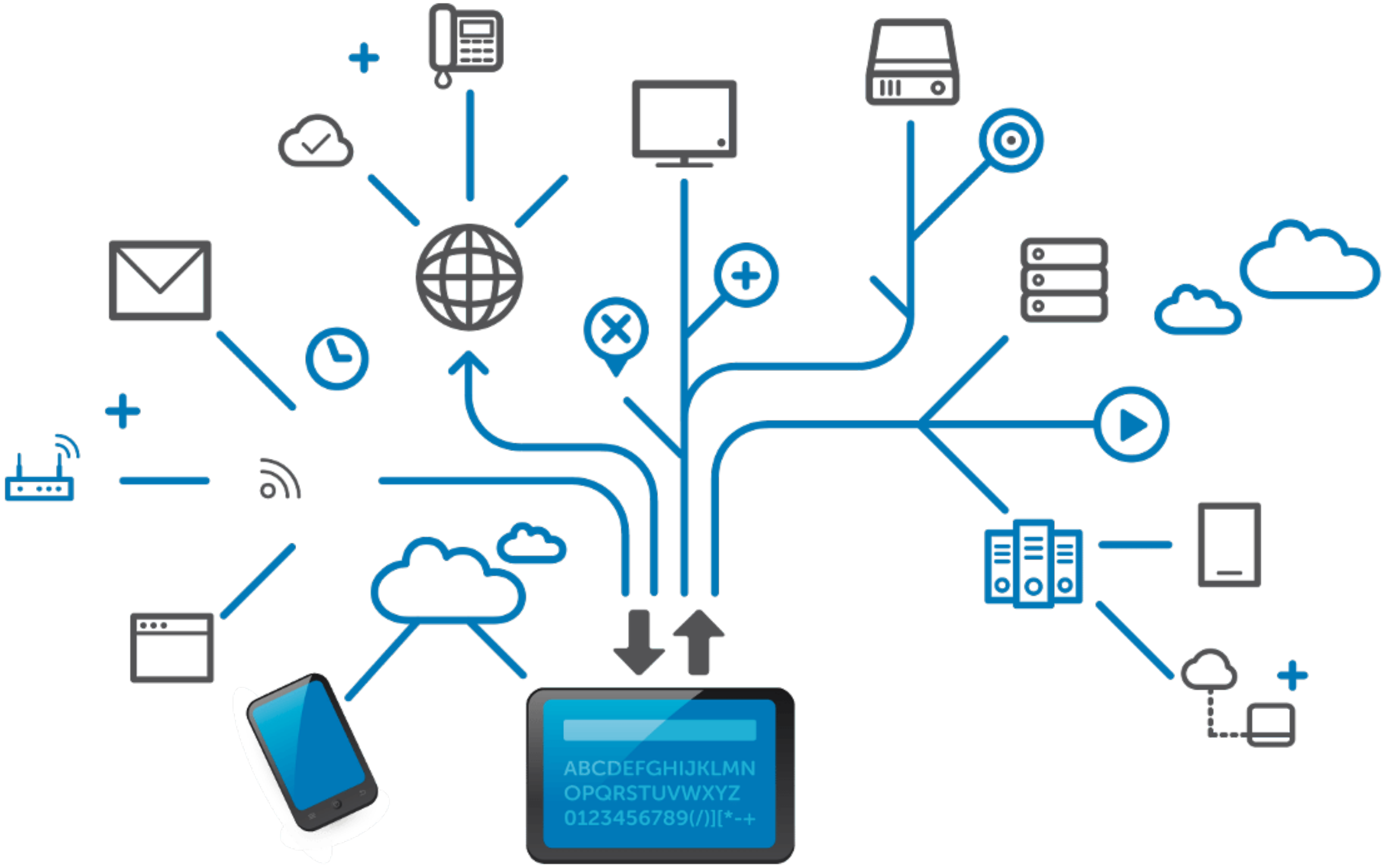
How should we connect things?



https://assignmentstudio.net/what-are-networks/

Things to consider

- Application needs
    - What kind of connectivity needed?
- Resources
    - How much resources available
- Context
    - Where and environmental factors
- Scalability
    - How many devices? What will happen in future?
- Safety
    - What can go wrong?

Networking Architectures

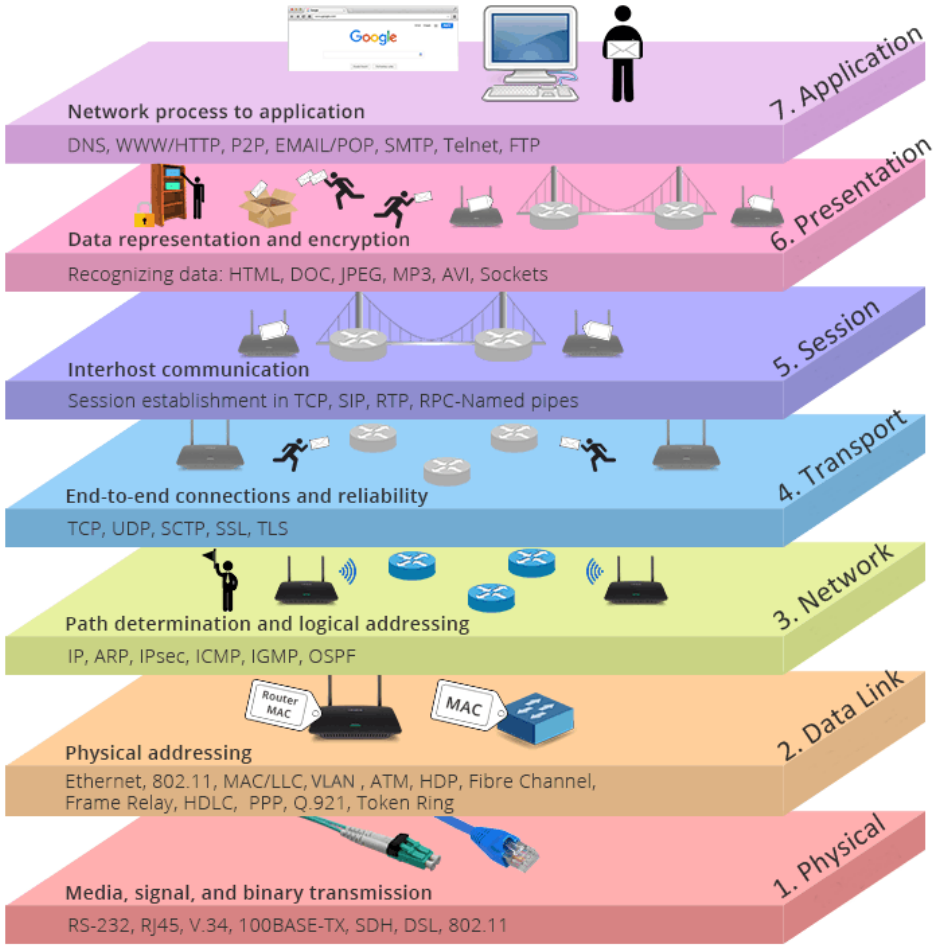
- So many aspects to consider
  - Hardware
  - Protocols
  - Software and APIs
  - Manufacturers
  - Users
- How we make sure interoperability/scalability?

Open Systems Interconnection (OSI)

- A conceptual model that describes the universal standard of communication functions.
  - No regard to the system's underlying internal technology.
- Assure the interoperability of all diverse communication systems through:
  - **encapsulation and de-encapsulation of data**

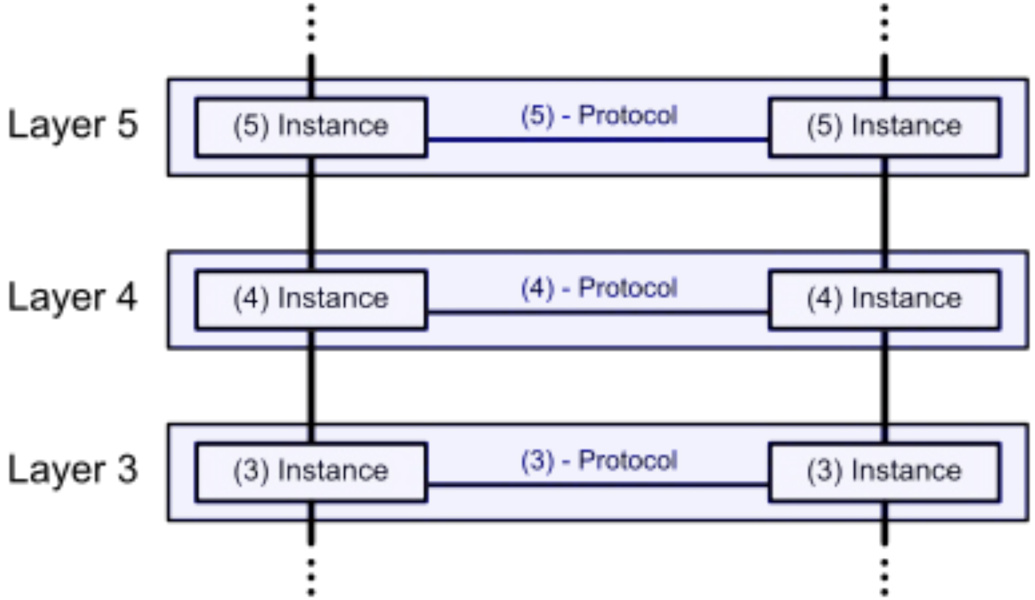
Adapted from Wikipedia

Open Systems Interconnection (OSI)



7. Application
Network process to application
DNS, WWW/HTTP, P2P, EMAIL/POP, SMTP, Telnet, FTP
6. Presentation
Data representation and encryption
Recognizing data: HTML, DOC, JPEG, MP3, AVI, Sockets
5. Session
Interhost communication
Session establishment in TCP, SIP, RTP, RPC-Named pipes
4. Transport
End-to-end connections and reliability
TCP, UDP, SCTP, SSL, TLS
3. Network
Path determination and logical addressing
IP, ARP, IPsec, ICMP, IGMP, OSPF
2. Data Link
Router MAC
MAC
Physical addressing
Ethernet, 802.11, MAC/LLC, VLAN , ATM, HDP, Fibre Channel, Frame Relay, HDLC, PPP, Q.921, Token Ring
1. Physical
Media, signal, and binary transmission
RS-232, RJ45, V.34, 100BASE-TX, SDH, DSL, 802.11

https://community.fs.com/



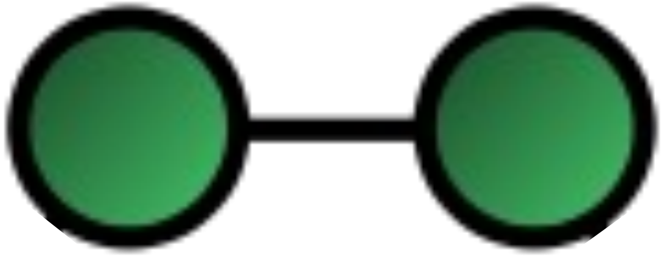
Adapted from Wikipedia

Network Topologies

- How different parts are connected?

Point-to-Point

- Possibly the simplest
- Simple wiring
- But only two devices connect to each other



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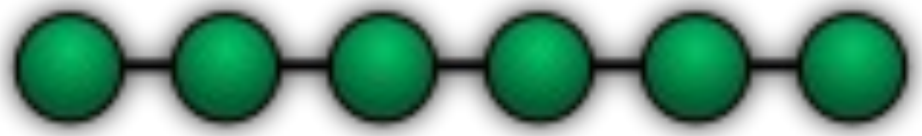
Line

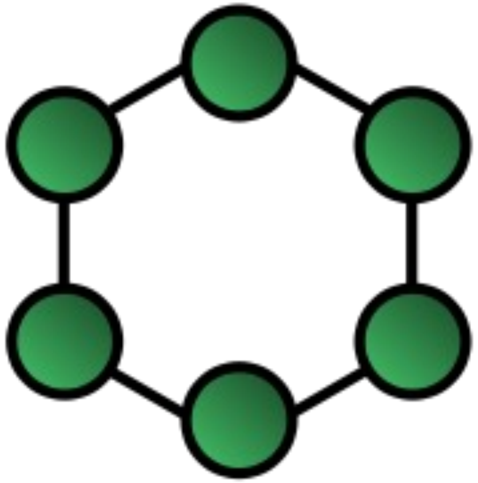
- Extended point to point
- Simple wiring
- One node failure can disconnect the network



Images: https://en.wikipedia.org/

Ring Topology

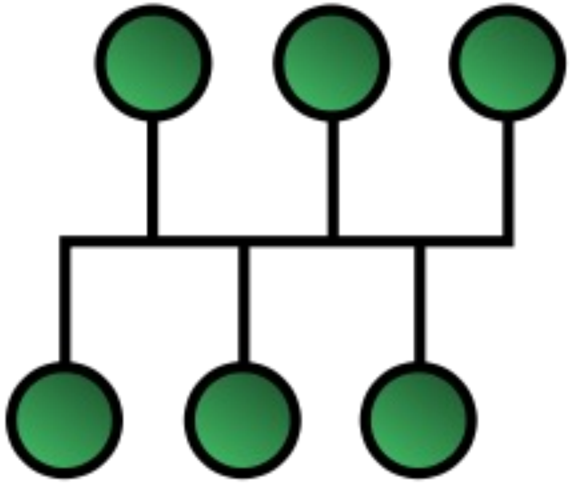
- Simple wiring
  - Connects device to device
- One link failure will not affect the network
- One device failure doesn't mean the network is broken if bidirectional



Images: https://en.wikipedia.org/

Bus Topology

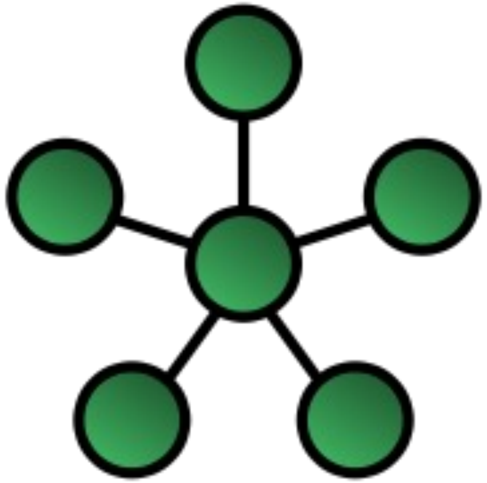
- Simple wiring
- Connects many devices together
- Performance depends on the bus
  - Speed
  - Failure



Images: https://en.wikipedia.org/

Star or Hub-and-Spoke Topology

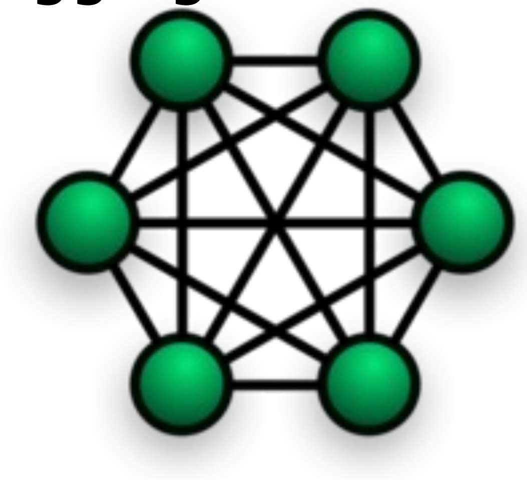
- Simple wiring
  - But complicated than bus
- Connects many devices to a hub
  - E.g. your microcontroller to peripheral
- Scalability is low
  - Need many connections to the hub

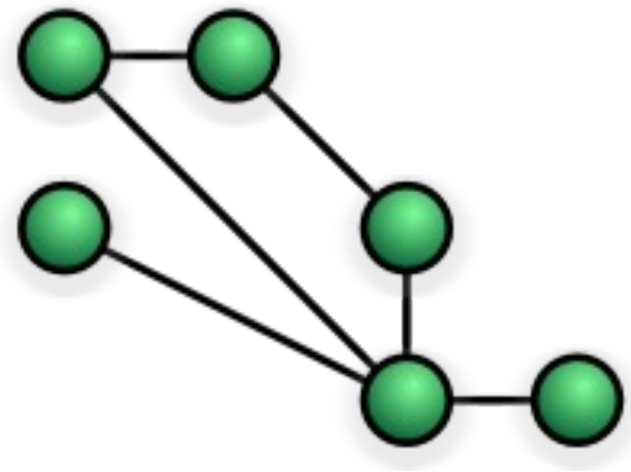


Images: https://en.wikipedia.org/

Mesh Topology

- Can be a fully or partially connected mesh
  - Most practical networks are partially connected
  - Some redundancy
- Complicated wiring
  - Debugging could be hard

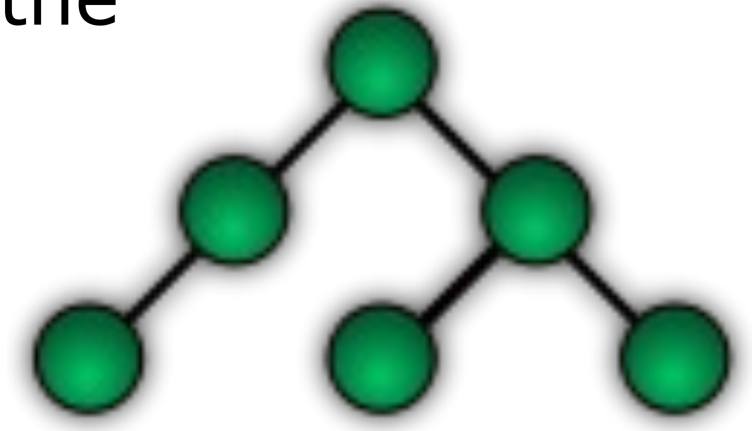




Images: https://en.wikipedia.org/

Tree Topology

- Hierarchical wiring
- Good for edge computing
- One hub failure could lead to loss of the whole branch



Images: https://en.wikipedia.org/

Hybrid Topologies

- Many real networks are hybrid

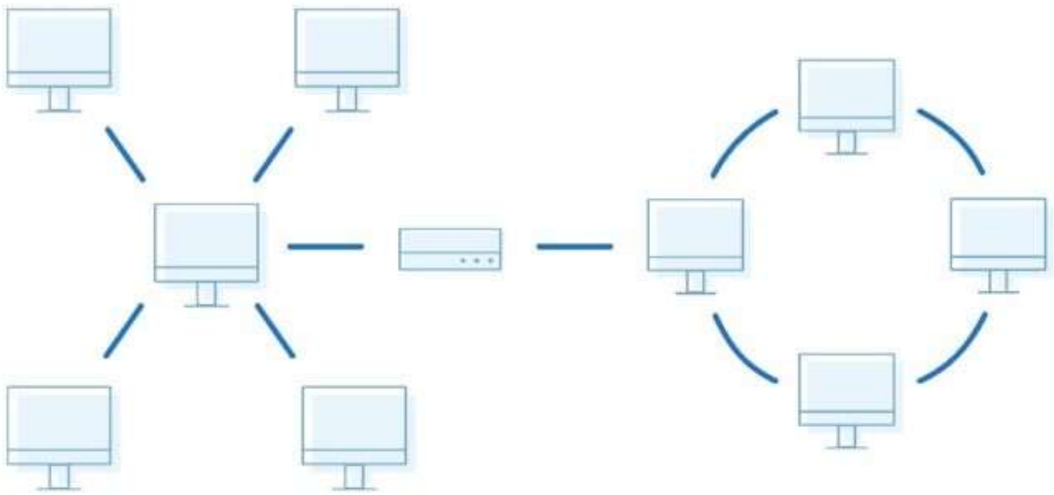


Image https://www.dnsstuff.com/

How to decide the topology?

- Application Context and Needs
- Capabilities of the devices
- Scalability
- Safety

Technologies for Networking

- Once you decide the topology, how to connect them?
- Two main approaches
  - Wired
  - Wireless

Image https://www.dnsstuff.com/

Wired Networking

- We discuss many approaches already
  - COM port
  - ADC / Digital IO / PWM
  - SPI, I^{2}C
- Some other methods
  - Ethernet
  - USB
  - Optical
  - Communication over power lines

Image https://www.dnsstuff.com/

Wireless Networking

- Some commonly used wireless methods
  - Bluetooth
  - Wi-Fi
  - Zigbee
  - LoRa
- Some other methods
  - Analog
    - E.g. VHF/UHF TV, AM/FM Radio
  - Digital
    - 3G/ 4G / 5G / LTE-M / Z-Wave

Wireless Networking

	Bluetooth LE	Wi-Fi	ZigBee	LoRa
Range	Typical ~10m (some ~100m)	~100m	~100m	2-5 Km (urban areas), 15 Km (suburban areas)
Data Rate	~1Mbps	Upto 1.3Gbps	250kbps	0.3 to 100 Kbps
Power	Medium	High	Low	Low
Context	Indoor/Outdoor	Indoor	Indoor/Outdoor	Outdoor
Application	Personal Area Network (PAN)	Local Area Network (LAN)	LAN/PAN	LAN

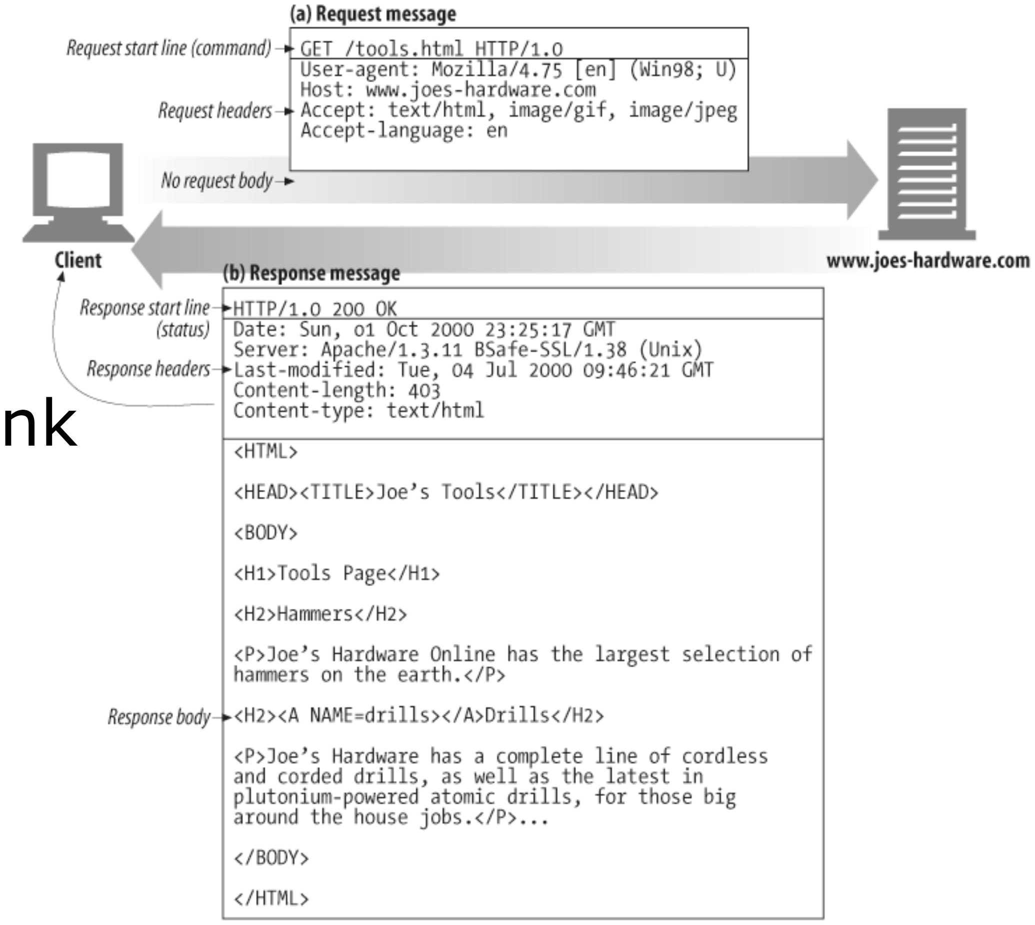
Homework: Read up about each of these network methods

Higher Level Communication Protocols

- IoT devices are powerful enough to use high level protocols
    - This was not the case 10 years ago
- Some popular protocols
    - Web - HTTP
    - Pub/Sub services - MQTT

Hypertext Transfer Protocol (HTTP)

- Application layer protocol
- Text based – lines of text
- A message has two parts
  - header and body separated by a blank line
  - The header has the message type (GET, PUT,…) and parameters.
  - The body has content.
- Mainly for web content, but now used for others



```
GET /tools.html HTTP/1.0
User-agent: Mozilla/4.75 [en] (Win98; U)
Host: www.joes-hardware.com
Accept: text/html, image/gif, image/jpeg
Accept-language: en
```

```
HTTP/1.0 200 OK
Date: Sun, 01 Oct 2000 23:25:17 GMT
Server: Apache/1.3.11 BSafe-SSL/1.38 (Unix)
Last-modified: Tue, 04 Jul 2000 09:46:21 GMT
Content-length: 403
Content-type: text/html

<HTML>

<HEAD><TITLE>Joe's Tools</TITLE></HEAD>

<BODY>

<H1>Tools Page</H1>

<H2>Hammers</H2>

<P>Joe's Hardware Online has the largest selection of
hammers on the earth.</P>

<H2><A NAME=drills></A>Drills</H2>

<P>Joe's Hardware has a complete line of cordless
and corded drills, as well as the latest in
plutonium-powered atomic drills, for those big
around the house jobs.</P>...

</BODY>

</HTML>
```

https://www.oreilly.com/

Try out HTTPie:

```
[~]
```

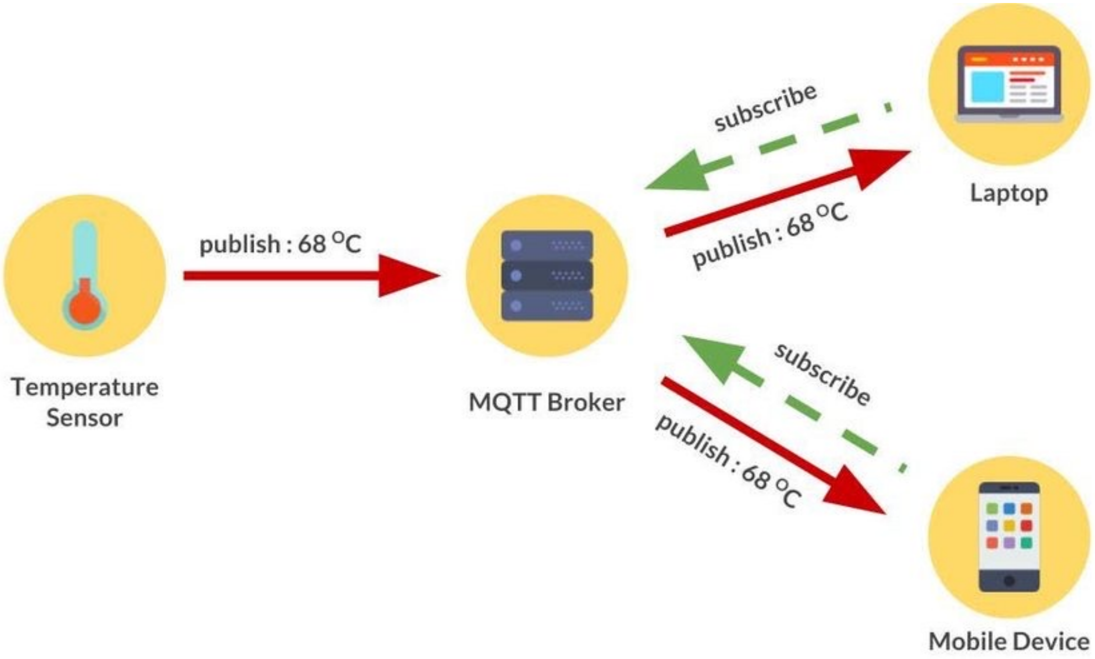
https://github.com/httpie/httpie

Publish/Subscribe Services

- The pub/sub architecture allows devices to “publish” data to a central server or a “broker” under a “topic”.
- Other applications can “subscribe” to that “topic” and receive data whenever a new value is published.
- The are many Pub/Sub systems. Some use web protocols, others are lower level.
- Some Pub/Sub systems use HTTP to carry messages.

MQTT (Message Queuing Telemetry Transport)

- A simple and lightweight Pub/Sub protocol
- IoT devices can
  - Publish data (e.g. sensing)
  - Subscribe (e.g. output)
- MQTT is available for many platforms and languages including arduino, python, javascript, node-red



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Summary

- Understand layered architecture used in networks
- Understand different topologies and when to use them
- Knowledge of different wired and wireless networking technologies
- Some basics of high level protocols

Image https://www.dnsstuff.com/

Here is a problem to solve

Remember: Write a program to control the LED through Bluetooth.

- Check out section “10.4 Bluetooth Tutorial”
  - https://wiki.dfrobot.com/FireBeetle_Board_ESP32_E_SKU_DFR0654#target_24