ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE
FAKULTA ELEKTROTECHNICKÁ
KATEDRA TELEKOMUNIKAČNÍ TECHNIKY

Integration of wireless networks into TCP/IP environment

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RM ISO/OSI

- How to use TCP/IP over various communication technologies?

OSI Reference Model		TCP/IP
7	Application	Application
6	Presentation	
5	Session	
4	Transport	Transport
3	Network	Internet
2	Data Link	Network Interface
1	Physical	

Encapsulation Types

- **How to use TCP/IP over various wireless technologies?**
- Communication technologies and devices:
  - L2 over Wireless: Ethernet - **Bridging**
    - Wi-Fi, Bluetooth (BNEP), Mobile Network Modems – 802.3
  - L3 over Wireless: Mobile networks – **Routing**
    - Mobile Network Modems – Raw IP, PPP, NB-IoT
  - Non-IP over Wireless
    - IEEE 802.15.4 based systems, LoRaWAN, Sigfox, etc.
    - Binary Lines over Ethernet/IP, USB, UART, RS-232, Modbus etc.

Layer Interconnection Issues

- **Physical layer issues:**
  - One Way Delay, Round Trip Time
  - Jitter – packed delay variation
  - Bitrate – data per time
  - constant vs. burst vs. instantaneous
- **Upper layer issues**
  - Data encapsulation and decapsulation process
  - Target application and user behavior
- **Security**

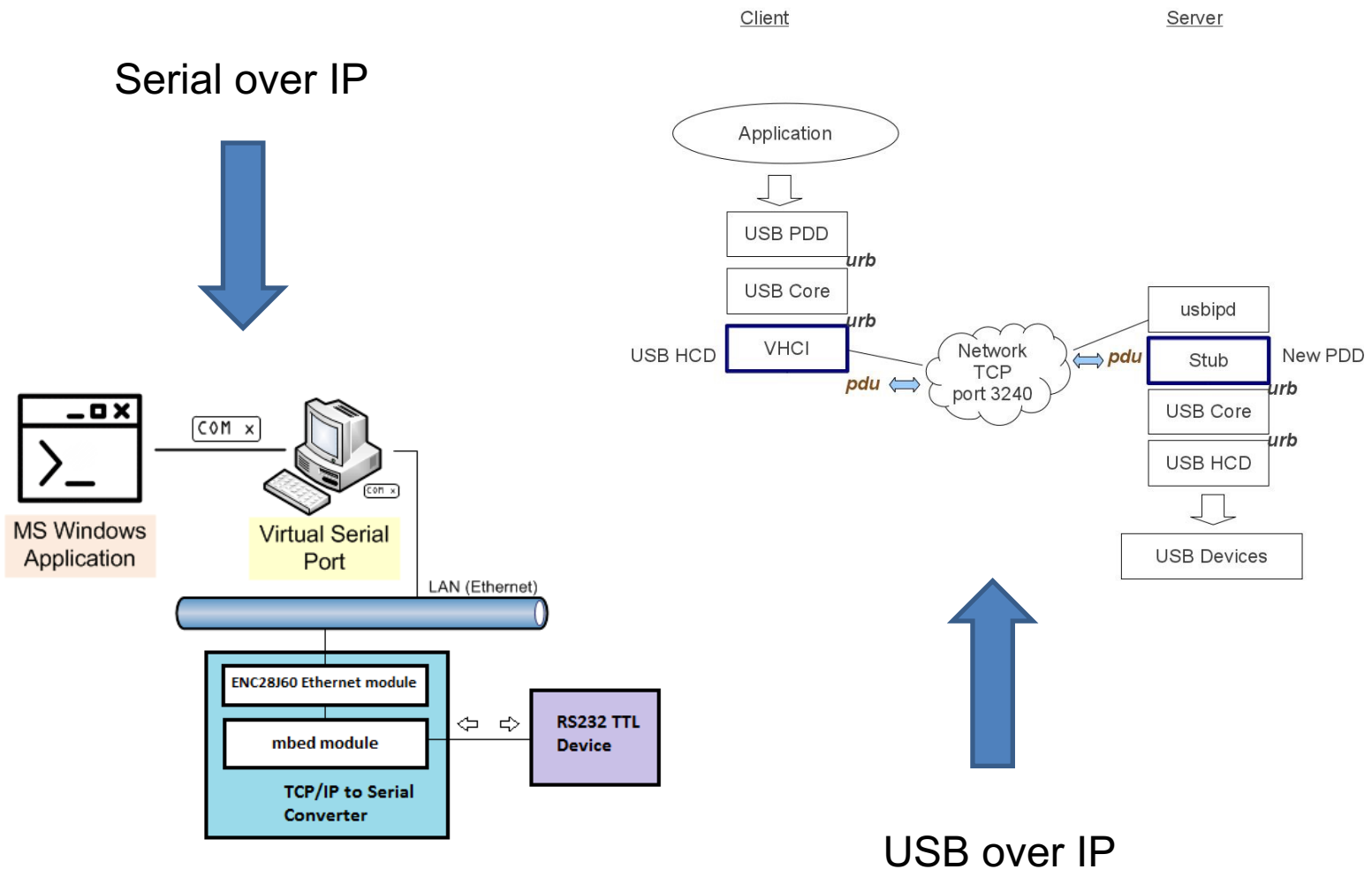
Binary Lines over IP

- Transmitting IP data over a serial (UART) line is haunted by several problems, among them:
  - lack of framing
  - lack of flow control
  - lack of session management

- Binary lines transmission technologies:
  - SLIP (Serial Line IP) – RFC 1055
  - PPP (Point to Point) – RFC 1661, 1662
  - HDLC (High-level Data Link Control)
  - Serial (UART) or USB over IP protocols

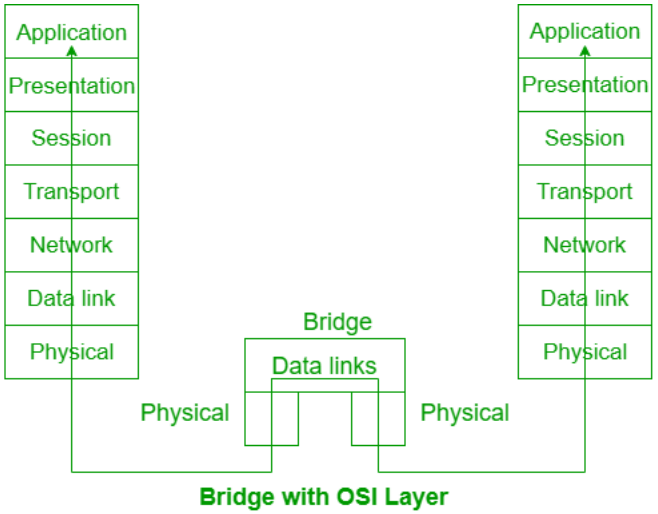
```
7e a0 5f ce ff 03 13 c9 33 e6 e7 00 0f 00 02 cf d6 0c 07 e7 05 10 02
06 00 0a ff 80 00 00 02 0c 09 08 36 32 31 32 38 38 39 31 09 0c 07 e7
05 10 02 06 00 0a ff 80 00 80 06 00 00 00 2b 06 00 00 00 00 06 00 00
00 00 06 00 00 00 00 12 00 00 12 00 00 12 00 00 12 00 eb 12 00 00 12
00 00 c7 3e 7e
```

Binary Lines over IP

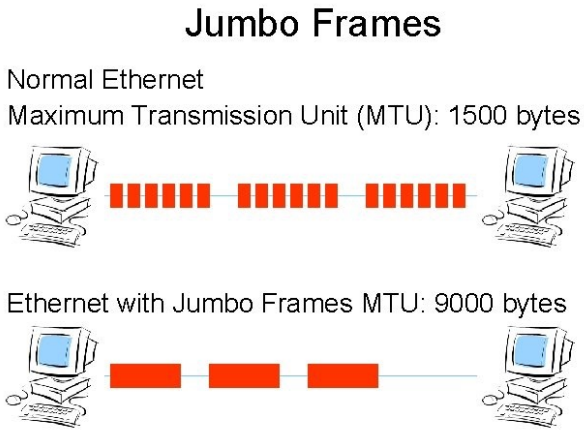


Network Environment

- Network Bridging
  - 2nd ISO/OSI layer (Data Link)
  - Logical device interconnection by physical address (MAC)
  - Ethernet Frame Size
    - Minimum IPv4 frame size = 18 (Ethernet) + 20 (IPv4) + 8 (UDP) + 18 (payload) = 64 bytes
    - Minimum IPv6 frame size = 18 (Ethernet) + 40 (IPv6) + 8 (UDP) + 18 (payload) = 84 bytes
    - Ethernet Jumbo Frames – 9000 B per frame on Ethernet

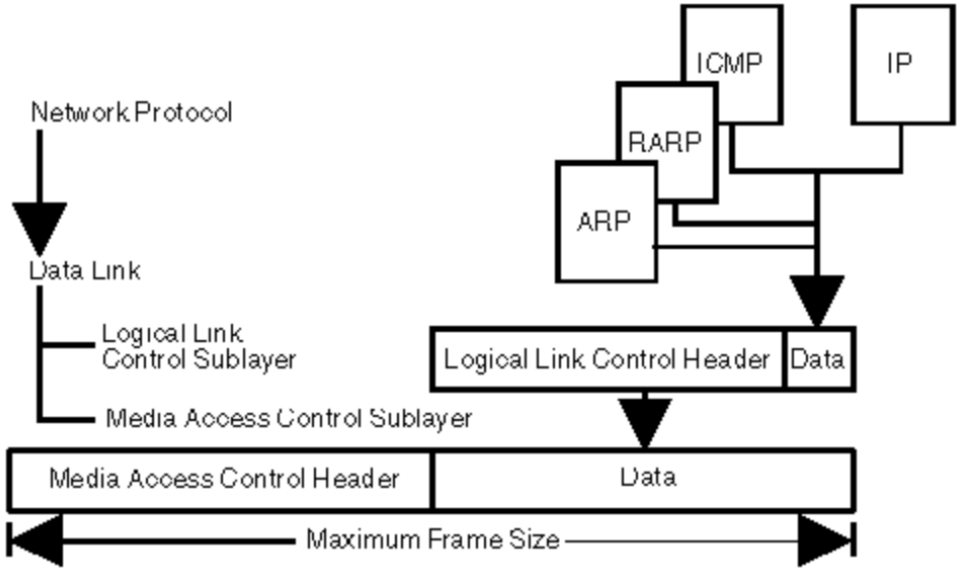


Bridge with OSI Layer



TCP/IP Environment

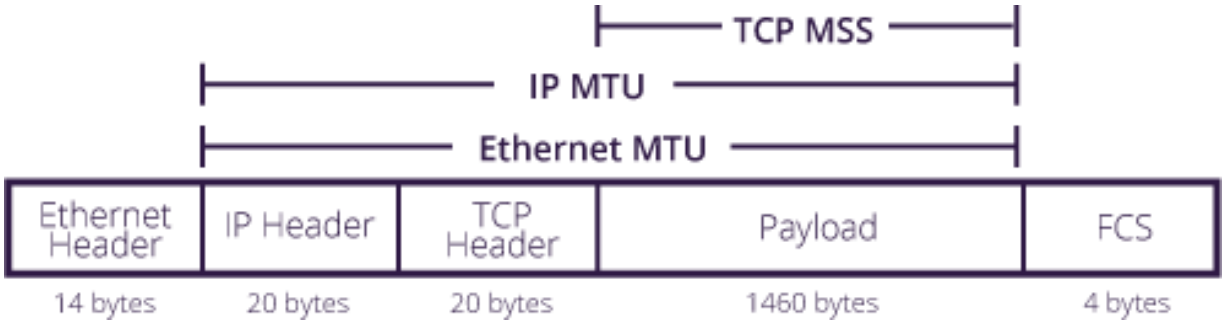
- IP - Internet Protocol
  - 3rd ISO/OSI layer protocol (Network)
  - Network path selection by **ROUTING**
  - End-to-End communication schema
    - Unicast, multicast, broadcast
  - **MTU – Maximum Transmission Unit**
    - Maximum size of IP packet, default 1500 B
    - Packet Fragmentation – if user DATA > MTU



TCP/IP Environment

- MSS vs. MTU
  - MTU is maximum IP packet size of a given link. MSS is Maximum TCP segment size
  - MTU is used for fragmentation – packet larger than MTU is fragmented But in case of MSS, packet larger than MSS is discarded
  - MSS is specified during TCP handshake basically in SYN and its value can't be changed after the connection is established

  - **MSS = MTU – 40 B (IP header(20 bytes) + TCP header(20 bytes))**

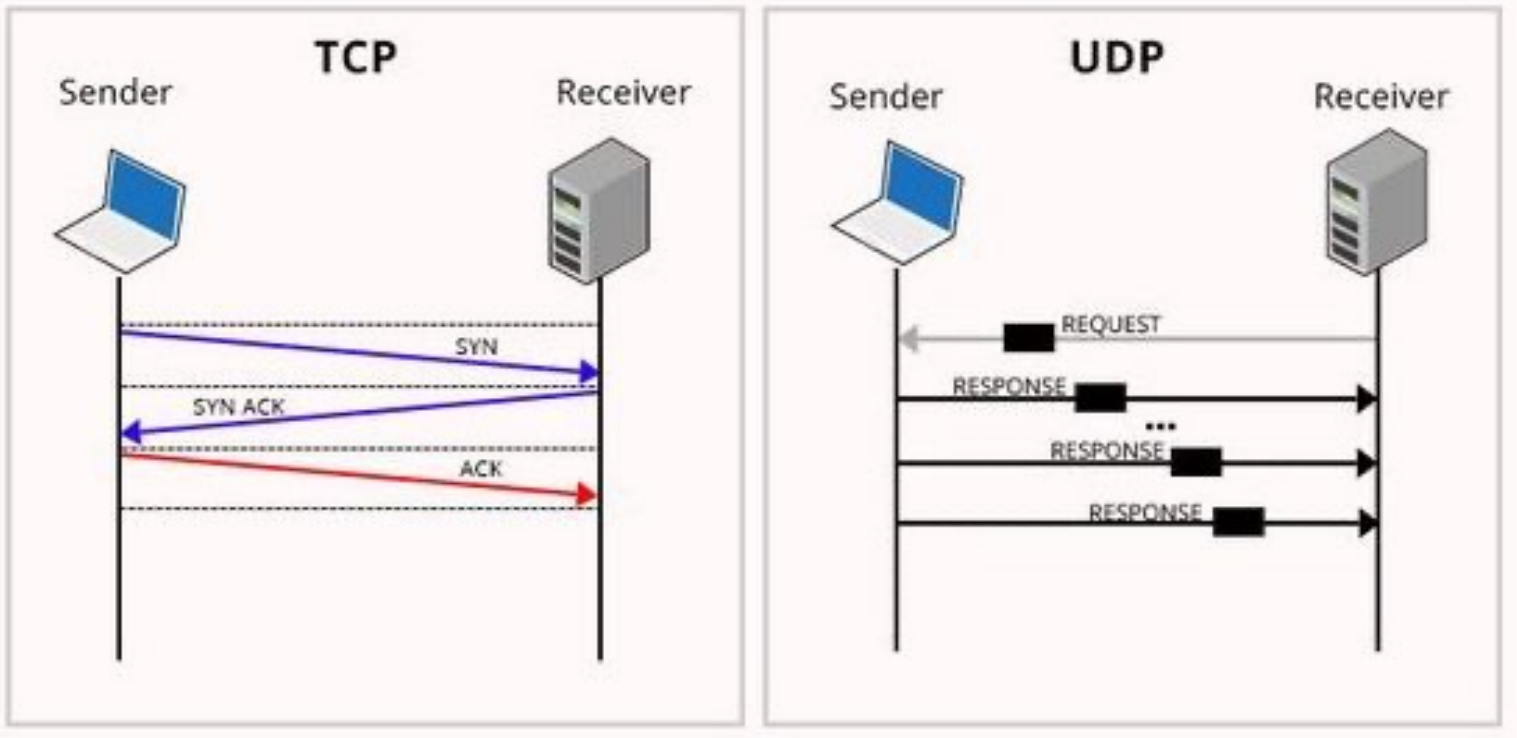


TCP/IP Environment

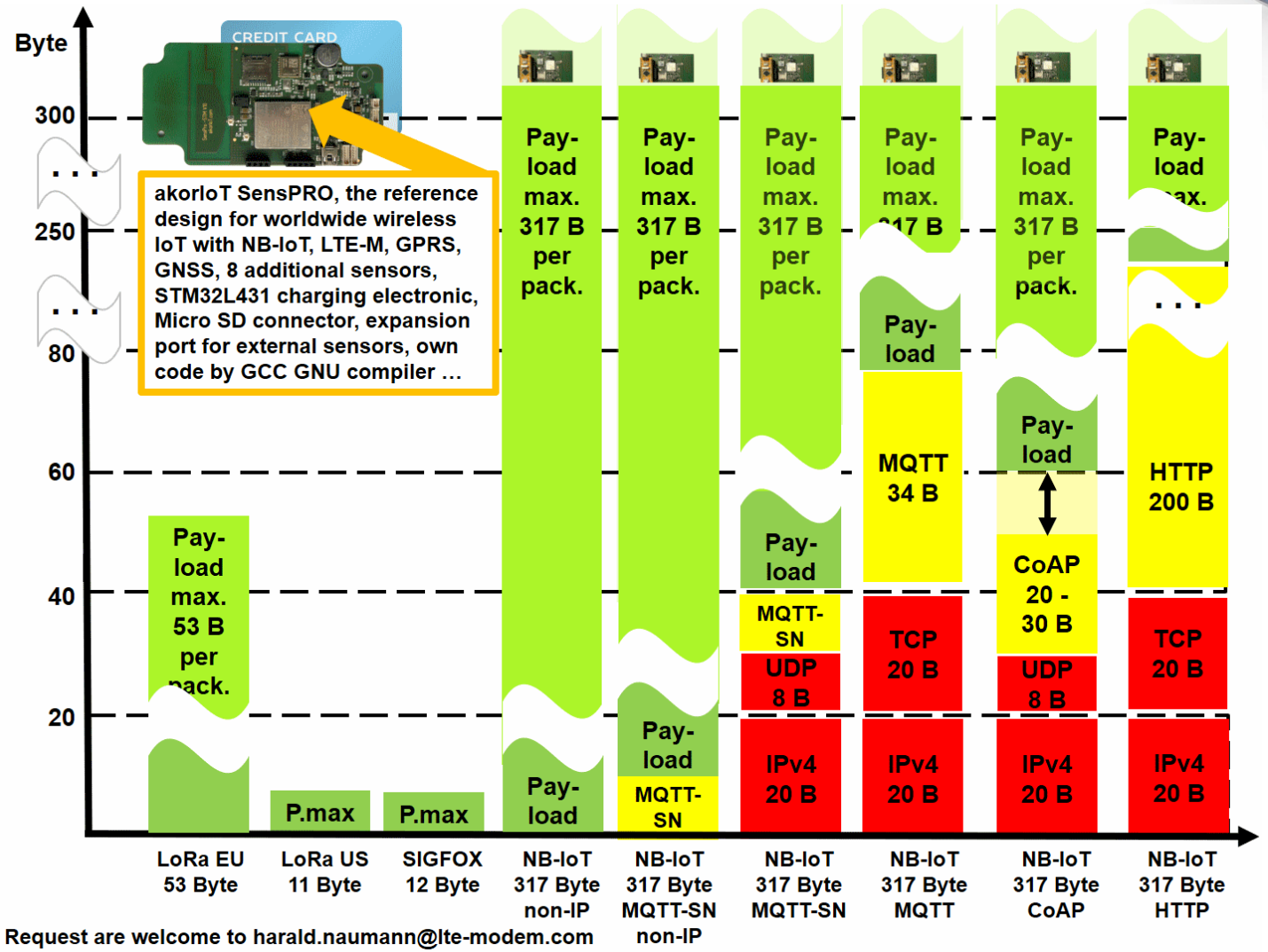
- TCP – Transmission Control Protocol
  - 4th ISO/OSI layer protocol (Transport)
  - Connection oriented protocol
    - RTT - Round Trip Time
    - Retransmissions
    - Congestion Algorithms (Reno, Cubic etc.)
  - **MSS - Maximum Segment Size** in bytes
    - Path MTU Discovery – ICMP based MTU size checking
  - Three-way Handshake
    - Connection initialization
    - Set used MSS, congestion algorithms features etc.

TCP/IP Environment

- UDP – User Datagram Protocol
  - 4th ISO/OSI layer protocol (Transport)
  - Connectionless protocol



IoT Technologies

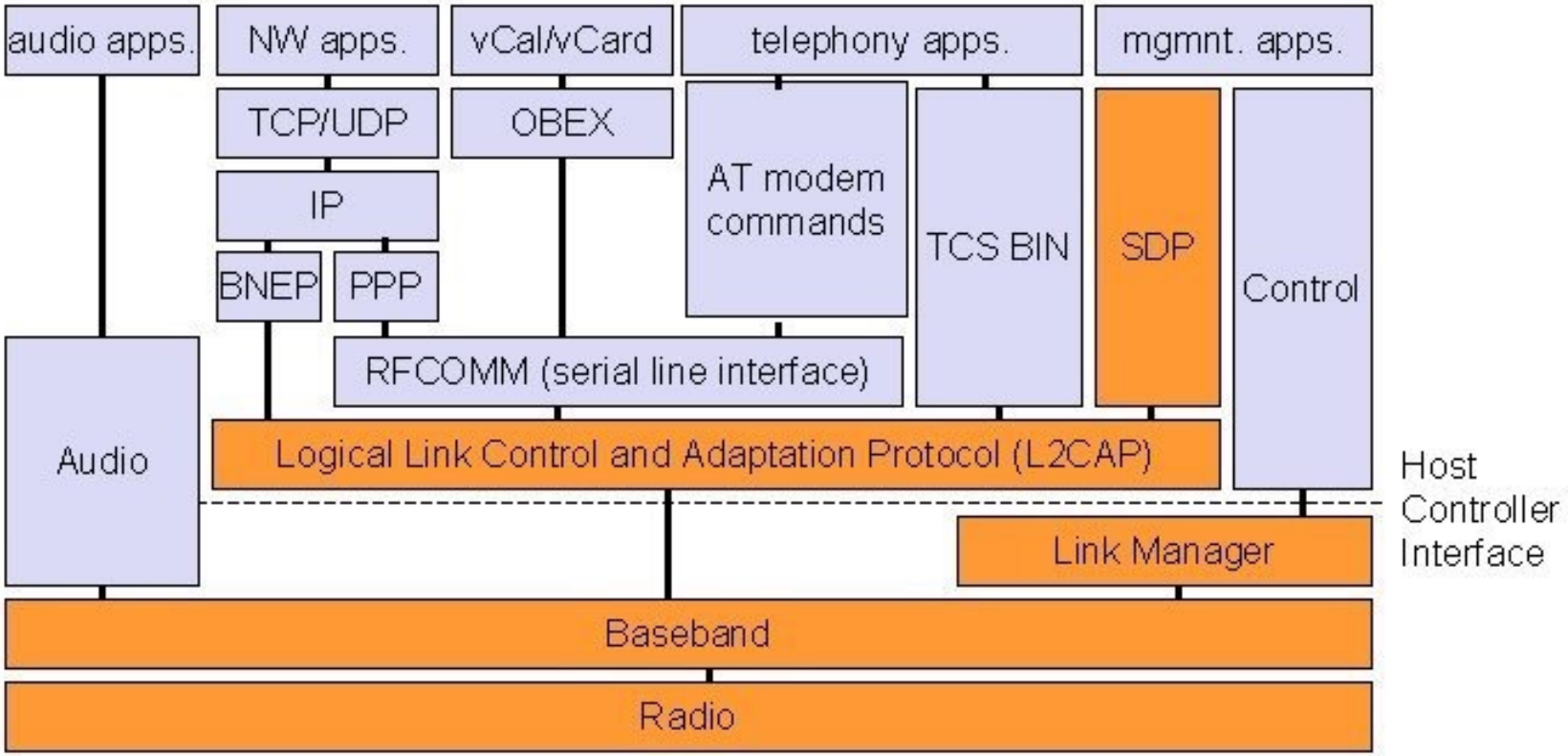


Request are welcome to harald.naumann@lte-modem.com

Wi-Fi Frames Encapsulation

- How to transmit TCP/IP over Wi-Fi?
  - Ethernet frame encapsulation (RM ISO/OSI layer - L2)
  - Two modes:
    - **Station Mode**
      - Standard based on IEEE 802.11
      - For simple access networks / users home networks
      - For end user devices (laptop, phones etc.)
      - Data flow from AP is “terminated” on end user device
    - **Station Bridge Mode**
      - Proprietary (developer dependent)!!!
      - Impact on performance and compatibility
      - For Wi-Fi infrastructure / “complicated” wireless networks
      - Data flow from AP is “terminated” on “edge” wireless client

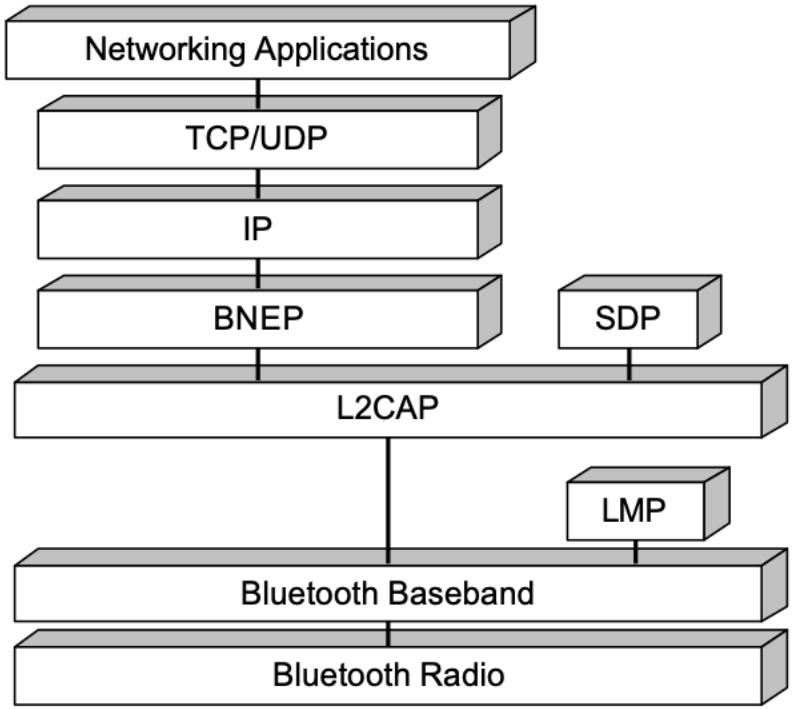
Bluetooth Encapsulation



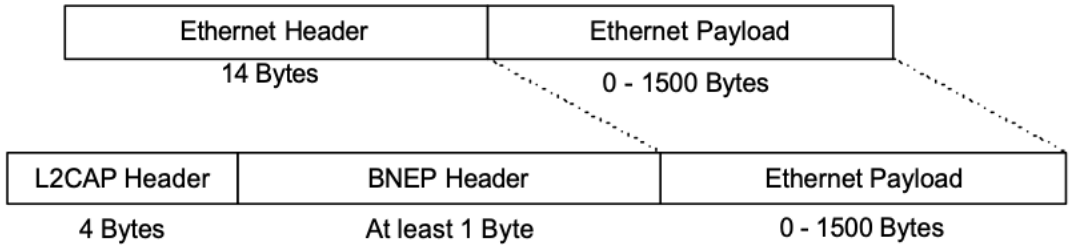
AT: attention sequence
OBEX: object exchange
TCS BIN: telephony control protocol specification – binary
BNEP: Bluetooth network encapsulation protocol

SDP: service discovery protocol
RFCOMM: radio frequency comm.

Bluetooth Encapsulation



BNEP (Bluetooth Network Encapsulation Protocol (BNEP) is used for transporting both control and data packet over Bluetooth. BNEP provides similar capabilities provided by Ethernet.



Mobile Networks Encapsulation

- Three types of data transmission through a mobile network:
  - **PPP** – Point to Point Protocol
    - Tunnel over serial line – tunneling IP protocol
    - Easy and very simple tunneling protocol over serial line
    - Multiprotocol encapsulation
    - Usable up to ones Mbps
  - **IEEE 802.3** – Ethernet frame transmission
    - Full support of L2 bridge – transmit all data on L2 (Ethernet)
    - Usable up to tens and hundreds Mbps
  - **Raw IP** – Packet transmission
    - The most effective way how to connect to the mobile network, no more L2 overhead
    - Usable up to hundreds Mbps and ones Gbps

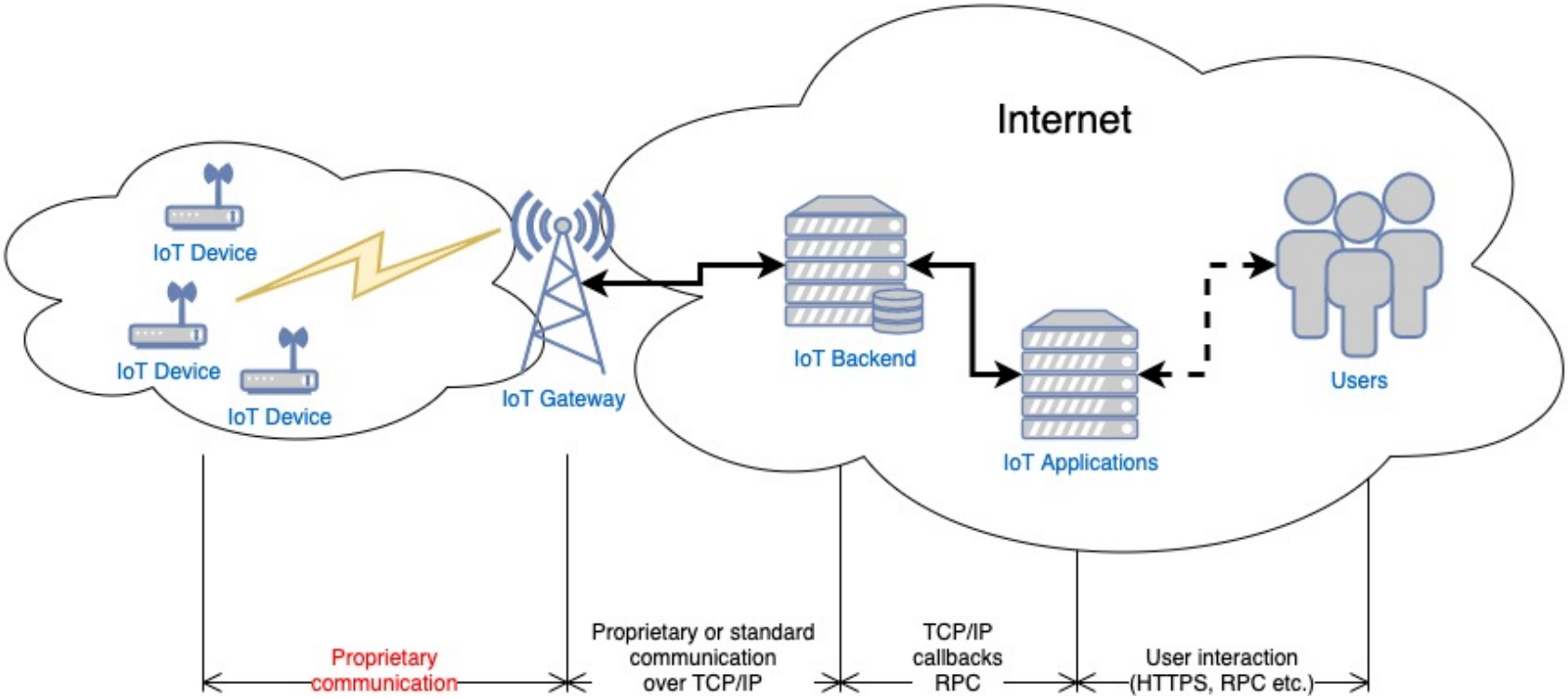
IoT Networks

- TCP/IP support in IoT Networks
  - Non-IP communication
  - Direct IP communication

- Application services
  - **RPC** (Remote Call Procedure)
    - **XML-RPC**
    - **JSON-RPC**
  - **MQTT** (The Message Queuing Telemetry Transport)
  - **OPC UA** (Open Platform Communications United Architecture)

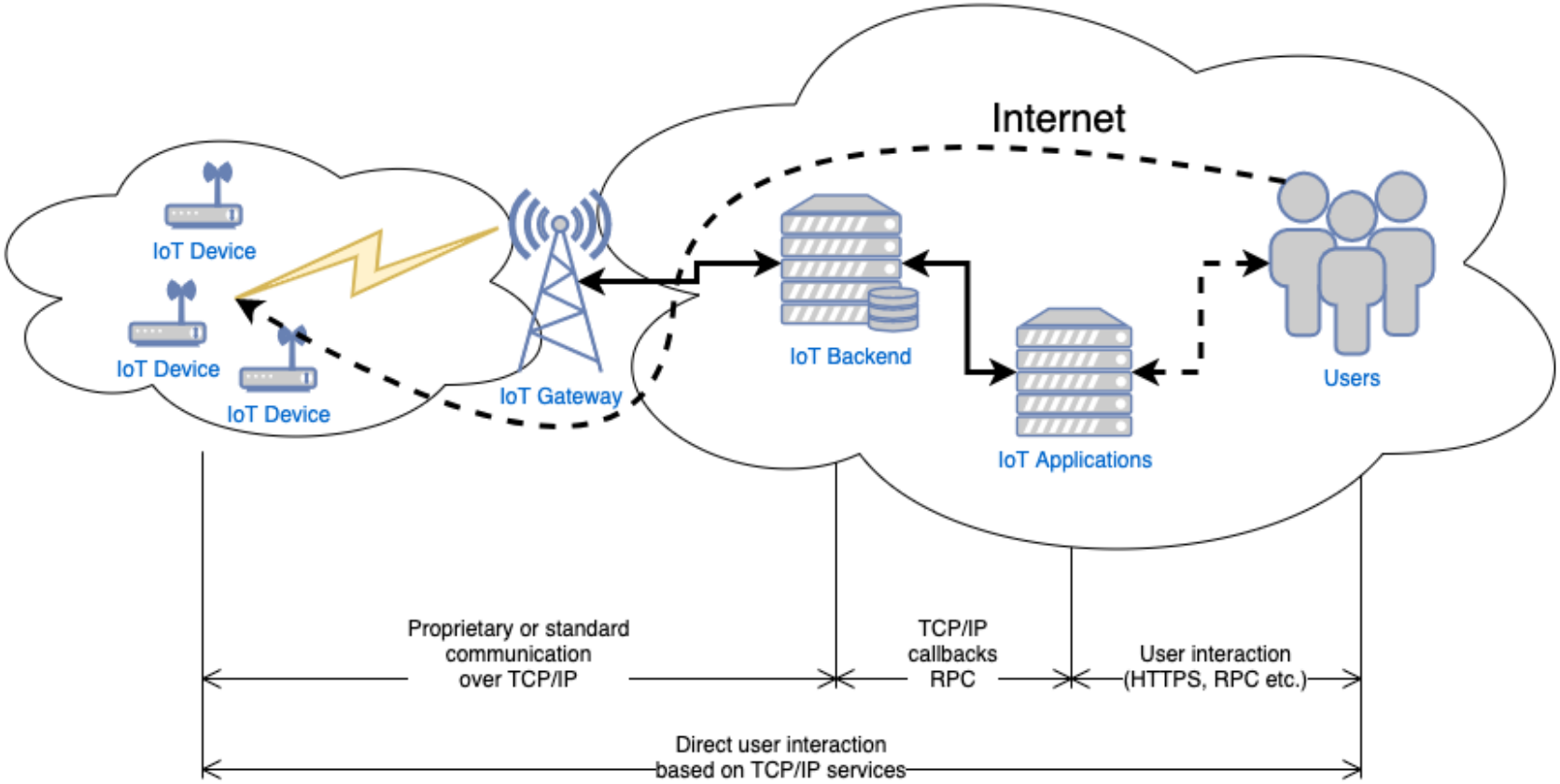
IoT Networks

- Non-IP communication – NB-IoT, LoRaWAN, Sigfox, Z-Wawe, Zigbee etc.
  - Communication path - by non-IP technology
  - No direct connection between user and device
  - A gateway or hub is needed



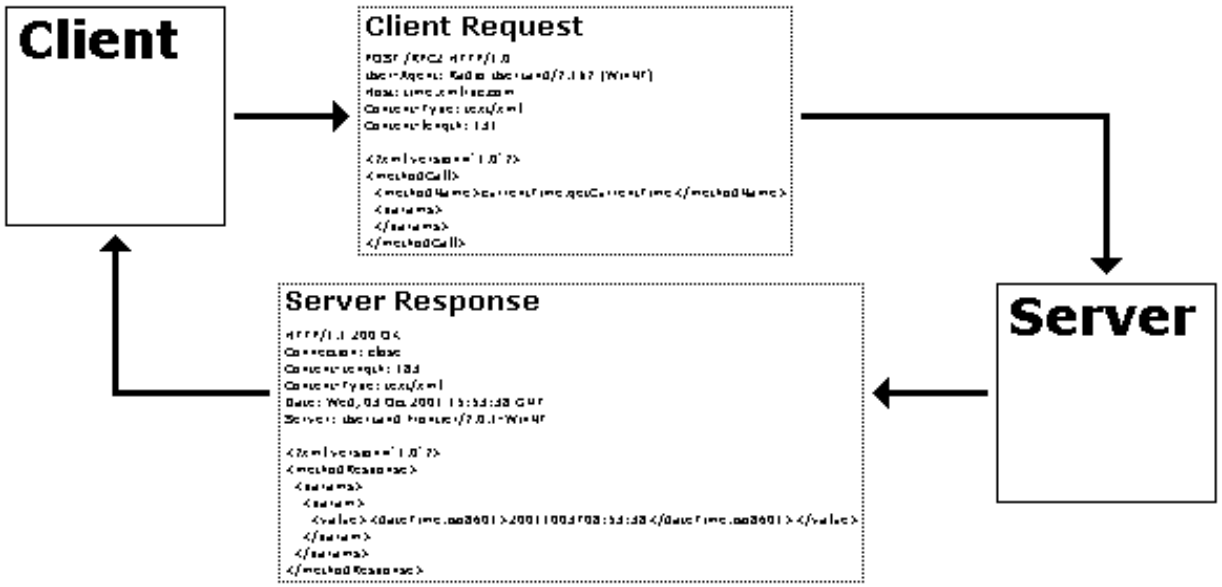
IoT Networks

- Direct IP communication – NB-IoT, ZigBee IP, 6LoWPAN etc.
  - End to End IP communication – based on TCP or UDP
  - A common use of IPv6



IoT Application Services

- **XML-RPC** is a remote procedure call (RPC) protocol which uses XML to encode its calls and HTTP as a transport mechanism.
- **JSON-RPC** is a remote procedure call protocol encoded in JSON. It is similar to the XML-RPC protocol, defining only a few data types and commands.



IoT Networks

- Example of the LoRaWAN Application Message
- https://lora-alliance.org/about-lorawan

------ Request Begin ------
Authorization: null
breadcrumbId: ID:fuse3-36282-1589571082283-1:154:1:1:4068
Content-Length: 1017
Content-Type: application/json
Host: iotdemo.develict.com:8888
Connection: Keep-Alive
User-Agent: Apache-HttpClient/4.5.2 (Java/1.8.0_222)
Accept-Encoding: gzip, deflate
------ Request End ------

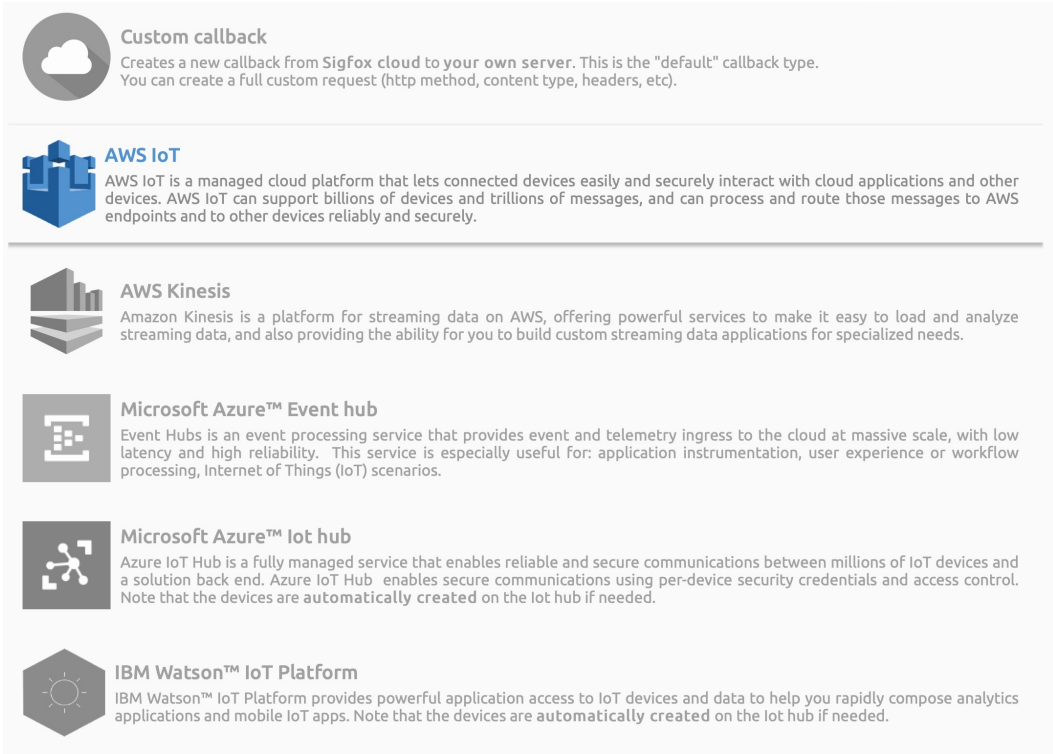
data: {"type": "D", "data":
"{\"cmd\":\"gw\",\"seqno\":**219714128**,\"EUI\":\"**0004A30B001EE7D3**\",\"ts\":1589830071887,\"fcnt\":181173,\"port\":1,\"freq\":868300000,\"toa\":185,\"dr\":\"SF9 BW125 4/5\",\"ack\":false,\"gws\":[{\"rssi\":-106,\"snr\":7.2,\"ts\":1589830071889,\"tmms\":2870,\"time\":\"2020-05-18T19:27:51.870353611Z\",\"gweui\":\"***024B08FFFF0500AD***\",\"lat\":49.8308989,\"lon\":18.2658243},{\"rssi\":-109,\"snr\":7,\"ts\":1589830071887,\"tmms\":1870,\"time\":\"2020-05-18T19:27:51.870355623Z\",\"gweui\":\"***024B0BFFFF0308BB***\",\"lat\":49.8414408,\"lon\":18.2903566},{\"rssi\":-118,\"snr\":-3.8,\"ts\":1589830071893,\"tmms\":1870,\"time\":\"2020-05-18T19:27:51.870350246Z\",\"gweui\":\"***024B0BFFFF030787***\",\"lat\":49.830888136600606,\"lon\":18.280487194348098},{\"rssi\":-119,\"snr\":0.2,\"ts\":1589830071895,\"tmms\":2000,\"time\":\"2020-05-18T19:27:51.870362000Z\",\"gweui\":\"***647FDAFFFF006A11***\",\"lat\":49.84717770879522,\"lon\":18.305467887104783}],\"bat\":167,\"data\":\"**05ff080ce90000**\"}", "tech": "L", "tags": []}

IoT Networks

- Example of the Sigfox Application Message
- https://www.sigfox.com/en

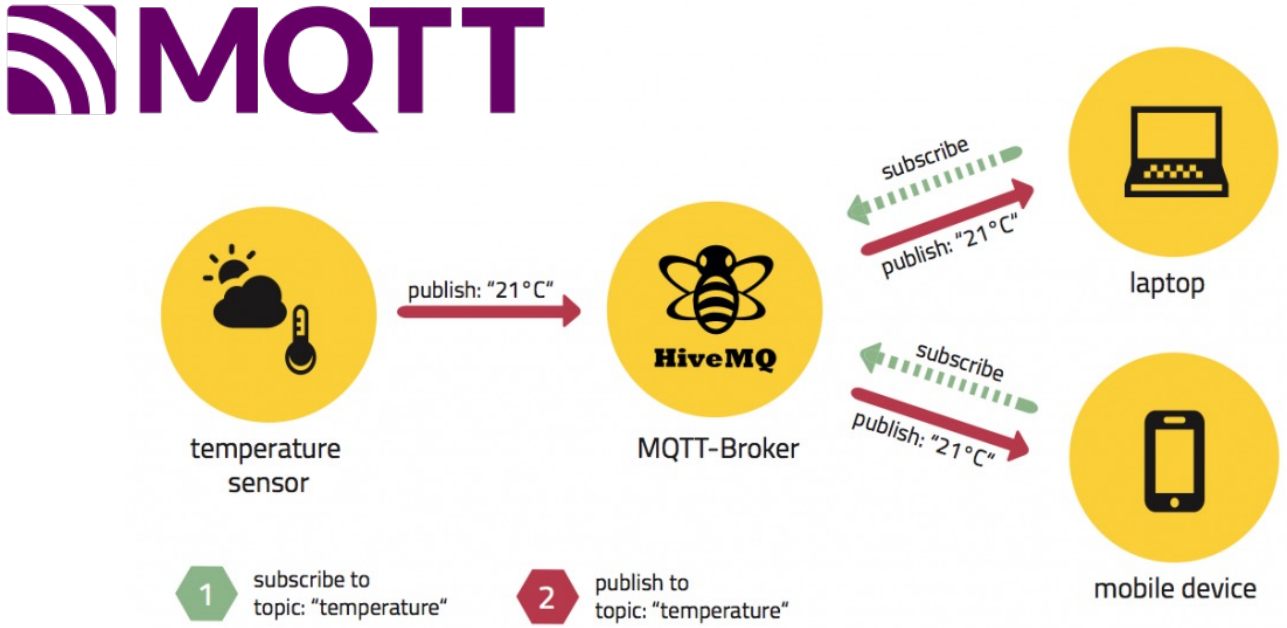
```
[OK] - Base station 77FB - 1 second
204 -  - #1
POST http://147.32.209.209:44144/sigfox HTTP/1.1
content-length: 219
accept-encoding: gzip, deflate
accept-language: fr
host: 147.32.209.209:44144
accept-charset: UTF-8;q=0.9,*;q=0.7
user-agent: SIGFOX
x-iot: sigfox
content-type: application/json

{
  "device" : "1415EEA",
  "deviceTypeId": "5e2187b4284f064318737872",
  "time": 1619375730,
  "data": "000163d00036bd000007b574",
  "rssi": -117.00,
  "snr": 15.00,
  "station": "77FB",
  "seqNumber": 130
}
```



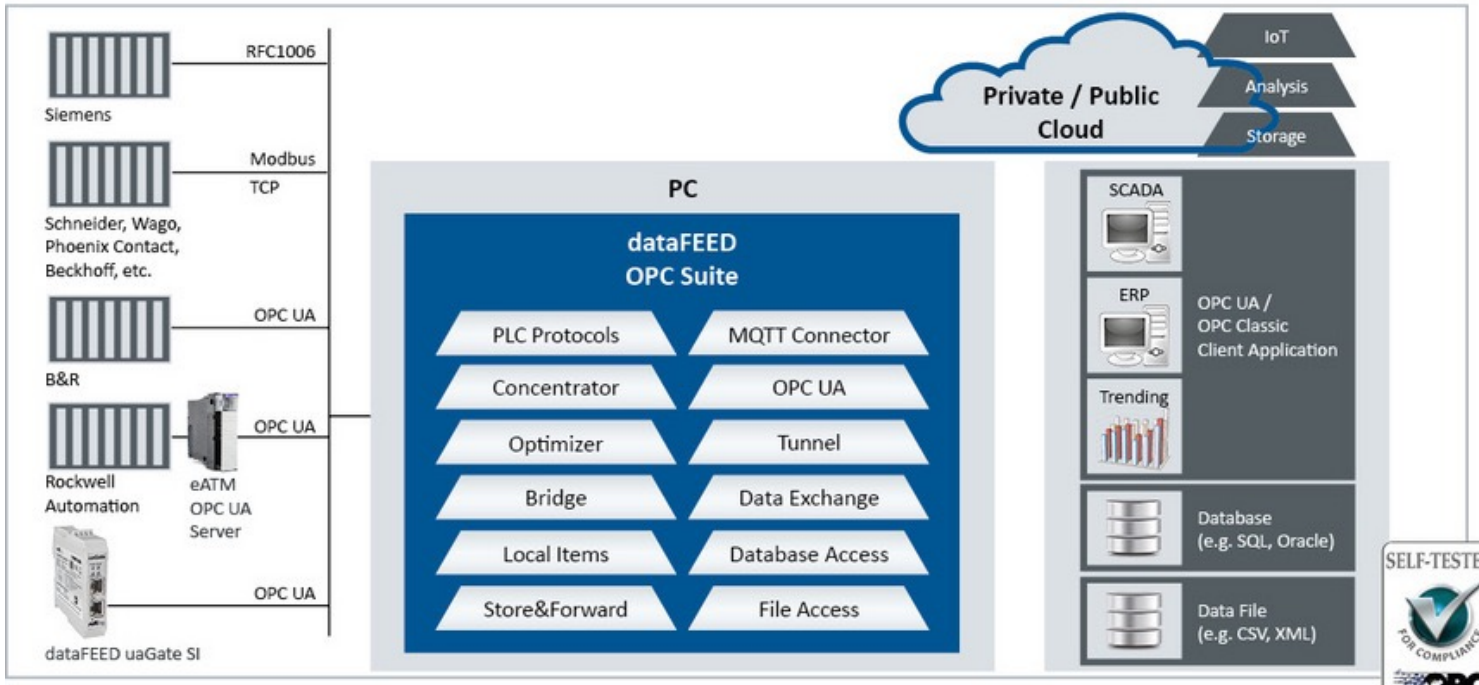
IoT Application Services

• **MQTT** (Message Queue Telemetry Transport) is a lightweight, publish-subscribe network protocol (ISO/IEC PRF 20922) that transports messages between devices.



IoT Application Services

- **OPC UA** (OPC Unified Architecture)
  - Standard: IEC 62541
  - OPC UA is a platform-independent standard for the communication of various types of systems and devices through the transmission of messages between clients and servers over various types of networks
  - Standard for use in Industry 4.0 systems



Thank you for your attention