Computer Network

Lecture 4

MAC/DLC Part.1

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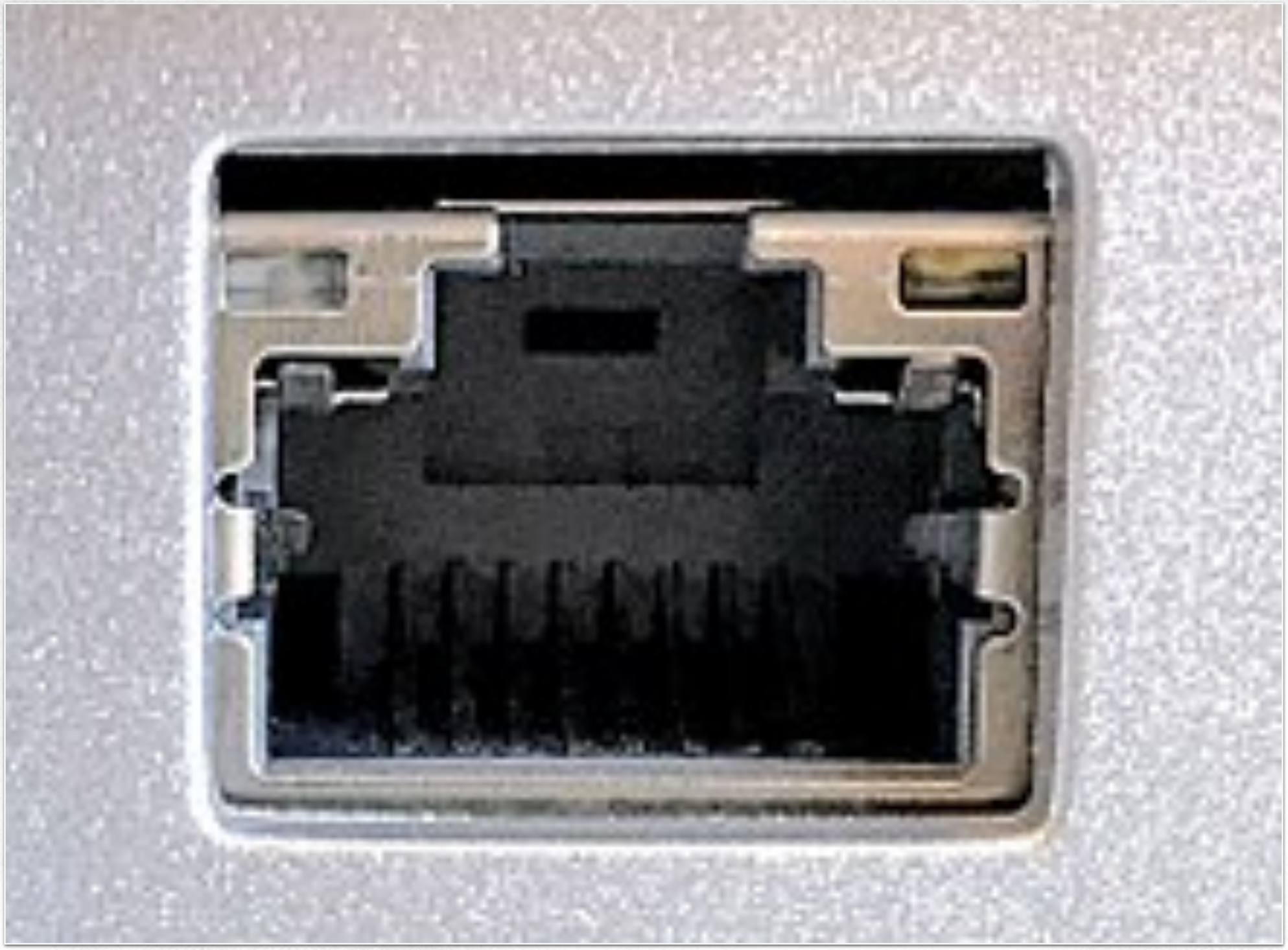
Contents

- **Ethernet**
- WiFi
- Bluetooth
- Bluetooth Low Energy
- LoRa
- LoRaWAN
- LoRa/LoRaWAN Implementation

What is this?



Reference: https://en.wikipedia.org/wiki/Ethernet

Overview

- Ethernet /ˈiːθərnɛt/ is a family of computer networking technologies commonly used in local area networks (LAN), metropolitan area networks (MAN) and wide area networks (WAN).
- It was commercially introduced in 1980 and first standardized in 1983 as IEEE 802.3, and has since been refined to support higher bit rates and longer link distances.
- Over time, Ethernet has largely replaced competing wired LAN technologies such as Token Ring, FDDI and ARCNET.

Overview

- The original 10BASE5 Ethernet uses coaxial cable as a shared medium, while the newer Ethernet variants use twisted pair and fiber optic links in conjunction with switches.
- Over the course of its history, Ethernet data transfer rates have been increased from the original 2.94 megabits per second (Mbit/s) to the latest 400 gigabits per second (Gbit/s).
- The Ethernet standards comprise several wiring and signaling variants of the OSI physical layer in use with Ethernet.

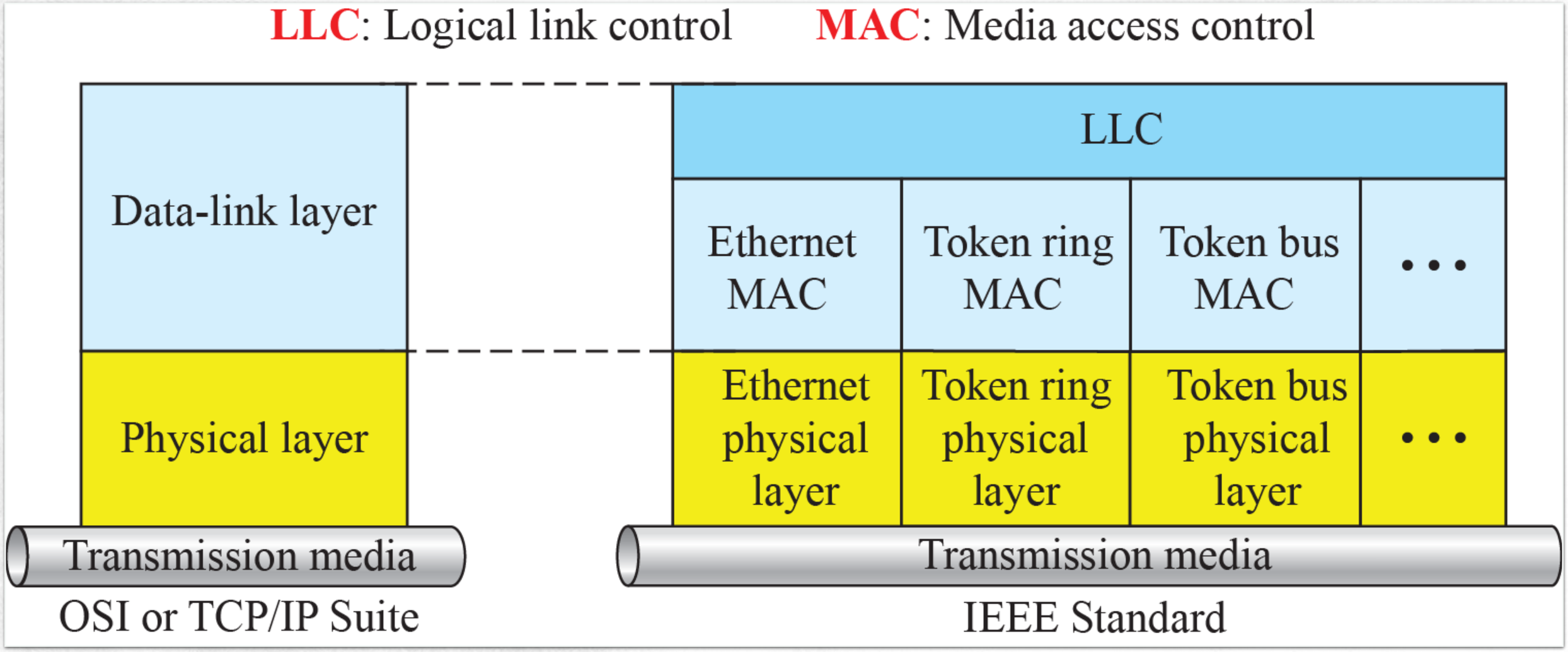
Reference: https://en.wikipedia.org/wiki/Ethernet

Overview

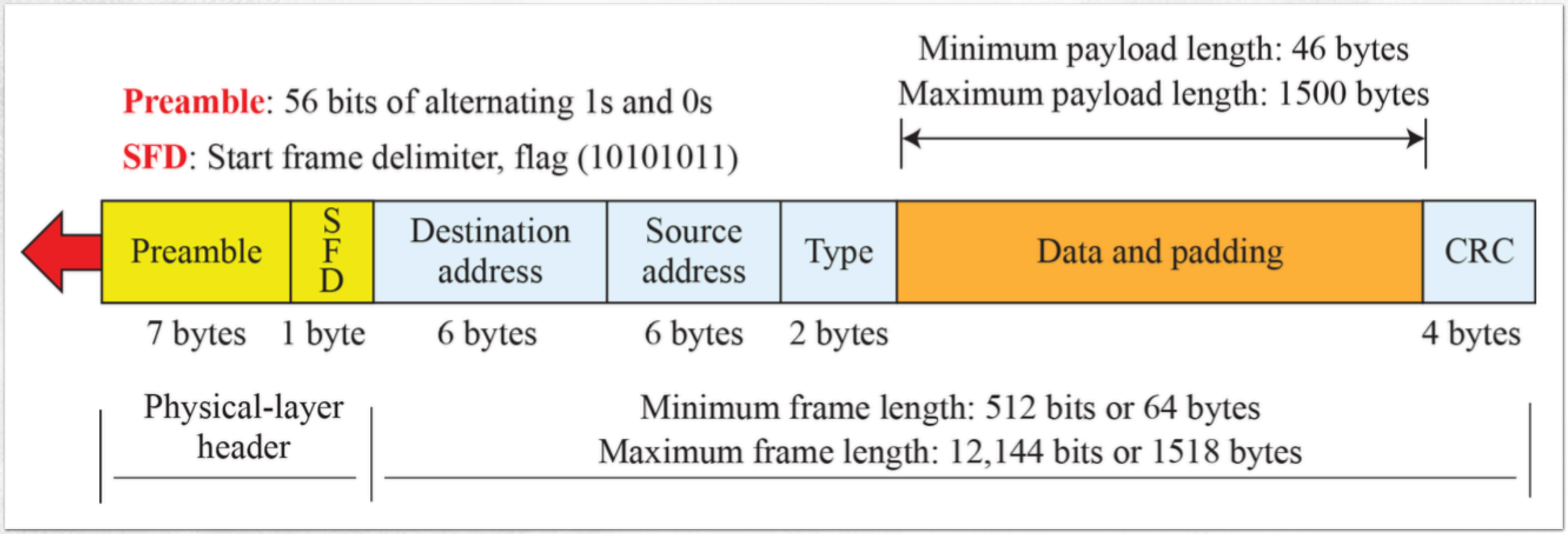
- Systems communicating over Ethernet divide a stream of data into shorter pieces called frames.
- Each frame contains source and destination addresses, and error-checking data so that damaged frames can be detected and discarded; most often, higher-layer protocols trigger retransmission of lost frames.
- As per the OSI model, Ethernet provides services up to and including the data link layer.
- Since its commercial release, Ethernet has retained a good degree of backward compatibility. Features such as the 48-bit MAC address and Ethernet frame format have influenced other networking protocols.

Reference: https://en.wikipedia.org/wiki/Ethernet

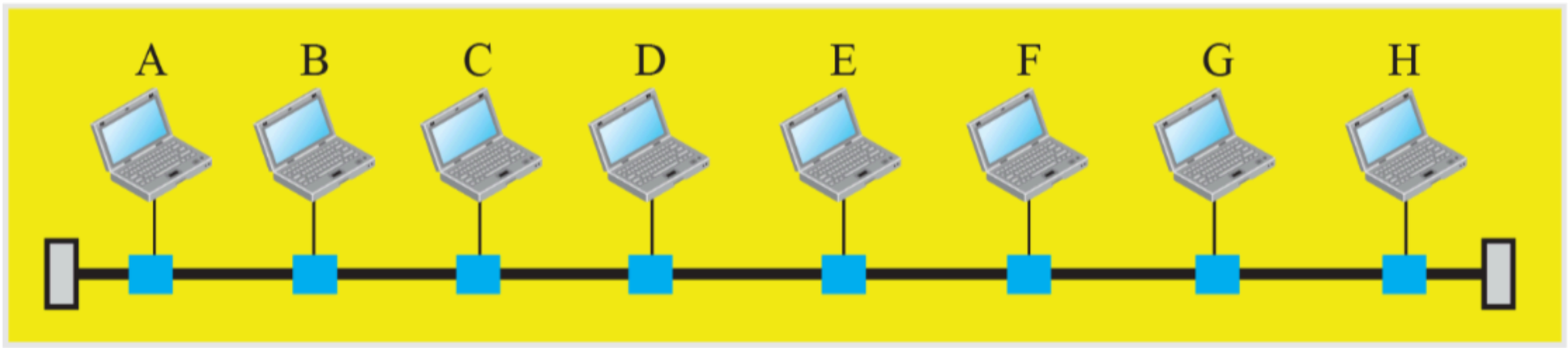
IEEE 802.3 Standard



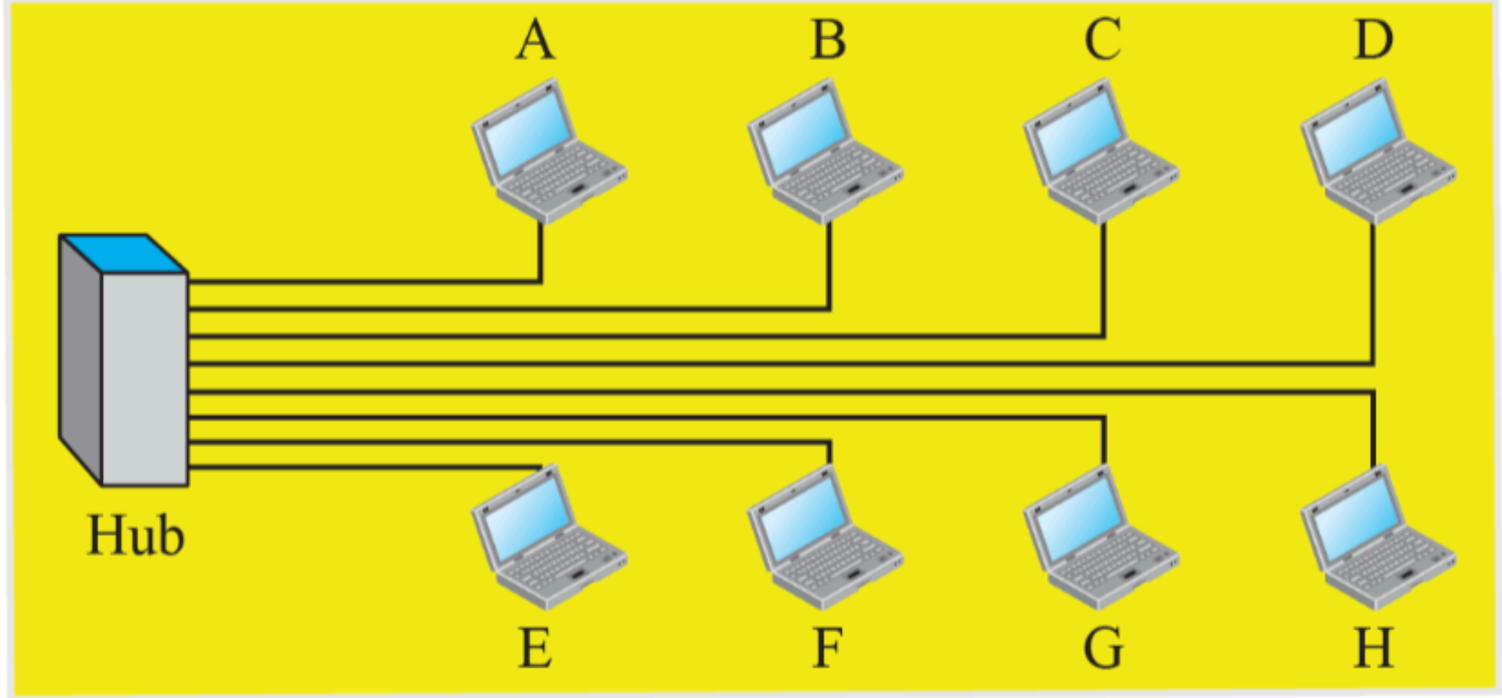
IEEE 802.3 Frame Format

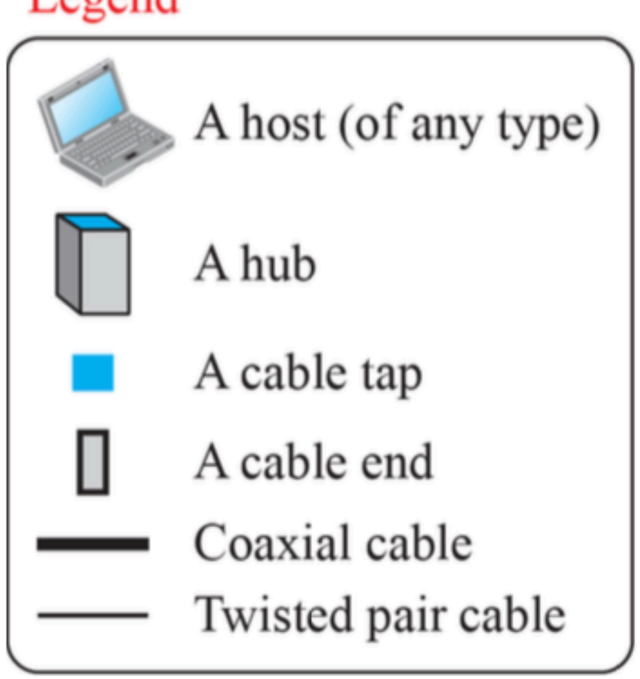


Topologies



a. A LAN with a bus topology using a coaxial cable

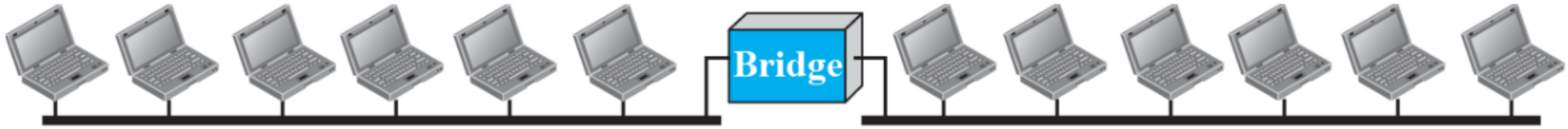




b. A LAN with a star topology using a hub

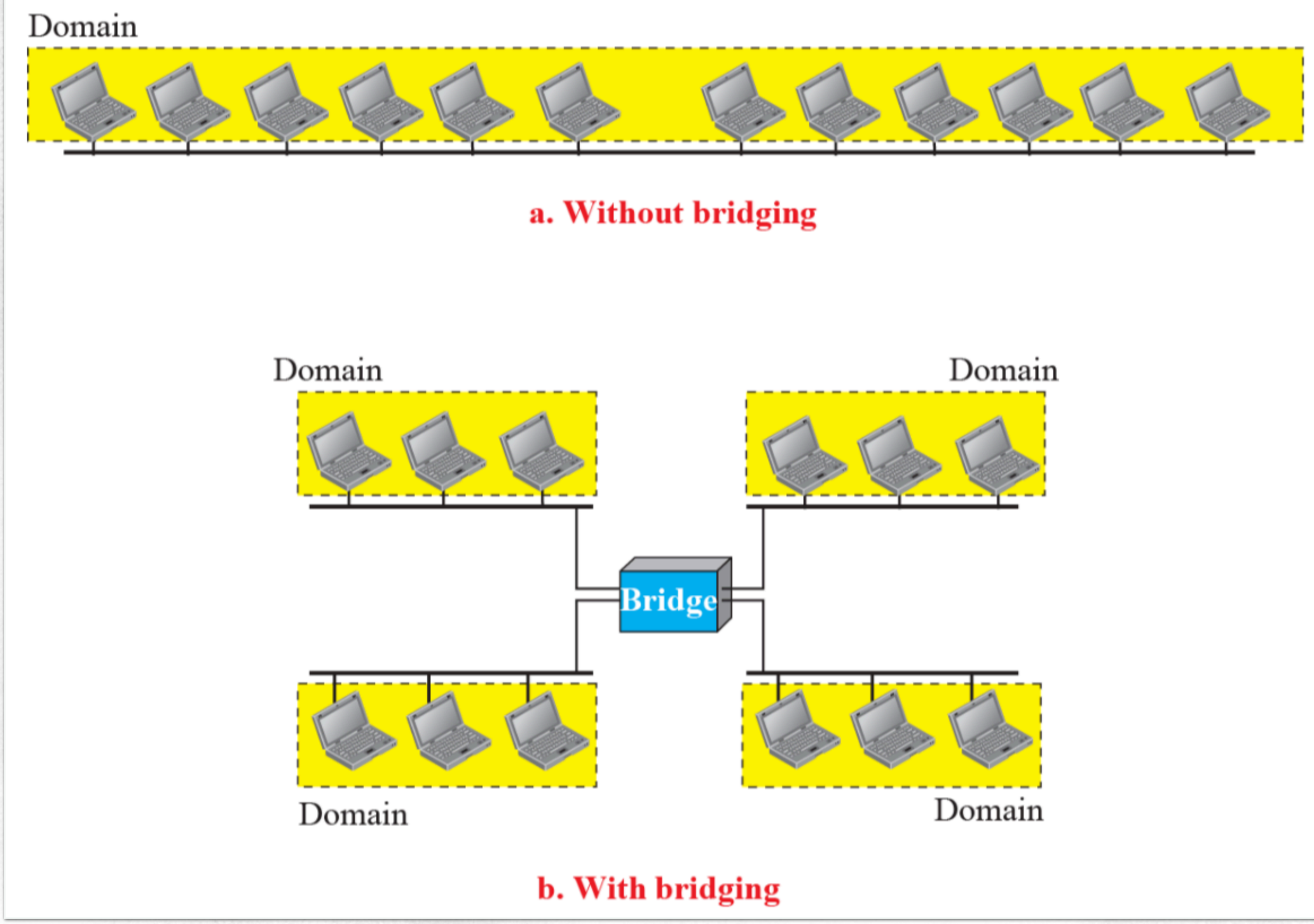
Bridging

a. Without bridging



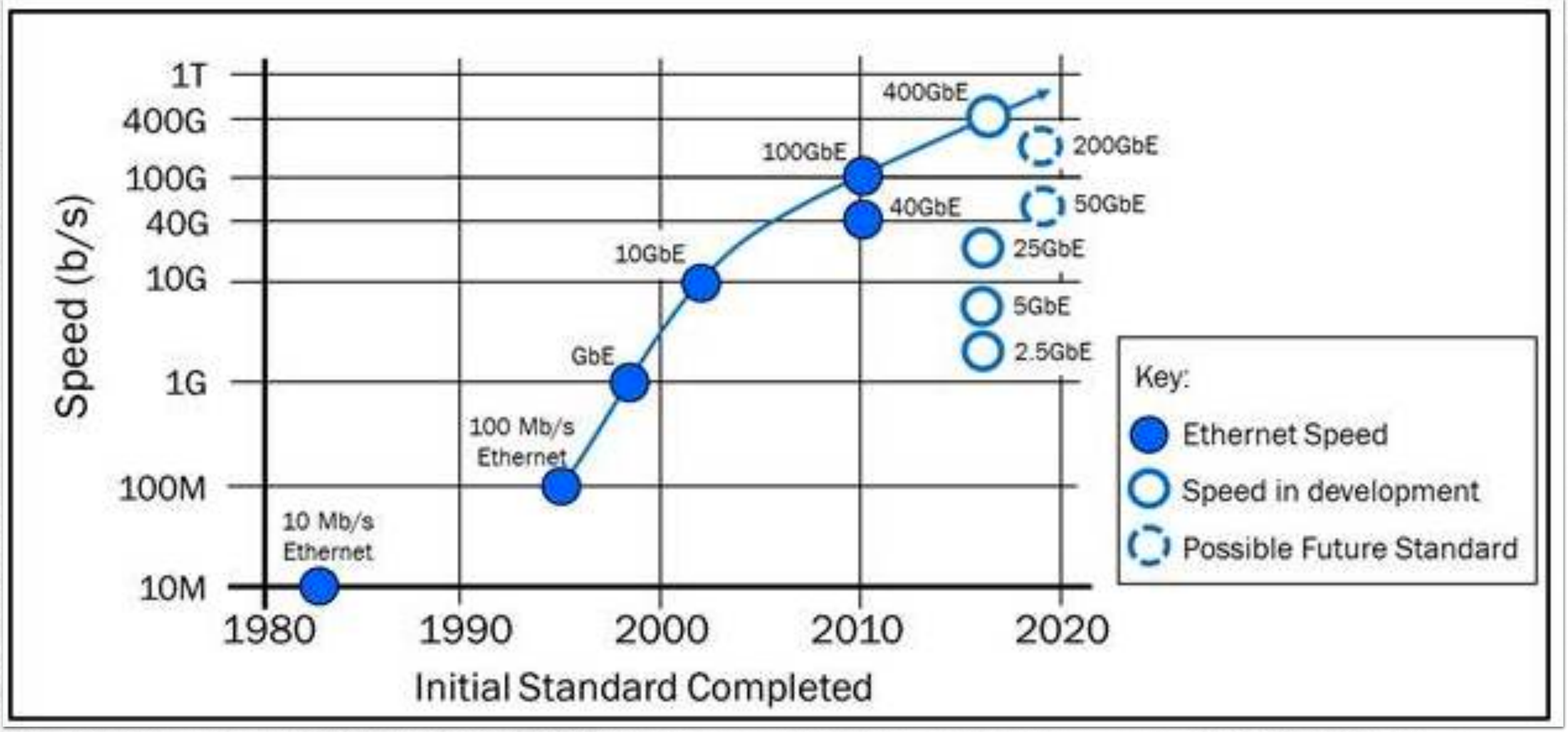
b. With bridging

Bridging for Collision Reduction



Ethernet Speed Roadmap

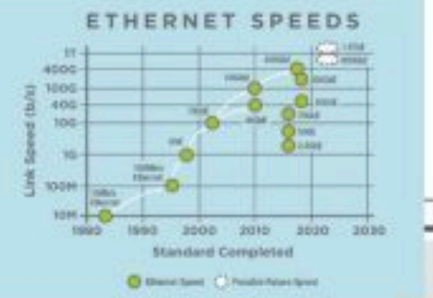
- Max 400Gbps at Today



Reference: https://www.lightwaveonline.com/articles/2015/02/a-dozen-speeds-in-the-ethernet-roadmap.html

2018 ETHERNET ROADMAP

THE PAST, PRESENT AND FUTURE OF ETHERNET



NEXT ETHERNET ERA
ethernet alliance
www.ethernetalliance.org
Designed by Scott Kipp and John D'Ambrosia

$9.95

INTEROPERABILITY AND CERTIFICATION

The Ethernet Alliance is committed to leading the charge to instilling industry confidence in Ethernet standards through its multivendor interoperability demonstrations and plugfests. Our PoE Certification Program takes this mission to the next level!

Our industry-defined PoE Certification Test Plan is based on the Ethernet PoE standard, and products passing this test will be granted the Ethernet Alliance PoE Certification Logo. This logo will provide instant recognition for products that based on the IEEE 802.3 PoE standard, and provide confidence in the multi-vendor interoperability of those products bearing it. The logos will also provide clear guidance on which devices will work with each other.

The first generation of the program certifies Type 1 and Type 2 products that use 2-Pair of wires. The second generation of the program will tackle the forthcoming IEEE 802.3bt PoE standard. This table explains the capabilities of the Types.

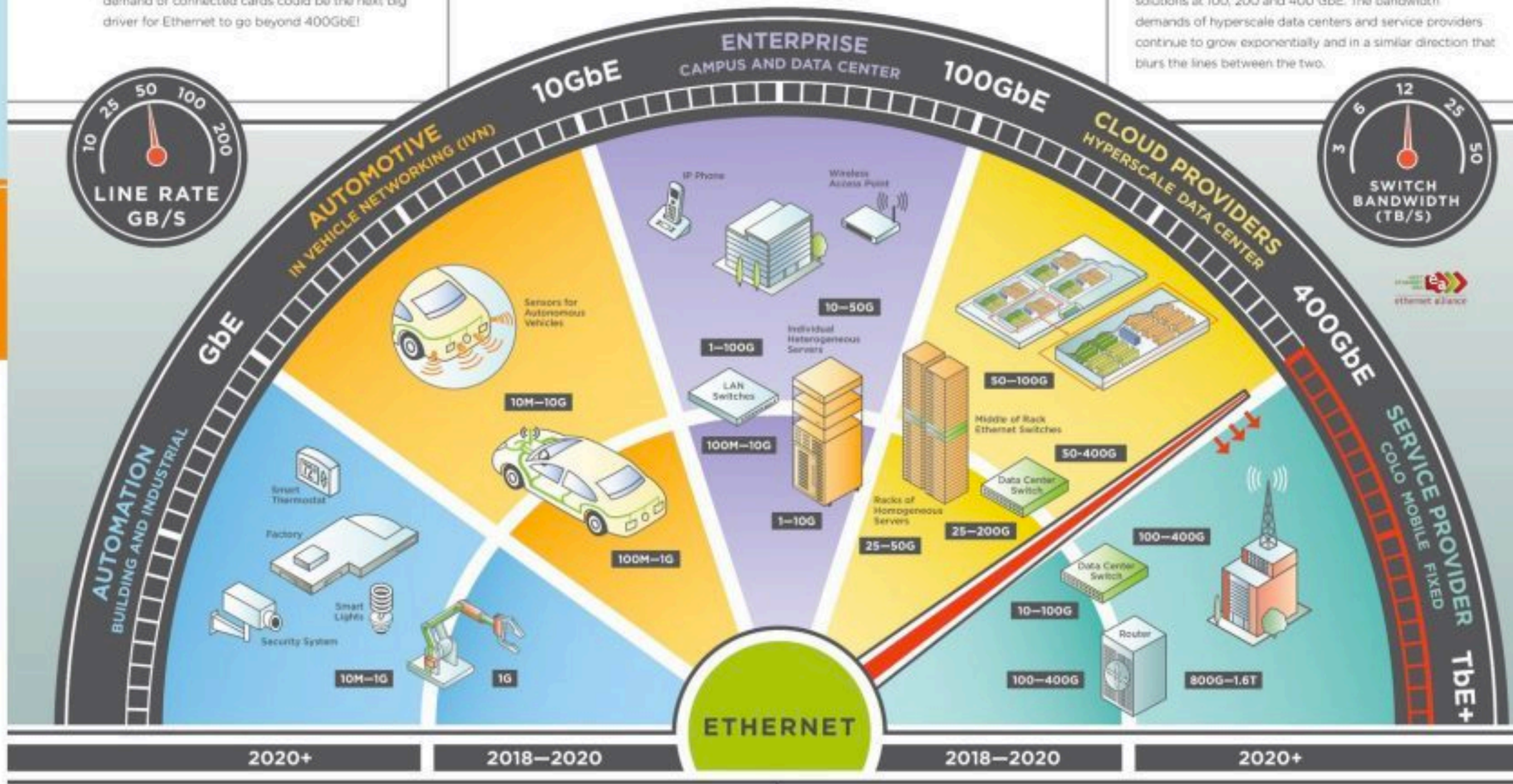
EA Certified™
https://ethernetalliance.org/poecert/

ETHERNET APPLICATIONS

AUTOMOTIVE Ethernet is one of Ethernet's latest success stories. Forecasts predict up to 500 million ports of Ethernet will ship in 119 million vehicles by 2019. Ethernet links within cars provide data and power to reduce the cost and weight in vehicles while providing economies of scale and interoperability. And the bandwidth demand of connected cards could be the next big driver for Ethernet to go beyond 400GbE!

ENTERPRISE and Campus applications drive the bulk of Ethernet port shipments with hundreds of millions of ports shipping per year. Ethernet's roots are in enterprise local area networks (LANs) where the entire Ethernet family, including the BASE-T products, can be found. LANs are rich in copper where over 70 Billion meters of cable have been deployed over the past 15 years. Enterprise data centers are very cost sensitive and most servers deploy GbE and 10GbE.

CLOUD PROVIDERS were the first to adopt 10GbE servers on a large scale in 2010 for hyperscale data centers. With voracious appetites for east-west traffic, hyperscale servers have moved to 25GbE today and will move to 50GbE by the end of 2018. Unique networking architectures within these warehouse scale data centers have driven multiple multimode and single-mode fiber solutions at 100, 200 and 400 GbE. The bandwidth demands of hyperscale data centers and service providers continue to grow exponentially and in a similar direction that blurs the lines between the two.



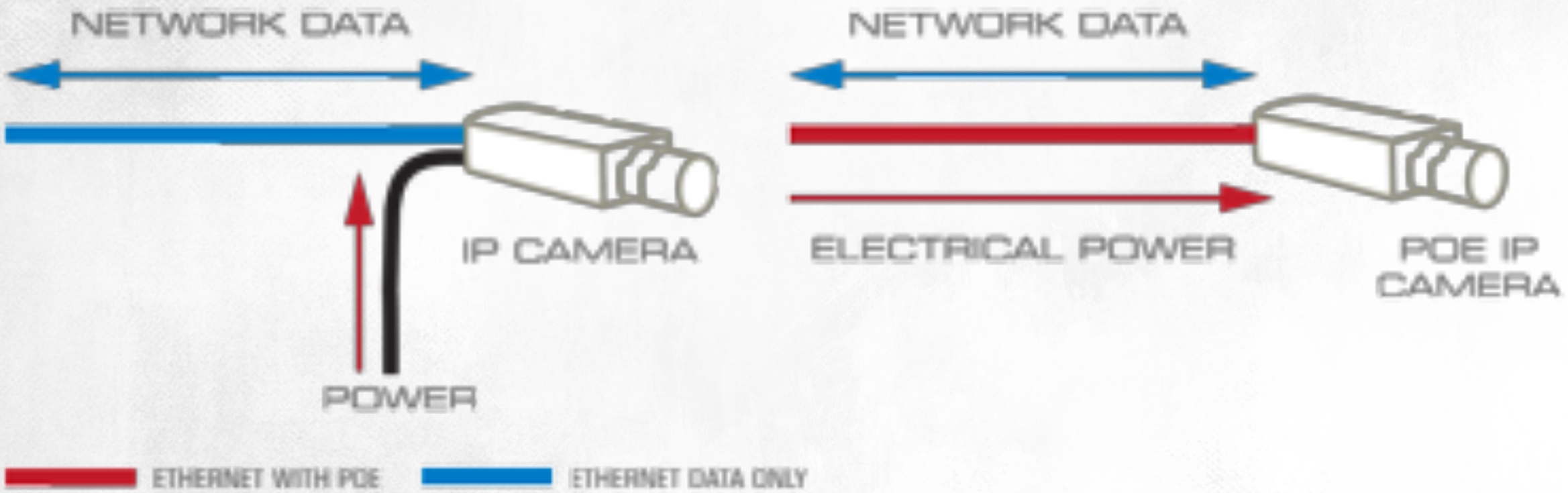
BUILDING AND INDUSTRIAL applications highlight the need for lower speed Ethernet solutions in harsh environments. The Ethernet community is working to define a single standard for 10 Mb/s operation plus power delivery over a single twisted pair. This will consolidate a landscape of multiple legacy protocols, driving the promise of Ethernet's multi-level interoperability to new heights for these spaces, as 2019 forecasts point to 165 million ports per year.

SERVICE PROVIDERS have driven higher speed Ethernet solutions for decades. Router connections, client side optics for optical transport networks (OTN) equipment, and wireless backhaul have continually pushed Ethernet to higher rates and distances to meet the demands for wireless connectivity. And with global demand by consumers for video, this shows no signs of changing.

To get a PDF version of the roadmap and to find out more about the roadmap, please go to: **www.ethernetalliance.org/roadmap/**

Power over Ethernet

- Single cable for both data and power



Reference: http://www.veracityglobal.com/resources/articles-and-white-papers/poe-explained-part-1.aspx

IEEE 1588

- GPS level synchronization using Ethernet

Reference: http://www.excelnex.com/enews/aug10/get_in_sync_with_the_latest_precision_time_protocol.html

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What is this?

Reference: https://en.wikipedia.org/wiki/Wi-Fi_Alliance

Overview

- IEEE 802.11 is part of the IEEE 802 set of LAN protocols, and specifies the set of media access control (MAC) and physical layer (PHY) protocols for implementing wireless local area network (WLAN) Wi-Fi computer communication in various frequencies, including but not limited to 2.4, 5, and 60 GHz frequency bands.

IEEE 802.11

Overview

- They are the world's most widely used wireless computer networking standards, used in most home and office networks to allow laptops, printers, and smartphones to talk to each other and access the Internet without connecting wires. They are created and maintained by the Institute of Electrical and Electronics Engineers (IEEE) LAN/MAN Standards Committee (IEEE 802). The base version of the standard was released in 1997, and has had subsequent amendments. The standard and amendments provide the basis for wireless network products using the Wi-Fi brand. While each amendment is officially revoked when it is incorporated in the latest version of the standard, the corporate world tends to market to the revisions because they concisely denote capabilities of their products. As a result, in the marketplace, each revision tends to become its own standard.

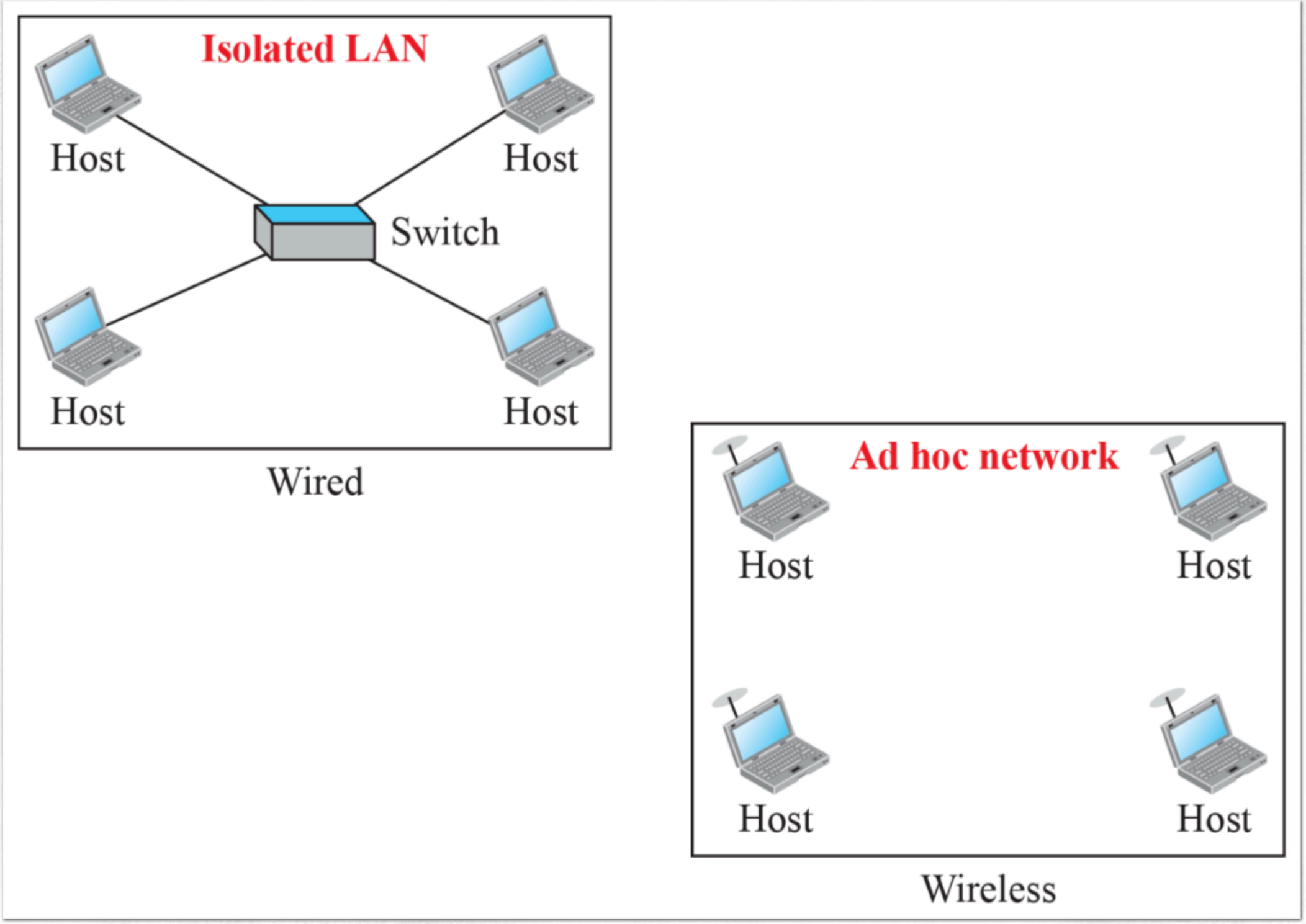
Reference: https://en.wikipedia.org/wiki/IEEE_802.11

Overview

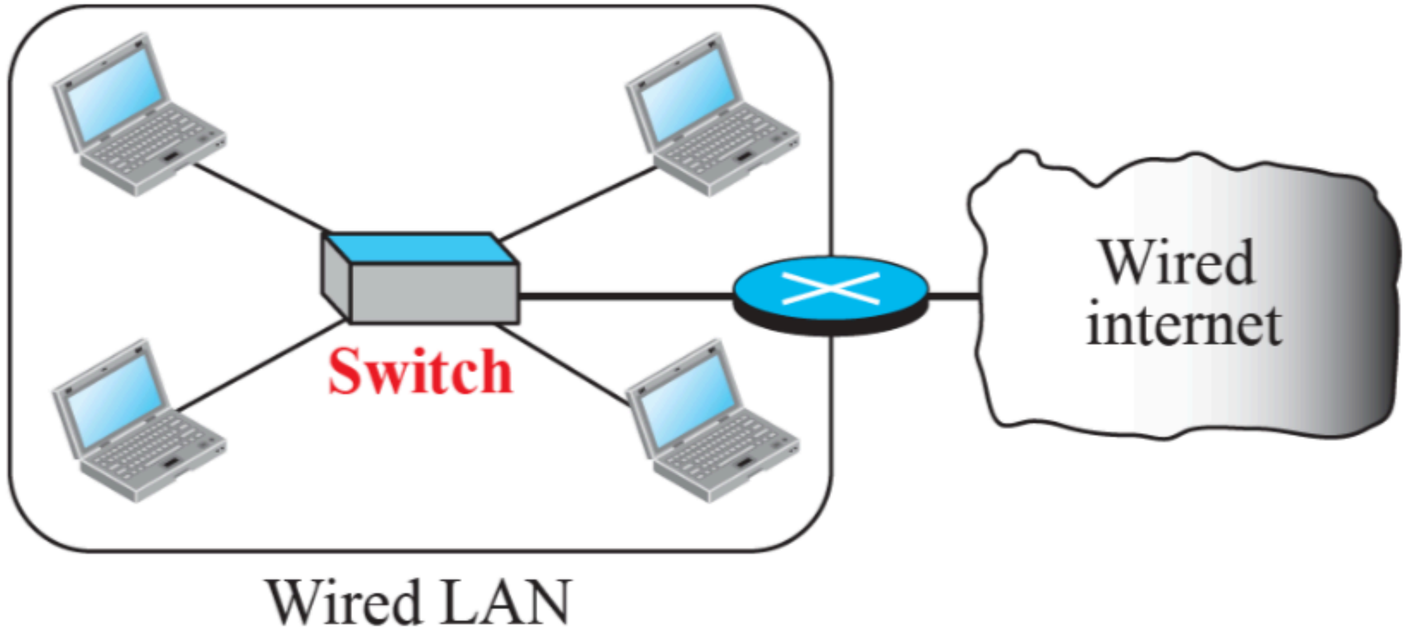
- The protocols are typically used in conjunction with IEEE 802.2, and are designed to interwork seamlessly with Ethernet, and are very often used to carry Internet Protocol traffic.

Reference: https://en.wikipedia.org/wiki/IEEE_802.11

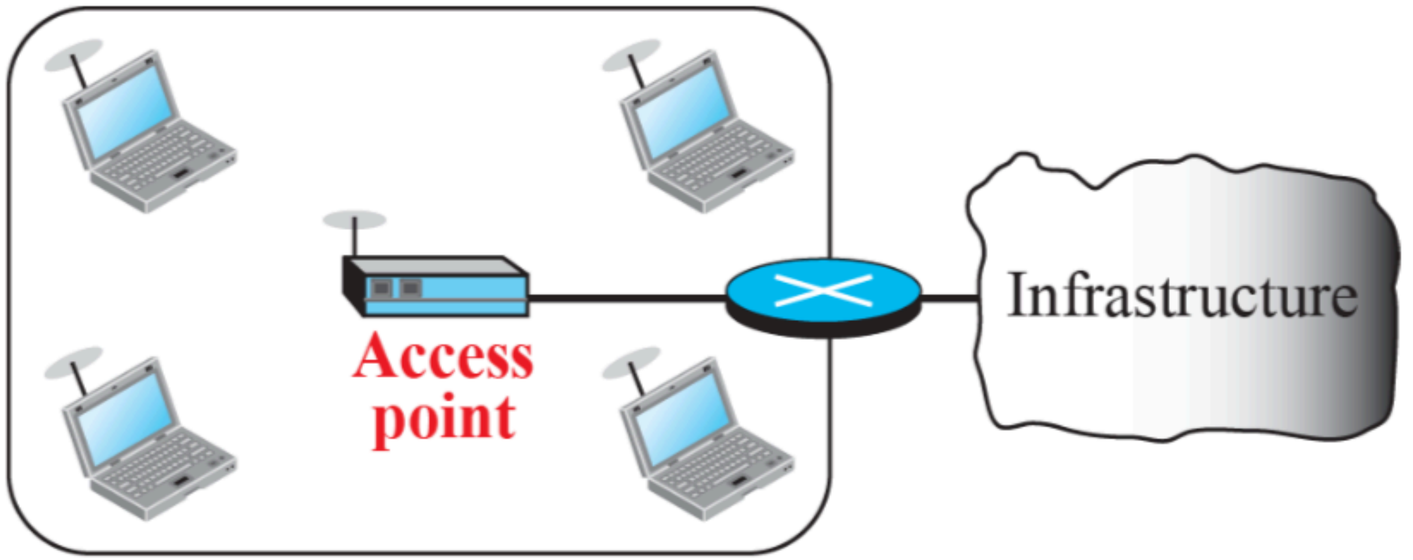
Topologies


Isolated LAN
Host
Host
Switch
Host
Host
Wired
Ad hoc network
Host
Host
Host
Host
Wireless

Topologies

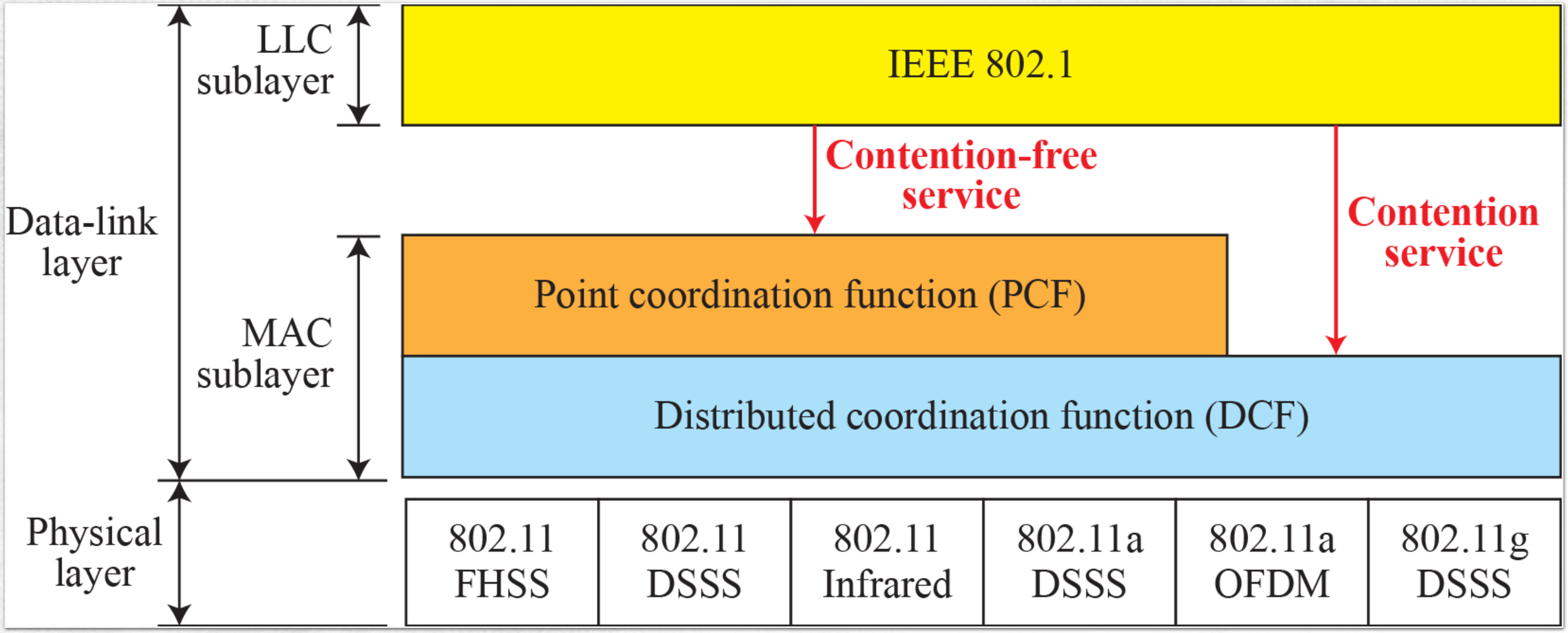


Wired LAN

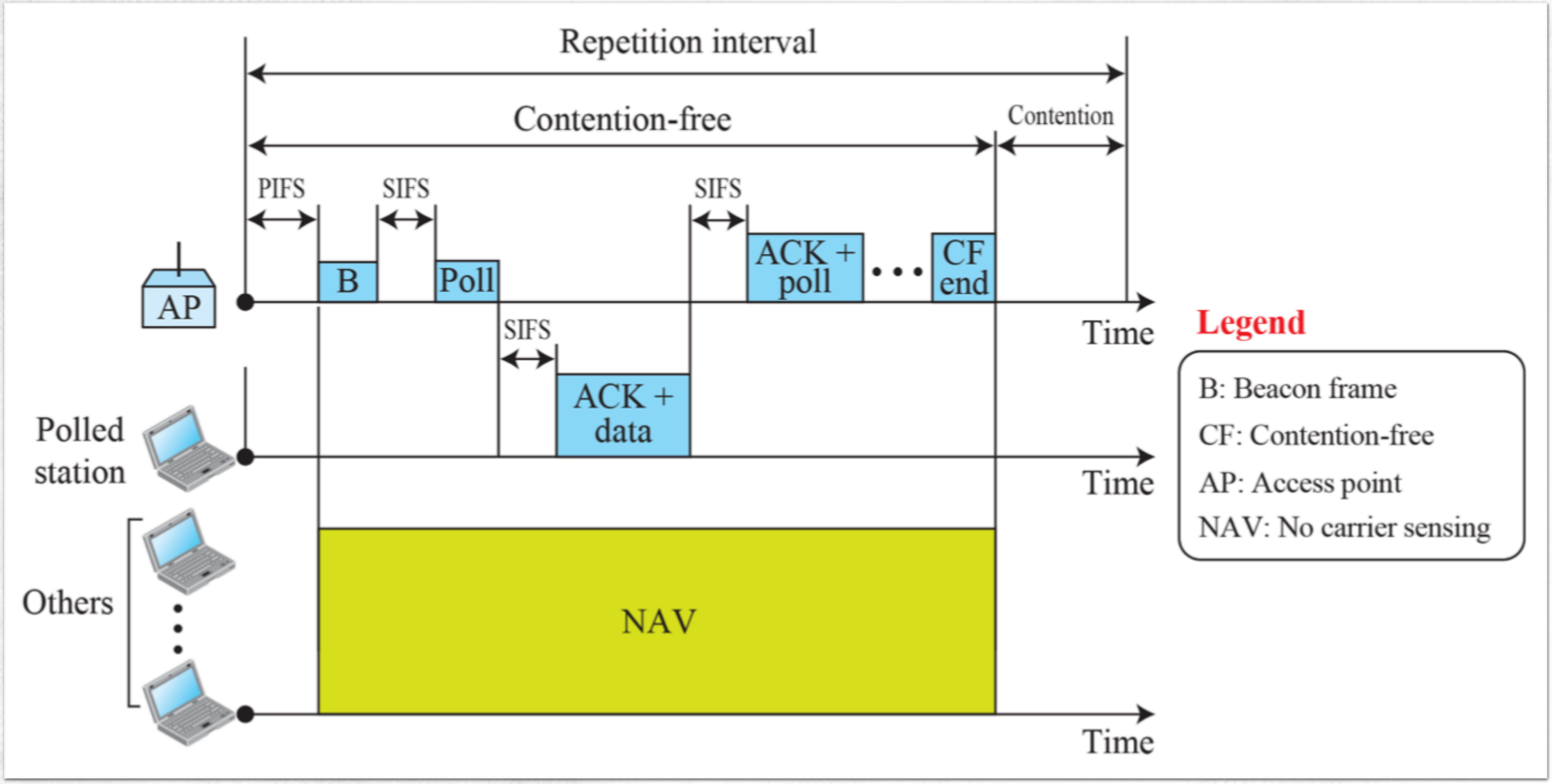


Infrastructure network

Layers


LLC sublayer
IEEE 802.1
Contention-free service
Contention service
Data-link layer
MAC sublayer
Point coordination function (PCF)
Distributed coordination function (DCF)
Physical layer
802.11 FHSS
802.11 DSSS
802.11 Infrared
802.11a DSSS
802.11a OFDM
802.11g DSSS

AP Repetition



IEEE 802.11 Speed Roadmap

- Old Technologies

IEEE	*Technique*	*Band*	*Modulation*	*Rate (Mbps)*
802.11	FHSS	2.400–4.835 GHz	FSK	1 and 2
	DSSS	2.400–4.835 GHz	PSK	1 and 2
	None	Infrared	PPM	1 and 2
802.11a	OFDM	5.725–5.850 GHz	PSK or QAM	6 to 54
802.11b	DSSS	2.400–4.835 GHz	PSK	5.5 and 11
802.11g	OFDM	2.400–4.835 GHz	Different	22 and 54
802.11n	OFDM	5.725–5.850 GHz	Different	600

IEEE 802.11 Speed Roadmap

- Today and Future Technologies

	802.11 (Legacy)	802.11b (Legacy)	802.11a (Legacy)	802.11g (Legacy)	802.11n (HT)	802.11ac (VHT)	802.11ax (HE)
Year Ratified	1997	1999	1999	2003	2009	2014	2019 (Expected)
Operating Band	2.4 GHz/IR	2.4 GHz	5 GHz	2.4 GHz	2.4/5 GHz	5 GHz	2.4/5 GHz
Channel BW	20 MHz	20 MHz	20 MHz	20 MHz	20/40 MHz	20/40/80/160 MHz	20/40/80/160 MHz
Peak PHY Rate	2 Mbps	11 Mbps	54 Mbps	54 Mbps	600 Mbps	6.8 Gbps	10 Gbps
Link Spectral Efficiency	0.1 bps/Hz	0.55 bps/Hz	2.7 bps/Hz	2.7 bps/Hz	15 bps/Hz	42.5 bps/Hz	62.5 bps/Hz
Max # SU Streams	1	1	1	1	4	8	8
Max # MU Streams	NA	NA	NA	NA	NA	4 (DL only)	8 (UL & DL)
Modulation	DSSS, FHSS	DSSS, CCK	OFDM	OFDM	OFDM	OFDM	OFDM, OFDMA
Max Constellation / Code Rate	DQPSK	CCK	64-QAM, 3/4	64-QAM, 3/4	64-QAM, 5/6	256-QAM, 5/6	1024-QAM, 5/6
Max # OFDM tones	NA	NA	64	64	128	512	2048
Subcarrier Spacing	NA	NA	312.5 kHz	312.5 kHz	312.5 kHz	312.5 kHz	78.125 kHz

Reference: https://www.rcrwireless.com/20180706/network-infrastructure/wi-fi/wi-fi-roadmap-wigig-and-beyond-tag17-tag99

Contents

- Ethernet
- WiFi
- **Bluetooth**
- Bluetooth Low Energy
- LoRa
- LoRaWAN
- LoRa/LoRaWAN Implementation

Bluetooth

What is this?

Overview

- Bluetooth is a wireless technology standard for exchanging data over short distances (using short-wavelength UHF radio waves in the ISM band from 2.400 to 2.485 GHz from fixed and mobile devices, and building personal area networks (PANs). It was originally conceived as a wireless alternative to RS-232 data cables.

Reference: https://en.wikipedia.org/wiki/Bluetooth

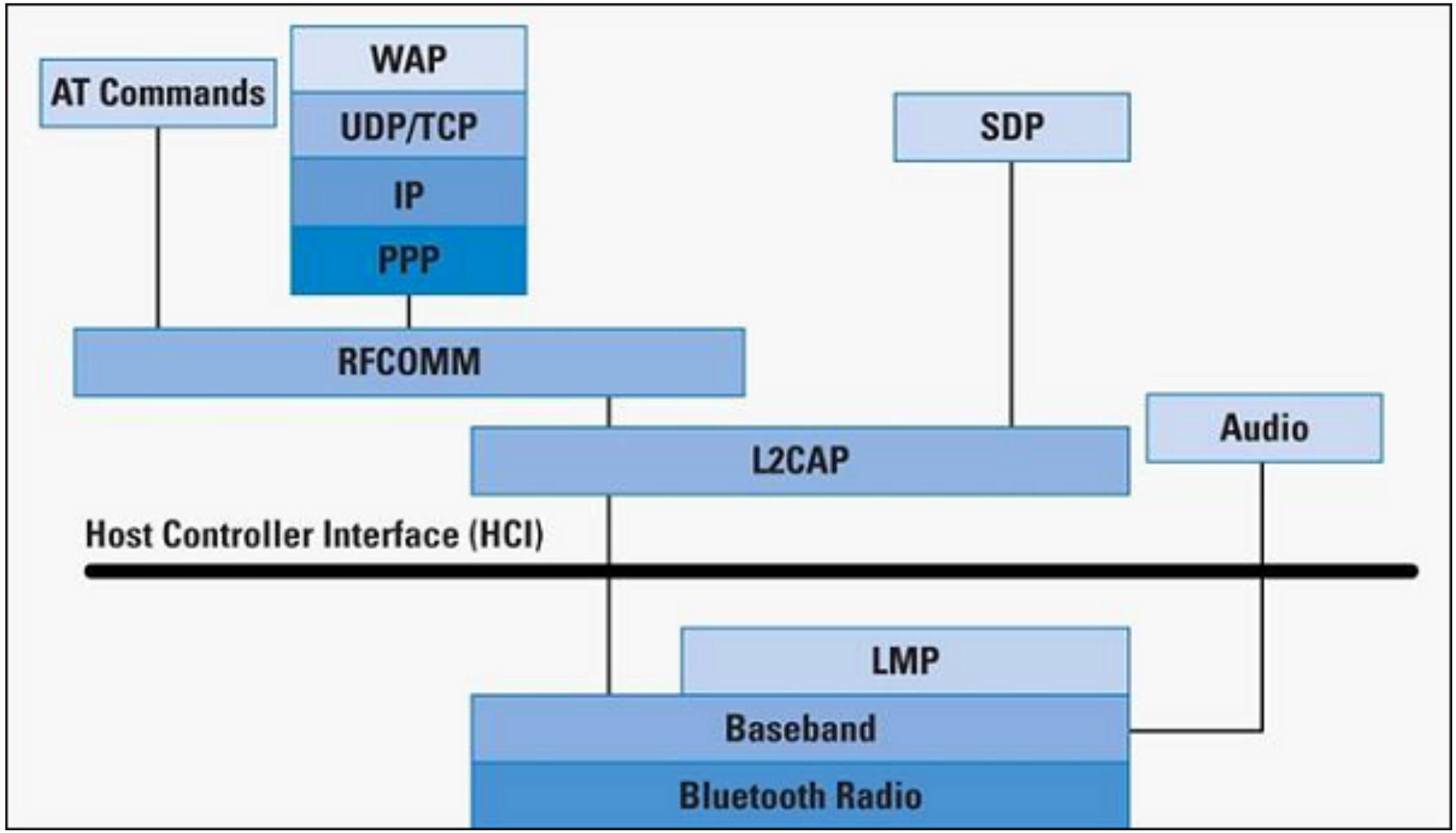
Overview

- Bluetooth is managed by the Bluetooth Special Interest Group (SIG), which has more than 30,000 member companies in the areas of telecommunication, computing, networking, and consumer electronics.
- The IEEE standardized Bluetooth as IEEE 802.15.1, but no longer maintains the standard. The Bluetooth SIG oversees development of the specification, manages the qualification program, and protects the trademarks.
- A manufacturer must meet Bluetooth SIG standards to market it as a Bluetooth device. A network of patents apply to the technology, which are licensed to individual qualifying devices.

Bluetooth Speed Roadmap

Bluetooth version	Max data rate
Bluetooth v1.0 and v1.0B	768 kbps
Bluetooth v1.1	768 kbps
Bluetooth v1.2	1 Mbps
Bluetooth v2.0 (and v2.1)+ EDR (Enhanced Data Rate)	3 Mbps
Bluetooth v3.0 + HS (High Speed)	24 Mbps
Bluetooth Smart (v4.0 and 4.1)	24 Mbps

Bluetooth Layer Stack



Reference: https://www.tutorialspoint.com/wireless_security/wireless_security_bluetooth_stack.htm

Voice & Music

Bluetooth Applications

Personal Audio

- Mono headset
- After market car kit
- DECT phones with Bluetooth®
- Stereo headset and headphones
- Gaming headset
- Enterprise headset

Shareable Audio

- Streaming Speakers and Docks
- Sound bars (and Home Theatre)
- Wireless sub woofers
- Networked Audio

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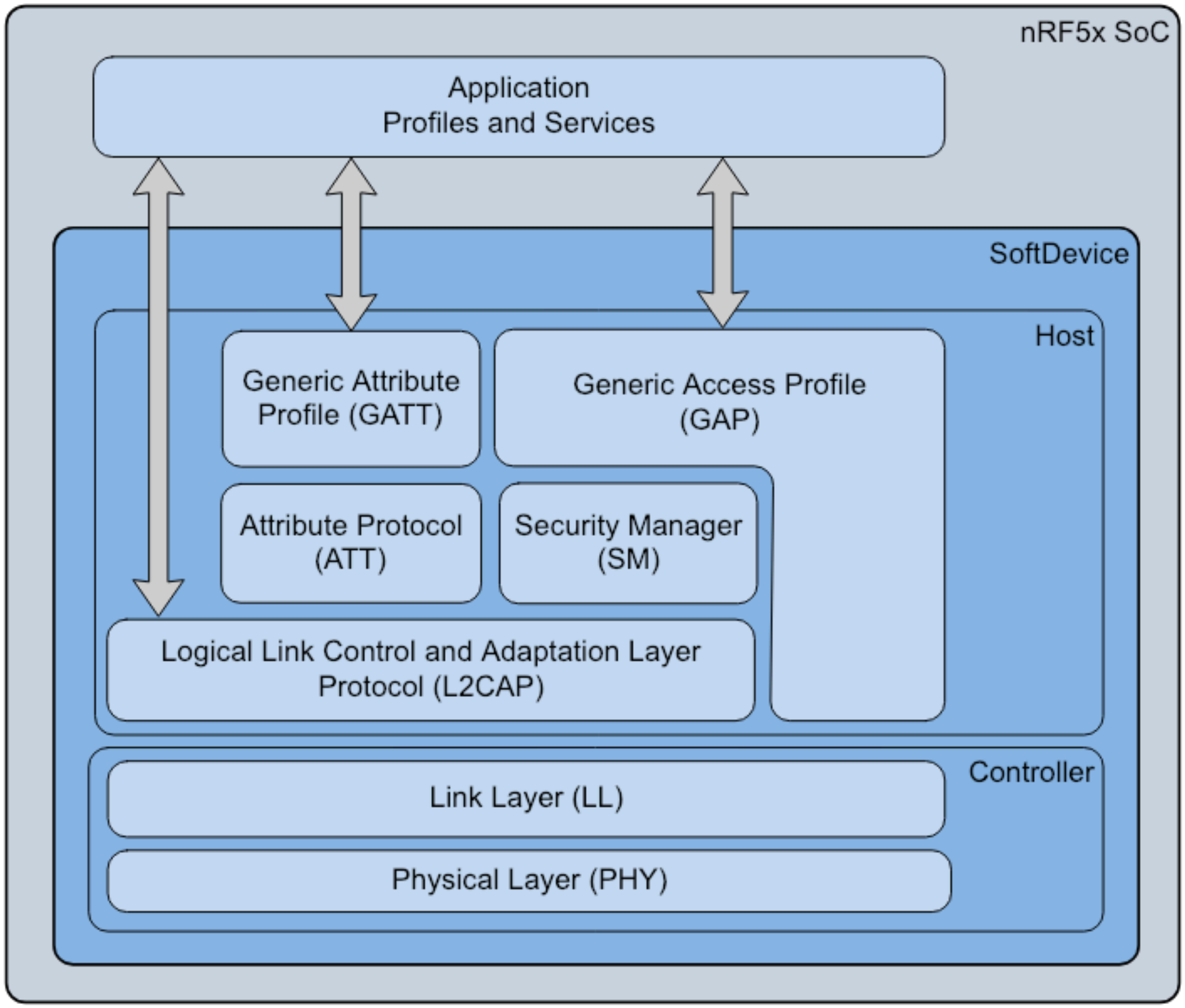
Bluetooth vs BLE Compare

Technical Specification	Classic Bluetooth technology	Bluetooth low energy technology
Radio Frequency	2.4GHz	2.4GHz
Distance/Range	10m	10m
Over the air data rate	1–3 Mbit/s	1 Mbit/s
Application throughput	0.7–2.1 Mbit/s	0.2 Mbit/s
Active slaves	7-16,777,184	Unlimited
Security	64/128bit and application layer user defined	128bit AES and application layer user defined
Robustness	Adaptive fast frequency hopping, FEC, fast ACK	Adaptive fast frequency hopping
Latency (from a non-connected state)	Typically 100 ms	6 ms
Total time to send data	100 ms	<6 ms
Government Regulation	Worldwide	Worldwide
Certification Body	Bluetooth SIG	Bluetooth SIG
Voice capable	Yes	No
Network topology	Scatternet	Star-bus
Power consumption	1 as the reference	0.01 to 0.5 (depending on use case)
Peak current consumption	<30 mA	<15 mA
Service discovery	Yes	Yes
Profile concept	Yes	Yes
Primary use cases	Mobile phones, gaming, headsets, stereo audio streaming, automotive, PCs etc.	Mobile phones, gaming, PCs, watches, sports and fitness, healthcare, security & proximity, automotive, home electronics, automation, Industrial, etc.

Reference: https://archive.eetindia.co.in/www.eetindia.co.in/ART_8800692953_1800005_TA_2739daba.HTM

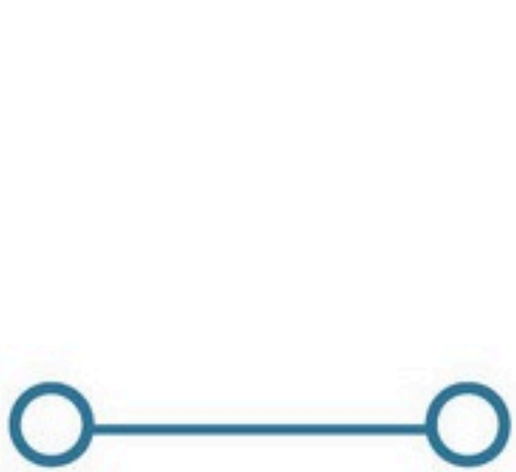
BLE
Layer Stack



Reference: http://infocenter.nordicsemi.com/index.jsp?topic=%2Fcom.nordic.infocenter.s140.sds%2Fdita%2Fsoftdevices%2Fs130%2Fble_protocol_stack%2Fble_protocol_stack.html

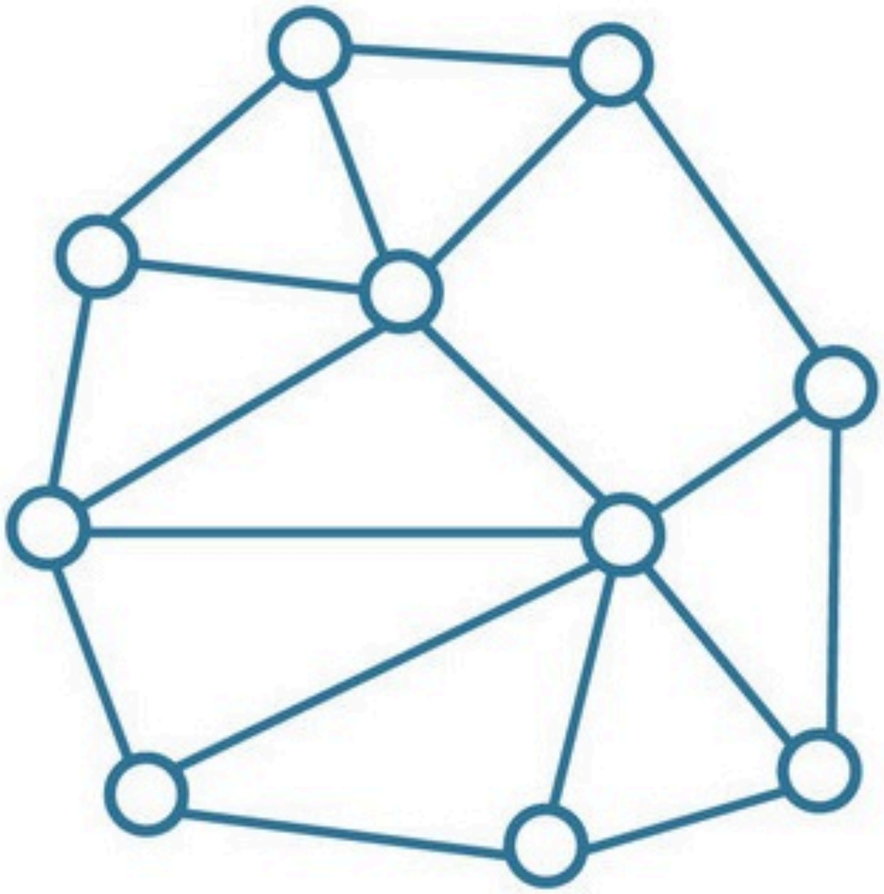
BLE Network

Pairing



Broadcasting

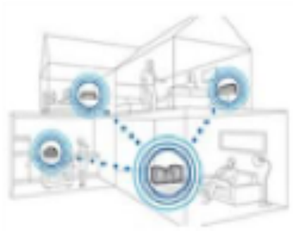
Mesh



Reference: http://powerpulse.net/bluetooth-mesh-solution-helps-cut-time-to-market-by-six-months/

Home entertainment ecosystem

Bluetooth & BLE Applications



CSR Network Audio for streaming audio around the house

CSRmesh for Home Control

CSR Soundbar Solutions DDFA / MAP-X

CSR BT Wireless Sub-woofer

Active 3D Glasses

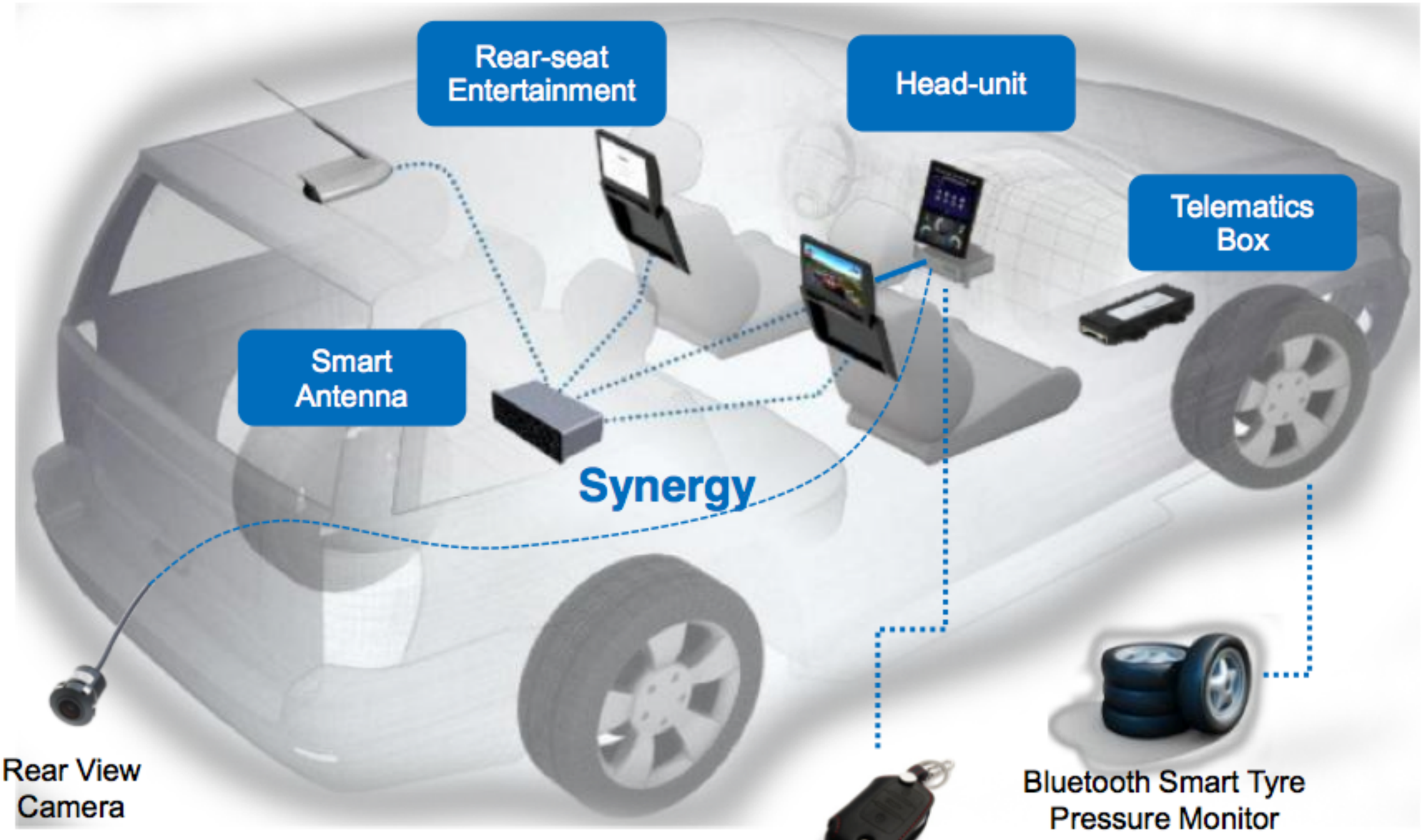
CSR Headset Solutions aptX Low latency

CSR Game controller Solutions

CSR BLE for Remote Controls, Active glasses & Keyboards

Automotive connectivity

Bluetooth & BLE Applications



cVc csr

apt X csr

µEnergy csr

SiRFDrive csr

SiRFInstantFixII csr

Synergy

Bluetooth Smart ecosystem

Bluetooth & BLE Applications

HID

CSR1010

Glucose meter

CSR1010

HID

CSR1011

Bluetooth® SMART READY

Weight scale

CSR1010

HID

CSR1011

Heart Rate

CSR1010

Cycle Speed

CSR1010

Insulin pump

CSR1010

Bluetooth® SMART

What is Bluetooth Smart?

Bluetooth & BLE Applications

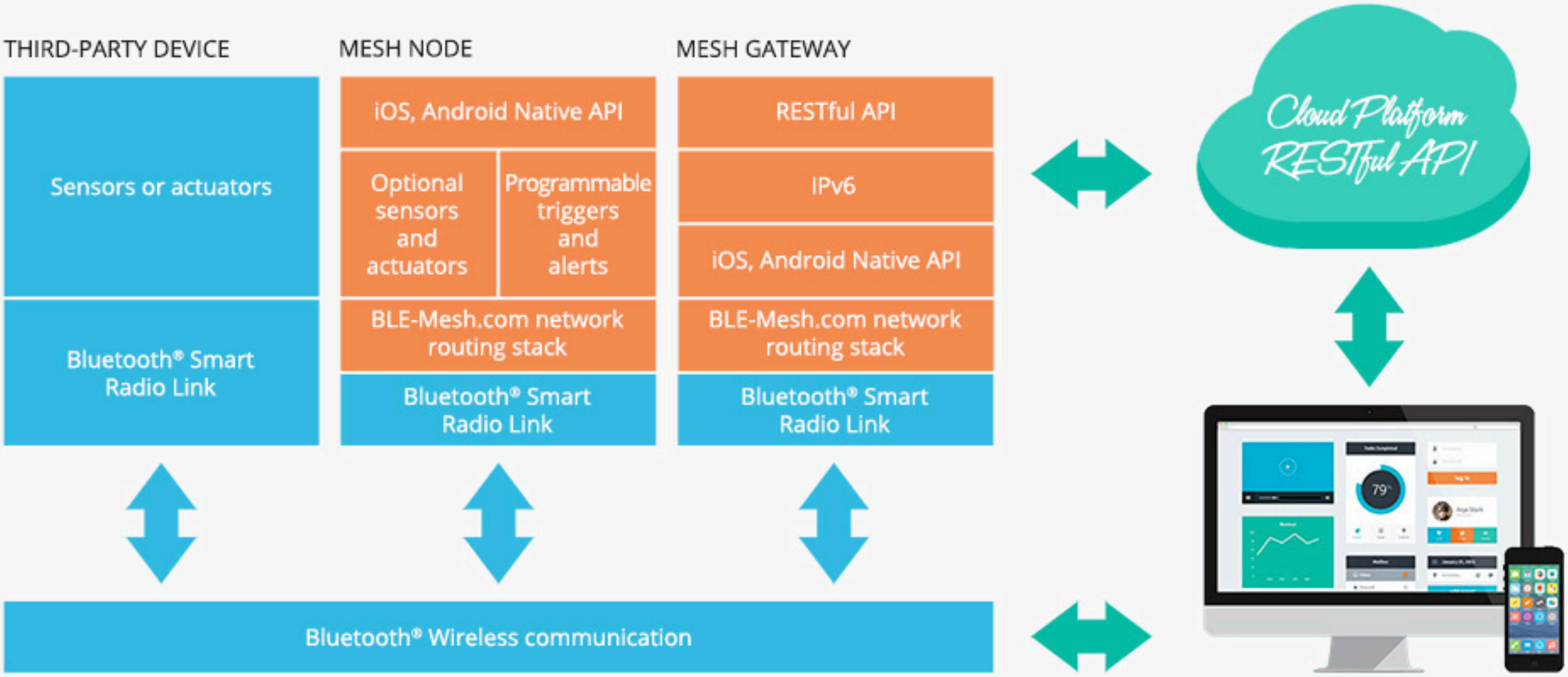
Bluetooth SMART

Bluetooth SMART READY

Bluetooth SMART

Bluetooth SMART READY

Bluetooth & BLE Software Stack



CSRmesh™ - Get ready to be inspired…

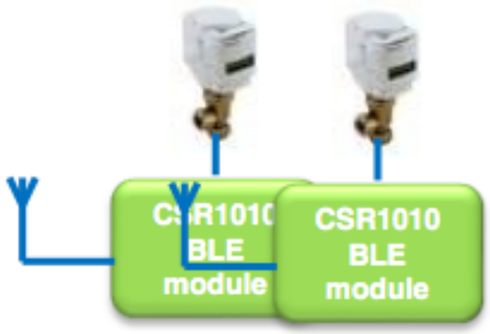
BLE Mesh Applications

CSRmesh network

BLE Mesh Applications

Lighting

Heating



Thermostats

Sensors

Switches

Allows you to control anything from anywhere in the world

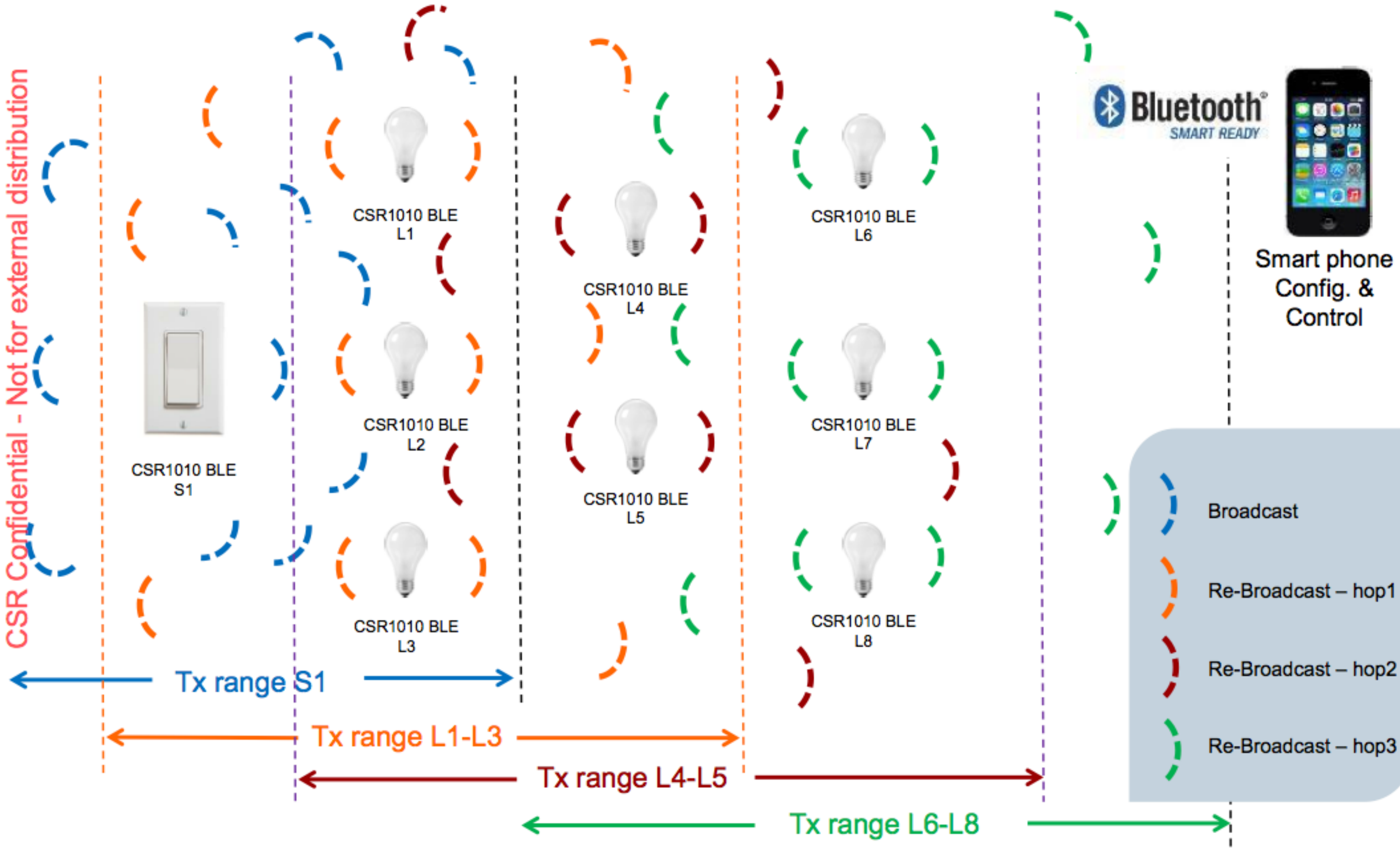
OR

OR

Android iPhone PC

Access

BLE Mesh Applications



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What is this?

LoRa™ Alliance

Wide Area Networks for IoT

Overview

- LoRa (Long Range) is a patented digital wireless data communication technology developed by Cycleo of Grenoble, France, and acquired by Semtech in 2012.
- LoRa uses license-free sub-gigahertz radio frequency bands like 169 MHz, 433 MHz, 868 MHz (Europe) and 915 MHz (North America). LoRa enables very-long-range transmissions (more than 10 km in rural areas) with low power consumption.
- The technology is presented in two parts — LoRa, the physical layer and LoRaWAN (Long Range Wide Area Network), the upper layers.

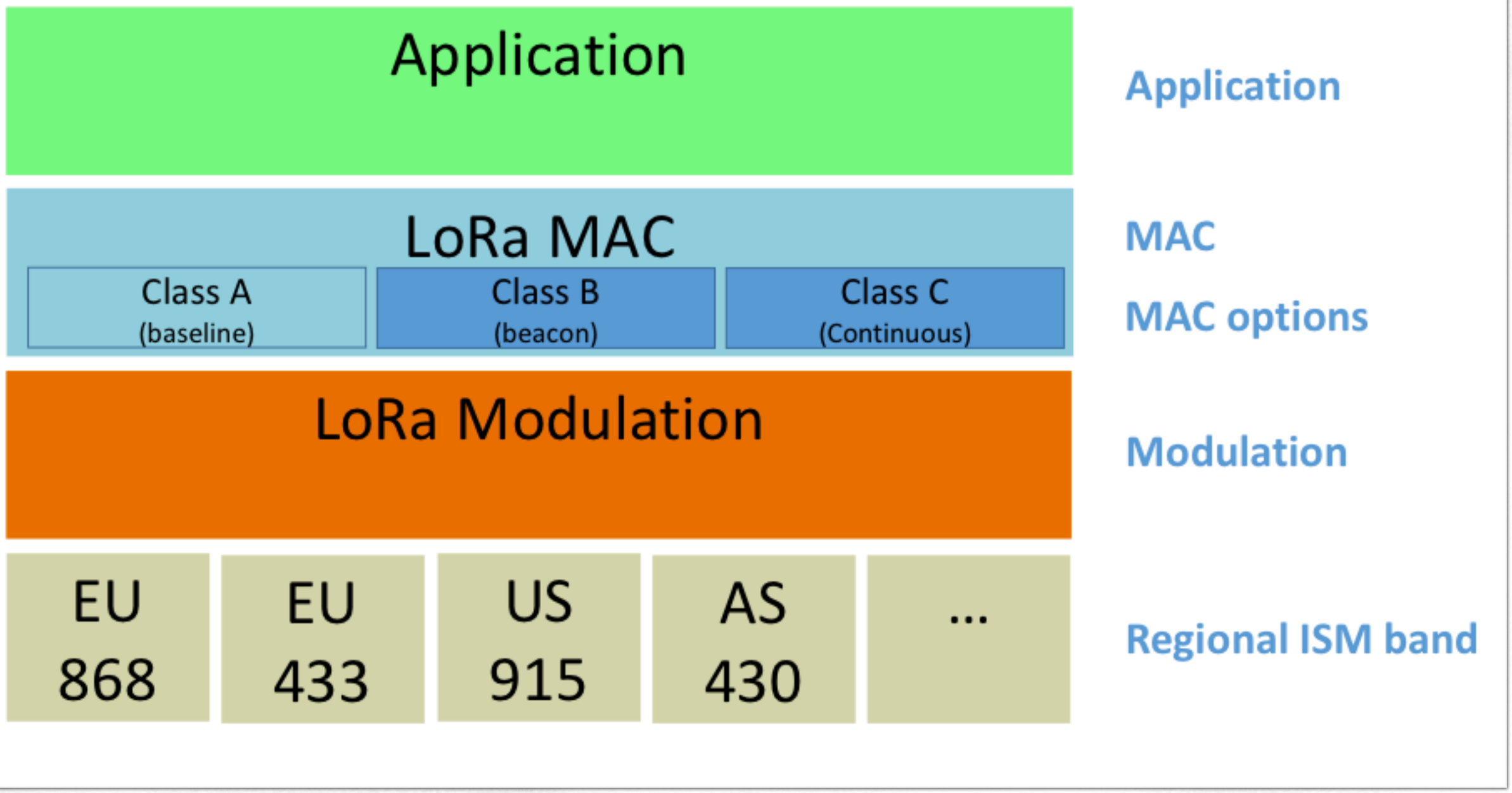
Reference: https://en.wikipedia.org/wiki/LoRa

Overview

- LoRa and LoRaWAN permit inexpensive, long-range connectivity for Internet of Things (IoT) devices in rural, remote and offshore industries.
- They are typically used in mining, natural resource management, renewable energy, transcontinental logistics, and supply chain management.

Reference: https://en.wikipedia.org/wiki/LoRa

Protocol Layer



Reference: https://enablingsupport.zendesk.com/hc/en-us/articles/206069491-LoRaWAN-device-classes

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- WiFi
- Bluetooth
- Bluetooth Low Energy
- LoRa
- **LoRaWAN**
- LoRa/LoRaWAN Implementation

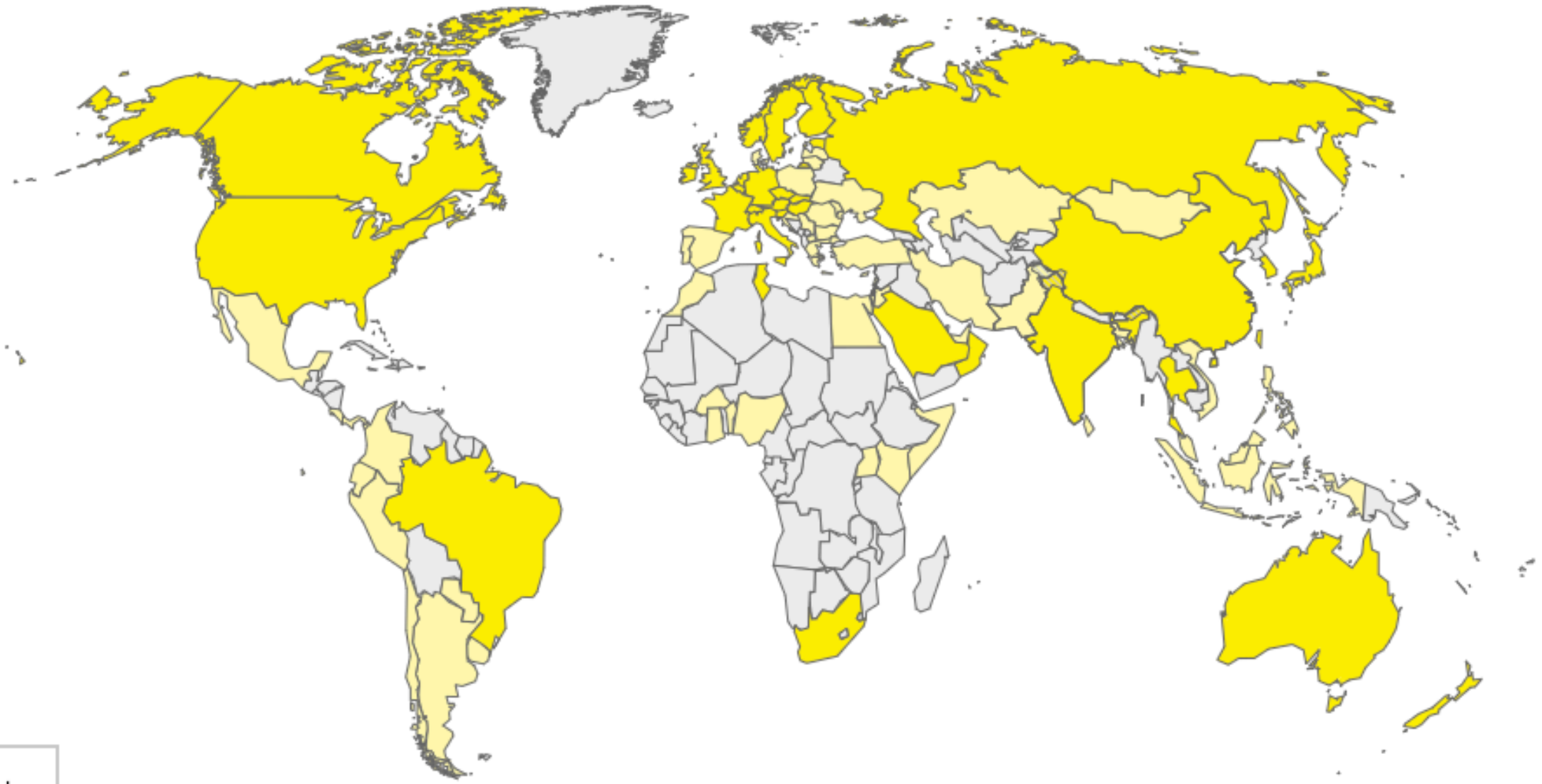
What is this?

100
Network Operators

68
Alliance Member Operators

51
Countries operating in

100
Countries with LoRaWAN Deployments



Reference: https://lora-alliance.org/

Overview

- LoRaWAN is the network on which LoRa operates, and can be used by IoT for remote and unconnected industries.
- LoRaWAN is a media access control (MAC) layer protocol but mainly is a network layer protocol for managing communication between LPWAN gateways and end-node devices as a routing protocol, maintained by the LoRa Alliance.
- Version 1.0 of the LoRaWAN specification was released in June 2015. In basic terms, one can consider LoRaWAN to be a new WiFi to connect new IoT devices across every industry.

Reference: https://en.wikipedia.org/wiki/LoRa

Overview

- LoRaWAN defines the communication protocol and system architecture for the network, while the LoRa physical layer enables the long-range communication link.
- LoRaWAN is also responsible for managing the communication frequencies, data rate, and power for all devices.
- Devices in the network are asynchronous and transmit when they have data available to send.
- Data transmitted by an end-node device is received by multiple gateways, which forward the data packets to a centralized network server.

Reference: https://en.wikipedia.org/wiki/LoRa

Overview

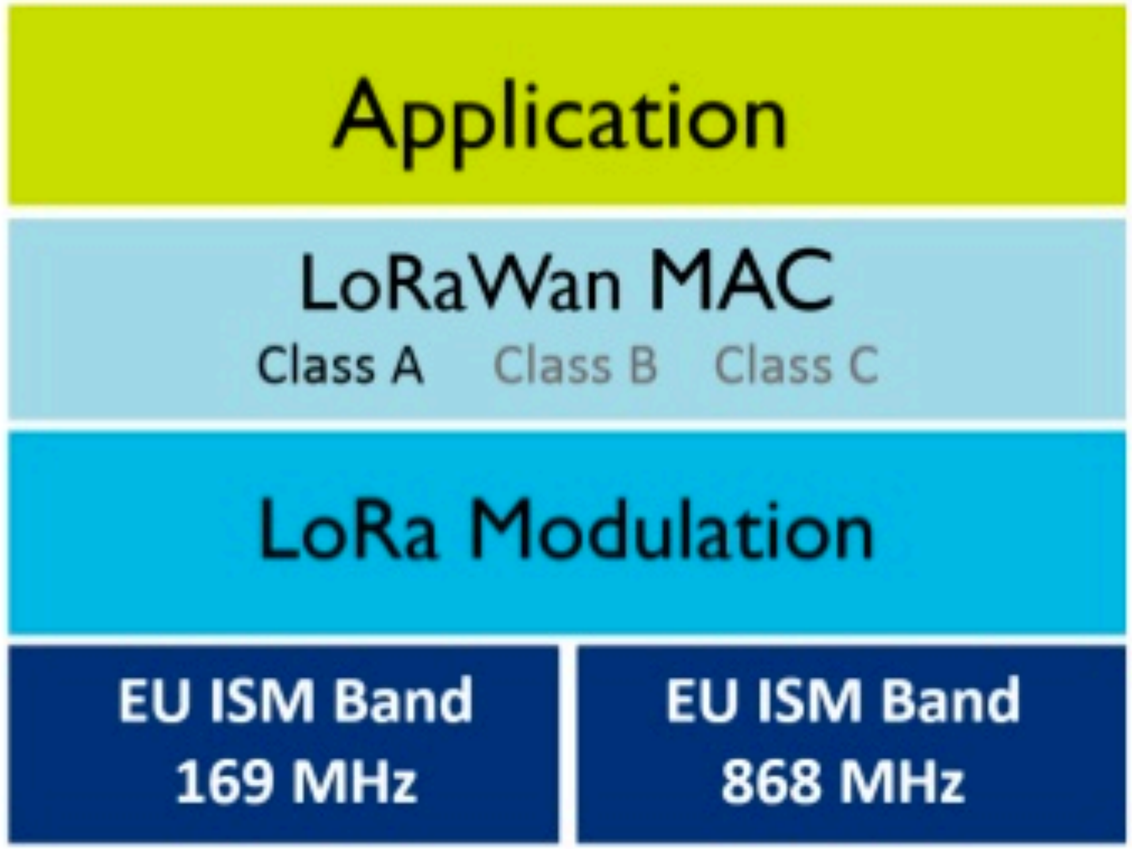
- The network server filters duplicate packets, performs security checks, and manages the network.
- Data is then forwarded to application servers.
- The technology shows high reliability for the moderate load, however, it has some performance issues related to sending acknowledgements.

Reference: https://en.wikipedia.org/wiki/LoRa

Protocol Layer

LoRa Layers

AMIHO technology



Application layer for end user development

LoRaWAN protocols **only available at 868MHz**
Currently AMIHO provides Class A.

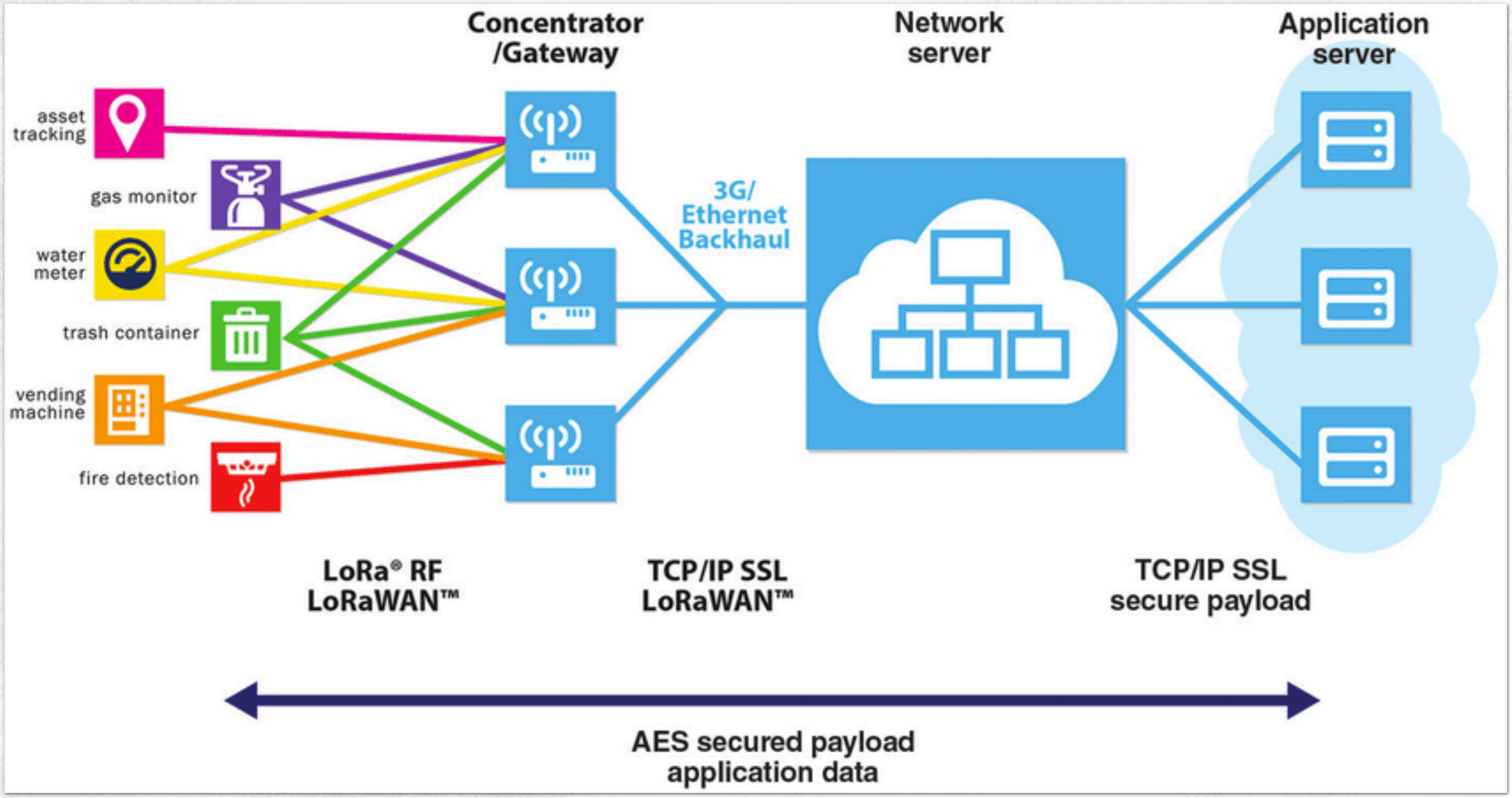
LoRa spread spectrum long range capability

Radio Band – Licence-free spectrum in Europe

Reference: https://enablingsupport.zendesk.com/hc/en-us/articles/206069491-LoRaWAN-device-classes

LoRaWAN

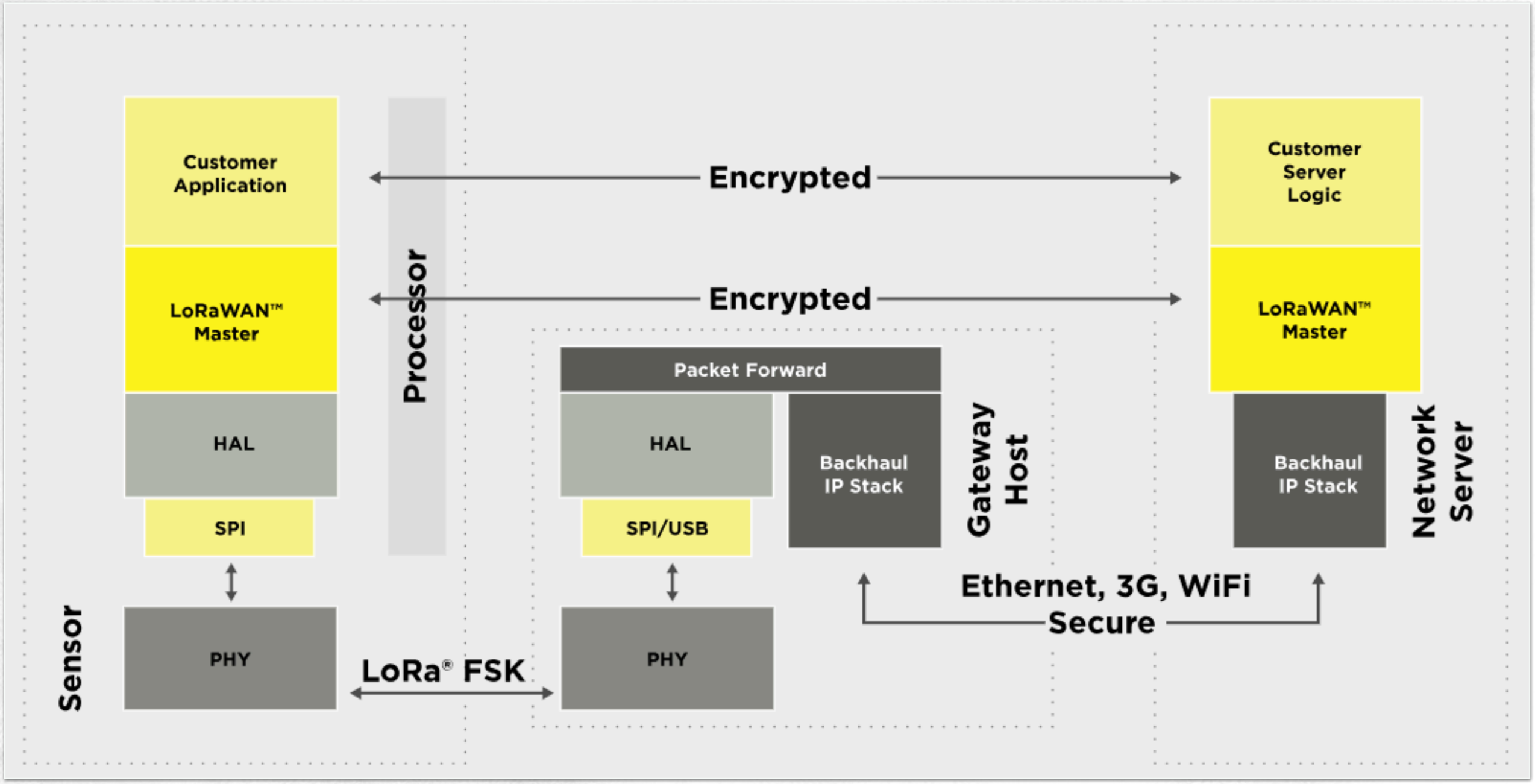
Network Architecture



Reference: https://en.wikipedia.org/wiki/LoRa

LoRaWAN

Protocol Stack



Reference: https://en.wikipedia.org/wiki/LoRa

Contents

- Ethernet
- WiFi
- Bluetooth
- Bluetooth Low Energy
- LoRa
- LoRaWAN
- **LoRa/LoRaWAN Implementation**

Outdoor Opened!

Open is Everything

{Standard, Hardware, Software, Spectrum}

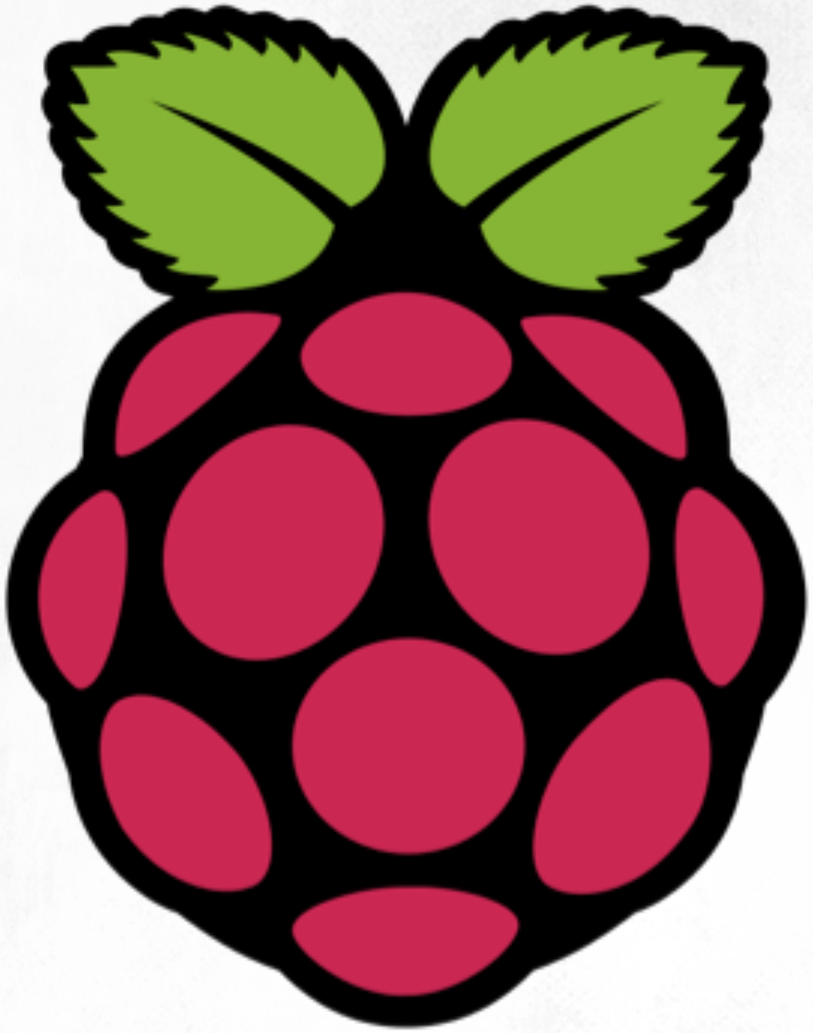
Open Ecosystem

Hardware

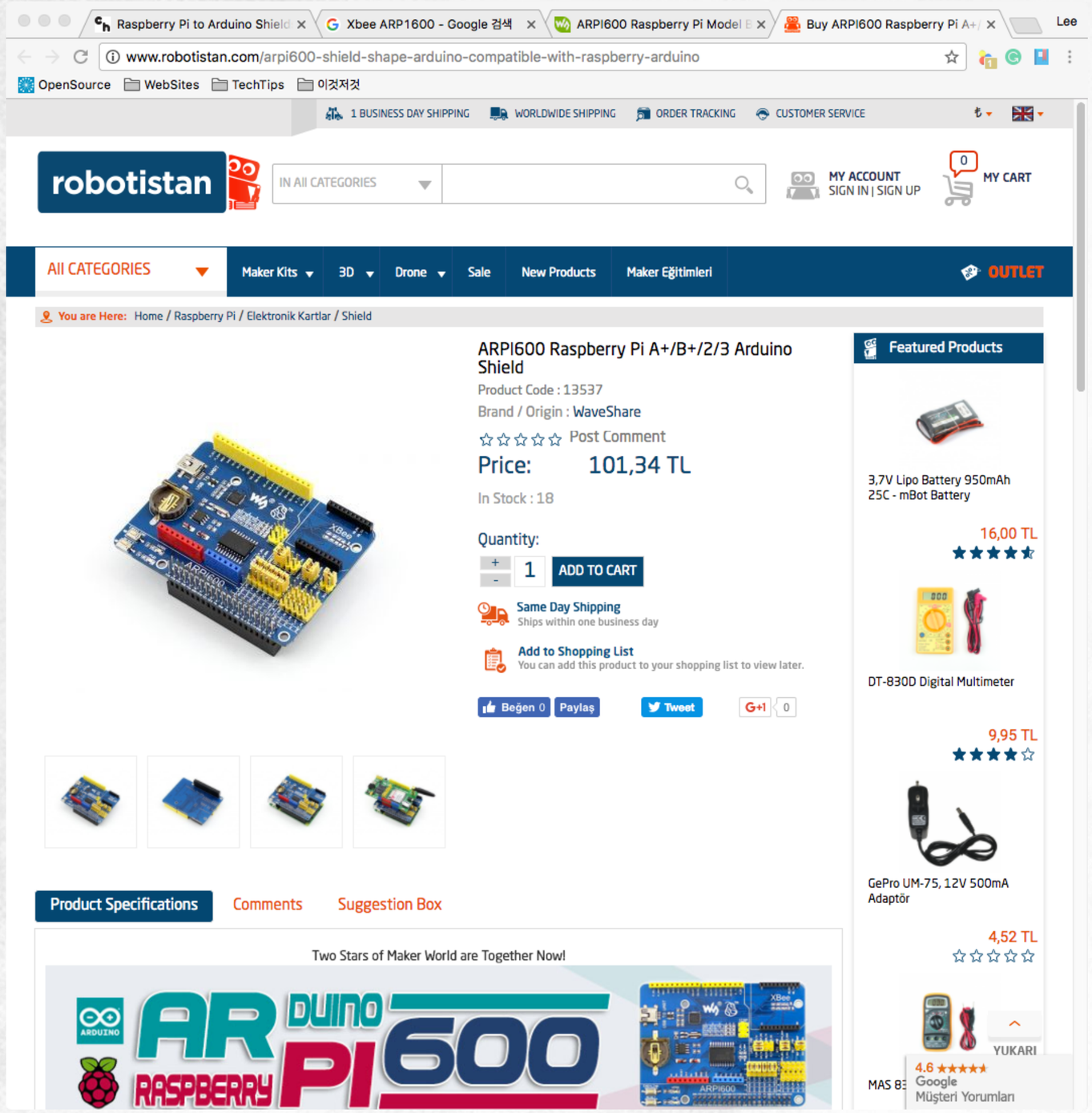
참조: https://www.lora-alliance.org/What-Is-LoRa/Technology

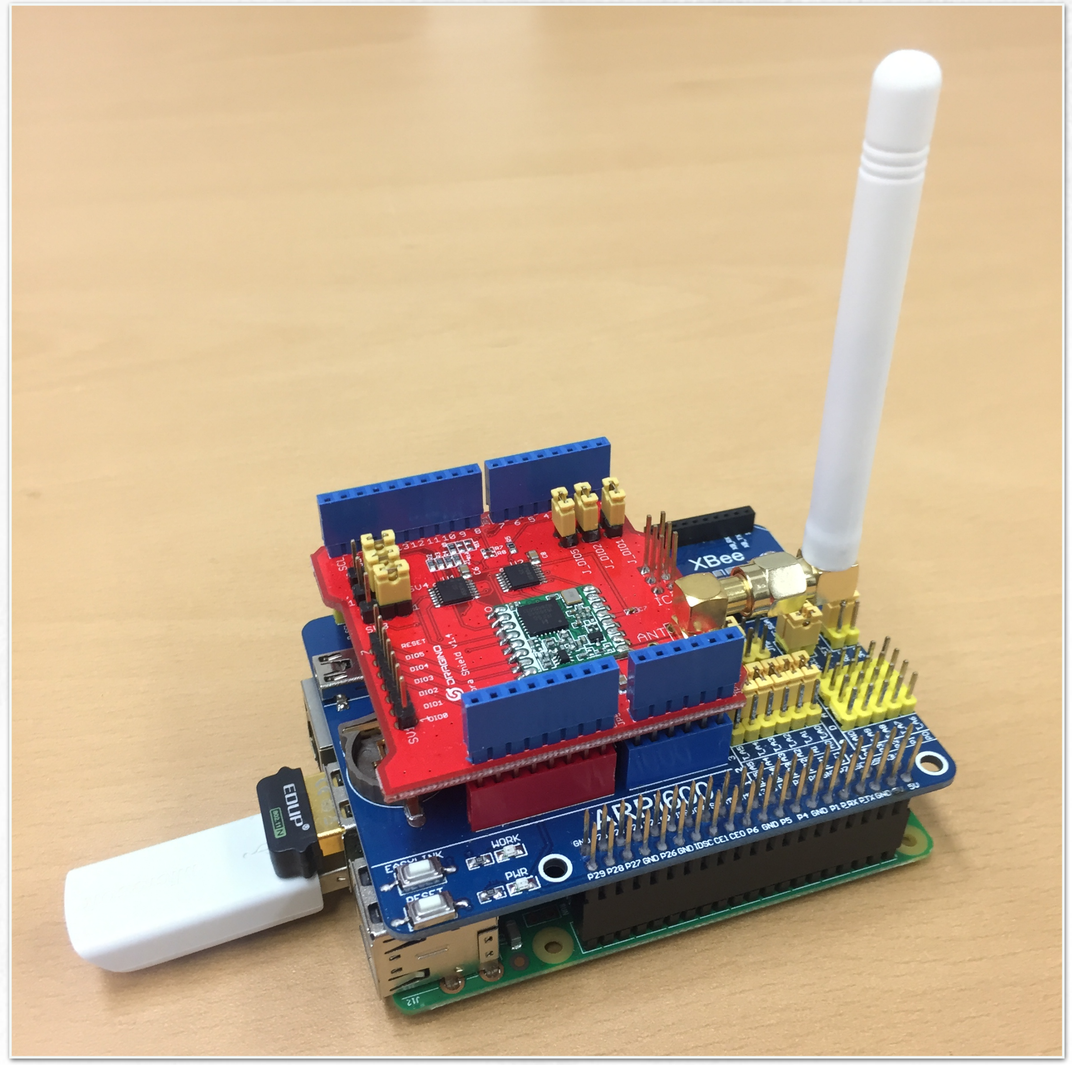
Open Ecosystem

Hardware



Development using RPi & Shield





참조: http://www.robotistan.com/arpi600-shield-shape-arduino-compatible-with-raspberry-arduino

Development using Arduino

ARDUINO MKR WAN 1300 (LORA CONNECTIVITY)

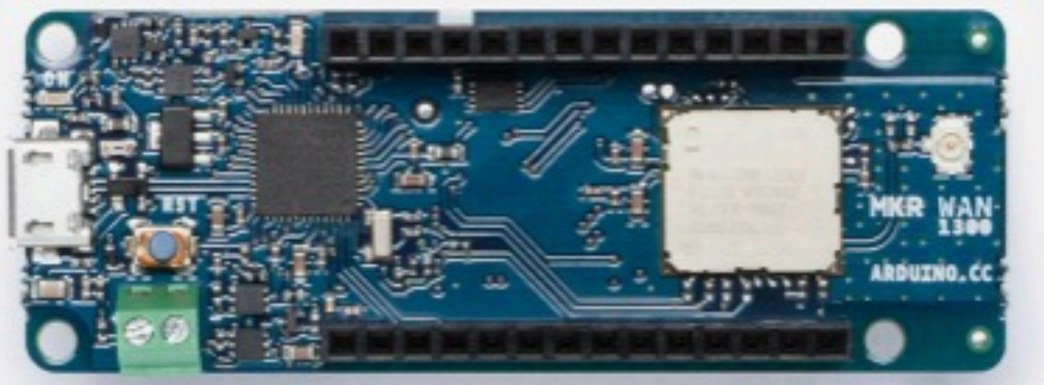
Code: ABX00017-B

$39.90

tax not included

Quantity: 1

ADD TO CART



Want to learn more?

GETTING STARTED

참조: https://store.arduino.cc/usa/mkr-wan-1300

Open Ecosystem

Software

Features Business Explore Pricing

LoRa™ network

Grenoble (FR), Neuchâtel (CH), Camarillo... http://www.semtech.co

Repositories People 1

Search repositories...

LoRaMac-node

Reference implementation and documentation of a LoRa network node.

C ★ 387 291 Updated 2 days ago

packet_forwarder

A LoRa packet forwarder is a program running on the host of a LoRa gateway that forwards RF packets receive by the concentrator to a server through a IP/UDP link, and emits RF packets that are sent by the server.

C ★ 174 199 Updated 12 days ago

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Lora-net / LoRaMac-node

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Code Issues 12 Pull requests 1 Projects 0 Wiki Pulse Graphs

Reference implementation and documentation of a LoRa network node.

265 commits 4 branches 17 releases 8 contributors BSD-3-Clause

Branch: master New pull request Find file Clone or download

djaeckle Merge branch 'release/v4.3.2' Latest commit e506c24 on 20 Apr

Doc	Added NAMote72 platform support.	3 months ago
Keil	Added NAMote72 platform support.	3 months ago
coIDE	Added NAMote72 platform support.	3 months ago
src	Removed extra line at the end of the file.	a month ago
.gitignore	Addition of Motell platform based on the IMST module iM881A (STM32L05...	6 months ago
LICENSE.txt	COnvert line endings to windows.	11 months ago
readme.md	Update readme file	a month ago

readme.md

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    (C)2013 Semtech
```

LoRaWAN endpoint stack implementation and example projects.

agrint

Meet The Red Palm Weevil

LOS-ALCAZARES.COM

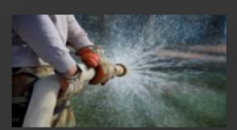
LoRa Alliance™ Wide Area Networks for IoT

4B Palm Trees Worldwide Are Suffering From a Global Catastrophe

2% of Palm Trees are infected **every year** by the **Red Palm Weevil**, a flying insect which lays eggs inside the trees.

The larvae feeds on the core of the tree and evolves inside it.

The tree, **does not show any signs of distress** until the treetop collapses and the **tree is DEAD**.



Today there are NO methods to detect, all solutions are about prevention -

Spraying ALL trees with "Spray and Pray" strategy.

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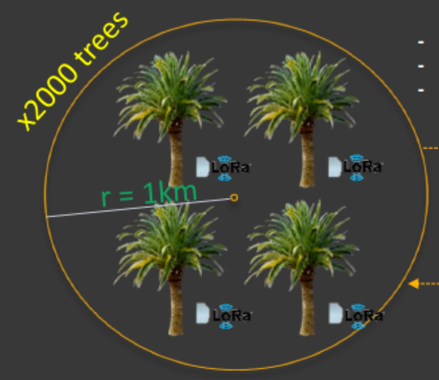
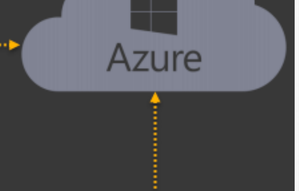
LoRa-Alliance.org

IoTree Communication Architecture



- Sensor Status
- Tree Status
- Energy Status

- Activation
- Debug
- FW Upgrade



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Why we chose LoRa for the IoTree Communication?

Covers plantations throughout large areas → Long Range Communication

Low bandwidth and robustness → Refining and transmission of the relevant information only

Compatible, easy worldwide deployment → Free-to-use Frequencies Range

Relaying on lasting batteries for 3+ years → Low Energy Consumption

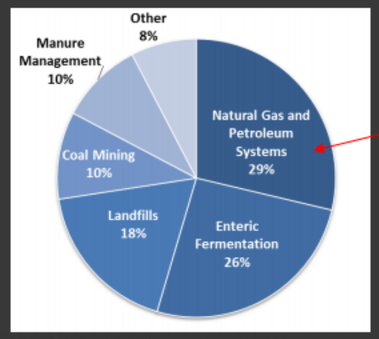
Affordable for each farmer → Cost-Effective

LoRa Alliance™ Wide Area Networks for IoT

LoRa-Alliance.org

Pix CONTROLLER

Global Warming due to Methane Emissions



Global Methane Inventory

Global warming is recognized as a serious worldwide challenge. Methane gas is a strong greenhouse gas with a global warming potential of 25 time over CO2.

US Oil & Gas Industry alone releases more than 7.3 million metric tons of fugitive methane emissions at a loss of nearly $2 billion and is responsible for close to 30 percent of global methane emissions.

Current methane detection methods are manual sampling, do not provide accurate data, and are costly to the industry.

Methane Gas Sensor

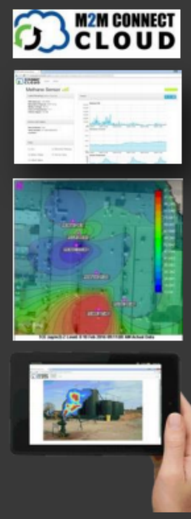
Thermal Camera

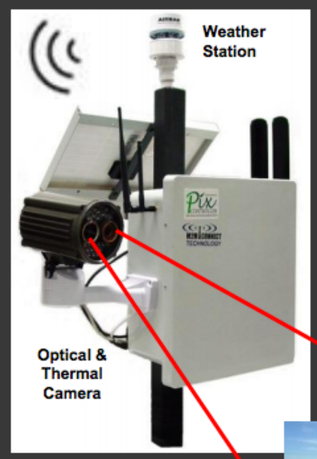
Bi-Annual Manual Inspection
Industry average cost $12K to $18K USD per site

LoRa Alliance™ Wide Area Networks for IoT

LoRa-Alliance.org

OMEDS System Overview





OMEDS Base Station

LoRa Wireless Methane Sensor

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OMEDS LoRaWAN Technology

OMEDS Base Station

LoRaWAN Gateway
MultiTech
MultiConnect® Conduit™

PixController
M2M Connect Technology

- Camera Control
- Power Management

LoRa Wireless Methane Sensor

LoRa Sensor Transmitter
MultiTech
MultiConnect® mDot™

PixController Methane Sensor

- Methane
- Barometric Pressure
- Relative Humidity
- GPS
- Battery Level

LoRa Alliance™ Wide Area Networks for IoT

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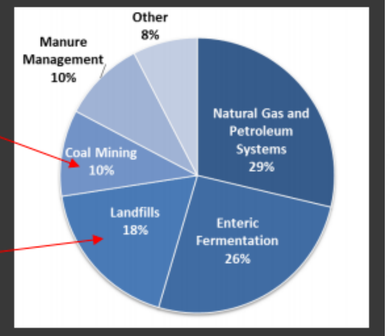
OMEDS Sub-System Global Warming Reduction Solutions

Landfills

Coal Mines



As a result, reducing methane emissions has the potential to achieve considerable climate benefits in just a few decades.

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LoRa-Alliance.org

Thank you

경희대학교
KYUNG HEE UNIVERSITY