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Internet of Things (IoT): Shaping the Network of the Future

Dr. Shaiful Jahari Hashim

Contents

- IoT Technology Overview
- UPM WiPNET IoT Experiences
- Future Networks for IoT
- Conclusions

IoT Technology Overview

Technology

- The most profound technologies are those that are disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it ….

- Mark Weiser 1991

Internet Definition

- The **Internet** is the global system of interconnected computer networks that use the Internet protocol suite (TCP/IP) to link devices worldwide.
- It is a *network of networks* that consists of private, public, academic, business, and government networks of local to global scope, linked by a broad array of electronic, wireless, and optical networking technologies.

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

IoT Definition

- The **Internet of things** (**IoT**) is the inter-networking of physical devices embedded with electronics, software, sensors, actuators, and network connectivity which enable these objects to collect and exchange data.
  - "things" as an *inextricable mixture of hardware, software, data and service*.
  - "things" include humans

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

IoT Definition *(continue)*

“Anything Can Be Connected, Will Be Connected”

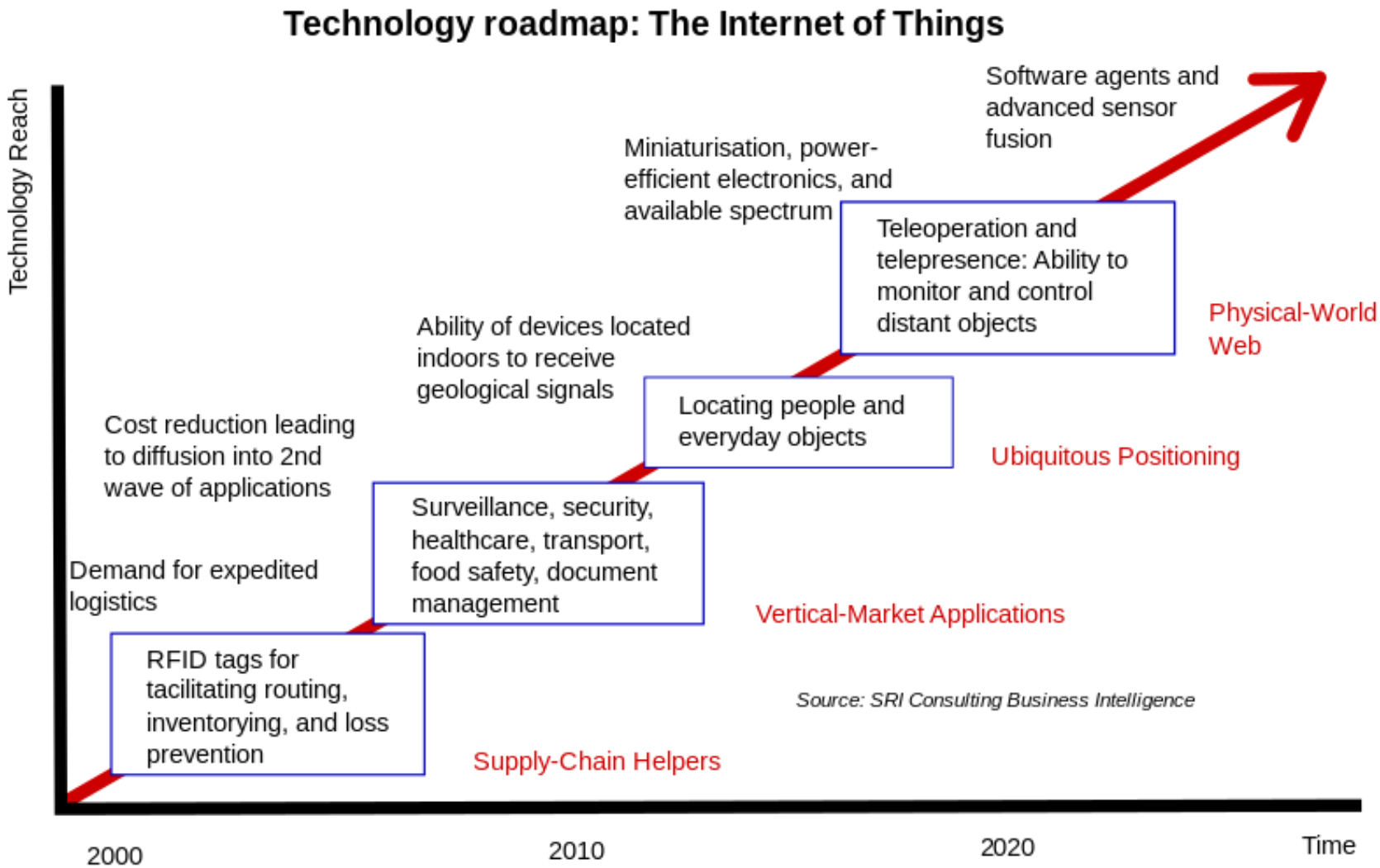
Source: “ARM and the Open IoT”, Simon Ford, IoT Director

The Variety of IoT

- It is a set of discrete applications that have highly divergent requirements:
  - Radius of connectivity varies from mm to kilometers
  - Bandwidth varies from bits to gigabits per second
  - Data volumes vary from bytes to petabytes
  - Connectivity models may be push or pull
  - Connectivity may be ad-hoc relays to dedicated wired
  - Transactions may be unicast, multicast or anycast in nature
  - Applications include sensing and reporting, command and control, adaptation and interfacing

Source: “Some thoughts on IoT”, Geoff Huston, Chief Scientist, APNIC

IoT Technology Roadmap



IoT is Big Part of 5G: Use Cases

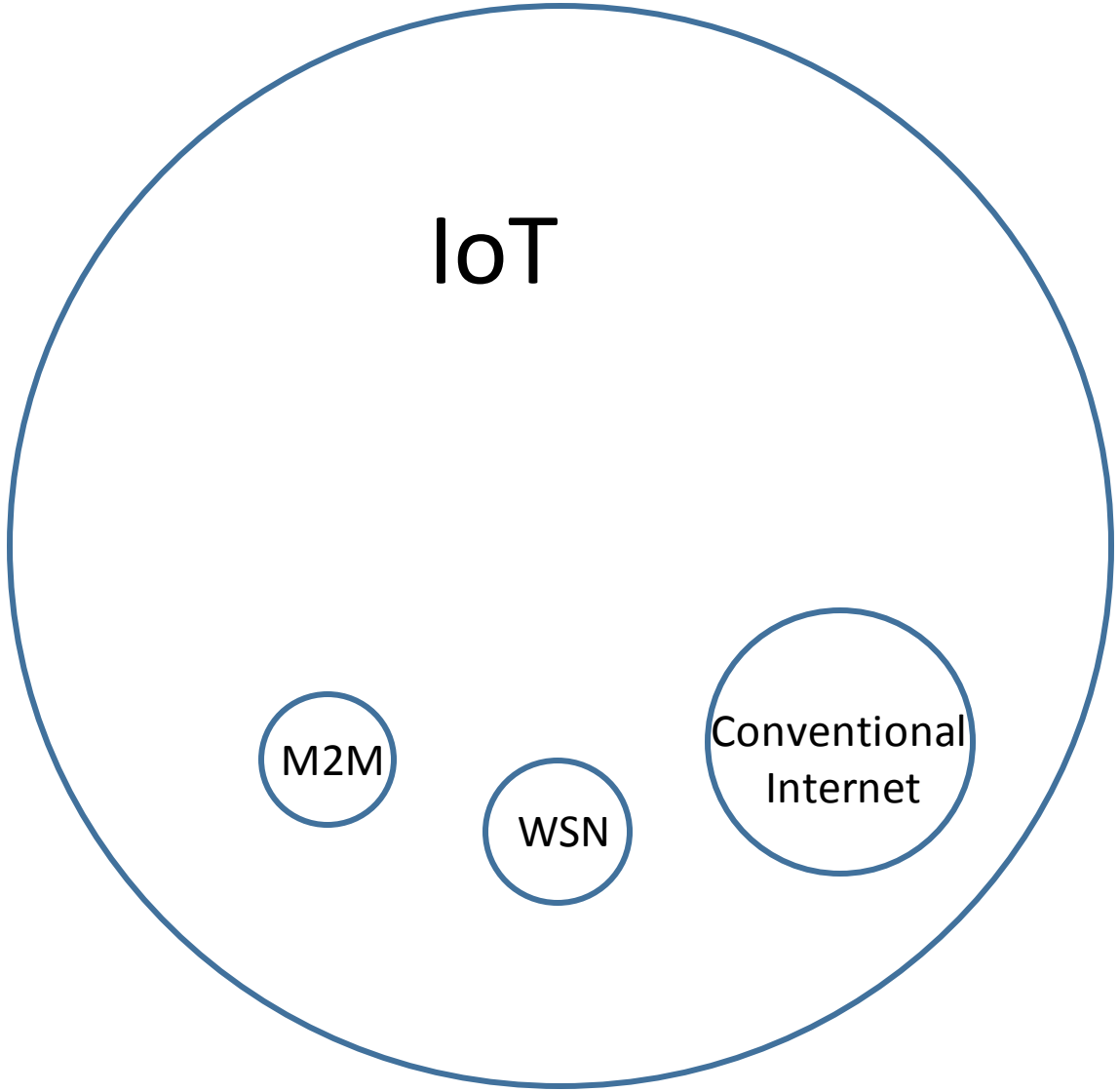
- Broadband media everywhere
- Smart vehicle and transport
- Critical services and infrastructure control
- Critical control of remote devices
- Human machine interaction
- Sensors networks

Conventional Internet

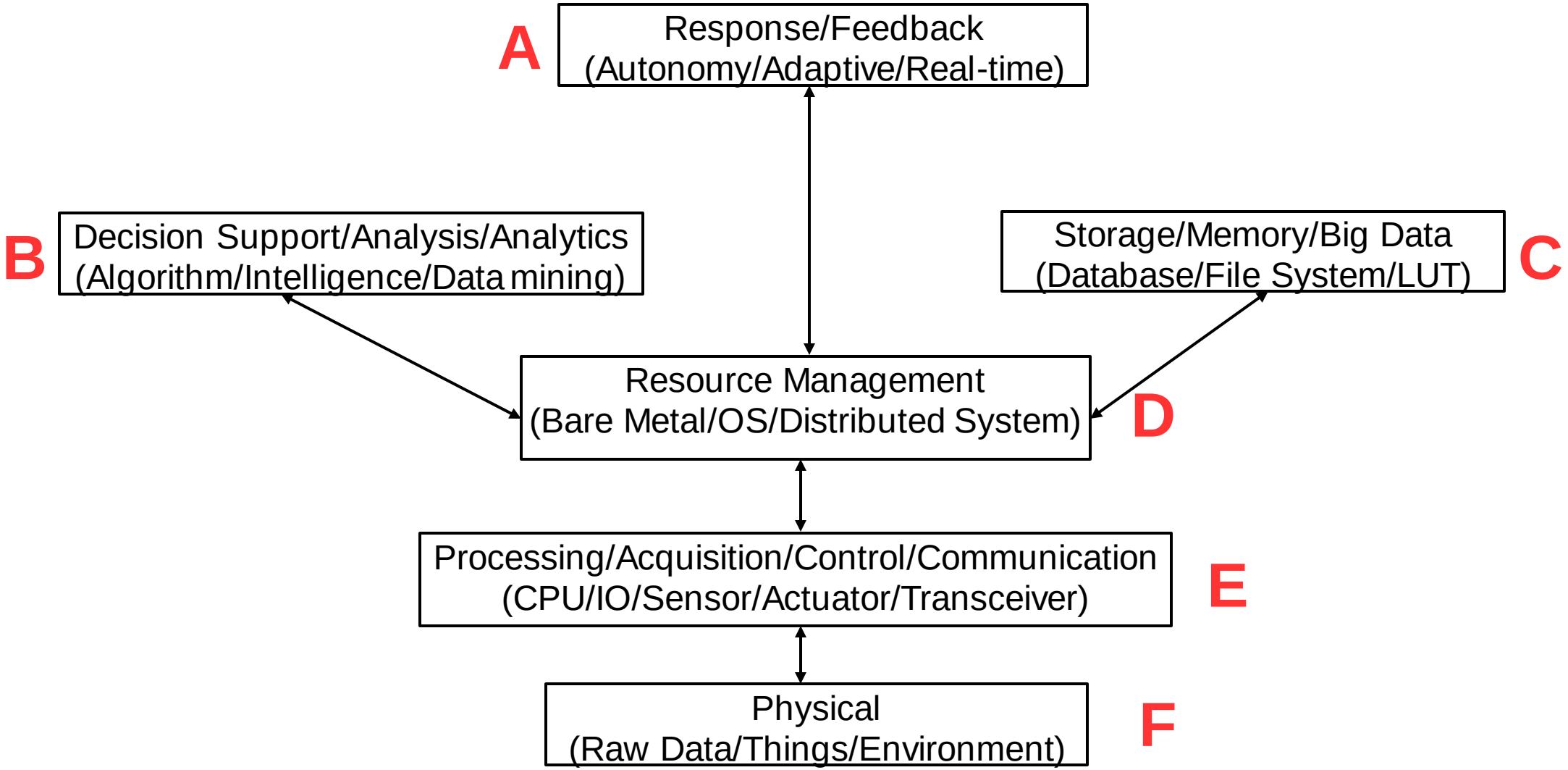
IoT

Source: https://www.ericsson.com/en/5g/use-cases

IoT Paradigm



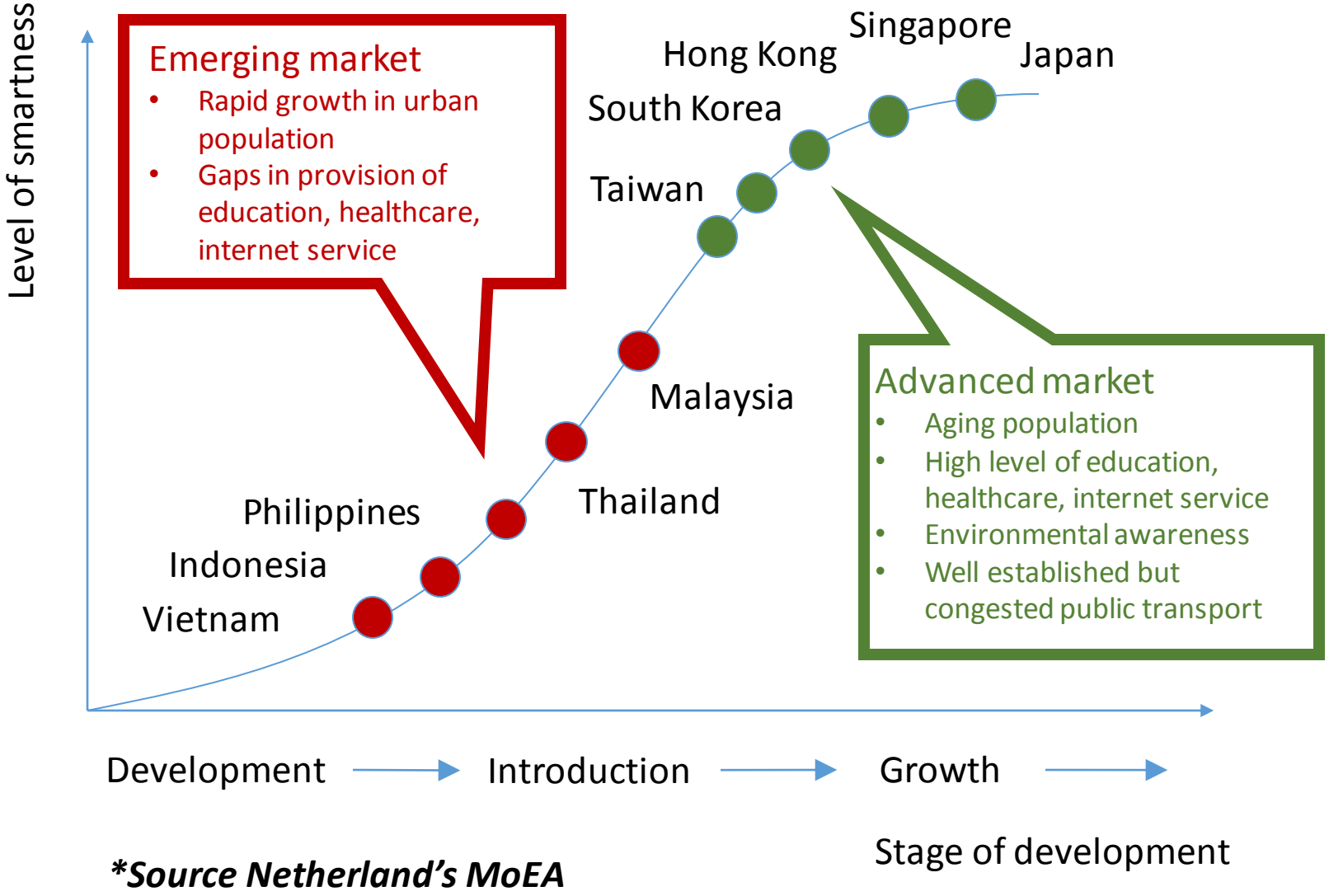
New IoT Framework



IoT Device Types

- Constrained devices with limited resources
  - Low bandwidth
  - Low cost
  - Limited processing and memory
  - Battery powered
- Unconstrained devices with ample resources

Smart Cities in Malaysia*



Source Netherland's MoEA

UPM WiPNET IoT Experiences

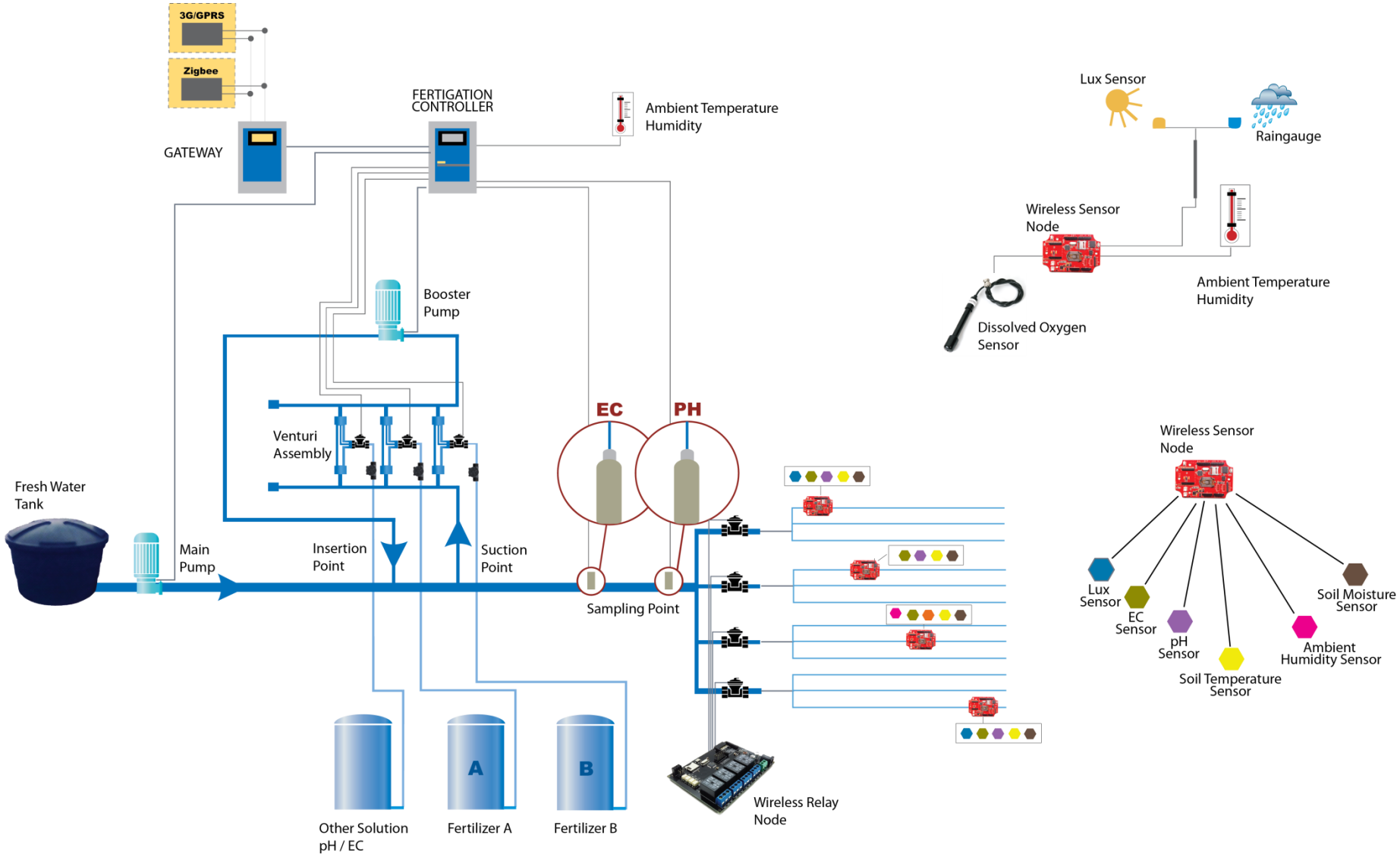
UPM WiPNET IoT Experiences

- Precision agriculture
- Slope monitoring
- Bridge monitoring

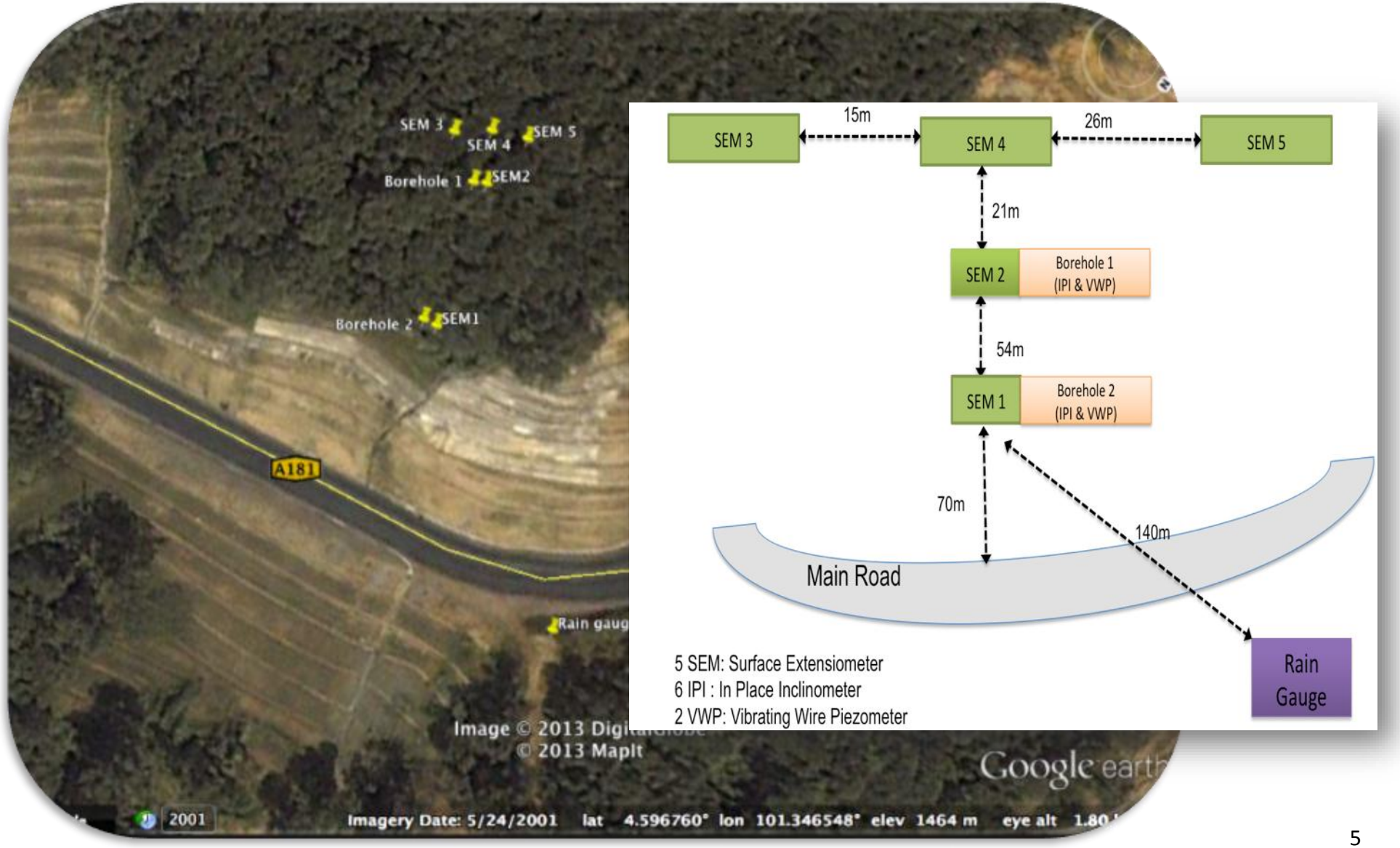
Precision Agriculture

Rockmelon : Taman Kekal Pengeluaran Makanan (TKPM) Besut, Terengganu

Fertigation Controller

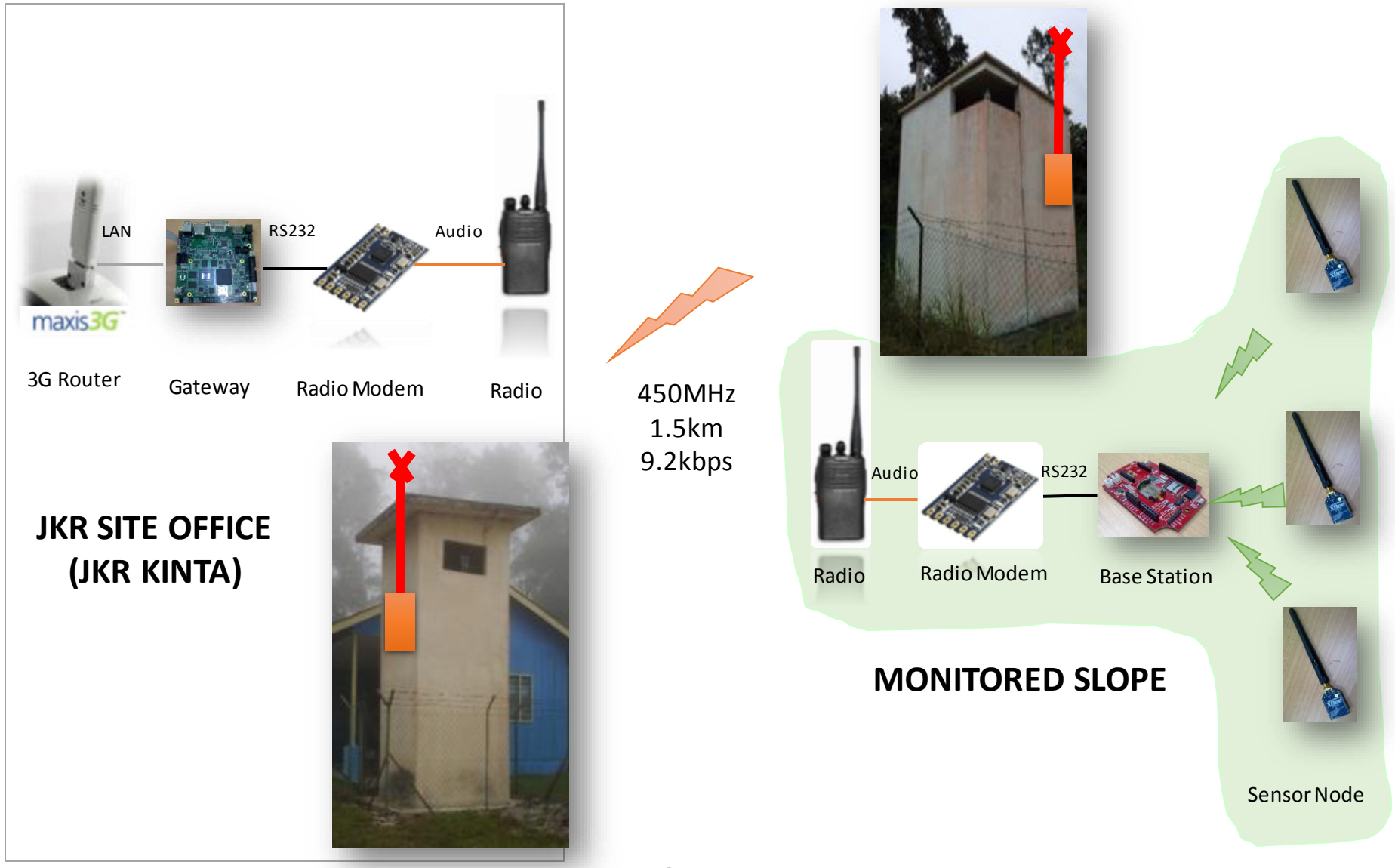


Slope Monitoring



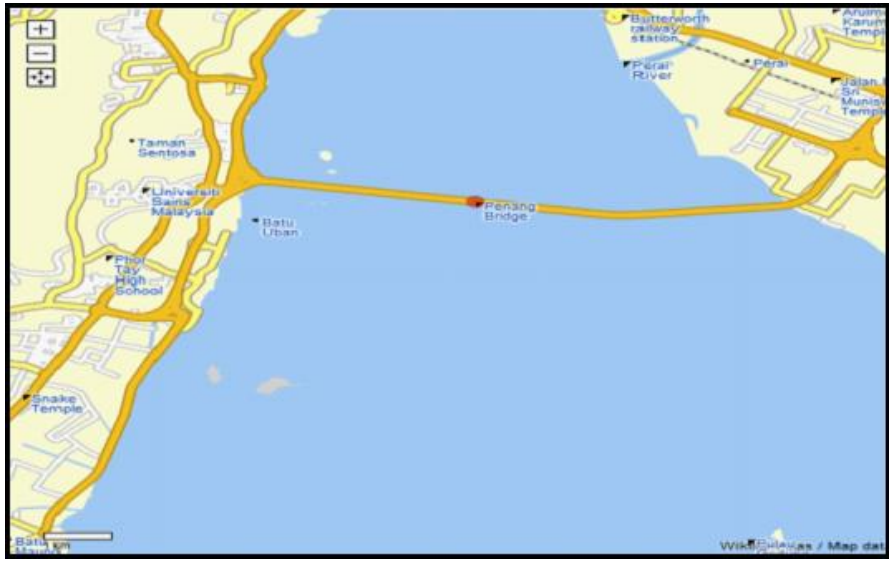
Simpang Pulai-Cameron Highland Road

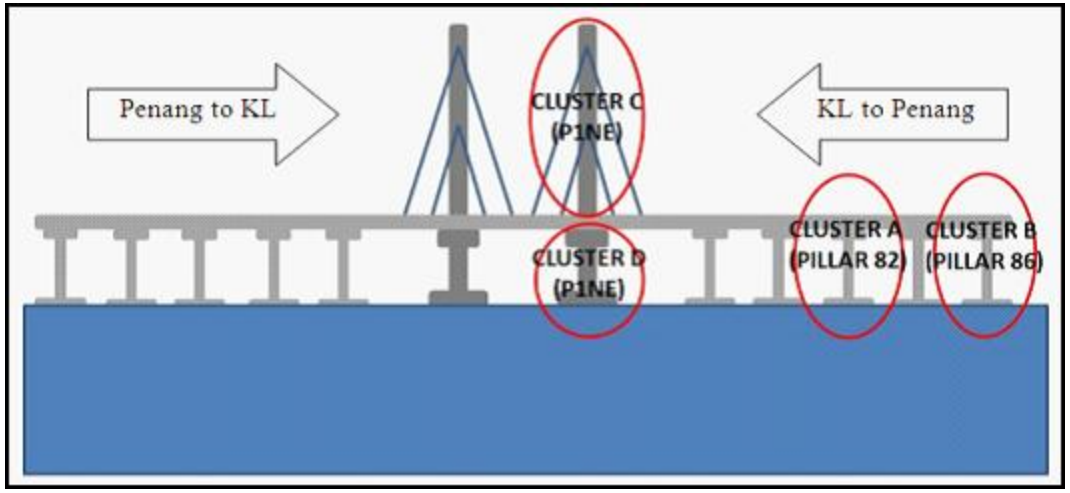
Network Topology



Penang Bridge Monitoring

- Sensor nodes divided into 4 clusters:
  - Cluster A: Pillar 82
  - Cluster B: Pillar 86
  - Cluster C: P1NE cable stays
  - Cluster D: P1NE pillar





System Architecture

1

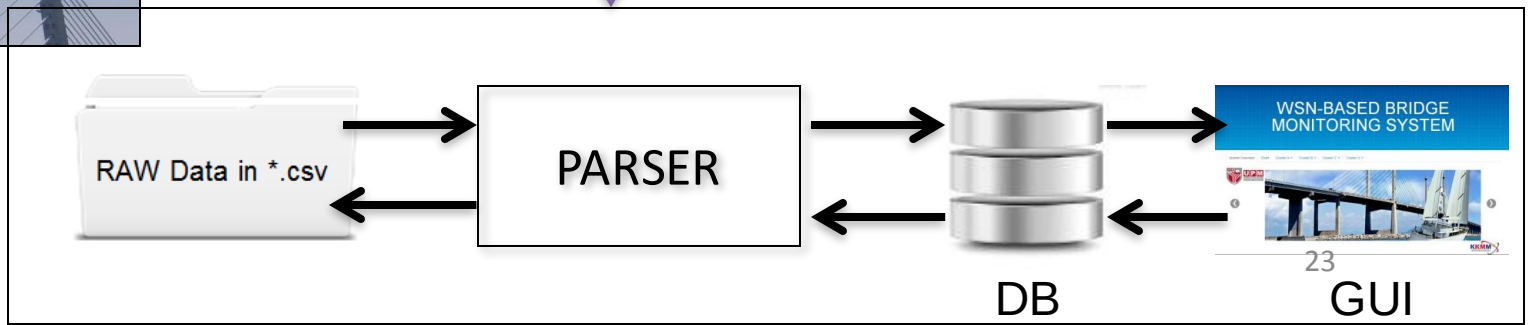
Penang Bridge

2

Server at UPM

3

GUI can be access from web



Lessons Learnt from IoT Perspectives

- Controlling is more useful than just monitoring
- Some areas in Malaysia simply do not have Internet or any available connections (and probably never will)
- Sending persistent sensor data over cellular network can be problematic
- Most of the times star topology is all you need

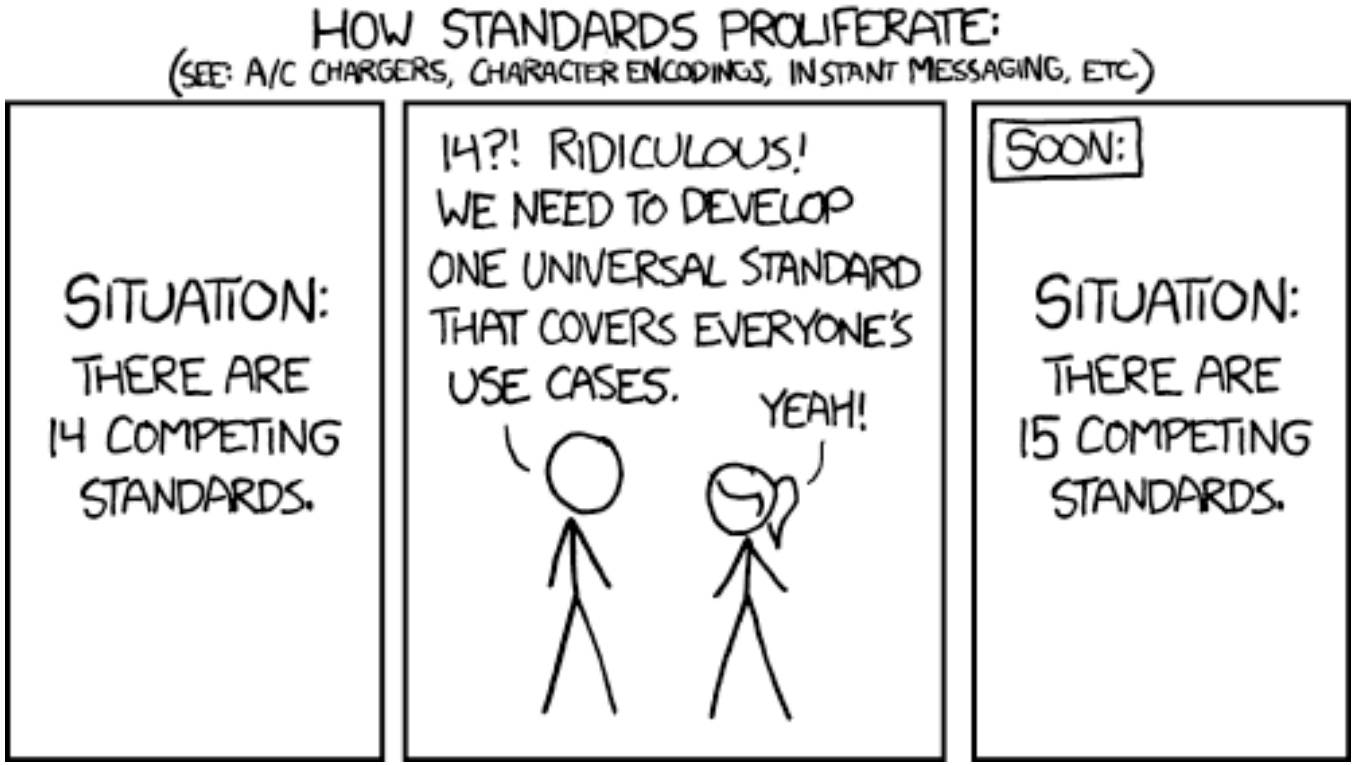
Future Networks for IoT

Future Networks for IoT

- Future Networks
- Future Higher-level Network Protocols

Future Network for IoT *(continue)*

"IP Over Everything, Everything Over IP" - Anonymous



https://xkcd.com/927

Future Networks for IoT

- Long Range Wireless
  - Cellular
  - Wireless local loop
- Short Range Wireless
  - Bluetooth
  - IEEE 802.15.4
- Satellites
  - Geo Synchronous Orbit (GSO)
  - Non Geo Synchronous Orbit (NGSO)
- Ad Hoc Wireless
- Wired
  - Fieldbus

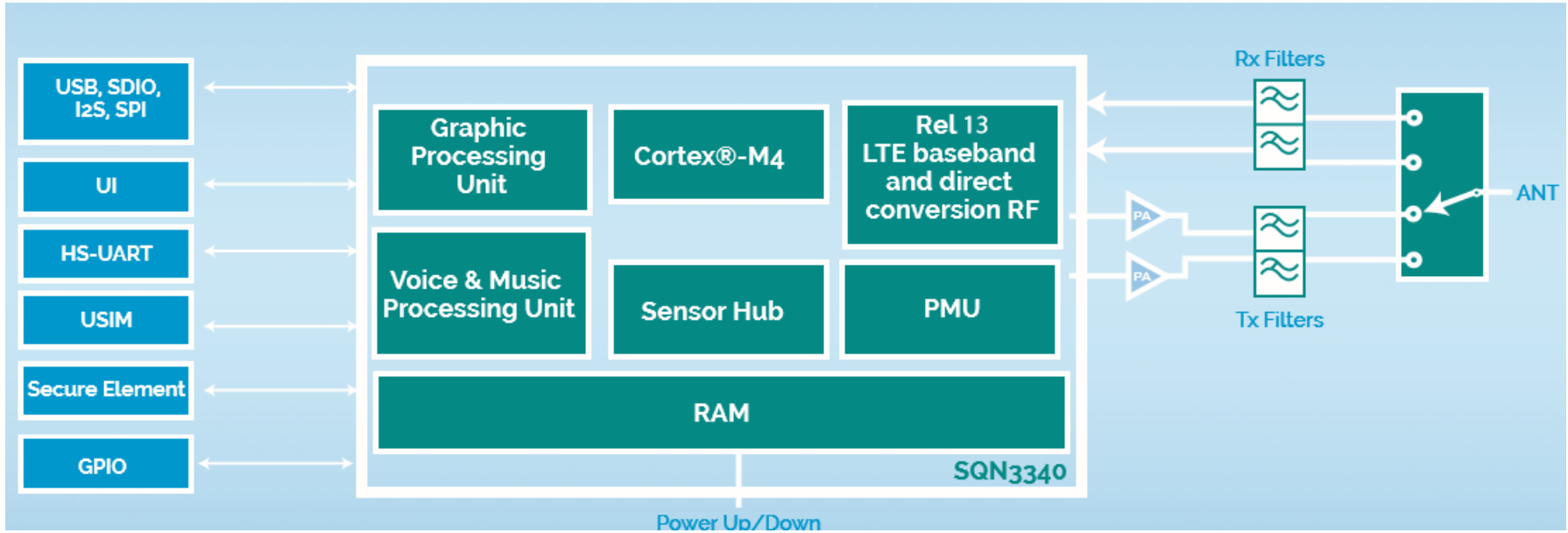
Cellular Network

- 3GPP standards
- CAT NB-1 (NB-IoT)
- CAT M1 (LTE-M)

LTE-M/NB-IoT Chip

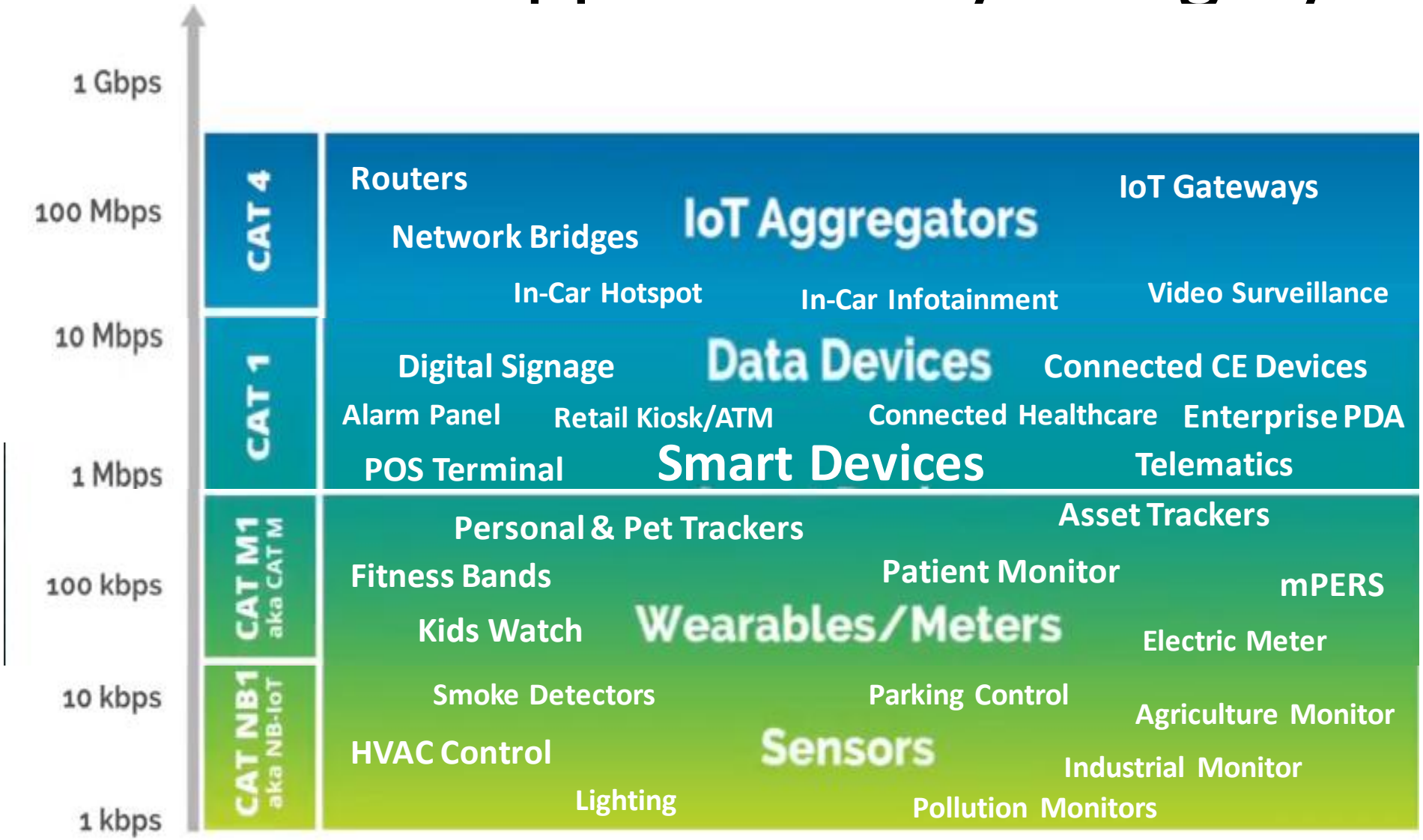
- Sequans Communications
  - Monarch and Monarch SX
- Altair Semiconductors - Sony
  - ALT1250
- Qualcomm
  - MDM9206
- ARM - Soft Bank
  - IPs

SoC Monarch SX: LTE-M & NB-IoT



Source: http://www.eetimes.com/document.asp?doc_id=1331379

LTE Applications By Category

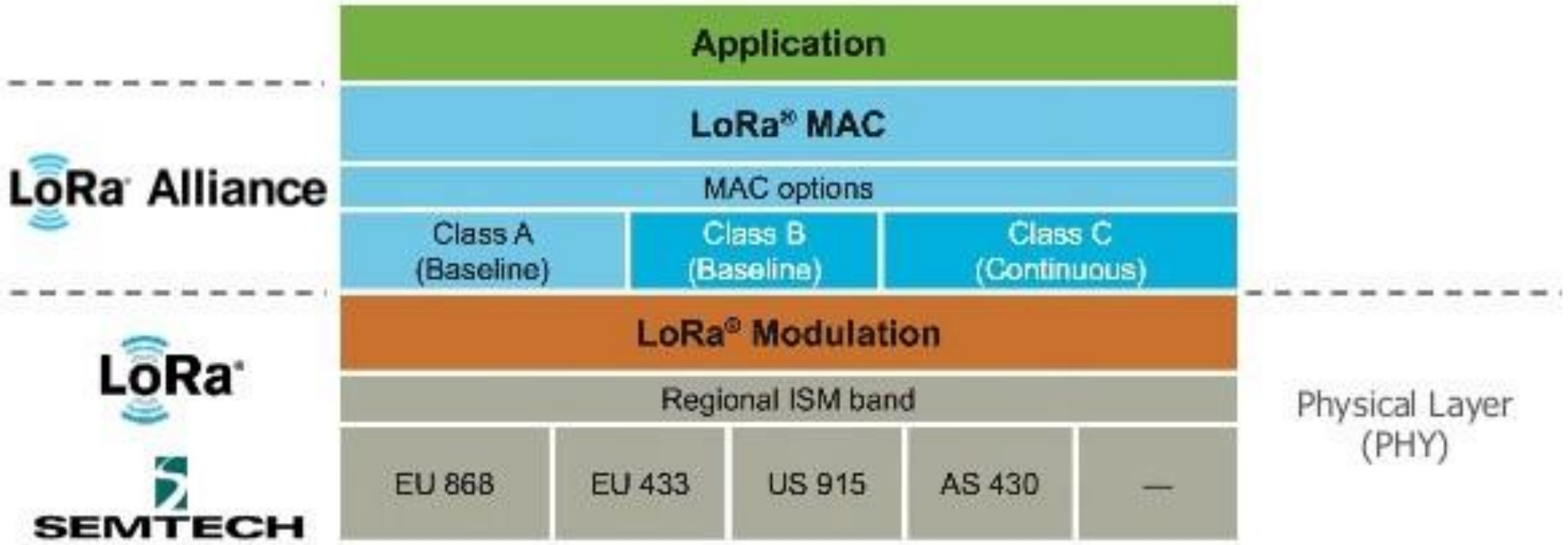


Source: http://www.sequans.com/

Wireless Local Loop Networks

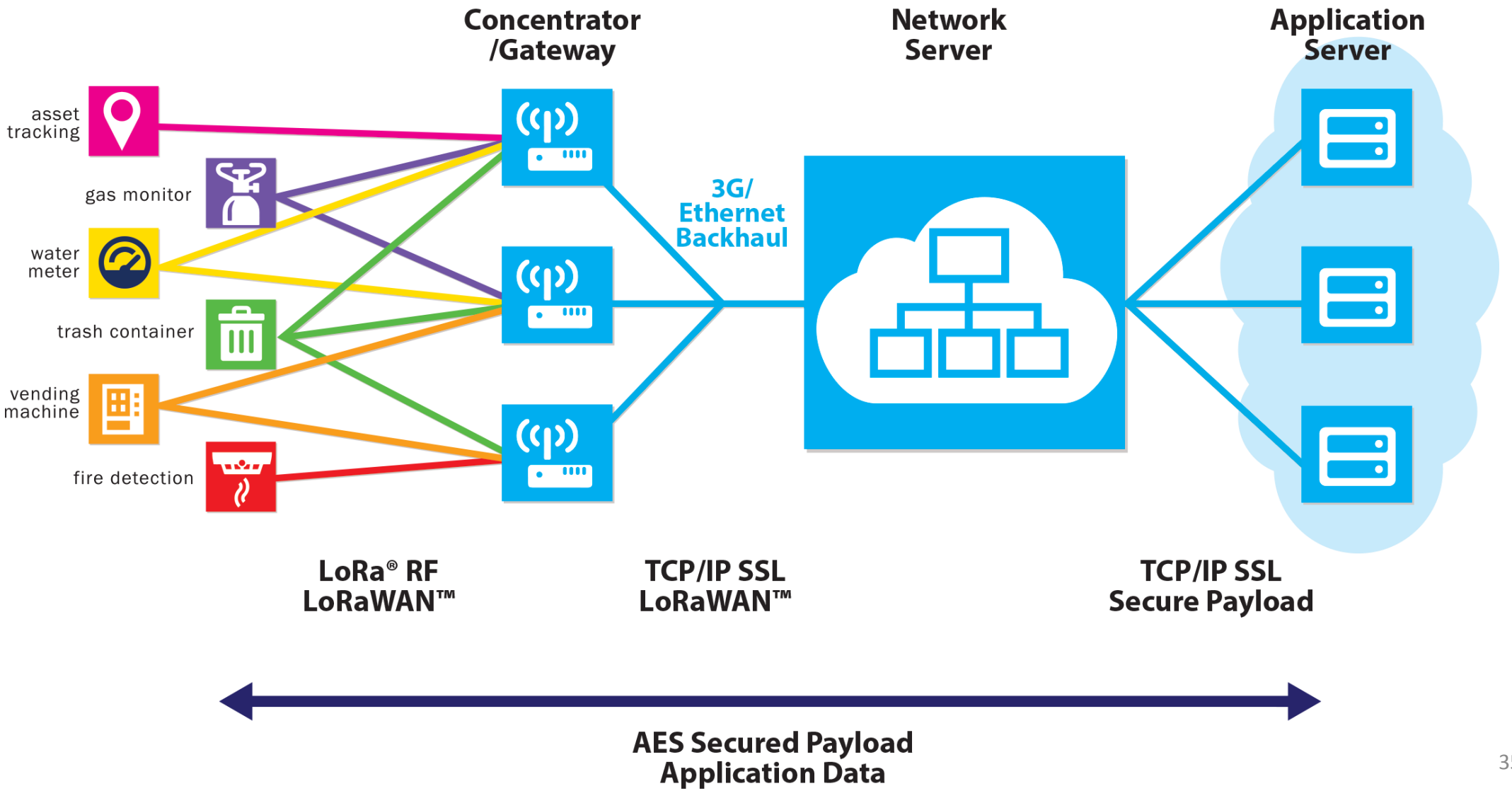
- LoRa
  - Sub 1 GHz
  - Thousands devices for one gateway
  - Tens of kilometers range
  - CSS modulation
  - 0.3 to 50 kbps
  - Development kit for one gateway and two nodes USD$499!
- 802.11 ah (Wi-Fi HaLow)
  - Sub 1 GHz
  - Thousands devices for one gateway
  - 1 km range
  - OFDM modulation (based on 802.11 a/g)
  - Up to 100 kbps

LoRa/LoRaWAN Protocols Stack



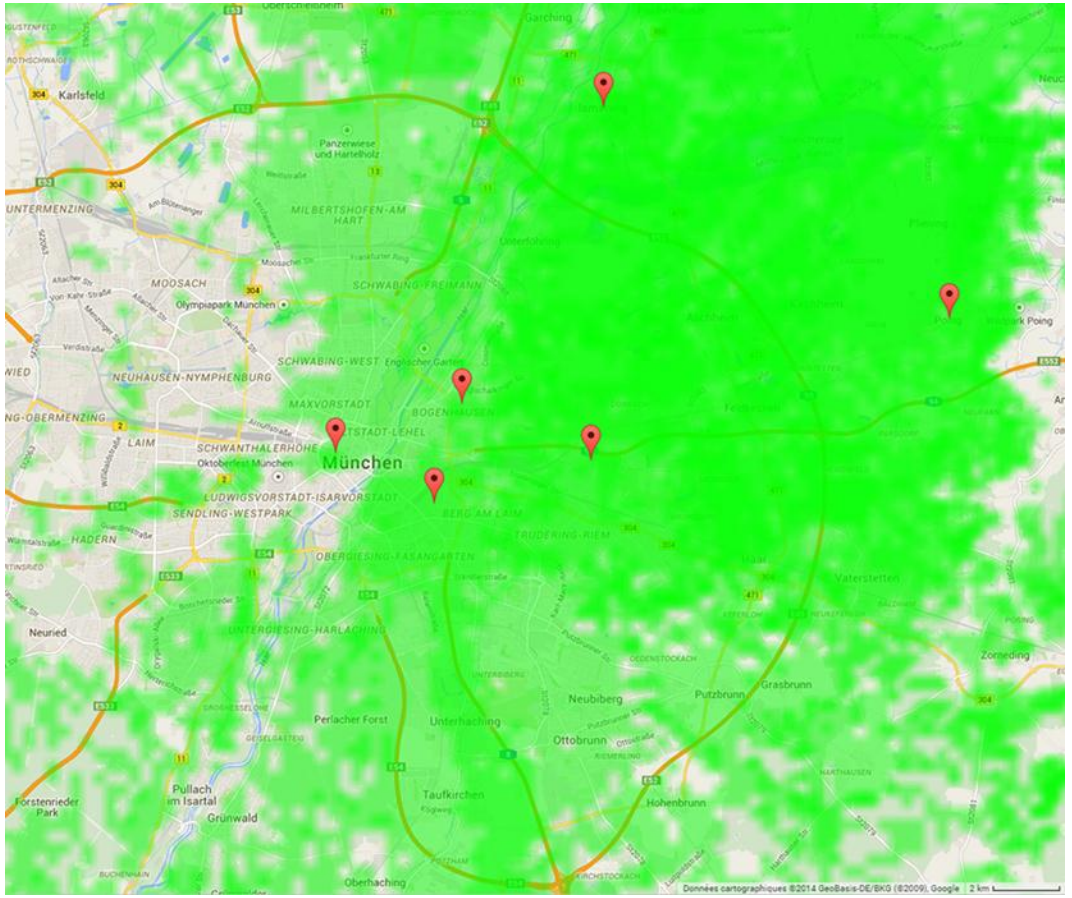
Source: https://medium.com/iotforall/a-primer-for-lora-lorawan-7658fd9f9620

LoRa/LoRaWAN Network Topology



Real World Example

- Deployment of LoRa technology gateways creates IoT network coverage for most of Munich (310.43 km^2/119.86 square miles)!

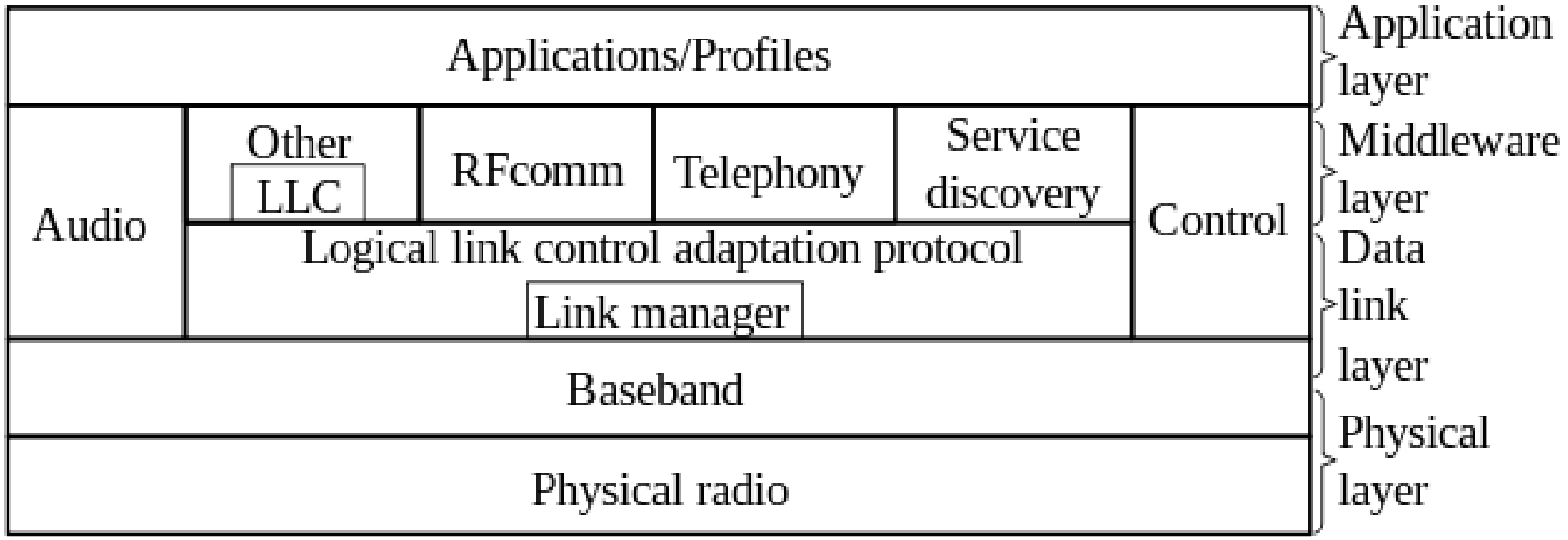


http://www.microchip.com/design-centers/wireless-connectivity/embedded-wireless/lora-technology

Short Range Wireless

- Bluetooth
  - Based on IEEE 802.15.1
- IEEE 802.15.4

Bluetooth Standard Protocol



Bluetooth Versions

Bluetooth Version	***Maximum Speed/* Mbps**	***Maximum Range/ m***
3.0	25	10
4.0	25	60
5	50	240

802.15.4

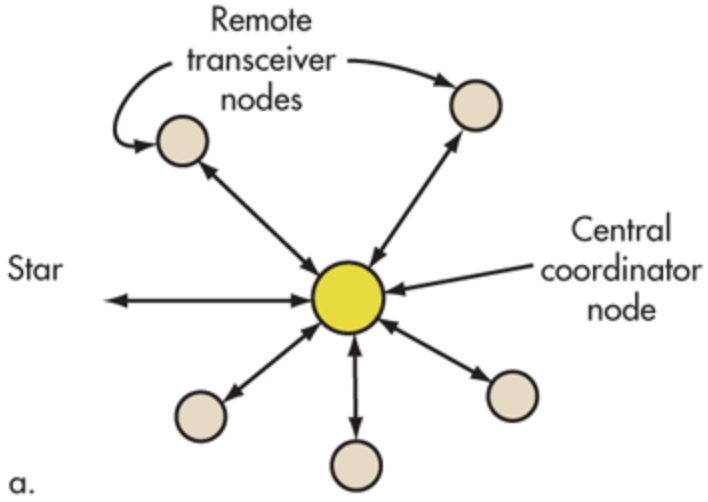
OPTIONS FOR FREQUENCY ASSIGNMENTS			
Geographical regions	Europe	Americas	Worldwide
Frequency assignment	868 to 868.6 MHz	902 to 928 MHz	2.4 to 2.4835 GHz
Number of channels	1	10	16
Channel bandwidth	600 kHz	2 MHz	5 MHz
Symbol rate	20 ksymbols/s	40 ksymbols/s	62.5 ksymbols/s
Data rate	20 kbits/s	40 kbits/s	250 kbits/s
Modulation	BPSK	BPSK	Q-QPSK

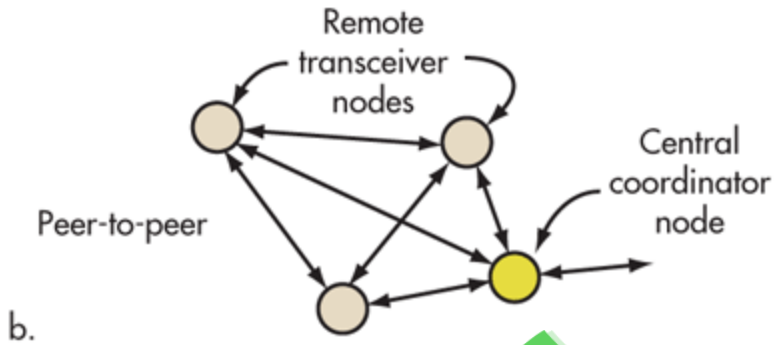
Source: http://www.electronicdesign.com/what-s-difference-between/what-s-difference-between-ieee-802154-and-zigbee-wireless

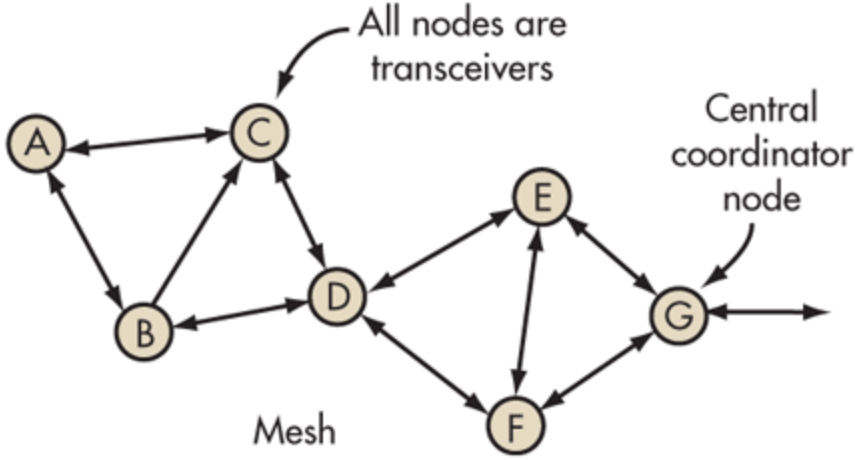
802.15.4 (continue)

- CSMA-CA
  - multiple users or nodes access the same channel at different times without interference
  - most transmissions are short packets that occur infrequently for a very low duty cycle (<1 %)
- DSSS and FHSS (802.15.4e)
- Transmission power
  - 0.5 mW (-3dBm) - minimum
  - 1 mW (0 dBm) - typical
  - 100 mW (20 dBm) - maximum

802.15.4 Network Topology Support

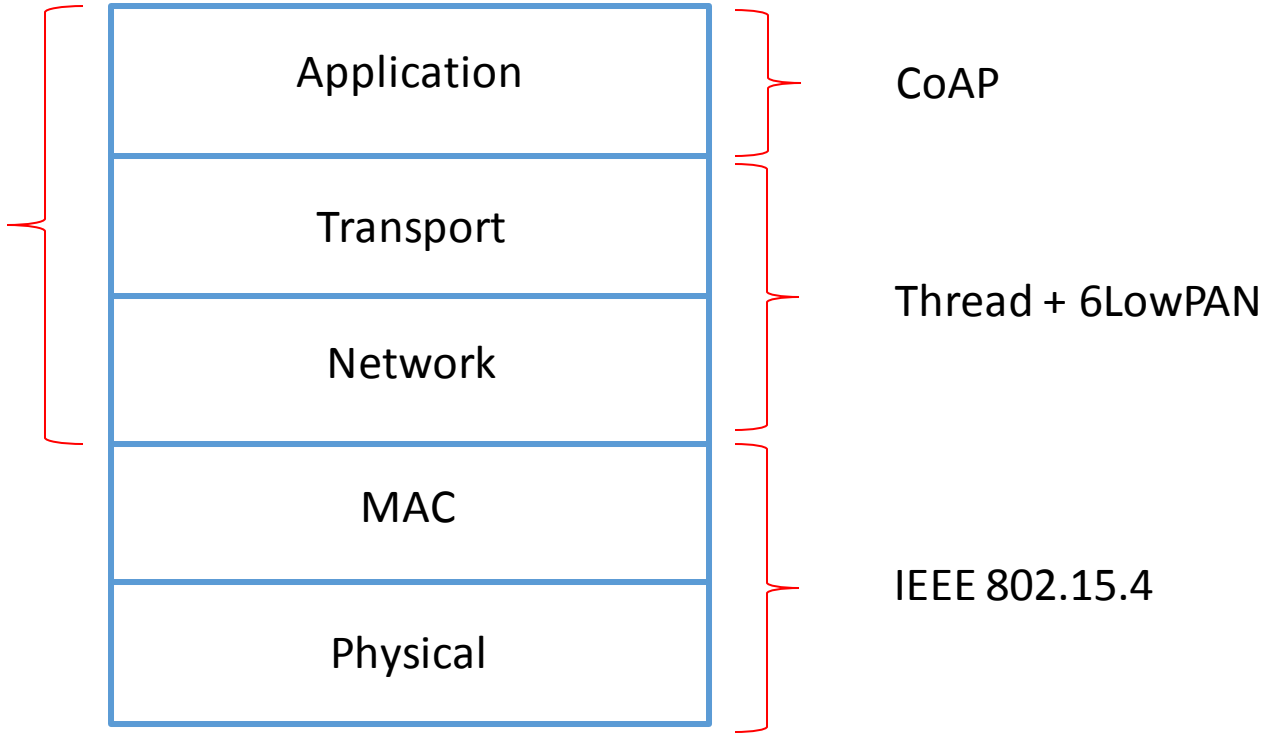




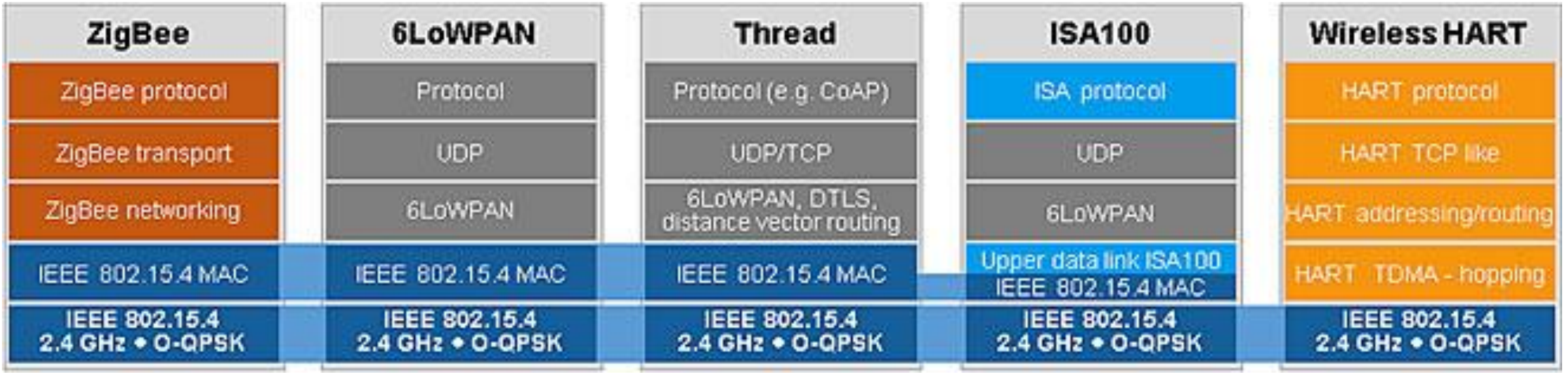


Short Range Wireless Networks

ZigBee,
Wireless HART (IEC 62591)



Short Range Wireless Networks Standards Comparison*



*Z-Wave is based on ITU-T G.9959 (<1 GHz) not 802.15.4

Source: https://www.rohde-schwarz.com/us/solutions/wireless-communications/lr-wpan/zigbee/lr-wpan-zigbee_230610.html

Satellite Network

- Truly global network
- Ship/Vessel tracking
- Flight tracking
  - In 2016 UN announces real-time flight tracking rules on the 2nd anniversary of MH370 disappearance

https://www.icao.int/safety/globaltracking/Pages/GADSS-Update.aspx

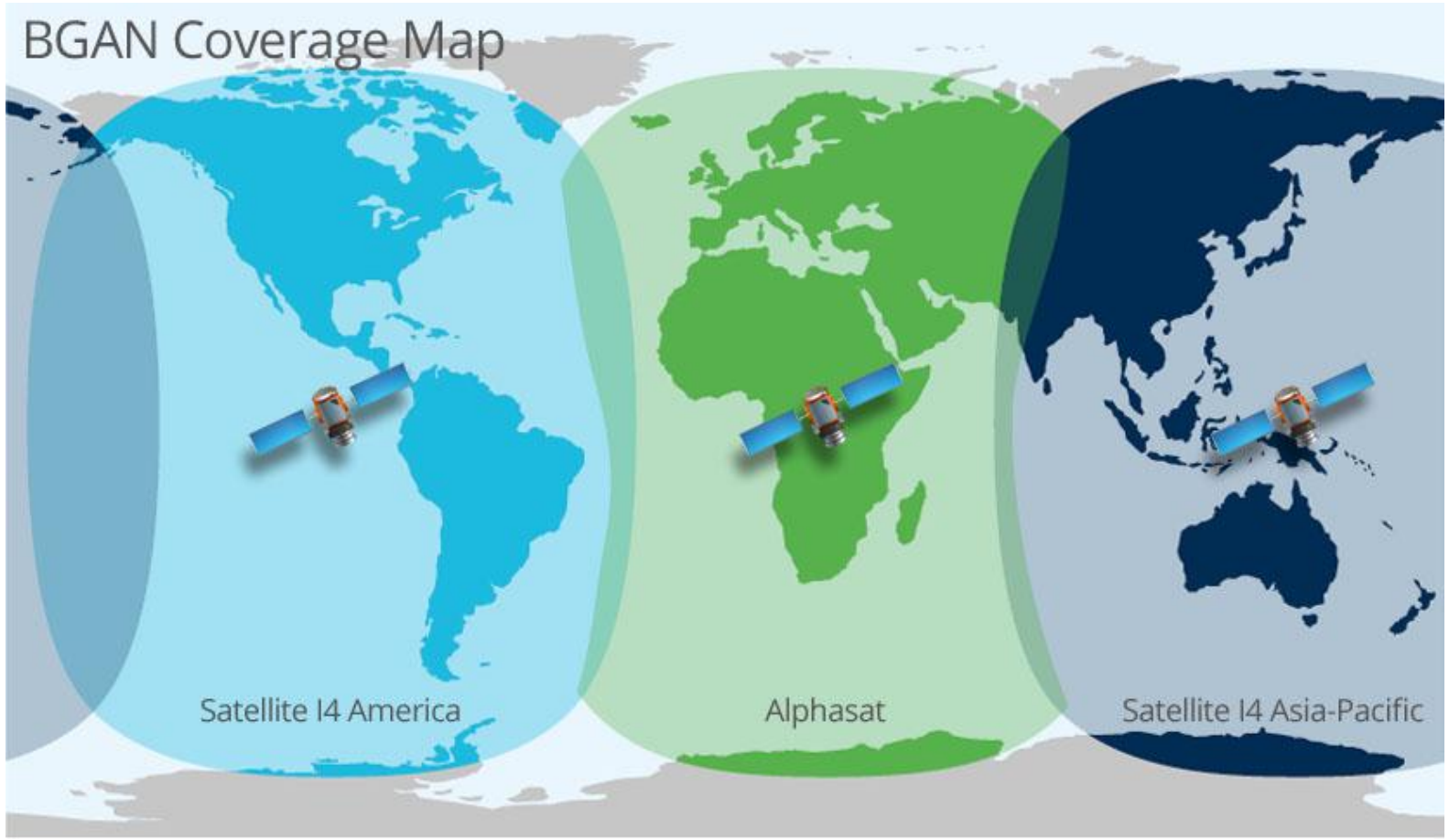
Satellite Network Operator

- Geo Synchronous Orbit (GSO) satellites operator
  - Inmarsat
  - Thuraya
- Non- Geo Synchronous Orbit (NGSO) satellites operator
  - Iridium
  - Intelsat
  - SES
  - Telesat
  - Sky Perfect- JSAT
  - Thuraya

Inmarsat's IP Based M2M

BGAN M2M satellite service is designed for unmanned equipment communication (via an Internet connection) with costs of 1 to 2 cents per Kilobyte transferred (2 MB plan – USD24)
Source: http://www.groundcontrol.com/BGAN_M2M.htm

Inmarsat’s BGAN Satellite Coverage Map



Ad Hoc Network

- RFID
  - Forest tree inventory
- Energy Harvesting and Backscattering
  - UAV based environmental monitoring

Fieldbus

- **Fieldbus** is the name of a family of industrial computer network protocols used for real-time distributed control
- Standardized as **IEC 61158**
  - Part 1: Overview and guidance for the IEC 61158 series
  - Part 2: Physical Layer specification and service definition
  - Part 3: Data Link Service definition
  - Part 4: Data Link Protocol specification
  - Part 5: Application Layer Service definition
  - Part 6: Application Layer Protocol specification
- AS-Interface, CAN, EtherCAT, FOUNDATION fieldbus, Interbus, LonWorks, Modbus, Profibus, BITBUS, CompoNet, SafetyBUS p, RAPIEnet

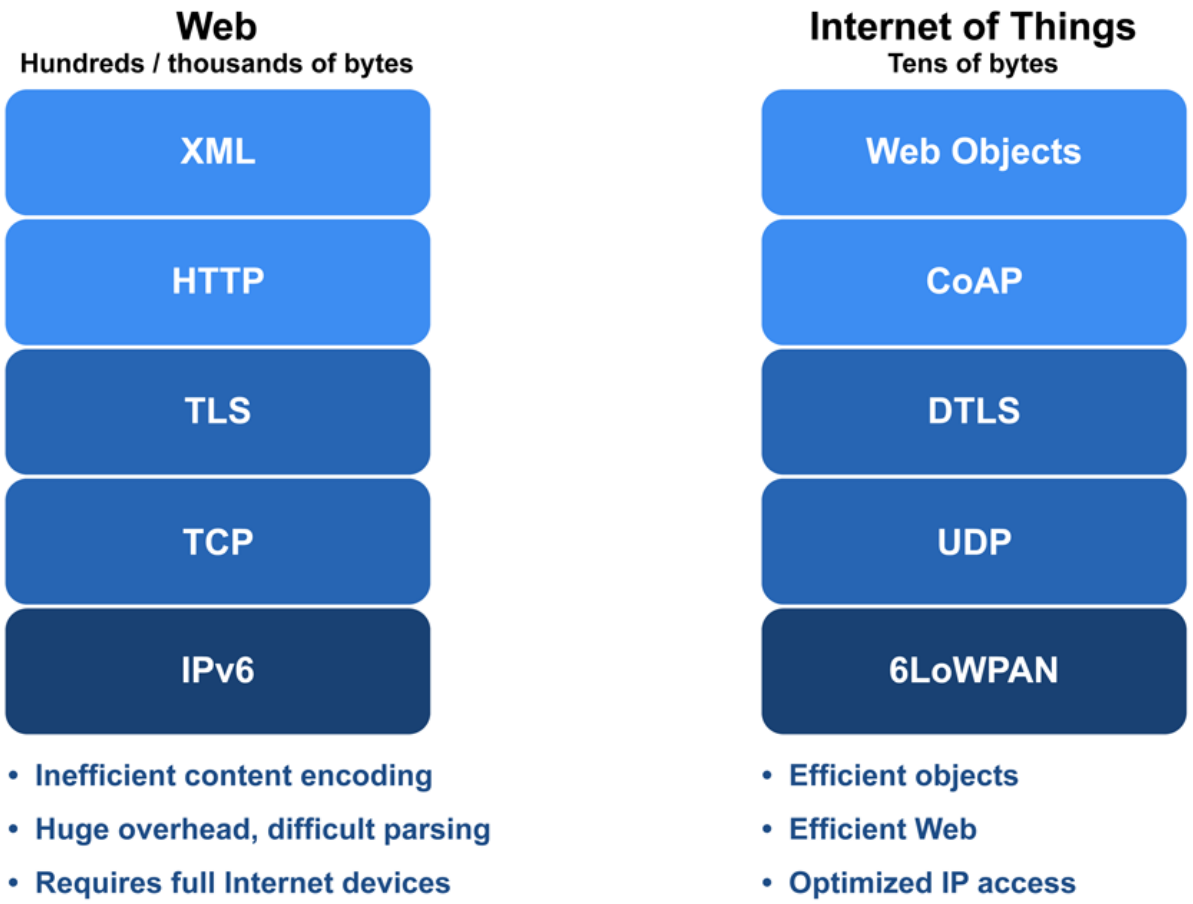
Future Higher-level Network Protocols

Future Higher-level Network Protocols

Protocol	CoAP	XMPP	RESTful HTTP	MQTT	ZeroMQ
Transport	UDP	TCP	TCP	TCP	UDP
Messaging	Request/Response	Publish/Subscribe Request/Response	Request/Response	Publish/Subscribe Request/Response	Publish/Subscribe Request/Response
2G, 3G, 4G Suitability (1000s nodes)	Excellent	Excellent	Excellent	Excellent	Fair
LLN Suitability (1000s nodes)	Excellent	Fair	Fair	Fair	Fair
Architecture	Tree	Client Server	Client Server	Tree	P2P
Compute Resources	10Ks RAM/Flash	10Ks RAM/Flash	10Ks RAM/Flash	10Ks RAM/Flash	10Ks RAM/Flash
Success Stories	Utility Field Area Networks	Remote management of consumer white goods	Smart Energy Profile 2 (premise energy management, home services)	Extending enterprise messaging into IoT applications	CERN

Source: http://www.embedded-computing.com/embedded-computing-design/internet-of-things-requirements-and-protocols

Web and IoT Protocols Comparison



Source: https://www.micrium.com/iot/internet-protocols/

6LowPAN

- IPv6 Over Low Power Personal Area Network
- Encapsulation and header compression mechanisms that allow IPv6 packets to be sent and received over IEEE 802.15.4 based networks
- A simple low throughput wireless network comprising typically low cost and low power devices
- Devices in the network typically work together to connect the physical environment to real world applications, e.g. WSN
- Common topologies include – star, mesh, and combinations of star and mesh

Source: 6LoWPAN Overview, Assumptions, Problem Statement & Goals, Nandu Kushalnagar et. al

Shape of Future Networks for IoT?

VSCP	CoAP	MQTT	HTTP	ZeroMQ
	UDP with DTLS	TCP with TLS	ICMP	
	IP	IPv6 with 6LowPAN/etc*		
LoRaWAN	Fieldbus	802.14.5	LTE	Satellite MAC
LRW**	Wired	SRW***	LRW	LRW

*6LowPAN :IPv6 over 802.15.4 (RFC 6282)
IPv6 over Ethernet (RFC 2462)
IPv6 over PPP (RFC 5072)
IPv6 over Bluetooth BLE (RFC 7668)
**LRW: Long Range Wireless
***SRW: Short Range Wireless

Conclusions

- Internet for human's communication is a special case, Internet for things or IoT is a general case
- Do not forget the "I" of the IoT to avoid re-inventing the wheels
- For long range network satellite is super expensive, cellular can be expensive and wireless local loop is the most cost effective
- We need to open up ***full 902 – 928 MHz*** for ISM bands thus IoT can proliferate and prosper in Malaysia
- IoT networks is enabler for a better future together with Industrial IoT (IIoT) and Industry 4.0

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- RFC 7228, Terminology for Constrained-Node Networks, IETF, https://tools.ietf.org/html/rfc7228