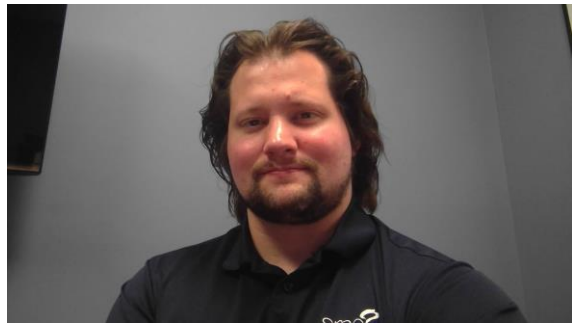
IIoT Fundamentals and Applications

Presented by SME Chapter 112

Who Am I?

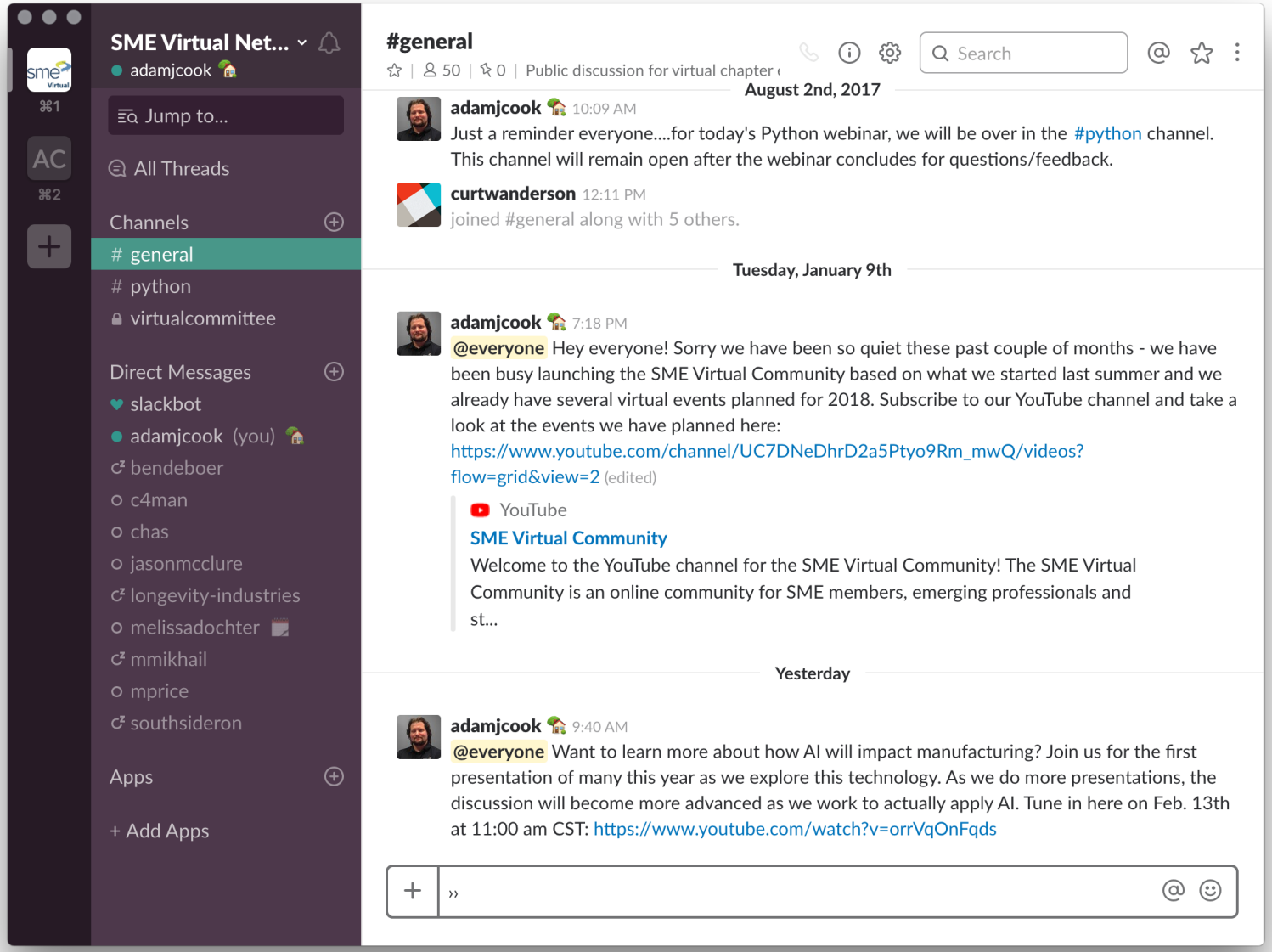


- **My name is Adam Cook.**
- **Studied Mechanical Engineering at Purdue University West Lafayette.**
- **Chief Technical Officer of Alliedstrand in Chicago (we also have engineers in Dallas).**
- **Chair of** SME Chapter 112 **(Northwest Indiana and Chicagoland). Check out sme112.org.**
- **I work with** embedded systems, robotics, automation systems and industrial software.
- **Contact my chapter at hello@sme112.org.**

SME Virtual Network Slack

slack

Are you an SME member? Do you want access to Slack? Fill out this short form: http://bit.ly/2BpjMiE



Agenda

Slides:
http://bit.ly/2HOb7GE

Part 1 - **IIoT High-Level Tour and Engineering/Manufacturing Use Cases.**

Break

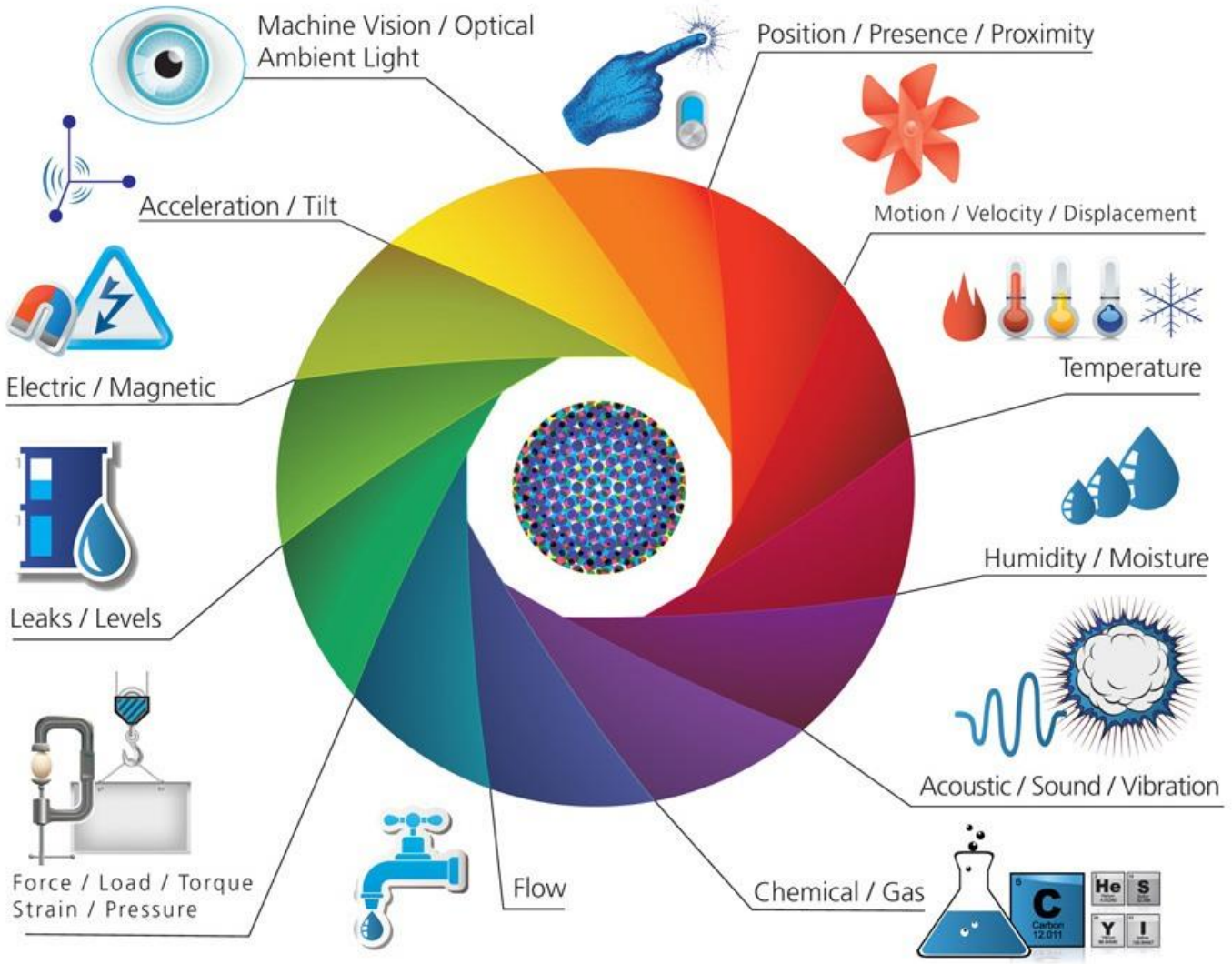
Part 2 – **IIoT protocols, architectures, communications, IT/OT considerations and security.**

Slides:
http://bit.ly/2HOb7GE

- Internet of Things (IoT) **is (loosely) a broad term referring to a network of devices (or "things") which can interoperate with the Internet.**
- **IoT is sometimes called** Internet of Everything (IoE).
- **A** Thing **is a** physical **object that can communicate via a network.**
- **Things are** decoupled **from software applications/services in IoT.**

Sensors

Slides:
http://bit.ly/2HOb7GE



Source: http://bit.ly/2G7VEny

Actuators

Slides:
http://bit.ly/2HOb7GE

Motors

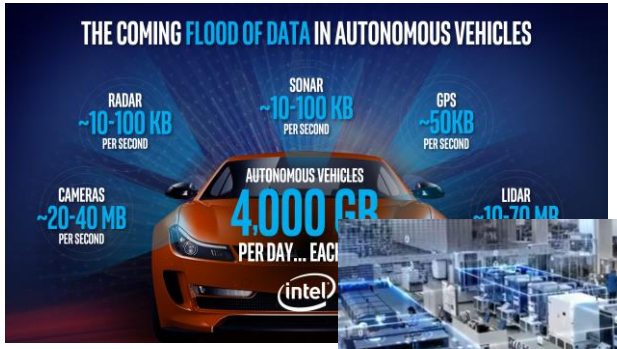
Cylinders

Servo Valve

IoT connects…

Slides:
http://bit.ly/2HOb7GE

Things



Systems

Business Applications

ERP **CRM**

PLM

Control Systems

People

Consumers

Partners

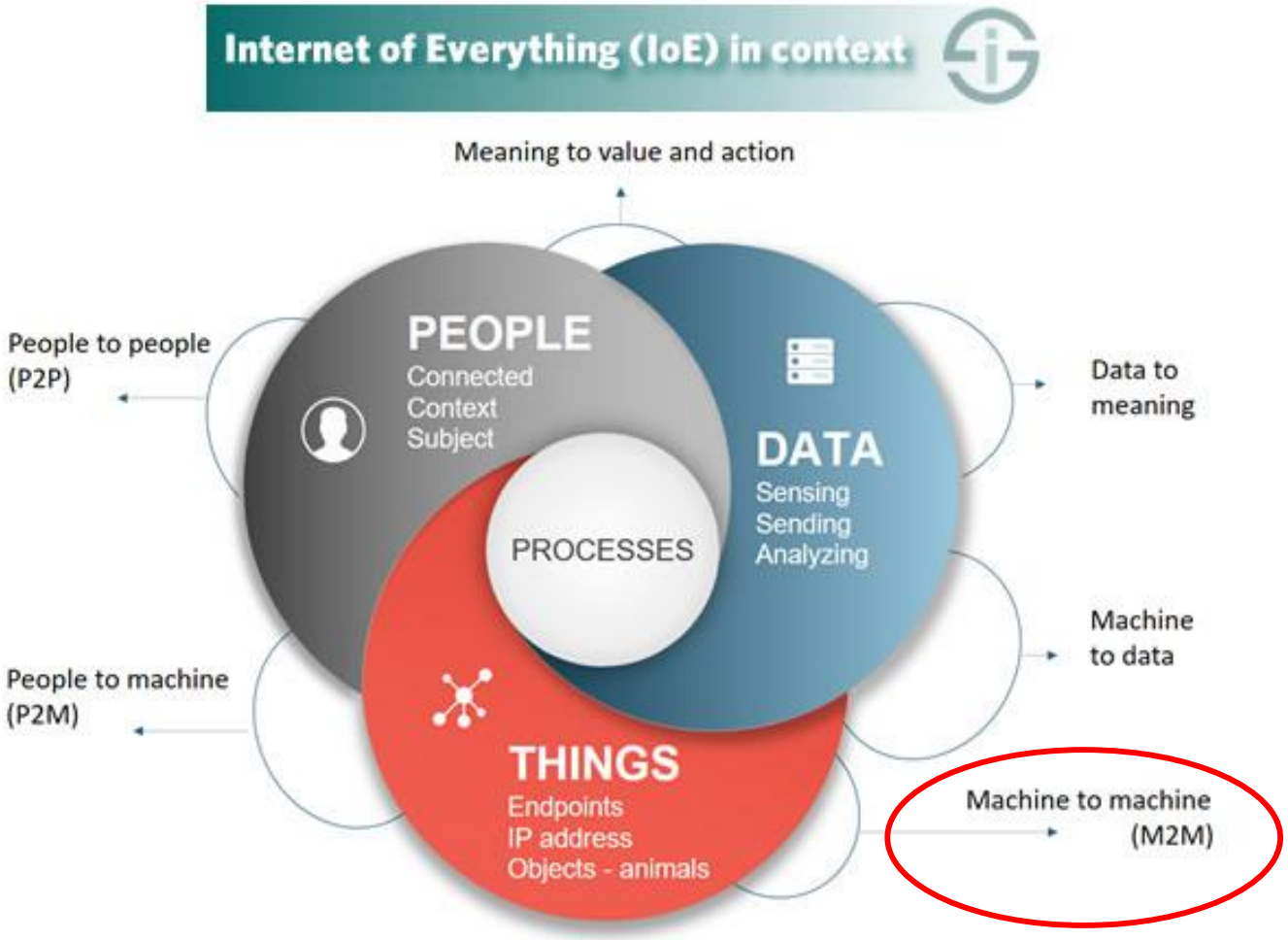
Decision Makers

Employees

Can you think of any commonly-used IoT devices?

Connection Types

Slides:
http://bit.ly/2HOb7GE

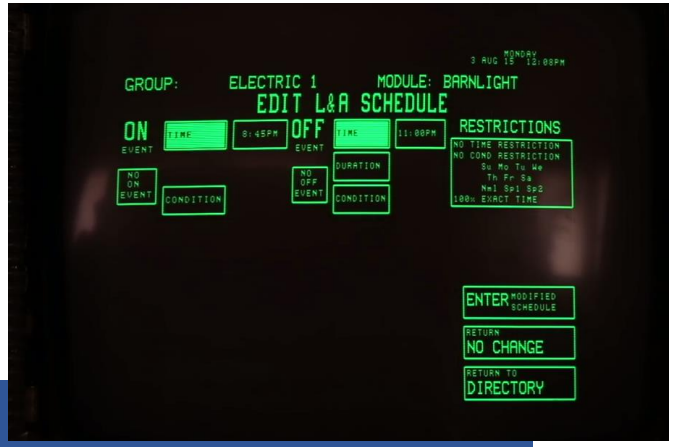


Source: http://bit.ly/2otKGih

Coupled

Slides:
http://bit.ly/2HOb7GE

Relay



Early 1990s Home Automation System

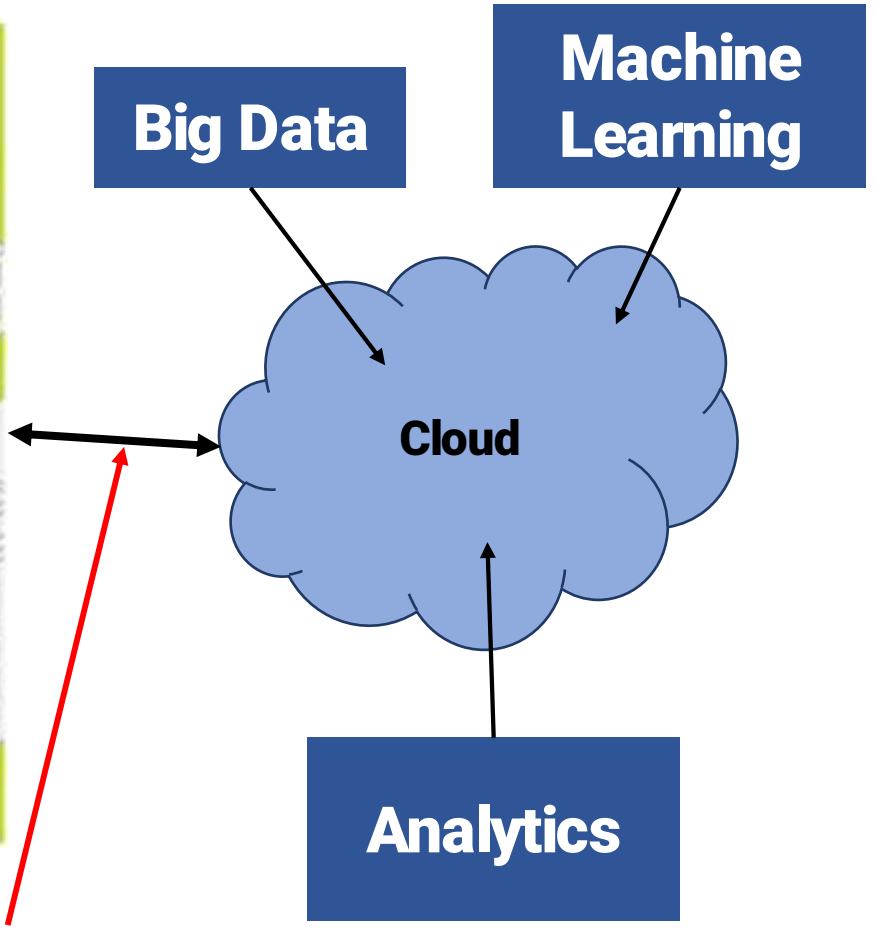
What is the ROI on this?

Decoupled

Slides:
http://bit.ly/2HOb7GE

sme

Device Network

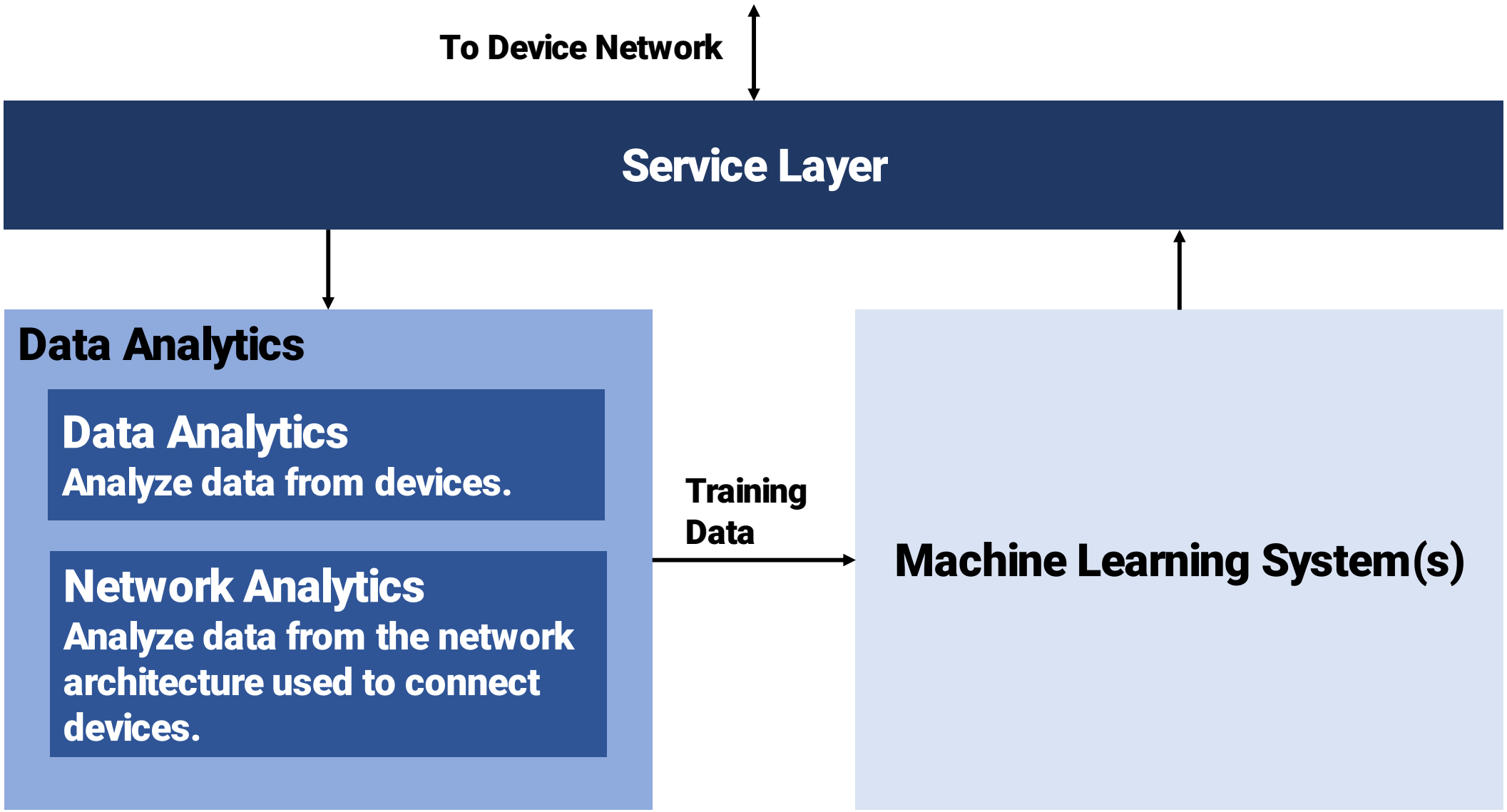


Source: http://dell.to/2u5mF6t

Probably an IoT Gateway here.

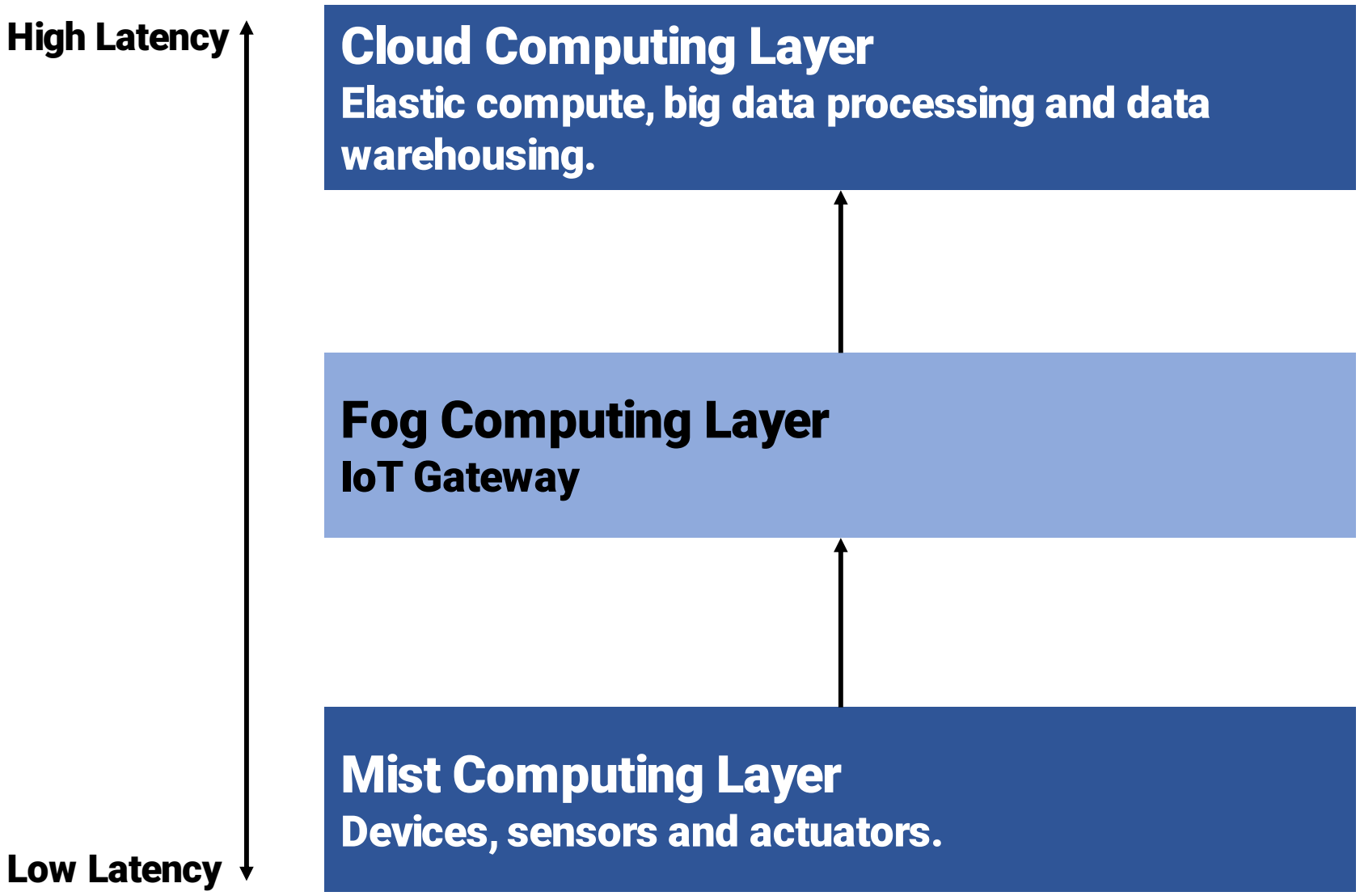
Decoupled

Slides:
http://bit.ly/2HOb7GE



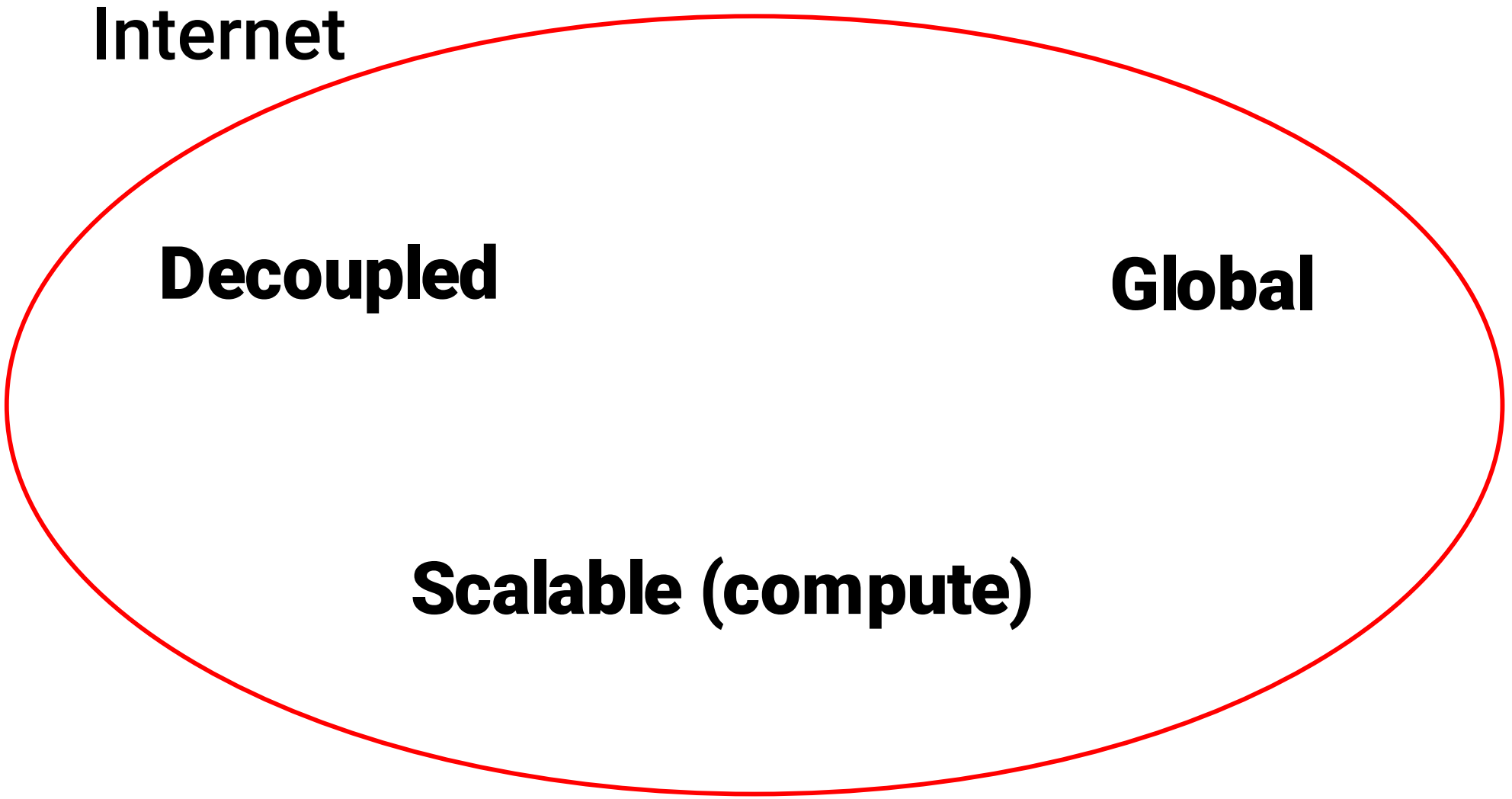
Latency

Slides:
http://bit.ly/2HOb7GE



So what's with the "Internet" in IoT?

Slides:
http://bit.ly/2HOb7GE



IoT Challenges

Slides:
http://bit.ly/2HOb7GE

Scale (Data and Network)
IoT has the possibility to scale to millions of devices.

Security/Privacy
Physical assets and IP can be at risk. This is a big one.

Interoperability
Devices and networks need to talk the same "language".

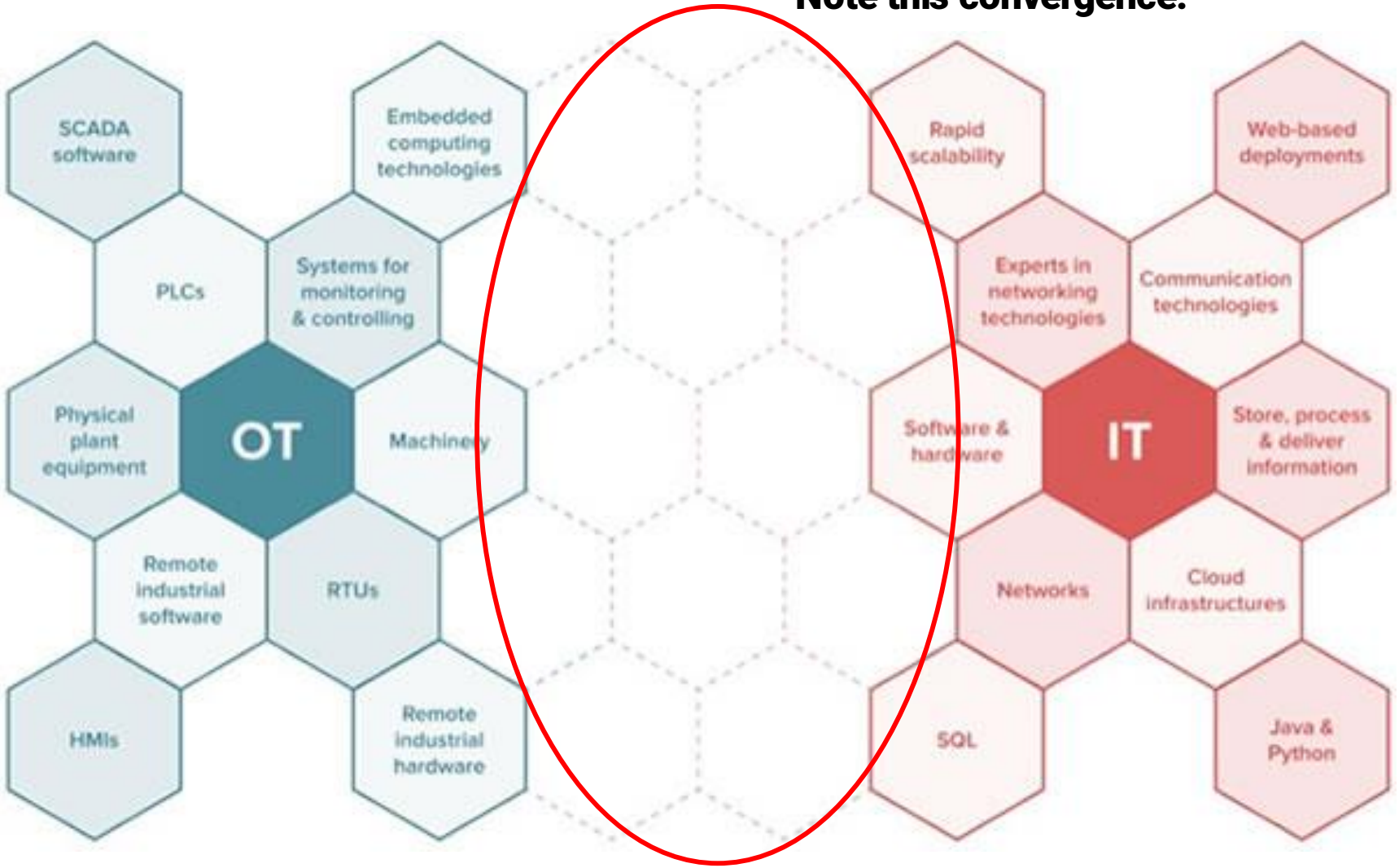
Operational Issues
IoT needs tight IT/OT coordination.

Implementation Commonality
IoT implements are largely made to order – particularly for the cloud services. Cost implications.

IT and OT

Slides:
http://bit.ly/2HOb7GE

Note this convergence.

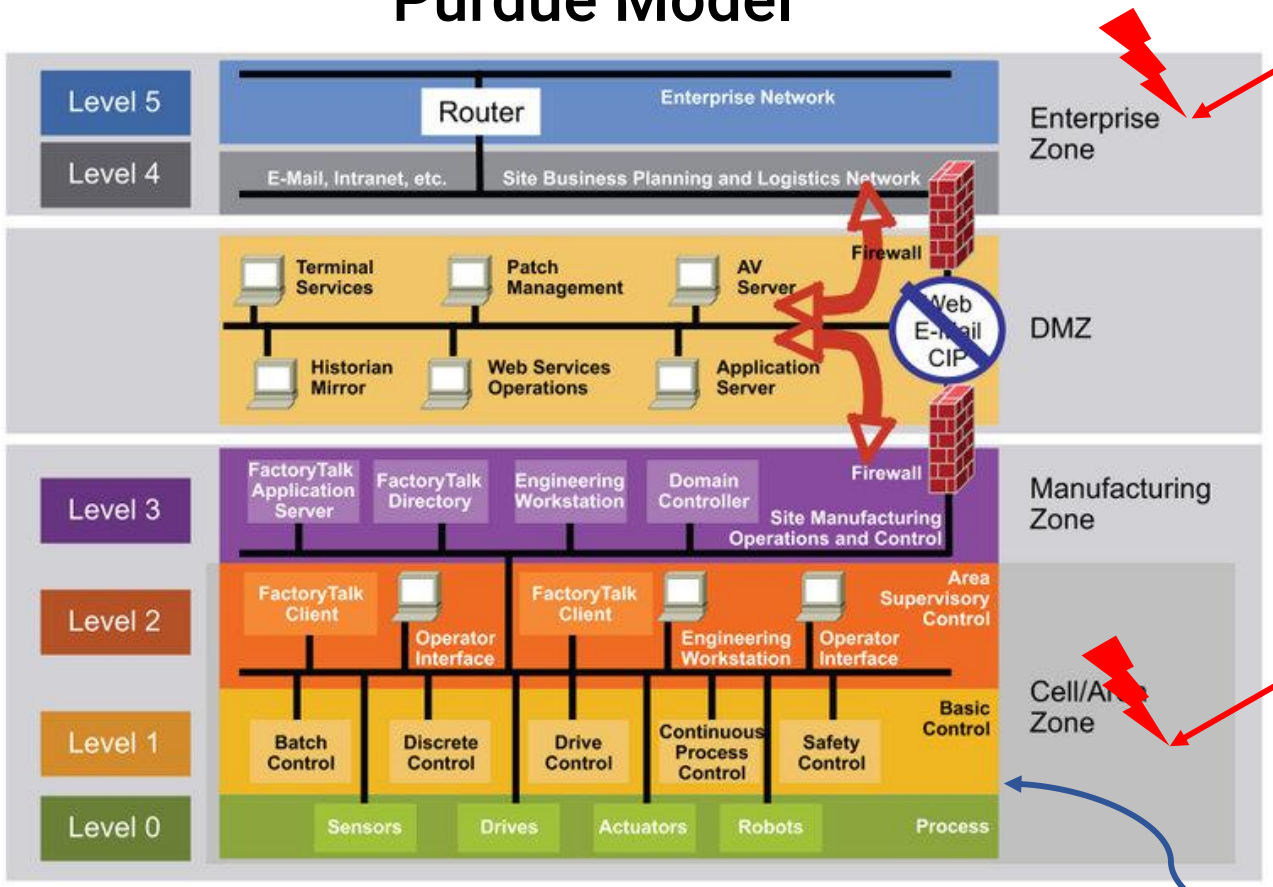


Source: http://bit.ly/2GKH6bk

IT and OT Separation

Slides:
http://bit.ly/2HOb7GE

Purdue Model



Phishing
Spear phishing

USB/Physical equipment access

PLCs, HMIs

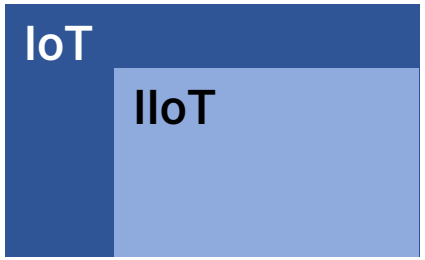
Cyberattack Example Cases

Slides:
http://bit.ly/2HOb7GE

- December 2015 Ukraine power grid cyberattack
- German steel mill cyberattack
- Saudi Aramco and Qatar RasGas cyberattack (2012)
- WannaCry ransomware attack

Slides:
http://bit.ly/2HOb7GE

- **IIoT stands for** Industrial Internet of Things.
- **IIoT is sometimes called** Industrial Internet.
- **IIoT is really a subcategory of IoT. Many of the technologies are the same (but not all) but it focuses on "industrial" use cases.**



- **The business case for IIoT is increasing efficiency and safety while reducing costs.**

Slides:
http://bit.ly/2HOb7GE

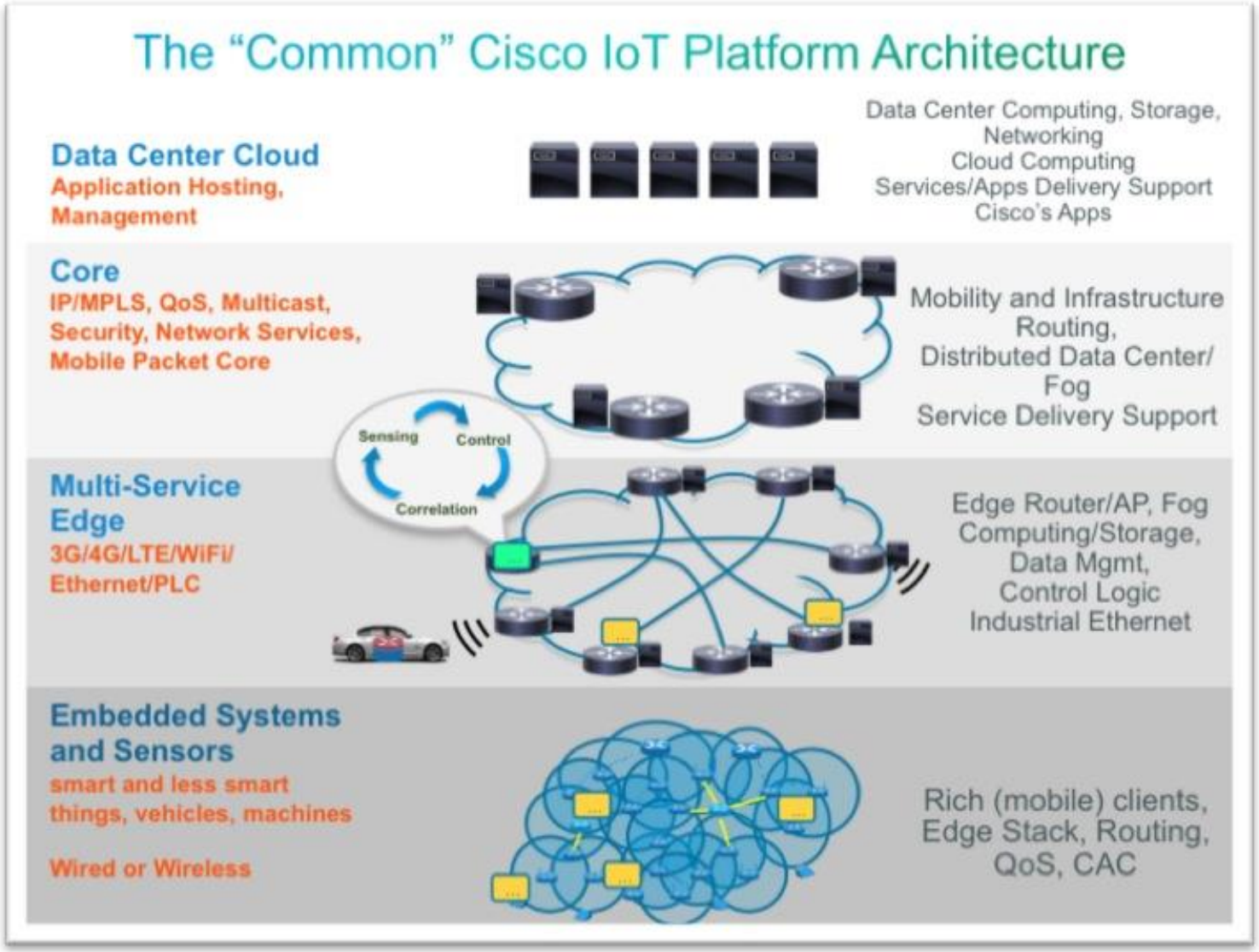
- **Sometimes will hear that Industry 4.0 and IIoT are the** same.
- Technically, **they are not.**
- **Industry 4.0 (Industrie 4.0) is/was a German government program in digitizing manufacturing.**
- **Industry 4.0 is also called the** 4^{th} Industrial Revolution.
- **Cyber Physical Systems, IIoT, advanced data analytics and machine learning.**

Slides:
http://bit.ly/2HOb7GE

- Purdue Enterprise Reference Architecture
- Industrial Internet Reference Architecture (IIRA) by Industrial Internet Consortium (IIC).

IIoT Reference Models/Architectures

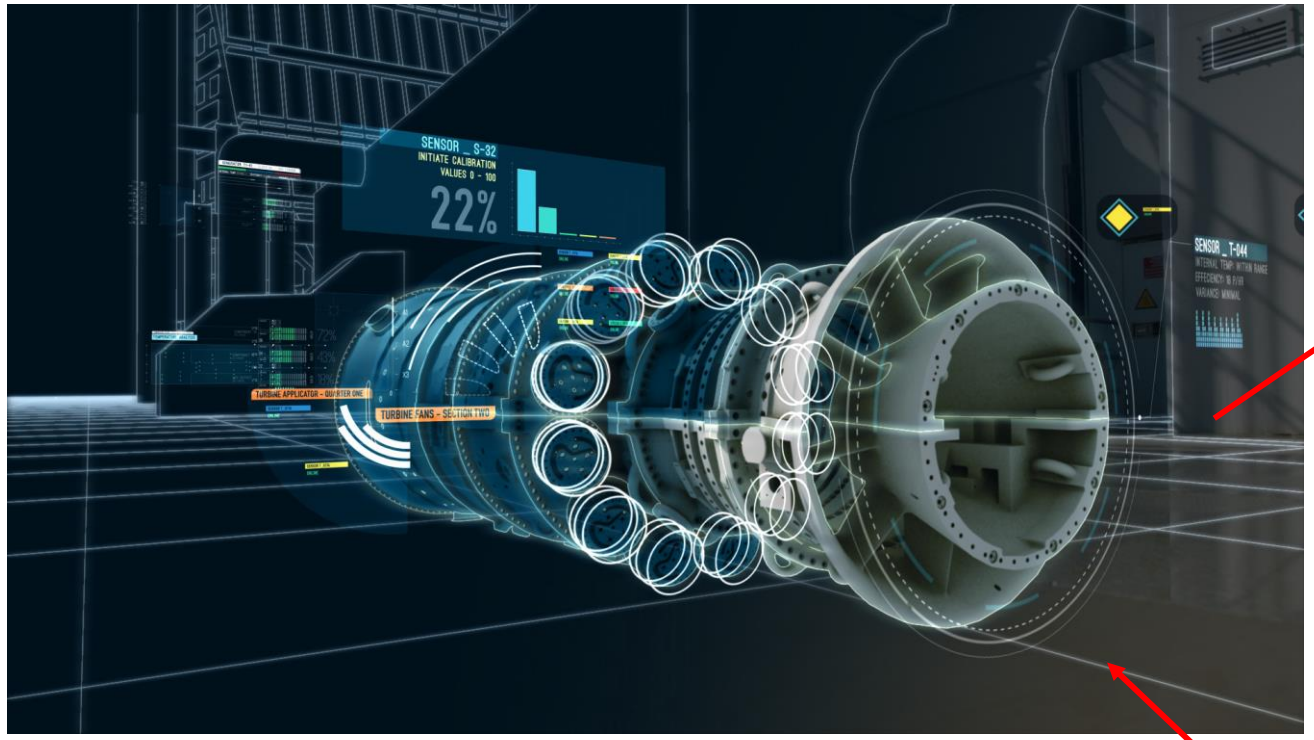
Slides:
http://bit.ly/2HOb7GE



Source: http://bit.ly/2zpBpeN

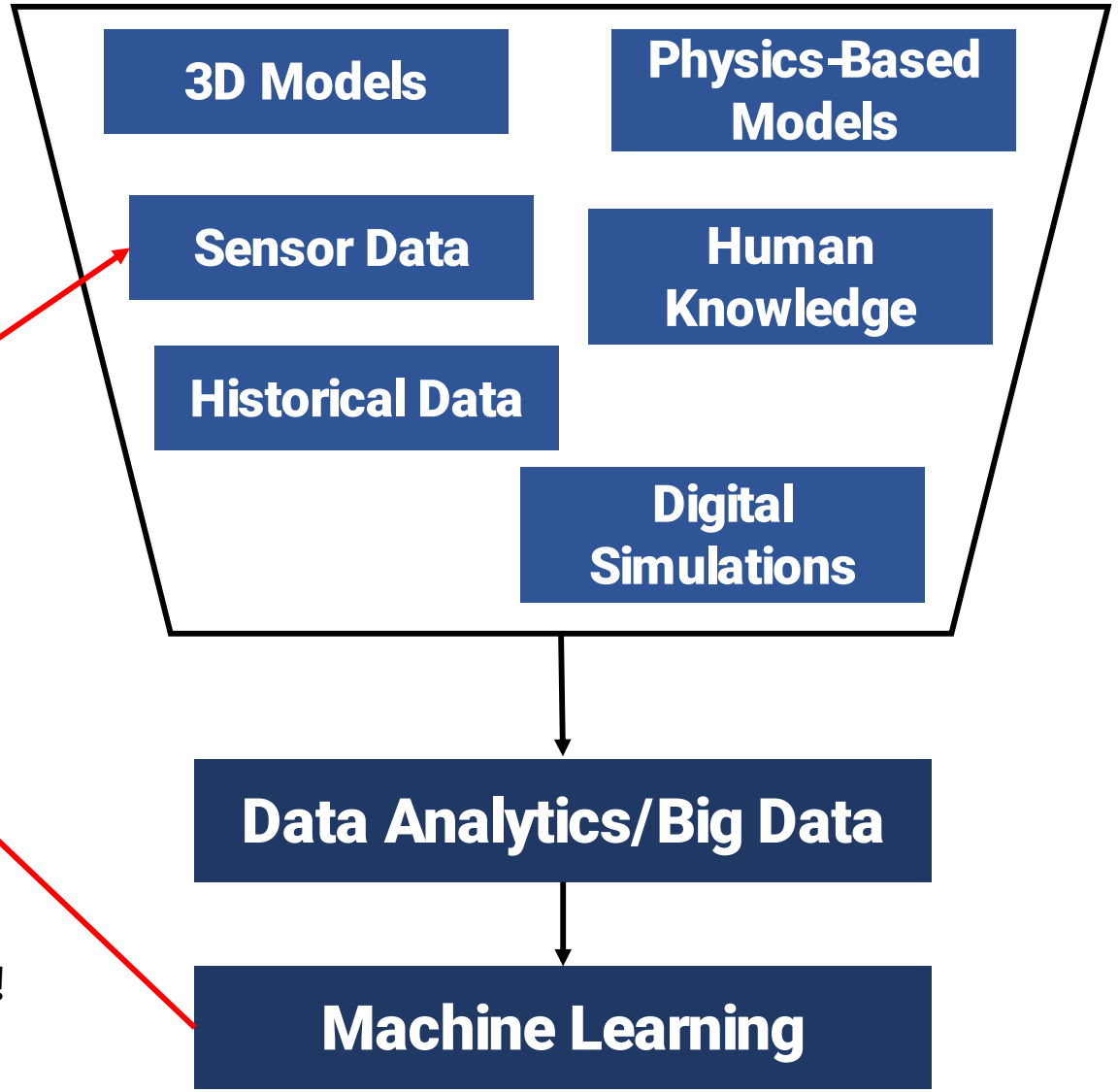
Use Case – Digital Twin

Slides:
http://bit.ly/2HOb7GE



Source: http://bit.ly/2pqVZbo

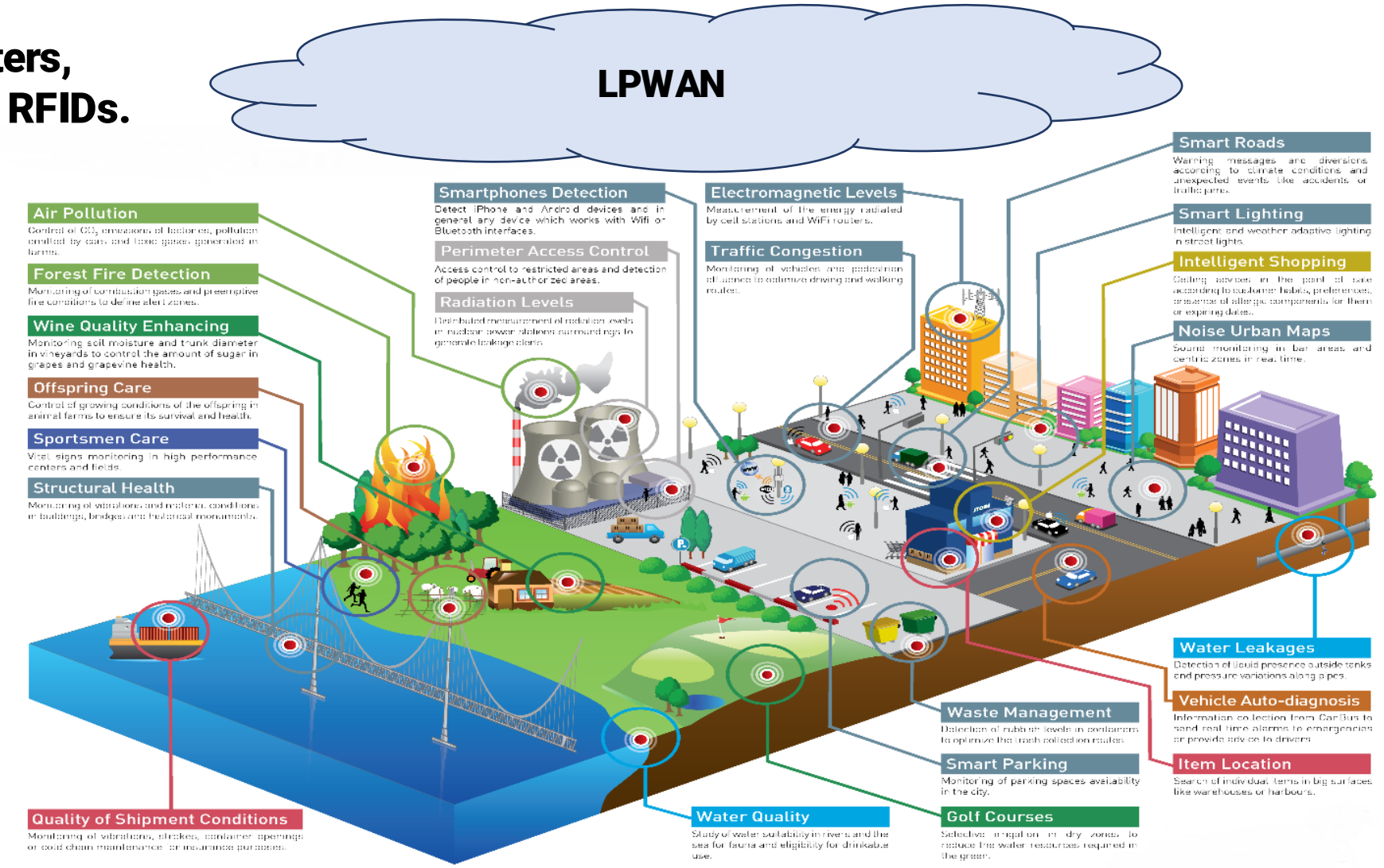
Note: **There is something like 20,000 sensors on a jet engine!**



Use Case – Smart City/Smart Building

Slides:
http://bit.ly/2HOb7GE

Smart phones, smart meters,
networks of sensors **and RFIDs.**

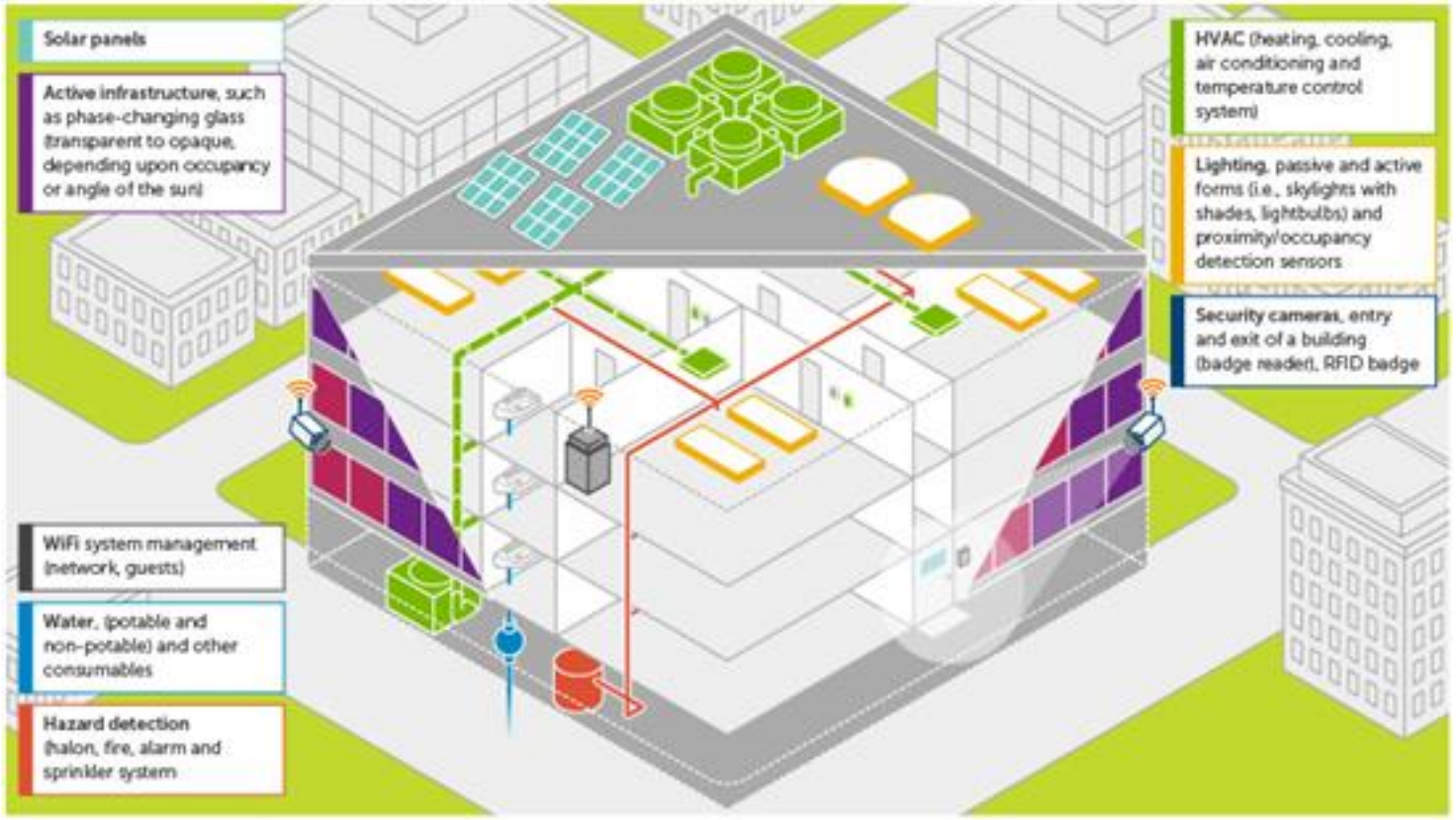


Check out UI Labs' City Tech iniatives.

Use Case – Building Automation

Slides:
http://bit.ly/2HOb7GE

Can also be tied to larger "smart cities" effort.



Use Case – Predictive Maintenance

Slides:
http://bit.ly/2HOb7GE

Using historical operational data to determine failure windows prior to them occurring.

Heat sensors on ball screws

Spindle bearing heat and vibration sensors

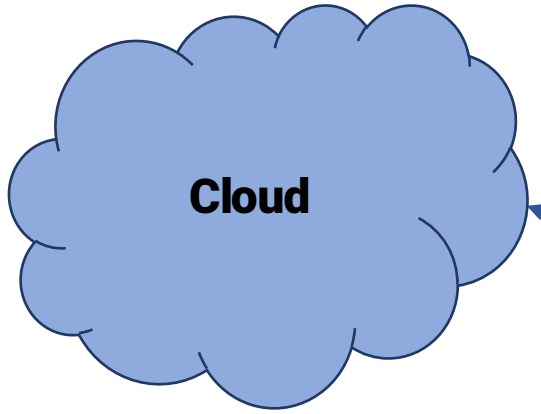
Machine bed vibration sensors

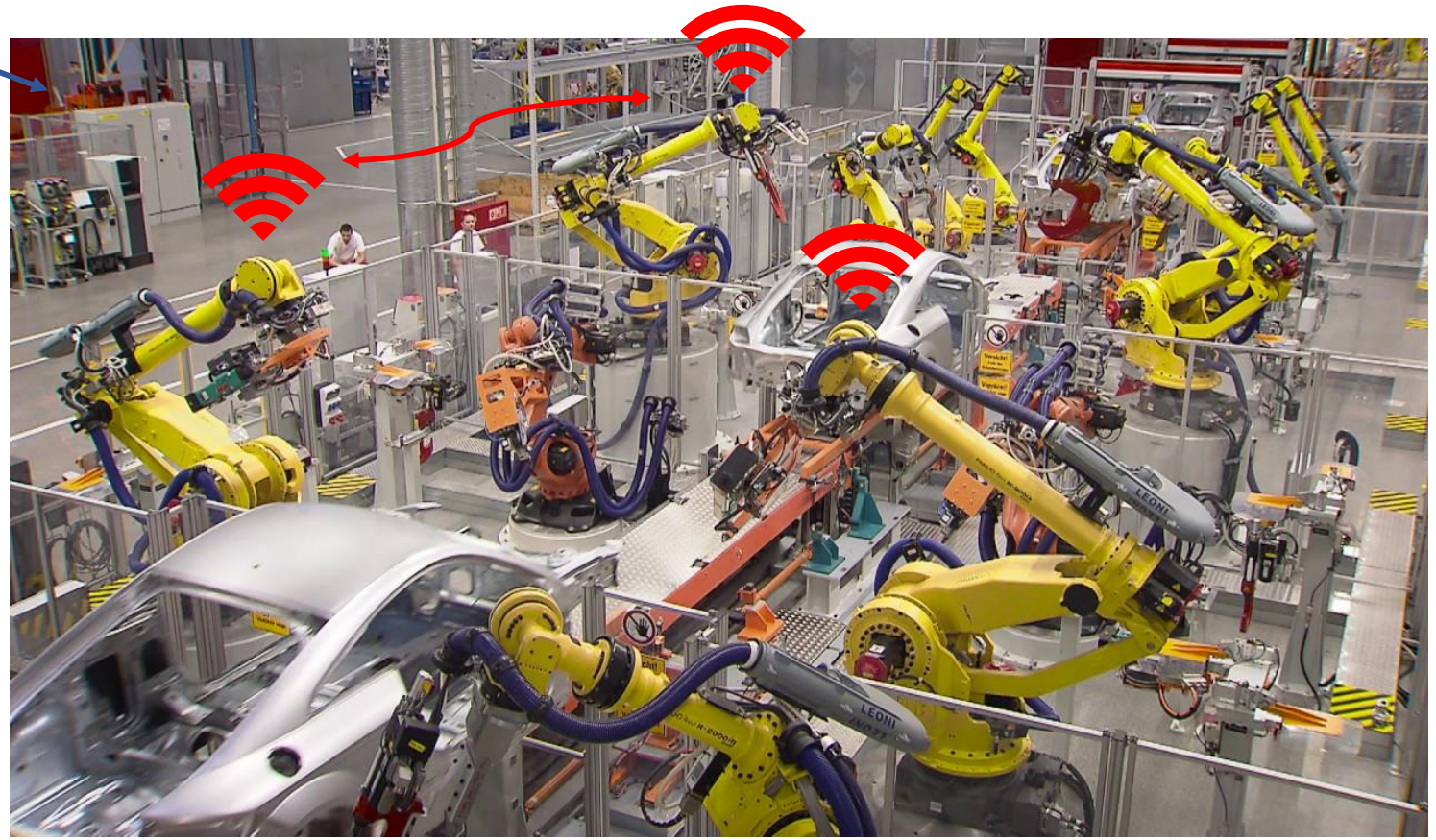
Coolant filter pressure sensors

What else can this data be used for?

Use Case – (Smart) Factory Automation

Slides:
http://bit.ly/2HOb7GE

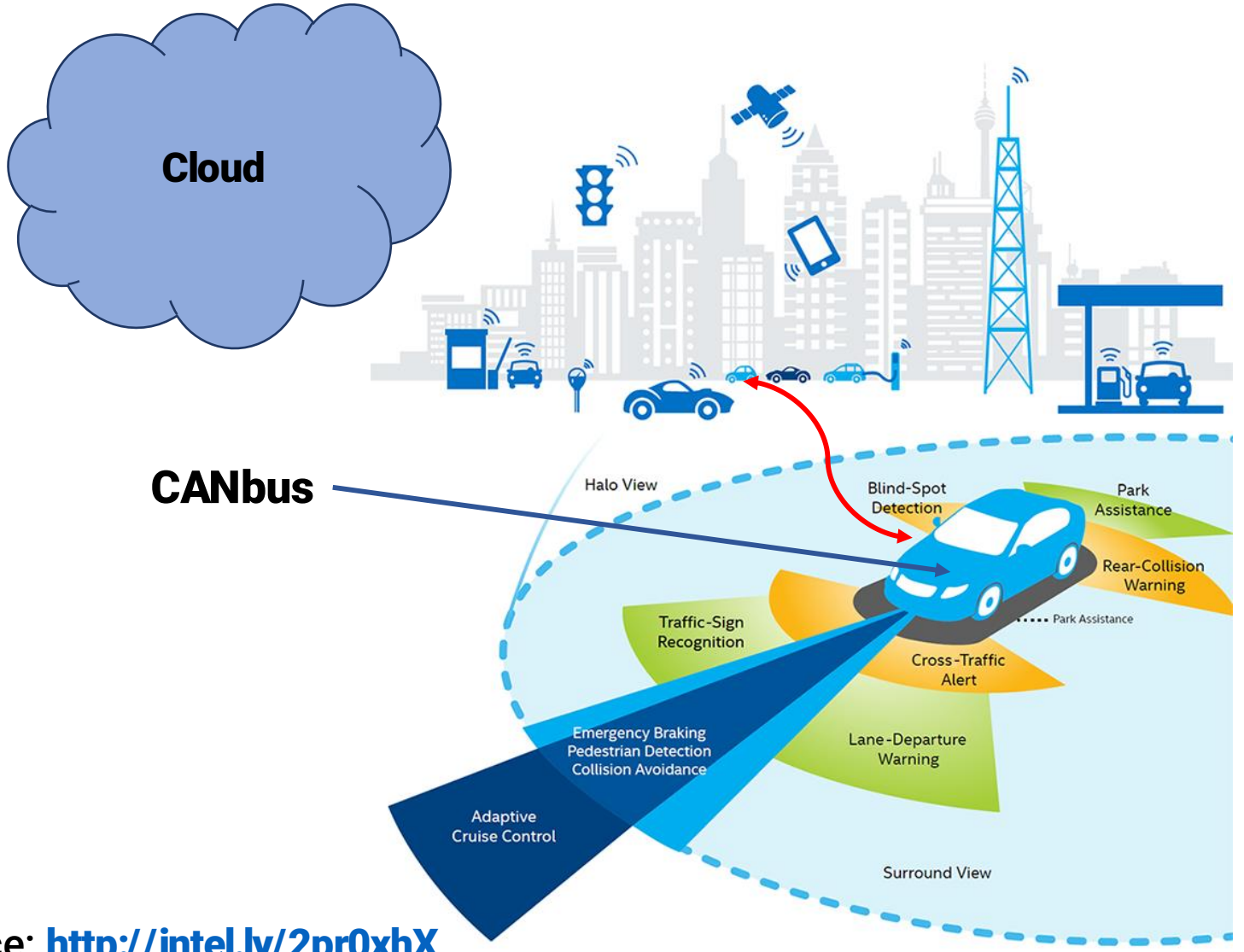




- **Robot-to-robot.**
- **Factory-to-cloud.**
- **Factory-to-factory.**
- **Finished product-to-factory.**

Use Case – Autonomous Vehicles

Slides:
http://bit.ly/2HOb7GE

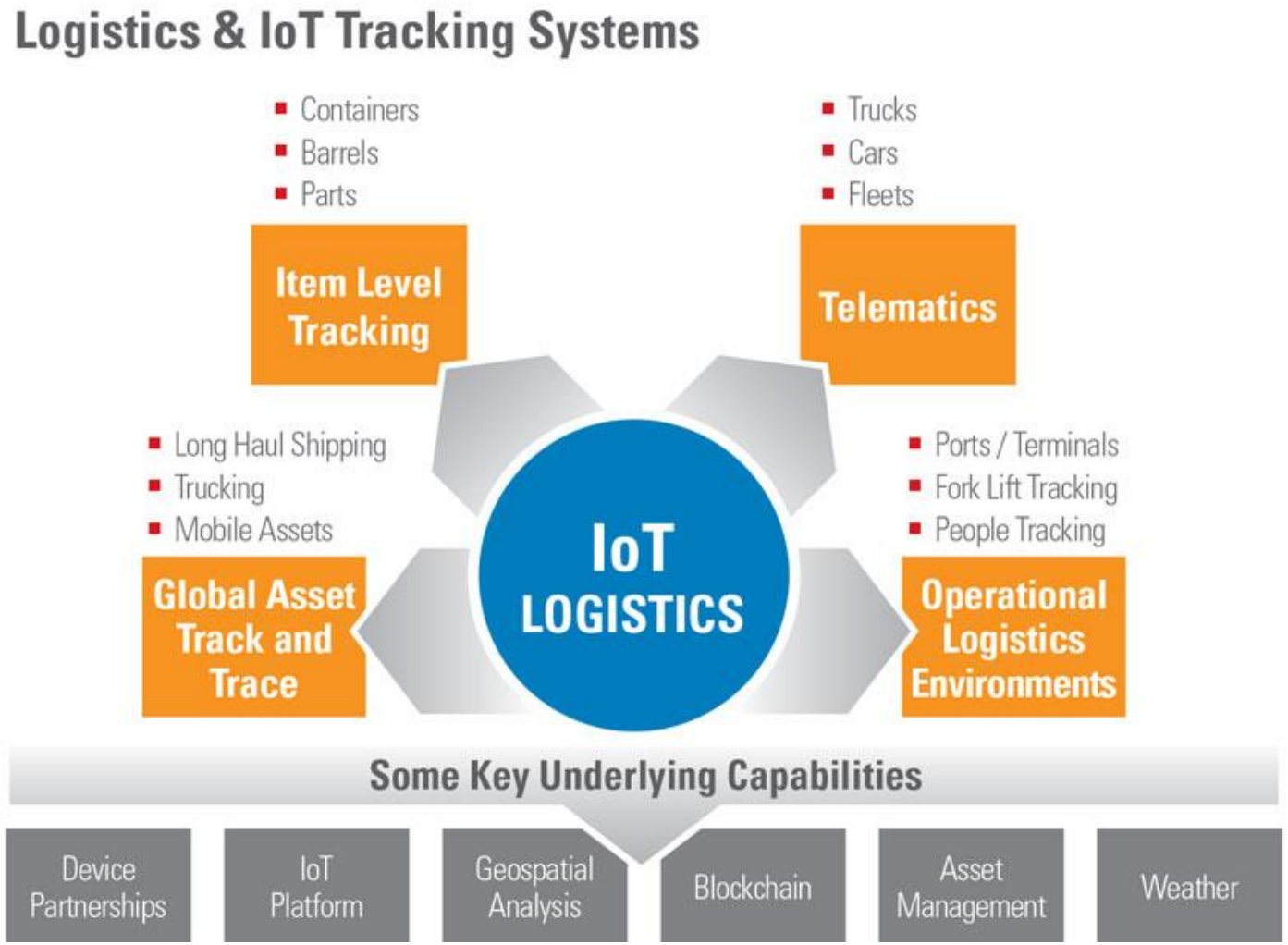


- **Vehicle-to-vehicle.**
- **Vehicle-to-cloud.**
- **Vehicle-to-smart city.**

Source: http://intel.ly/2pr0xhX

Use Case – Asset Tracking

Slides:
http://bit.ly/2HOb7GE



Source: http://bit.ly/2HPC64z

What about small/medium businesses?

Slides:
http://bit.ly/2HOb7GE

- **Favor** incremental steps **to IIoT adoption over large projects.**
- **IIoT is** not **magic. It is most useful when finding that "last mile" of efficiency.**
- **Having the IT and OT personnel and expertise is critical.**
- **Security needs to be budgeted in and enforced enterprise-wise. In a lot of ways, the attack surface is larger in IIoT.**
- **Beware of legacy equipment challenges.**
- **Careful! It can transform your enterprise (hopefully, for the better).**

Slides:
http://bit.ly/2HOb7GE

Next up. **We take a deeper technical dive into IoT/IIoT.**

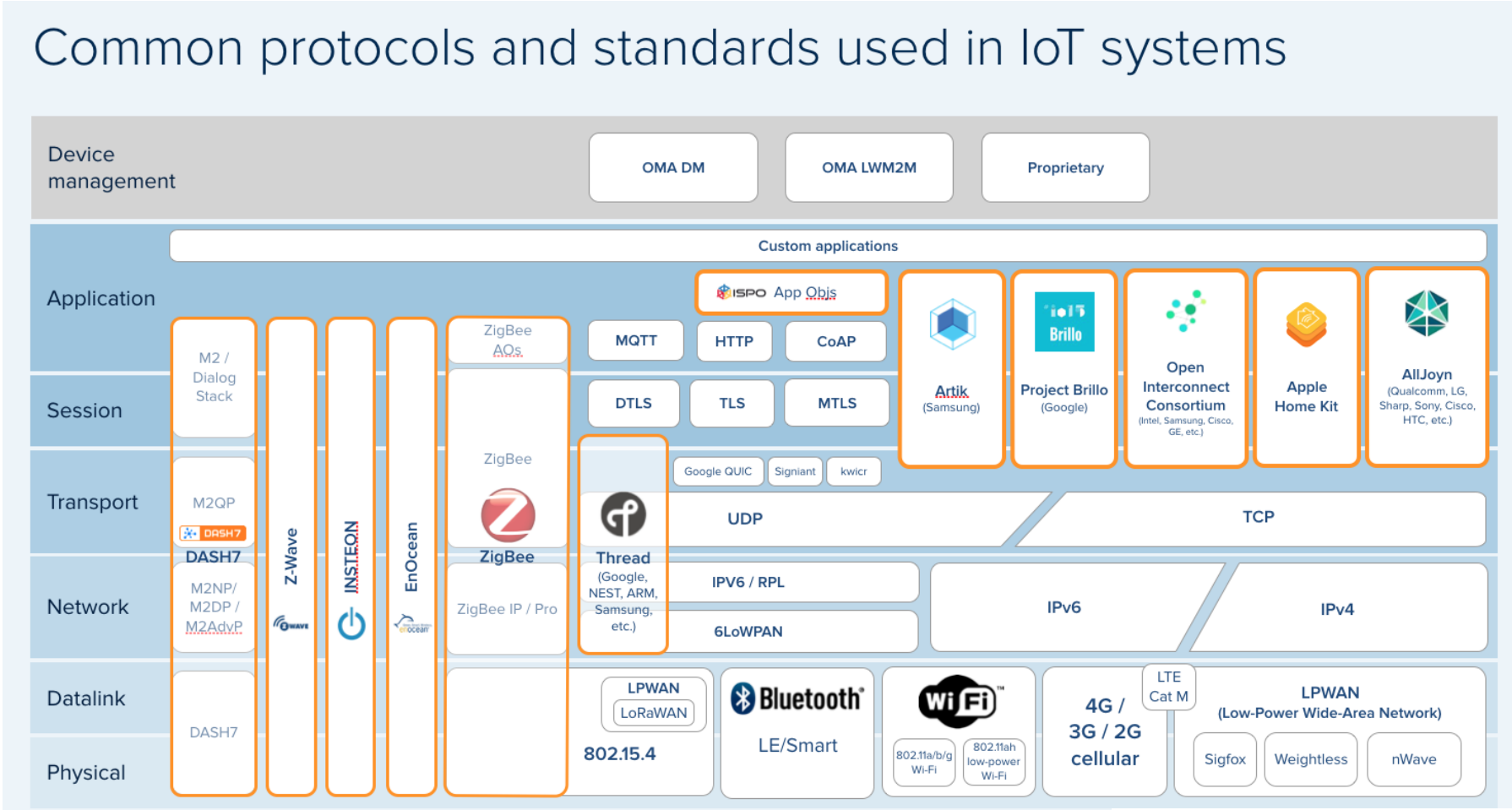
6LoWPAN: http://bit.ly/2GQSJ0E

IoT Stack Overview

Slides:
http://bit.ly/2HOb7GE

Layers based on the OSI Model

We will work up this way.



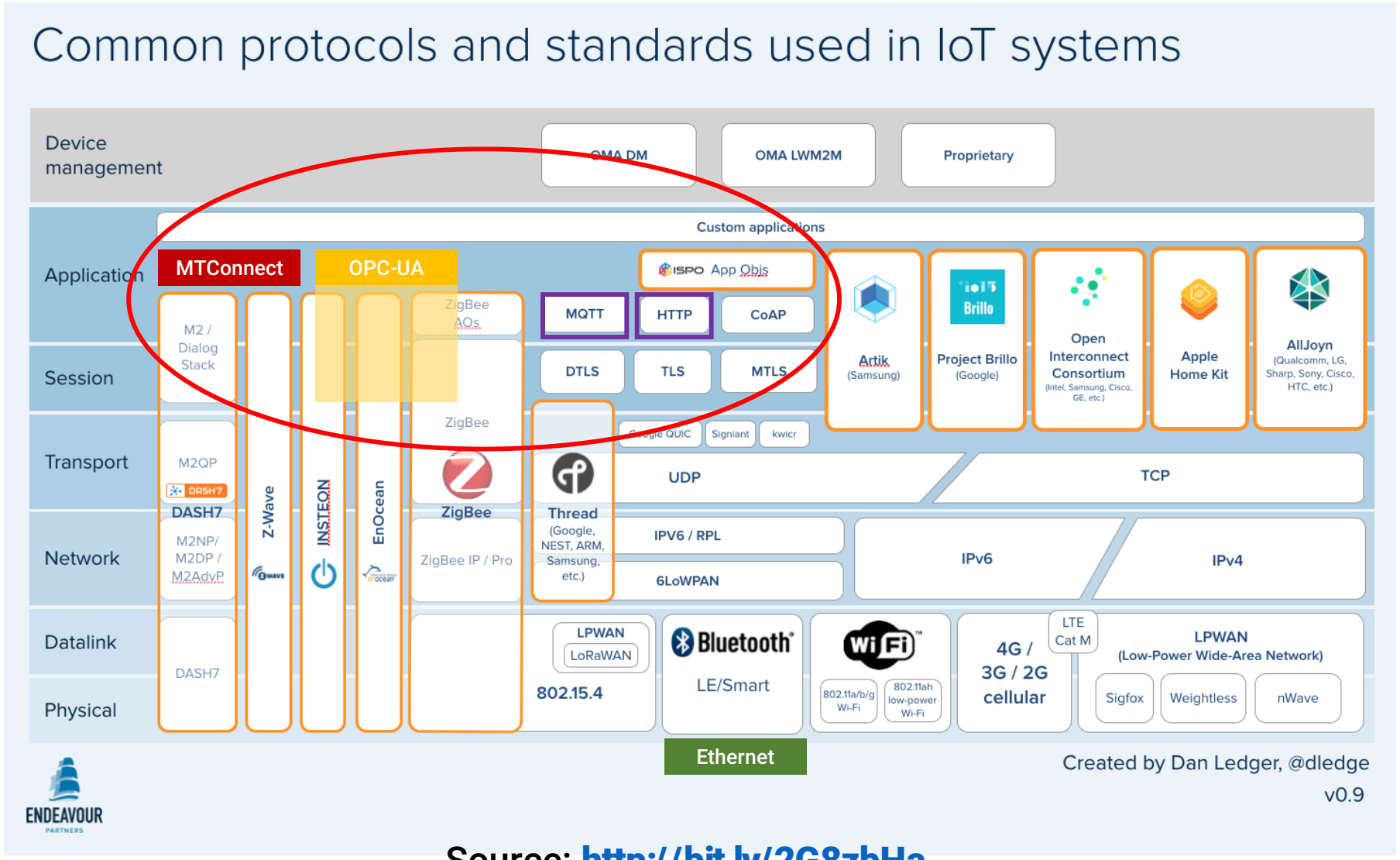
Layers based on the OSI Model

Source: http://bit.ly/2G8zbHa

Theoretically, you can pick and choose technologies from each layer independently from one another.

IoT Stack Overview + Some More Industrial

Slides:
http://bit.ly/2HOb7GE



Source: http://bit.ly/2G8zbHa

- **Contains embedded systems and sensors, but, more importantly, the standards which will connect to the Internet.**

Ethernet

GSM, 3G, LTE, 4G, 5G

WiFi (802.11b, g, n)

LPWAN

Slides:
http://bit.ly/2HOb7GE

- WLAN – **Wireless Local Area Network (WiFi)**
- WWAN – **Wireless Wide Area Network (Cellular)**
- LPWAN – Low-Power **Wide Area Network**
- LPWANs are great for:
  - **Filling gaps between WLAN and WWAN.**
  - **Devices that need great battery life.**
  - **Transmission distance over 15 km.**
  - **Capable of outdoor use.**
  - **Low-cost.**

Other LPWAN Technologies

Slides:
http://bit.ly/2HOb7GE

sme

Why LPWAN?

Connectivity Options for IoT

INTERNET OF THINGS DEVELOPERS CONFERENCE

Existing Technologies	Business Cases	IoT Technologies
strongly address short-range and long-range, high-power cases	many long-range technologies are expensive and only use public networks	optimized for their task - communication aspects must be, too

Short Range High Speed	Short Range Moderate Speed	Long Range High Power	Long Range Low Power
• Ethernet • Wi-Fi	• 802.15.4 • ZigBee • ZWave • Bluetooth • Thread	• Cellular • Satellite • Microwave	SIGFOX, INGENU, LoRa, waviot

infiswift

NIST IoT Lab - Sebastián Barillaro

aka WWAN

aka LPWAN

aka WLAN

aka LoRaWAN

Source: http://bit.ly/2IE7JPG

Slides:
http://bit.ly/2HOb7GE

- Internet **is here.**
- **Provides a connection between networks and a connection between physical layers (to each other or to cloud services).**
- **Unique identifier called an** IP Address **is here.**

IPv4

RPL

IPv6

Network Layer – IPv4 vs. IPv6

Slides:
http://bit.ly/2HOb7GE

The Internet Protocol (IP) is the method or protocol by which data is sent from one computer to another on the Internet. Each computer (known as a host) on the Internet has at least one IP address that uniquely identifies it from all other computers on the Internet.*

IPv6 Advantages:

- **Larger address space.**
- **Better built-in security.**
- **Harmonizes IoT datalink layer.**

	Internet Protocol version 4 (IPv4)	Internet Protocol version 6 (IPv6)
Deployed	1981	1999
Address Size	32-bit number	128-bit number
Address Format	Dotted Decimal Notation: 192.149.252.76	Hexadecimal Notation: 3FFE:F200:0234:AB00: 0123:4567:8901:ABCD
Prefix Notation	192.149.0.0/24	3FFE:F200:0234::/48
Number of Addresses	2^{32} = ~4,294,967,296	2^{128} = ~340,282,366, 920,938,463,463,374, 607,431,768,211,456

Source: http://bit.ly/2IATz21

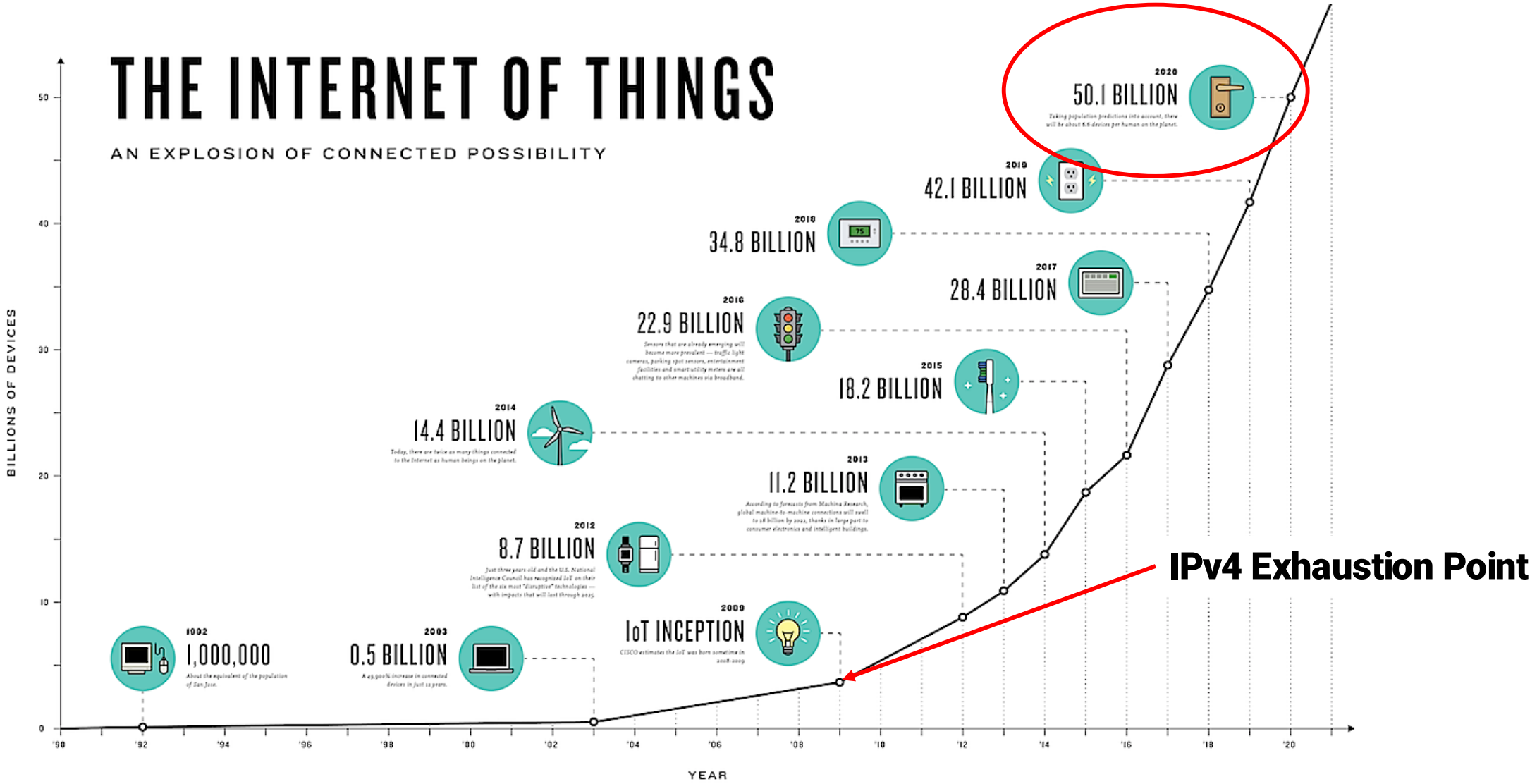
Slides:
http://bit.ly/2HOb7GE

sme

IPv6 creates a common network layer for these technologies.

Network Layer – IPv4 Address Exhaustion

Slides:
http://bit.ly/2HOb7GE



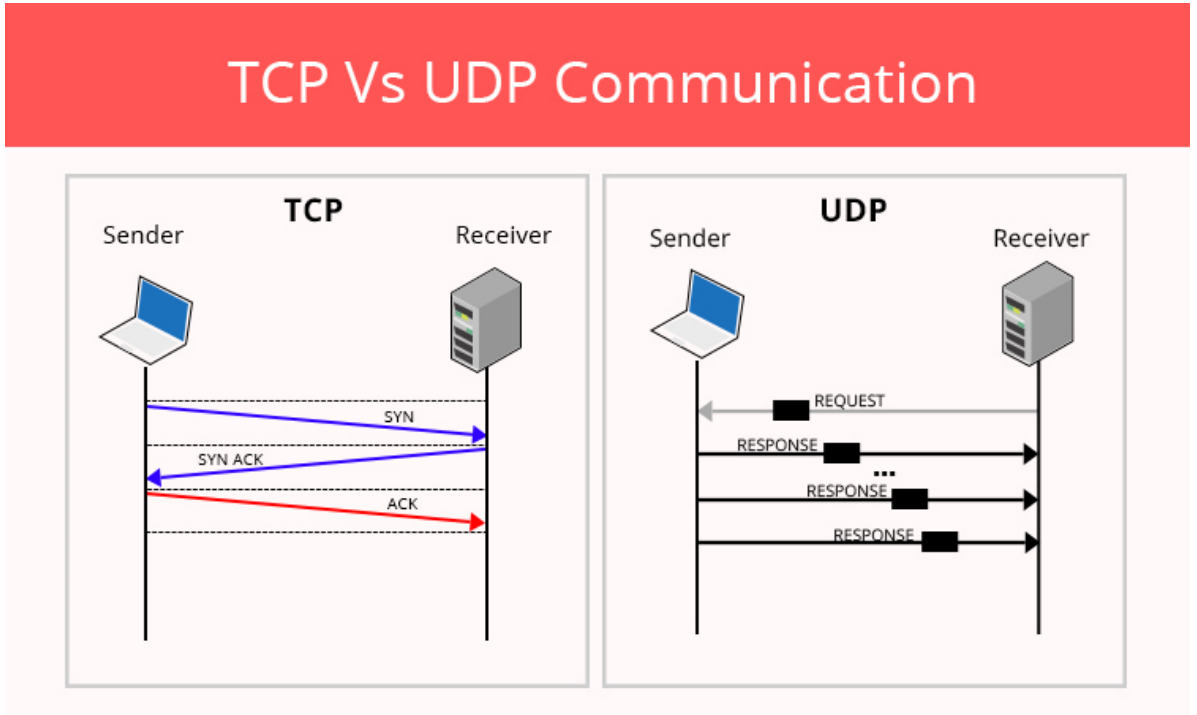
Source: http://bit.ly/2GLxey5

Slides:
http://bit.ly/2HOb7GE

- **TCP and UDP are here.**
- **Data stream handling.**
- **TCP – Transmission Control Protocol**
- **UDP – User Datagram Protocol**
- **UDP is popular for IoT use. TCP is popular for IIoT.** These are not hard rules.

TCP vs. UDP

Slides:
http://bit.ly/2HOb7GE



Source: http://bit.ly/2FNTfPz

TCP vs. UDP

Slides:
http://bit.ly/2HOb7GE

TCP	UDP
Reliable—monitors message transmission, tracks data transfer to ensure receipt of all packets	Unreliable—no concept of acknowledgment, retransmission, or timeout –
Ordered—buffering provisions to ensure correct order of data packets	Not ordered—data arrives in order of receipt
Heavyweight—dedicated connection, provisions for speed and congestion control	Lightweight—no dedicated end-to-end connection, no congestion control
Streaming	Datagram oriented
Heavy overhead	Light overhead
Lower speed	Higher speed

Source: http://bit.ly/2DHqwG4

Slides:
http://bit.ly/2HOb7GE

- **Contains value-added applications, communications protocols and interface methods for a network.**
- **Does not really say anything about data formats used. It is common for large sensor networks to be involved in** unstructured **data transfer.**

MTConnect

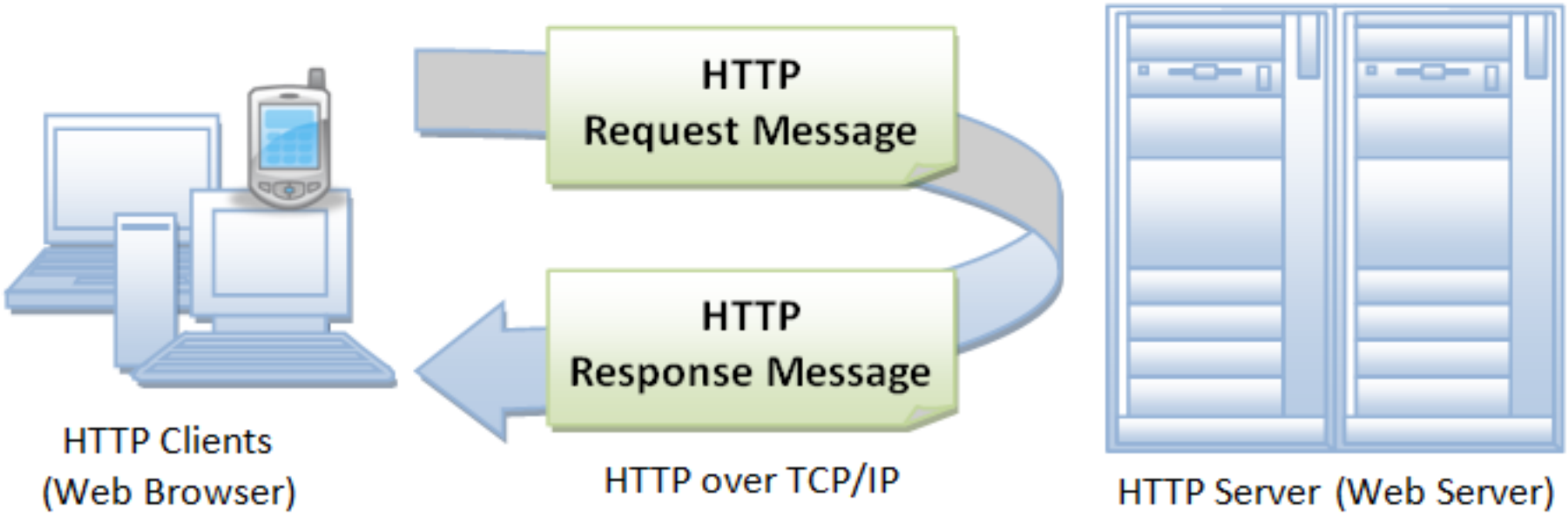
OPC-UA

HTTP

MQTT

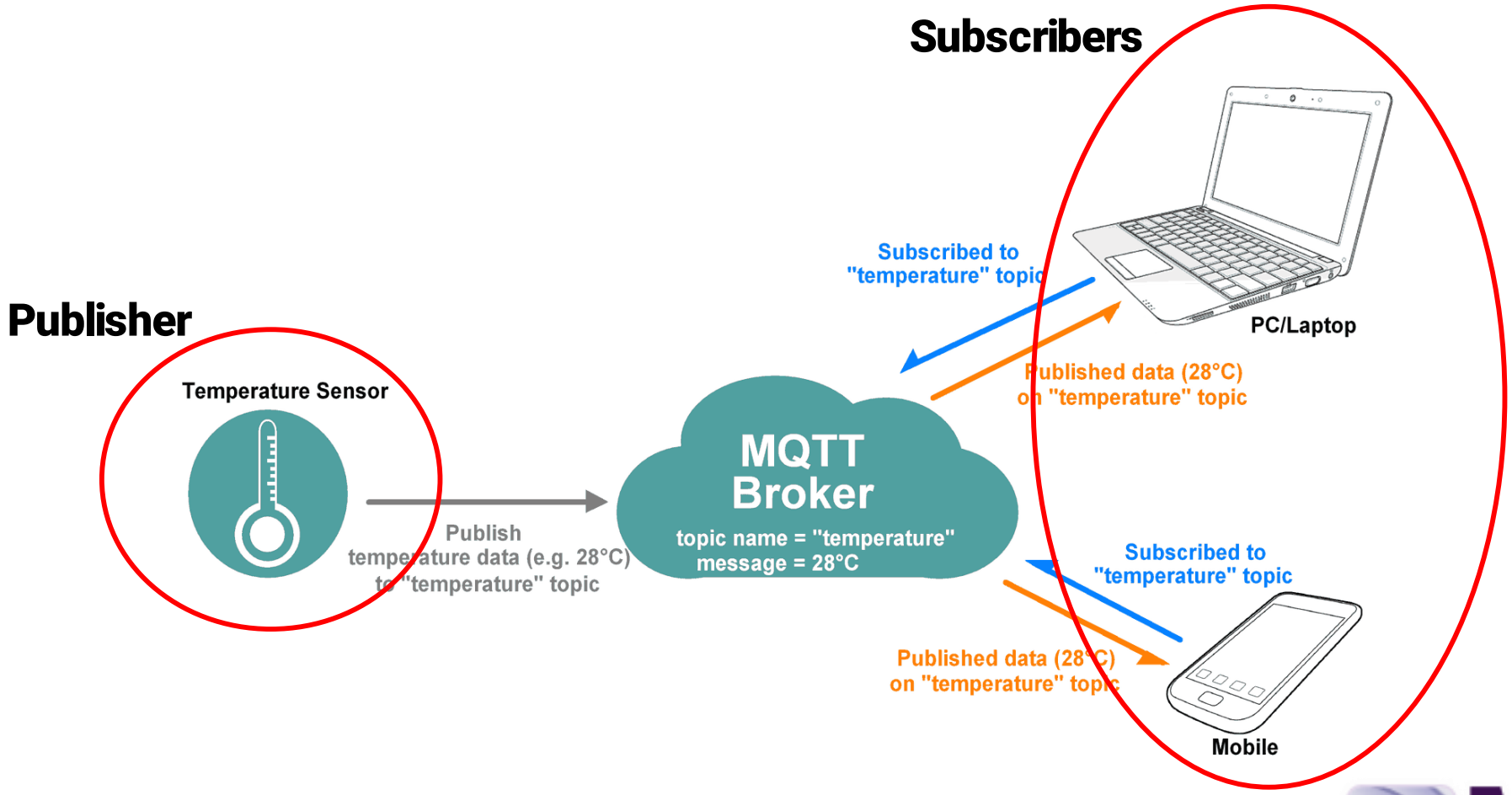
Application Layer - HTTP

Slides:
http://bit.ly/2HOb7GE



Application Layer - MQTT*

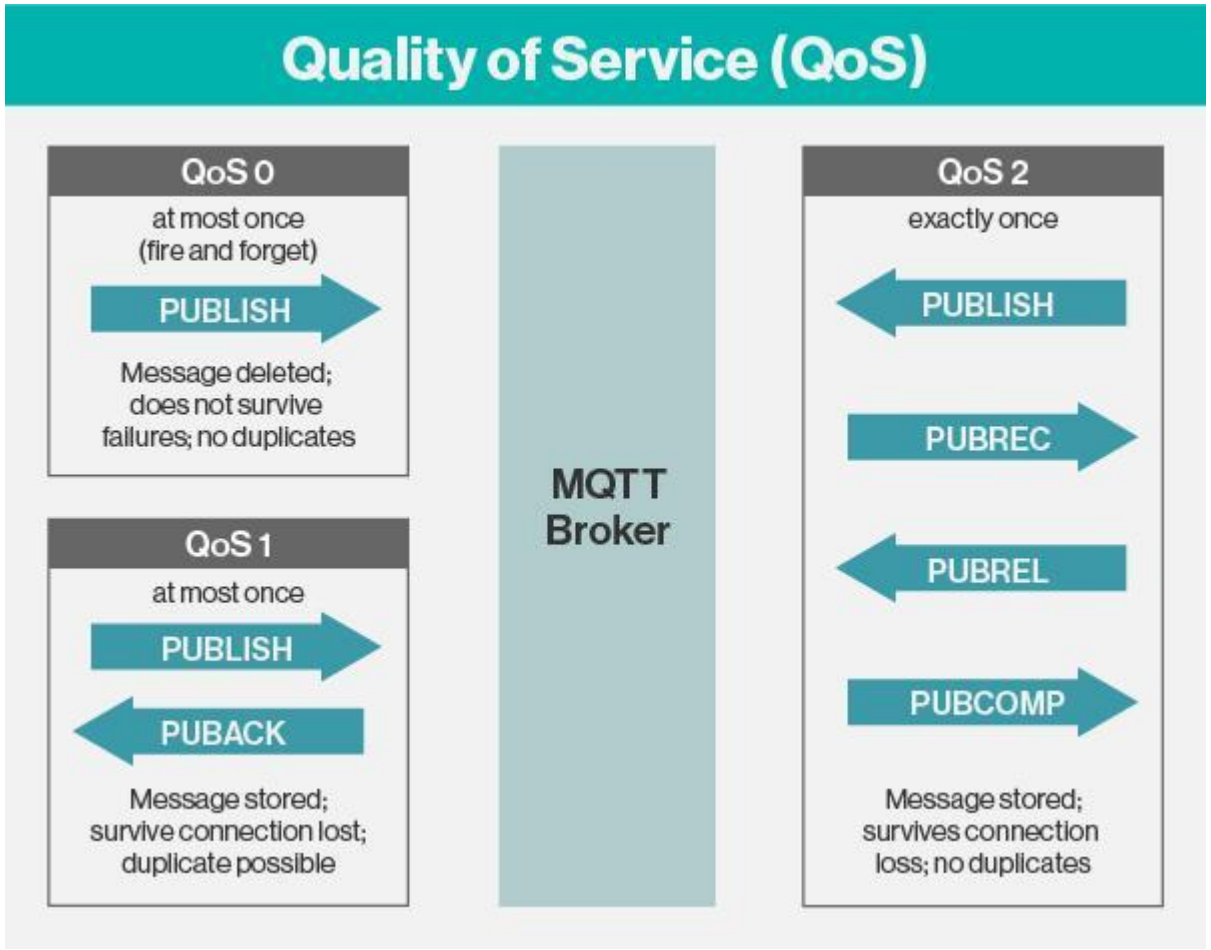
Slides:
http://bit.ly/2HOb7GE



Source: http://bit.ly/2GLXCrG

Application Layer – MQTT QoS

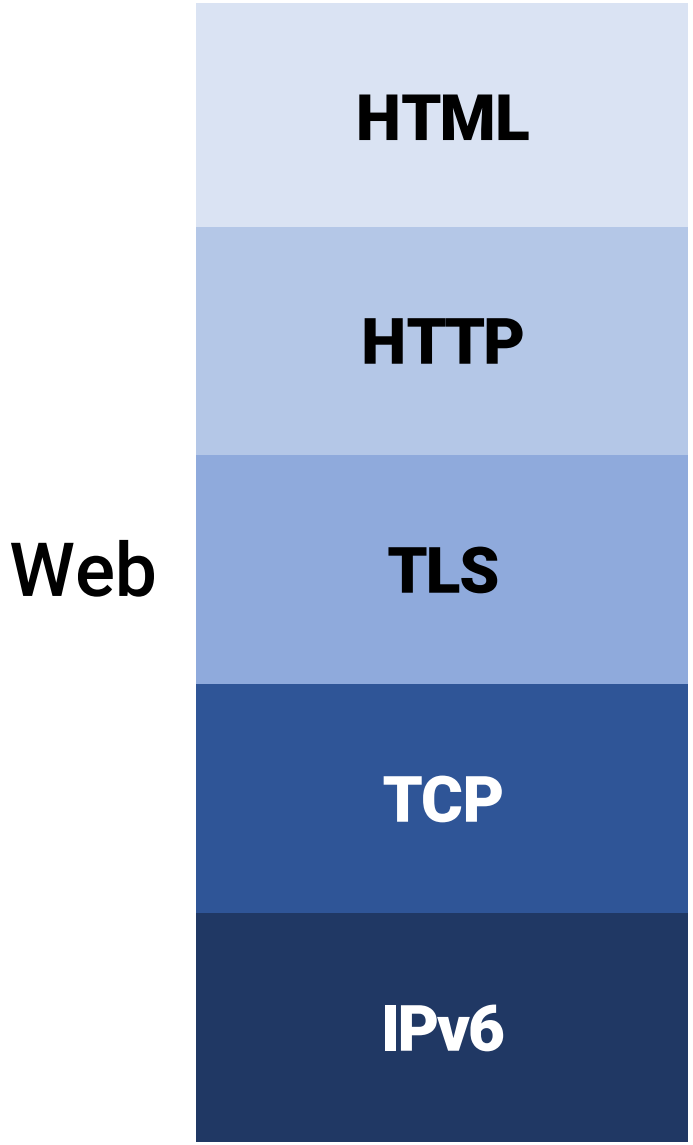
Slides:
http://bit.ly/2HOb7GE

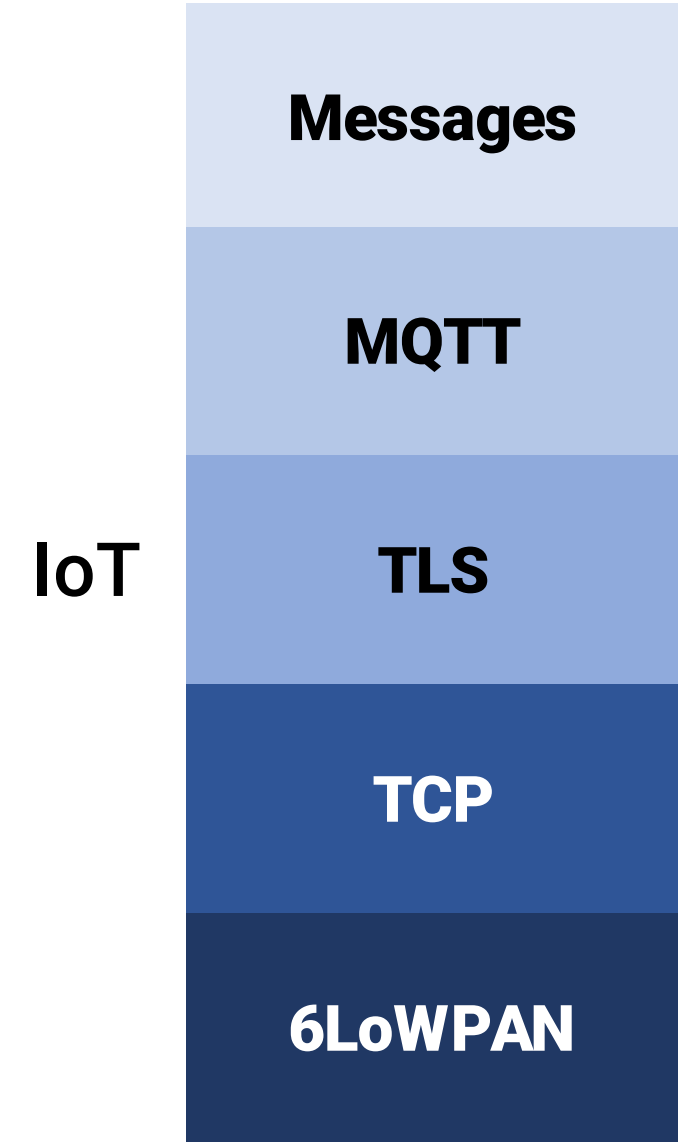


Source: http://bit.ly/2FW4iSO

Web Stack vs. IoT Stack

Slides:
http://bit.ly/2HOb7GE

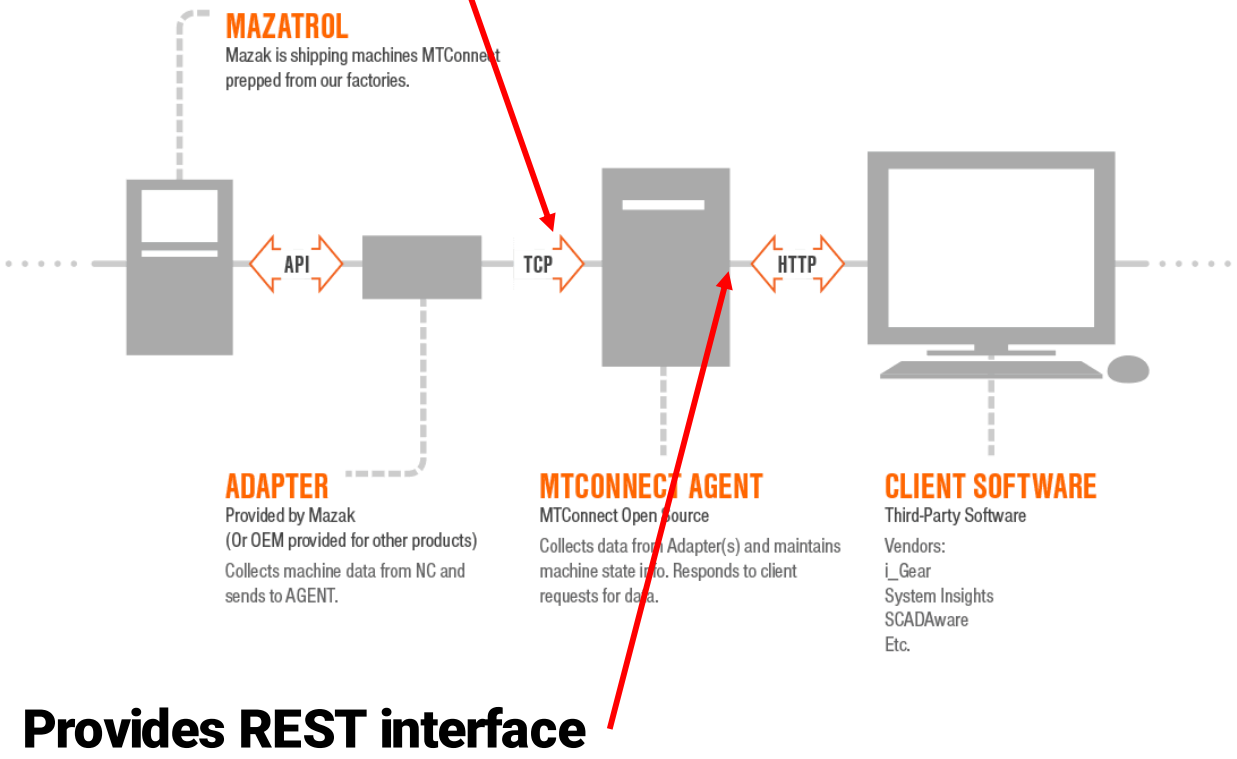




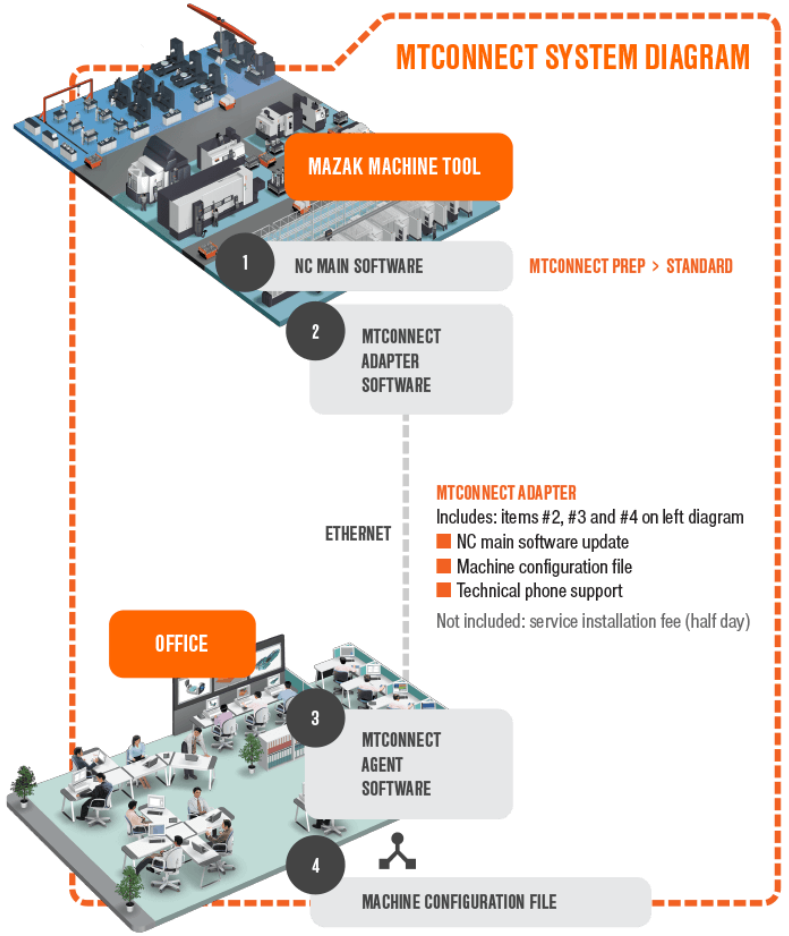
MTConnect*

Slides:
http://bit.ly/2HOb7GE

XML data format



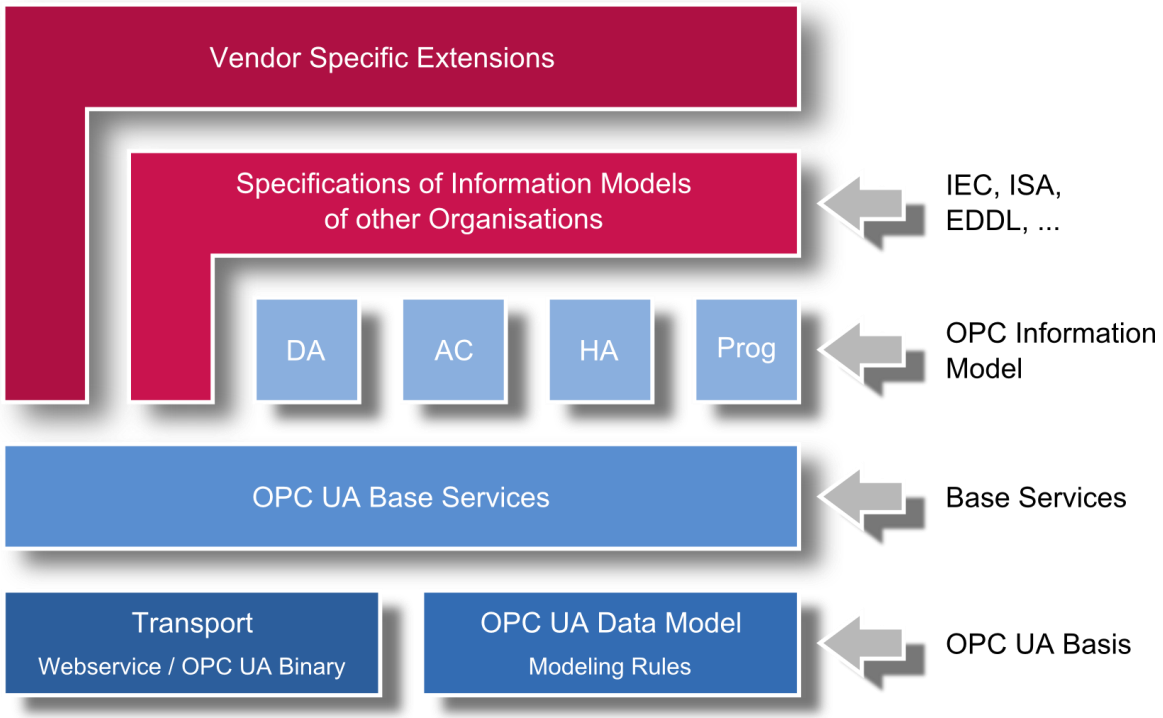
Provides REST interface



Source: http://bit.ly/2G4QMjh

OPC-UA*

Slides:
http://bit.ly/2HOb7GE



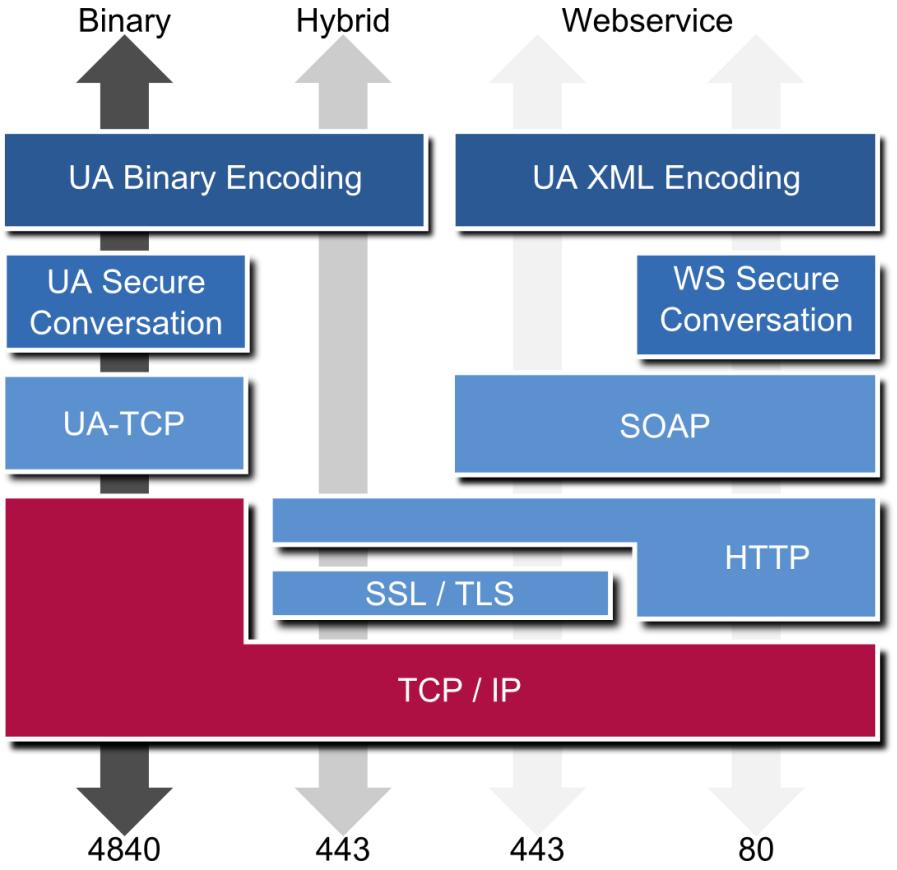


Image credit [ascolab]

Other Automation Protocols*

Slides:
http://bit.ly/2HOb7GE

CANbus

Slides:
http://bit.ly/2HOb7GE

We will dive down to the code level **with these technologies:**

Thank you!

Slides:
http://bit.ly/2HOb7GE

Want to learn more about  **?**

Check out [sme.org](sme.org)

Questions?

Ask in the Live Chat or Slack or check the feedback link in the description!