Industrial Internet of things(IIOT)

Introduction

Industrial Internet of things(IIOT)

- Application of IOT in industry is known as IIOT or Industrial internet of things or **Industry 4.0**.
- Industrial Internet integrates ***big data technologies, machine learning, sensor data, machine-to-machine (M2M) communication to architect intelligent commercial-ready industrial equipment and facilities***.
- Industrial IoT platform will allow you to connect and process IoT data securely at a larger scale.

Syllabus

Module 1

- Introduction to Industrial IoT (IIoT) Systems: The Various Industrial Revolutions, Role of Internet of Things (IoT) & Industrial Internet of Things (IIoT) in Industry, Industry 4.0 revolutions, Support System for Industry 4.0, Smart Factories.

Module 2

- Basic of IIoT systems: An Overview of Sensors and Actuators for Industrial Processes, Sensor networks, Process automation and Data Acquisitions on IoT Platform, Concepts of MQTT, CoAP, REST Api and gRPC, Different Communication protocols :(RFID, IEEE 802.15.4, Zigbee, 6LoWPAN, Bluetooth), LoRa, Machine-to-Machine (M2M) Communications

Module 3

- IIoT Data Monitoring & Control: IoT Gate way, IoT Edge Systems, IIoT cloud platforms like predix, thingworks, azure etc., Real Time Dashboard for Data Monitoring, Data Analytics and Predictive Maintenance with IIoT technology.

Module 4

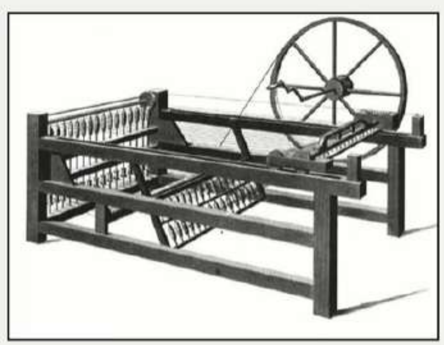
- Industrial IoT- Applications: In Smart cities, Industrial Automation, Autonomous Vehicles, Predictive Maintenance, Smart agriculture, Aerospace etc.
- Case studies of IIoT in Healthcare, Power Plants and Inventory Management & Quality Control.

How Industrial IoT Works

- **Industrial IoT** (IIoT) is a network of devices which are connected through communications technologies.
- These devices analyze data, collect and exchange information to provide complete operational visibility to make rapid operational decisions that can **enhance your business**.
- Industrial IoT increases **visibility**, enhances operational **efficiency**, reduces complexities and **boosts productivity in the industry**.
- **Industrial IoT Platform** makes use of modern sensor technology to architect various industrial equipments with remote monitoring and maintenance capabilities.
- It helps in enhancing **productivity, quality and safety and machine life.**

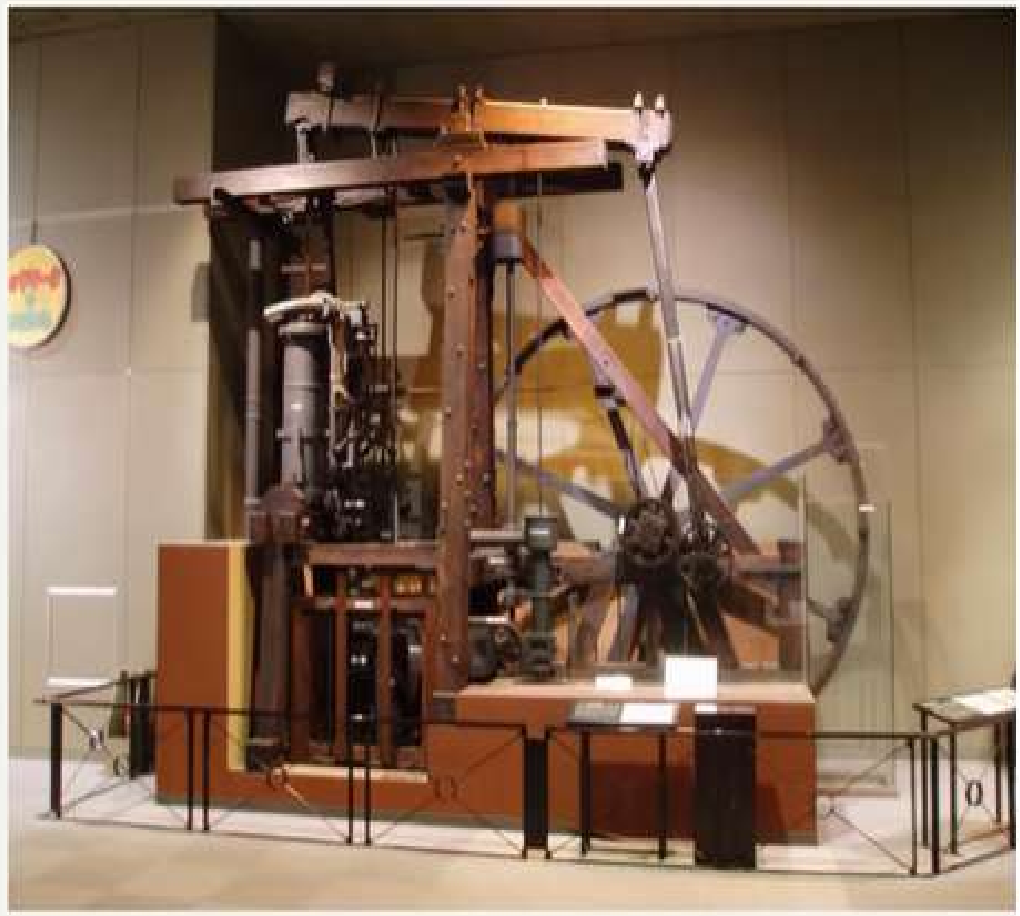
Industry Revolution

- Textile industry was the first to be affected by industry revolution.
- John key`s Flying shuttle- weaving industry
- Spinning jenny-enabling the spinning of 100 of yan together.
- The power loom



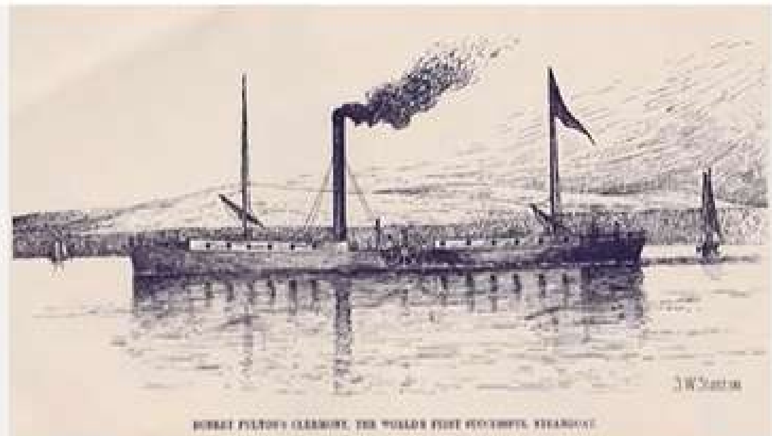
Industry Revolution

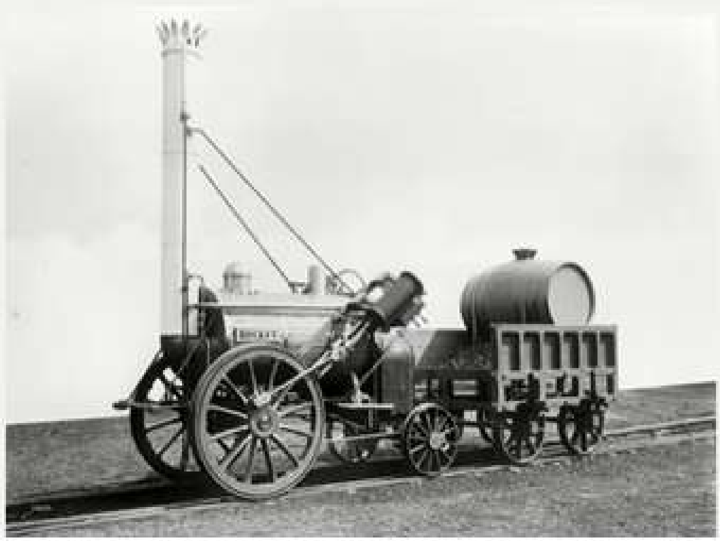
- Steam Engine – James Newcomen (1705)
- **James Watt's** Steam engine (1769) - heat energy into mechanical energy



Industry 1.0

Steam Locomotives -
Railroads
Steam boats





What is Industrial Revolution?

- It is the transition to new manufacturing processes from about 1760 to 1870. It brought some radical changes to the world.
- This transition included: going from **hand production methods to machines**, new chemical manufacturing and iron production, the increasing use of steam power, the development of machine tools and the rise of the factory system.

Transformation of Information

Transformation of Transportation

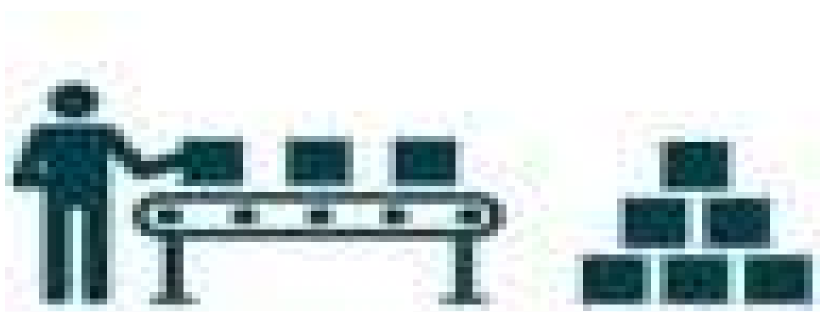
Transformation of Communication

Industry 1.0

- The industrial revolution started with the mechanization (water/steam power) of the production pipelines. Steam engines are used in production and transportation.

Industry 2.0

- The second transformation has happened once the steam power is replaced with electricity and because of electricity there was mass production.



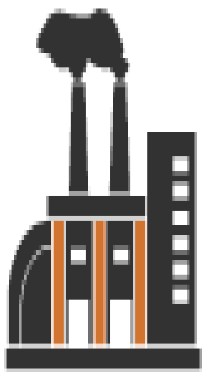
Industry3.0

- Breakthrough in transistor and electric circuits technology produced computers which triggered the third industrial revolution.

Industry4.0

Mass device connectivity pushes the fourth industrial revolution which is enhanced with smart devices and advanced artificial intelligence algorithms like machine learning.

INDUSTRIAL REVOLUTIONS

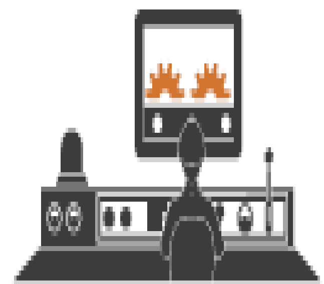


1st
1760s

Steam engine
Mechanization

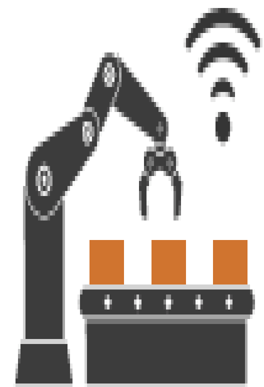
2nd
1870s

Electricity
Mass production



3rd
1960s

Computers
Automation
Internet



4th
NOW

Hyper-connectivity

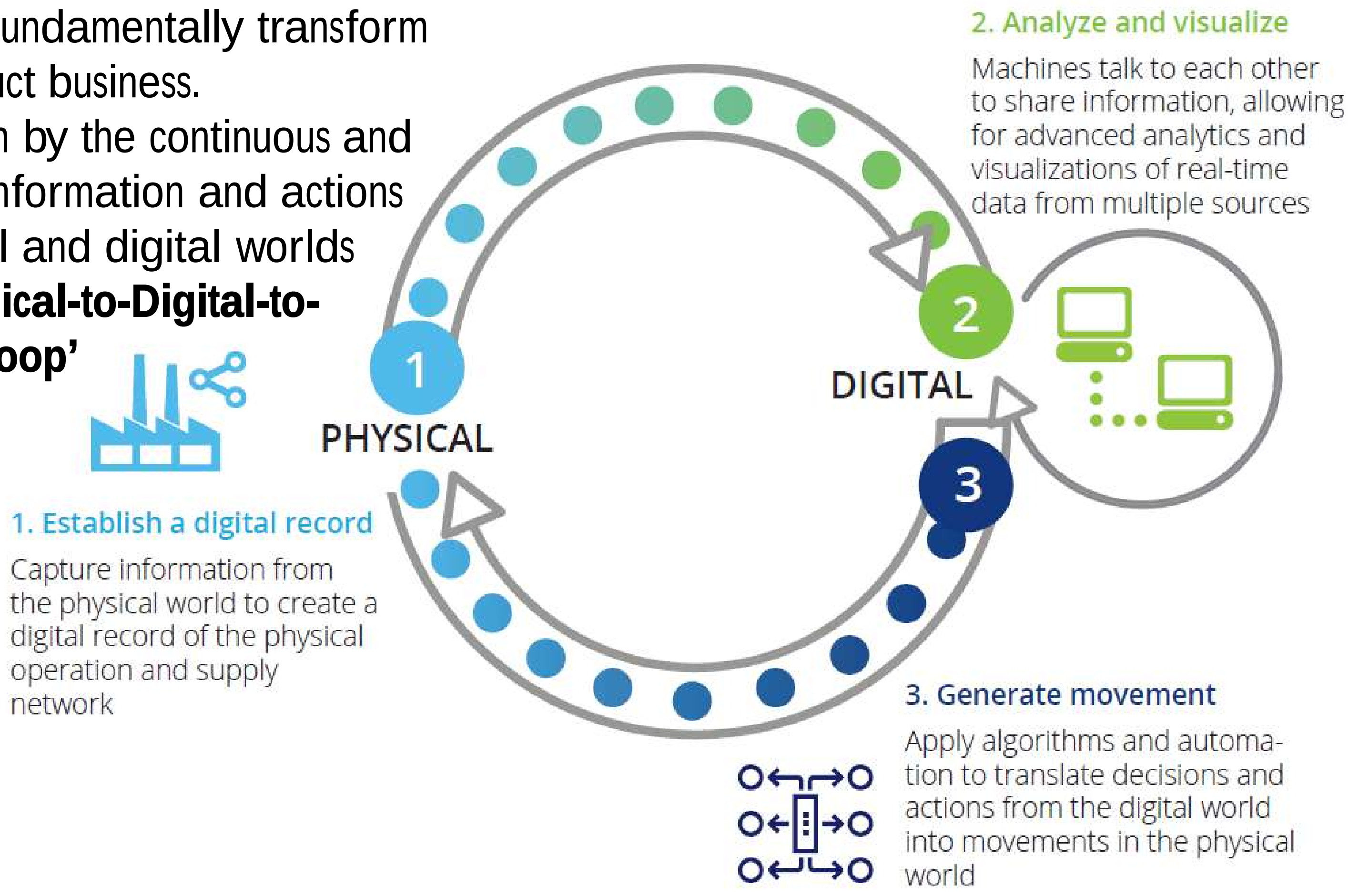
Revolutions have triggered profound changes in economic systems and social structures.

INDUSTRY REVOLUTION

- Industry 4.0 industry revolution basically started in German to push German economy.
- This term coined in Hannover university in 2011 in Germany.

Transformation and Integration of digital information

- Shifting to real-time access to data and intelligence will fundamentally transform the way to conduct business.
- This shift is driven by the continuous and cyclical flow of information and actions between physical and digital worlds called ‘**The Physical-to-Digital-to-Physical (PDP) loop’**



Source: Center for Integrated Research.

Deloitte Insights | deloitte.com/insights

History of IIoT

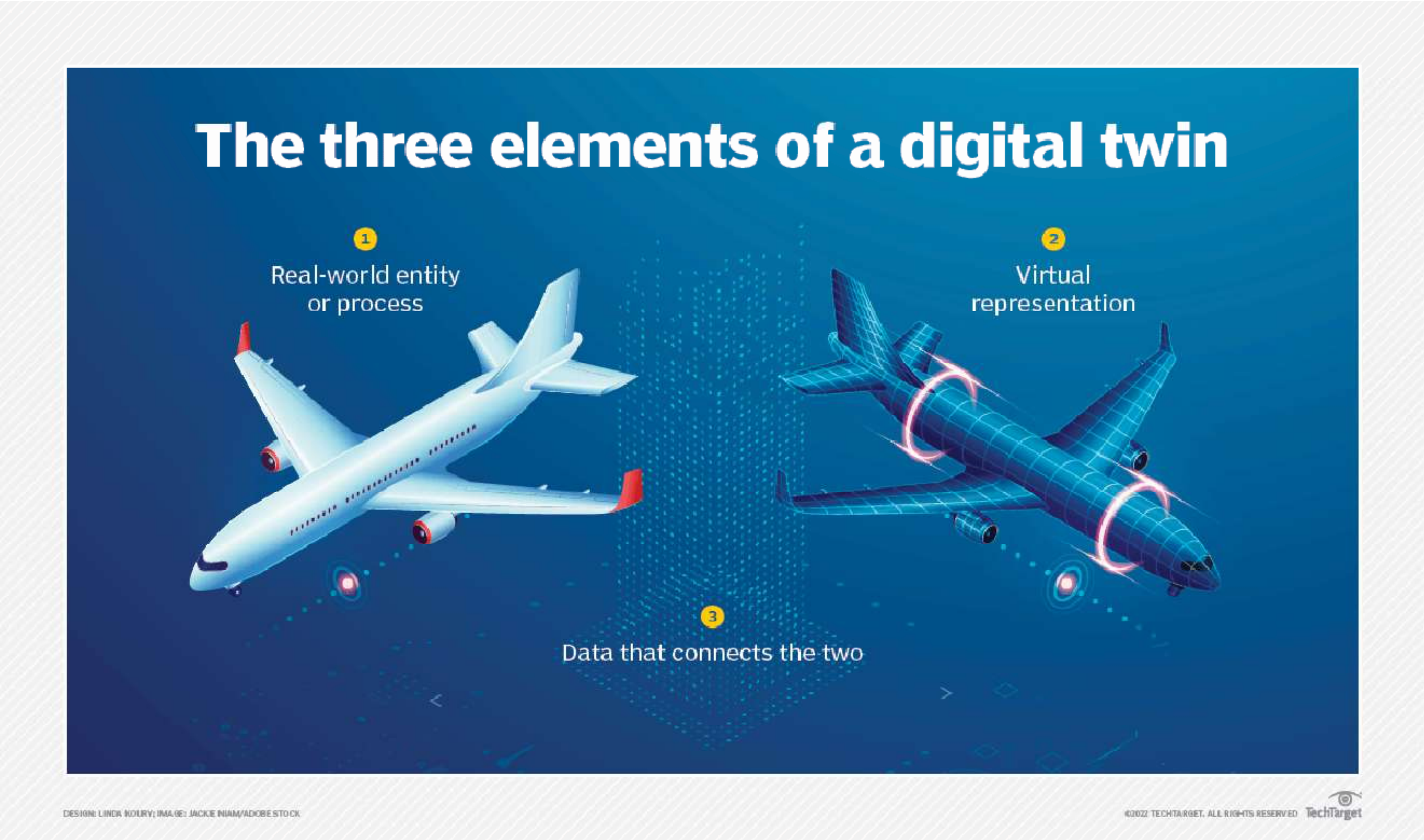
- The history of the IIoT begins with the invention of the **programmable logic controller** (PLC) by Richard E. Morley in 1968, which was used by **General Motors** in their automatic transmission manufacturing division. These PLCs allowed for fine control of individual elements in the manufacturing chain.
- In 1975, Honeywell and Yokogawa introduced the world's first DCSs, the TDC 2000 and the CENTUM system, respectively. These DCSs were the next step in allowing flexible process control throughout a plant, with the added benefit of backup redundancies by distributing control across the entire system, eliminating a singular point of failure in a central control room.

How IIoT connects to Digital Twin?

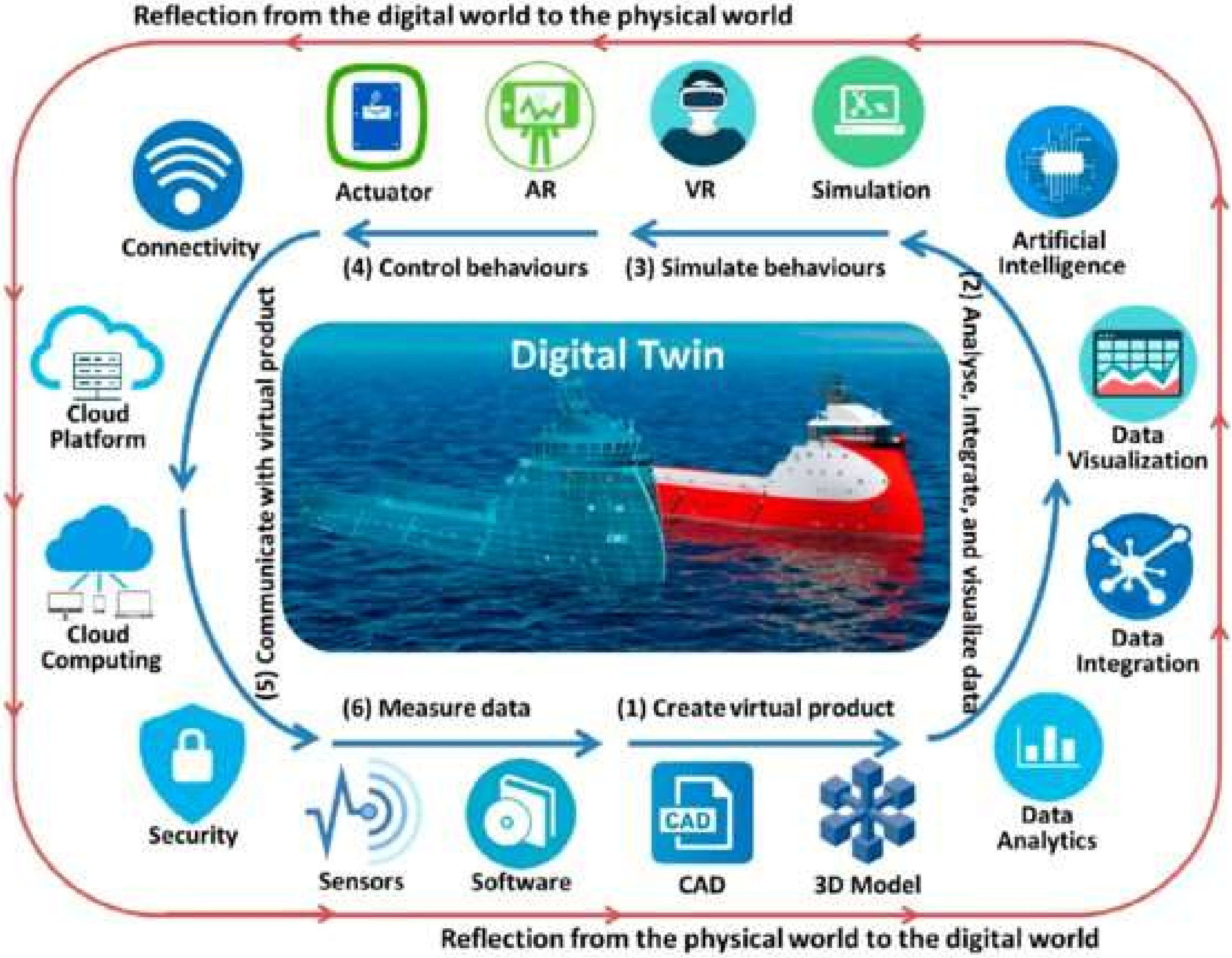
- Another benefit of implementing an IIoT system is the ability to create a **digital twin** of the system. Using this digital twin allows for further optimization of the system by allowing for experimentation with new data from the cloud without having to halt production or sacrifice safety, as the new processes can be refined virtually until they are ready to be implemented.
- A **digital twin** can also serve as a training ground for new employees who won't have to worry about real impacts on the live system.

Digital Twin

A digital twin is a virtual model of a physical object, system, or process. It's a digital counterpart that can be used for simulation, testing, monitoring, and maintenance.



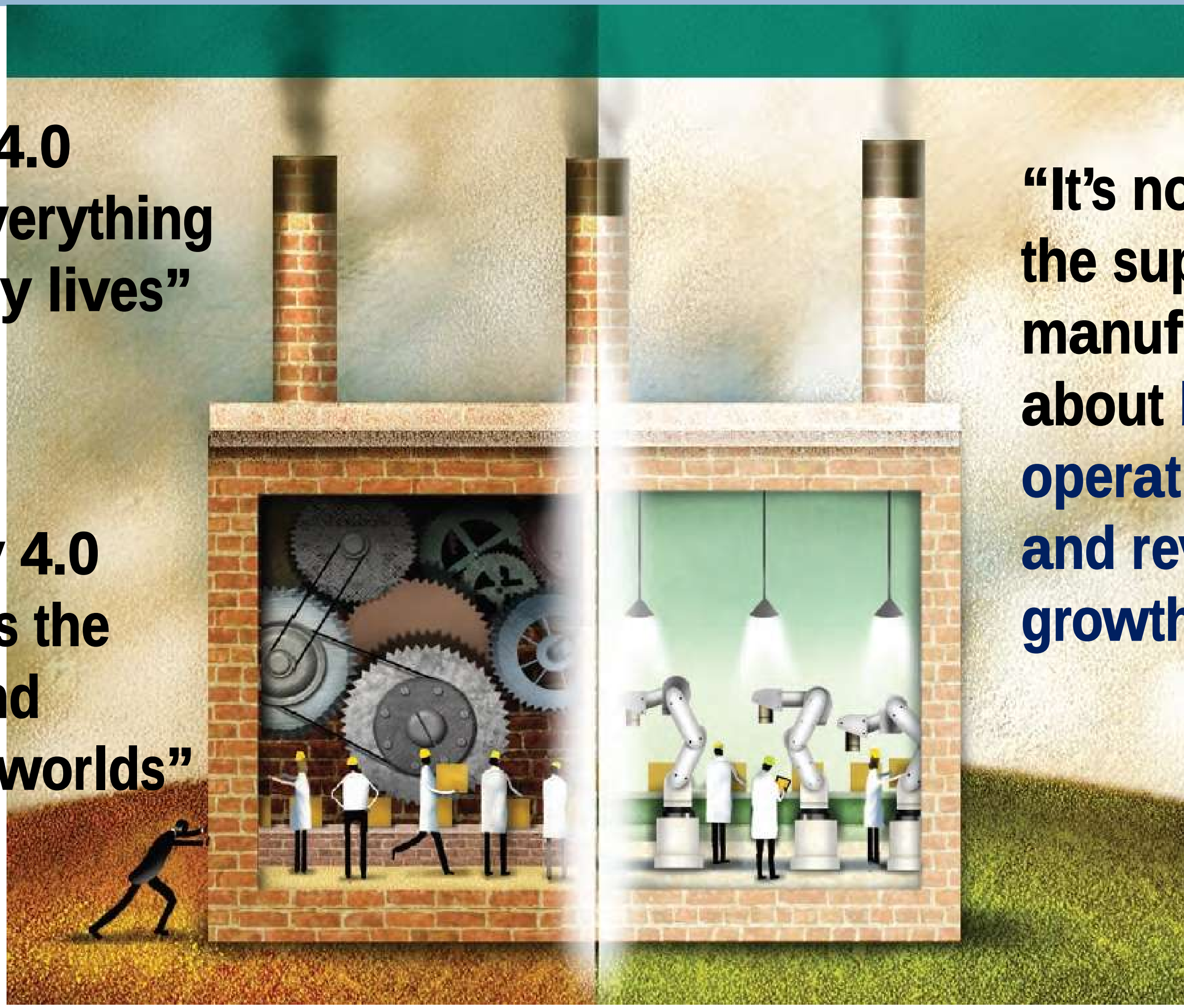
Enabling technology of Digital Twin



Why does Industry 4.0 matter?

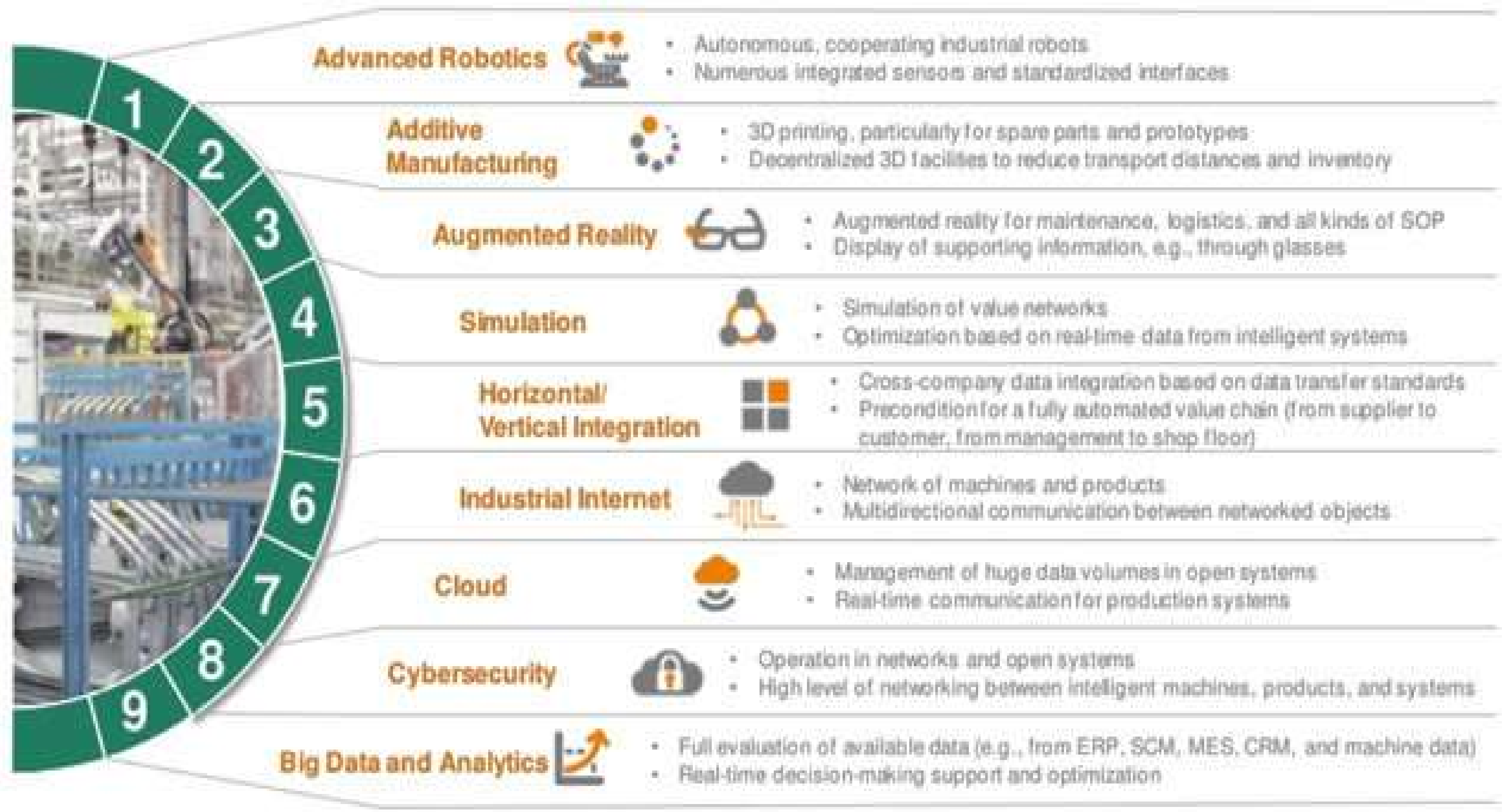
"Industry 4.0 touches everything in our daily lives"

"Industry 4.0 integrates the digital and physical worlds"



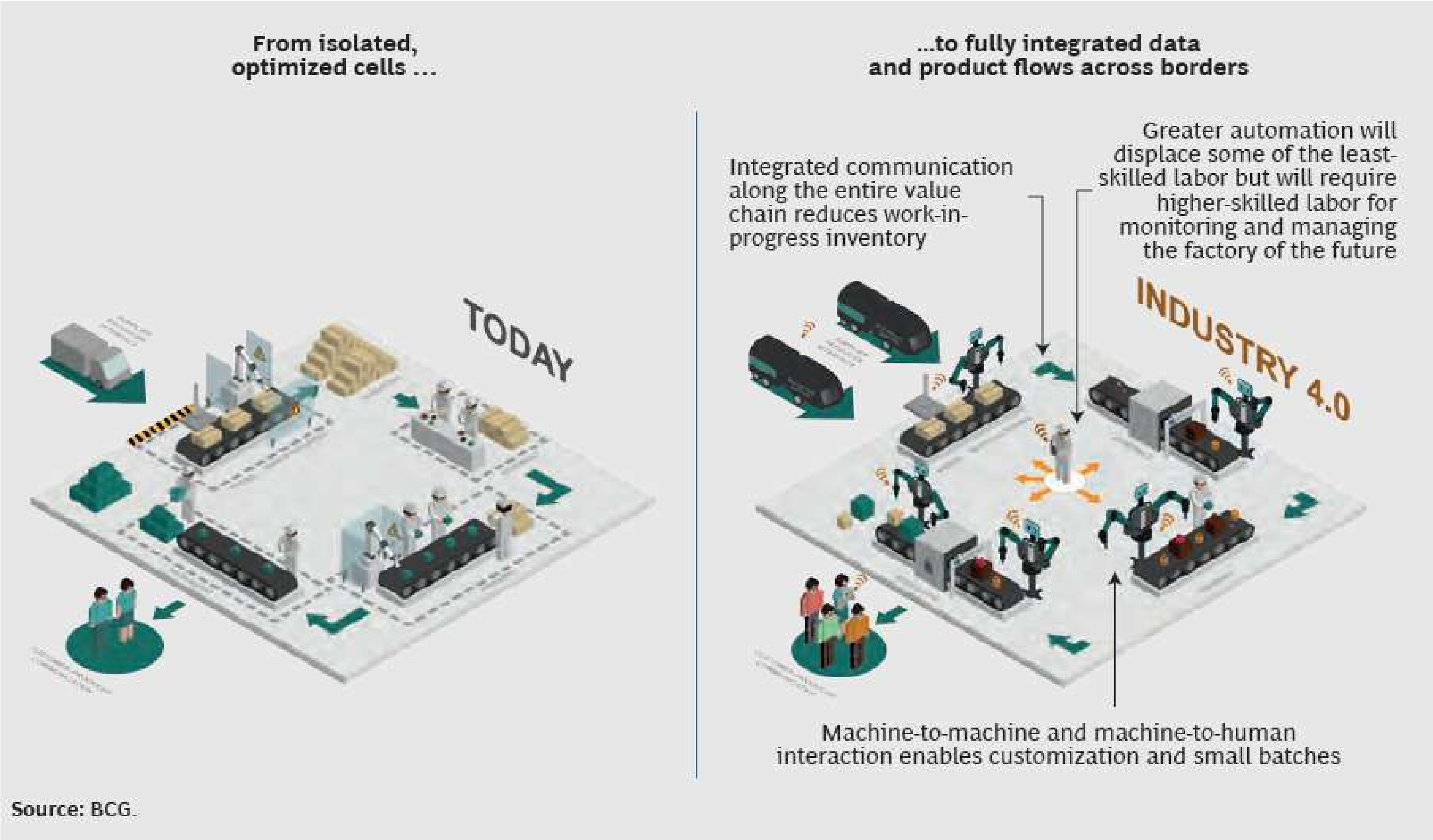
"It's not just about the supply chain or manufacturing–it's about business operations and revenue growth"

The Nine Pillars of Technological Advancement of Industry 4.0



Changing Traditional Manufacturing to Smart Factory

- With industry 4.0, the nine pillars of technological advancement will transform production from isolated, optimized cells to a fully integrated, automated and optimized production flow, leading to great efficiencies and changing traditional production relationships among suppliers, producers and customer – as well as between human and machine



Difference between IOT &IIOT

- IoT devices are commonly used by the hobbyist or another consumer usage.
- IIoT is designed for heavy-duty tasks such as manufacturing, monitoring, etc.
- IIoT uses more precise and durable (heat/cold resistant) devices, actuators, sensors, etc.
- Both IoT and IIoT have the same core principles such as sensors, data management, network, security, cloud, etc.
- IIoT requires data streaming, big data, machine learning or artificial intelligence practices.

Cont…Difference between IOT &IIOT

- The main differences between IoT and IIoT are scalability and the volume of generated data and how data has been handled. Since IIoT devices generate massive amount of data.
- In a home network, loss of the generated data would be trivial but in IIoT it is vital.
- The data in IIoT should be more precise, continuous and sensitive.
- For instance, considering a monitoring system in a nuclear power plant or a manufacturing facility should be precise, continuous and sensitive to prevent hazardous events.

Architecture of IIOT

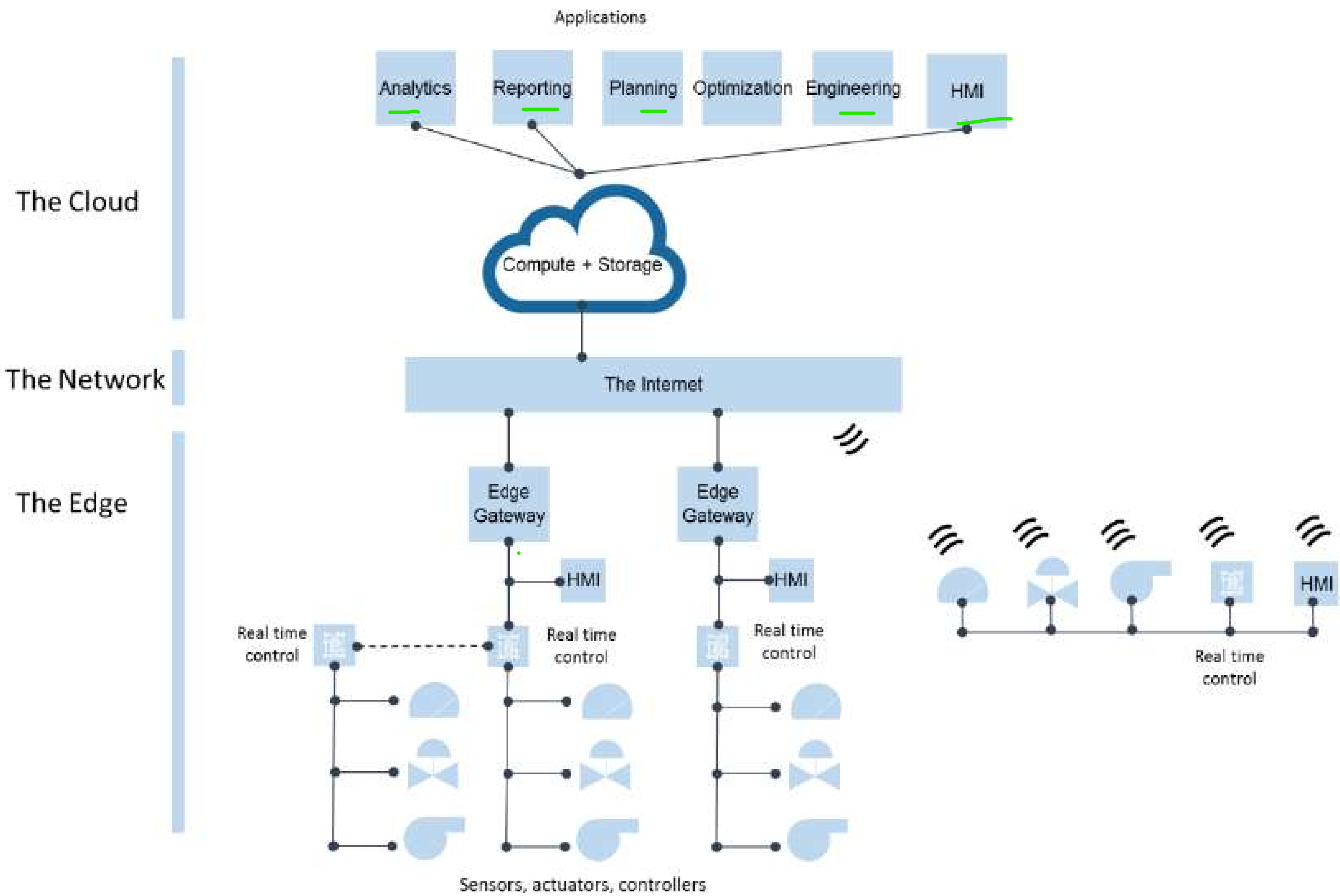
Layered Modular Architecture In IIoT	
Content layer	User interface devices (e.g. computer screens, PoS stations, tablets, smart glasses, smart surfaces)
Service layer	Applications, software to analyze data and transform it into actionable information
Network layer	Communications protocols, Wi-Fi, Bluetooth, Lora, cellular
Device layer	Hardware: CPS, machines, sensors

Overview

- The IIoT is enabled by technologies such as cyber security, cloud computing, edge computing, mobile technologies, machine-to-machine, 3D printing, advanced robotics, big data, internet of things, RFID technology, and cognitive computing.
- Five of the most important ones are given below:

1. Cyber-physical systems (CPS)
2. Cloud computing
3. Edge computing
4. Big data analytics
5. AI and machine learning

Visualization of IIoT concept



IIoT applications and examples

- The term industrial internet of things is often encountered in the manufacturing industries, referring to the industrial subset of the IoT. Potential benefits of the industrial internet of things include improved productivity, analytics and the transformation of the workplace.
- While connectivity and data acquisition are imperative for IIoT, they are not the end goals, but rather the foundation and path to something bigger. Of all the technologies, predictive maintenance is an "easier" application, as it is applicable to existing assets and management systems.
- Integration of sensing and actuation systems connected to the Internet can optimize energy consumption as a whole.
- Using advanced metering infrastructure (AMI) devices connected to the Internet backbone, electric utilities can not only collect data from end-user connections, but also manage other distribution automation devices like transformers and reclosers.

Industrial IoT application areas

- **Smart manufacturing:** Businesses gather data from customer feedback, media trends, and the global market. AI-powered systems can amalgamate this and other relevant data to inform product development and quality control. Based on such insights, an IIoT network of machines and robotic devices can be automated to optimize product manufacturing in smart factories.
- **Resilient supply chains:** IIoT networks let supply chain managers know things like where their products are, which suppliers have them, and how many are in stock.
- **Intelligent logistics:** Real-time data from IoT sensors can also help to amalgamate loads, minimise waste, and speed up deliveries.
- **Healthcare:** For medical practitioners, the data delivered by these devices can give a more complete picture of patient health.
- **Agriculture:**
- **Smart building management:**
- **Sustainable utilities and energy management:** Monitoring usage pattern

Concept of Smart factory

- In a real-world IIoT deployment of smart robotics, ABB, a power and robotics firm, uses connected sensors to monitor the maintenance needs of its robots to prompt repairs before parts break. Likewise, commercial jetliner maker Airbus has launched what it calls the factory of the future, a digital manufacturing initiative to streamline operations and boost production. Airbus has integrated sensors into machines and tools on the shop floor and outfitted employees with wearable tech -- e.g., industrial smart glasses -- aimed at cutting down on errors and enhancing workplace safety

IIoT and 5G

- 5G is the emerging standard for mobile networks. It has been specifically designed to deliver fast data throughput speeds with low latency. 5G will support download speeds of up to 20 Gbps (gigabits per second) with sub-millisecond latency.
- The emergence of 5G will likely affect the use of IIoT devices in two main ways. First, 5G's high throughput and low latency will make it possible for devices to share data in real time. Previously, this was only possible when the devices were located on private networks with highspeed connectivity. This real-time connectivity will support use cases such as driverless cars and smart cities.
- The other way 5G will affect IIoT adoption is that it will likely result in device proliferation. Industrial operations might use thousands of 5G connected devices. 5G's high speed and low latency also means we'll likely see IIoT devices used in remote sites whose lack of high-speed connectivity previously made IIoT use impractical.

Future of IIoT

- The future of IIoT is tightly coupled with a trend known as Industry 4.0. Industry 4.0 is, essentially, the fourth Industrial Revolution.
- Industry 1.0 was the first Industrial Revolution and occurred in the late 1700s as companies began to use water-powered or steam-powered machines in manufacturing.
- Industry 2.0 started at the beginning of the 20th century and was brought about by the introduction of electricity and assembly lines.
- Industry 3.0 occurred in the latter part of the 20th century and was tied to the use of computers in the manufacturing process.

IIoT vendors

There are several vendors with IIoT platforms, including:

- **ABB Ability**. An IIoT company specializing in connectivity, software and machine intelligence. Aveva Wonderware. A company that develops human-machine interface (HMI) and IoT edge platforms for OEMs (original equipment manufacturers) and end users.
- **Axzon**. An IIoT company focusing on smart automotive manufacturing, predictive maintenance and cold chain.
- **Cisco IoT**. A networking company offering platforms for network connectivity, connectivity management, data control and exchange, and edge computing.
- **Fanuc Field System**. A company that has developed a platform for connecting various generations, makes and models of industrial IoT equipment.
- **Linx Global Manufacturing**. A product development and manufacturing company offering custom IIoT, application and data management platforms.
- **MindSphere by Siemens**. An industrial IoT solution based around artificial intelligence (AI) and advanced analytics.
- **Plataine**. An IIoT company specializing in using AI to generate actionable insights in manufacturing.
- **Predix by GE**. A platform for connecting, optimizing and scaling digital industrial applications.

Risks and challenges of IIoT

- **Security:** As manufacturing processes are becoming smarter (with the use of SCADA Systems), the production processes are becoming more technology-driven, in terms of wireless M2M technologies. Most of the connected machines share information directly to the cloud and hence get exposed to security threats and attacks. In other words, any ‘thing’ or “device” or “asset” that is controlled by the network, or the internet is vulnerable to attacks and hacks.
- **Interoperability:** As per IoT Nexus survey, 77% of IoT professionals saw interoperability as the biggest challenge in the Industrial Internet. The manufacturing environment is flooded with machines and protocols that are yet to be interconnected and most often not interoperable. So, connecting the legacy industrial systems and ensuring interoperability between them is a challenge.

Concluding remarks

- Although IoT and IIoT have many technologies in common, including cloud platforms, sensors, connectivity, machine-to-machine communications and data analytics, they are used for different purposes.
- IoT applications connect devices across multiple verticals, including agriculture, healthcare, enterprise, consumer and utilities, as well as government and cities. IoT devices include smart appliances, fitness bands and other applications that generally don't create emergency situations if something goes amiss.
- IIoT applications, on the other hand, connect machines and devices in such industries as oil and gas, utilities and manufacturing. System failures and downtime in IIoT deployments can result in high-risk situations, or even life-threatening ones.
- IIoT applications are also more concerned with improving efficiency and improving health or safety, versus the user-centric nature of IoT applications.

IIOT SENSORS – THE FOUNDATION OF DIGITAL INDUSTRY

Industrial IoT (IIoT) refers to the implementation in industrial settings of IoT technology, especially concerning the instrumentation and control of sensors and devices involved in cloud technologies.

What are IIoT sensors?

- IIoT sensors are industrial sensors with **integrated sensor and computing functions** that are **connected to larger systems** via wireless communications technology.
- They are a key part of the industrial internet of things (IIoT), the industrial extension within the internet of things (IoT): In this emerging paradigm, the connected nature of the internet extends to the physical world, where individual objects receive their IP address, technology, and wireless connectivity.
- The increasing availability of compact, high-quality, affordable sensors is a major driver for IIoT.
- This **synergy between the digital and physical worlds is particularly important for industrial applications**, where sensors have traditionally operated in isolation and required local monitoring.

Attributes of IIoT Sensors

- IIoT sensors deliver the **automated measurement of the condition and state of industrial equipment and devices**. Their wireless connection to centralized systems enables **round-the-clock monitoring**, analysis, and control of process elements such as liquids and gases, vibration and temperature, device position, and flow.
- **Wireless IIoT sensors** transmit asset data and alerts wirelessly to platforms such as Control Systems or Edge that provide global management of all company technical systems such as CMMS (computerized maintenance management system) as well as to the Cloud. This data contributes to the pool of all company data, which then undergoes cutting-edge analysis and visualization for optimum decision-making.

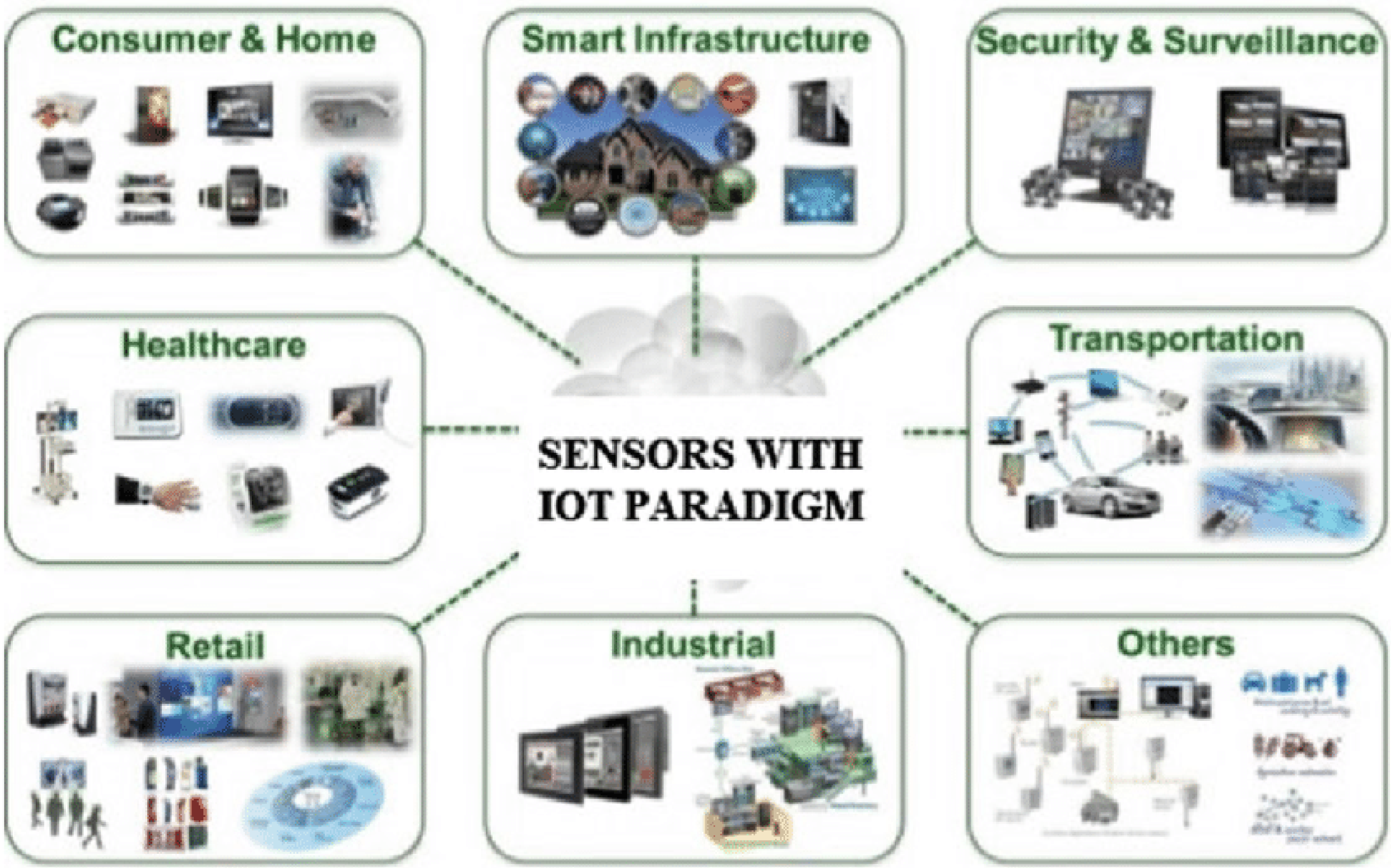
What are the benefits of IIoT sensors?

- IoT sensors have significantly contributed to the **increase of quality, efficiency, and profitability and reduction of downtime**. In contrast to monitoring rounds by human staff which are costly, intermittent, and vary by operator skill, IIoT sensors provide 24/7, real-time information at consistently high quality.
- The integration of IIoT sensors into intelligent digital systems expands not only the organization's data insights but also the reach of its control of physical processes. Additionally, IIoT sensors enable much safer and better access to hard-to-reach or hazardous locations.
- IIoT sensors provide a foundation for connectivity and interoperability in an Industry 4.0 context. As a source of big data, they also greatly enable any industrial enterprise to become more data-driven.
- This makes IIoT sensors indispensable for **data availability, knowledge growth, trend analysis, and improving company models and products**. Combined with artificial intelligence and machine learning, IIoT sensor data serves as the basis for predictive maintenance.

What are the most important types of IIoT sensors?

- The field of IIoT sensors is very broad, though there are a few key types that are relevant for most industrial applications.
- The most important function of IIoT sensors is covering process- and safety-critical components. Because vibration often signals potential problems, for example, **vibration sensors** are one of the most critical types of IIoT sensors.
- **Pressure sensors** help avoid damage, and **temperature sensors** monitor potentially dangerous assets and prevent product spoilage. Ensuring that plant assets are operating correctly – both individually and together – requires physical data from wireless **positioning and proximity sensors**.

Sensors-IoT



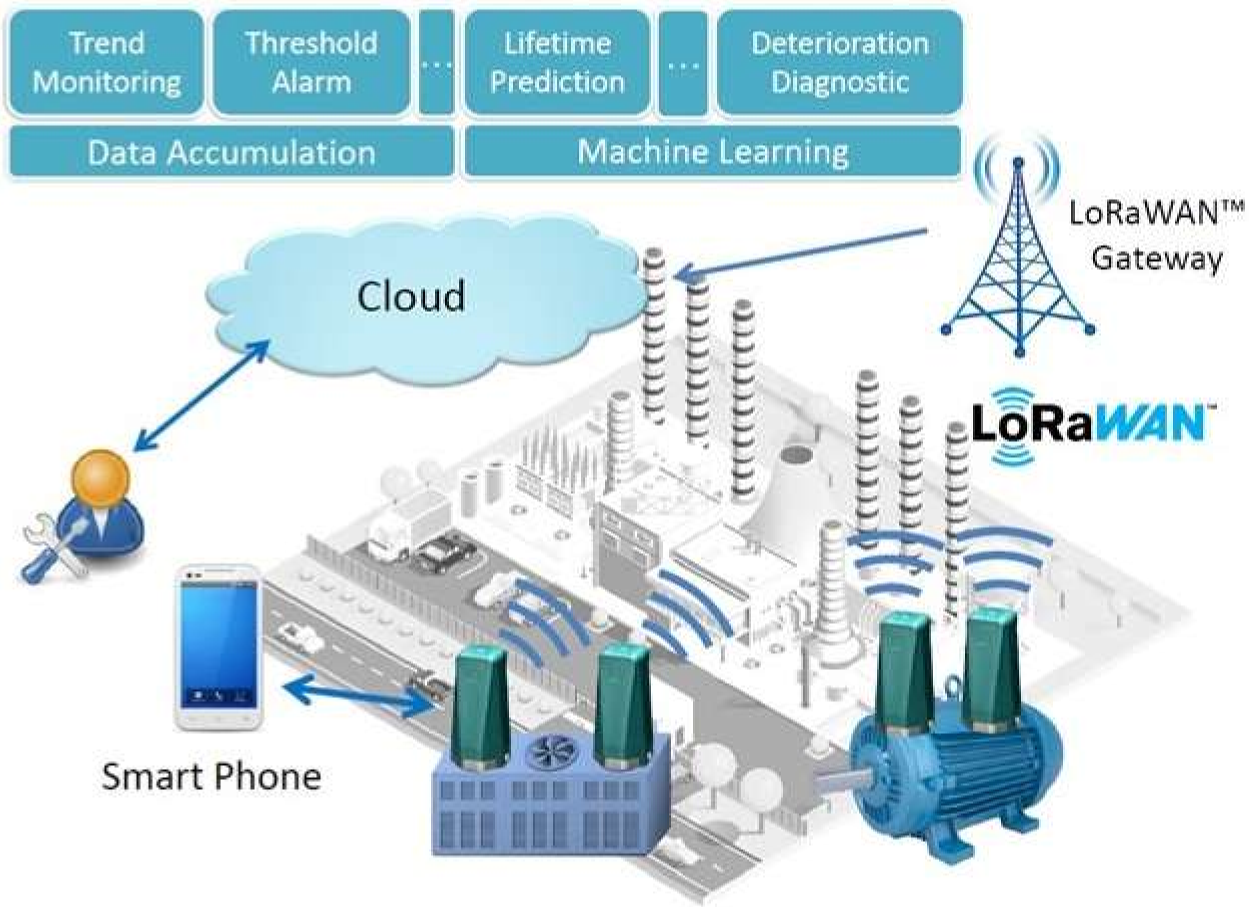
Consumer & Home
Smart Infrastructure
Security & Surveillance
Healthcare
SENSORS WITH IOT PARADIGM
Transportation
Retail
Industrial
Others

What are examples of other smart sensors?

- IIoT sensors are part of a broad family of smart sensors that can add value to industrial organizations. Sensors for managing materials are an example of that. Paired with digital infrastructure and fire safety systems, **smoke and gas sensors** enable automated safety measures and help evacuate human staff. Real-time data from **flow sensors** and **level sensors** ensure efficient process control for liquids.
- For dangerous or off-limits areas, **security sensors** identify security breaches and **infrared sensors** detect the presence of humans or animals. **Optical sensors** are not only important for computer vision, but they can detect any kind of light or electromagnetic radiation. **Image sensors** help integrate drones and robotics into IIoT systems and visualize spaces invisible to the human eye.

Example

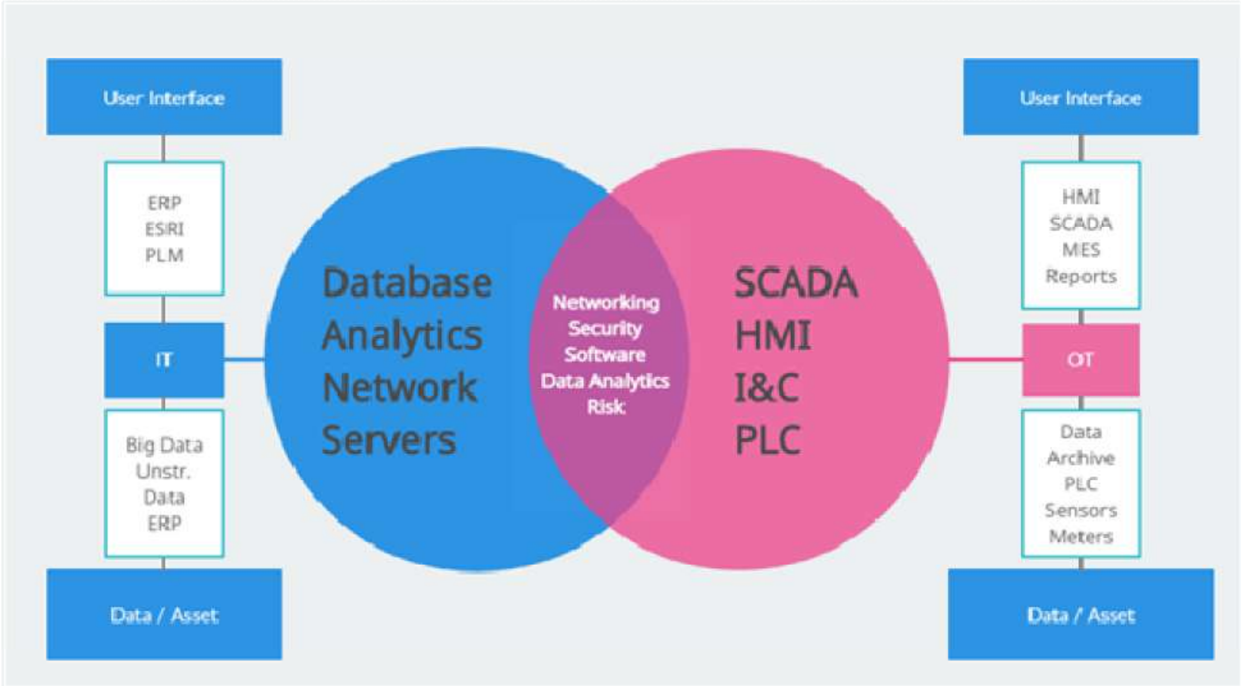

Vibration/Temperature
integrated type
Sushi Sensor®
(LoRaWAN™ compliant)


Trend Monitoring
Threshold Alarm
...
Lifetime Prediction
...
Deterioration Diagnostic
Data Accumulation
Machine Learning
Cloud
LoRaWAN™ Gateway
LoRaWAN
Smart Phone

IIoT continues to grow

- The emergence of IIoT sensors has brought IoT to industrial applications. New organizational approaches have also expanded the strategic landscape: Plant asset management combines the operational and economic significance of equipment data, enabling the efficient, systematic management of industrial systems in harmony with business goals.

IoT has yet to become the norm – and IIoT is still in its infancy. The fundamentals – sensor and automation technology, analytics enhanced by AI and machine learning, IT/OT convergence, and agile, holistic models – can be seen today.

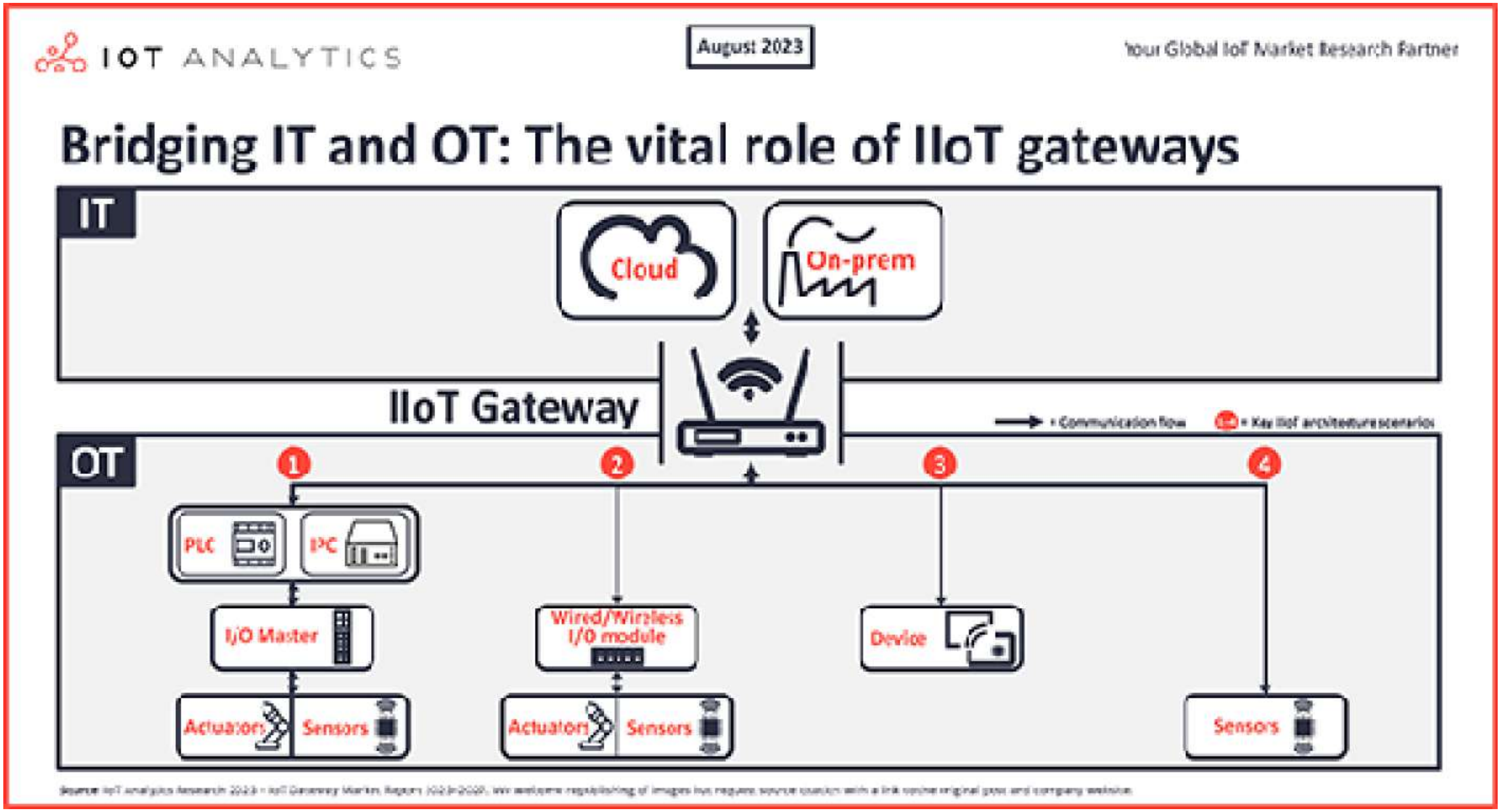


IIoT Actuators

- Remotely control and automate the operation of your pumps, drives, motors, valves, pressure sensitive equipment and other critical and non-critical equipment with IIOT Actuators. These devices relay across key data points and metrics to our cloud based IIOT dashboards which provide valuable information and calls to action when required.

Gateway Devices

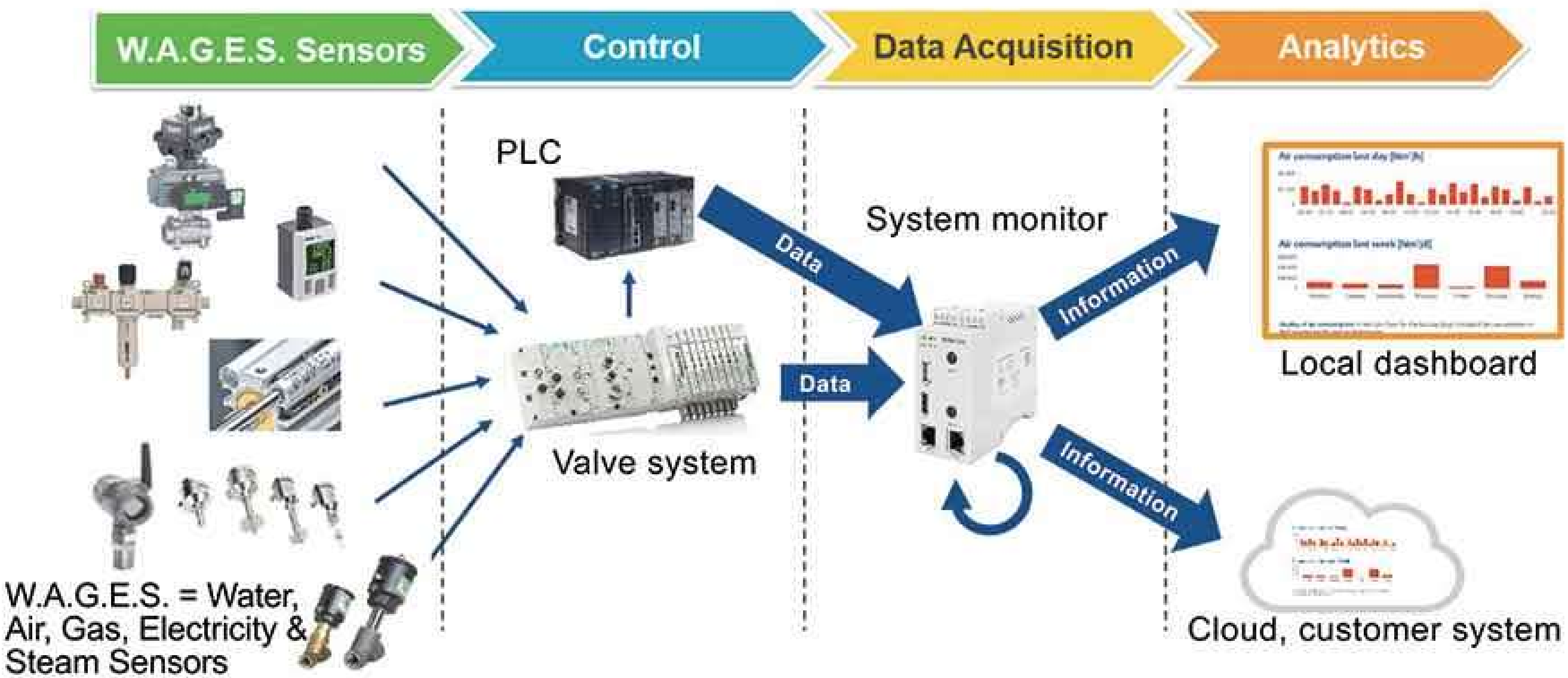
- **Gateway devices are essential to ensure connectivity between IOT sensors and instrumentation with your local servers** or POMO Robotics Cloud based solutions. With flexible connectivity options, IIOT Devices can enable you to bring your factory into the Industry 4.0 space today!



Connectivity Solutions

- 5G Connectivity solutions and machine connectivity solutions can transfer across your machinery intelligence all in one user friendly dashboard. The remote connectivity solutions helps to access data from anywhere in world securely and safely.

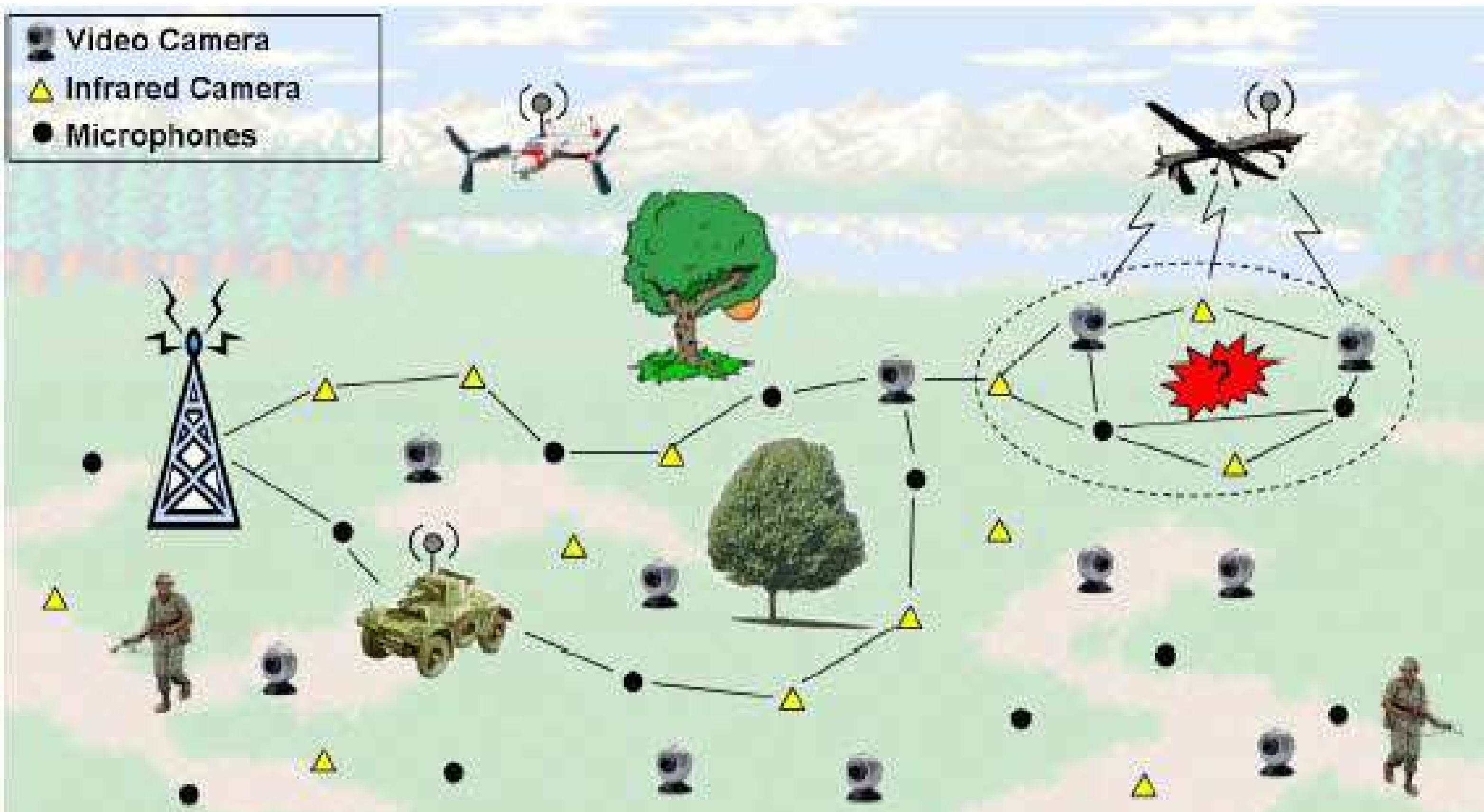
Example



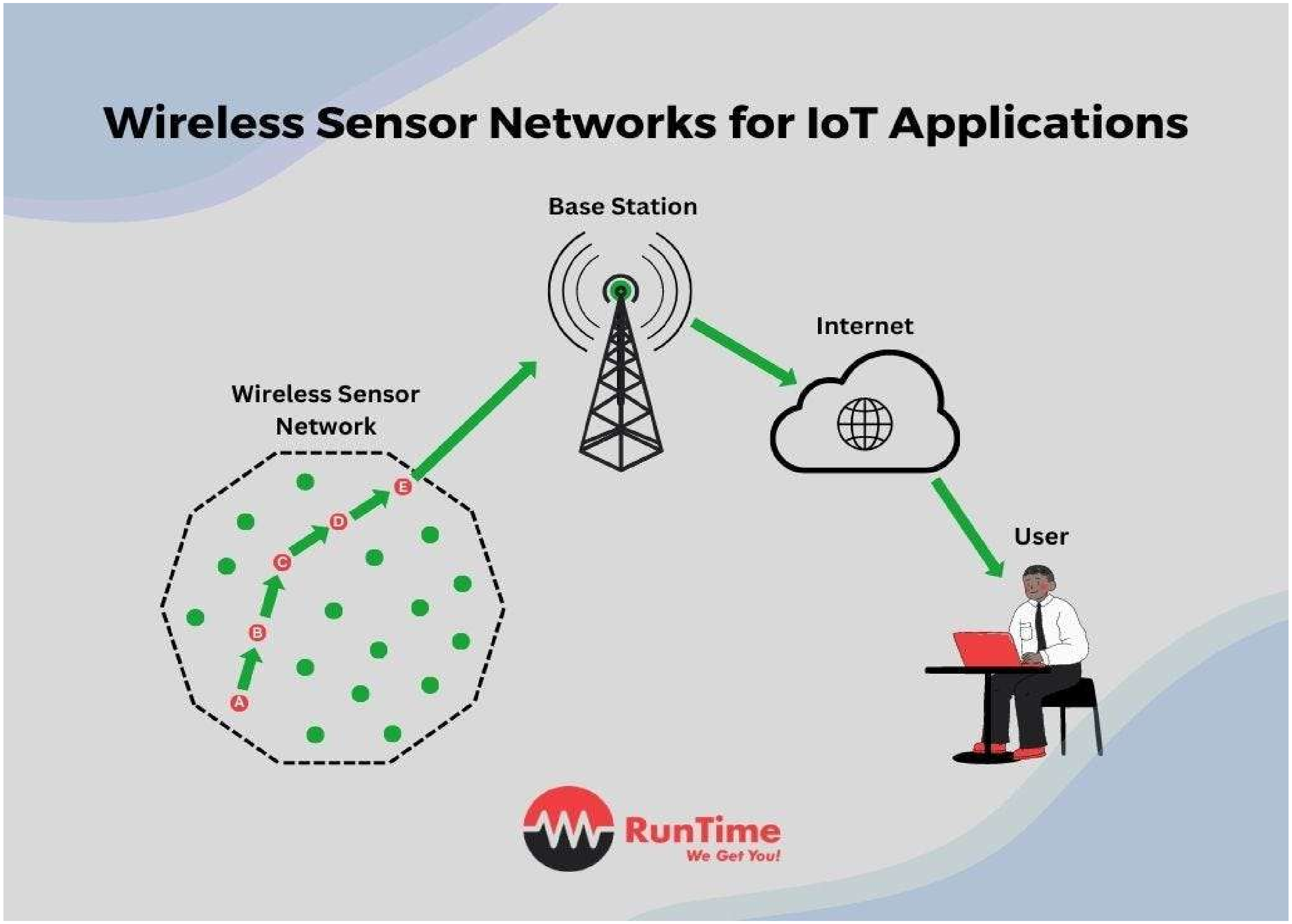
IIoT gateways with edge computing capabilities are simple, intuitive, reliable and easy to use.

Wireless sensor network(WSN)

A Wireless sensor network can be defined as a network of devices that can communicate the information gathered from a monitored field through wireless links. The data is forwarded through multiple nodes, and with a gateway, the data is connected to other networks like wireless Ethernet.

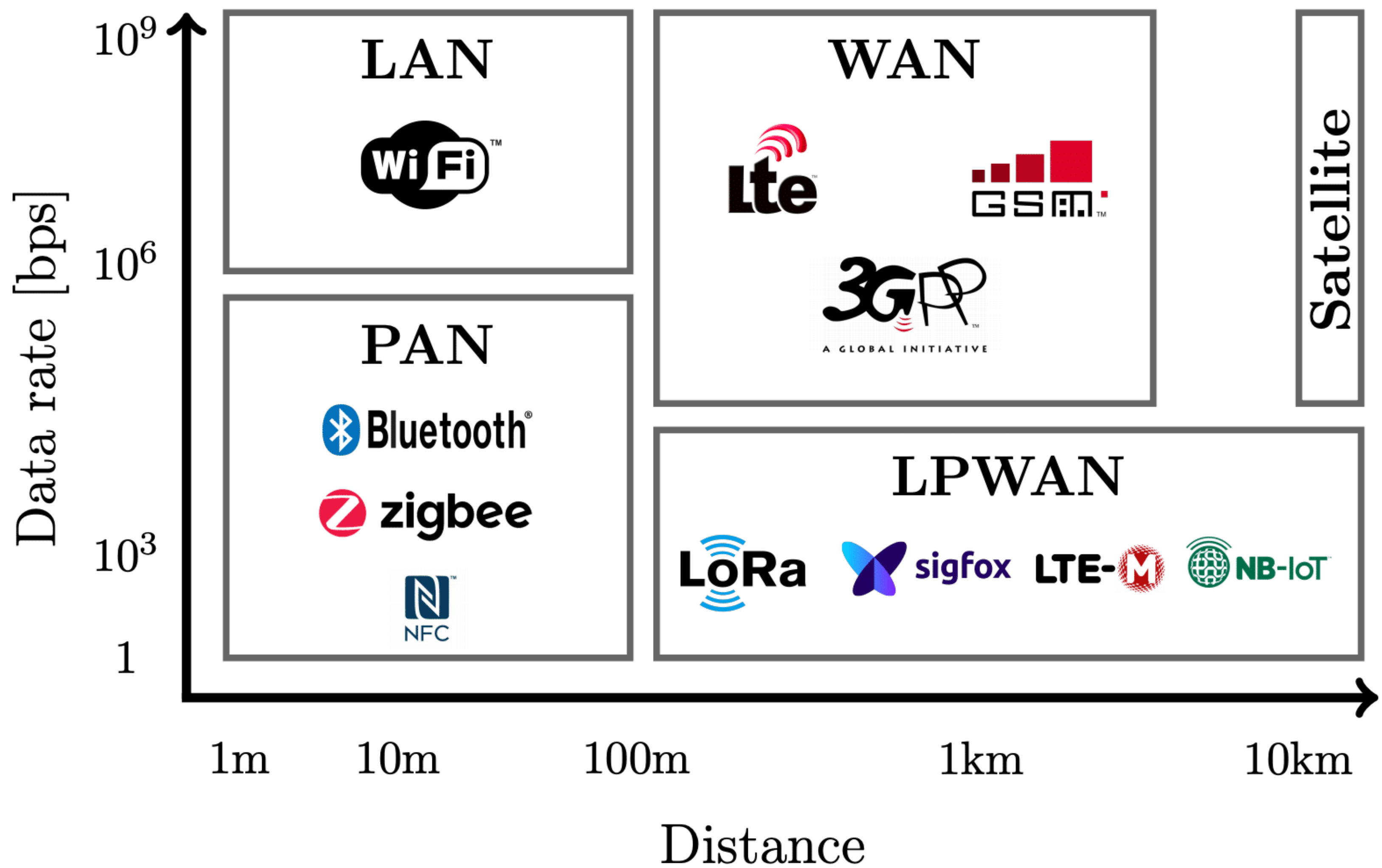


WSN in IoT



Wireless Sensor Networks for IoT Applications
Base Station
Internet
Wireless Sensor Network
A
B
C
D
E
User
RunTime
We Get You!

Communication Protocol



Bluetooth 4.0: Low Energy

The wireless data exchange standard Bluetooth uses a variety of protocols. Core protocols are defined by the trade organization Bluetooth SIG. Additional protocols have been adopted from other standards bodies.

Short range wireless application areas

	Voice	Data	Audio	Video	State
Bluetooth ACL/HS	x	Y	Y	x	x
Bluetooth SCO/eSCO	Y	x	x	x	x
Bluetooth low energy	x	x	x	x	Y
Wi-Fi	(VoIP)	Y	Y	Y	x
Wi-Fi Direct	Y	Y	Y	x	x
ZigBee	x	x	x	x	Y
ANT	x	x	x	x	Y

State = low bandwidth, low latency data

Low Power

How much energy does traditional Bluetooth use?

- Traditional Bluetooth is *connection oriented.* When a device is connected, a link is maintained, even if there is no data flowing.
- Sniff modes allow devices to sleep, reducing power consumption to give months of battery life
- Peak transmit current is typically around 25mA
- Even though it has been independently shown to be lower power than other radio standards, it is still not low enough power for coin cells and energy harvesting applications

What is Bluetooth Low Energy?

- Bluetooth low energy is a NEW, open, short range radio technology
  - Blank sheet of paper design
  - Different to Bluetooth classic (BR/EDR)
  - Optimized for ultra low power
  - Enable coin cell battery use cases
    - < 20mA peak current
    - < 5 uA average current

Basic Concepts of Bluetooth 4.0

- Everything is optimized for lowest power consumption
  - Short packets reduce TX peak current
  - Short packets reduce RX time
  - Less RF channels to improve discovery and connection time
  - Simple state machine
  - Single protocol
  - Etc.

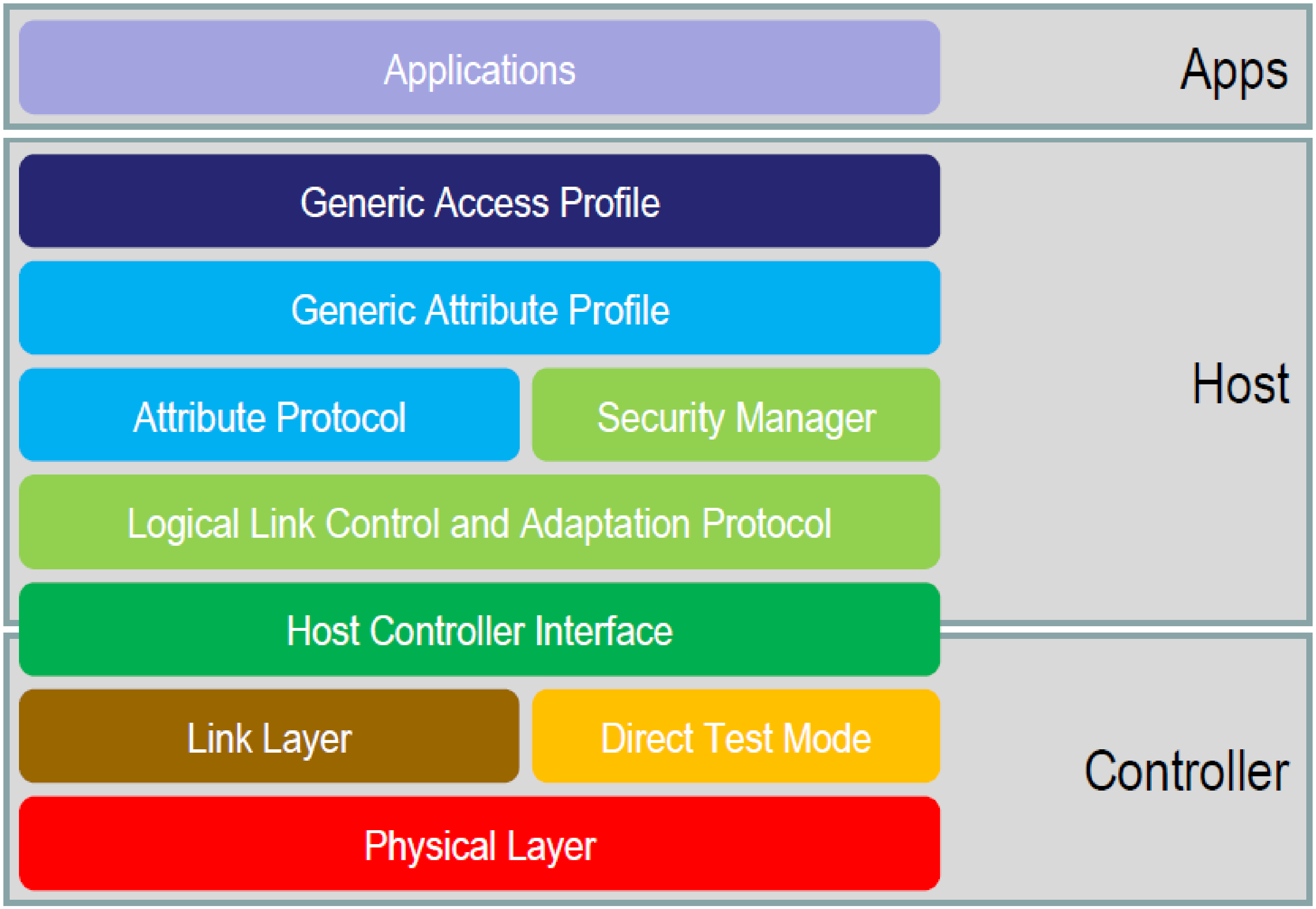
Bluetooth low energy factsheet

Range:	~ 150 meters open field
Output Power:	~ 10 mW (10dBm)
Max Current:	~ 15 mA
Latency:	3 ms
Topology:	Star
Connections:	> 2 billion
Modulation:	GFSK @ 2.4 GHz
Robustness:	Adaptive Frequency Hopping, 24 bit CRC
Security:	128bit AES CCM
Sleep current:	~ 1µA
Modes:	Broadcast, Connection, Event Data Models, Reads, Writes

Bluetooth low energy factsheet #2

- Data Throughput
  - For Bluetooth low energy, data throughput is not a meaningful parameter. It does not support streaming.
  - It has a data rate of 1Mbps, but is not optimized for file transfer.
  - It is designed for sending small chunks of data (exposing state)

Bluetooth Low Energy Architecture



Device Modes

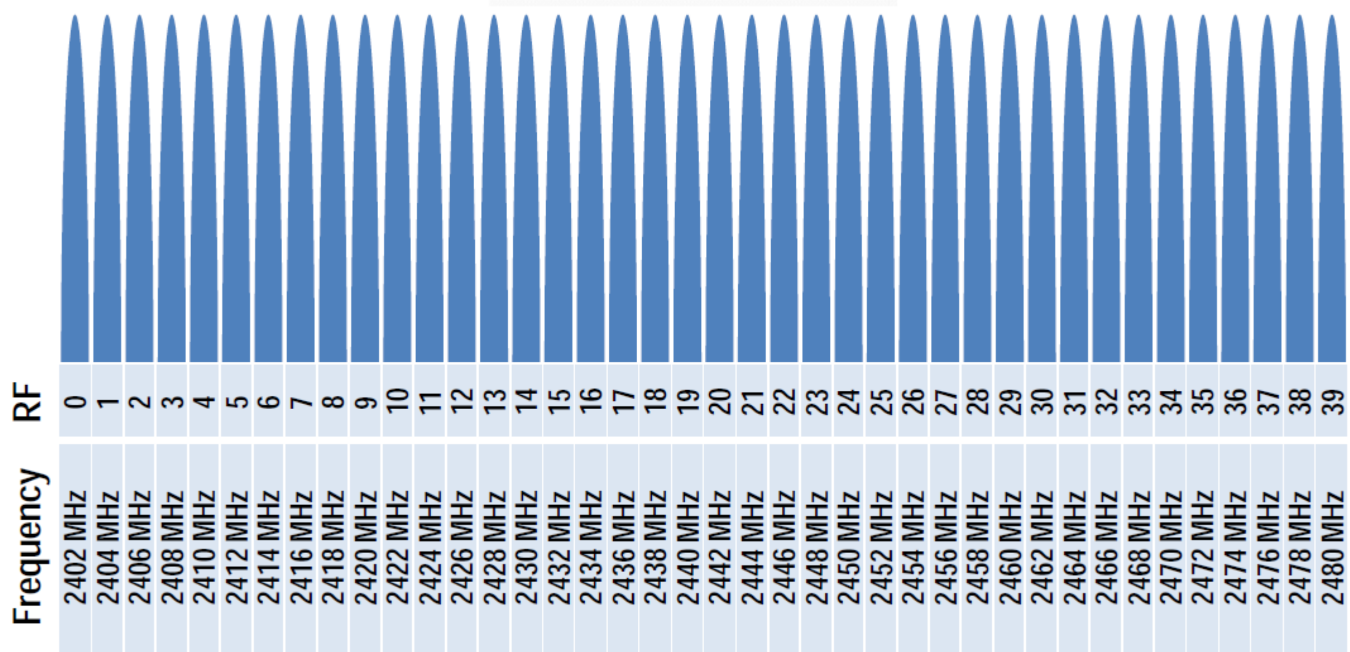
- Dual Mode
  - Bluetooth BR/EDR and LE
  - Used anywhere that BR/EDR is used today
  - Device to device

- Single Mode
  - Implements only Bluetooth low energy
  - Will be used in new devices / applications
  - Head phone(master to slave)

Physical Layer

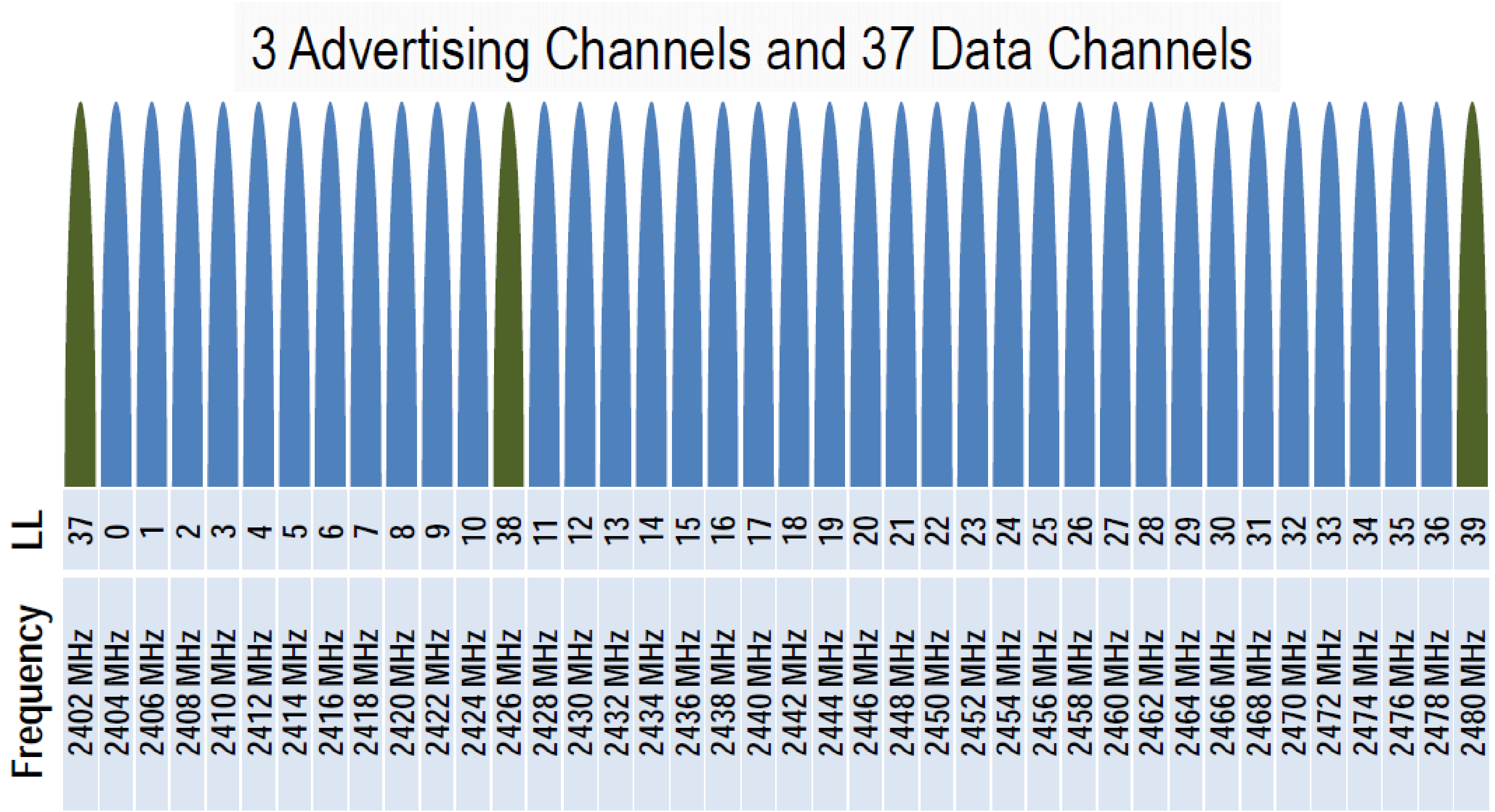
- 2.4 GHz ISM band
- 1Mbps GFSK
  - Larger modulation index than Bluetooth BR (which means better range)
- 40 Channels on 2 MHz spacing

$$f = 2402 + 2 \cdot k \text{ MHz}$$



Physical Channels

- Two types of channels



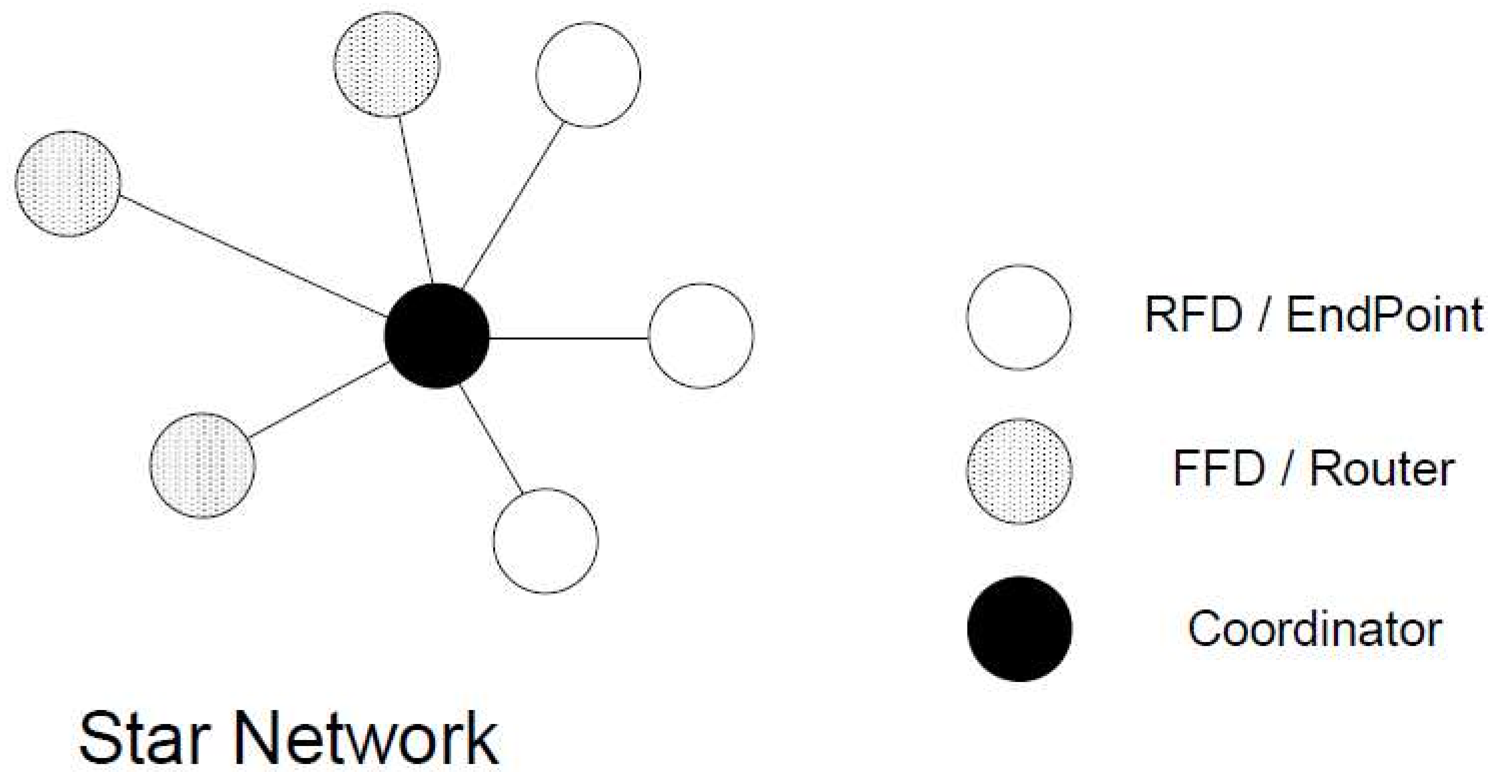
How low can the energy get?

- From the previous slide, calculate energy per transaction
  - Assume an upper bound of 3ms per minimal transaction
  - Estimated TX power is 15mW (mostly TX power amp for 65nm chips)
  - For 1.5v battery, this is 10mA. 0.015W * 0.003 sec = 45 micro Joule
- How long could a sensor last on a battery?
  - An example battery: Lenmar WC357, 1.55v, 180mAh, $2-5
  - 180mAh/10mA = 18Hr = 64,800 seconds = 21.6M transactions
  - Suppose this sensor sends a report every minute = 1440/day
  - For just the BT LE transactions, this is 15,000 days, or > 40 years
  - This far exceeds the life of the battery and/or the product
- This means that battery will cost more than the electronics
  - This sensor could run on scavenged power, e.g. ambient light

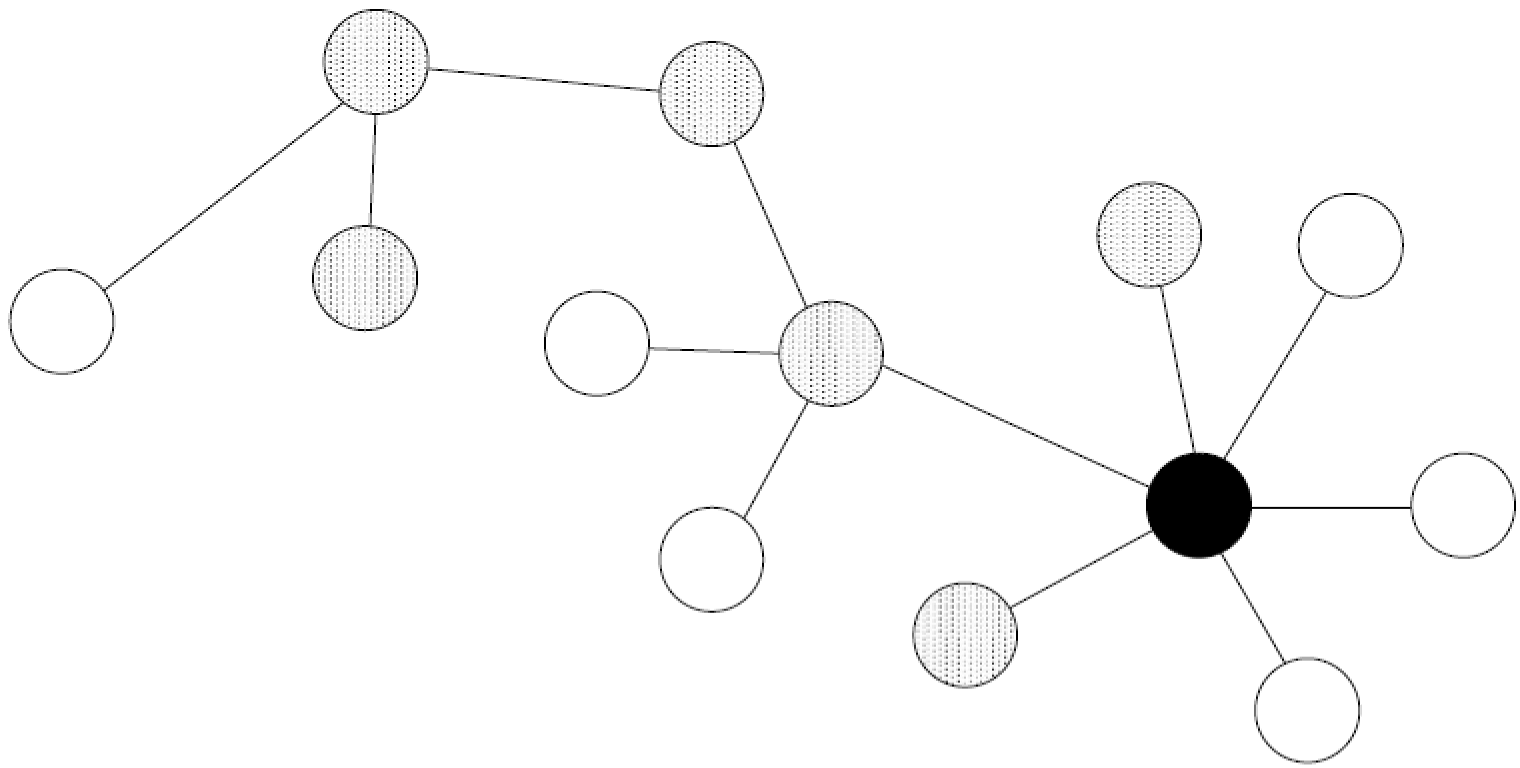
Competitive perspective

Technology	Classic *Bluetooth* technology (BR/EDR)[1]	*Bluetooth* low energy technology[2]	ZigBee
Radio Frequency	2.4 GHz	2.4 GHz	2.4 GHz
Distance / Range	10 to 100 meters[3]	10 to 100 meters[3]	10 to 200 meters[4]
Over the air Data Rate	1-3Mbps	1Mbps	250kbps at 2.4 GHz.
Application Throughput	0.7-2.1 Mbps	0.2 Mbps	<0.1 Mbps
Nodes/Active Slaves	7 / 16777184[5]	Unlimited[6]	65535[7]
Security	64b/128b and applications layer user defined	128b AES and application layer user defined	128b AES and application layer user defined
Robustness	Adaptive fast frequency hopping, FEC, fast ACK	Adaptive fast frequency hopping	DSSS, Uses only 16 ch. in ISM band, optional mesh topology has long recovery time
Latency (from a non connected state)			
Total time to send data (det.battery life)[8]	100ms	<3ms	<10ms
Government Regulation	Worldwide	Worldwide	Worldwide
Certification Body	Bluetooth SIG	Bluetooth SIG	ZigBee Alliance
Voice capable	Yes	No	No
Network topology	Scatternet	Star-bus	Star or Mesh
Power Consumption	1 as the reference	0.01 to 0.5(depending on use-case)	2 (router) / 0.1 (end point)
Peak current consumption (max 15 mA to run on coin cell battery)	<30 mA	<15 mA	<15 mA
Service discovery	Yes	Yes	No
Profile concept	Yes	Yes	Yes
Primary Use Cases	Mobile phones, gaming, headsets, stereo audio streaming, automotive, PCs, consumer electronics, etc.	Mobile phones, gaming, PCs, watches, sports & fitness, healthcare, automotive, consumer electronics, automation, industrial, etc.	Fixed location industrial, building & home automation, AMI/SmartEnergy

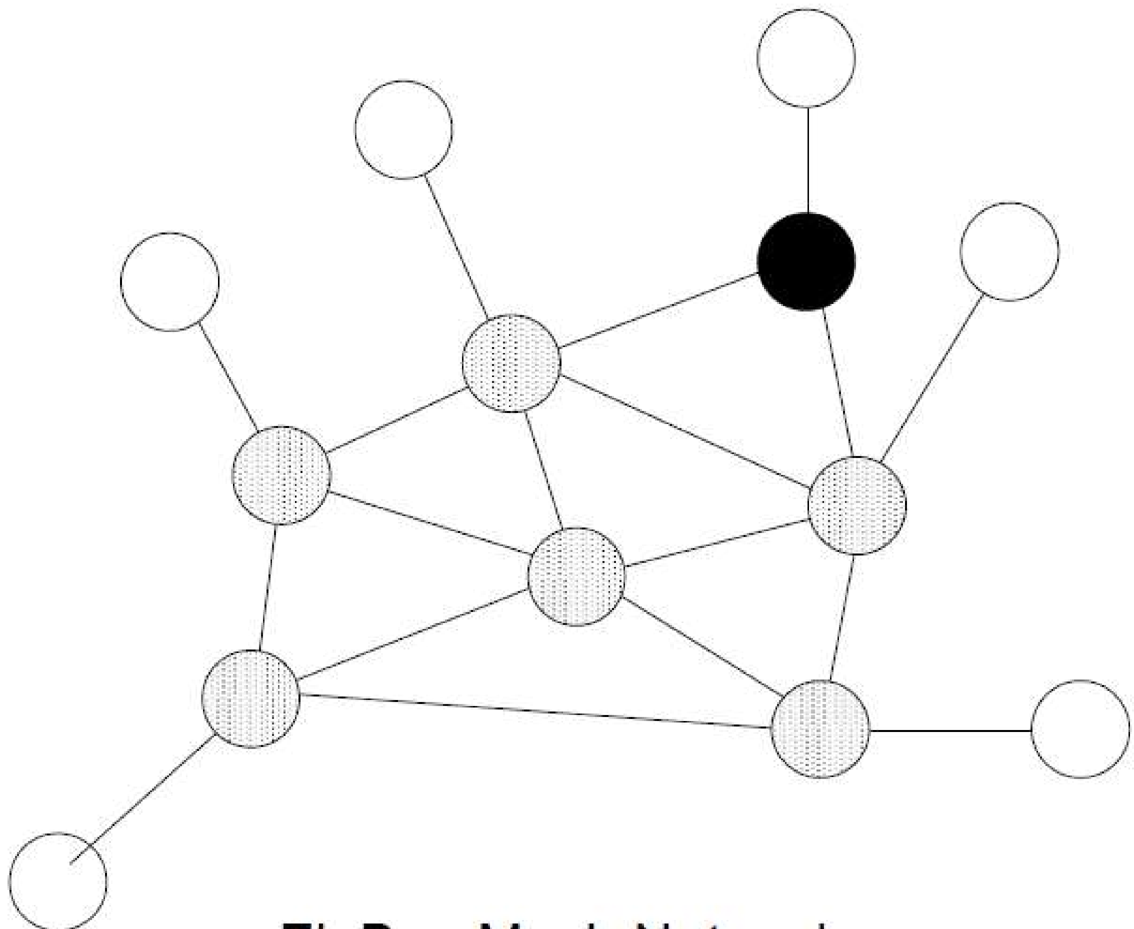
Basic topology of 802.15.4



ZigBee: Cluster tree network

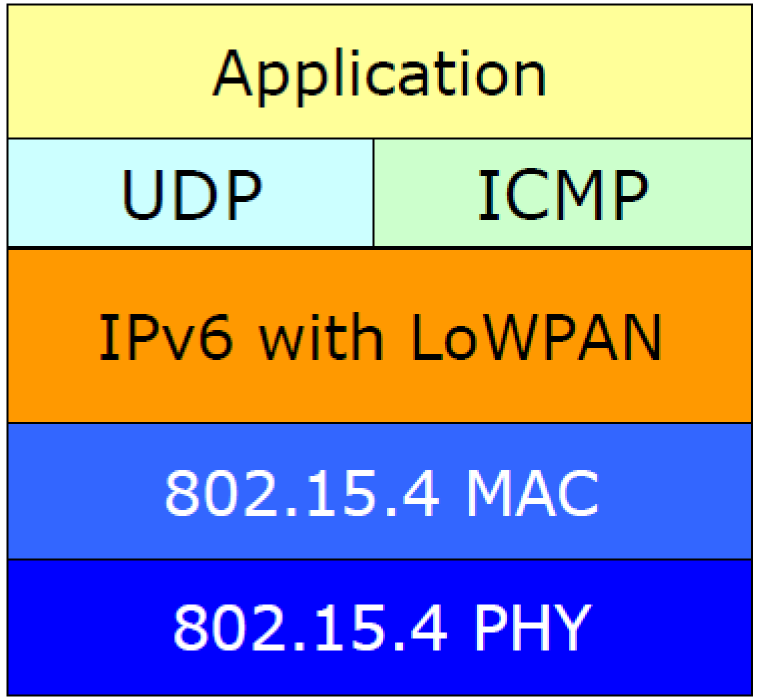


ZigBee PRO: mesh



ZigBee Mesh Network

Future ZigBee: 6LoWPAN



- An initiative to “squeeze” IPv6 addressing into reasonably sized wireless packets
- Being adopted for ZigBee’s Smart Energy Profile 2.0

ZigBee and Bluetooth Low Energy

- Business comparison:
  - ZigBee is older. It has gone through some iterations
  - ZigBee has market mindshare, but not a lot of shipments yet.
  - Market barriers: connectivity – ZigBee is not in PCs or mobile phones yet.
- Technical comparison:
  - Zigbee is low power; Bluetooth LE is even lower. Detailed analysis depends on specific applications and design detail, no to mention chip geometry.
  - ZigBee stack is light; the Bluetooth LE/GATT stack is even simpler
- Going forward:
  - ZigBee has a lead on developing applications and presence
  - Bluetooth low energy has improved technology, and a commanding presence in several existing markets: mobile phones, automobiles, consumer electronics, PC industry
  - Replacing “classic Bluetooth ” with “dual mode” devices will bootstrap this market quickly

What are the USE CASES planned for BT 4.0?

- Proximity
- Time
- Emergency
- Network availability
- Personal User Interface
- Simple remote control
- Browse over Bluetooth
- Temperature Sensor
- Humidity Sensor
- HVAC
- Generic I/O (automation)
- Battery status
- Heart rate monitor
- Physical activity monitor
- Blood glucose monitor
- Cycling sensors
- Pulse Oximeter
- Body thermometer

Example use: proximity

- It can enable proximity detection
  - – I'm in the car
  - – I'm in the office
  - – I'm in the meeting room
  - – I'm in the movie theater

- It can enable presence detection
  - – Turn the lights on when I walk around the house
  - – Automatically locks the door when I leave home
  - – Turn the alarm off if I'm already awake

Everyday objects can become sensors

My pulse is …

My blood glucose is …

My temperature is …

… and monitor things unobtrusively

M2M Communications in IIoT

March, 2024

M2M system

- Each machine in embeds a smart device
- Device senses the data or status of the machine
- Performs the computation and communication functions
- A device communicates via wired or wireless systems
- Protocols: 6LowPAN, LWM2M, MQTT, XMPP
- Each device assigned 48-bits Ipv6 addresses.

Machine-to-Machine (M2M) to IoT

- Technology closely relates to IoT which use smart devices to collect data that is transmitted via the Internet to other devices.
- Close differences lies in M2M uses for device to device communication also for coordinated monitoring and control purposes.

M2M Application Areas

- Connected Cars for Safety and Infotainment
- Remote Monitoring
- ATMs/Point of Sales Terminal Connected for centralized Security
- Remote Monitoring, Trucks Fleet Management

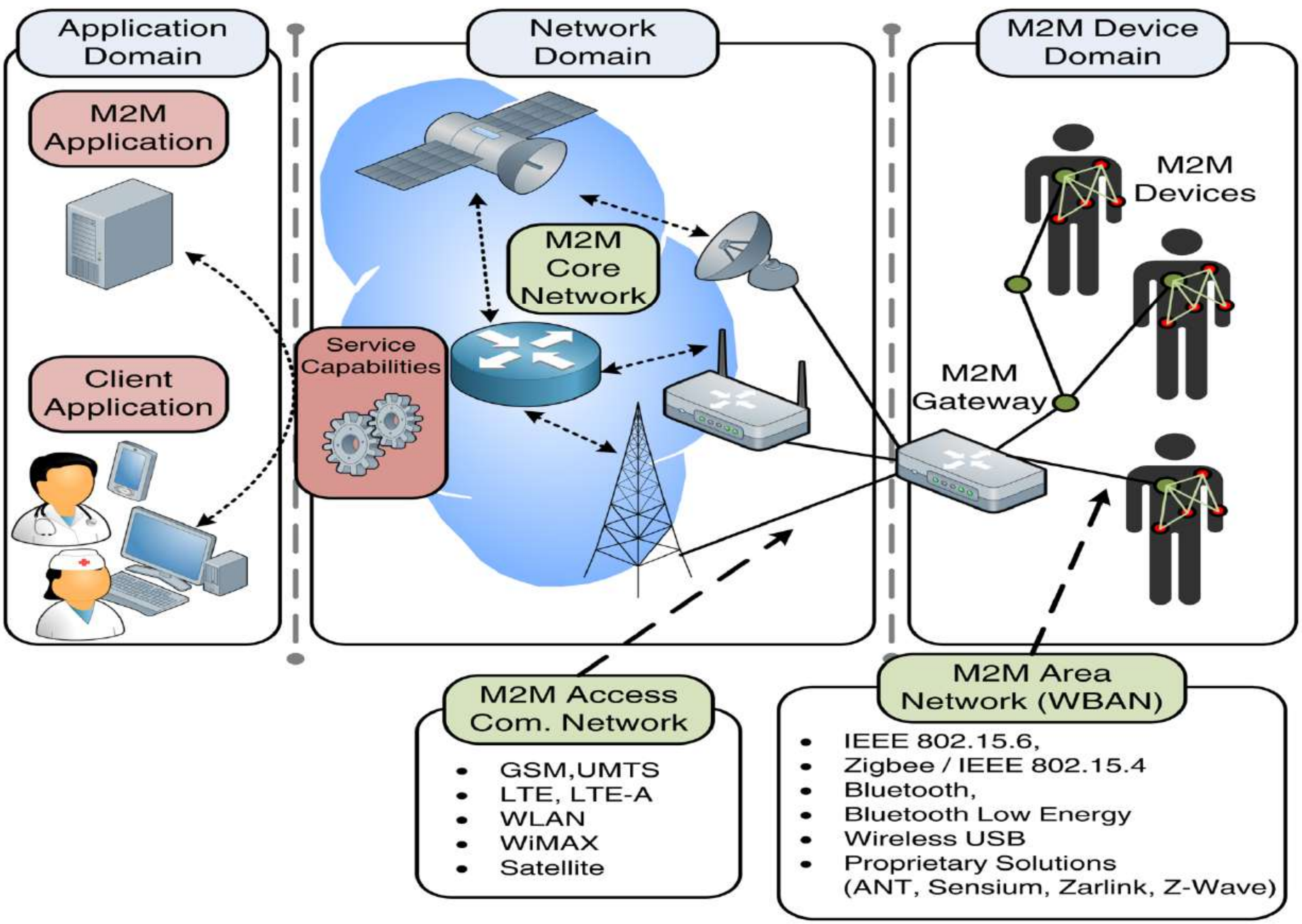
M2M Communication Framework

- DeviceHive
- Enables connecting devices to the IoTs
- Web-based management software that creates security rules based networks and monitors devices

M2M Architecture

- Three domains
- M2M Device domain,
- M2M network
- M2M Application domain

M2M Application Domain



Layer 3:M2M device communication domain

- M2M Devices Domain Communication
- Gateway
- Physical devices and Controllers (the things in IoT) [Sensors, machines, devices, Intelligent Edge nodes of Different Types

Layer 2: Network Domain

- M2M server, device identity, device and device-network management, Data Analysis, Abstraction, Accumulation, and Management
- uni-cast and multicast message delivery
- Core functionalities for monitoring
- Connectivity (Communication and Processing Units)

Layer 1: M2M Application Domain

- Integration, Collaboration and M2M Application Services
- Application (Reporting, Analysis, control)

M2M Protocols

- Eclipse M2M Industry Working Group Various projects
- • Koneki
- • Eclipse SCADA for open standards for communication protocols, tools, and frameworks
- ITU-T Focus Group M2M (global standardization initiative for a common M2M service layer • Weightless (wireless communications) Group for standards and using wireless spaces for M2M

M2M Usages

- Coordinated movement of tools, robots, drones
- Refinery operations, sequential control at each stage during manufacturing
- Manufacturing of food packets
- Assembly in assembly lines and
- Tracking of failures along the railway tracks.

IIoT usages

- Manufacturing at multiple locations, railways, mining, agriculture, oil and gas, utilities, transportation, logistics and healthcare services along usages of the Internet, and
- Usages of software for analytics, machine learning, and knowledge discovery in these areas

Summary

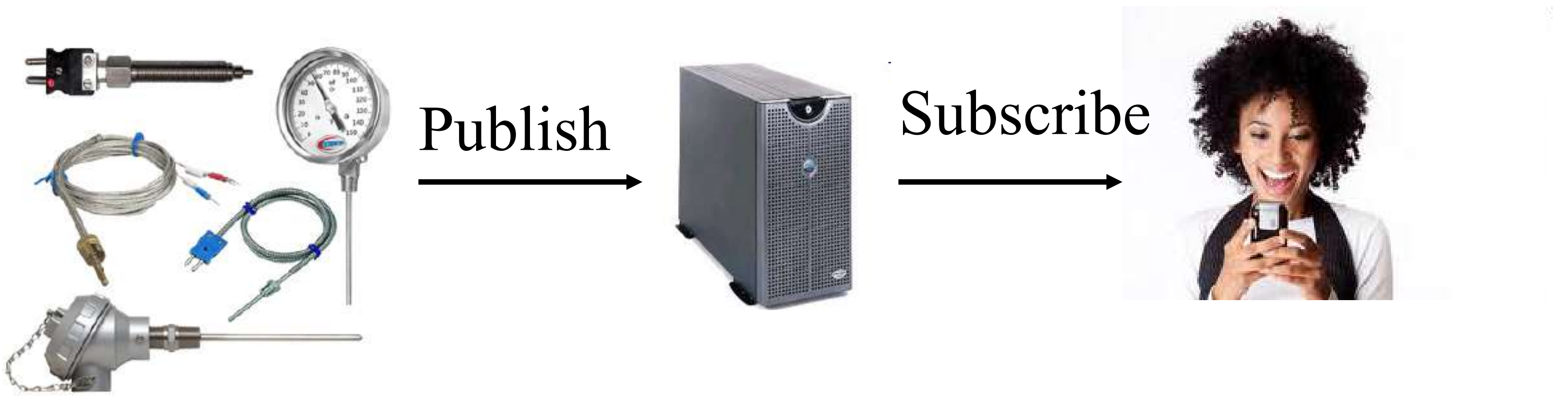
We learnt

(i) M2M devices Network connect to Internet

- (ii) Close differences lies in M2M uses for device to device communication also for coordinate monitoring plus control purposes
- (iii) IoT usages of remote computers, systems, servers connected through Internet protocols, and
- (iv) Three Layer Architecture: Devices Communication Domain, Network domain and Application Domain
- (v) M2M Devices and Network Tools
- (vi) M2M usages examples and
- (vii) IIoT usages examples

Messaging Protocols for Internet of Things: MQTT

MQTT



- MQ Telemetry Transport (MQTT)
  - MQTT Concepts
  - MQTT Application 2
  - MQTT vs. HTTP
- Single-Board Microcontrollers
-

IoT Ecosystem

		Security	Management
Applications	Smart Health, Smart Home, Smart Grid Smart Transport, Smart Workspaces, …	TCG, Oath 2.0, SMACK, SASL, ISASecure, ace, CoAP, DTLS, Dice	IEEE 1905, IEEE 1451, …
Session	**MQTT**, CoRE, DDS, AMQP , …		
Routing	**6LowPAN**, **RPL**, 6Lo, 6tsch, Thread, 6-to-nonIP , …		
Datalink	WiFi, Bluetooth Smart, ZigBee Smart, Z-Wave, DECT/ULE, 3G/LTE, NFC, Weightless, **HomePlug GP**, 802.11ah, **802.15.4**, G.9959, WirelessHART, DASH7, ANT+ , LoRaWAN, …		
Software	Mbed, Homekit, AllSeen, IoTvity, ThingWorks, EVRYTHNG , …		
Operating Systems	Linux, Android, Contiki-OS, TinyOS, …		
Hardware	ARM, **Arduino**, Raspberry Pi, ARC-EM4, Mote, Smart Dust, Tmote Sky, …		

MQ Telemetry Transport (MQTT)

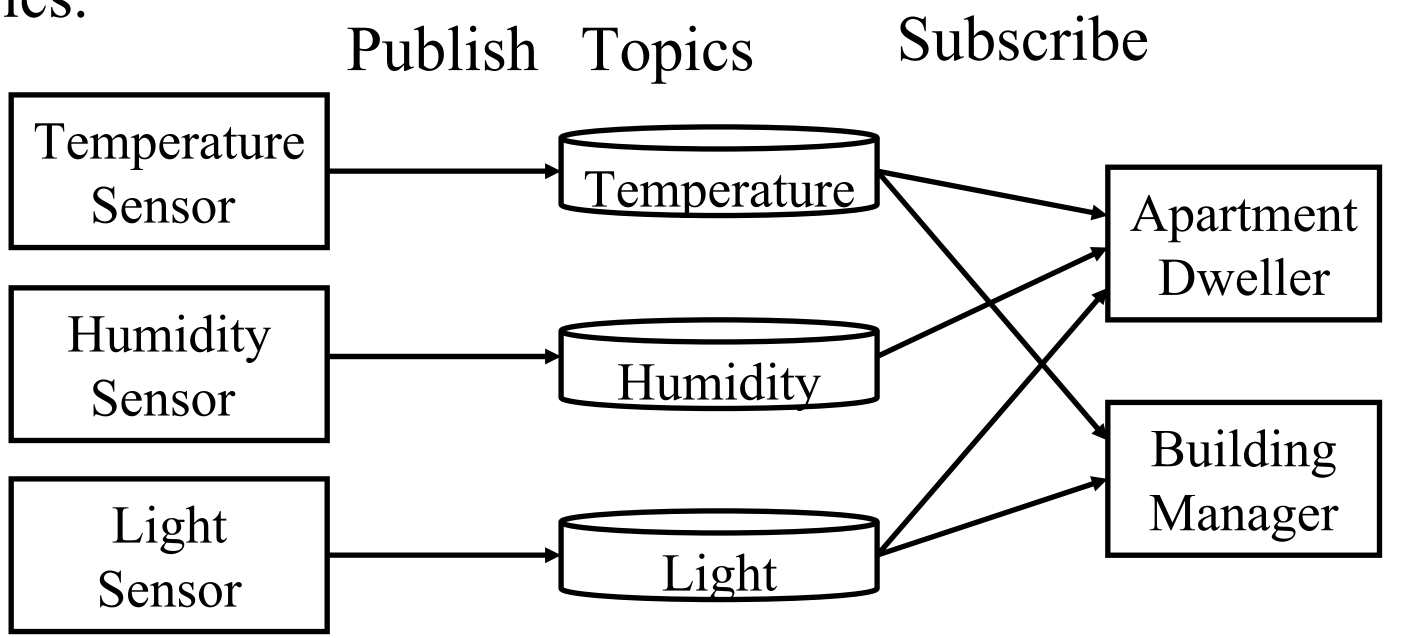
- Lightweight messaging protocol for M2M communication
- Telemetry = Tele-Metering = Remote measurements
- Invented and sponsored by IBM.
  Now Open source. Open Source libraries available.
- MQ originated from "message queueing (MQ)" architecture used by IBM for service oriented networks. There is **no** queueing in MQTT.
- Telemetry data goes from devices to a server or broker.
  Uses a publish/subscribe mechanism.
- Lightweight = Low network bandwidth and small code footprint

MQTT (Cont)

- Facebook messenger uses MQTT to minimize battery usage. Several other applications in medical, environmental applications
- Many open source implementations of clients and brokers are available
  - Really small message broker (RSMB): C
  - Mosquitto
  - Micro broker: Java based for PDAs, notebooks

MQTT Concepts

- **Topics/Subscriptions**: Messages are published to topics. Clients can subscribe to a topic or a set of related topics
- **Publish/Subscribe**: Clients can subscribe to topics or publish to topics.



Ref: V. Lampkin, et al., "Building Smarter Planet Solutions with MQTT and IBM WebSphere MQ Telemetry," IBM Redbooks, SEP-2012, ISBN: 0738437085, 268 pp., (Safari Book), http://www.redbooks.ibm.com/redbooks/pdfs/sg248054.pdf

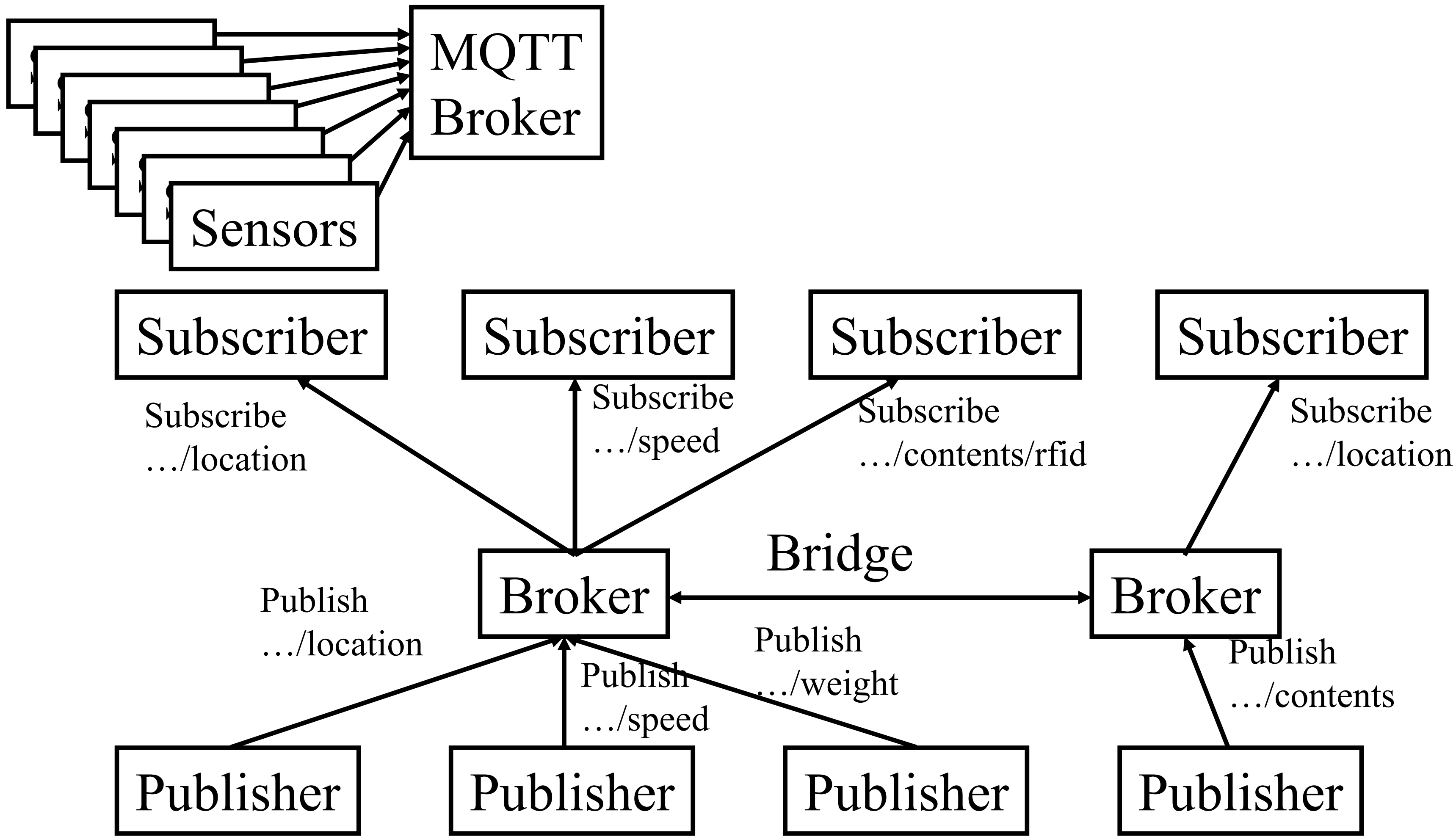
MQTT Concepts (Cont)

- **Quality of Service Levels**: Three levels:
  0 = At most once (Best effort, No Ack),
  1 = At least once (Acked, retransmitted if ack not received),
  2 = Exactly once [Request to send (Publish), Clear-to-send (Pubrec), message (Pubrel), ack (Pubcomp)]
- **Retained Messages**: Server keeps messages even after sending it to all subscribers. New subscribers get the retained messages

MQTT Concepts (Cont)

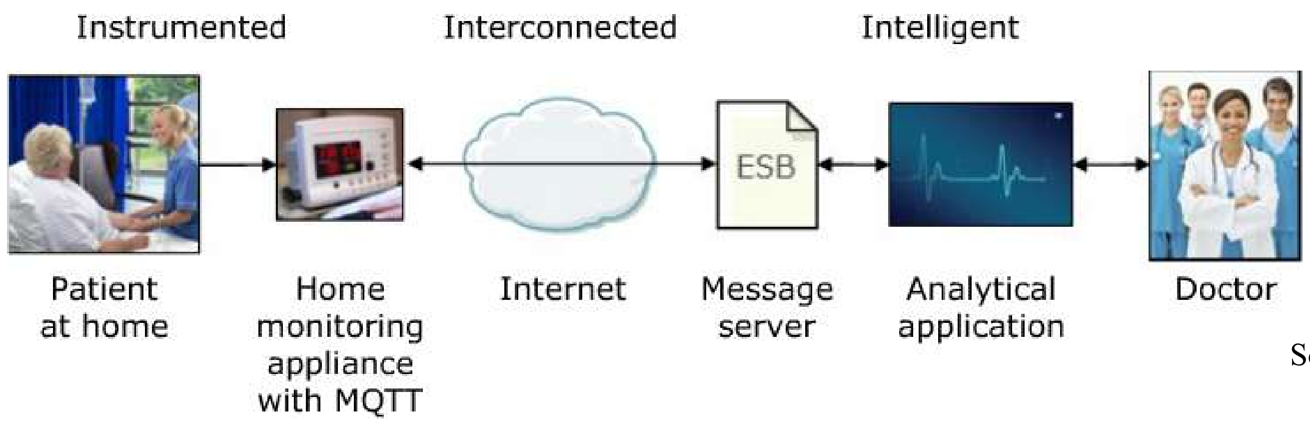
- **Clean Sessions** and **Durable Connections**: At connection set up: Clean session flag ⇒ all subscriptions are removed on disconnect
  Otherwise subscriptions remain in effect after disconnection
  ⇒ Subsequent messages with high QoS are stored for delivery after reconnection
- **Wills**: At connection a client can inform that it has a will or a message that should be published if unexpected disconnection
  ⇒ Alarm if the client looses connection
- Periodic **keep alive** messages ⇒ If a client is still alive
- **Topic Trees**: Topics are organized as trees using / character
  /# matches all sublevels
  /+ matches only one sublevel

MQTT Example



MQTT Application Examples

- Home pacemaker monitoring solution
  - Sensors on patient
  - Collected by a monitoring equipment in home (broker) using MQTT
  - Subscribed by a computer in the hospital
  - Alerts the doctor if anything is out-of-order



Source: Lampkin 2012

MQTT vs. HTTP

	MQTT	HTTP
Design	Data centric	Document centric
Pattern	Publish/Subscribe	Request /Response
Complexity	Simple	More Complex
Message Size	Small. Binary with 2B header	Large. ASCII
Service Levels	Three	One
Libraries	30kB C and 100 kB Java	Large
Data Distribution	1 to zero, one, or n	1 to 1 only

- Open source, http://www.eclipse.org/paho/
- Clients available in .NET, Perl, Python, REXX, Rube,
- Also for Arduino, Mbed, Nanode, Netduino

Ref: V. Lampkin, et al., "Building Smarter Planet Solutions with MQTT and IBM WebSphere MQ Telemetry," IBM Redbooks, SEP-2012, ISBN: 0738437085, 268 pp., (Safari Book), http://www.redbooks.ibm.com/redbooks/pdfs/sg248054.pdf

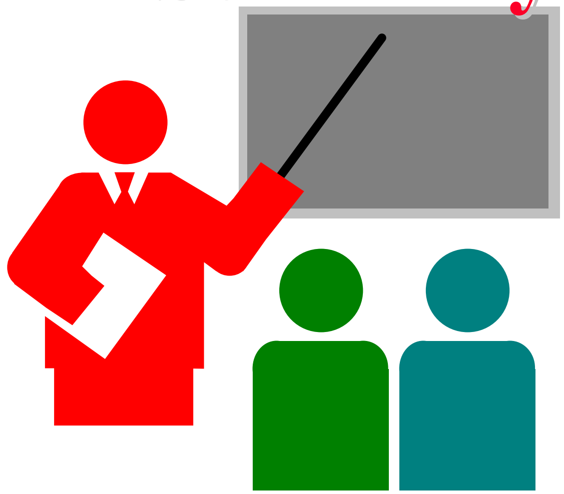
Single-Board Microcontrollers

- Open-source hardware designs
- **Arduino**: 8-bit Atmel AVR or 32-bit Atmel ARM
  Comes with a compiler and a boot loader
  Currently $20. Arduino Nano, $9
  - Bare Bones Board kit (Boarduino): $18
  - Shields: Expansion boards for motors, Ethernet, GPS, Display, …
  - Arduino IDE in Java w programming in C or C++
  - Applications: Oscilloscope, Drone, Phone, …

- **Netduino**: 32-bit ARM using .NET
  Pin compatible with Arduino shields
- **Mbed**: 32-bit ARM Corex-M microcontroller
- 126 microcontrollers listed in Wikipedia

Ref: http://en.wikipedia.org/wiki/Arduino, http://en.wikipedia.org/wiki/Netduino, http://en.wikipedia.org/wiki/Mbed, http://en.wikipedia.org/wiki/Category:Microcontrollers

Summary



- MQTT is a protocol used to publish and subscribe sensor information
- Lightweight, low code size, open source

Reading List

- V. Lampkin, et al., "Building Smarter Planet Solutions with MQTT and IBM WebSphere MQ Telemetry," IBM Redbooks, SEP-2012, ISBN: 0738437085, 268 pp., (Safari Book), http://www.redbooks.ibm.com/redbooks/pdfs/sg248054.pdf
- http://en.wikipedia.org/wiki/MQ_Telemetry_Transport
- http://en.wikipedia.org/wiki/Category:Microcontrollers

Acronyms

.NET	Microsoft's software framework
3G	Third Generation
AMQP	Advanced Queueing Message Protocol
ARC-EM4	Name of a Product
ARM	Acorn RISC Machine
ASCII	American Standard Code for Information Exchange
AVR	Name of Atmel 8-bit RISC processor
CoAP	Constrained Application Protocol
DDS	Data Distribution Service
DECT	Digital Enhanced Cordless Telecommunication
DTLS	Datagram Transport Level Security
GP	Green Physical Layer
GPS	Global Positioning System
HTTP	Hypertext Transfer Protocol
IDE	Integrated Development Environment
IEEE	Institution of Electrical and Electronics Engineers

Acronyms (Cont)

IoT	Internet of Things
IP	Internet Protocol
ISASecure	Security Certification by ISCI
ISCI	ISA Security Compliance Institute
kB	Kilo Byte
LoRaWAN	Long-Range Wide Area Network
LTE	Long-Term Evolution
MQ	Message Queueing
MQTT	MQ Telemetry Transport
NFC	Near Field Communication
PDA	Personal Digital Assistant
QoS	Quality of Service
REXX	REstructed eXtended eXecutor (an interpreted programming language)
RPL	Routing over Low-Power and Lossy
RSMB	Really small message broker

Acronyms (Cont)

❑	SASL	Simple Authentication and Security Layer
❑	SMACK	Simplified Mandatory Access Control Kernel
❑	TCG	Trusted Control Group
❑	TinyOS	Tiny Operating System
❑	ULE	Ultra-Low Energy
❑	URL	Uniform Resource Locator
❑	WiFi	Wireless Fidelity
❑	WirelessHART	Wireless Highway Addressable Remote Transducer Protocol