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Introduction: Sensing & Actuation

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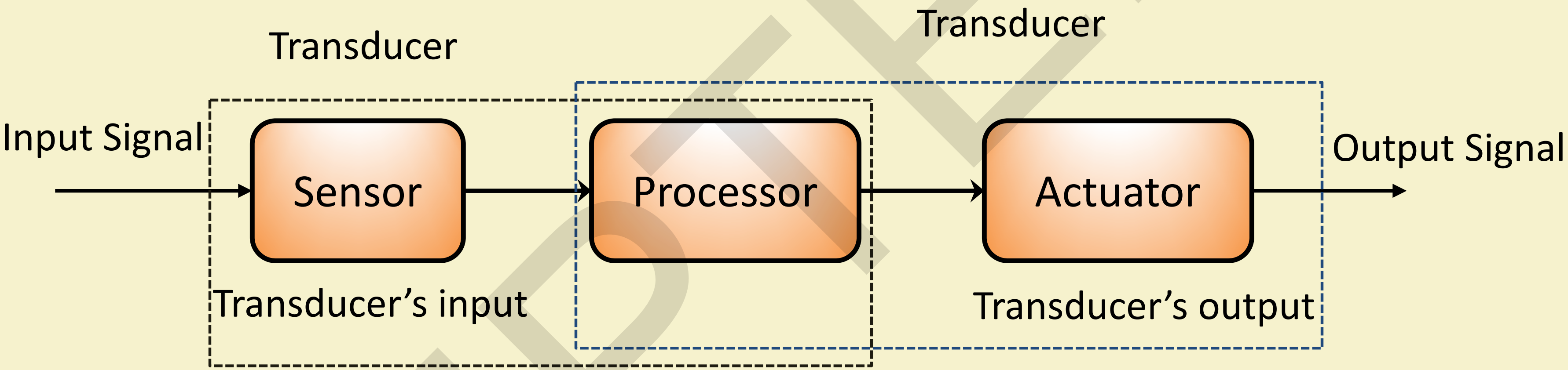
Transducer



Source: "Sensor" Online: https://ielm.ust.hk/dfaculty/ajay/courses/alp/ieem110/lecs/sensors/sensors.html

Transducer (Contd.)

- Transducer:
  - Converts a signal from one physical form to another physical form
  - Physical form: thermal, electric, mechanical, magnetic, chemical, and optical
  - <u>Energy converter</u>
  - Example:
    - Microphone : Converts sound to electrical signal
    - Speaker : Converts electrical signal to sound
    - Antenna : Converts electromagnetic energy into electricity and vice versa
    - Strain gauge : Converts strain to electrical

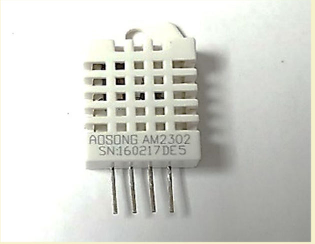
Definition of Sensor

- The characteristic of any device or material to detect the presence of a particular <u>physical quantity</u>
- The output of sensor is signal, which is converted to human readable form

Sensor

- Performs some function of input by sensing or feeling the physical changes in the characteristic of a system in response to stimuli
- Input: Physical parameter or stimuli
  - Example: Temperature, light, gas, pressure, and sound
- Output: Response to stimuli

Sensor (Contd.)

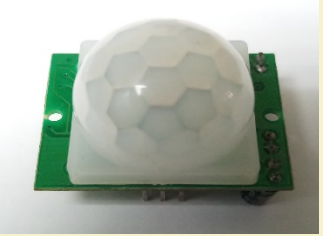


Temperature and Humidity sensor – DH22

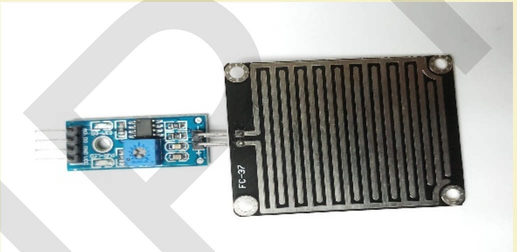
Gas (LPG, CH4, and CO) detector sensor - MQ-5

Ultrasonic sensor - HC-SR04

CMOS Camera



PIR sensor



Rain detector sensor

Fire detector sensor

Sensor Characteristics

- Static characteristics
  - After steady state condition, how the output of a sensor change in response to an input change
- Dynamic characteristics
  - The properties of the system's transient response to an input

Static characteristics

- Accuracy
  - Represents the correctness of the output compared to a superior system
  - The different between the standard and the measured value
- Range
  - Gives the highest and the lowest value of the physical quantity within which the sensor can actually sense
  - Beyond this value there is no sensing or no kind of response

Static Characteristics (Contd.)

- Resolution
  - Provides the smallest change in the input that a sensor is capable of sensing
  - Resolution is an important specification towards selection of sensors.
  - Higher the resolution better the precision
- Errors
  - The difference between the standard value and the value produced by sensor

Static Characteristics (Contd.)

- Sensitivity
  - Sensitivity indicates ratio of incremental change in the response of the system with respect to incremental change in input parameter.
  - It can be found from slope of output characteristic curve of a sensor
- Linearity
  - The deviation of sensor value curve from a particular straight line

Sensor Characteristics (Contd.)

- Drift
  - The difference in the measurements of sensor from a specific reading when kept at that value for a long period of time
- Repeatability
  - The deviation between measurements in a sequence under same conditions

Source : “Sensor”, Hong Kong University of Science and Technology, online: https://ielm.ust.hk/dfaculty/ajay/courses/alp/ieem110/lecs/sensors/sensors.html
Source: “Repeatability”, MIT, Online: https://ocw.mit.edu/courses/mechanical-engineering/2-693-principles-of-oceanographic-instrument-systems-sensors-and-measurements-13-998-spring-2004/

Dynamic Characteristics

How well a sensor responds to changes in its input

- Zero order system
  - Output shows a response to the input signal with no delay
  - Does not include energy-storing elements
  - Example: Potentiometer measures linear and rotary displacements

Dynamic Characteristics (Contd.)

- First order system
  - When the <u>output approaches its final value gradually</u>
  - Consists of an energy storage and dissipation element
- Second order system
  - <u>Complex output response</u>
  - The output response of sensor oscillates before steady state

Sensor Classification

- Sensor
  - Passive and active
  - Analog and digital
  - Scalar and vector

Passive Sensor

- Cannot independently sense the input
- Example: Accelerometer, soil moisture, water-level, and temperature sensors

Active Sensor

- Independently sense the input
- Example: Radar, sounder, and laser altimeter sensors

Analog Sensor

- The response or output of the sensor is some <u>continuous function</u> of its input parameter
  - Example: Temperature sensor, LDR, analog pressure sensor, and Analog Hall effect/Magnetic Sensor
    - A LDR shows continuous variation in its resistance as a function of intensity of light falling on it

Digital Sensor

- Responses in binary nature
- Designs to overcome the disadvantages of analog sensors
- Along with the analog sensor it also comprises of extra electronics for bit conversion
- Example: Passive infrared (PIR) sensor and digital temperature sensor (DS1620)

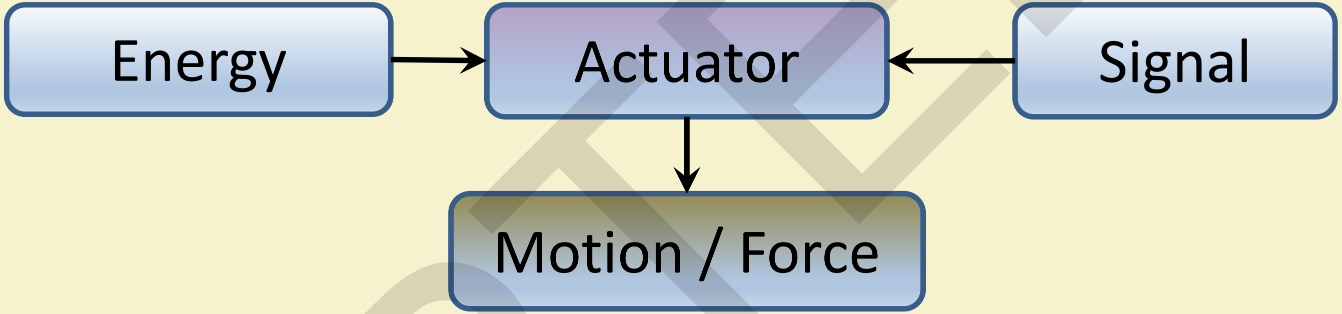
Scalar Sensor

- Detects the input parameter only based on its magnitude
- The response of the sensor is a function of magnitude of the input parameter
- Not affected by the direction of the input parameter
- Example: Temperature, gas, strain, color, and smoke sensors

Vector Sensor

- The response of the sensor depends on the magnitude of the direction and orientation of input parameter
- Example : Accelerometer, gyroscope, magnetic field, and motion detector sensors

Actuator

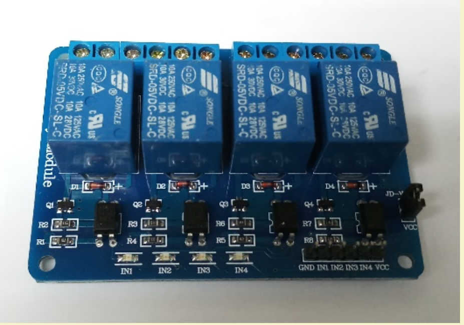


- An actuator is part of the system that deals with the control action required (mechanical action)
- Mechanical or electro-mechanical devices

Actuator (Contd.)

- A control signal is input to an actuator and an energy source is necessary for its operation
- Available in both micro and macro scales
- Example: Electric motor, solenoid, hard drive stepper motor, comb drive, hydraulic cylinder, piezoelectric actuator, and pneumatic actuator

DC Motor



Relay

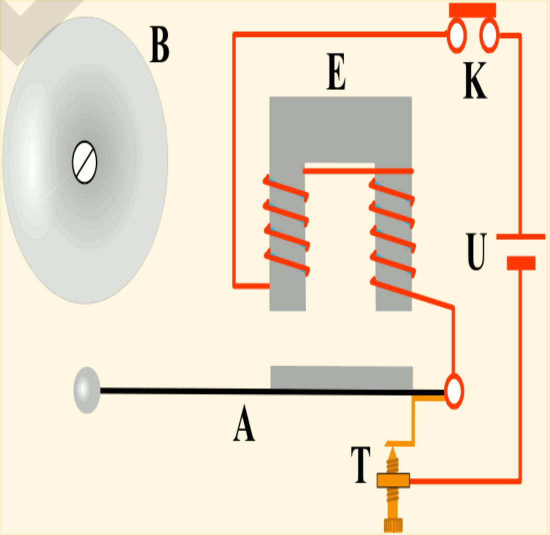
Classification of Actuators

- Electric Linear
- Electric Rotary
- Fluid Power Linear
- Fluid Power Rotary
- Linear Chain Actuators
- Manual Linear
- Manual Rotary

Source : “Classification of actuators” Online: https://www.thomasnet.com/articles/pumps-valves-accessories/types-of-actuators

Electric Linear Actuator

- Powered by electrical signal
- Mechanical device containing linear guides, motors, and drive mechanisms
- Converts <u>electrical energy</u> into <u>linear displacement</u>
- Used in automation applications including electrical bell, opening and closing dampers, locking doors, and braking machine motions

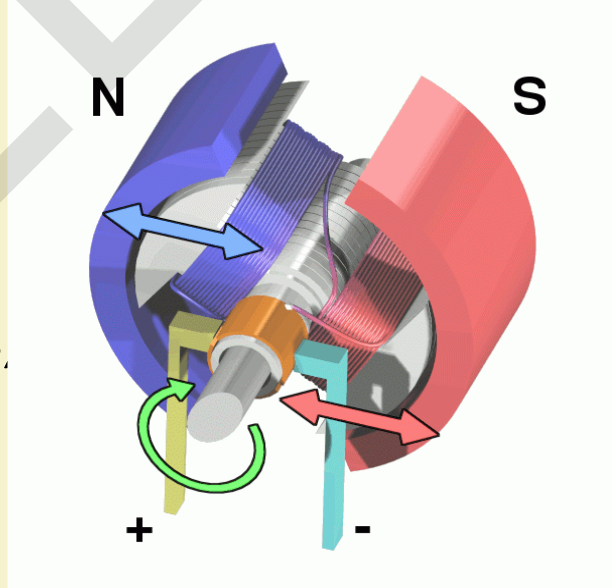


Source: "Electric bell", ЮК/ Wikimedia Commons/, Published date: 18 February 2008, Online: https://commons.wikimedia.org/wiki/File:Electric_Bell_animation.gif

Source: "Classification of actuators" Online: https://www.thomasnet.com/articles/pumps-valves-accessories/types-of-actuators

Electric Rotary Actuator

- Powered by electrical signal
- Converts electrical energy into rotational motion
- Applications including quarter-turn valves, windows, and robotics



Source: “Electric motor”, Abnormaal / Wikimedia Commons / CC-BY-SA-3.0 Unported/ GFDL. Published date: 21 May 2008, Online: https://commons.wikimedia.org/wiki/File:Electric_motor.gif

Source: “Classification of actuators” Online: https://www.thomasnet.com/articles/pumps-valves-accessories/types-of-actuators

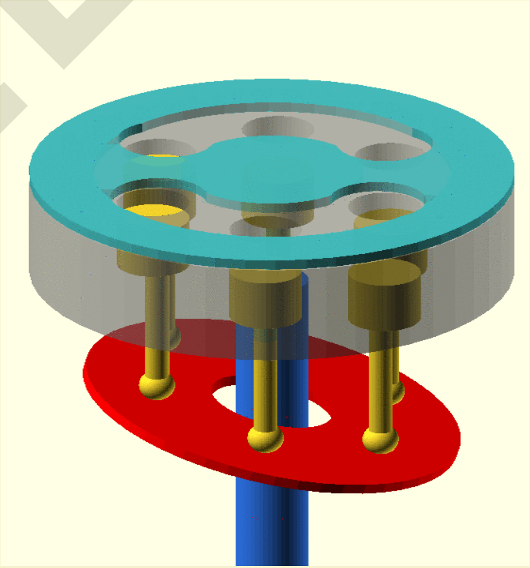
Fluid Power Linear Actuator

- Powered by hydraulic fluid, gas, or differential air pressure
- Mechanical devices have cylinder and piston mechanisms
- Produces linear displacement
- Primarily used in automation applications including clamping and welding

Source : "Classification of actuators" Online: https://www.thomasnet.com/articles/pumps-valves-accessories/types-of-actuators

Fluid Power Rotary Actuator

- Powered by fluid, gas, or differential air pressure
- Consisting of gearing, and cylinder and piston mechanisms
- Converts hydraulic fluid, gas, or differential air pressure into rotational motion
- Primarily applications of this actuator are opening and closing dampers, doors, and clamping

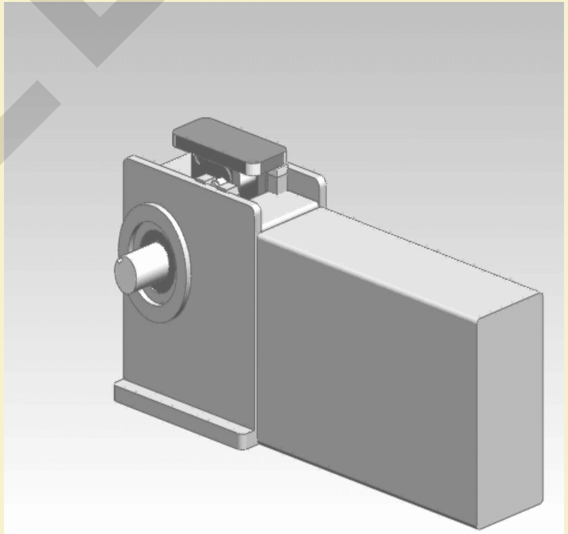


Source: "Axial piston pump", MichaelFrey / Wikimedia Commons / CC-BY-SA-4.0 International/. Published date: 11 August 2017, Online: https://commons.wikimedia.org/wiki/File:Axialkolbenpumpe_-_einfache_Animation.gif

Source: "Classification of actuators" Online: https://www.thomasnet.com/articles/pumps-valves-accessories/types-of-actuators

Linear Chain Actuator

- Mechanical devices containing sprockets and sections of chain
- Provides linear motion by the free ends of the specially designed chains
- Primarily used in motion control applications



Source: "Rigid chain actuator", Catsquisher/ Wikimedia Commons/, Published date: 11 January 2011, Online: https://commons.wikimedia.org/wiki/File:Rigid_Chain_Actuator.gif

Source: "Classification of actuators" Online: https://www.thomasnet.com/articles/pumps-valves-accessories/types-of-actuators

Manual Linear Actuator

- Provides linear displacement through the translation of manually rotated screws or gears
- Consists of gearboxes, and hand operated knobs or wheels
- Primarily used for manipulating tools and workpieces

Source: “Classification of actuators” Online: https://www.thomasnet.com/articles/pumps-valves-accessories/types-of-actuators

Manual Rotary Actuator

- Provides rotary output through the translation of manually rotated screws, levers, or gears
- Consists of hand operated knobs, levers, handwheels, and gearboxes
- Primarily used for the operation of valves

Source: "Classification of actuators" Online: https://www.thomasnet.com/articles/pumps-valves-accessories/types-of-actuators

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Introduction: IoT Connectivity – Part I

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Communication Protocols

- The following communication protocols are important for IoT:
  - IEEE 802.15.4
  - Zigbee
  - 6LoWPAN
  - Wireless HART
  - Z-Wave
  - ISA 100
  - Bluetooth
  - NFC
  - RFID

IEEE 802.15.4

Introduction to IEEE 802.15.4

- This standard provides a framework meant for lower layers (MAC and PHY) for a wireless personal area network (WPAN).
- PHY defines frequency band, transmission power, and modulation scheme of the link.
- MAC defines issues such as medium access and flow control (frames).
- This standard is used for low power, low cost (manufacturing and operation), and low speed communication between neighboring devices (< ~75m).

Source: What's The Difference Between IEEE 802.15.4 And ZigBee Wireless? Fenzel, L.

Features of IEEE 802.15.4

- This standard utilizes DSSS (direct sequence spread spectrum) coding scheme to transmit information.
- DSSS uses phase shift keying modulation to encode information.
  - BPSK - 868/915 MHz, data transmission rate 20/40 kbps respectively.
  - OQPSK - 2.4 GHz, data transmission rate 250 kbps.
- DSSS scheme makes the standard highly tolerant to noise and interference and thereby improving link reliability.

Source: What's The Difference Between IEEE 802.15.4 And ZigBee Wireless? Fenzel, L.

Features of IEEE 802.15.4 (contd.)

- The preferable nature of transmission is line of sight (LOS).
- The standard range of transmission - 10 to 75m.
- The transmission of data uses CSMA-CA (carrier sense multiple access with collision avoidance) scheme.
- Transmissions occur in infrequent short packets for duty cycle (<1 %), thus reducing consumption of power.
- Star network topology and peer-to-peer network topology is included.

Source: What's The Difference Between IEEE 802.15.4 And ZigBee Wireless? Fenzel, L.

Variants of IEEE 802.15.4

Version	Feature
802.15.4 - 2003	Basic version. The modulation schemes and data rates were fixed for different frequency band – 868, 915 MHz, and 2.4 GHz.
802.15.4 - 2006	Also known as 802.15.4b. Provides higher data rate even on the lower frequency bands. In the 868 MHz, the data transmission rate is up to 100 kb/s while in 915 MHz, the data transmission rate is up to 250 kb/s. Uses OQPSK for all the frequency bands.

Source: Poole, I. IEEE 802.15.4 Technology & Standard.

Variants of IEEE 802.15.4 (contd.)

Version	Feature
802.15.4 a	Increases range capability. Defines two new physical layers – Direct Sequence ultra-wideband (UWB) – 249.6 - 749.6 MHz (sub-gigahertz band), 3.1 - 4.8 GHz (low band), and 6 - 10 GHz (high band). Chirp spread spectrum (CSS) approach in ISM band at 2.4 GHz.
802.15.4 c	This version provides 780 MHz band in China. It uses either O-QPSK or MPSK (Multiple frequency-shift keying) using data transmission rate 250 kb/s.
802.15.4 d	This version provides 950 MHz band in Japan. It uses either GFSK (Gaussian frequency-shift keying) using data rate 100 kb/s or BPSK using data rate 20 kb/s.

Source: Poole, I. IEEE 802.15.4 Technology & Standard.

Variants of IEEE 802.15.4 (contd.)

Version	Feature
802.15.4e	Defines MAC developments to IEEE 802.15.4 towards ISA SP100.11a application (industrial applications).
802.15.4f	Defines fresh PHYs for 433 MHz frequency band (RFID applications), 2.4 GHz frequency band and UWB.
802.15.4g	Defines fresh PHYs for smart utility networks for 902 - 928 MHz band (smart grid applications, majorly for the energy industry).

Source: Poole, I. IEEE 802.15.4 Technology & Standard.

Zigbee

Introduction to Zigbee

- Provides a framework for <u>medium-range</u> communication in IoT connectivity.
- Defines PHY (Physical) and MAC (Media Access Control) layers enabling interoperability between multiple devices at <u>low-data</u> rates.
- Operates at 3 frequencies –
  - 868 MHz (1 channel using data transmission rate up to 20 kbps)
  - 902-928MHz (10 channels using data transmission rate of 40 kbps)
  - 2.4 GHz (16 channels using data transmission rate of 250 kbps).

Source: Agarwal, T. ZigBee Wireless Technology Architecture and Applications.

Features of Zigbee

- The lower frequency bands use BPSK.
- For the 2.4 GHz band, OQPSK is used.
- The data transfer takes place in 128 bytes packet size.
- The maximum allowed payload is 104 bytes.
- The nature of transmission is line of sight (LOS).
- Standard range of transmission – upto 70m.

Source: Agarwal, T. ZigBee Wireless Technology Architecture and Applications.

Features of Zigbee (contd.)

- <u>Relaying</u> of packets allow transmission over greater distances.
- Provides <u>low power consumption</u> (around 1mW per Zigbee module) and better efficiency due to
  - adaptable duty cycle
  - low data rates (20 - 250 kbit/s)
  - low coverage radio (10 -100 m)
- Networking topologies include star, peer-to-peer, or cluster-tree (hybrid), mesh being the popular.

Source: Agarwal, T. ZigBee Wireless Technology Architecture and Applications.

Features of Zigbee (contd.)

- The Zigbee protocol defines <u>three types of nodes</u>:
  - **Coordinators** - Initializing, maintaining and controlling the network. There is one and only one per network.
  - **Routers** - Connected to the coordinator or other routers. Have zero or more children nodes. Contribute in multi hop routing.
  - **End devices** - Do not contribute in routing.
- **Star topology** has no router, one coordinator, and zero or more end devices.
- In **mesh** and **tree** topologies, one coordinator maintains several routers and end devices.

Source: Agarwal, T. ZigBee Wireless Technology Architecture and Applications.

Features of Zigbee (contd.)

- Each cluster in a cluster-tree network involves a coordinator through several leaf nodes.
- Coordinators are linked to parent coordinator that initiates the entire network.
- ZigBee standard comes in two variants:
  - **ZigBee**
  - **ZigBee Pro** - offers scalability, security, and improved performance utilizing many-to-one routing scheme.

Source: Agarwal, T. ZigBee Wireless Technology Architecture and Applications.

6LoWPAN

Introduction to 6LoWPAN

- 6LoWPAN is IPv6 over Low-Power Wireless Personal Area Networks.
- It optimizes IPv6 packet transmission in low power and lossy network (LLN) such as IEEE 802.15.4.
- Operates at 2 frequencies:
  - 2400–2483.5 MHz (worldwide)
  - 902–929 MHz (North America)
- It uses 802.15.4 standard in unslotted CSMA/CA mode.

Source: Olsson, J. 6LoWPAN demystified.

Features of 6LoWPAN

- 6LowPAN converts the data format to be fit with the IEEE 802.15.4 lower layer system.
- IPv6 involves MTU (maximum transmission unit) of 1280 bytes in length, while the IEEE 802.15.4 packet size is 127 bytes.
- Hence a supplementary adaptation layer is introduced between MAC and network layer that provides:
  - Packet fragmentation & packet reassembly
  - Compression of header
  - Routing of data link layer.

Source: Olsson, J. 6LoWPAN demystified.

Features of 6LoWPAN (contd.)

- Fragmentation is required to fit the intact IPv6 packet into a distinct IEEE 802.15.4 frame (> ~106 bytes).
- The fragmentation header allows 2048 bytes packet size with fragmentation.
- Using fragmentation and reassembly, 128-byte IPv6 frames are transmitted over IEEE 802.15.4 radio channel into several smaller segments.
- Every fragment includes a header.

Source: Sulthana, M. R. A Novel Location Based Routing Protocol For 6LoWPAN.

Features of 6LoWPAN (contd.)

- Header compression reduces the transmission overhead and allows efficient transmission of payload.
- IPv6 addresses are compressed in 6LoWPAN:
  - 8-byte UDP header
  - 40-byte IPv6 header
- Stateless auto configuration allows any device to create the IPv6 address automatically devoid of external dealing using a DHCP server.

Source: Sulthana, M. R. A Novel Location Based Routing Protocol For 6LoWPAN.

Features of 6LoWPAN (contd.)

- Data link layer routing is classified into two schemes:
  - **mesh-under** - utilizes link layer address to forward data packets.
  - **route-over** - utilizes network layer IP address.
- Provides link layer security (AES-128) from IEEE 802.15.4 such as authentication of link and encryption.

Source: Sulthana, M. R. A Novel Location Based Routing Protocol For 6LoWPAN.

Wireless HART

Introduction to Wireless HART

- WirelessHART is based on HART (Highway Addressable Remote Transducer).
- It is the first international industrial wireless standard (IEC 62591), based upon the standard IEEE 802.15.4.
- Functions in the 2.4GHz ISM band using data rate of up to 250 kb/s.
- 11 to 26 channels are supported, with a gap of 5MHz between two adjacent channels.
- The same channel can't be used consecutively.

Source: Feng, A. WirelessHART- Made Easy.

Features of Wireless HART

- Exploits IEEE 802.15.4 accustomed DSSS coding scheme.
- A WirelessHART node follows channel hopping every time it sends a packet.
- Modulation technique used is offset quadrature phase shift keying (OQPSK).
- Transmission Power is around 10dBm (adjustable in discrete steps).

Source: Feng, A. WirelessHART- Made Easy.

Features of Wireless HART (contd.)

- Maximum payload allowed is 127 bytes.
- It employs TDMA (time division multiple access) that allots distinct time slot of 10ms for each transmission.
- TDMA technology is used to provide collision free and deterministic communications.
- A sequence of 100 consecutive time slots per second is grouped into a super frame.
- Slot sizes and the super frame length are fixed.

Source: Salman, T. and Jain, R. (2017). A Survey of Protocols and Standards for Internet of Things.

Features of Wireless HART (contd.)

- The devices support multiple super frames with differing numbers of timeslots.
- At least one super frame is always enabled while additional super frames are enabled and disabled according to the demand of bandwidth.
- For any message, communication occurs in the alloted timeslot and frequency channel.
- Supports both star and mesh topologies.

Source: Salman, T. and Jain, R. (2017). A Survey of Protocols and Standards for Internet of Things.

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Introduction: IoT Connectivity – Part 2

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Z-Wave

Introduction to Z-Wave

- Z-wave is a low power radio communication technology primarily used for home automation and security systems.
- It was designed as a simpler and cheaper alternative to Zigbee for small to medium range connectivity.
- It operates on the unlicensed part of the industrial, scientific and medical (ISM) band: 908.42 MHz in the US & 868.42 MHz in Europe, avoiding any interference with the 2.4Ghz band(Wi-Fi, Bluetooth and others).
- Z-wave uses a Mesh Network Topology to communicate among the devices, supporting up to 232 nodes in a network.

Source: Paul Lamkin. April 26, 2018. Z-Wave explained: What is Z-Wave and why is it important for your smart home

Features of Z-Wave

- A Z-wave network has 2 device categories: **Controller** and **Slave**
- The **Controller** is a central entity which sets up the Z-wave network and manages other slave devices in the network.
- Each logical Z-wave network has 1 Home (Network) ID and multiple unique Node IDs for the devices in the network.
- The Network ID is of length 4 Bytes and Node ID is of length 1 Byte.
- The nodes can communicate only within their home network
- It offers a data rate of up to 100kbps and an average communication range of 30 meters.

Source: Paul Lamkin. April 26, 2018. Z-Wave explained: What is Z-Wave and why is it important for your smart home

Features of Z-Wave (contd.)

- It uses source routed network mesh topology using 1 primary controller.
- Z-wave considers only static devices in the network due to its source routed network topology.
- The devices communicate with one another only when they are in range.
- Messages are routed through different nodes in case of any obstruction due to interior layout and other household appliances.
- These obstructions are called radio dead-spots and can be bypassed using a process called **Healing.**

Source: Paul Lamkin. April 26, 2018. Z-Wave explained: What is Z-Wave and why is it important for your smart home

Application

- Primarily used in Home/Office Automation
- Systems for Smart Energy Management
- System for Smart Security and Surveillance
- Voice control enabled applications
- Appliances automation and control

Source: Applications of Z-wave technology, (March 2018)

ISA 100.11a

➢Introduction to ISA 100.11a

- ISA 100.11a is a Standard for wireless network technology developed by the International Society of Automation(ISA).
- The primary focus of the technology is the implementation of automation in the industrial environment.
- The protocol stack of ISA 100.11a is in compliance with IoT.
- It is based on the IEEE 802.15.4 protocol along with other wireless networks.

Source: ISA100 Wireless tutorial | What is ISA100 Wireless

Features of ISA 100.11a

- It supports multiple devices working on different protocols to interact in a single network, simultaneously.
- It is an open standard which enables interoperability and communication between different devices.
- It uses the IPv6 based technology and adds the associated benefits such as increased address space and security.
- 128 bits AES encryption security.
- Hence, it offers essential scalability and reliability for industrial network.
- It supports 2 network topologies for operation: 1)Star and 2)Mesh.
- Uses TDMA/CSMA schemes for resource sharing, collision avoidance.

Source: ISA100 Wireless tutorial | What is ISA100 Wireless?

Application

- It is primarily used for automation in large scale complex industries.
- Wireless monitoring of the industrial network and devices.
- Process monitoring and control automation in the industrial environment with large and complex setups.

Bluetooth

Introduction to Bluetooth

- A short range wireless communication technology.
- Its is aimed at replacing the cables with wireless medium to communicate between portable devices.
- It is based on Ad-hoc technology, also known as Ad-hoc Piconets.
- Network can be established between 2 to 8 Bluetooth devices.

Source: Bluetooth Basics (March 31, 2018)

Features of Bluetooth

- It is a low cost wireless communication technology.
- Low power consumption.
- Bluetooth technology uses the unlicensed industrial, scientific and medical (ISM) band at 2.4 to 2.485 GHZ.
- Supports 1Mbps and 3Mbps data rate for version 1.2 and 2.0, respectively.
- The operating range: 1 meter for Class 3 radios, 10 meters for Class 2 radios, and 100 meters for Class 1 radios.

Source: Bluetooth Basics (March 31, 2018)

Application

- Bluetooth is suitable for a network of devices with smaller radius.
  - Connectivity with desktop and laptop peripherals
  - Wireless connectivity between mobile phones and other portable devices.
  - Multimedia transfer between devices
  - Automobiles use Bluetooth for connecting with multimedia and navigation devices.
  - GPS devices are connected with the end user.

Source: Tarun Agarwal. April 11, 2016. How does Bluetooth work?

RFID

Introduction to RFID

- RFID stands for “radio-frequency identification” .
- An RFID system consists of RFID tag, RFID reader and RFID software.
- RFID tag stores digitally encoded data, which is read by a RFID reader.
- RFID tag data can be read outside the line-of-sight, as compared to traditional barcodes and QR codes.

Source: RFID Radio Frequency Identification Technology Tutorial

Features of RFID

- RFID tag consists of an integrated circuit and an antenna, covered with a protective material.
- Tags can be classified as <u>passive</u> or <u>active</u>.
- **Active** tags use their own power supply for operation and data transfer.
- **Passive** tags have to be powered by a reader inductively in order to transmit data.

Source: RFID Radio Frequency Identification Technology Tutorial

Application

- Store product tracking.
- Asset and baggage tracking.
- Supply chain management.
- Livestock tracking and management.
- Automobile tracking.
- Authentication and access control

NFC

Introduction to NFC

- **Near field communication**, or NFC, has been derived from radio-frequency identification (RFID).
- NFC works within close proximity without any physical contact between the devices unlike RFID which has a longer range of communication.
- A NFC device can be any of the two types: 1) Active and 2) Passive.
- An **Active** type of device can both read and transmit data.
- A **Passive** device can only transmit data but cannot read from other NFC devices.

Source: NFC Near Field Communication Tutorial | NFC Tutorial (2016)

Features of NFC

- NFC operates at 13.56 MHz frequency.
- The communication range of NFC devices is less then 10 centimeters.
- Data rate supported are 106, 212 or 424 Kbps (kilobits per second).
- Two communication modes are supported between two devices: Active-Active or Active-Passive mode.

Source: NFC Near Field Communication Tutorial | NFC Tutorial (2016)

Application

- Banking and payments using NFC enabled smartphones, transaction cards.
- Tracking goods.
- Data Communication between smart phones.
- Security and authentication using NFC enabled ID cards.
- Low-power home automation systems.

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Introduction:
IoT Networking- Part I

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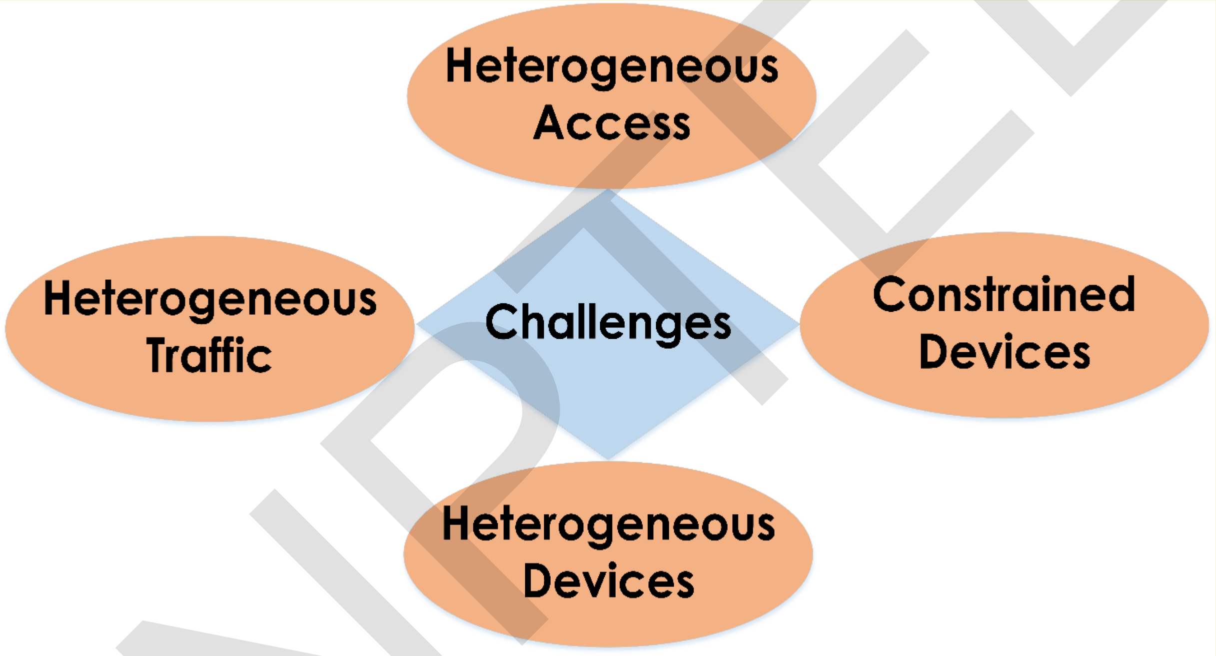
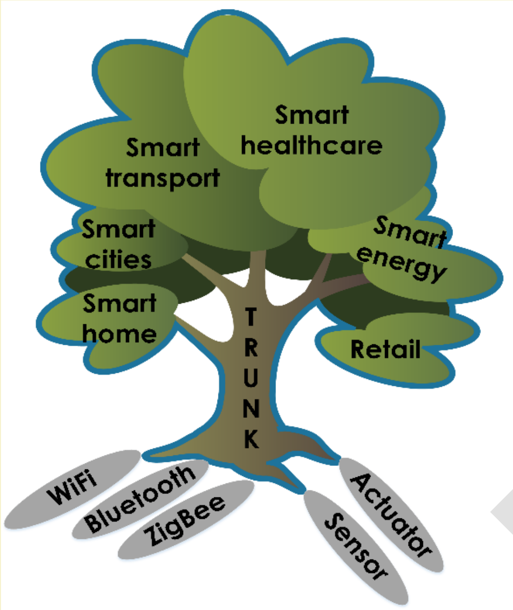
Introduction

- Characteristics of IoT devices
  - Low processing power
  - Small in size
  - Energy constraints
- Networks of IoT devices
  - Low throughput
  - High packet loss
  - Tiny (useful) payload size
  - Frequent topology change
- Classical Internet is not meant for constrained IoT devices.

Introduction



Introduction



- Analogy
  - Roots - Communication Protocol and device technologies
  - Trunk- Architectural Reference Model (ARM)
  - Leaves – IoT Applications
- Goal
  - To select a minimal set of **roots** and propose a potential **trunk** that enables the creation of a maximal set of the **leaves**.

Source: FhG, I. M. L., et al. "Internet of things-architecture iot-a deliverable d1. 3–updated reference model for iot v1. 5."

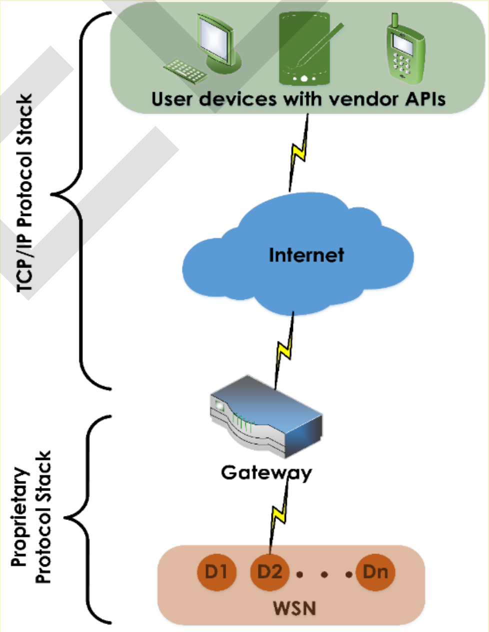
Enabling Classical Internet for IoT Devices

- Proprietary non-IP based solution
  - Vendor specific gateways
  - Vendor specific APIs
- Internet Engineering Task Force (IETF) IP based solution
  - Three work groups
    - IPv6 over Low power Wireless Personal Area Networks (6LoWPAN)
    - Routing Over Low power and Lossy networks (ROLL)
    - Constrained RESTful Environments (CoRE)

Source: I. Ishaq, et al. , "IETF standardization in the field of the internet of things (IoT): a survey", J. of Sens. and Act. Netw. 2, vol. 2 (2013): 235-287.

Proprietary non-IP based solution

- Drawbacks
  - **Limited flexibility to end users**: vendor specific APIs
  - **Interoperability**: vendor specific sensors and gateways
  - **Limited last-mile connectivity**



Source: I. Ishaq, et al. , "IETF standardization in the field of the internet of things (IoT): a survey", J. of Sens. and Act. Netw. 2, vol. 2 (2013): 235-287.

IETF IP based solution

- Three work groups
  - IPv6 over Low power Wireless Personal Area Networks (6LoWPAN)
    - By header compression and encapsulation it allows IPv6 packets to transmit and receive over IEEE 802.15.4 based networks.
  - Routing Over Low power and Lossy networks (ROLL)
    - New routing protocol optimized for saving storage and energy.
  - Constrained RESTful Environments (CoRE)
    - Extend the Integration of the IoT devices from network to service level.

Constrained RESTful Environments (CoRE)

CoRE

- Provides a platform for applications meant for constrained IoT devices.
- This framework views sensor and actuator resources as web resources.
- The framework is limited to applications which
  - Monitor basic sensors
  - Supervise actuators
- CoAP includes a mechanism for service discovery.

CoRE: Service Discovery

- IoT devices (act as mini web servers) register their resources to **Resource Directory (RD)** using **Registration Interface (RI)**.
- RD, a logical network node, stores the information about a specific set of IoT devices.
- RI supports Representational State Transfer (REST) based protocol such as HTTP (and CoAP- optimized for IoT).
- IoT client uses **Lookup interface** for discovery of IoT devices.

IoT Network QoS

IoT Network QoS

- Quality-of-service (QoS) of IoT network is the ability to guarantee intended service to IoT applications through controlling the heterogeneous traffic generated by IoT devices.
- QoS policies for IoT Network includes
  - Resource utilization
  - Data timeliness
  - Data availability
  - Data delivery

Source: Rayes, A., & Salam, S. (2016), "Internet of Things from hype to reality: the road to digitization", Springer.

Resource utilization

- Requires control on the storage and bandwidth for data reception and transmission.
- QoS policies for resource utilization:
  - **Resource limit policy**
    - Controls the amount of message buffering
    - Useful for memory constrained IoT devices
  - **Time filter policy**
    - Controls the data sampling rate (interarrival time) to avoid buffer overflow
    - Controls network bandwidth, memory, and processing power

Source: Rayes, A., & Salam, S. (2016), "Internet of Things from hype to reality: the road to digitization", Springer.

Data timeliness

- Measure of the **freshness** of particular information at the receiver end
- Important in case of healthcare, industrial and military applications
- Data timeliness policies for IoT network include
  - **Deadline policy**
    - Provides maximum interarrival time of data
    - Drops the stale data; notify the missed deadline to the application end
  - **Latency budget policy**
    - Latency budget is the maximum time difference between the data transmission and reception from source end to the receiver end.
    - Provides priority to applications having higher urgency

Source: Rayes, A., & Salam, S. (2016), "Internet of Things from hype to reality: the road to digitization", Springer.

Data availability

- Measure of the amount of valid data provided by the sender/producer to receiver/consumer
- QoS policies for data availability in IoT network include
  - **Durability policy**
    - Controls the degree of data persistence transmitted by the sender
    - Data persistence ensures the availability of the data to the receiver even after sender is unavailable
  - **Lifespan policy**
    - Controls the duration for which transmitted data is valid
  - **History policy**
    - Controls the number of previous data instances available for the receiver.

Source: Rayes, A., & Salam, S. (2016), "Internet of Things from hype to reality: the road to digitization", Springer.

Data delivery

- Measure of successful reception of reliable data from sender to receiver
- QoS policies for data delivery include
  - **Reliability policy**
    - Controls the reliability level associated with the data distribution
  - **Transport priority**
    - Allows transmission of data according to its priority level

Source: Rayes, A., & Salam, S. (2016), "Internet of Things from hype to reality: the road to digitization", Springer.

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Introduction:
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Requirements of IoT Network

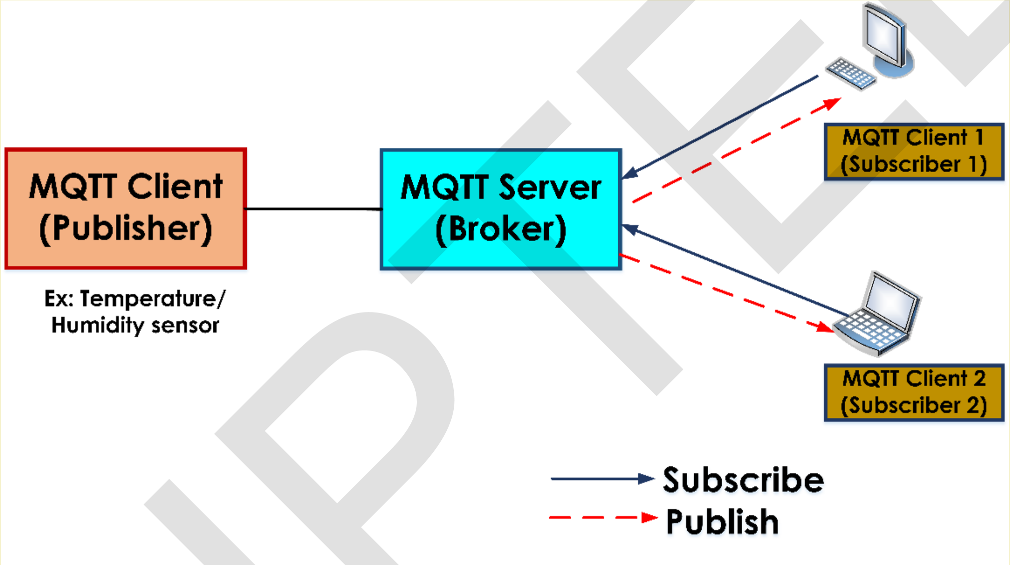
- Coverage
- High throughput
- Low latency
- Ultra reliability
- High power efficiency

MQTT

MQTT

- Message Queue Telemetry Transport
- Introduced by IBM and standardized by Organization for the Advancement of Structured Information Standards (OASIS) in 2013
- Works on Publish/Subscribe framework on top of TCP/IP architecture
- Advantages
  - Reliable, Lightweight, and cost-effective protocol

MQTT Publish/Subscribe Framework



Source: Hanes, D, et al. (2017), "IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things", Cisco Press.

MQTT QoS

- QoS of MQTT protocol is maintained for two transactions
  - First transaction: Publishing client → MQTT Server
  - Second transaction: MQTT Server → Subscribing Client

- Client on each transaction sets the QoS level
  - For the first transaction, publishing client sets the QoS level
  - For second transaction, client subscriber sets the QoS level

Source: Hanes, D, et al. (2017), "IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things", Cisco Press.

MQTT QoS Levels

- Supports 3-level of QoS
- **QoS 0:**
  - Also known as “at most once” delivery
  - Best effort and unacknowledged data service
  - Publisher transmits the message one time to server and server transmits it once to subscriber
  - No retry is performed

Source: Hanes, D, et al. (2017), "IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things", Cisco Press.

MQTT QoS Levels

- **QoS 1:**
  - Also known as “at least once” delivery
  - Message delivery between the publisher, server and then between server and subscribers occurs at least once.
  - Retry is performed until acknowledgement of message is recieved
- **QoS 2:**
  - Also known as “exactly once” delivery
  - This QoS level is used when neither packet loss or duplication of message is allowed
  - Retry is performed until the message is delivered exactly once

CoAP

CoAP

- Constrained Application Protocol
- CoAP was designed by IETF Constrained RESTful Environment (CoRE) working group to enable application with lightweight RESTful (HTTP) interface
- Works on Request/Response framework based on the UDP architecture, including Datagram Transport Layer Security (DTLS) secure transport protocol

Source: Hanes, D, et al. (2017), "IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things", Cisco Press.

CoAP

- CoAP defines four types of messages
  - CON: Conformable
  - NON: Non-conformable
  - RST: Reset
  - ACK: Acknowledgement
- For conformable type message, the recipient must explicitly either acknowledge or reject the message.
- In case of non-conformable type message, the recipient sends reset message if it can't process the message.

Source: Hanes, D, et al. (2017), "IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things", Cisco Press.

CoAP

- Utilizes GET, PUT, OBSERVE, PUSH, and DELETE messages requests to retrieve, create, initiate, update, and delete subscription respectively.
- Supports caching capabilities to improve the response time and reduce bandwidth consumption.
- Uses IP multicast to support data requests sent to a group of devices.
- Specialized for machine-to-machine (M2M) communication.

Source: Hanes, D, et al. (2017), "IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things", Cisco Press.

XMPP

XMPP

- Extensible Messaging and Presence Protocol
- Supports Publish/Subscribe messaging framework on top of TCP protocol
- The communication protocol is based on Extensive Markup Language (XML).
- Uses Datagram Transport Layer Security (DTLS) secure transport protocol

Source: Rayes, A., & Salam, S. (2016), "Internet of Things from hype to reality: the road to digitization", Springer.

XMPP

- XMPP model is decentralized, no central server is required.
- Advantages of XMPP
  - Interoperability: Supports interoperability between heterogeneous networks
  - Extensibility: Supports privacy lists, multi-user chat, and publish/subscribe chat status notifications
  - Flexibility: Supports customized markup language defined by different organizations according to their needs

Source: H. Wang et. al., "A Lightweight XMPP Publish/Subscribe Scheme for Resource-Constrained IoT Devices," IEEE Access, vol. 5, pp. 16393-16405, 2017.

AMQP

AMQP

- Advance Message Queuing Protocol
- Optimized for financial applications
- Binary message-oriented protocol on top of TCP
- Supports Publish/Subscribe framework for both
  - Point-to-point (P2P)
  - Multipoint communication

Source: Rayes, A., & Salam, S. (2016), "Internet of Things from hype to reality: the road to digitization", Springer.

AMQP

- Uses token-based mechanism for flow control
  - Ensures no buffer overflow at the receiving end
- Message delivery guarantee services:
  - At least once: Guarantees message delivery but may do so multiple times
  - At most once: Each message is delivered once or never
  - Exactly once: No message drop and delivered once one

Source: Rayes, A., & Salam, S. (2016), "Internet of Things from hype to reality: the road to digitization", Springer.

IEEE 1888

IEEE 1888

- Energy-efficient network control protocol
- Defines a generalized data exchange protocol between network components over the IPv4/v6-based network.
- Universal Resource Identifiers (URIs) based data identification
- Applications: Environmental monitoring, energy saving, and central management systems.

Source: Rayes, A., & Salam, S. (2016), "Internet of Things from hype to reality: the road to digitization", Springer.

DDS RTPS

DDS RTPS

- Distributed Data Service Real Time Publish and Subscribe
- Supports Publish/Subscribe framework and on top of UDP transport layer protocol.
- Data-centric and binary protocol
- Data is termed as “topics”.
- The users/listeners may subscribe to their particular topic of interest

Source: Rayes, A., & Salam, S. (2016), "Internet of Things from hype to reality: the road to digitization", Springer.

DDS RTPS

- A single topic may have multiple speakers of different priorities
- Supports enlisted QoS for data distribution
  - Data persistence
  - Delivery deadline
  - Reliability
  - Data freshness
- Applications: Military, Industrial, and healthcare monitoring

Source: Rayes, A., & Salam, S. (2016), "Internet of Things from hype to reality: the road to digitization", Springer.

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Industry 4.0: The Fourth Revolution

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Historical Context

- Revolution: instantaneous and complete shift
- First Shift: from foraging to farming (10,000 years ago)
  - Results: production, transportation, communication
  - Growth in food production, prodding of population growth
- Industrial Revolution
  - Developments of new technologies and new approaches
  - Prompts shifts in economic models and social architecture

Source: Schwab, K., 2017. The fourth industrial revolution. Crown Business.

Historical Context

- First Industrial Revolution
  - During 1760 – 1840
  - Driver: invention of steam engine and construction of railway stimulated the revolution
  - Results: utilization of machines in production
- Second Industrial Revolution
  - During the transition from 19^{th} century to 20^{th} century
  - Driver: electricity and assembly line trigged the revolution
  - Results: mass production

Source: Schwab, K., 2017. The fourth industrial revolution. Crown Business.

Historical Context

- Third Industrial Revolution
  - Prompted in 1960s
  - Computer or Digital Revolution
  - Driver: production of semiconductor trigged the revolution
  - Results: mainframe, personal computer, and internet

Source: Schwab, K., 2017. The fourth industrial revolution. Crown Business.

Fourth Industrial Revolution

- Stimulated in 21st century
- Proposed to uplift German economy*
- Digital Revolution triggered the revolution
- Extensive use of ubiquitous and mobile internet
- During the revolution, sensors become cheaper, reduced in size, powerful
- Extensive use of Artificial Intelligence, Machine Learning, Cyber Physical System (CPS)

Source: Schwab, K., 2017. The fourth industrial revolution. Crown Business.
Source *: Lu, Y., 2017. Industry 4.0: A survey on technologies, applications and open research issues. Journal of Industrial Information Integration, 6, pp.1-10.

Fourth Industrial Revolution

- Computers have become more sophisticated and integrated
  - Results: radical transformation of societies and global economies
- Fourth Industrial Revolution is coined as "The second Machine Age"* by Prof. Erik Brynjolfsson, MIT and Andrew McAfee, MIT
- Industry 4.0, another synonym of Fourth Industrial Revolution, is coined by Hannover Fair in 2011.

Source: Schwab, K., 2017. The fourth industrial revolution. Crown Business.
Source *: Brynjolfsson, E. and McAfee, A., 2014. The second machine age: Work, progress, and prosperity in a time of brilliant technologies. WW Norton & Company

Fourth Revolution

- Scope of Fourth Revolution:
  - Smart Connected Machines
  - Smart Factories
  - Gene Sequencing
  - Nanotechnology
  - Renewables
  - Quantum Computing

Source: Schwab, K., 2017. The fourth industrial revolution. Crown Business.

Profound and Systematic Change

- The scale and scope of innovation of Fourth Industrial Revolution defines today's acute disruption and innovation
- Airbnb, Uber, Alibaba, etc., disruptors of today, are relatively new
- Ubiquitous iPhone launched in 2007 → Billions of smart phones are being mass produced currently
- Google announced fully autonomous car in 2010 → AI-based self navigating cars are on the way

Source: Schwab, K., 2017. The fourth industrial revolution. Crown Business.

Profound and Systematic Change

- Not only the speed of profound change, but scale of profound change is equally staggering
- Example *:
  - In 1990, industry giants in Detroit had a combined market of $36 billion capitalization, $250 billion revenues, 1.2 million employee
  - In 2014, industry giants in Silicon Valley had a combined market of $1.09 trillion capitalization, $247 billion revenues, 1,37,000 employee

Source: Schwab, K., 2017. The fourth industrial revolution. Crown Business.
Source *: Manyika, J. and Chui, M., 2014. Digital era brings hyperscale challenges. Financial Times, 13.

Profound and Systematic Change

- With marginal costs, digital business creates unit of today's wealth with fewer workers
- Business, providing information goods, has virtually zero transportation and replication cost
- In the context of Industry 4.0, Instagram, WhatsApp, etc. do not require much capital to begin with, but it changes the role of capital and scaling business

Source: Schwab, K., 2017. The fourth industrial revolution. Crown Business.

Profound and Systematic Change

- In the context of Fourth Industrial Revolution
  - Digital fabrication technologies are able to communicate with biological world
  - Designers and architects are, now, combining
    - Computational design
    - Additive manufacturing
    - Material engineering
    - Synthetic biology
  - Results: producing objects that are mutable and adaptable

Source: Schwab, K., 2017. The fourth industrial revolution. Crown Business.

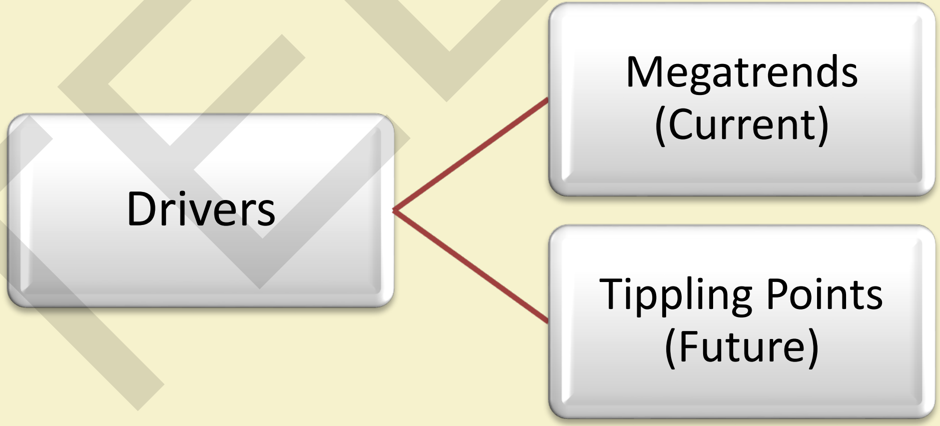
Profound and Systematic Change

- In context of Fourth Industrial Revolution
  - Use of AI
    - Self driving car
    - Virtual assessment
    - Transitional software
    - Discover new drugs
    - Prediction of cultural Interest
  - Application of Siri in Apple is one of the examples of strength of AI (Voice Search) – Also, Cortana for Windows.

Source: Schwab, K., 2017. The fourth industrial revolution. Crown Business.

Drivers

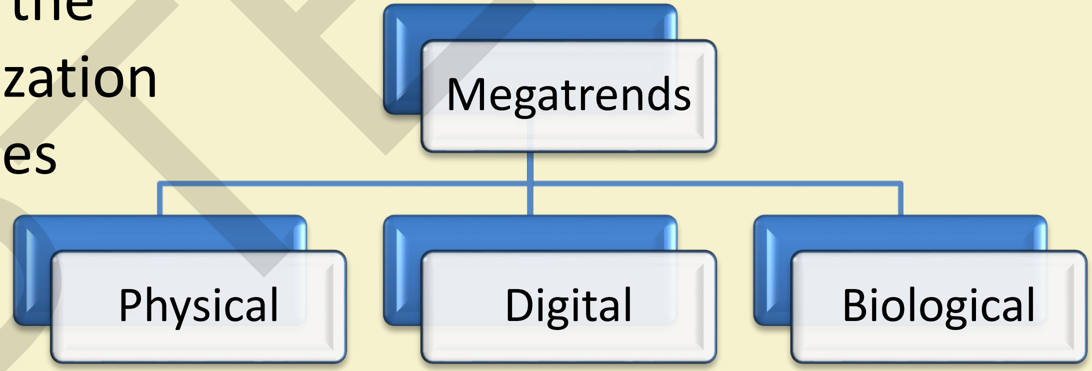
- Various aspects that drive the fourth industrial revolution
  - Scientific Breakthroughs
  - New Technologies



Source: Schwab, K., 2017. The fourth industrial revolution. Crown Business.

Megatrends

- All recent technologies and development that leverage the pervasive potential of digitization and information technologies



Source: Schwab, K., 2017. The fourth industrial revolution. Crown Business.

Physical Megatrends

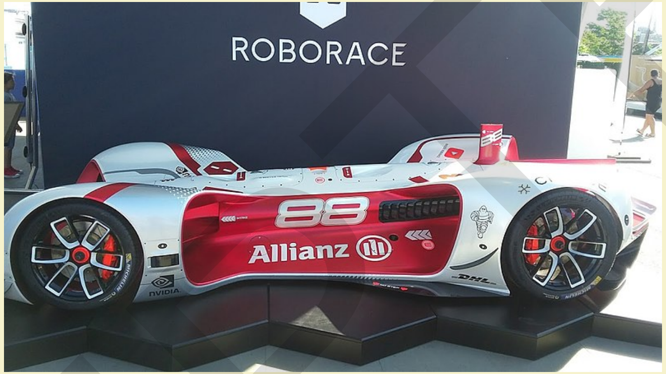
Physical Megatrends

- Autonomous Vehicle
- 3D Printer
- Advanced Robotics
- New Materials

Source: Schwab, K., 2017. The fourth industrial revolution. Crown Business.

Autonomous Vehicle

- Driver-less vehicles
  - Trucks
  - Drones
  - Aircrafts
  - Boats



Source: Wikipedia, By Dllu, Published: Nov 19, 2017, Online: https://en.wikipedia.org/wiki/Autonomous_car

Source: Wikipedia, By Bcschneider, Published: Jul 16, 2017, Online: https://en.wikipedia.org/wiki/Autonomous_car

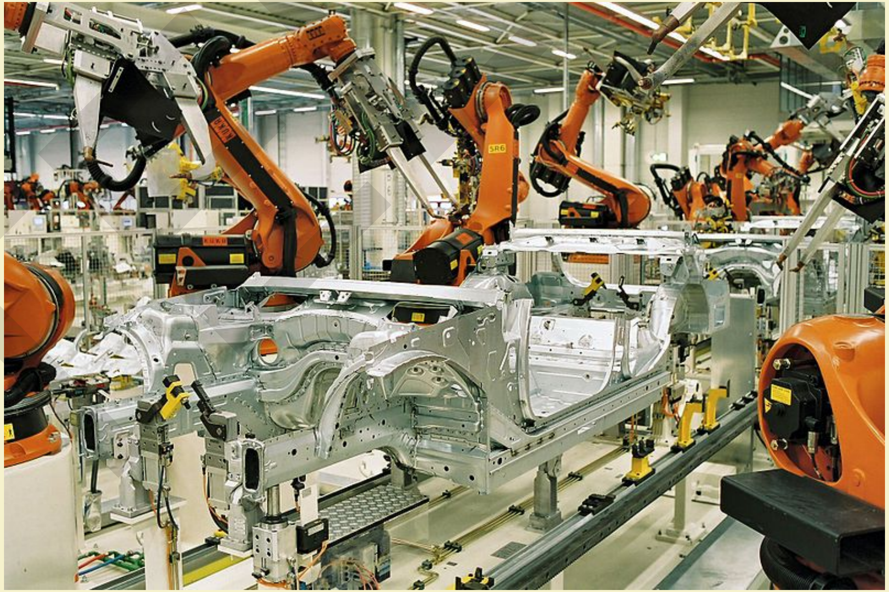
3D Printers

- Manifesting physical objects based on digital specifications
- Application
  - Wind Turbines
  - Medical Implants

Source: Wikipedia, By Tyler Caros, Published: Feb 20, 2015, Online: https://en.wikipedia.org/wiki/Airwolf_3D

Advanced Robotics

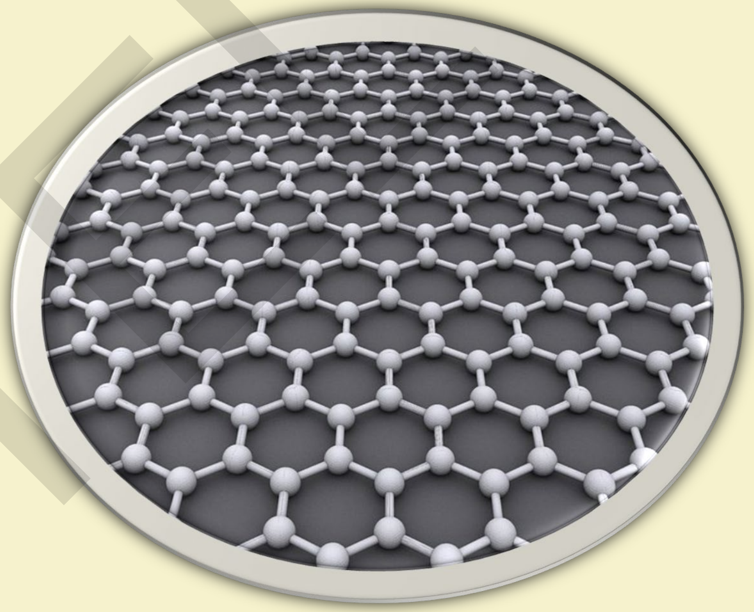
- Conventional application of robots: <u>automotive</u>
- Recently, robotics are used from precision <u>agriculture</u> to <u>nursing</u>



Source: Wikipedia, By BMW Werk Leipzig, Published: Jul 19, 2005, Online: https://en.wikipedia.org/wiki/Smart_manufacturing

New Materials

- Lighter, stronger, recyclable and adaptive
- Example: Thermoset plastics, Graphene



Source: Wikipedia, By AlexanderAlUS, Published: Aug 26, 2010, Online: https://en.wikipedia.org/wiki/Graphene

Digital

- Internet of Things (IoT)
- Application of IoT in Industry
  - RFID
  - Tracking of package delivery
  - Complex supply chain
  - Monitoring systems
- Bitcoin (digital currency) and Blockchain (securing bank/government transactions)
- Uber model for transportation (car pooling etc.)

Source: Schwab, K., 2017. The fourth industrial revolution. Crown Business.

Biological

- Genetic sequencing
- DNA writing
- Recommender system (IBM Watson)
- Cell Modification
- Genetic Engineering (CRISPER)

Source: Schwab, K., 2017. The fourth industrial revolution. Crown Business.

Tipping Points

- Tipping points represent the <u>radical changes</u> in that are required in near future
- Probable tipping points in 2025
  - Clothes connected to the internet
  - Unlimited and free storage
  - 1 trillion sensors connected to the internet
  - Robotic pharmacist, etc.

Source: Schwab, K., 2017. The fourth industrial revolution. Crown Business.

References

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Industry 4.0:
Sustainability Assessment of Manufacturing Industry

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Introduction to Sustainable Industry

- Sustainability: means to continue at a fixed rate*
- Sustainable Industry provides**:
  - Energy efficiency
  - Conservation of resource
  - Low-waste production
- Example: Sustainable Manufacturing Industries

Source*: "Google Defination“
Source **:” Wikipedia”

Sustainability in Industry 4.0

- Industry 4.0 proposes inclusion of the characteristics of the previous industry revolution in more sustainable way.
- Industry 4.0 or the fourth industrial revolution
  - A comprehensive industrial revolution
  - It incorporates globalization and emerging issues.

Source Garbie, I., 2016. Sustainability in manufacturing industries: Concepts, analyses and assessments for industry 4.0. Springer

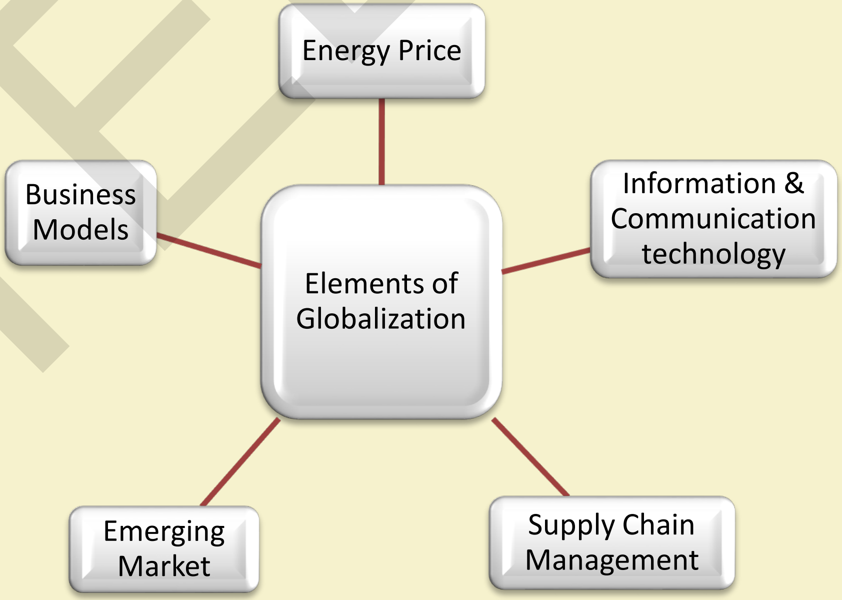
Sustainability Assessment

- Manufacturing industry is considered as
  - Base of modern industrialized society
  - Corner stone of world economy
- Strong manufacturing base stimulates other aspects of the economy of any country
- Evaluation of S/SD or sustainability assessment of manufacturing industry in Industry 4.0 incorporates evaluation of relevant issues and performance metrics

Source Garbie, I., 2016. Sustainability in manufacturing industries: Concepts, analyses and assessments for industry 4.0. Springer

Introduction to Globalization Issues

- Globalization is one of the drivers of sustainable industries
- Globalization issues affect the sustainability of any development/ manufacturing
- These issues are one of the most fundamental requirements



Source Garbie, I., 2016. Sustainability in manufacturing industries: Concepts, analyses and assessments for industry 4.0. Springer

Supply Chain Management (SCM)

- Strategic function in manufacturing industry
  - Many different stages including supplier, production system, and customer
  - Sequencing the stages for the whole system
- The most important stage in SCM is selection for outsourcing components/parts or raw material
- SCM must have environmental concerns: Climate change, contamination and resource consumption

Source Garbie, I., 2016. Sustainability in manufacturing industries: Concepts, analyses and assessments for industry 4.0. Springer

Information and Communication Technology (ICT)

- Main nervous system of any manufacturing industry
  - In absence of ICT, no communication within the enterprise
- Share information between customer, producer, and supplier
- Examples of ICT
  - Enterprise Resource Planning (ERP)
  - Wireless Communication Technology
  - Global Positioning System (GPS)
  - Radio Frequency Identification (RFID) system

Source Garbie, I., 2016. Sustainability in manufacturing industries: Concepts, analyses and assessments for industry 4.0. Springer

Energy Prices

Energy → Created → Transferred → Transformed → Consumed

- For enterprise, less energy consumption brings significant economic advantages
- Main issues: Energy supply at reasonable price
- Increase in energy price affects sustainability
- Reduction in energy consumption form non-renewable sources and increase in energy consumption form renewable will have significant positive effect in sustainability.

Emerging Markets

Dictatorship Period → Emerging Market → Free market and Free Economy

- Markets: able to meet the standards of newly developed, innovative product
- Issue: difficult to identify all of the world's emerging markets
- Emerging markets are expected to be found in developing countries

Source Garbie, I., 2016. Sustainability in manufacturing industries: Concepts, analyses and assessments for industry 4.0. Springer

Business Models

- **Mass Customization:** incorporates the knowledge including international and local cultures
- Business Models ≅ Mass Customization
- Business Model:
  - Strategic approach
  - Maximizing economic profits for an enterprises
  - Taking into account competitive benefits, promoting product value

Source Garbie, I., 2016. Sustainability in manufacturing industries: Concepts, analyses and assessments for industry 4.0. Springer

Introduction to Emerging Issues

- **Emerging Issues:** changes in manufacturing industries based on the world-wide aggressive competition
- Major aspects in case of <u>sustainable development</u> in designing manufacturing industry.

Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

Technology

- One of the important issues in sustainability.
- Advancement in technology facilitates manufacturing with
  - High quality products
  - Low-cost products
  - Reduces manufacturing time
- Role of technology advancement in global market
  - Converting from traditional system to automated system
  - Introducing more agility and flexibility

Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

Government Regulation

- Necessary to protect public and private sector
- It consists of Enterprise Requirements for achieving government purpose such as demands for better services and low cost goods
- Government Regulation
  - Prevents the manufacturing industry from unfair competition
  - Enact laws to provide suitable environments for the employees

Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

Government Regulation

- Employment
- Advertising
- Labor
- Environmental
- Safety And Health
- Privacy

Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

Government Regulation

- Employment & Labor rules represents laws
  - Concerning wages/salaries
  - Benefits (e.g. retirement plans)
  - Compliance with health and safety issue
  - Proper working condition
  - Expatriate employee issue (e.g. Visas)
  - Equal opportunity in employment (including promotion)
  - Provisioning of Authority or High ranking position

Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

Government Regulation

- Advertisement Regulation focuses on
  - Protection of customers
  - Firm honesty about a product
  - Information regulation publicly
  - Transparency on distribution and manufacturing process

Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

Government Regulation

- Environmental rules
  - Maintained by Environmental Protection Agencies(EPA)
  - Maintains clean air, reduction of chemical effects in soil, river
- Privacy Regulations
  - Safety procedure to sensitive information collected during hiring process
  - Information includes ID card, names, personal information, personal history, health condition, and banking information
  - Inappropriate disclosure of this information risks legal issues

Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

Government Regulation

- Safety and Health regulations
  - Ensures healthy working environment
  - Enterprise must distribute information on maintaining a healthy workplace to avoid dangerous events
  - Need to update safety regulation information due to yearly changes in Governments

Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

Population Growth

- Monitoring population growth is important for manufacturing industry
- It affects
  - Industry growth
  - Food supplies
  - Fertility
  - Sociology
  - Economics
  - Politics
  - Industry Location
  - Use of Available lands

Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

Population Growth

- Three different category of countries based on population growth
  - Developed
  - Emerging
  - Developing
- Population growth of countries (developing and disadvantaged) > Population growth of countries (developed and advantaged)

Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

Population Growth

- Based on the United Nations (UN) report, population growth from1950 to 2050
  - Reduced between 32 to 13 % in developed countries
  - Increased between 8 to 20 % in emerging and developing countries
- Economic view on population growth
  - Pessimistic
  - Optimistic

Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

Population Growth

- Pessimistic view of population growth
  - Hinders the economic growth
  - Consumes most of the economic investments in safety, need for schools, hospitals, universities
- Optimistic view of population growth
  - Dissemination of knowledge and information
  - Increases globalization issue such as trade and commerce

Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

Population Growth

- Despite the advantages of population growth, if there is no plan to control it, it would turn out to be disaster for any developing country
- Human capital and respective skills are one of the most important aspects of manufacturing industries.
- Example: A location of manufacturing industry requires politics and skill level provided by the local population

Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

Economic Crisis/Recession and Depression

- Economic crisis takes place over a duration not more than a few months
- Recession: exponential decline in economic activity
  - Commence after economic crisis arrives at the activity peak
  - Completion after economy arrives at its trough
  - Duration: more than few months but not more than two years
  - Observable on gross domestic product (GDP), actual income, employment, industrial production, and wholesale-retail sales

Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

Economic Crisis/Recession and Depression

- Depression: extremity of recession
  - Observed by exponential unemployment increase
  - Reduction in available credit
  - Significant reduction in trade and commerce
  - Huge number of bankruptcies
  - Volatility in currency value
  - Duration: more than two years

Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

Economic Crisis/Recession and Depression

- An economic crisis and recession → observing reduction in prices of few major commodities
- Increasing productivity and reduction in cost is one of the solution
- Applying same solution, it takes more time to recover form depression
- Example of avoiding crisis→ The main economy of manufacturing location should not be based only one resources

Consumption of Natural Resources

- One of the biggest issues in contrast of economically sustainable development
- As natural resources are main source of revenue in developing countries, it is one of the major source of social conflicts
  - Mining
  - Oil and Gas extraction
  - Demography shifts
  - Difficult economic situations
  - Negative societal behavior
  - Politics
  - Technology

Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

Consumption of Natural Resources

Renewable

- Naturally Available
- Source: Solar, Air, Water, Wind etc.
- Renewable energies can be generated easily

Non-renewable

- Usage is selective based on the type of the industry
- Source: Coal, Oil, Gas, etc.
- Can not be recycled

Source: Garbie, I.H., 2013. DFSME: Design for sustainable manufacturing industries (an economic viewpoint). International Journal of Production Research, 51(2), pp.479-503

Sustainability Assessment of Emerging Issues

Parameters of Emerging Issues (E2)

Technology (E21)	Percentage of Using new Technology comparing with existing one
Government Regulation (E22)	Changes in government regulation (including economy, environment and society)
Growth of Population (E23)	Number of population increased per year
Crisis/ recession/ Depression (E24)	Profitability=productivity X price/cost (opposite of crisis/recession/ depression)
Consumption of Natural resources	Percentage of utilization of re3sources

Sustainability Assessment of Emerging Issues

- Sustainability/Sustainable development
  - $S/SD_{E2} = f(E21, E22, E23, E24, E25)$
  - $S/SD_{E2} = \left(I_{E21}^{Y_{E21}} . I_{E22}^{Y_{E22}} . I_{E23}^{Y_{E23}} . I_{E25}^{Y_{E24}} . I_{E25}^{Y_{E25}}\right)$
  - Where $I_{E2i} = S_{E2i}/E2i$,
  - S_{E2i}= The change towards the sustainability
  - Y_{E2i}= Exponent of the change towards sustainability (S_{E2i}) of $E2i$

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Industry 4.0:
Lean Production System

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What is Lean Production System?

Finishing good inventories through eliminating wastes from processes

- Developed by **Toyota motor corporation**
- It is mainly focusses on **customer's need**

Source: Toyota Production System or Lean Manufacturing
URL: https://www.slideshare.net/haiggg/lean-production-system-tps

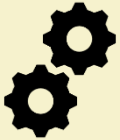
Lean in simple term

Lean Approach

Looks from customers perspective

Other Approach

Looks from tasks and production perspective



Source: The Origin of Lean Manufacturing
URL:https://www.coursera.org/lecture/lean-manufacturing-services/the-origins-of-lean-manufacturing-TKEXN

Lean production system established on...

JIDOKA

- When there is a problem, stop production and stop producing defective products

JUST-IN-TIME

- Each process produces what is needed by the next process in a continuous flow

Source: Toyota Production System or Lean Manufacturing
URL: https://www.slideshare.net/haiggg/lean-production-system-tps

7 Types of wastes

- **Transportation** – Excessive movements of people for materials or information
- **Waiting** – Period of inactivity of people for material or information
- **Motion** – Non value-added movement of people
- **Inventory** – Cost of inventory such as raw materials, work in process, finished goods

Source: The 7 Types of Waste, Lean U
URL: https://www.youtube.com/watch?v=8gExNBPzSJk

7 Types of wastes (Contd..)

- **Over-processing** – Doing more work in product than customer values
- **Defects** – Defects can be in products or paper works
- **Overproduction** – Producing more product sooner than the customers ready for

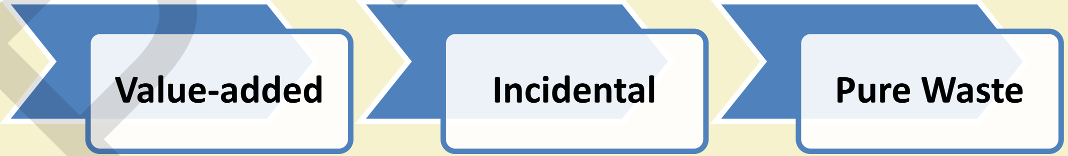
Source: The 7 Types of Waste, Lean U
URL: https://www.youtube.com/watch?v=8gExNBPzSJk

Value streams in Lean

Value streams - All the actions required for a product from <u>order</u> to <u>delivery</u>

It can be done by simply walking through the lifecycle of the product

3 types of works to be noticed ➡



Source: Lean U - Value Streams
URL: https://www.youtube.com/watch?v=U985dxED7e4

5 steps of walk in value streams

- Focus on single value stream
- Build a leadership team
- Schedule date and time
- Walk it – Discuss value, walk together, list and prioritize ideas
- Schedule follow up

Source: Lean U - Walking a Value Stream
URL: https://www.youtube.com/watch?v=P3v5EI6EEog

Lean production in Industry 4.0

- **Concerns integration of humans in plant**
- **Continuous improvement**
- **Concerns on value-added activities**
- **Identifying waste in processes and eliminate**

Source: Mrugalska B, Wyrwicka MK. Towards lean production in industry 4.0. Procedia Engineering. 2017 Jan 1;182:466-73.

Impacts of Lean production system

Through the elimination of waste in processes, it provides best quality, lowest cost, shortest lead time

Source: Lean Production System - TPS
URL: https://www.slideshare.net/haiggg/lean-production-system-tps

Implementation of Lean implies

Implementation of lean → implementation of full manufacturing system

- It does not only focus on lean tools
- In addition it focuses on four main areas such as business requirements, operation improvement, people management, performance governance

Source: The lean manufacturing system; Coursera
URL: https://www.coursera.org/lecture/lean-manufacturing-services/the-lean-manufacturing-system-mqbGU

Implementation of Lean implies (Contd...)

1. Business Requirements

- Set right objectives
- Clear about strategy
- Clear about contributions

Business Requirement

Source: The lean manufacturing system; Coursera
URL: https://www.coursera.org/lecture/lean-manufacturing-services/the-lean-manufacturing-system-mqbGU

Implementation of Lean implies (Contd...)

2. Performance Management

- Refers to people management
- Should have clear **KPI** (**K**ey **P**erformance **I**ndicator) structure
- Top-down management
- Key topics to be covered- **P**roductivity, **Q**uality, **C**osts, **D**elivery, **S**afety

Performance Management

Source: The lean manufacturing system; Coursera
URL: https://www.coursera.org/lecture/lean-manufacturing-services/the-lean-manufacturing-system-mqbGU

Implementation of Lean implies (Contd...)

3. Operation Improvement

- Company should have clear knowledge about all tools of toolbox
- Should not have massive toolbox with unnecessary tools

Operation Improvement

Source: The lean manufacturing system; Coursera
URL: https://www.coursera.org/lecture/lean-manufacturing-services/the-lean-manufacturing-system-mqbGU

Implementation of Lean implies (Contd...)

4. People Engagement

- Develop right capabilities
- Should follow **L**earn, **D**o, **T**each

  Learn – Clear knowledge about tools

  Do – Perform all tools

  Teach – Move into role of teacher to teach about tools

People Engagement

Source: The lean manufacturing system; Coursera
URL: https://www.coursera.org/lecture/lean-manufacturing-services/the-lean-manufacturing-system-mqbGU

Why company should decide to implement lean?

Company should implement lean motivated by three drivers;
Cost, Time, Quality

This leads to company's continuous improvement

Source: How Lean delivers impact in manufacturing; Coursera
URL: https://www.coursera.org/lecture/lean-manufacturing-services/how-lean-delivers-impact-in-manufacturing-S32fw?authMode=signup

References

[1] Source: Toyota Production System or Lean Manufacturing

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[4] Source: Lean U - Value Streams

URL: https://www.youtube.com/watch?v=U985dxED7e4

[5] Source: Lean U - Walking a Value Stream

URL: https://www.youtube.com/watch?v=P3v5EI6EEog

References (Contd..)

[6] Source: Mrugalska B, Wyrwicka MK. Towards lean production in industry 4.0. Procedia Engineering. 2017 Jan 1;182:466-73

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[8]Source: The lean manufacturing system; Coursera
URL: https://www.coursera.org/lecture/lean-manufacturing-services/the-lean-manufacturing-system-mqbGU

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Industry 4.0: Smart and Connected Business Perspective

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Why smart and connected products?

- Connecting the physical objects.
- Sharing the data between physical objects.
- Increasing the resource efficiency.
- Increasing the productivity.

Source: "Industry 4.0:Managing The Digital Transformation", Springer.

Benefits of smart and connected products

- Faster.
- Cheaper.
- Better usage of product.
- Improved recall process of product.
- Decreased environmental impact.
- Smart supply chain.

Source: "Why Your Products Must be Smart and Connected ", TCS.

Medium of getting smart and connected

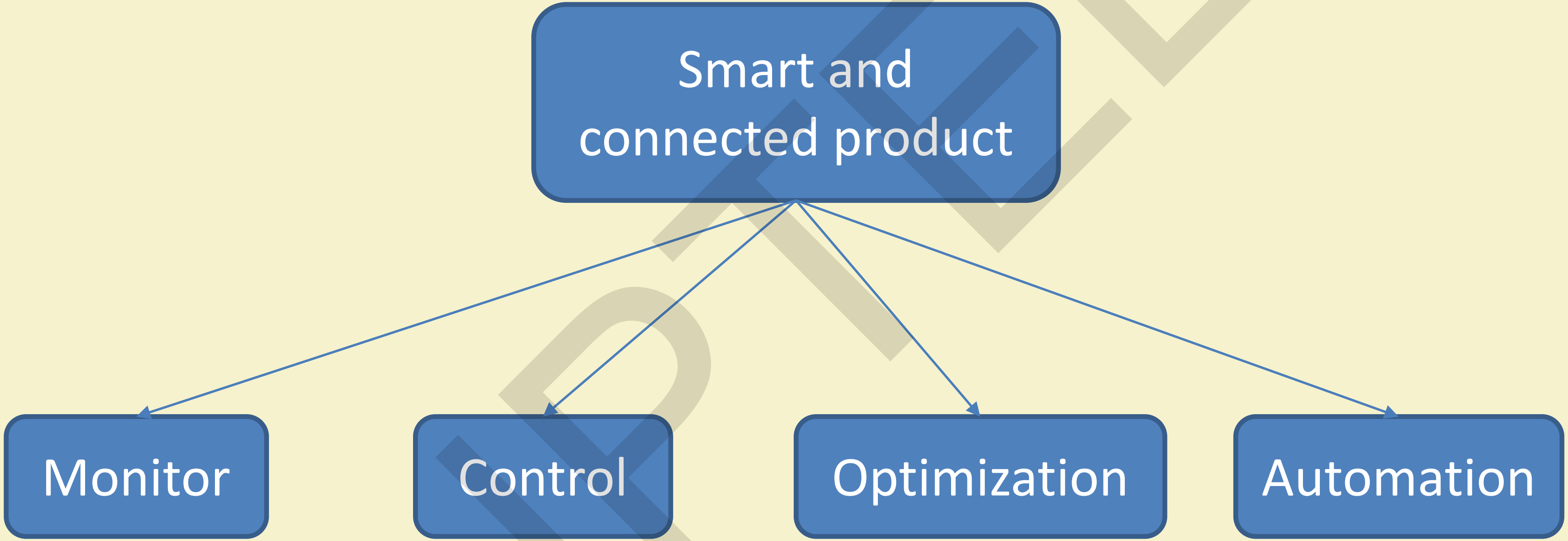
- Embedded Systems.
- Cloud computing.
- Internet of things (IOT).
- Sensors.

Source: “Industry 4.0:Managing The Digital Transformation”, Springer.

Fundamental building blocks

- Customer values.
- Blueprint of profits.
- Key resources.
- Key processes.

Categorization



Monitor

- **Resource:**
  - Sensors.
  - External data sources.
- **Effects :**
  - Health monitoring of products.
  - Generating alerts.
  - Taking action against the odds.

Control

- **Resource**:
  - Custom software.
- **Effects:**
  - Controlling the products.
  - Personalization.

Optimization

- **Resource:**
  - Optimization algorithms.

- **Effects:**
  - Enhances the performance.
  - Enables remote services.
  - Assists in repairing the product.

Automation

- **Resource:**
  - Monitor, control, and optimization capabilities.
  - Software algorithms.
- **Effect:**
  - Autonomous performance of products.

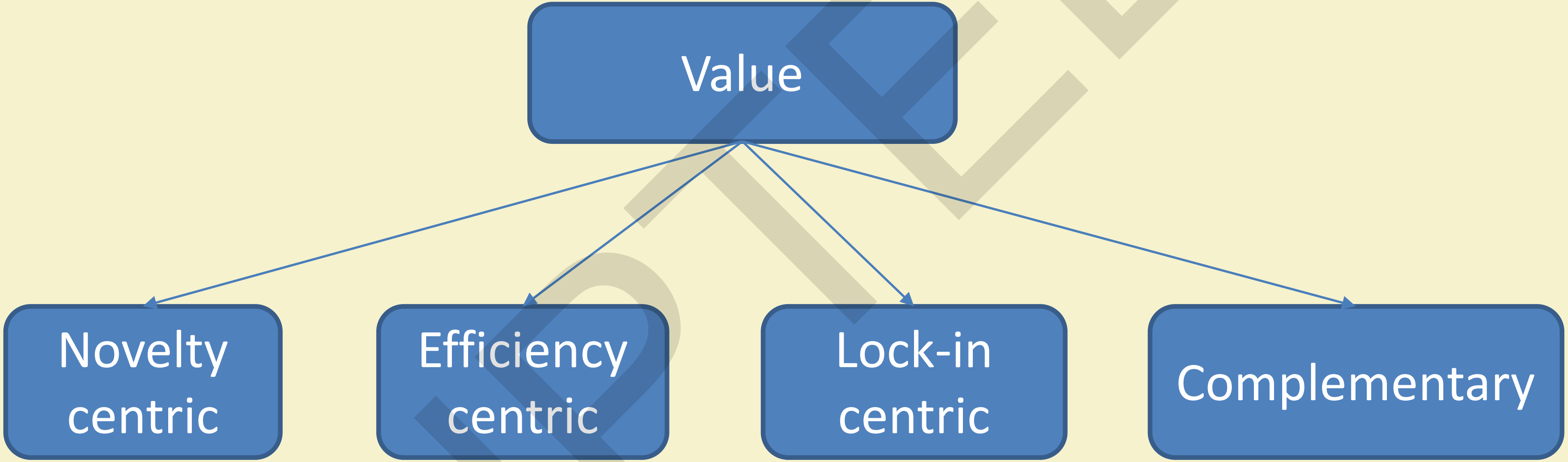
Why smart business model?

- Make the current process less costly.
- Make the process efficient.
- Meet the expected revenue.

Key attributes of smart business model

- Value proposition.
- Revenue streams.
- Technologies.

Value creation in smart business model



Value centric business model

- New market.
- New services.
- Innovation.

Efficiency centric business model

Efficiency makes the transaction –

- Faster.
- Simple.
- Transparent.
- Eliminating the errors.

Lock-in centric business model

- Prevents the customer migration.
- Switching cost.
- Building trust.

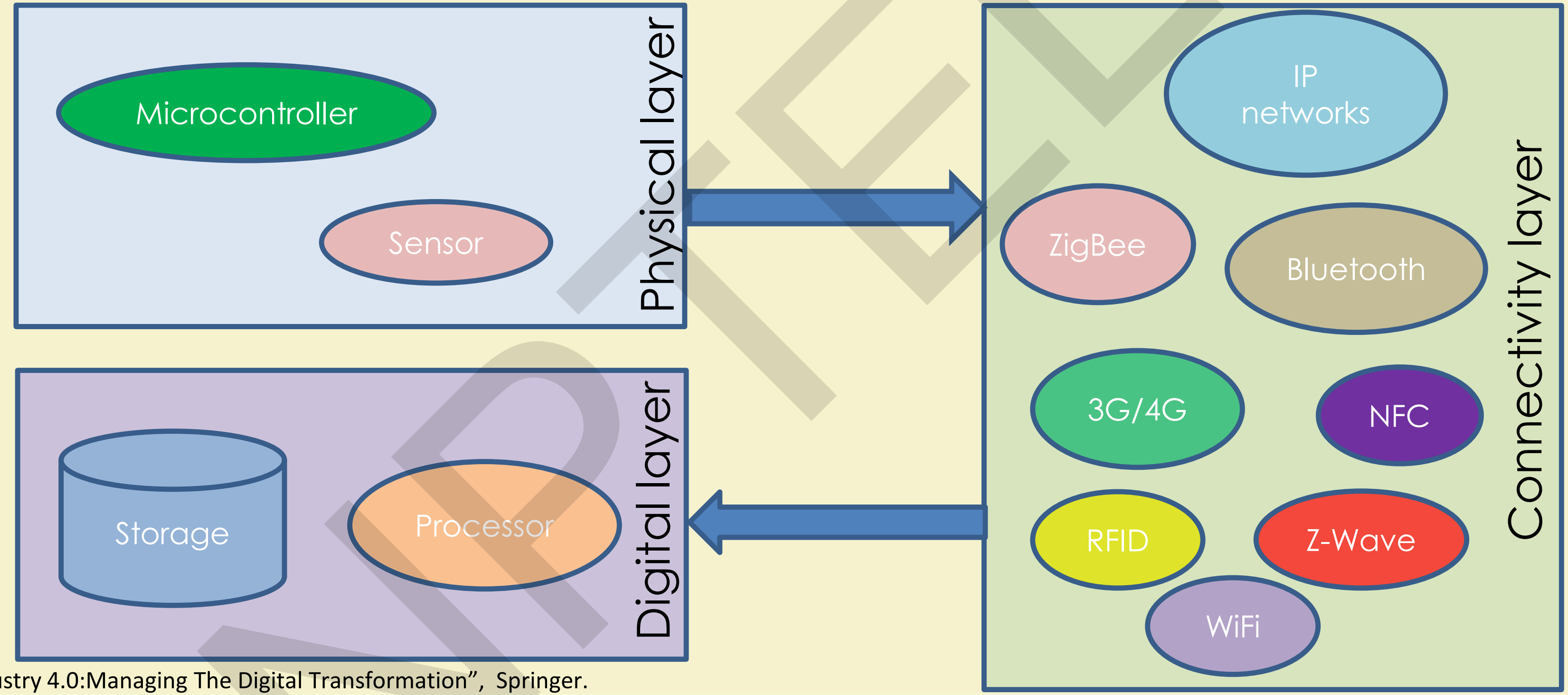
Complementary business model

- Product and services.
- On-line and off-line assets.
- Technologies.
- Activities.

Layers and technologies for creating values

- Physical layer.
- Connectivity layer.
- Digital layer.

Architecture



Source: "Industry 4.0:Managing The Digital Transformation", Springer.

Physical layer

- Responsible for collecting and acquiring data from object or environment.
- Equipped with micro-controllers and sensors.

Connectivity layer

- Connects smart devices, servers.
- Equipped with different communication technology including IP networks, ZigBee, NFC, Bluetooth etc.

Digital layer

- Stores the data.
- Analyzes the data.
- Processes the data

Examples of smart and connected business model

Product	Value proposition	Revenue streams	Physical layer	Connectivity layer	Digital layer
Amazon's dash button	Lock-in	Low cost	WiFi enabled embedded device	WiFi	Connected through mobile application
Semios	Efficiency	Yearly subscription, 24/7 monitoring and assistance	Sensor for soil moisture, insect, disease, climate monitoring	Cellular connectivity	Mobile application.

Source: "Industry 4.0:Managing The Digital Transformation", Springer.

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Thank You!!

Industry 4.0: Smart Factories

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What is smart factory?

➢ According to Deloitte University Press –

"The smart factory is a flexible system that can self-optimize performance across a broader network, self-adapt to and learn from new conditions in real or near-real time, and autonomously run entire production processes. "

Source : "The smart factory", Deloitte

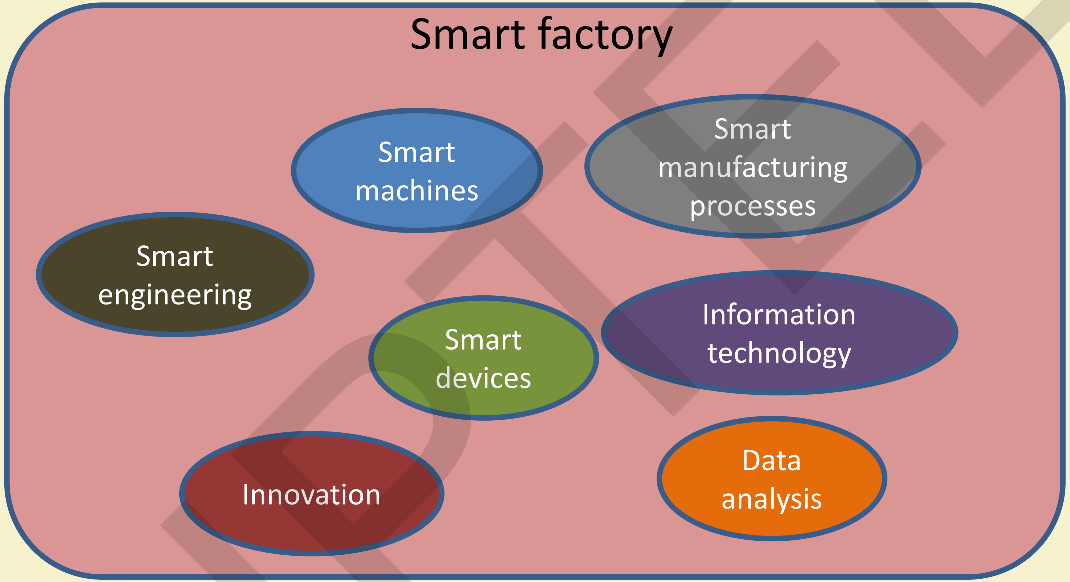
Why do we need smart factories?

- Evolution of technologies.
- High competitive market.
- High amount of production within minimum timeline.
- Reduce risk of failure.

Advantages of running smart factories

- Reducing cost.
- Increasing efficiency.
- Improving quality.
- Improving predictability.
- Improving safety.

Components of smart factory



Source: "Smart factories in Industry 4.0: A review of the concept and of energy management approached in production based on the Internet of Things paradigm. **",** IEEE ICIEEM.

Smart machines

- Communicate with other machines.
- Communicate with other smart devices.
- Communicate with humans.

Smart devices

- Connected with smart devices including
  - Field devices.
  - Mobile devices.
  - Operating devices.

Smart manufacturing process

- Dynamic.
- Automation.
- Real-time.
- Efficient.

Smart engineering

- Smart design of product.
- Smart development of product.
- Smart planning.

Information technology

- Smart software application.
- Monitoring.
- Control.
- Smart management process.

Characteristics of smart factories

- Connection.
- Optimization.
- Transparent.
- Proactivity.
- Agility.

Connection

- Connected smart devices.
- Connected smart machines.
- Connected with data.
- Connected processes.

Optimization

- Optimizing the task scheduling.
- Optimizing the use of energy.
- Optimizing the cost of production.
- Optimizing the tracking.
- Optimizing the throughput.
- Optimizing the reliability.

Transparent

- Real-time monitoring.
- Taking required action on time.
- Generating alert messages.
- Real-time tracking.

Proactivity

- Predicting the quality issues.
- Improving safety.
- Forecasting the future outcomes.
- Predicting the future challenges.

Agility

- Flexibility.
- Adaptation.
- Self-configuration.

Supporting technologies for smart factories

- Big Data.
- Cloud computing.
- Smart grid.

Use of Cloud computing in smart factories

- Provides the capability of high-performance computing.
- Easy access for product designing software and tools.
- Easy access for present and past data for analyzing.
- Scalability provides freedom in terms of computing and data storage.

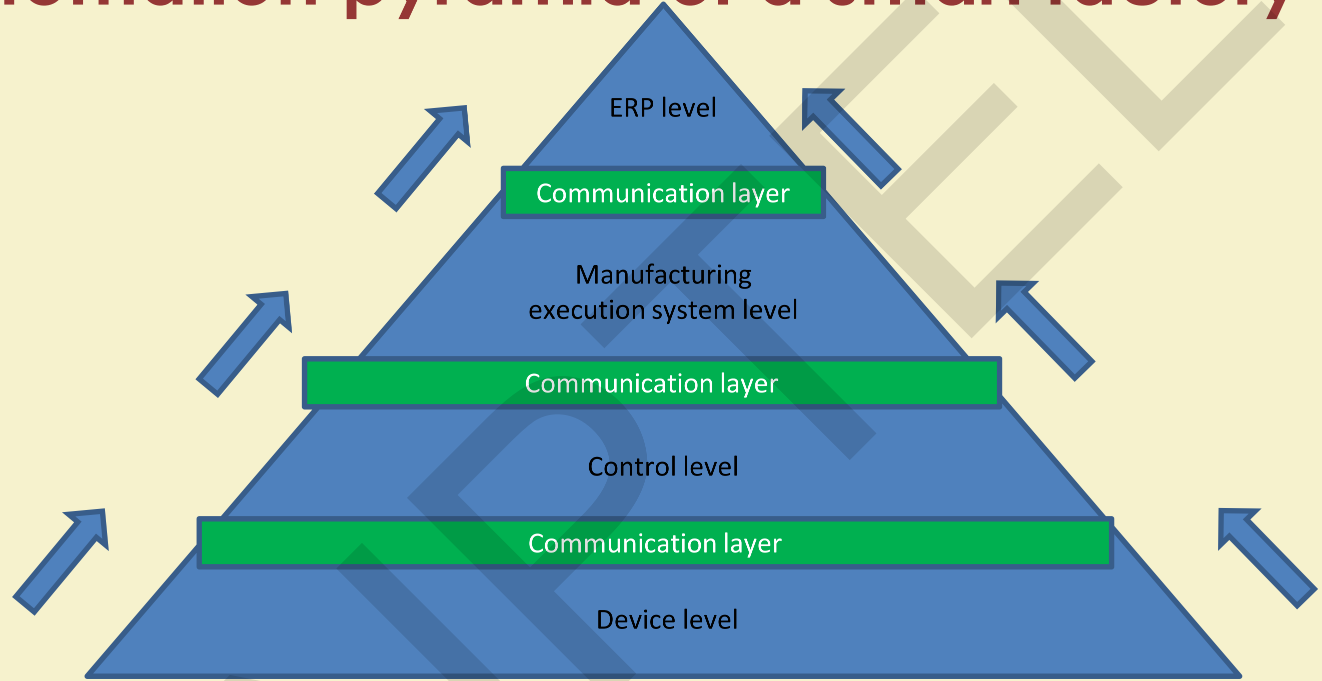
Use of Big Data analytics in smart factories

- Generating knowledge.
- Improving value streams.
- Future prediction.
- Key Performance Indicator (KPI).

Use of smart grid in smart factories

- Persistence in energy consumption.
- Load balancing.
- Reduction of energy consumption cost.
- Increase the life cycle of electronic equipment.

Automation pyramid of a smart factory



Source: "Towards a factory-of-things", ESLEVIER

Use of augmented reality in smart factories

- Operate instruments from remote.
- Providing precision.
- Providing safety especially for radio active zones.

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Industry 4.0:
Cyber-Physical Systems and Next-Generation Sensors

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What are Cyber-Physical Systems?

- *"Cyber-Physical Systems or 'smart' systems are co-engineered <u>interacting networks of physical and computational components</u>. These systems will provide the foundation of our critical infrastructure, form the basis of emerging and future <u>smart services</u>, and improve our <u>quality of life</u> in many areas."*

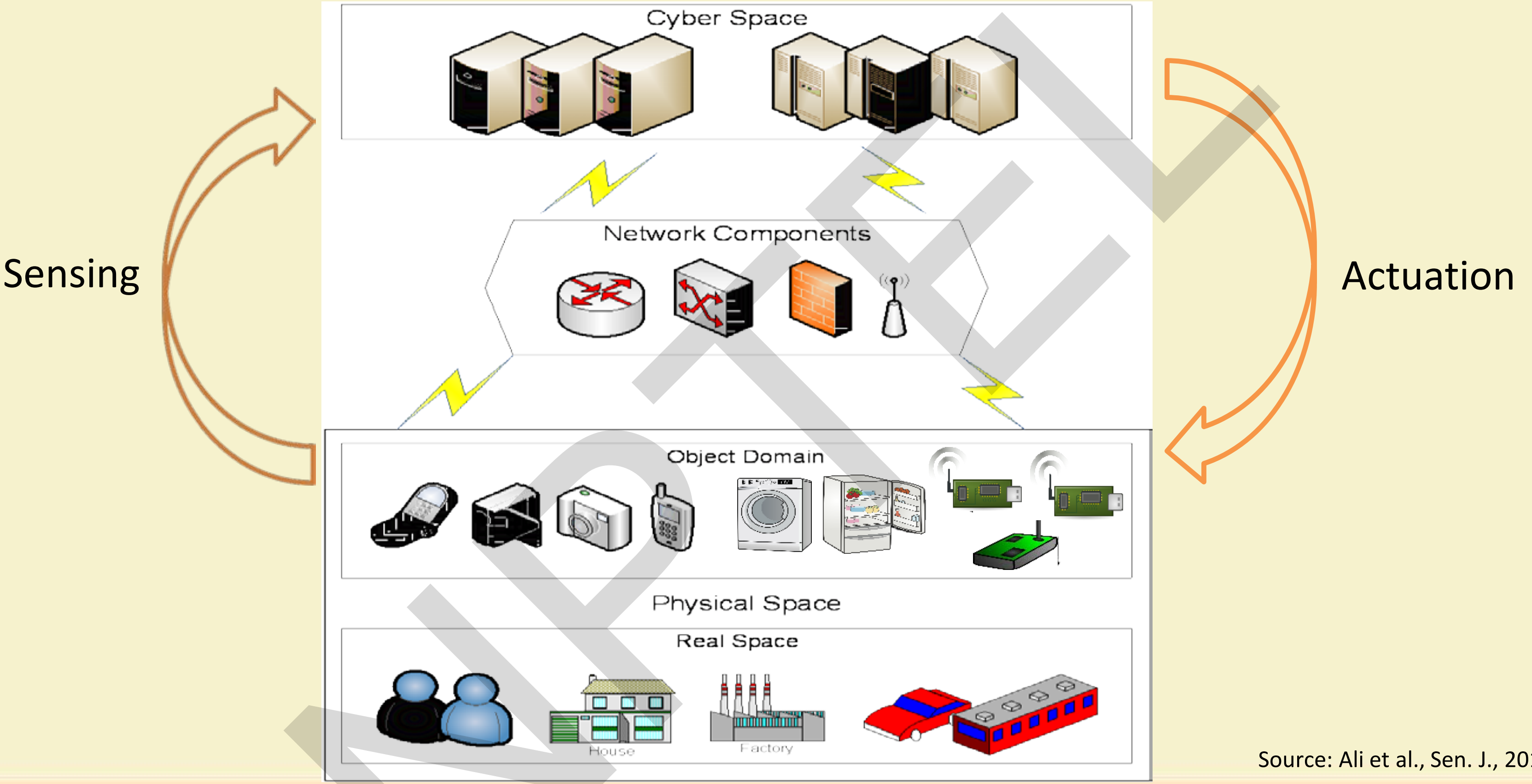
  -- NIST, Engineering Laboratory

What are Cyber-Physical Systems? (Contd.)

- Generalization of “embedded” systems
  - Possess *compute, communicate* and *control* capabilities
  - Interaction with the physical world through sensors and actuators.

- Examples:
  - Medical instruments
  - Transportation vehicles
  - Defense systems
  - Robotic equipment
  - Process monitoring and factory automation systems

Source: Lee, IEEE ISORC, 2008



Source: Ali et al., Sen. J., 2015

Differences with Embedded Systems

Embedded Systems	CPS
Devices having information processing systems embedded into them	Complete system having physical components and software
Typically confined to a single device	Networked set of embedded systems
Limited resources for performing limited number of tasks	Not resource constrained
Main issues are real-time response and reliability	Main issues are timing and concurrency

Source: Lee, IEEE ISORC, 2008

Features of Cyber-Physical Systems

- Reactive Computation:
  - Interact with environment in an ongoing manner
  - Sequence of observed inputs and outputs
- Concurrency:
  - Multiple processes running concurrently
  - Processes exchange information to achieve desired result
  - Synchronous or asynchronous modes of operation

Source: R. Alur, Principles of Cyber-Physical Systems, The MIT Press

Features of Cyber-Physical Systems (Contd.)

- Feedback Control of the Physical World:
  - Equipped with *control systems* with feedback loop
  - Sensors sense environment and Actuators influence it
  - *Hybrid* control systems for complex tasks
- Real-Time Computation:
  - Time sensitive operations such as coordination, resource-allocation
- Safety-Critical Applications:
  - Precise modelling and validation prior to development

Source: R. Alur, Principles of Cyber-Physical Systems, The MIT Press

Applications of CPS: Healthcare

- Highly accurate medical devices and systems
  - Image-guided surgery and therapy
  - Control of fluid flow for medicinal purposes and biological analysis
  - Intelligent operating theatres and hospitals
- Engineered systems based on cognition and neuroscience (e.g., brain-machine interfaces, therapeutic and entertainment robotics, orthotics and exoskeletons, and prosthetics)

Source: Baheti and Gill, Cyber Physical Systems, Tech. Rep., IOCT, 2011

Applications of CPS: Transportation

- Infrastructure-based transportation CPS
  - Real-time monitoring of traffic infrastructure (traffic signals, cameras, etc.) and traffic control
- Vehicle-Infrastructure-coordinated transportation CPS
  - Transit signal priority, queue warning (for e.g., ambulances)
- Vehicle-based transportation CPS
  - Proximity detection for safety
  - Vehicle health monitoring

Source: Baheti and Gill, Cyber Physical Systems, Tech. Rep., IOCT, 2011

Applications of CPS: Smart Grid

- Smart meters
  - Demand management with distributed generation
  - Automated distribution with intelligent substations
  - Wide-area control of Smart grids
- Phasor measurement units (PMUs)
- Data aggregation units (DAUs)

Source: Rajkumar et al., DAC, 2010

Applications of CPS: Industry

- Manufacturing systems and logistics integrated with communication abilities, sensors and actuators
  - Smart control
  - Optimal resource utilization
  - Smart diagnostics and maintenance
- Flexibility of development of systems
- End products customized specific to needs of customers

Source: Rajkumar et al., DAC, 2010

CPS Architecture for Industry 4.0

- Designing CPS-based manufacturing systems for Industry 4.0
- “5C architecture” comprising of 5-levels
  - Connection
  - Conversion
  - Cyber
  - Cognition
  - Configuration

Source: Lee et al., Manufacturing Letters, 2015

CPS Architecture for IIoT: Connection

- Smart connections to ensure accurate data is obtained from the IIoT devices
- Two factors to be considered:
  - Obtaining seamless and tether-free data
  - Selection of sensors with proper specifications

Source: Lee et al., Manufacturing Letters, 2015

CPS Architecture for IIoT: Conversion

- Conversion of machine data to meaningful information
- Data analysis tools and methodologies to be developed for
  - Prognostics and health monitoring of machine components
  - Multi-dimensional data-correlation
- Machines become self-aware

Source: Lee et al., Manufacturing Letters, 2015

CPS Architecture for IIoT: Cyber

- Central information hub
  - Gathers system information from fleet of machines
    - Obtaining precise status information of individual machines
    - Rating of performance of individual machines among fleet
    - Predicting future behavior of machines based on historical data
  - Utilize clustering for data mining
- Machines achieve self-comparison ability

Source: Lee et al., Manufacturing Letters, 2015

CPS Architecture for IIoT: Cognition

- Proper presentation of information to users for generating thorough knowledge of the system
- Collaborative diagnostics
- Decision making for:
  - Prioritization
  - Optimization processes

Source: Lee et al., Manufacturing Letters, 2015

CPS Architecture for IIoT: Configuration

- Supervisory control to determine actions to be taken by the machines:
  - Self-configuration for resilience
  - Self-adjustment for variations
  - Self-optimization for disturbances
- Machines become self-adaptive

Source: Lee et al., Manufacturing Letters, 2015

Challenges for CPS Development

- Safety, security and robustness
- Hybrid control systems
- Computational and real-time embedded system abstractions
- Sensor and mobile networks
- Architecture and modelling
- Verification, validation and certification
- Education and training

Source: Sha et al., IEEE SUTC, 2008

Next-Generation Sensors

Need for Next-Generation Sensors

- Interoperability of networks, transducers and control systems of different manufacturers
- Compatibility of sensors with multiple sensor actuator bus standards, reducing wiring cost and complexity
- Interconnection of analog transducers with digital networks
- Increasing usage of existing networks instead of proposing new standards

Source: Gervais-Ducouret, IEEE SAS, 2011

What are Next-Generation Sensors?

- "Smart Sensors" –
  - Integration of sensors and actuators with a processor and a communication module.
  - Defined in IEEE 1451 Standard as:

    "Sensors with small memory and standardized physical connection to enable the communication with processor and data network"
  - Functionalities - Self calibration, Communication, Computation, Multi-sensing, Cost improvement

Source: Spencer Jr et al., J. STC, 2004

What are Next-Generation Sensors? (Contd.)

- Limitations of Smart Sensors –
  - Pre-defined embedded functions, customization not possible
  - Narrow application spectrum
  - Sensor data aggregation not possible
  - External processor for sensor calibration
  - Basic communication protocols
- To overcome these, next generation sensors–

  "Intelligent Sensors"

Source: Gervais-Ducouret, IEEE SAS, 2011

What are Next-Generation Sensors? (Contd.)

- "Intelligent Sensors" –
  - Capable of processing sensed data and performing pre-defined functions by processing data
  - Capable of customizing embedded algorithms on the fly
  - Capable of managing and controlling external sensors/devices
  - Comprises of a sensor, a microcontroller, a memory unit comprising of flash, RAM and ROM, and a platform for running sensor applications

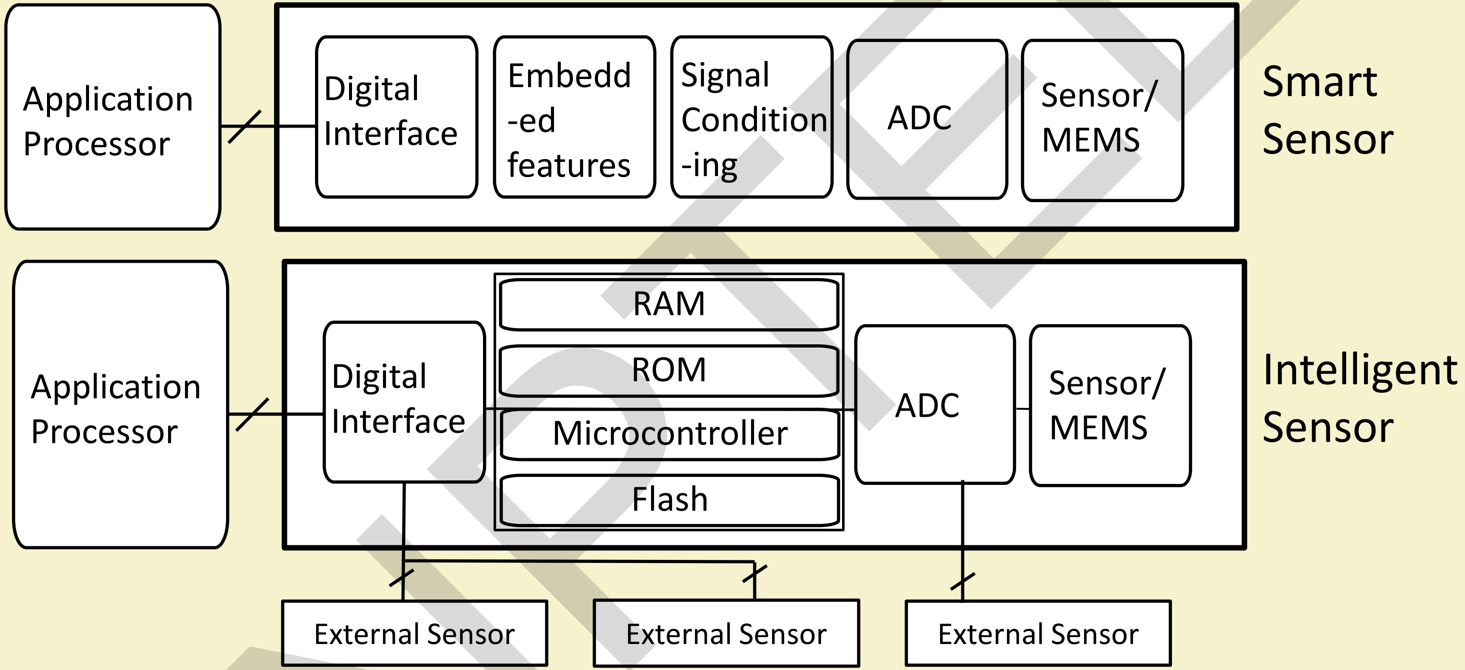
Source: Gervais-Ducouret, IEEE SAS, 2011

What are Next-Generation Sensors? (Contd.)

- Advantages of Intelligent Sensors –
  - Reduce data communication
  - Reduced power consumption
  - Application-specific customization of sensor nodes
  - Continuous calibrating and monitoring of the sensors
  - Adaptive sampling rate and sleep-wake cycles
  - Shorter software development time
  - Improved compatibility of sensors

Source: Gervais-Ducouret, IEEE SAS, 2011

What are Next-Generation Sensors? (Contd.)



Source: Gervais-Ducouret, IEEE SAS, 2011

Next-Generation Sensors: Applications

- Automatic assembly in factories
- Smart fabric and intelligent textiles
- Advanced driving assistance systems
- Fault detection and forecast using machine intelligence
- Non-invasive biomedical analysis
- Chemical composition analysis
- Resource lifecycle management

Source: Gervais-Ducouret, IEEE SAS, 2011

Next Generation Sensors: Design Challenges

- Hardware Issues –
  - Limited power
  - High response time
  - Synchronization
  - Limited bandwidth
  - Security issues
- Software Issues –
  - Software partitioning with applications processor

Source: Gervais-Ducouret, IEEE SAS, 2011

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Industry 4.0:
Collaboration Platform and Product Lifecycle Management

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What is Collaboration platform?

- Category of business software which combines organizational networking capacities to operations.
- It includes <u>knowledge management</u> into business operation to encourage renovation.
- Collaboration platform helps employees to <u>share information</u> and solve business problems.

Source: Techtarget.com: Collaboration-platform

What is Collaboration platform? (Contd.)

- There are some perspectives to build collaboration platforms.
  - A social layer is combined with provision of business utilizations.
  - New products are implanted with collaboration tools.
- There are some common attributes in business collaboration platforms.
  - Easily accessible and easy to use.
  - They require some familiar functions which help team collaboration.
- Example: **ProWork Flow**
  - Web-based project management designed for Managers
  - Collaborate to improve project delivery

Source: Techtarget.com: Collaboration-platform

Collaboration Productivity in Industry 4.0

- Collaboration Productivity
  - There are four key parts, which enable collaboration productivity:
    - IT Proliferation
    - Single Source of Truth
    - Industrialization
    - Coordination

Source: Collaboration Mechanisms to increase Productivity in the Context of Industries 4.0

Collaboration Productivity in Industry 4.0 (Contd.)

- IT Proliferation
  - It shows the huge impact of computers on economic growth and their impact on increased capital stock's shares.
  - Industries are required to consider and promote global information technology and computing power.
  - Storage capacity and high speed computing are increasing day by day.

Source: Collaboration Mechanisms to increase Productivity in the Context of Industries 4.0

Collaboration Productivity in Industry 4.0 (Contd.)

- Single Source of Truth
  - It is a kind of practice of formatting <u>information models to store every data element exactly once</u>.
  - SSoT must employ the right software for decision making.
  - SSoT is needed to be realized across the whole product lifecycle, so that even a single change in product associated information is visible.

Source: Collaboration Mechanisms to increase Productivity in the Context of Industries 4.0

Collaboration Productivity in Industry 4.0 (Contd.)

- Industrialization
  - It is the bridge between the virtual world and the physical environment.
  - Physical environment is linked with the virtual world using CPS, which fix computers and sensors into an application platform.
  - It requires intuitive and self-effective elements.
  - For dynamic objectives in technology and industrial area, it adapts the system behaviour like smart factories.

Source: Collaboration Mechanisms to increase Productivity in the Context of Industries 4.0

Collaboration Productivity in Industry 4.0 (Contd.)

- Coordination
  - Stronger coordination between multiple industry agents is required in Industry 4.0 for enabling collaboration productivity.
  - It can be initiated in two steps:
    - First, establish a network which communicates with overall target.
    - Second, provide authority to decision-makers in a decentralized system.
  - This network is maintained by encouraging the exchange of the employees or by using smart devices.

Source: Collaboration Mechanisms to increase Productivity in the Context of Industries 4.0

Product Lifecycle Management (PLM)

- It is a type of business activity to manage the lifecycle of a product.
- PLM works as a management system for a company's products.
- PLM handles a product completely, from single part of the product to entire portfolio of that product.
- **Example**: Computational Intelligence System (CIS)

Source: Product Lifecycle Management: Stark

Product Lifecycle Management (PLM) (contd.)

- The main goal of PLM is:
  - To maximise product revenues.
  - To decrease product-associated costs.
  - To increase product's value.

Source: Product Lifecycle Management: Stark

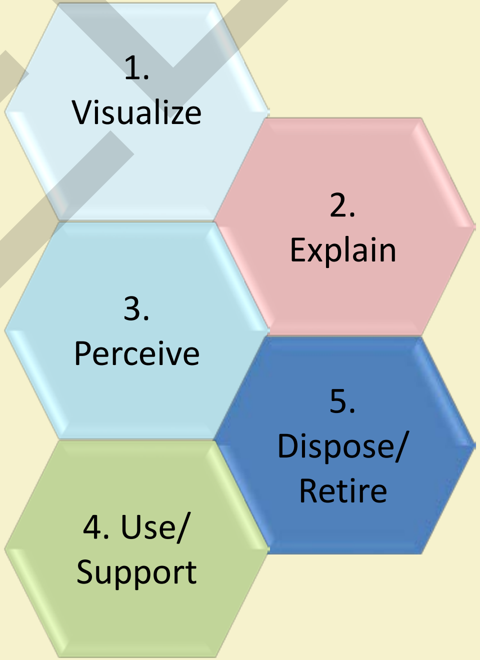
P, L and M in PLM

- The P of PLM
  - P means product in PLM.
  - The product has an essential role in industry.
  - The product is origin of <u>company earnings</u>.
  - There are <u>no services without product</u>.
  - An industry leads in industry sector because of its products.
  - Product has different type of shapes and sizes.

Source: Product Lifecycle Management: Stark

P, L and M in PLM (Contd.)

- The L of PLM
  - L stands for lifecycle.
  - Product lifecycle has five phases.



Source: Product Lifecycle Management, Stark J

The P, L and M in PLM (Contd.)

- **Visualization**: People have an idea regarding the product.
- **Explanation**: This idea is transformed into a representation.
- **Perceiveness**: By the end of the phase, the product is in its final form.
- **Use/Support**: The customer starts to use the product in use/support phase.
- **Retire**: Company retires a product when it is not useful.

Source: Product Lifecycle Management: Stark

P, L and M in PLM (Contd.)

- The M in PLM
  - M means management in PLM.
  - Product management has:
    - Coordination and institution of product-related devices.
    - Fix objectives, capability of decision taking and result control.
  - To ensure that a product works well, it is managed across its lifecycle and management guarantees that the product will earn the profit for the company.

Source: Product Lifecycle Management: Stark

PLM for Industry 4.0

- The efficiency and effectiveness of PLM has an important role in today's enterprise operation systems.
- This efficiency and effectiveness of PLM improves market share and market size with increasing revenue.
- PLM system manages product's portfolio. It also manages the services from the initial concept to the final disposal.

Source: Product Lifecycle Management: Stark

Business Objectives of PLM for Industry 4.0

- Financial Performance
  - Increase market revenue, reduce development cost, etc.
- Time Reduction
  - Reduce project time overrun, decrease profitable time(in less time more profit) , etc.
- Improve Quality
  - Decrease defect rate in manufacturing , increase customer satisfaction rate, etc.
- Business Improvement
  - Decrease the delay time in new product release, ensure 100% configuration conformity, etc.

Source: Product Lifecycle Management: Stark

Scope of PLM

- There are nine components in PLM to handle a product across its lifecycle.

Source: Product Lifecycle Management, Stark J

Scope of PLM (Contd.)

- **Objectives and Metrics**
  - The objective of the company for PLM is to improve quality and business, reduce the time, improve financial performance.
  - Key Performance Indicators (KPIs), which are known as metrics set targets for the company.
- **Organisation and Management**
  - Resource management and company's effectiveness are crucial for PLM.
  - Plans must organize in such a way such that all resources are managed to fulfil the desired objectives.

Source: Product Lifecycle Management: Stark

Scope of PLM (Contd.)

- **Activities**
  - There are many product associated activities such as idea management, program management, new product development.
- **People**
  - Many people are involved to progress and maintain a product. E.g.- Business analyst, cost accountant etc.
- **Product Data**
  - It is a major asset throughout the product lifecycle.
  - Product will face problem, if we provide false product data.

Source: Product Lifecycle Management: Stark

Scope of PLM (Contd.)

- **Product Data Management System**
  - It manages all the generated product data and it is used for product lifecycle.
  - It provides correct information at the right time.
- **PLM Applications**
  - To get desired performance levels, these applications are responsible for enabling the people to take decisions.
  - These applications support the people to build and maintain the products.

Source: Product Lifecycle Management: Stark

Scope of PLM (Contd.)

- **Equipment and Facilities**
  - Product lifecycle use equipment and facilities in every phase.
  - They are required to produce, maintain and service the product.
  - Cost and quality of the product are effected by them.
- **Techniques and Methods**
  - To refine production across the lifecycle by means of product progress time, product cost etc. many methods and techniques are proposed:
    - ABC (Activity Based Costing)
    - Concurrent Engineering
    - DFS (Design For Sustainability)
    - LCA (Life Cycle Assessment)

Source: Product Lifecycle Management: Stark

Challenges in PLM for Industry 4.0

- **Business Drivers**
  - There are new business challenges for PLM in Industry 4.0.
  - Challenges
    - Product lifecycle is short.
    - Outsourcing is increasing.
    - Products' structure is complex.
  - Increase in speed, increase in demand and quality of product are the other challenges to drive a business.

Source: Product Lifecycle Management: Stark

Challenges in PLM for Industry 4.0 (Contd.)

- **Industrial Requirement**
  - To design products virtually, geographically dispersed design teams and supply chain partners are required to collaborate.
  - A new perspective must be generated to hold net-centric technology. This perspective will be able to free the inherent value in today's enlarged business model.
  - Perform project management, exchange and maintain product information is a challenge in industry.

Source: Product Lifecycle Management: Stark

The Ten Step Approach: PLM solution in Industry4.0

- It is based on working experience of companies in Industry sector.
- This approach has ten steps.

Data Gathering	Education of PLM	Practice of management in PLM	PLM Concept Generation	PLM Roadmap Generation
Development Strategy	Rate of Interest Calculation	Management Report Preparation	Executive Presentation	Executive Decision Support

Source: Product Lifecycle Management: Stark

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Industry 4.0:

Augmented Reality and Virtual Reality

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Augmented Reality and Virtual Reality in IIoT

- From the technological perspective, Augmented Reality (AR) and Virtual Reality (VR) are used in several contexts and sectors in Industry 4.0.
  - AR and VR plays important role in the primary stages where optimization and productivity are important in manufacturing industry.
  - The efficiency of warehouses are improved using various AR applications.
  - AR and VR also plays an important role in safety training, thereby the potential safety hazards can be easily located.

“Manufacturing”, Reality technologies

Augmented Reality and Virtual Reality in IIoT (contd.)

- Use cases:
  - Machining and production
  - Education and collaboration
  - Assembly
  - Safety and security
  - Digital prototyping
  - Factory planning
  - Maintenance and inspection

"Virtual-reality-vr-augmented-reality-ar-trends", I-scoop

Augmented Reality (AR)

- Augmented Reality is
  - an enhanced version of reality
  - direct/indirect views of physical world environments are "augmented" with computer-generated superimposed images
  - adds digital elements into their actual environment
  - amplifies the present perception of reality.

"Augmented Reality", Reality technologies
" Augmented Reality", Techtarget

Key Features of AR

- The key features of AR are:
  - It lies in the middle of the mixed reality spectrum.
  - It provides multiple sensor modalities – visual, auditory, and haptic.
  - It utilizes the existing environment and overlays new information on top of it.

“Augmented Reality”, Reality technologies
“ Augmented Reality”, Techtarget

Chronological order of Augmented Reality

Idea of Electronic display/ spectacles
L. Frank Baum (author, 1901)

Published heads up display for teaching real-world flight skills
Gavan Lintern (University of Illinois, 1980)

Coined the term Augmented Reality
Thamos Caudell (Boeing Researcher, 1990)

First functioning AR system
Louis Rosenberg (1992)

Battlefield Augmented Reality System (BARS)
US Naval research laboratory (1999)

Google glass
Google (2013)

"Augmented Reality", Wikipedia

Applications of Augmented Reality

“Augmented Reality”, Wikipedia

Applications of Augmented Reality (contd.)

AR Eyeglasses

Head-up display

Medical Applications

Key components of devices:

- Sensors and Cameras
- Projection Screen
- Processing unit
- Reflection

"Ar glasses", Uploadvr
"Medical Research", Pehub

Types of Augmented Reality

- Marker-Based Augmented Reality
- Markerless Augmented Reality
- Projection Based Augmented Reality
- Superimposition Based Augmented Reality

"Augmented Reality", Reality technologies

Types of Augmented Reality (contd.)

- Marker-based augmented reality gives an outcome when the reader is sensed by the camera and visual marker.
  - camera: differentiates between a marker and a real object.
  - marker: recognizes simple, distinct patterns and can be easily processed.

- Markerless augmented reality is commonly utilized for mapping directions. The location is provided based on the GPS, digital compass, or accelerometer, which is attached to the device.

"Augmented Reality", Reality technologies

Types of Augmented Reality (contd.)

- Projection-based augmented reality gives an outcome by projecting light onto real world surfaces.
  - It allows human interaction by sending light.
  - It differentiates between the expected projection and altered projection.

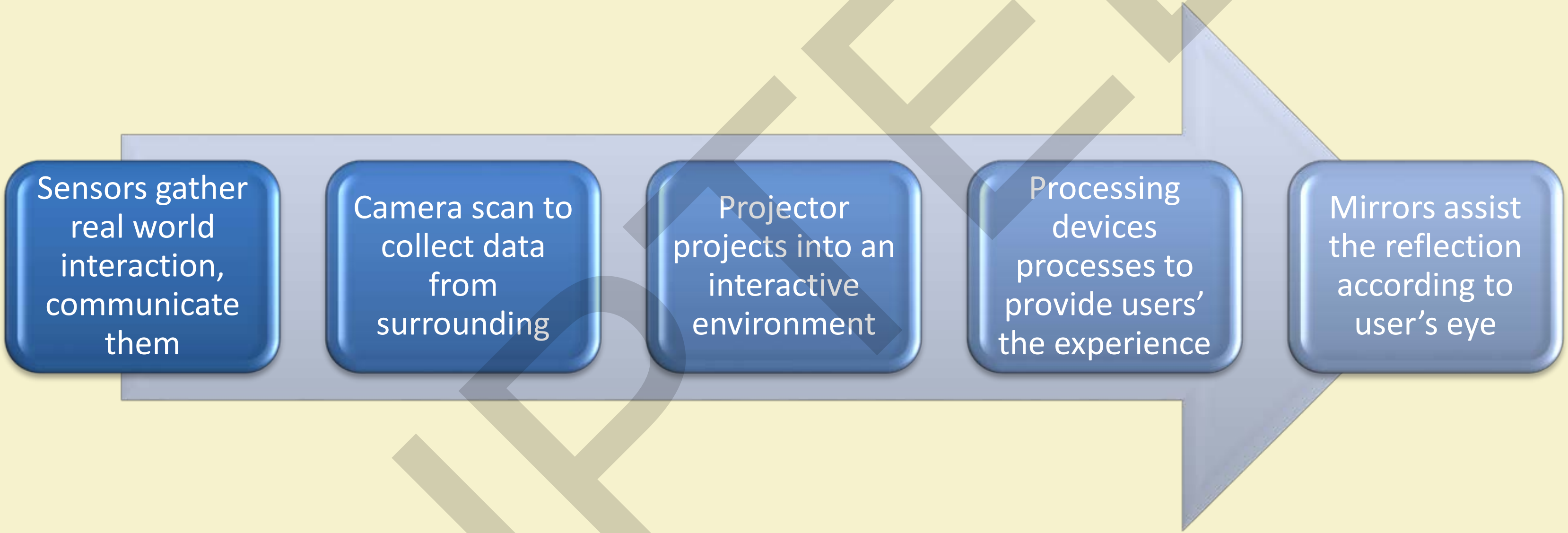
"Augmented Reality", Reality Technologies

Types of Augmented Reality (contd.)

- Superimposition-based augmented reality partially or fully substitutes the original view of the object with the augmented view.
  - Object recognition plays an important role
  - Application cannot replace the original view with the augmented one.

"Augmented Reality", Reality technologies

How do Augmented Reality works ?



"Augmented Reality", Reality technologies

Virtual Reality (VR)

- Virtual Reality is
  - a mixture of interactive hardware and software based artificial environment
  - a realistic three-dimensional image is created
  - presented to the user, in such a way so that they interacts with the real or physical world.

"Augmented Reality", Reality technologies

Key Features of VR

- The key features of VR are:
  - It creates and enhances an imaginary reality.
  - It gives the perception of being physically present in a non-physical world.
  - It incorporates auditory and visual sensory feedback.
  - It allows users to get naturally absorbed into the virtual environment.

"Augmented Reality", Reality technologies

Chronological order of Virtual Reality

Experience Theatre

Morton Heilig (film-maker, 1962)

Sword of Damocles

Ivan Sutherland (MIT Computer Scientist, 1968 God father of VR displays)

Coined the term Virtual Reality

Jaron Lanier (American Philosopher and Scientist, 1987)

Produced navigable virtual worlds

David EM (First artist, 1977 - 1984)

Large Expanse, Extra Perspective (LEEP) optical system

Eric Howlett (1979)

Google's first-ever "resident artist"

Michael Naimark (2015)

"Virtual Reality", Wikipedia

Applications of Virtual Reality

- Real estate agents
- Entertai nment
- Robotics
- Astronauts
- Health and Safety
- 3-D artists
- Educati on
- Mass surveillance

"Virtual Reality", Wikipedia

Applications of Virtual Reality (contd.)

VR Headset

Military Applications

Key components of headsets:

- Sensors – Magnetometer, Accelerometer, and Gyroscope
- Lenses
- Display screens
- Processing unit

"Glasses", Uploadvr
"Sony-hmz", Polygon

Types of Virtual Reality

- Non-immersive Simulations
- Semi-immersive Simulations
- Fully-immersive Simulations

"Virtual Reality", Reality Technologies

Types of Virtual Reality (contd.)

- Non-immersive simulations utilizes only a subset of the user's senses.
  - User enters into the virtual environment through a portal or window
  - Users allows a peripheral awareness of the reality outside the virtual reality simulations.

"Augmented Reality", Reality Technologies

Types of Virtual Reality (contd.)

- Semi-immersive simulations provides a partial or fully immersive experience of the user's senses. The simulations are :
  - powered by high performance graphical computing system, and
  - coupled with a large screen projector.

"Virtual Reality", Wikipedia

Types of Virtual Reality (contd.)

- Fully-immersive simulations provides realistic experience to the users. The simulations
  - delivers a wide field of view, and
  - uses head-mounted displays and motion detecting devices to simulate user's experiences.

"Virtual Reality", Reality Technologies

How do Virtual Reality works ?

Sensors estimate the user's motion and direction in space

Lenses focus and reshape the image for each eye

Processing units takes the input information from user, process them, and creates sensations for user.

Display screen displays the user view through the lenses.

"Virtual Reality", Reality Technologies

Similarities of AR and VR

"Virtual Reality", Reality Technologies

Comparison of AR and VR

Augmented Reality	Virtual Reality
• It adds digital elements to the actual environment. • It delivers virtual elements as an encrust of the real world.	• Immersive application, which affects the experience of user. • It offers a digital recreation of a real life setting.

"Virtual Reality", Reality Technologies

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Industry 4.0: Artificial Intelligence

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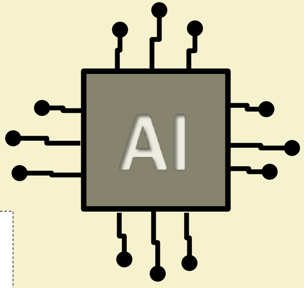
What is Artificial Intelligence (AI)?



"AI is a branch of computer science that deals with the study and the creation of computer systems that exhibit some form of intelligence."

- Patterson

"AI is the study of mental faculties through the use of computational models."

- Eugene Charniak and Drew McDermott

Source: Artificial Intelligence by David L. Poole, Alan K. Macworth, Artificial Intelligence by Rajiv Chopra

What is Artificial Intelligence (AI)? (Contd..)

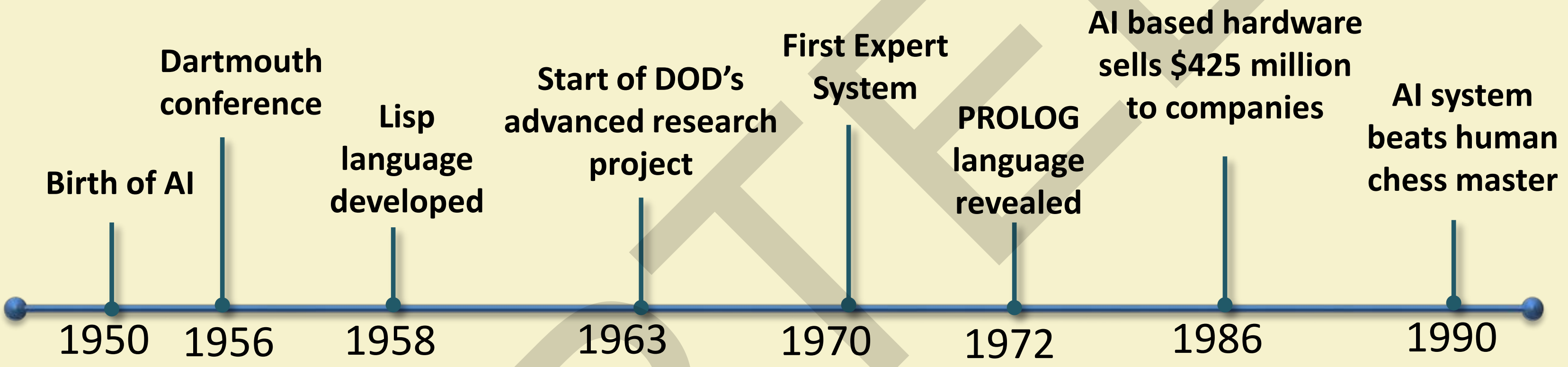
Artificial + Intelligence = Artificial Intelligence

- Artificial → *Manmade*
- Intelligence → *Thinking power*
- Artificial Intelligence → *Creation of manmade thinking power*

In simple way, *Artificial Intelligence* is a creation of software having intuitive decision making ability.

Source: Artificial Intelligence by David L. Poole, Alan K. Macworth, Artificial Intelligence by Rajiv Chopra

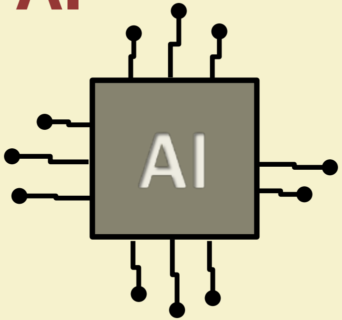
History of AI



The first use of phrase Artificial Intelligence was proposed by **John McCarthy** in 1956 in the article *A Proposal for Dartmouth Summer Research Project on Artificial Intelligence*

Source: Artificial Intelligence by David L. Poole, Alan K. Macworth, Artificial Intelligence by Rajiv Chopra

Difference between program with and without AI



A computer program without AI uses large database and uses <u>algorithmic search</u> method whereas computer program with AI uses large knowledge base and <u>heuristic search</u> method

Source: Artificial Intelligence by Rajiv Chopra

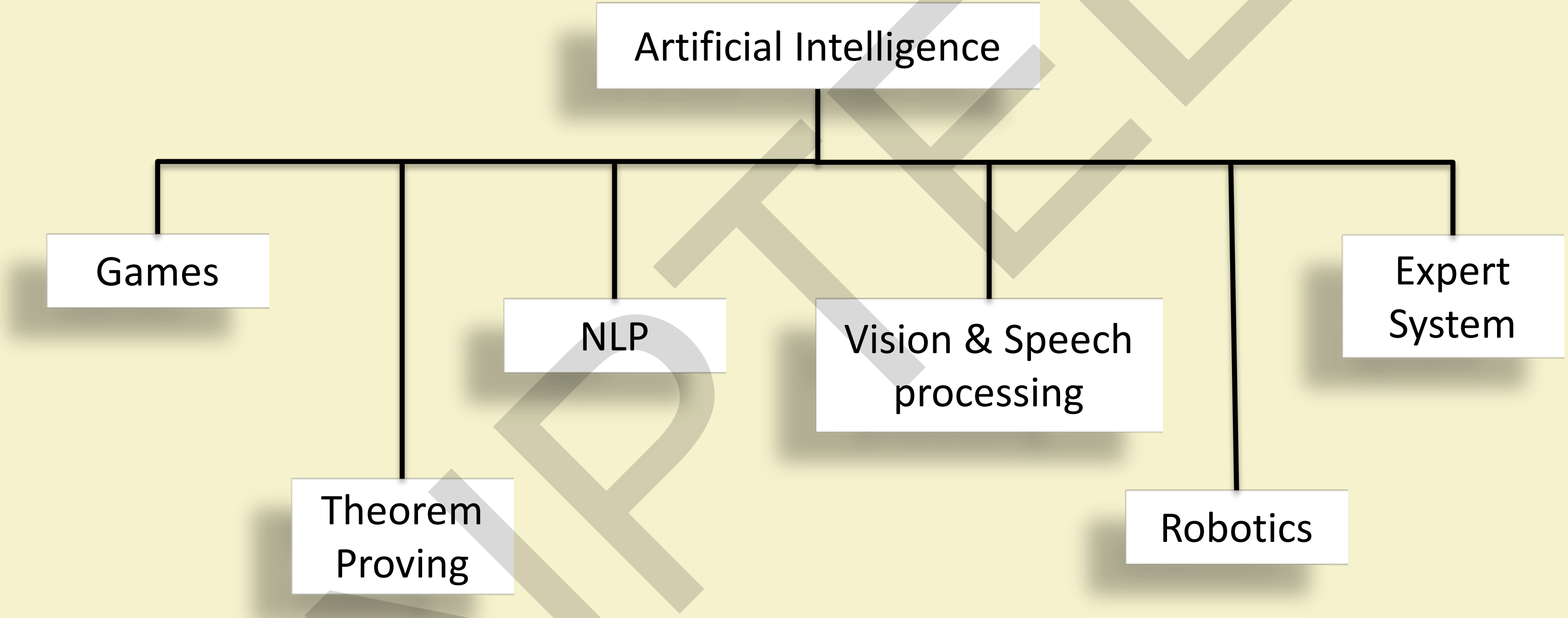
AI Techniques

Knowledge is the information that can be used to perform a particular task

Knowledge
- Procedural or Operational knowledge
- Declarative or Relational knowledge
- Heuristic knowledge

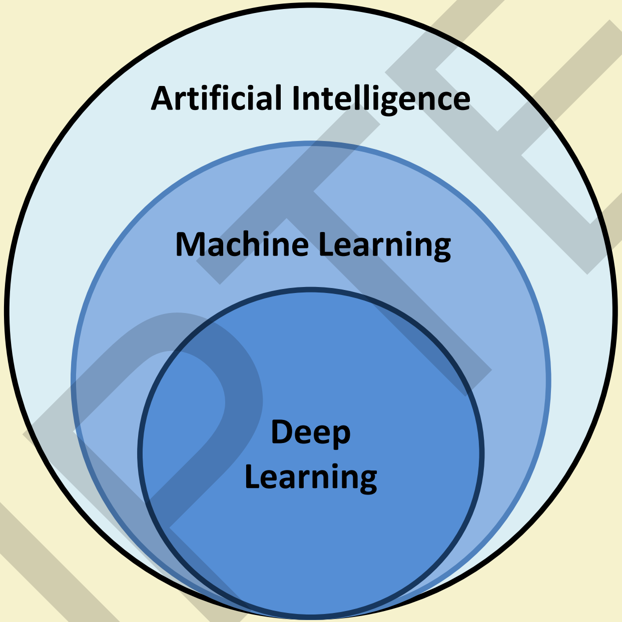
Source: Artificial Intelligence by David L. Poole, Alan K. Macworth, Artificial Intelligence by Rajiv Chopra

Scopes of AI



Source: Artificial Intelligence by Rajiv Chopra

AI vs Machine learning vs Deep learning



Source: Artificial Intelligence by David L. Poole, Alan K. Macworth, Artificial Intelligence by Rajiv Chopra

Machine learning

Machine learning is a part of Artificial Intelligence which empower machines to make decisions based on their experience rather than being explicitly programmed.

Source: Artificial Intelligence by David L. Poole, Alan K. Macworth, Artificial Intelligence by Rajiv Chopra

Deep learning

Deep learning is a subset of machine learning which can learn automatically by finding the features of the object by own.

Source: Artificial Intelligence by David L. Poole, Alan K. Macworth, Artificial Intelligence by Rajiv Chopra

Role of AI in Industry 4.0

- ✓ **Industry 4.0:** Human-machine interaction, CPS, cloud computing, cognitive computing, IoT/IIoT, etc – in Manufacturing
- ✓ **Smart Factory:** Virtualized instances of physical objects in a factory interacting with one another.
- ✓ **Role of AI:** Machine safety, efficient product lifecycle, efficient manufacturing processes, etc.

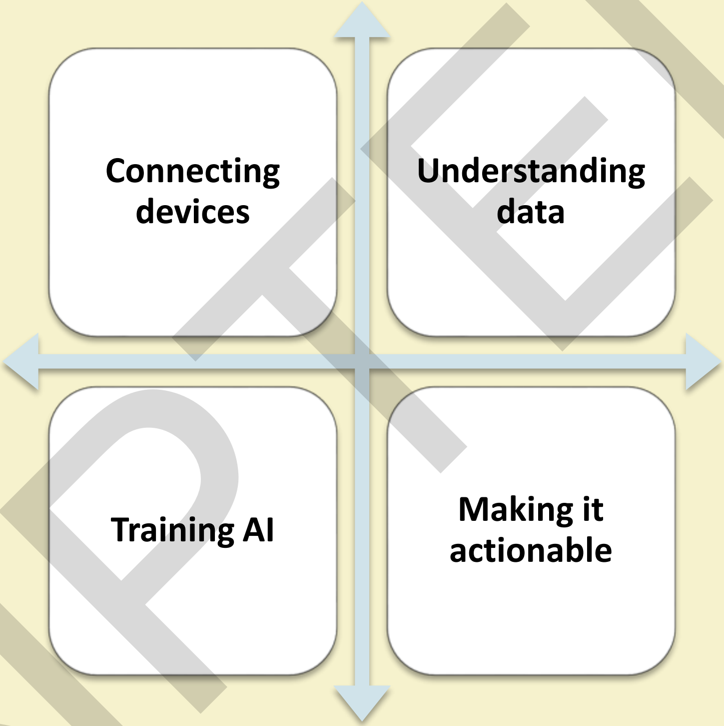
AI in IIoT

- Use of AI helps machines and equipment to communicate and relay information with one another
  - Examples: Computer Vision, Robotics, NLP, ML, DL, RL, etc.
- With the help of AI industries are capable of taking the advantage of large amount generated data by machines
  - Example: Prediction of yield, quality of yield etc in Manufacturing

Finance | **Retail** | **Healthcare** | **Agriculture**

Source: The Significance of AI and Machine Learning in IIoT, Inc42

Challenges of AI in IIOT



Source: Four Artificial Intelligence challenges in facing the Industrial IoT, Clearblade

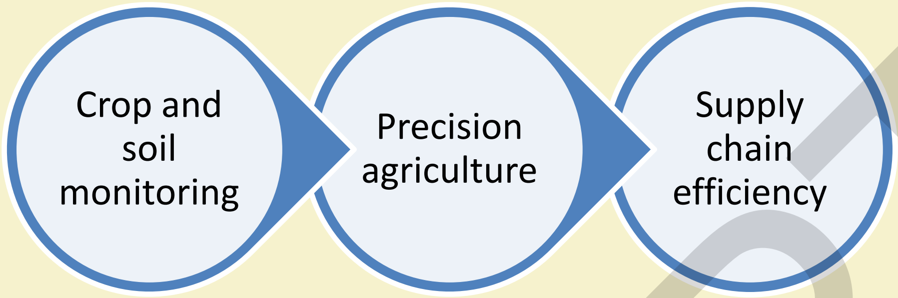
Advantages of AI in IIoT

The usefulness of AI in industrial scale are,

- Increase efficiency
- Save costs
- Improve security
- Augment performance
- Boost resources

Source: The Significance of AI and Machine Learning in IIoT, Inc42

Significance of AI in Agriculture industry



- **CropIn's** smart farm solution
- **Intello lab** using AI based solution for crop health monitoring
- **Microsoft India AI** based sowing app
- **Gobasco AI** based Agri supply chain

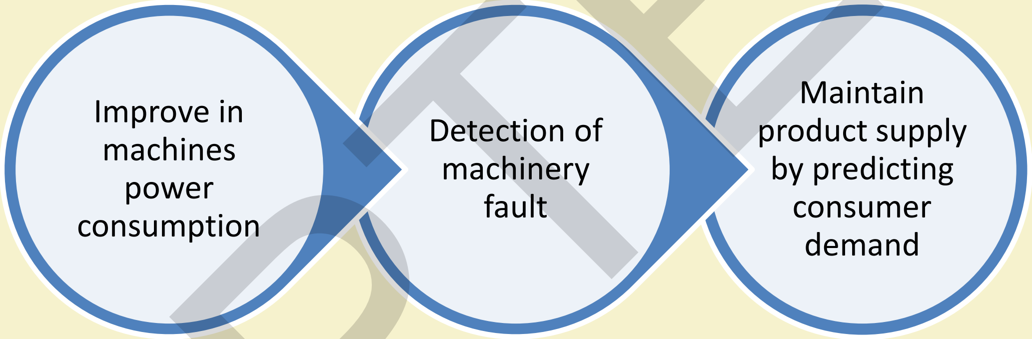
Source: Artificial Intelligence in Indian Agriculture – An Industry and Startup Overview

Significance of AI in Education industry

- Smart learning systems by **Carnegie Learning**
- **Querium Corporation** AI based education system

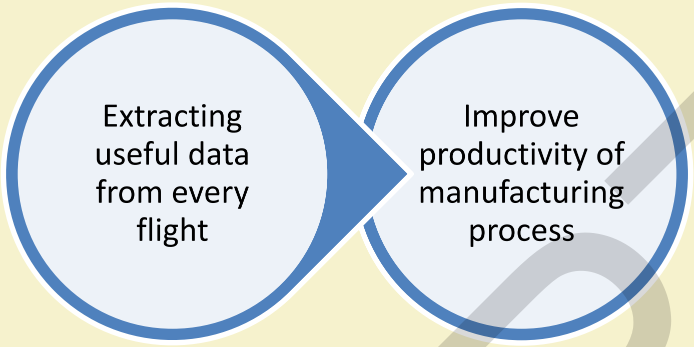
Source: AI in Education: 3 Industry Defining Trends in 2018

Significance of AI in Manufacturing factories



Source: The Significance of AI and Machine Learning in IIoT, Inc42

Significance of AI in Aerospace industry



- **Boeing 787** generates large amount of data at each flight where AI is used to extract useful information

- **Airbus** is moving on with “Factory of Future”, to improve the productivity of manufacturing process.

Source: The Significance of AI and Machine Learning in IIoT, Inc42
https://inc42.com/resources/the-significance-of-ai-and-machine-learning-in-iiot/

Significance of AI in Transportation industry

Assist to prevent accidents

Self driving car

- **Indian railways** utilizes AI to secure safety of trains
- **Tesla** first automotive brand to launch self driving car

Source: The Significance of AI and Machine Learning in IIoT, Inc42

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Industry 4.0:
Big Data and Advanced Analysis

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What is Big Data?

- Big data means
  - data which is "too big" to be handled by
    - processing tools, and
    - conventional databases.
- Big data consists of
  - structured and
  - non-structured data

such as web blogs, FB chats, images, news, tweets, comments, etc.

Source: cs.kent.edu: Big data

Big Data: Definition

- *"Big data will represent the data of which acquisition speed, data volume or data characterization restricts the capacity of using conventional associated methods to manage successful analysis or the data which can be successfully operated with important horizontal zoom technologies."*

  [NIST(National Institute of Standards and Technology)]

Source: cs.kent.edu: Big data

Data Types

- Structured data
  - Data that can be easily organized.
  - It is stored in relational databases.
  - It is managed by Structured Query Language (SQL) in databases.
  - It accounts for only 20% of the total available data today in the world.

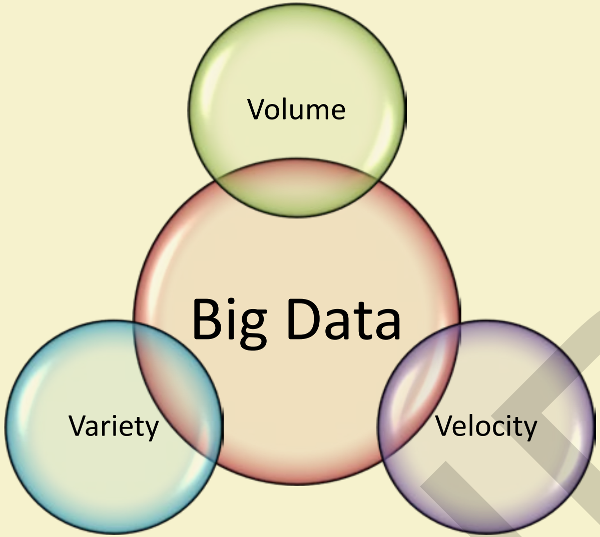
Source: Big data analytics : Srinivasa

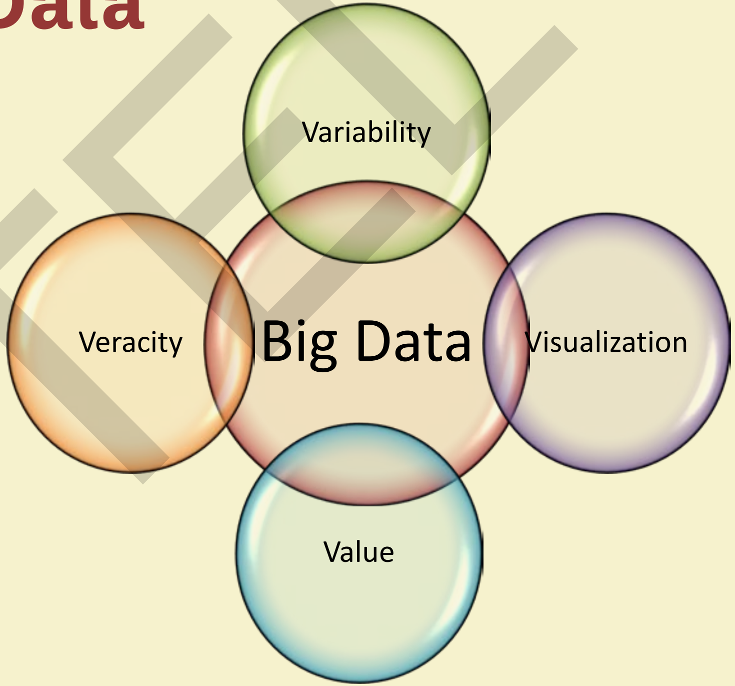
Data Types(Contd.)

- Unstructured data
  - Data that do not possess any pre-defined model.
  - Traditional RDBMSs are unable to process unstructured data.
  - Enhances the ability to provide better insight to huge datasets.
  - It accounts for 80% of the total data available today in the world.

Source: Big data analytics : Srinivasa

Characteristics of Big Data





- There are mainly 3 Vs in Big Data
- Some authors also include another 4 Vs

Source: Big data analytics : Srinivasa

Characteristics of Big Data (Contd.)

- Volume
  - Quantity of created data.
  - Sources of data are added continuously.
  - Example of *volume* -
    - More than 32TB of pictures will be created each night from the Large Synoptic Survey Telescope (LSST).
    - In every minute, 70 hours of video is uploaded to Youtube.

Source: Big data analytics : Srinivasa

Characteristics of Big Data (Contd.)

- Velocity
  - Speed of generation of data.
  - Data processing time is decreasing day by day to provide real-time services.
  - Older processing technologies can not help to handle high velocity of data.
  - Example of *velocity* –
    - 140 million tweets per day on average (according to a survey conducted in 2011)
    - NYSE(New York Stock Exchange) measures 1TB of exchange data during every exchanging session.

Source: Big data analytics : Srinivasa

Characteristics of Big Data (Contd.)

- Variety
  - Category of the data.
  - No restriction over the input data formats.
  - Mostly data are not structured.
  - Example of *variety* –
    - Pure text, images, audio, video, web, GPS data, sensor data, SMS, documents, PDFs, flash etc.

Source: Big data analytics : Srinivasa

Characteristics of Big Data (Contd.)

- Variability
  - Variability is different from variety.
  - Data whose meaning is constantly changing.
  - Such data appear as an indecipherable mass without structure.
  - Example:
    - Language processing, Hashtags, Geo-spatial data, Multimedia, Sensor events.

Source: Big data analytics : Srinivasa

Characteristics of Big Data (Contd.)

- Veracity
  - Veracity indicates biasness in the data, unusualness and noise in data.
  - It is important in programs which involve automated decision-making.
  - It is also important for feeding the data into an unsupervised machine learning algorithm.
- Veracity deals about the data understandability, not just the data quality.

Source: Big data analytics : Srinivasa

Characteristics of Big Data (Contd.)

- Visualization
  - Data can be in form of pictures or in form of a graphical format.
  - Visualization provides the power to decision makers to see visually.
  - It is helpful to identify new patterns.
- Value
  - It means extracting useful business information from scattered data.
  - Simple to access and provides quality investigation that empowers informed decisions.

Source: Big data analytics : Srinivasa

Data Sources

Enterprise data
- Online trading & data analysis
- Production and inventory data
- Sales and other financial data

IoT data
- Industrial data
- Healthcare data
- Agricultural data

Source: The Making of ENCODE: Lessons for Big-Data Projects : Birney

Data Sources

Biomedical data
- Data generated from gene sequencing
- Data from medical clinics

Others
- Computational biology
- Astronomy
- Nuclear research

Source: The Making of ENCODE: Lessons for Big-Data Projects : Birney

Data Acquisition

- Data collection
  - Data sources automatically generate log files or record files to record activities for further analysis.
  - Complex and variety of data collection through mobile devices. E.g. – geographical location, 2D barcodes, pictures, videos etc.
- Data transmission
  - Categorized as – Inter-DCN transmission and Intra-DCN transmission.
  - Collect data and transfer to storage system for further processing and analysis of the data.

Source: The Making of ENCODE: Lessons for Big-Data Projects : Birney

Data Acquisition (Contd.)

- Data pre-processing
  - Pre-processing of data is necessary as collected datasets suffer from noise, redundancy etc.
  - Pre-processing of relational data mainly follows-

Source: The Making of ENCODE: Lessons for Big-Data Projects : Birney

Data Acquisition (Contd.)

- Integration:
  - combine data from various sources and
  - delivers the users a constant data view.
- Clearing:
  - spot incorrect, insufficient, or uncooperative data, and
  - correct or remove such data.
- Redundancy mitigation:
  - eliminate data repetition through detection, filter and compression of data to avoid unnecessary transmission.

Source: The Making of ENCODE: Lessons for Big-Data Projects : Birney

Data Storage

- File system
  - Distributed file systems that store massive data and ensure – consistency, accessibility, and fault tolerance of data.
    - GFS is a distributed file system that supports large-scale file system.
    - HDFS(Hadoop Distributed File System) is a notable file systems, derived from the open source codes of GFS.
- Databases
  - Emergence of non-traditional relational databases (NoSQL) in order to deal with the characteristics that big data possess.

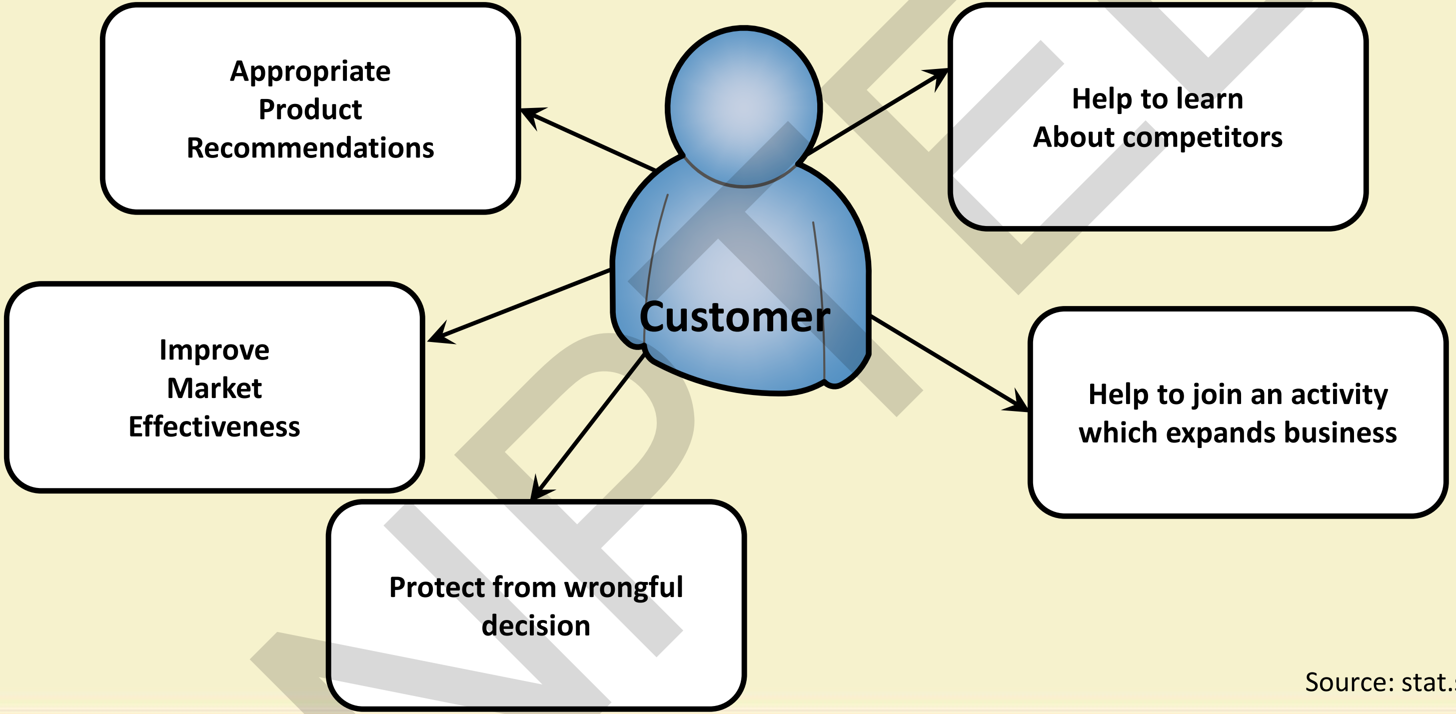
Source: The Making of ENCODE: Lessons for Big-Data Projects : Birney

Why Data Analytics?

Sensors are very small in sizes. They can be placed anywhere and transfer the data over wireless technology, because of this explosion of data moving to systems from sensors. Some data are irrelevant for systems. How can one know which data are relevant, this requires analysis of the data.

Source: Industry 4.0:The Industrial Internet of Things: Gilchrist

Why Data Analytics?(Contd.)



Source: stat.si: Big data tutorial

Big Data Analytics

- Big data is different from conventional Data Warehouse (DW) approaches.
- Big data apps cannot be fit in traditional DW architectures (e.g. Exadata, Teradata).
- Distributed nothing, mighty parallel performing, scale out frameworks are convenient for big data apps.

Source: Industry 4.0:The Industrial Internet of Things: Gilchrist

Big Data Analytics for Industry 4.0

- Industrial Internet require an approach to manage and process data coming from thousand of sensors for precious perceptions .
- To manage and handle the huge data in health services and manufacturing etc. is not new. For example-
  - An event is detected by a sensor and sent to the operational recorder. An operational recorder is a database which stores data. After that this data is optimized by querying such as, what about this hour's production from the norm.

Source: Industry 4.0:The Industrial Internet of Things: Gilchrist

Big Data Analytics for Industry 4.0 (Contd.)

- IIoT can be recognized as a big benefactor of Big Data.
- It needs new technologies to manage vast data.
- Cloud services are accessible to handle Big Data with no-limit of storage on demand.
- In IIoT, Hadoop (open source cloud based distributed data storage) is also available for managing the data.

Source: Industry 4.0:The Industrial Internet of Things: Gilchrist

Cloud-Based Method for Analytics

- Essential features (according to NIST)
  - On-demand self service
  - Wide network access
  - Method grouping
  - Fast flexibility
  - Measured service

Source: Industry 4.0:The Industrial Internet of Things: Gilchrist

Types of Analytics

Prescriptive Analytics

-> Best action?

-> Should we try this?

Predictive Analytics

->What next?

->Pattern?

Descriptive Analytics

->When, where?

->What happened?

Source: Industry 4.0:The Industrial Internet of Things: Gilchrist

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Industry 4.0: Cybersecurity

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What is Cybersecurity?

- In computing, security consists of
  - Cybersecurity
  - Physical security

- Protection of internet-connected systems from cyber-attacks is known as cybersecurity.

Source: Techtarget.com: Cybersecurity

What is Cybersecurity?

- This protection involves protection of
  - hardware
  - software
  - data
- Enterprises use cybersecurity and physical security simultaneously against unofficial access to data centres.

Source: Techtarget.com: Cybersecurity

Protect against what?

- Unofficial change in the data
- Unofficial deletion of the data
- Uncertified access

Source: Techtarget.com: Cybersecurity

Components of Cybersecurity

- Application Security
- Information Security
- Network Security
- Operational Security
- End-user Education

Source: Techtarget.com: Cybersecurity

Elements of cybersecurity(Contd.)

- Application security
  - It ensures the protection of applications from outer threats.
  - Some software, hardware and procedural methods are used for protection.
  - Some actions are needed to certify application security; these actions are known as countermeasures. There are two types of countermeasures.
    - Software countermeasure: application firewall
    - Hardware countermeasure: router/proxy

Source: Techtarget.com: Cybersecurity

Elements of cybersecurity(Contd.)

- Information Security
  - Information security is recognized as a subset of cybersecurity.
  - A set of strategies is known as information security, which handles some tools and policies. These policies filter the threats.
  - These strategies help maintain the availability, integrity and confidentiality of business data.

Source: Techtarget.com: Cybersecurity

Elements of cybersecurity(Contd.)

- Network Security
  - Network security is a process by which we take physical and software actions for protecting the network architecture.
  - It provides protection from unofficial access, improper use, fault, deletion, demolition.
  - Create a protective platform for users and computers.
  - It combines multiple layers of defences at the edge and in the network.

Source: Cisco: Security

Elements of cybersecurity(Contd.)

- Operational Security
  - Operational security (OPSEC) is an analytical action which categorizes information benefits.
  - For protection of these information benefits, it regulates the control.
  - Protection is an important factor in business perspectives; because of this OPSEC operations are commonly used in business actions.

Source: Cisco: Security

Elements of cybersecurity(Contd.)

- End-User education
  - End-users are the biggest security risk for an industry. They are the first to compromise the security.
  - Employees do not have all information about all the attacker, hence they can easily open the doors for the attackers.
  - As cybercrimes are increasing, it will be more important for industry to educate their employees about cyber-attacks.

Source: Cisco: Security

Types of Cybersecurity threats

- Ransom-ware
  - It provides a facility to the attacker in which the attacker locks the user's computer files by using an encryption and demand some money to unlock them.
  - Example: Locky
- Malware
  - A computer program which is used to disturb the computer user, such as computer viruses, spyware etc.
  - Example: Trojan Horse

Source: Techtarget.com: Cybersecurity

Types of Cybersecurity threats(Contd.)

- Social Engineering
  - This attack involves human interaction to mislead users.
  - It breaks security policy to get critical information, which is typically secured.
  - Example : Watering hole and Pretexting.
- Phishing
  - Phishing is in the form of false information. These information are basically false emails which have been sent through recognizable sources.
  - The aim is to get critical data, such as login information or credit card information.
  - Example: Google docs Phishing and Dropbox Phishing.

Source: Techtarget.com: Cybersecurity

Industrial Internet (II)

- Internet of things, computers and people, machines all together make Industrial Internet.
- It enables industrial intelligent actions to use advanced data analytic tools for gettable business results.
- Autonomous cars, intelligent rail-road systems are applications of industrial internet.

Source: i-scoop.eu : Cybersecurity-IIoT

Why IIoT Security Standards is required?

- Industries will need to use diverse systems and equipment but everything will be integrated on smart factory floor.
- Legacy systems must be brought under implementation.
- Every weak line in the chain puts whole factory at risk.
- Leaving security at the hands of individual IIoT implementers is dangerous.

Source: i-scoop.eu : Cybersecurity-IIoT

Cybersecurity Requirements

CIA Triad

- C-Confidentiality
- I-Integrity
- A-Availability

IIoT requirements

- Reliability
- Safety

Source: Techtarget.com: Cybersecurity

CIA Triad

- C-Confidentiality
  - Confidentiality stops unauthorized disclosure of Information.
- I-Integrity
  - Integrity ensures that data cannot be changed in any unauthroized manner.
- A-Availability
  - Availability guarantees that information must be available only to the authorized user.

Source: Techtarget.com: Cybersecurity

Cybersecurity: Challenge in IIoT

- Cybersecurity has a major role in digital economy and it certainly is a big challenge in IIoT as well.
- In current digital transformation, capabilities such as manufacturing, logistics, shipping, healthcare and industries, which comes under the industrial internet, data breaches can occur, which increases different kinds of cybercrimes and cyber threats.

Source: Cybersecurity for industry 4.0: Thames

Cybersecurity for Industry 4.0

- Traditional cybersecurity mechanisms have the characteristics- confidentiality, authenticity, integrity, non-repudiation and access-control.
- These methods provide safety in network and computer attacks.
- The **new internet security** deals with **other attacks** which are capacious and very fast.
- Some methods are required for Industry 4.0 systems which enables automatic detection to cyber-attacks.

Source: Cybersecurity for industry 4.0: Thames

Cyberattack Detection: Methodologies and Algorithms

- Computational Intelligence systems (CIS)
  - An algorithm is required for CIS which combines and filters the data. This data is created by different types of events in a cyber domain.
  - Cyber-attack recognition systems deal with <u>extensive volume of big dimensional data along with uniform advancing attack features</u>.
  - CIS have become reasonable preferences to build new categorization algorithms for detection systems.

Source: Cybersecurity for industry 4.0: Thames

Software-Defined Cloud Manufacturing Architecture (SDCMA)

- There are mainly three parts of SDCMA
  - Software Plane
  - Hardware Plane
  - Ensemble Intelligence Framework (EIF).
- Software plane consists of control elements (CE).
- CE are used as data tap points, since they have deep observation into the communications and activities.

Source: Cybersecurity for industry 4.0: Thames

SDCMA(Contd.)

- In SDCMA, the streaming data is supplied to EIF by CE.
- Sensed data is detected by EIF.
- EIF is also responsible for detecting abnormality.

Source: Cybersecurity for industry 4.0: Thames

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Thank You!!

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Basics of Industrial IoT: Introduction

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Introduction

- Industrial Internet of Things (IIoT) can be considered as a branch of Internet of Things (IoT)
- IIoT is the application of IoT in manufacturing and other industrial processes with the aim to enhance the working condition, increase machine life and optimize operational efficiency.

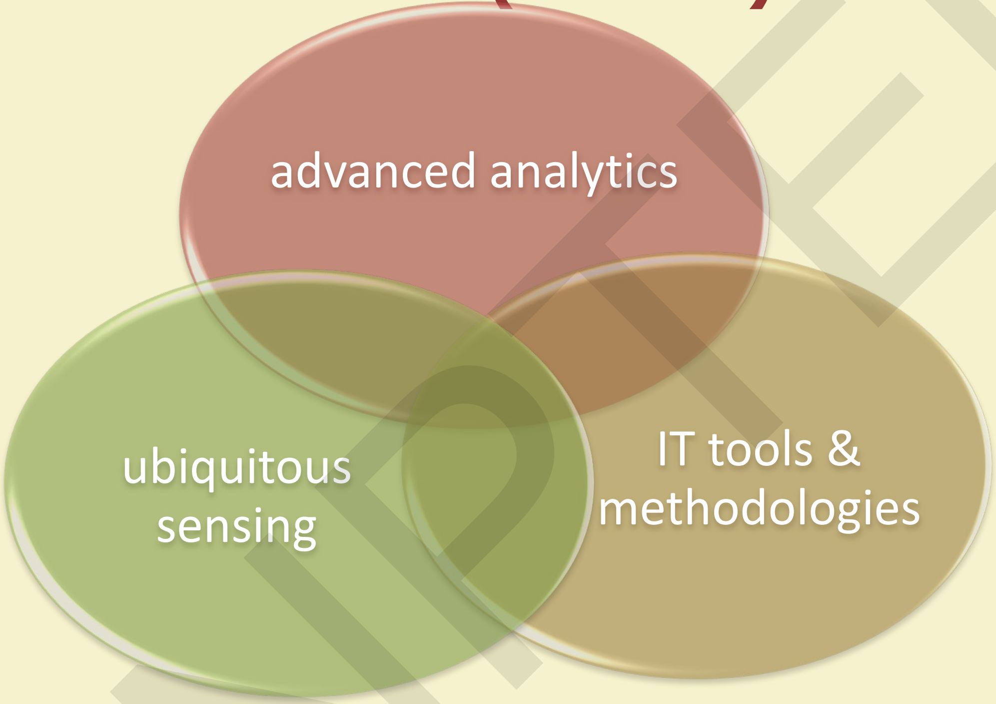
Source: "The Industrial Internet of Things (IIoT)"

IIoT vs Automation

- There are three key differences between IIoT and Automation which have been deployed in industries for decades.
- They are:
  - ubiquitous sensing
  - advanced analytics, and
  - IT tools and methodologies

Source: "Industrial Internet of Things, A high-level architecture discussion"

IIoT vs Automation (contd.)



Concept taken from: "Industrial Internet of Things, A high-level architecture discussion"

Ubiquitous Sensing

- In traditional automation, sensors and actuators are used to control critical elements (industrial machines, etc).
- In IIoT, sensors and actuators are used almost everywhere to control, enhance and optimize various functions.
  - E.g. To monitor machine health, to track various operations, emergency system etc.
- Ubiquitous Sensing enables Advanced Analytics

Source: "Industrial Internet of Things, A high-level architecture discussion"

Advanced Analytics

- The various data from array of deployed sensors and actuators can be exploited and extracted to decipher latent meanings using varieties of advanced analytic tools and algorithms.
- In IIoT, data much more and varied compared to traditional Automation.
- In IIoT, advanced analytics helps to enhance the working condition, increase machine life and optimize operational efficiency etc.

Source: “Industrial Internet of Things, A high-level architecture discussion”

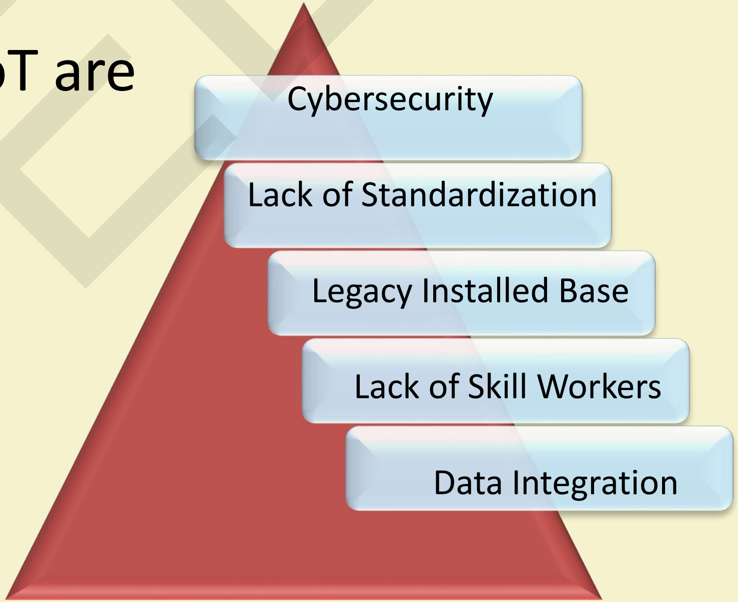
IT methodologies

- IIoT modifies the traditional automation techniques by exploiting IT technology.
- This modification gives three main benefits:
  - Availability of talent pool
  - Standardization
  - Accessibility of already available IT hardware and software solutions

Source: "Industrial Internet of Things, A high-level architecture discussion"

Challenges in IIoT

- The challenges in deployment of IIoT are
  - Data integration challenges
  - Cybersecurity
  - Lack of standardization
  - Legacy installations
  - Lack of skills



Source: "Industrial Internet of Things, A high-level architecture discussion"

Data integration challenges

- Big data volume
  - Complex and different varieties of data from different sensors and actuators
  - Frequency of data generated by multiple devices
- Data integration is one of the main challenges
- Understanding the generated data for analysis and application in business is not an easy task

Source: “Industrial Internet of Things, A high-level architecture discussion”

Cybersecurity

- Cybersecurity is one of the most essential elements of IIoT, because in IIoT all the devices are interconnected and these connected devices interact with the real world
- The two most important security concerns of IIoT are -
  - information security
  - data privacy protection

Source: "Industrial Internet of Things, A high-level architecture discussion"

Cybersecurity

- Examples:
  - Healthcare Industries: Data integrity is highly essential in healthcare industries
  - Food Industries : Information that can harm the reputation of the company should be made confidential
  - Power Grid: Collapse of a power grip can give huge impact
  - National Transportation: National Transportation is like the veins of the nation. Making them secure is very crucial

Source: "Industrial Internet of Things, A high-level architecture discussion"

Lack of Standardization

- Large automation supplier firms do not encourage open standardization, as it will reduce the customer's reliance on them
- Small automation supplier firms lacks the capability to incentivize this huge step

Source: "Industrial Internet of Things, A high-level architecture discussion"

Lack of Standardization

- Lack of standardization leads to different issues related to :
  - Device interoperability
  - Semantic interoperability (data semantics)
  - Security and privacy etc.

Source: “Industrial Internet of Things, A high-level architecture discussion”

Legacy Installations

- Technology evolves fast
- Coexistence of the fast evolving technology with legacy equipment is a huge complication

Source: "Industrial Internet of Things, A high-level architecture discussion"

Lack of skills

- Limitation of workers with IIoT related skills, like data integration etc. because
  - The technologies associated with IIoT are new
  - Workers should have vast and diverse knowledge

Source: “Industrial Internet of Things, A high-level architecture discussion”

Applications of IIoT

- The key application areas of IIoT are -
  - Healthcare industry
  - Mining industry
  - Manufacturing industry
  - Transportation & logistics
  - Firefighting

Source: "Industry 4.0: the industrial internet of things"

Healthcare industry

- Availability of the information and reputations of doctors helps the patients to choose the right doctor
- Connectivity of healthcare devices to the internet helps in location each devices and also knows the status of the connected devices and the patients monitor by them
- Availability of healthcare data helps in advance healthcare researches

Source: "Industry 4.0: the industrial internet of things"

Mining industry

- Sensor networks comprise of
  - different gas sensors for detecting oxygen, combustible gas like methane, poisonous gases etc.
  - strata monitoring device, rock mass deformation device to detect the internal structural condition of the mine
  - RFID tags for tracking miners
  - Wi-Fi and other wireless networking module

Source: “The Industrial Internet of Things (IIoT): the business guide to Industrial IoT”

Mining industry (contd.)

- These will benefit in
  - early disaster warning
  - working condition of the miners
  - locating and monitoring miners
  - Safety and increasing efficiency

Source: “The Industrial Internet of Things (IIoT): the business guide to Industrial IoT”

Manufacturing industry

- The interconnection and integration of devices, equipment, workforce, supply chain, work platform comprises smart manufacturing
- This provides
  - reduction in operational costs
  - efficiency of the worker
  - Improved safety at the workplace
  - resource optimization and waste reduction
  - end-to-end automation.

Source: “Industry 4.0: the industrial internet of things”

Transportation & logistics

- Easy monitoring of equipment, engines, tracks using the connected devices, deployed sensors, GPS etc.
- Analysis of data from devices will provide the information related to
  - maintenance
  - status and performance
  - optimum scheduling

Source: "Industry 4.0: the industrial internet of things"

Transportation & logistics (contd.)

- Optimum scheduling will
  - provide good customer services by reducing cancellation and delays
  - reduce fuel consumption
- Proper maintenance of the equipment will
  - provide better safety to both the on boarded passengers and machines
  - reduce maintenance expenses

Source: "Industry 4.0: the industrial internet of things"

Firefighting

- Sensor networks with RFID tags are deployed, which helps in
  - real-time monitoring
  - early warning of disaster
  - fast and automatic diagnosis
  - This makes the emergency rescue more effective.

Source: "Industry 4.0: the industrial internet of things"

Benefits of IIoT

- Improves connectivity among devices
- Improves operational efficiency
- Improves productivity
- Optimizes asset utilization
- Creates new jobs and business opportunities
- Reduces operation time

Source: "The Industrial Internet of Things (IIoT): the business guide to Industrial IoT"

Benefits (contd.)

- Remote diagnosis
- Cost effective
- Boost worker safety
- In depth knowledge of customer demand

Source: “The Industrial Internet of Things (IIoT): the business guide to Industrial IoT”

Conclusion

- IIoT has many promising features, but at the same time it has many barriers.
- It does not mean its future is bleak, but it is better to deploy it in the areas, where the hindrances are less

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Basics of Industrial IoT: Industrial Internet System

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Introduction

- The digital industrial company, General Electric (GE), coined the term Industrial Internet.
- Industrial Internet is not exactly the same as Industrial Internet of Things (IIoTs), but they are often used interchangeably.
- GE is also a founding member of Industrial Internet Consortium (IIC), which is also a huge contributor in shaping IIoTs

Source: "The Industrial Internet and the Industrial Internet of Things"

Three Waves of Innovation

- According to GE, there are three waves in industrial level
  - The First Wave or The Industrial Revolution
  - The Second Wave or The Internet Revolution
  - The Third Wave or The Industrial Internet

Source: "Industrial Internet: Pushing the Boundaries of Minds and Machines", GE

Three Waves of Innovation

Wave 1
Industrial Revolution

Wave 2
Internet Revolution

Wave 3
Industrial Internet

Concept taken from: “Industrial Internet: Pushing the Boundaries of Minds and Machines”, GE

The Industrial Revolution

- The Industrial Revolution lasted for around 150 years which began in 1750 and ended in 1900
- It had two stages.
- Commercialization and the mass production of steam engines marked the beginning of the First Stage. It was started in the middle of eighteenth century.

Source: “Industrial Internet: Pushing the Boundaries of Minds and Machines”, GE

The Industrial Revolution (contd.)

- The Second Stage started in 1870 with the invention of internal combustion engines and electricity
- The Second Stage is more powerful
  - Electricity brings new types of communications
  - Combustion Engines brings new forms of transportation systems

Source: "Industrial Internet: Pushing the Boundaries of Minds and Machines", GE

Drawbacks of Industrial Revolution

- Even though Industrial Revolution brought significant leap in the economy and society, it had some negative effects
  - The waste products harmed the environment
  - Bad working environment
  - Inefficient

Source: "Industrial Internet: Pushing the Boundaries of Minds and Machines", GE

The Internet Revolution

- The Internet Revolution started around 1950 and lasted for around 50 years
- It was started with a government sponsored experimentation on computer networks
- It became more eminent with the emergence World Wide Web
- Computing capacity had also increased
- Rapid information exchange over large geographical distance was made possible

Source: "Industrial Internet: Pushing the Boundaries of Minds and Machines", GE

The Industrial Internet

- Integration of Internet-based technologies to industries
- Currently we are under Third Wave or The Industrial Internet
- Third Wave has not reached its peak
- According to GE, Industrial Internet can be defined as "the association of the global industrial system with low-cost sensing, interconnectivity through internet, high-level computing and analytics"

Source: "Industrial Internet: Pushing the Boundaries of Minds and Machines", GE

The Industrial Internet (contd.)

- It has three key elements
  - Intelligent machines
  - Advanced analytics
  - People at work

Source: “Industrial Internet: Pushing the Boundaries of Minds and Machines”, GE

Three Key Elements

Intelligent Machines

- Connects different devices located at different places
- The devices are controlled through sensors and actuators using advance IT software

Advanced Analytics

- Huge amount of data are generated from device
- Data are input to the advance predictive algorithms

People at Work

- People are interconnected
- Regardless of their location, they can monitor the machines, to provide more flexible and quality services

Concept taken from: “Industrial Internet: Pushing the Boundaries of Minds and Machines”, GE

Intelligent machines

- Different kinds of machines located at different locations can be interconnected
- These machines can be monitored using advanced sensors and actuators using related software

Source: "Industrial Internet: Pushing the Boundaries of Minds and Machines", GE

Advanced analytics

- The huge data generated from different kinds of machines and sensors, advance analytic and prediction techniques make possible in shaping a whole new era of automation and intelligent machines.

Source: "Industrial Internet: Pushing the Boundaries of Minds and Machines", GE

People at work

- Through web and mobile interfaces, everybody can connect with one another regardless of their location.
- A doctor can interact with his patient virtually, a worker can control a machine from anywhere etc.
- This makes the system more intelligent, maintenance and operations become easier, safety and the quality of services also enhances at the same time.

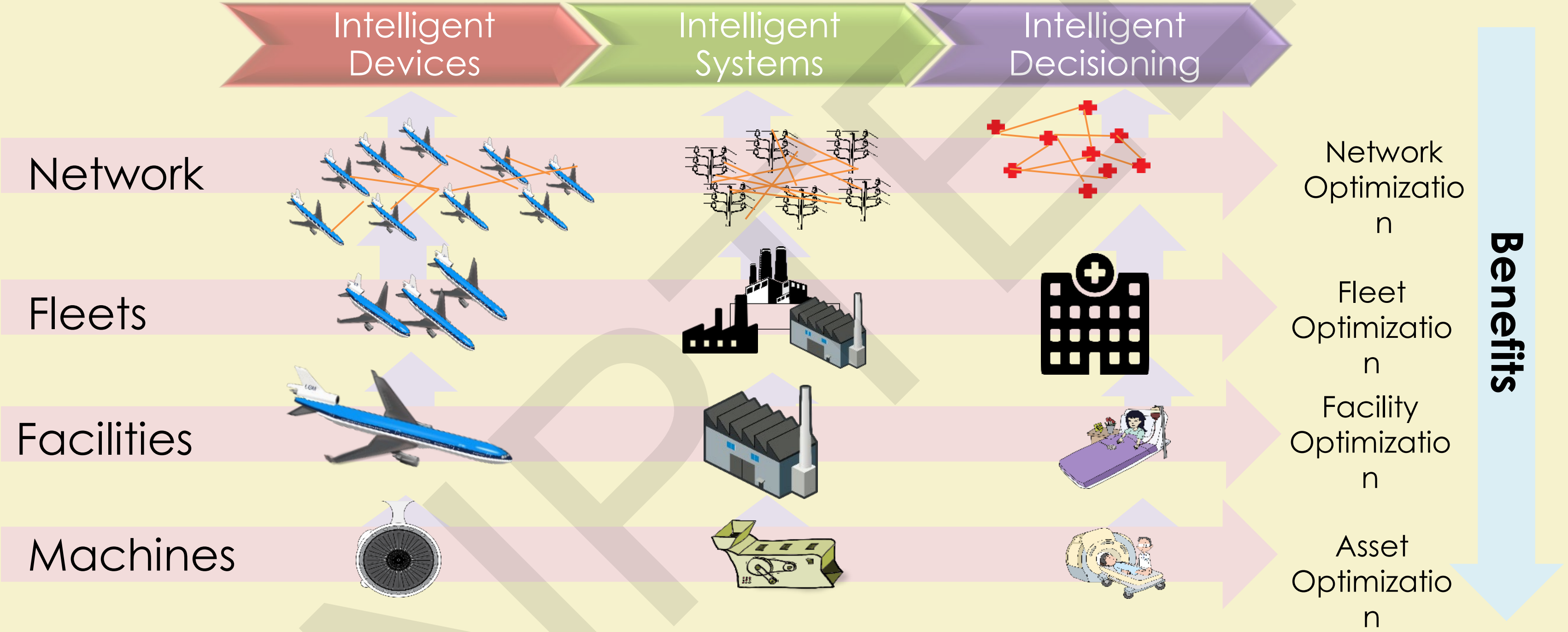
Source: “Industrial Internet: Pushing the Boundaries of Minds and Machines”, GE

Applications

- Commercial Aviation
- Rail Transportation
- Power Production
- Oil and Gas Sectors
- Healthcare

Source: "Industrial Internet: Pushing the Boundaries of Minds and Machines", GE

Applications of Industrial internet



Concept taken from: "Industrial Internet: Pushing the Boundaries of Minds and Machines", GE

Commercial Aviation

- The Industrial Internet can benefit commercial aviation industries by improving both <u>airline operations</u> and <u>asset management</u>
- Airline operation
  - Reducing fuel consumption
  - Effective management of crews, flight scheduling, minimizing delays and cancellations of flight

Source: "Industrial Internet: Pushing the Boundaries of Minds and Machines", GE

Commercial Aviation (contd.)

- Asset Management
  - Proper maintenance of engines and other parts
  - Timely repairing

Source: “Industrial Internet: Pushing the Boundaries of Minds and Machines”, GE

Rail Transportation

- Real-time analysis and application of <u>predictive algorithms</u> will help
  - in reducing the maintenance cost
  - in preventing engine breakdown
- Availability of software will help in providing a <u>real-time</u> overview of the entire system to operators. Therefore,
  - the rail operator can monitor the trains and make optimal decisions
  - optimal train scheduling

Source: “Industrial Internet: Pushing the Boundaries of Minds and Machines”, GE

Power Production

- In power industries, outage is a huge problem because locating a broken power line or equipment is not an easy task
- With the help of industrial internet, everything will be connected to internet. Therefore
  - status updates and performance related data will be easily available
  - analysis of the incoming data will provide new insights relating to potential problems which may occur in future
  - cost of field inspection before repairing will be reduced

Source: “Industrial Internet: Pushing the Boundaries of Minds and Machines”, GE

Oil and Gas Sectors

- Industrial Internet
  - reduces fuel consumption
  - enhances production
    - tracking events inside well, simulation of inside well, improve production flow
  - reduces costs
    - real-time monitoring and alert system for safety and optimization
- Predictive analysis of the incoming data from different devices helps in understanding the behavior of the underground reservoir

Source: "Industrial Internet: Pushing the Boundaries of Minds and Machines", GE

Healthcare

- Industrial Internet enables safe and efficient operations.
  - availability of the information and reputations of doctors helps the patients to choose the right doctor
  - connectivity of healthcare devices to the internet helps in location each devices and also know the status of the connected devices and the patients monitor by them
  - availability of healthcare data helps in advance healthcare researches

Source: “Industrial Internet: Pushing the Boundaries of Minds and Machines”, GE

Advantages of Industrial Internet

- One percent fuel savings (in 15 years)
  - Commercial Aviation Industries will save $30 billion
  - Gas and Power segment of Power plants will save $66 billion
- One percent reduction in system inefficiency in
  - Healthcare sector will save $63 billion
  - Freight transportation through world rail network will save $27 billion
- One percent reduction in capital expenditure during exploration and development in Oil and Gas industries will save $90 billion
- The emergence of cloud-based system will replace the isolated systems

Source: "Industrial Internet: Pushing the Boundaries of Minds and Machines", GE

Advantages of Industrial Internet

Industry	Segment	Type of Savings	Estimated Value (Over 15 Years)
Aviation	Commercial	One percent in fuel Saving	$30 Billion
Power	Gas-Fire Generation	One percent in fuel Saving	$66 Billion
Health	System Wide	One percent reduction in system inefficiency	$63 Billion
Oil	Freight	One percent reduction in system inefficiency	$27 Billion
Rail & Gas	Development and Exploration	One percent reduction in capital expenditure	$90 Billion

Source: "Industrial Internet: Pushing the Boundaries of Minds and Machines", GE

Catalysts

- Innovations in terms of
  - Equipment
  - Advance analytics
  - System platform
  - Business processes
- Infrastructure
- Cybersecurity management

Source: “Industrial Internet: Pushing the Boundaries of Minds and Machines”, GE

Catalysts (contd.)

- Talent Development
  - Next Generation Engineering
  - Data Scientists
  - User Interface Experts

Source: "Industrial Internet: Pushing the Boundaries of Minds and Machines", GE

Conclusion

- Industrial Internet has many benefits and promises across the globe
- But it needs a little innovation, capital, and platform

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Thank You!!

Basics of IIoT:
Industrial Sensing & Actuation

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Introduction

- **IoT** deployment in **Industry** (IIoT)
- **Sensor**: Primary source of IIoT data, Big analog/digital data
- **Intelligence** of IoT is developed based on sensor data
- **Actuator**: Follow control decision

Need of Sensing for Industry

- Higher degree of automation
- Raise Productivity
- Improve Quality
- Better Safety
- Reduced Downtime

Requirements for Industrial Standard

- Reliable Sensing
- Low cost sensing and actuation
- Perpetual sensor and actuation network connectivity

Industrial Sensing

Conventional Sensing

- Involved in feedback automation of a process in industrial control system
- Based on sensing (feedback), further action is taken as per the application requirements

Industrial sensing (Contd.)

Contemporary Sensing

- Sensors connected to the Internet
- Can sense
  - Product lifetime
  - Loop efficiency
  - Safety
  - Reliability

Smart Sensor

" Sensor with small memory and standardized physical connection to enable communication with the processor and data network "

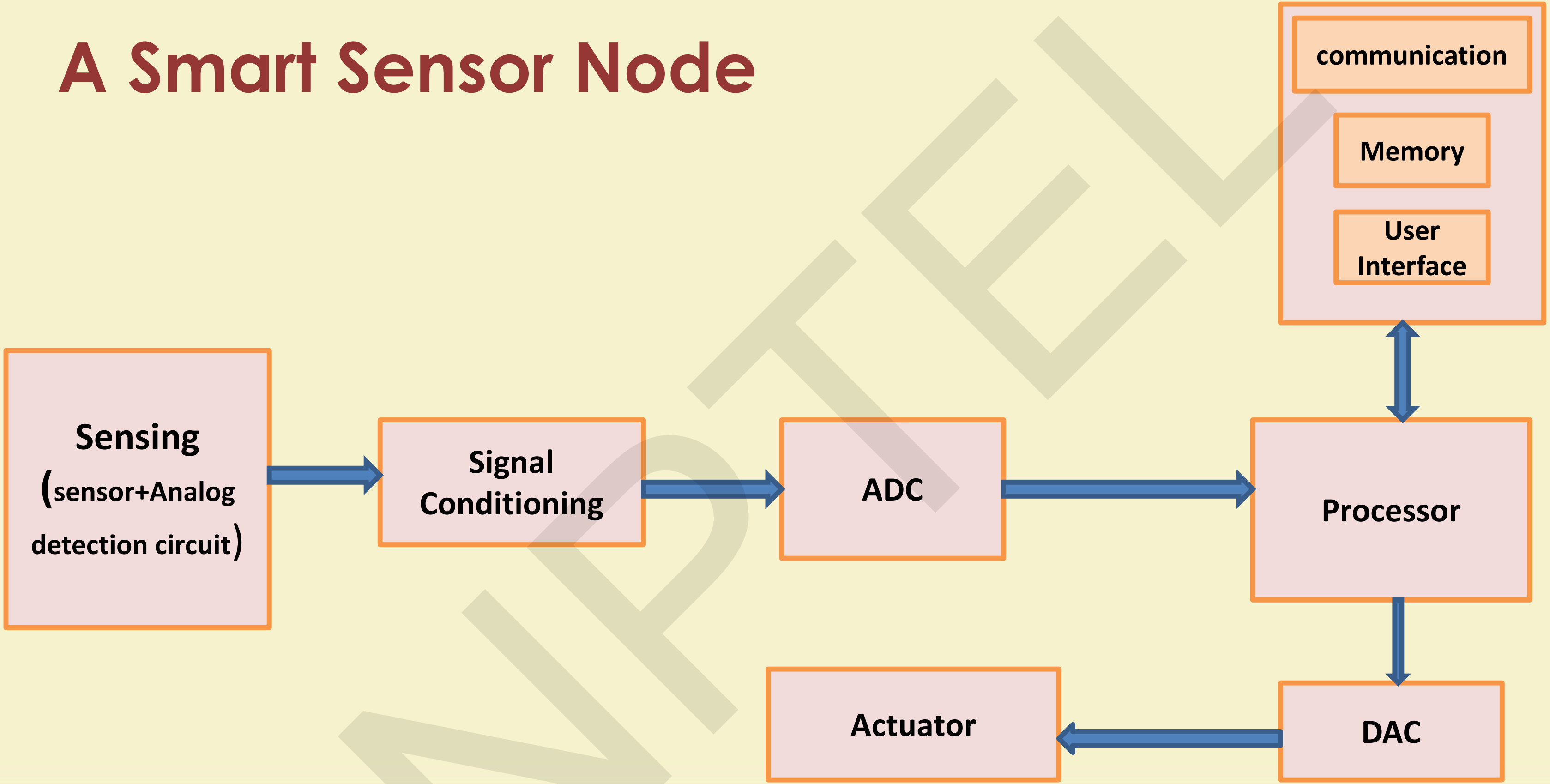
-defined by IEEE 1451 standard

Configurations involved in Smart Sensors

- Multiparameter Sensing Unit
- Analog Detection Circuit
- Digital Signal Conditioning Unit
- Interfacing Unit to bus

Source: T. Islam, S. C. Mukhopadhyay and N. K. Suryadevara, "Smart Sensors and Internet of Things: A Postgraduate Paper," in *IEEE Sensors Journal*, vol. 17, no. 3, pp. 577-584, 1 Feb.1, 2017

A Smart Sensor Node



Smart Sensor Functions

- Smart sensors can perform multiple functions
  - **Multisensing:** It can sense multiple parameters (temperature, pressure, light, humidity etc) at a single sensor node, which may help in the deciding factors in production unit of an industry
  - **Communicate data:** Communicating vital information like measured, callibration and compensation data to the Central control unit
  - **A/D or D/A Conversion:** The Analog data needs digital conversion to apply several signal processing methods for having reliable and accurate data

Smart Sensor Function (Contd.)

- **Self-Decision Making:** It can self-monitor its operation and changes in the ambience by taking proper decision for required compensation by itself or by alerting human for required action
- **Reduced Cost** : Cost continues to reduce as investment is recovered by reduced downtime in industries

Illustrating Sensing in Milk Packaging Unit

- **Install sensor in line with the outlet tap**
- **Sensor contain impellers inside**
- **Impeller spins when milk moves**
- **Sends electrical signal to the control unit**
- **Controller interprets amount of liquid flow and stops when threshold is reached**

Accessing Sensors & Actuators

- **Supporting OS** — Zephyr , Ubuntu , Opensuse , Ublinux , Archlinux , Androidthing
- **Programming Language** — C , C++ , Java , Python , Lua

Intel IoT Device Library used by sensors

MRAA	UPM
• Low-level skeleton library for communication in GNU/Linux platform • Not hardware specific • Better level of abstraction	• High level APIs for easier connectivity to sensors • Easier to control • Supporting industrial grade sensor

Source: " mraa 1.9.0" , Intel

Utility in Industrial Sub-Units

- Measurements
- Production
- Product Inspection
- Packaging & Shipping

Industrial Sensor Calibration

- It is the method adopted to improve the performance of the sensing system by readjusting and removing the error in the measured response of the sensor compared to the actual response
- Industrial grade sensors use highly complex signal processing algorithm and onboard circuitry to take care of calibration.

Industrial Sensor Calibration (Contd.)

- Calibrate in system to be used
- Standard references
- Proper calibration methods
- Re-calibration

Examples of Industrial sensors

- **Navigation industry** (Track sensors: GPS)
  - Spot significant places
  - Tracking real time object
  - Analyze traffics
  - Scanning at check post
  - Predict driver Destination

Examples of Industrial sensors (contd.)

- **Agriculture Industry** (Smart sensors)
  - Soil and water sensor, Weather tracking, RFID technology, Optical sensors
  - For accurate use of fertilizers and determining crop health; Crop sensors
  - Best time to plant crop
  - Remote monitoring
  - Agbots; To automate agricultural processes

Examples of Industrial sensors (contd.)

- **Health Care Industry**
  - Implantable sensors, MEMS ,biosensors, nano sensors
  - Smart pills
    - Pills sends alert message to other members when swallowed
    - Camera pills for imaging
  - Smart bed
    - Use sensors that prevent fall of the patient and sends report about the patient’s movement

Examples of Industrial sensors (contd.)

- **Retail Industry**
  - RFID tracking chip
  - Tracking location of shipment made possible with GPS and IoT
  - Sensors on shopping cart and product to avoid theft

Sensors Technology Manufacturers

- DTS
- BOSCH
- Honeywell
- adafruit
- MASSA
- ΩOMEGA
- μS MICRO-SENSOR

PLC: Industrial Applications

- Programmable Logic Controller (PLC) is
  - special computer device used in industrial automation systems
  - special-purpose digital computer in industries.
- Architecture of PLC
  - **CPU module:** consists of central processor and memory.
    - Central processor-performs the computations and processes data
    - Memory –stores the programs and data
  - **Power supply module:** supplies power to the entire circuitry
  - **I/O module:** connects the sensors and actuators.

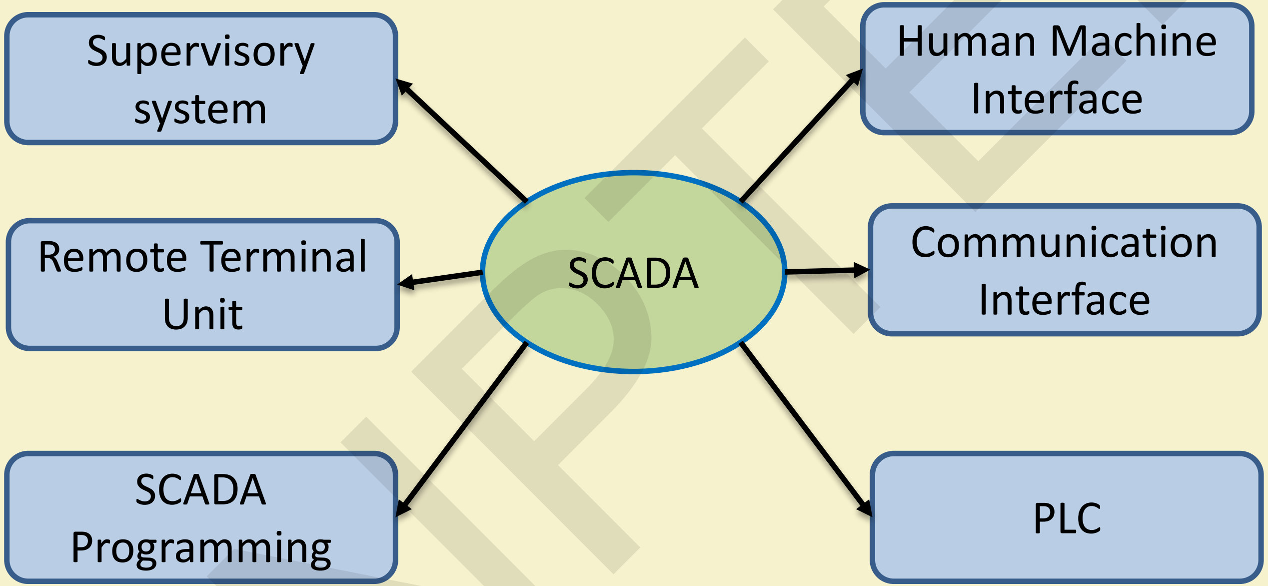
Source: edgefx.in

SCADA: Industrial Applications

- Supervisory control and data acquisition (SCADA) is
  - an **industrial control system**
  - process, monitor, and analyze data at the same time
  - used to collect data from remote sites and transmit data to a central site.
  - applicable for process, oil, power generation, energy, water and waste control, and manufacturing industries.

Source: edgefx.in

SCADA: Industrial Applications (contd.)



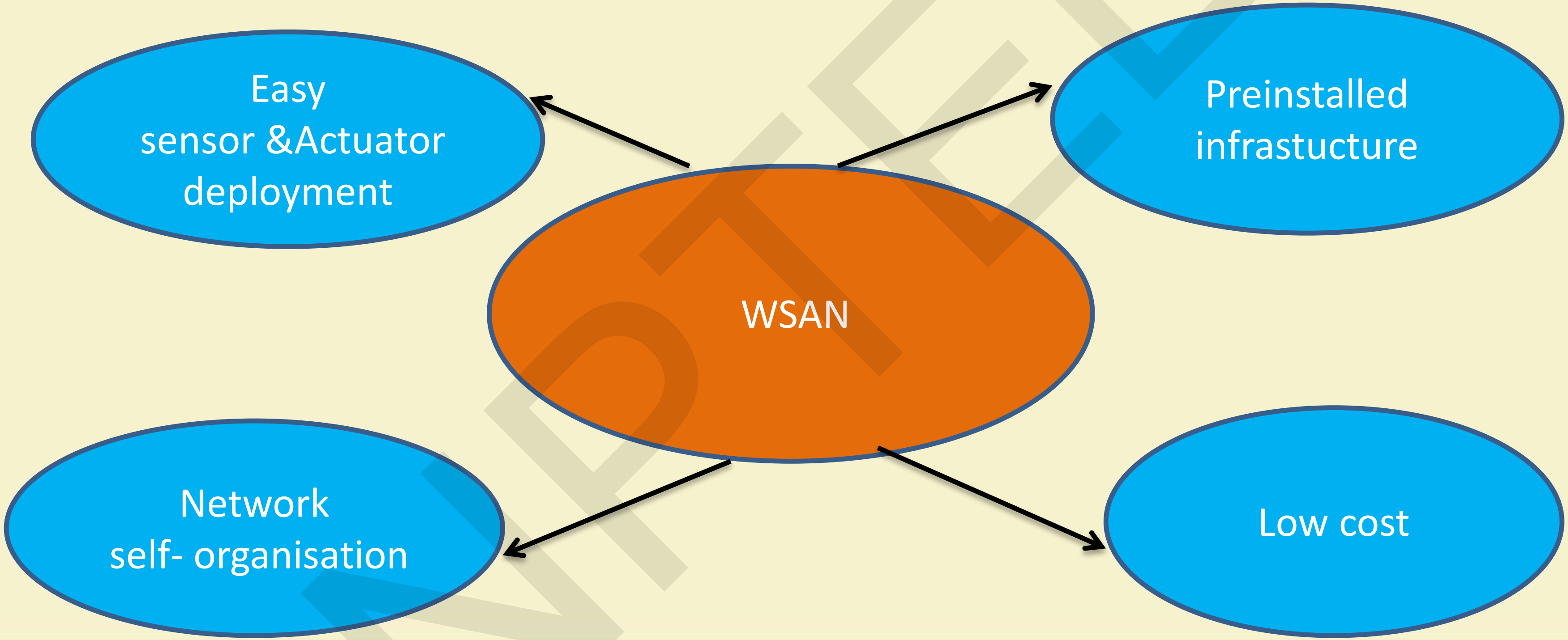
Source: edgefx.in

Industrial control with WSANs

- Industrial Monitoring and control are made easier with WSANs (Wireless Sensing & Actuation Network)
- "Integration of sensors and actuators with wireless network protocol, Real time task scheduling and control law form a WSAN"
  - HVAC control system in industries employ wireless sensor in order to measure temperature
  - Actuation depends on the controllers treatment on the sensors measurement
  - In HVAC control system Actuator can be an wireless air conditioner

Source: Distributed Collaborative Control for Industrial Automation With Wireless Sensor and Actuator Networks, *IEEE Transactions on Industrial Electronics*

WSANs Advantages



Electro-hydrostatic Actuation System

- A Substitute to traditional hydraulic and elecromechanical actuators
- Combined advantage of electric and hydraulic actuators
- High force capability
- High energy efficiency
- Decentralized Actuation

Source: Electrohydraustatic Actuation System , MOOG

Electro-pneumatic systems

- Precise flow control
- Advanced communication
- Better diagnostics
- Ultra high resolution
- Combine advantage of Electric and Pneumatic actuators

Source: Industrial pneumatic actuators ,Bray commertial

Actuators Technology Manufacturers

MOOG

SKF

KNR

FUYU

SPAT

SIRIUS ELECTRIC

ZABER

ECKART

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[8] Source: Industrial pneumatic actuators ,Bray commertial. OnlineURL:http://www.greenheck.com/media/pdf/submittals/Bray9293Series_submittal.pdf

Thank You!!

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Basics of Industrial IoT: Industrial Processes – Part 1

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Timeline of Industrial Revolution

Industry 1.0: Mechanization

(~ 1770-1820)

Industry 2.0: Mass Production

(~ 1870-1950)

Industry 3.0: Computer & Automation

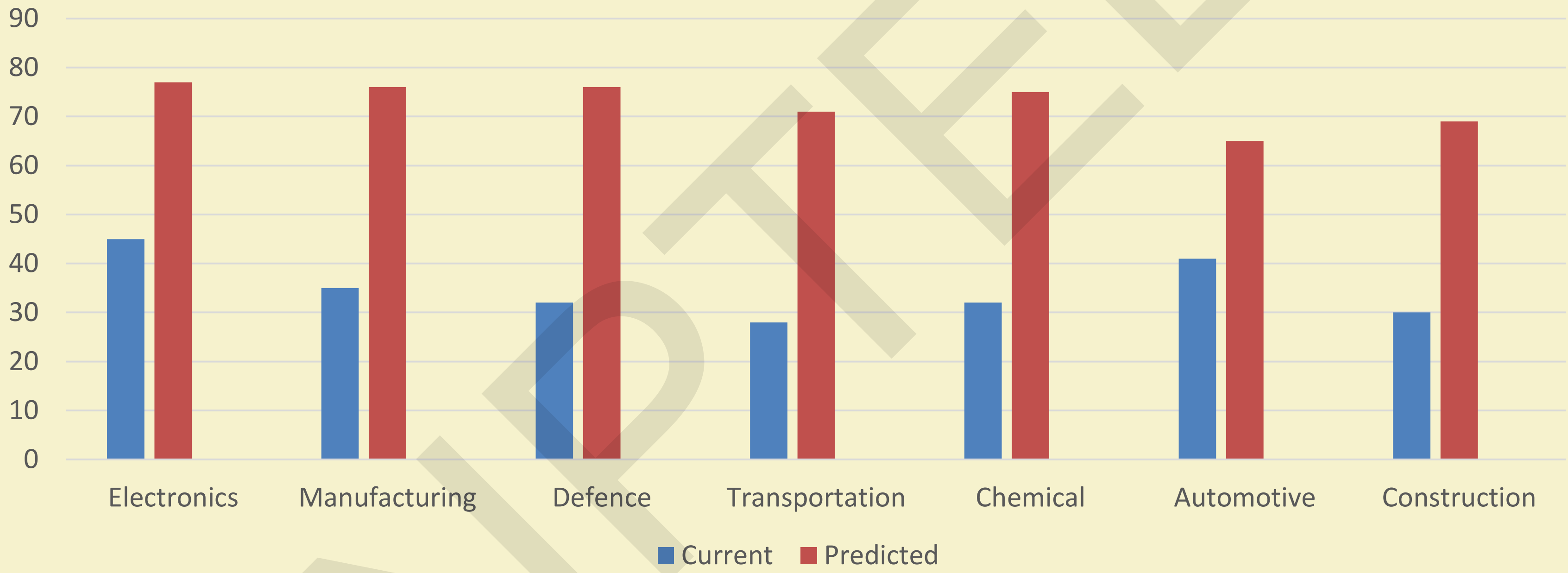
(~ 1950-2000)

Industry 4.0: Intelligent Things

(~ 2000-)

Source: "Industry 4.0 and Maintenance", Norsk Forening for Vedlikehold (NFV)

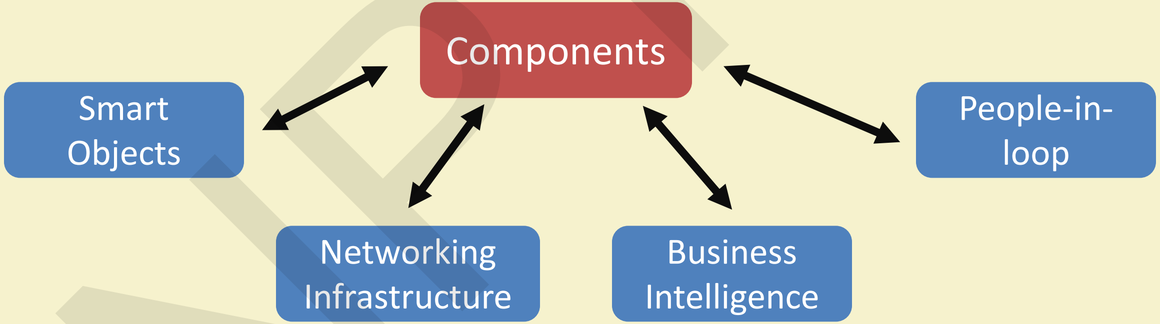
Predicted Growth in Industrial Sectors



Source: "Industry 4.0: Building the Digital Enterprise", PwC, *Global Industry 4.0 Survey*, 2016.

Industrial Internet of Things (IIoT)

- Network of objects ("things") embedded with computation and communication facilities to achieve industrial jobs by exchanging information among themselves



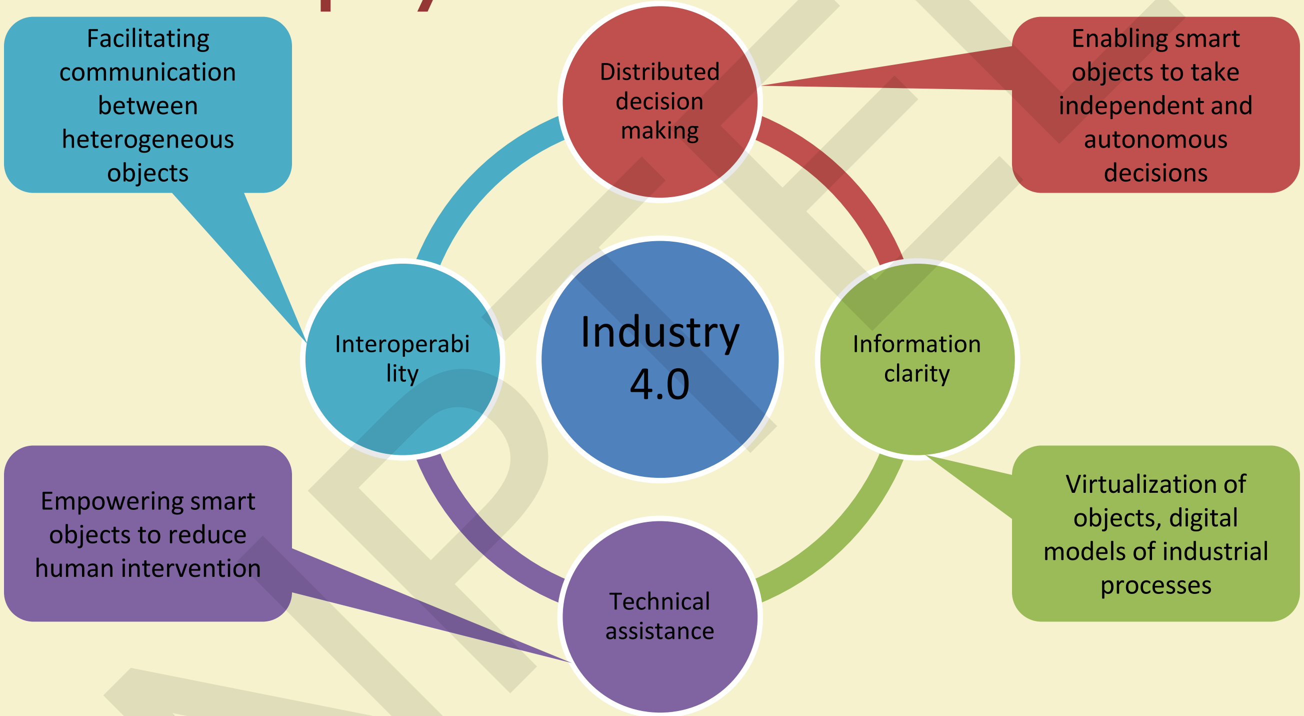
Source: Xu et al., 2014

Challenges for Industrial Processes in Industry 4.0

Dynamic market conditions	• High risk market • Target for lowering cost
Constrained workforce	• Lack of skilled workforce • Ageing society
Supply chain management	• Higher flexibility & convenience expected • Media influence
Resource utilization	• Efficient utilization of available resources • Increased cleanliness and lower waste footprint
Product management	• Increased product types • Lower product lifecycle expected

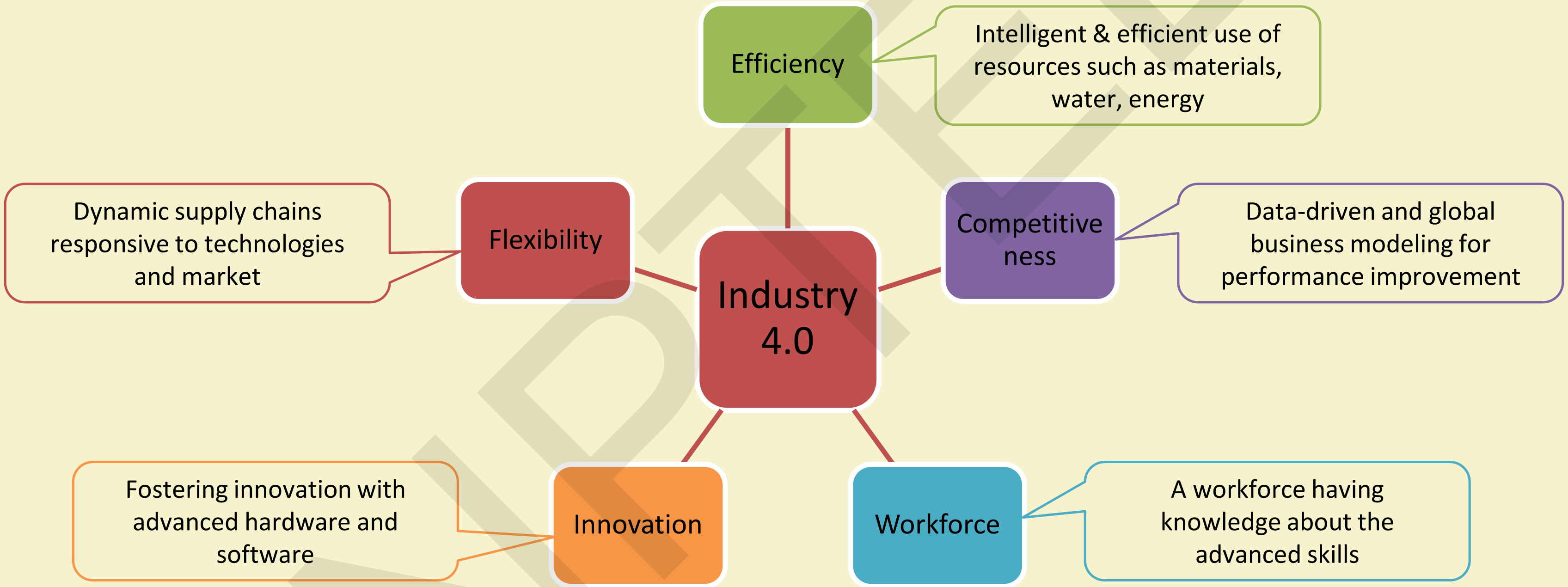
Source: “Industry 4.0”, Wikipedia

Design Philosophy: IIoT for Industrial Processes



Source: "Industry 4.0", Wikipedia

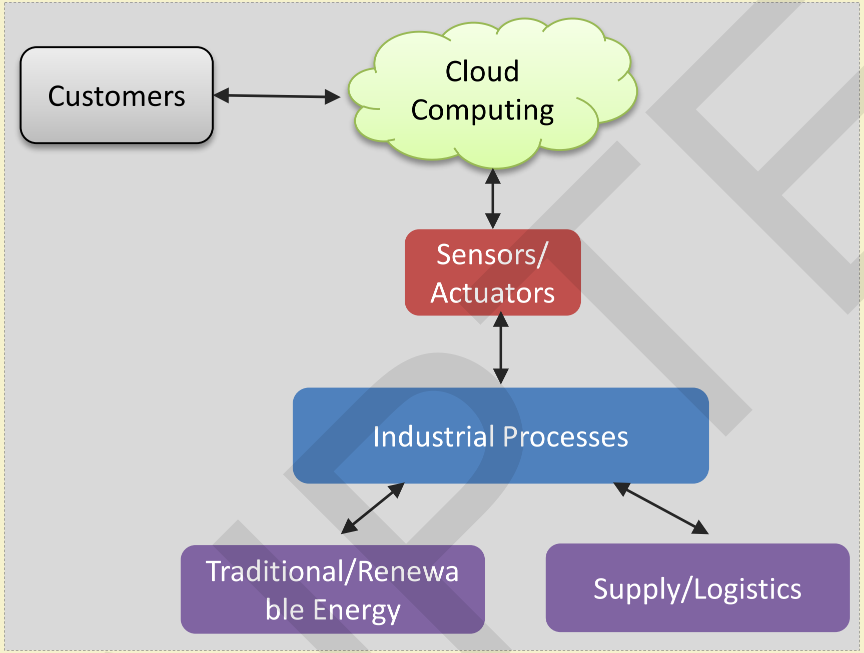
Expected Features of Industrial Processes with Industry 4.0



Source: “Industry 4.0”, Wikipedia; "Industry 4.0: the fourth industrial revolution – guide to Industrie 4.0", i-Scoop

Futuristic Industrial Plant

Customized application demands



Cloud-based advanced analytics, cyber security

Smart 'things' tasked with sensing, actuation, computation, communication, and decision making

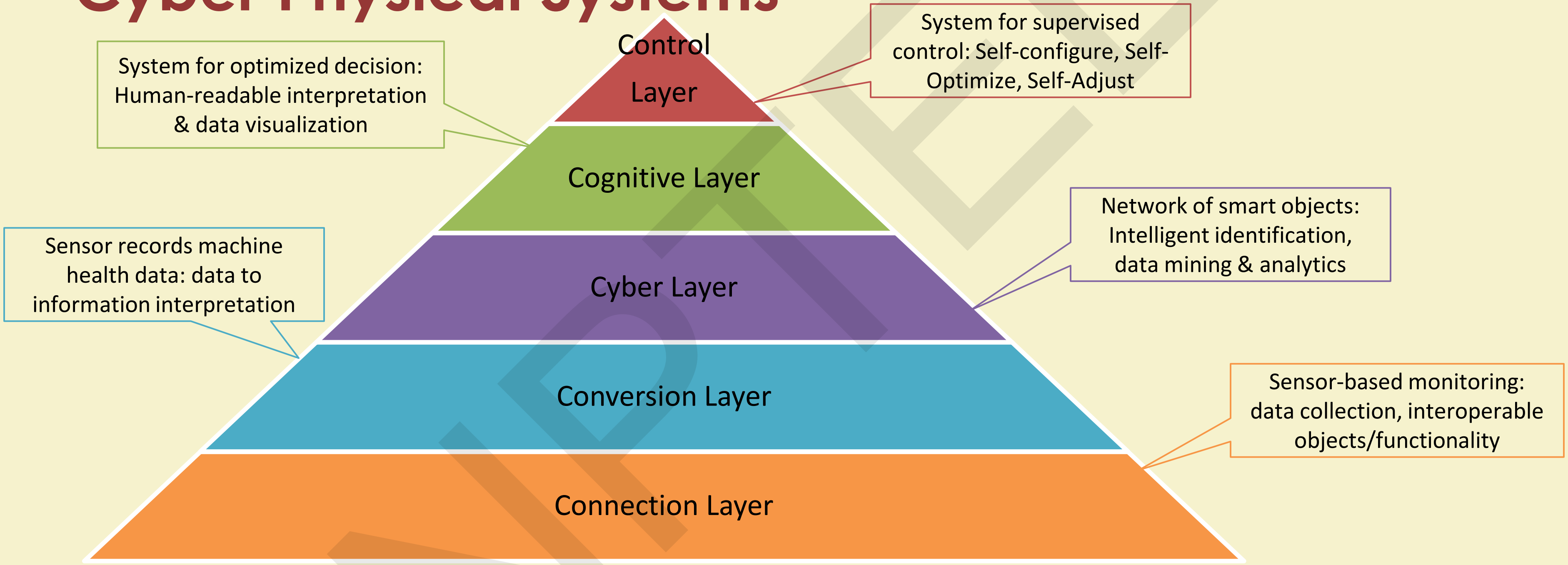
Different industrial processes – 3D printing, manufacturing, automation

Industrial resources, supply chain management

Figure: Components of Futuristic Industrial Plant in Industry 4.0

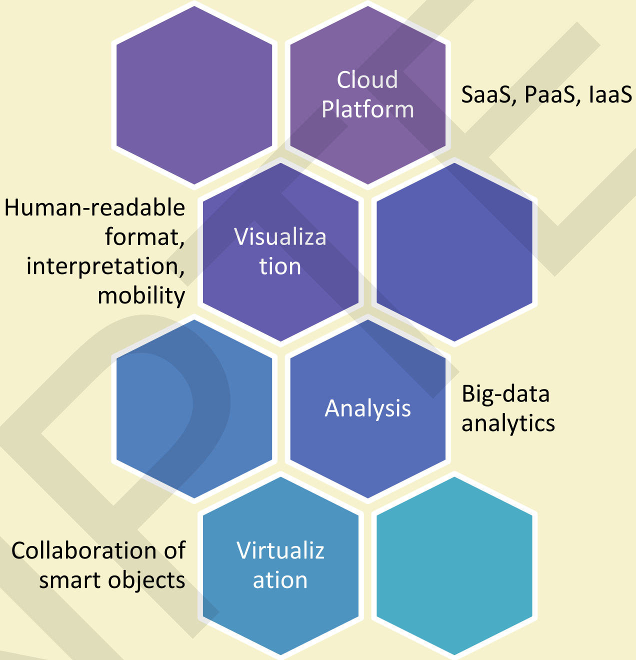
Source: Aazam et al., 2018.

Futuristic Industrial Plant: 5C Architecture for Cyber Physical Systems



Source: Lee et al., 2015; Aazam et al., 2018.

Industrial Processes Enablers



Source: Aazam et al., 2018.

Industrial Process 4.0: Operation Efficiency

- Benefits
  - Improved resource utilization
  - Increased productivity
  - Cost reduction

Smart Water Management by *Thames Water*
- Sensor-based equipment status monitoring
- Failure detection
- Critical condition monitoring
- Dynamic response to critical conditions

Oil & Gas Industry Maintenance by *Apache*
- Sensor-based leak detection in pipe lines
- Failure detection in pumps
- Production monitoring
- Predictive analysis of loss

Source: Thames Water, "Draft Water Resources Management Plan 2019"
MapR Technologies, "Big Data and Apache Hadoop for the Oil and Gas Industry"

Industrial Process 4.0: Product Innovation

- Benefits
  - Service-oriented deployment
  - Data monetization
  - Pay-per-use

Augmented Maintenance by *Volkswagen*
- Sensors collect data from automotive
- Augmented Reality-based app provide visual interpretation of on-board problem
- Problem analysis & diagnosis

Source: Volkswagen AG

Industrial Process 4.0: Enhanced Ecosystem

- Benefits
  - Connected ecosystem
  - Innovative product lines
  - Dynamic marketplace
  - Pay-per-outcome

Increased Renewable Energy Production by *General Electric*

- Controlled power generation by using weather forecast
- Sensor-controlled maintenance
- Lower operation cost by analyzing collected data

Increased reliability in aircraft engines by *Rolls-Royce*

- Sensor-based remote analytics tools
- Predictive maintenance
- TotalCare program increases the engine reliability

Source: GE Renewable Energy; Rolls-Royce plc

Industrial Process 4.0: Autonomous Pull Economy

- Benefits
  - End-to-end automation facility
  - Updated demand information
  - Low waste generation
  - Better resource optimization

Factory Maintenance by *General Electric*
- *Predix* platform for Cloud-as-a-Service
- Pay-per-use pricing model
- Secure and compatible environment
- Analytical services helps in service optimization

Source: General Electric Inc.

Smart Factory of Future

- *Application areas*
  - Facility management
  - Connected factory
  - Inventory management
  - Production line management
  - Process safety and security
  - Service quality control
  - Supply chain optimization
  - Packaging management

Source: "8 Uses, Applications, and Benefits of Industrial IoT in Manufacturing", New Generation Applications Pvt Ltd,

Smart Factory of Future (contd.)

Facility Management

- Sensor-equipped manufacturing facility
- Provision for condition-based monitoring
- Machinery health monitoring
- Optimization & remote functional control
- Higher efficiency, lower cost & energy expense

Connected Factory

- Connected components of factory – machinery, engineers, and manufacturers
- Enables automation and optimization
- Remote control and management
- Ease of command and control
- Facilitate identification of Key Result Areas (KRAs)

Source: "8 Uses, Applications, and Benefits of Industrial IoT in Manufacturing", New Generation Applications Pvt Ltd,

Smart Factory of Future (contd.)

Inventory management

- Tracking of items by monitoring events in supply chain
- Global inter-connectivity facilitates real-time updates
- Higher visibility & transparency
- Realistic and fail-safe estimate for customers
- Supply optimization & cost reduction

Production line management

- End-to-end production line management with sensors
- Ease of process re-adjustment facility
- Detailed understanding of production delay & failures
- Process flow analytics

Source: "8 Uses, Applications, and Benefits of Industrial IoT in Manufacturing", New Generation Applications Pvt Ltd,

Smart Factory of Future (contd.)

Process safety and security

- Safe & secure working environment
- Complete record & analytics on accidents, injuries & causes
- Optimized financial planning & insurance schemes
- Ensured precautions for safe environments

Service quality control

- End-to-end product cycle monitoring
- Provision to ensure quality for raw materials, factory environment
- Waste management
- Multi-level product quality check
- Enabling feedbacks from customers
- Holistic analytics

Source: "8 Uses, Applications, and Benefits of Industrial IoT in Manufacturing", New Generation Applications Pvt Ltd,

Smart Factory of Future (contd.)

Supply chain optimization

- Real-time monitoring of supply chain elements in multiple dimensions
- Ease & transparency for related personnel
- Identification of inter-block dependency

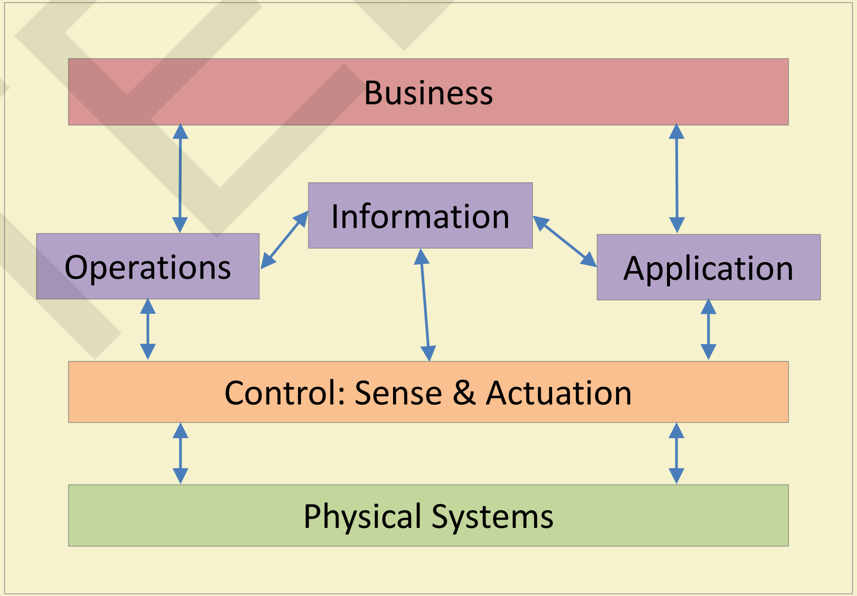
Packaging management

- Sensor-based packaging facility
- Real-time monitoring
- Detailed analytics on customers usage patterns
- Multi-point trace enables package condition monitoring
- Continued customer satisfaction & reduced cost

Source: "8 Uses, Applications, and Benefits of Industrial IoT in Manufacturing", New Generation Applications Pvt Ltd,

Functional Viewpoint of Industrial Processes

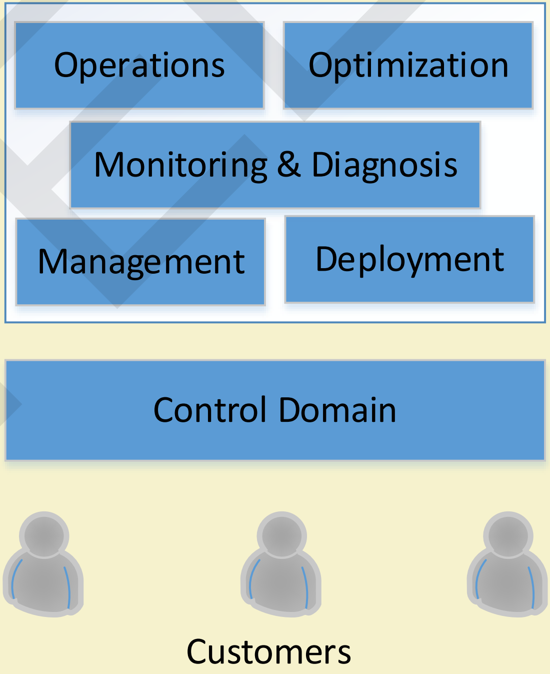
- Highlights the stakeholder's concerns regarding the industrial processes
- Flexible & applicable to various types of industrial processes
- Importance to specific domain varies across industries



Source: A. Gilchrist, "Industry 4.0 - The Industrial Internet of Things", APress

Operational Domain of Industrial Processes

- Cross-environment interconnected control system
- Intra and Inter factory communication
- Distributed analysis & learning



Source: A. Gilchrist, "Industry 4.0 - The Industrial Internet of Things", APress

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Basics of Industrial IoT: Industrial Processes – Part 2

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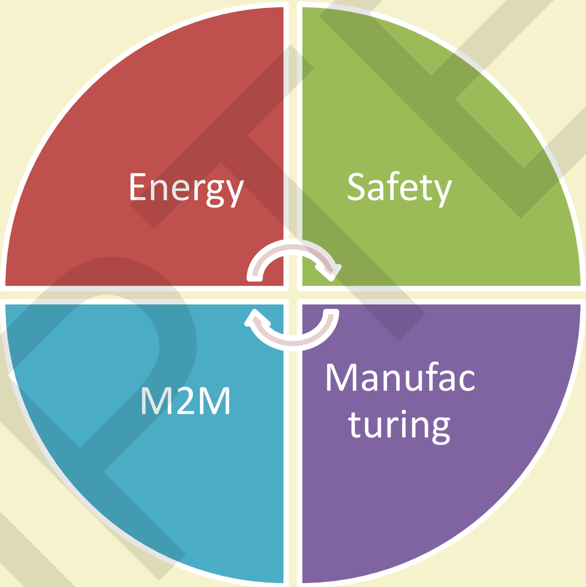
Industry 4.0 – Different Sectors

- Smart robotics
- Factory of future
- Intelligent manufacturing
- Smart warehousing
- Air-as-a-Service
- Improved mining
- Smart logistics
- Track & Trace Innovation

Industry 4.0 @ ICP DAS

- Energy management
- Pollution monitoring
- Environmental monitoring
- Smart home/office setup

- Plant safety
- Surveillance
- Information security
- Environmental safety



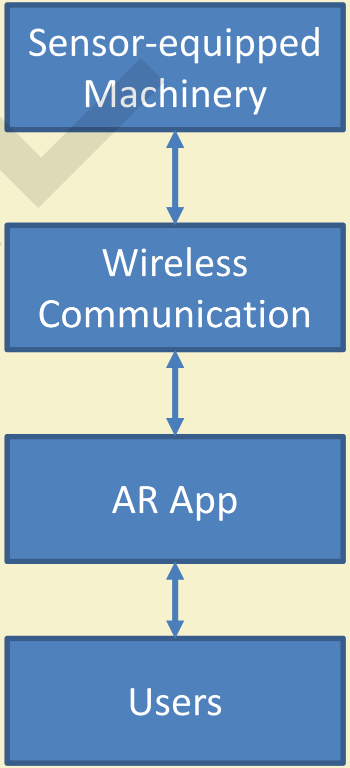
- Supply chain automation
- Logistics
- Motion control
- Storage & parking

- Machine internetworking
- System health diagnosis
- Production efficiency
- Remote management

Source: Industry 4.0 at ICP DAS Co. Ltd.

Caterpillar: IoT + AR

- Smart view using IoT and Augmented Reality (AR)
- Real-time machine status and condition monitoring
- Ease of interaction with machines
  - App-based instructions for novices
  - Custom alerts for parts replacement
- Long term data analytics to predict future failures & budget



Source: Caterpillar Inc.

Amazon: Smart Warehousing

- Logistics & supply chain management
  - Smart control of supply fleet
  - Logistic status update with future market demand
- Tech-drivers:
  - Warehouse Automation
  - Human-Machine Interaction
- Robot-equipped goods storage & pickup facility in warehouse
- Lower operational cost
- Faster operating time

Source: Industry 4.0 at ICP DAS Co. Ltd.

Boeing: Efficient Manufacturing

- Smart & digital manufacturing facility
  - Helps in assembling of millions of aircraft parts
  - Automation of assembly steps
- Lower assembly delay & response time
- Reduced errors in manufacture & assembly
- Enhanced production capability
- Tech-drivers
  - Smart glasses for fault detection
  - Sensor-equipped assembler tools

Source: The Boeing Company, "System And Method For Using An Internet Of Things Network For Managing Factory Production", US Patent 20160202692, 2016.

Cisco & Fanuc: Smart Factory

- The objective is to minimize downtime in industrial facility
- Tech-driver
  - Sensor-equipped robotic manufacturing facility
  - Cloud-based analytics
- Predictive maintenance & failure forecasting
- The system can place orders for replacing failed parts
- Zero Downtime (ZDT) system by Fanuc increases efficiency
- Connection between different production phases & accordingly refill of warehouse stocks

Source: NIKKEI Asian Review, “Boy, do Fanuc and Cisco have a deal for your factory”, Online article, 22 Jan 2016.

Hitachi: Integrated IIoT

- *Lumada* IoT platform
- AI-powered advanced analytics
- *Solution Core*: Replicable components for custom services
- *Co-creation Services*: Co-design facility for customers
- Production acceleration for application needs

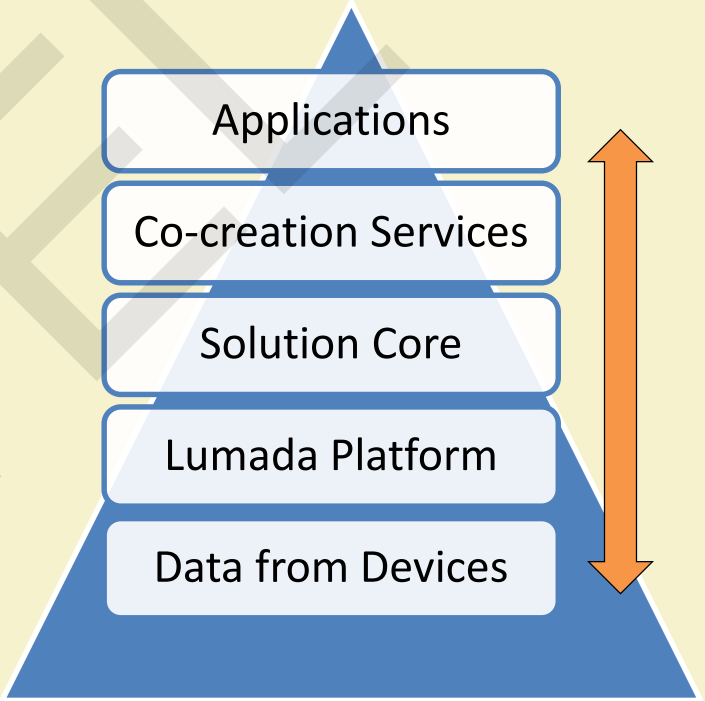


Figure: Hitachi IIoT platform hierarchy

Source: Lumada IoT Platform, Hitachi

John Deere: Precision Agriculture

- On-board GPS for real-time tracking of agricultural equipment
- Telematics technology for forecasting & maintenance
- Bale mobile app for geo-tagged yield mapping & bale monitoring
- Implementing remote control of tractor navigation
- The future goal is to enable autonomous agricultural operations without human intervention by self-driving tractors

Source: Agriculture Technology, Precision Agriculture, John Deere

Kaeser Kompressoren: Air-as-a-Service

- Sensor-equipped air compressors
- Ease of predicting the future failures and maintenance cost
- *Air-as-a-Service*: Users pay per cubic meter of air from company's owned compressors
- Service models: *Selling*, *Renting*, and *Air-as-a-Service*
- Operation cost reduction as lesser customer services requests are generated

Source: Kaeser Kompressoren – Service

Real-Time Innovations: Smart Grid

- Smart energy management system with *Connext DDS*
- Integrated apps and devices – scalable, secure & reliable
- Modular design, faster connectivity, high throughput
- Facility for deploying analytics in edge or cloud
- Product suite
  - Professional version: End-to-end solution, scalable & reliable
  - Secure version: Enhanced & secure version
  - Micro version: Specifically for resource constrained systems
  - Cert version: Safety-centric IIoT systems

Source: Real-Time Innovation Products

Komatsu: Improved Mining

- Technology sectors
  - *Mining Intelligence*: Higher profit by predictive machine performance analysis
  - *Proximity Detection*: Enables workers to stay safe from hazards & large machines
  - *Environmental*: Reduced dust, ignition – increased visibility, optimal use of water
- Tech-driver:
  - Internet connected robots
  - Self-driving trucks
  - Wireless sensors
- Systems
  - PreVail remote health monitoring system
  - JoyConnect
  - Longwall 3D Visualization

Source: Komatsu

Rio Tinto: Futuristic Mining

- Central control facility with visualization & collaboration tools
- Real-time monitoring and optimization of supply chain
- Autonomous haulage systems (AHS): a fleet of autonomous trucks
- Safe & efficient navigation resulting in increased productivity
- Automated drilling system (ADS): Enables remote operator to control drilling
- AutoHaul® is the system for autonomous trains to carry iron ore

Source: Rio Tinto – Mine of Future

Stanley Black & Decker: Smart Construction & Engineering

- Innovation Sectors:
  - Engineering: Solutions for product assembly – automotive, computer, home appliances, telecommunications, solar panels.
  - Pipeline: High quality reliable pipeline for oil & gas industry
  - Infrastructure: Solutions for equipment required in construction & maintenance
- Lightweight vehicles: ECOSMART™ innovative solution which reduces energy requirement and carbon footprint

Source: Stanley Black & Decker

Shell: Smart Oil & Gas

- Digital oil field: Sensor-equipped oil & gas machinery, valves and pumps
- Enabling precise operation for shale gas recovery
- Real-time monitoring and optimization facility
- Faster production decisions to reduce slower production rate
- Improved production, reduced downtime & risk, lower costs

Source: Shell – Energy & Gas

North Star BlueScope: Industrial Safety

- Worker death rate due to work-related disease/accident: ~1/15 seconds [Source: International Labor Organization]
- Wearable safety gadgets for industrial workers
- Analytics & IIoT: hazardous condition monitoring, work environment safety
  - Enforcing proper safety conditions
  - Interconnected workers

Source: International Labor Organization; North Star BlueScope

Maersk: Smart Logistics

- IoT and analytics to optimize the route & fuel consumption for containers
- Remote control & maintenance of containers according to its content – dry cargo, refrigerated cargo, or special cargo
- Facility for users to remotely monitor the condition inside cargo
- End-to-end shipment: Source to destination shipping covering intermodal transport
- Trade finance: Solution to control the flow of goods & optimize pricing
- Other solutions: *Supply Chain Optimization* & *Freight Forwarding*

Source: Maersk Solution

Magna Steyr: Smart Factory

- Digital mapping of entire production timeline
  - Vehicle engineering
  - Production line implementation
- Intelligent production system: Accurate, scalable, reliable & dynamic to changed needs
- Full autonomy of factory: network of humans, machines & resources
- Solutions: *Driver assistance system, Alternative energy storage system, Lightweight design & joining system*

Source: Magna Steyr – Capabilities

Gehring: Connected Manufacturing

- Internet-connected sensor-equipped machinery enables real-time data streaming
- Smart projection of machine functionalities to customers in real-time: precision & efficiency check
- Cloud-based analytics to reduce production downtime & increase productivity
- Provision for real-time tracking & monitoring of machinery
- Facility for data visualization & additional analytics

Source: Gehring Technologies

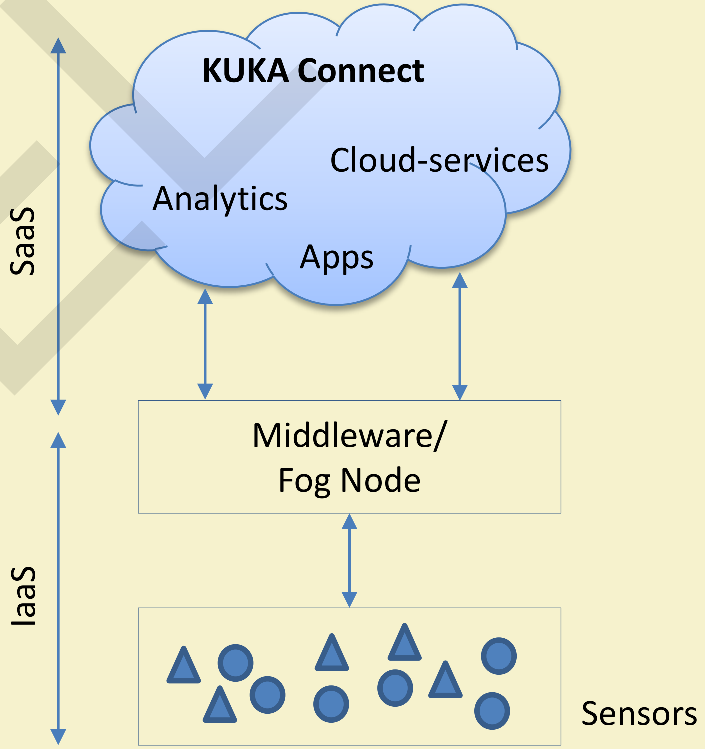
Bosch: Track & Trace Innovation

- Solution to ease the searching of the different tools/parts in a factory
- Sensor-equipped tools/parts can be tracked and traced
- Reduction in searching time and risk for using wrong tools
  - Asset/work management
  - Integrated manufacturing
- Future impact: Can help in automated sequencing of assembly operation
- Tools-as-a-Service: New business model for efficient productivity, enhanced safety & product quality
- The same technology can be applied to many other sectors of the industry – food, logistics, supply chain, pharmacy, etc.

Source: Bosch Track & Trace Innovator

KUKA: Connected Robotics

- <u>Connected robotics</u> system for <u>super-fast manufacturing</u>
- Internetwork between the robotic assemblers and components
- Smart factory with robots connected to private cloud as solution for the clients
- Analytics on collected data to generate better future strategies



Source: KUKA Connect

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Business Models and Reference Architecture for IIoT

Business Models – Part 1

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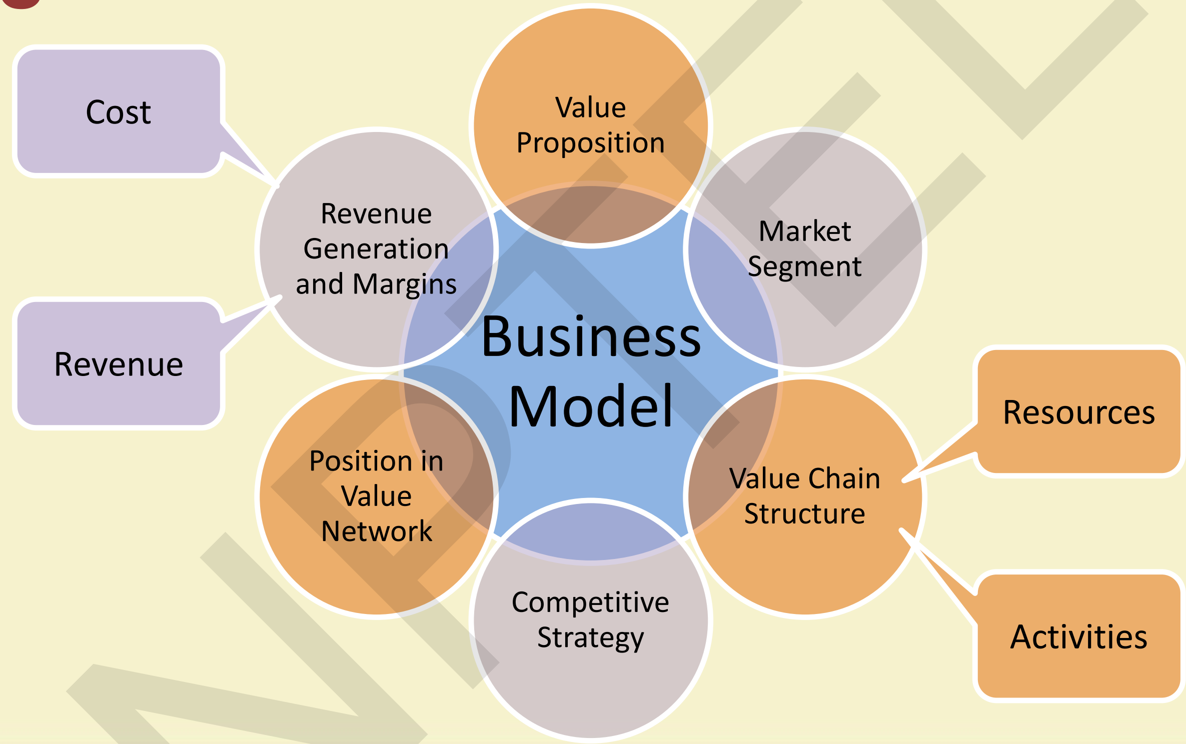
What is a Business Model?

- *"A business model describes the rationale of how an organization creates, delivers, and captures value"*

  [Business Model Generation]
- It is the embodiment of the organizational and financial architecture of a business
- Description of how a business intends to operate and earn profits in a specific marketplace

Building Blocks of a Business Model



Building Blocks of a Business Model (Contd.)

- Value Proposition
  - Products or services that create value for a customer segment
  - Values may be:
    - Quantitative
      - Price, product or service performance, post-purchase cost reduction
    - Qualitative
      - Design, customization, customer experience, brand

Building Blocks of a Business Model (Contd.)

- Market Segment
  - Different groups of customers or end-user organizations that the business enterprise aims to serve
  - There are different types of customer segments:
    - Mass market
    - Niche market
    - Segmented
    - Diversified
    - Multi-sided markets

Building Blocks of a Business Model (Contd.)

- Value Chain Structure
  - The key resources and activities that a business requires to create value proposition
  - Resources:
    - Can be Physical, Intellectual, Human, Financial
    - Key resources can be owned or leased by the company or acquired from key partners.
  - Activities:
    - Production, Problem solving, Platform/Network

Building Blocks of a Business Model (Contd.)

- Revenue Generation and Margins
  - The revenue that is generated from each customer segment in a business
  - Two different types of Revenue Streams -Transaction revenues and Recurring revenues
  - Ways to generate revenue – Asset sales, Subscription fees, Usage fee, Leasing/Renting, Licensing, Brokerage, Advertising
  - Two types of pricing – Fixed and Dynamic

Building Blocks of a Business Model (Contd.)

- Position in Value Network
  - Value proposition also depends on the network of suppliers and partners
  - Partnerships and alliances created to –
    - Optimize business models
    - Reduce risks
    - Acquire resources

Building Blocks of a Business Model (Contd.)

- Competitive Strategy
  - Strategy of a particular company to gain competitive advantage over its competitors in the market
  - Three generic competing strategies:
    - Cost leadership
    - Differentiation by bringing something unique to customers
    - Focus on a small market segment or a niche rather than the mass market

Need for New Business Models for IoT

- Advent of IoT has resulted in the following:
  - Increased business opportunities
  - Efficient processes
  - Enhanced asset utilization
  - Increased productivity
- Business challenges in IoT:
  - Diversity of objects
  - Immaturity of innovation
  - Unstructured ecosystems

Need for New Business Models for IoT (Contd.)

- IoT business models must address these requirements:
  - Extend scope beyond the company level to ecosystem level
  - Support design/visualization of complex value streams within the stakeholder network
  - Explicitly consider the value proposition for all key stakeholders (e.g., users, customers, and partners)
  - Consider data as an asset within and beyond the actual opportunity

Types of Business Models for IoT

- Subscription Model
- Outcome-Based Model
- Asset-Sharing Model
- IoT-as-a-Service
- Others:
  - IoT Products as a Proxy to Sell Another Product
  - IoT Products as a Vehicle to Monetize Data

Subscription Model

- Data generated by IoT devices is “consumable, measurable and repeatable”
- It is capable of generating “recurring” revenue
- Using this model:
  - Instead of a one-time charge, customers are offered a regular subscription
  - Here, a fee is charged for periodic usage

Subscription Model: Advantages

- Provides predictable, recurring revenue
- The product can be monetized by providing paid upgrades or by implementing a “freemium” model.
- Businesses are able to foster active relationships with customers due to repeated post-subscription interaction
- Businesses are able to learn more about their customers and are able to provide services specific to their requirements

Subscription Model: Challenges

- Customer management
- Automatic invoicing
- Plan management
- Requirement of skilled labor and organizational structure
- Requirement of regular updates

Outcome-Based Model

- Businesses deliver to the customer the outcome/benefits that the product/service provides – "Pay-per-outcome"
- Customer is relieved from the responsibilities of ownership, and maintenance
- It brings together the businesses and their customers to monetize the solutions

Outcome-Based Model: Advantages

- Increased profit margin
- Reduced negotiation cycle
- Higher customer satisfaction
- Reduced risks
- Better alignment of the value proposition of the vendor and consumer

Outcome-Based Model: Challenges

- Requirement of new infrastructure, policies and processes
- Price standardization
- Safe and reliable outcome delivery
- Lack of proven business models

Asset-Sharing Model

- Businesses virtually consolidate and share their IoT-enabled assets among multiple customers or with other business entities in exchange of revenue
- Revenue is charged based on time or nature of usage
- Aim is to minimize downtime and maximize utilization of the assets
- Can be used for Smart Energy

Asset-Sharing Model: Advantages

- Increased profit margin
- Reduced price for customers
- Ease of scaling of business
- Reduced wastage of resources

Asset-Sharing Model: Challenges

- Security of products/services
- Mutual arrangements among business entities
- Asset configuration
- Device synchronization and synergies

IoT-as-a-Service

- Businesses provide IoT-enabled products on lease to customers and earn revenue
- Products can be anything – software, hardware, information/data, results obtained from analysis of data, etc
- Revenue based on volume and quality
- Generates recurring revenue
- Example: Sensor-as-a-Service

IoT-as-a-Service: Advantages

- Reduced licensing costs
- Increased revenue from planned upgrades
- Better aligned value propositions
- Efficient operations and preventive maintenance by vendors
- Better customer relations

IoT-as-a-Service: Challenges

- Product compatibility
- Maintaining data accuracy
- Security of data

Other Models

- IoT Products as a Proxy to Sell Another Product
  - IoT products are sold at cost price or at loss to sell other products
  - For example, IoT devices keep track of status of products and perform actions accordingly
  - Used by manufacturers to sell products which require refills

Other Models (Contd.)

- IoT Products as a Vehicle to Monetize Data
  - IoT-enabled products collect data from users while providing services
  - This data is sold by businesses to third party businesses to earn revenue
  - As per requirement, data is processed and aggregated
  - Customers must be made aware beforehand about the usage of their data and privacy policies

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Business Models and Reference Architecture for IIoT

Business Models – Part 2

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Business Oppurtunities in IIoT

- Entrepreneurship theory:
  - Asset-driven opportunities
  - Service innovations that aid manufacturing
  - Service-driven opportunities targeted at end users
  - Information infrastructure ownership
- Transaction cost theory:
  - Non-ownership contracts
  - Performance contracts

Components of IIoT Business Models

- Value proposition
- Value capturing mechanism
- Value network
- Value communication

IIoT Business Models: Types

- IIoT business models can be divided into following categories:
  - Cloud-based Business Model
  - Service-Oriented Business Model
  - Process-Oriented Business Model

Cloud-Based Business Model

- Customers do not purchase software, platform or infrastructure
- Instead, they lease the cloud computing resources temporarily

- Infrastructure-as-a-Service
- Platform-as-a-Service
- Software-as-a-Service

Cloud-Based Business Model (Contd.)

- Cloud-based BMs comprise manifold offerings
  - Processing power
  - Data storage
  - Virtualization of the operating system online

- Infrastructure-as-a-Service (IaaS) model
  - Aim at providing required hardware and software online in the cloud

Cloud-Based Business Model (Contd.)

- Platform-as-a-Service (PaaS) model
  - Open toward external parties
  - Provide development-oriented platforms
  - Facilitate the development of applications
  - Facilitate the integration of applications into existing solutions
- Software-as-a-Service (SaaS) model
  - Offer online capable and customized applications

Cloud-Based Business Model (Contd.)

- Partner network
  - Risk reduction
  - Synergies due to economies of scale
  - Shared usage of resources
- Value configuration
  - Development of cloud services and applications
  - Establishment of partner network

Cloud-Based Business Model (Contd.)

- Core competencies
  - IT resources
  - Software infrastructure
  - Knowhow
- Relationships
  - Community networks
  - Forums

Cloud-Based Business Model (Contd.)

- Value proposition
  - Processing power
  - Data storage
  - Virtualization of the operating system
  - Development oriented platforms
  - Integration of applications
  - Applications

Cloud-Based Business Model (Contd.)

- Distribution channels
  - On demand
- Target customers
  - Educational institutions
  - Startups
  - Independent software vendors
  - Small and medium-sized enterprises

Cloud-Based Business Model (Contd.)

- Cost structure
  - Cost reduction
  - Initial costs for installation
  - Service costs
- Revenue model
  - Pay-per-use
  - Subscription fees
  - Advertisement

Service Oriented Business Model

- Offers
  - primarily utilization
  - Analysis of data
  - aggregation of data
- Example:
  - Medical environment

Service Oriented Business Model (Contd.)

- Offered to a mass market on demand through infrastructures and platforms established by Cloud-based BMs
- Provides to customers
  - Self-service interface
  - Automated services
- Target customers
  - Mass market

Service Oriented Business Model (Contd.)

- Partner network
  - Community
  - Infrastructure providers
  - Platform developers
- Distribution channels
  - Platforms
  - On demand

Service Oriented Business Model (Contd.)

- Value configuration
  - Maintenance and further development of
    - Platforms
    - Infrastructures
    - Applications
- Relationships
  - Self-service interface
  - Automated services

Service Oriented Business Model (Contd.)

- Value proposition
  - Utilization of data
  - Analysis of data
  - Aggregation of data
- Core competencies
  - Platforms
  - Data analysis methods
  - Data

Service Oriented Business Model (Contd.)

- Cost Structure
  - Initial establishment costs
  - Variable instead of fixed costs

- Revenue Model
  - Collected data
  - Direct and indirect monetization of data

Process Oriented Business Model

- Process optimization resulting in
  - Reduced downtimes
  - increased machine availability
- Optimize processes within a company and across company boarders
- Optimize data analyzed by Service-oriented BMs
- Results in reduced downtimes due to the eliminated delivery times

Process Oriented Business Model (Contd.)

- Value configuration
  - Master complex production processes
  - Various production technologies
- Core competencies
  - Platforms
  - Data
  - 3D printers

Process Oriented Business Model (Contd.)

- Value proposition
  - Reduced downtimes
  - Increased machine availability
- Target customers
  - Machine and plant engineering industry

Process Oriented Business Model (Contd.)

- Cost structure
  - Initial establishment costs
- Revenue model
  - Licenses
  - Higher prices possible

IIoT Business Model: Flow

Cloud-Based BM → Service Oriented BM

Service Oriented BM → Process Oriented BM

Cloud-Based BM → Process Oriented BM

IIoT Business Model: Flow (Contd.)

- Cloud-based BMs aim at providing an infrastructure
- Companies operating a Service-oriented BM employ Cloud-based BMs to gather data and information
  - Analyze and sell as a service
- Analyzed and prepared data help companies with a Process-oriented BM to optimize process flows

IIoT Business Model: Challenges

- Security and data privacy
  - Physical and virtual worlds combine at a large scale
- Need security frameworks for entire cyber physical stack
  - device-level authentication and application security
  - system-wide
    - Assurance
    - Resiliency
    - Incidence response models

IIoT Business Model: Challenges (Contd.)

- Lack of interoperability
- Increase complexity
- Increase cost
- Need for seamless data sharing between machines and other physical systems from different manufacturers

IIoT Business Model: Challenges (Contd.)

- Uncertain return on investments on new technologies
- Immature or untested technologies
- Lack of data governance rules across geographic boundaries
- Shortage of digital talent

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Thank You!!

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Business Models and Reference Architecture for IIoT

Reference Architecture – Part 1

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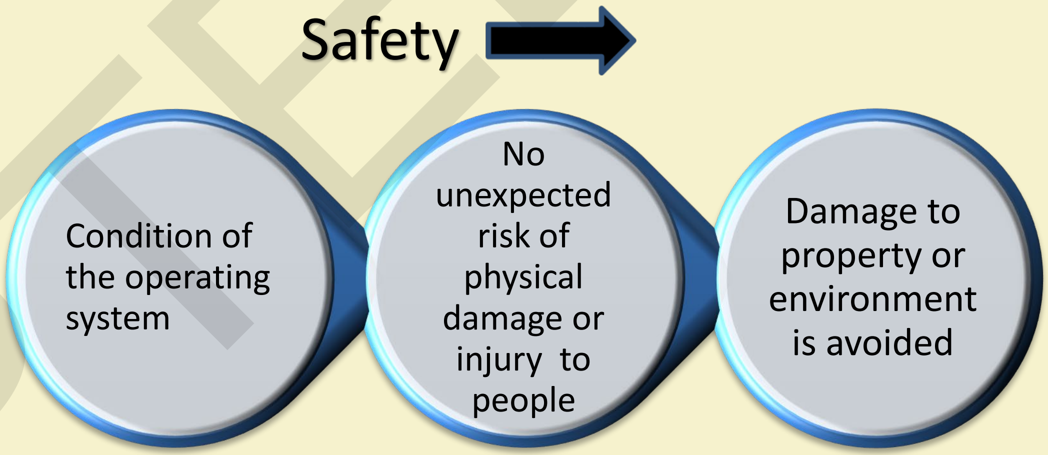
IIRA - Introduction

- Industrial Internet Reference Architecture (IIRA) is an standard architecture for IIoT systems.
- Standards-based architecture proposed by the IIC Technology Working Group
- Current Version: IIRA v1.8
- IIRA is broadly applicable in the industrial systems to
  - allow interoperability
  - map application technologies
  - guide technologies

Source: "IIoT Reference Architecture", IIoT World

IIRA - Introduction (contd.)

- Safety is the major concern in the IIRA infrastructure, and is to be followed by security.



Source: "IIoT Reference Architecture", IIoT World

Key Performance Indicators (KPIs) for Occupational Safety and Health (OSH):

- Key performance indicators for OSH is
  - a measure of the activities of an organization
  - connect/communicate with customer
  - provide valuable feedback
  - drive towards improvement

Source: "Performance Indicators", Oshkiwi
"KPIs", Beyondlean

Key Performance Indicators (KPIs) for Occupational Safety and Health (OSH) (contd.)

- Based on the leading and lagging OSH indicators, KPIs are also categorized into
  - **Leading KPI** is mainly used to predict the economy. It is
    - input-oriented, and
    - hard to measure.
  - **Lagging KPI** is a technical indicator which changes after the economy has begun. It is
    - output-oriented, and
    - hard to improve

Source: “Performance Indicators”, Oshkiwi
“Lagging and Leading Indicators”, Kplibrary

Key Performance Indicators (KPIs) for Occupational Safety and Health (OSH) (contd.)

Lagging KPIs

- Number of lost-time incident frequency rate
- Production days lost due to sickness absence
- Incidents or near misses
- Number of fatalities

Leading KPIs

- Percentage of managers with adequate OSH training
- Percentage of workers with adequate OSH training
- Frequency of observed unsafe behaviour
- Number of OSH audits

Source: "Performance Indicators", Oshkiwi

Industrial Internet Consortium (IIC)

- Industrial Internet Consortium (IIC) is a non-profit organization created for
  - promotion of open standards
  - interoperability for technologies

  used in industries and machine-to-machine (M2M) environments.
- Testbeds are an area of major focus and activity of the IIC members.

Source: “Test Beds”, IIConsortium

Industrial Internet Consortium (IIC) (contd.)

- In IIC, the innovations and opportunities of the new technologies, new applications, new processes, new products and new services are
  - initiated,
  - conceptualized, and
  - rigorously tested

  before they are launched in the market.

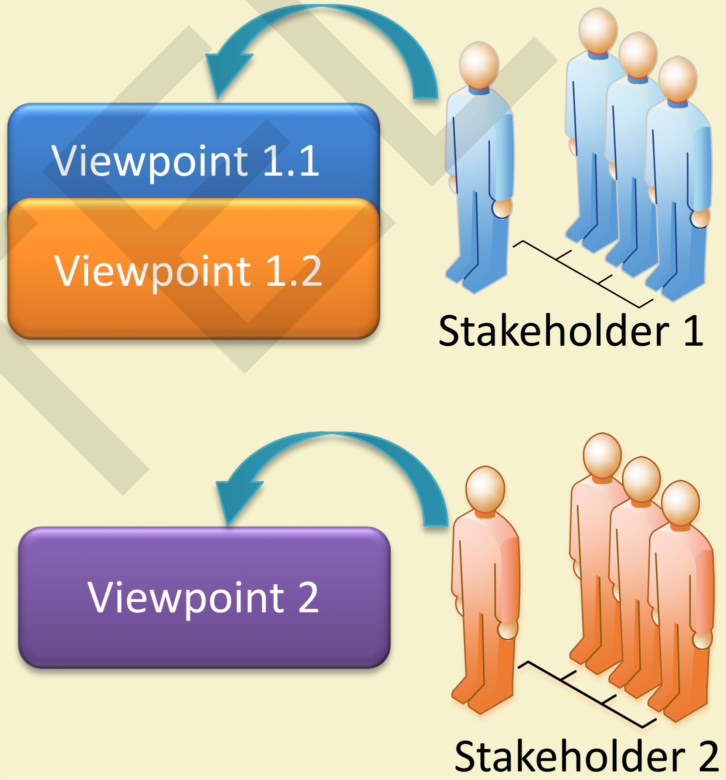
Source: "Test Beds", IIConsortium

IIRA Framework

- Stakeholders are the
  - individual, team or organizations having interest concerning to a system
  - interest in the viewpoint and system.
- Viewpoints are the collection of ideas which
  - describe,
  - analyze, and
  - solve the set of specific concerns.

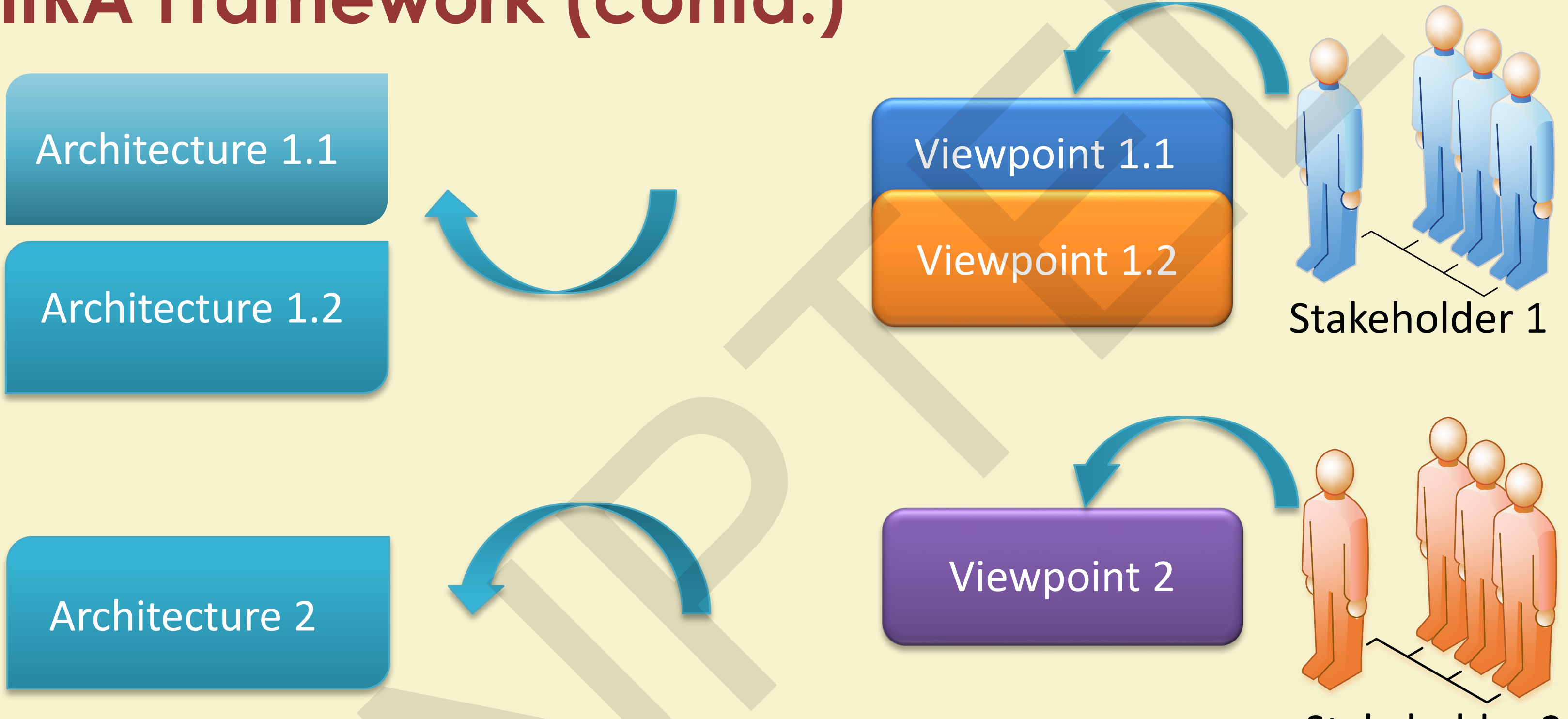
Source: "IIoT Reference Architecture", IIoT World

IIRA Framework (contd.)



Concept taken from: “IIoT Reference Architecture”, IIoT World

IIRA Framework (contd.)



Concept taken from: “IIoT Reference Architecture”, IIoT World

IIRA Framework (contd.)

- Architecture frame is the collection of ways which
  - identify,
  - describe, and
  - analyze the ideas of stakeholders

- Architecture representation is the collection of outcomes of
  - architecture frame, and
  - expressed as a view.

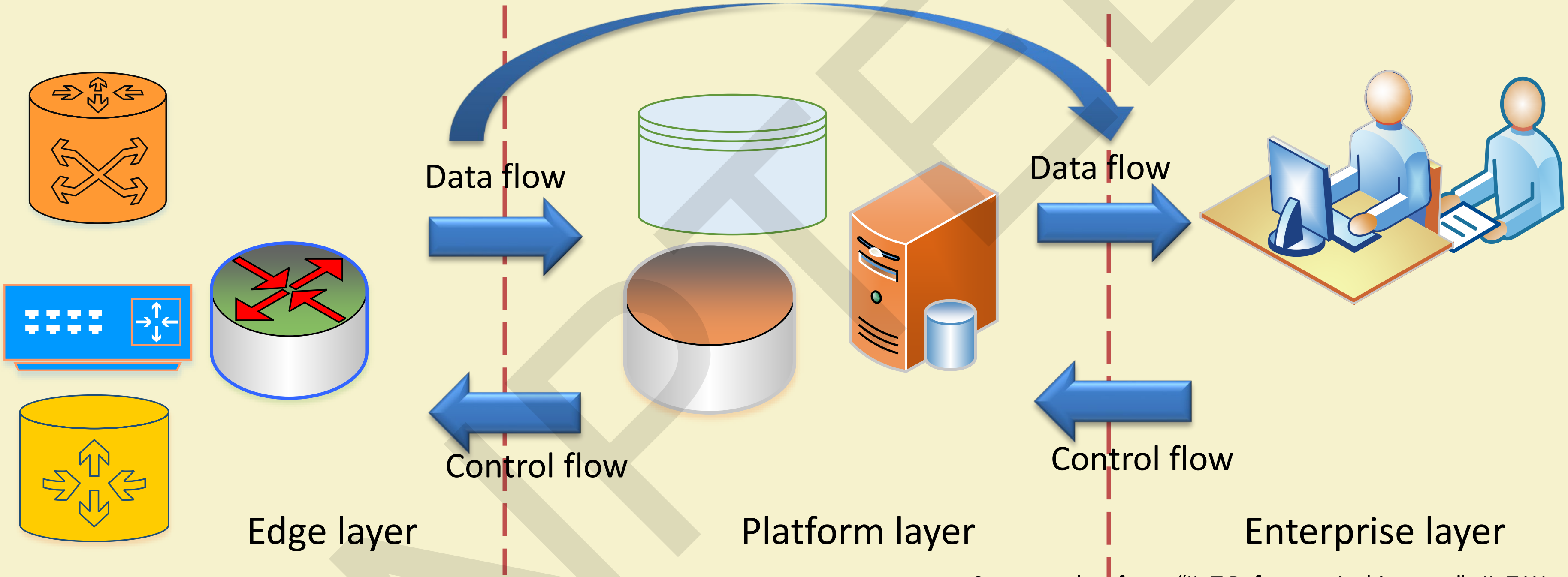
Source: "IIoT Reference Architecture", IIoT World

IIRA-Architecture Patterns

- Different **IIoT architecture implementation patterns** are as follows:
  - Three-tier architecture pattern
  - Gateway-mediated edge connectivity and management architecture pattern
  - Layered databus pattern

Source: “IIoT Reference Architecture”, IIoT World

IIRA: Three-tier architecture pattern



Concept taken from: "IIoT Reference Architecture", IIoT World

IIRA: Three-tier architecture pattern (contd.)

- **Edge layer** gathers data from the edge nodes. The architecture includes
  - breadth of distribution
  - governance
  - location
- **Platform layer** receives, process, and forwards control commands from the enterprise layer to the edge layer.

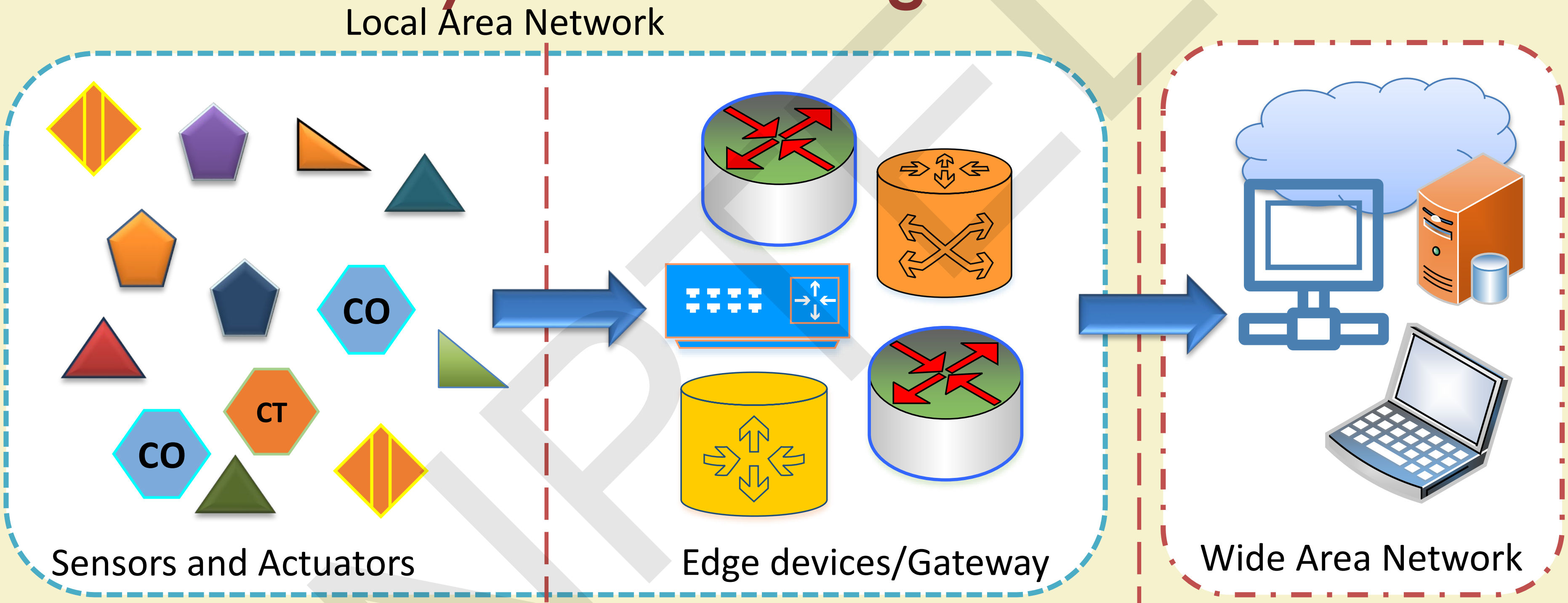
Source: "IIoT Reference Architecture", IIoT World

IIRA: Three-tier architecture pattern (contd.)

- **Enterprise layer** receives data flows from edge layer and platform layer. The Enterprise layer implements
  - domain-specific applications,
  - decision support systems, and
  - provides interfaces to end-users.

Source: "IIoT Reference Architecture", IIoT World

IIRA: Gateway-Mediated Edge Architecture



Concept taken from: "IIoT Reference Architecture", IIoT World

IIRA: Gateway-Mediated Edge Architecture (contd.)

- The **gateway-mediated edge architecture** consists of
  - a local area network for the IIoT edge system, and
  - the gateway connecting the Wide Area Network.

- The local area network may use
  - hub-and-spoke topology
  - mesh topology

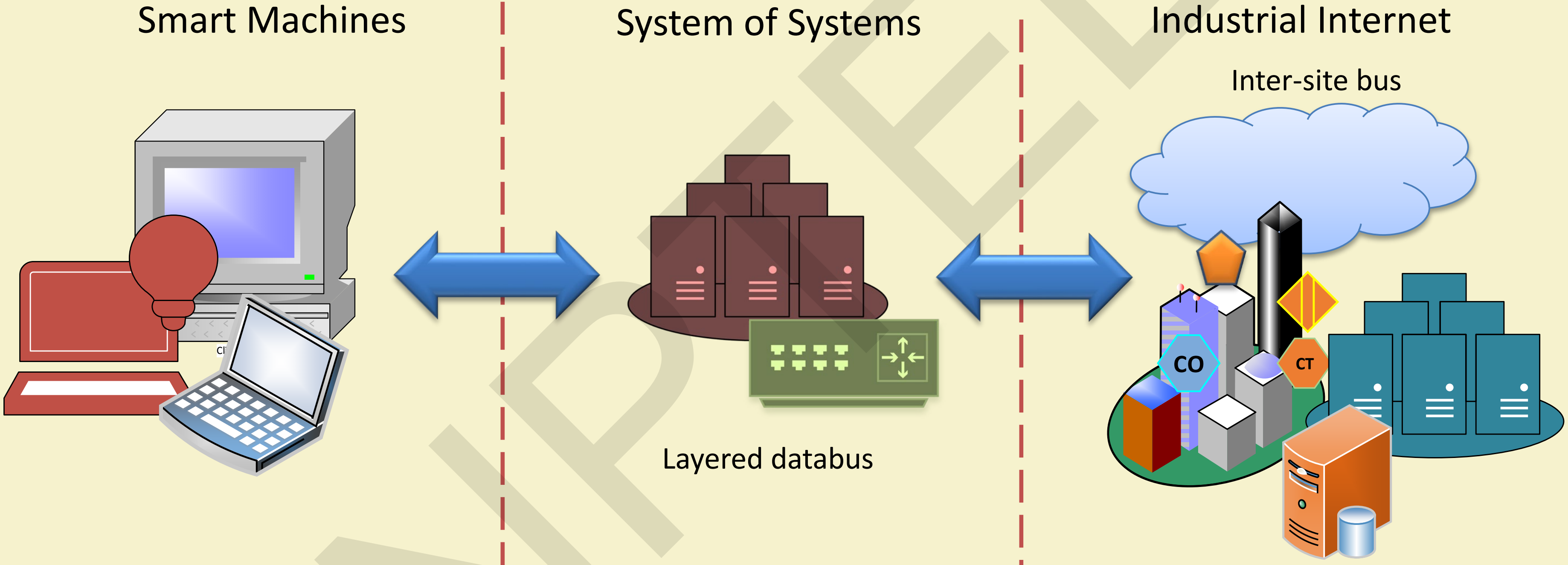
Source: "IIoT Reference Architecture", IIoT World

IIRA: Gateway-Mediated Edge Architecture (contd.)

- The gateway devices act as
  - management point for the edge devices locally
  - data transfer, processing and analytics
  - local connectivity among the devices
  - application logic which performs within the local scope.

Source: "IIoT Reference Architecture", IIoT World

IIRA: Layered Databus Pattern



Concept taken from: "IIoT Reference Architecture", IIoT World

IIRA: Layered Databus Pattern (contd.)

- Smart machines are present in the lowest level for
  - local control,
  - automation.
- System of systems allows
  - complex systems,
  - monitoring, and
  - analytic applications

Source: "IIoT Reference Architecture", IIoT World

IIRA: Layered Databus Pattern (contd.)

- Layered Databus pattern is applicable in the field of
  - control,
  - local monitoring, and
  - analytics.
- The databus communicates between applications and devices.
  - It allows interoperable communication between endpoints.
  - For communication between machines, another databus is used.

Source: "IIoT Reference Architecture", IIoT World

IIRA: Layered Databus Pattern (contd.)

- Layered Databus pattern allows
  - fast device-to-device integration with minimum response time.
  - automatic data and application delivery
  - scalable integration of devices
  - availability of the system is high, and
  - hierarchical subsystem isolation.

Source: “IIoT Reference Architecture”, IIoT World

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Business Models and Reference Architecture for IIoT
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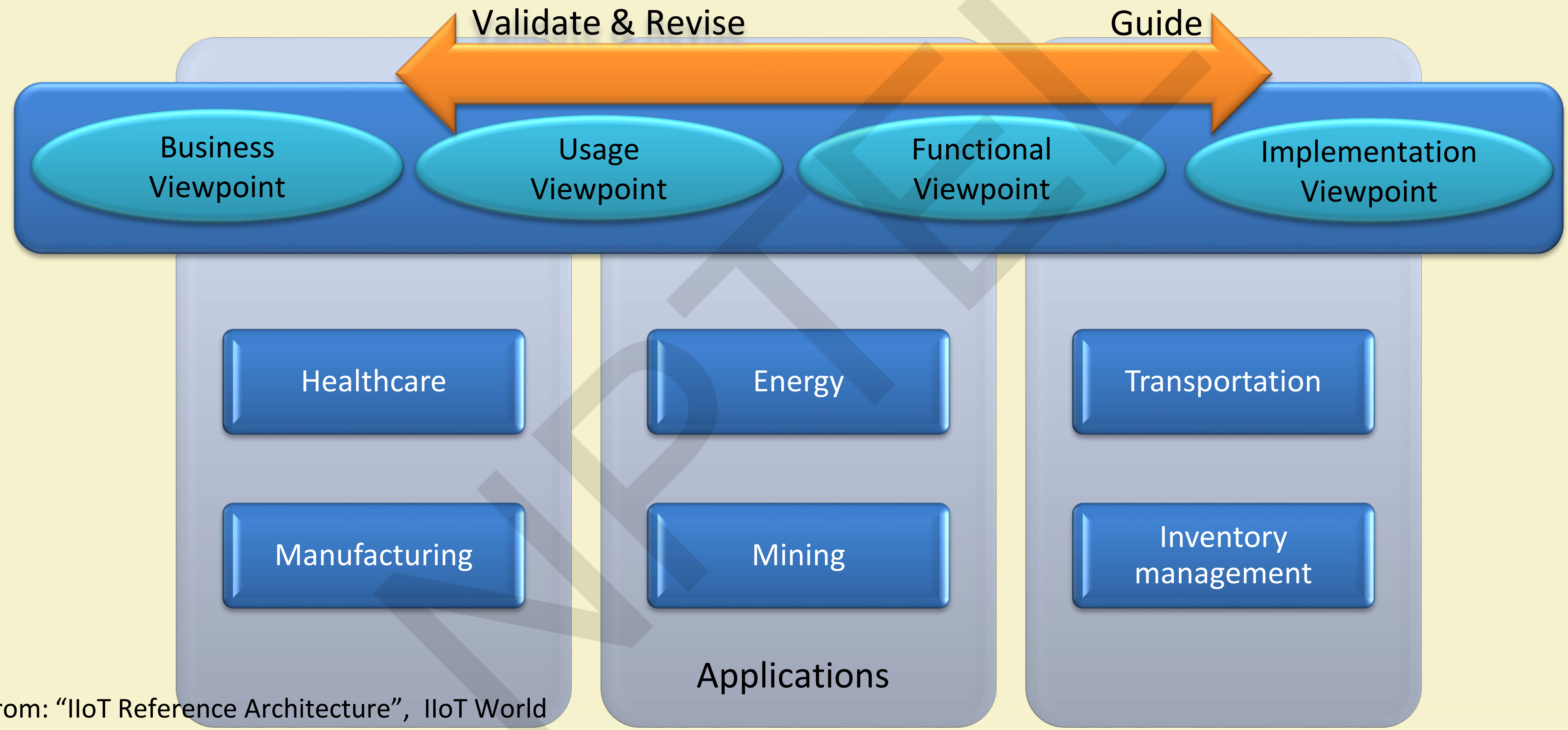
IIRA Viewpoints

- IIRA viewpoints are described analyzing the use cases developed by Industrial Internet Consortium (IIC), which are as follows:
  - Business viewpoint
  - Usage viewpoint
  - Functional viewpoint
  - Implementation viewpoint

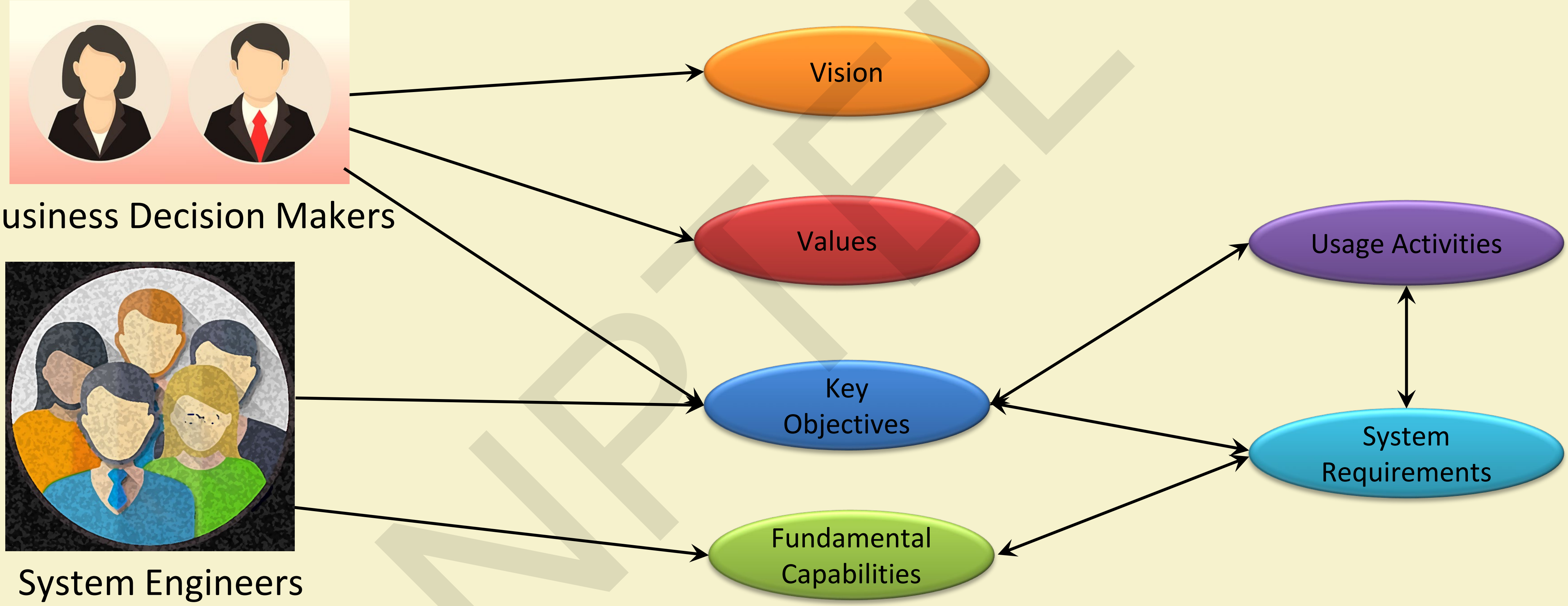
"IIoT Reference Architecture", IIoT World

IIRA Viewpoints (contd.)



Concept taken from: “IIoT Reference Architecture”, IIoT World

Business Viewpoint



Concept taken from: "IIoT Reference Architecture", IIoT World

Business Viewpoint (contd.)

- The business viewpoint from the perspective of an IIoT system is related with
  - business value
  - expected return on investment
  - cost of maintenance
  - product liability

"IIoT Reference Architecture", IIoT World

Business Viewpoint (contd.)

- Stakeholders play a
  - major supportive role in the business
  - strongly influence its direction
  - drives the conception and development of IIoT systems.

- Vision describes
  - future state of the organization
  - provides business direction towards which the organization works

"IIoT Reference Architecture", IIoT World

Business Viewpoint (contd.)

- Values indicate
  - vision recognized by stakeholders involved in funding
  - provide the logic regarding the merit of vision.
- Key objectives are measurable and time-bound. They are expressed as
  - high-level technical
  - business outcome expected from the system.

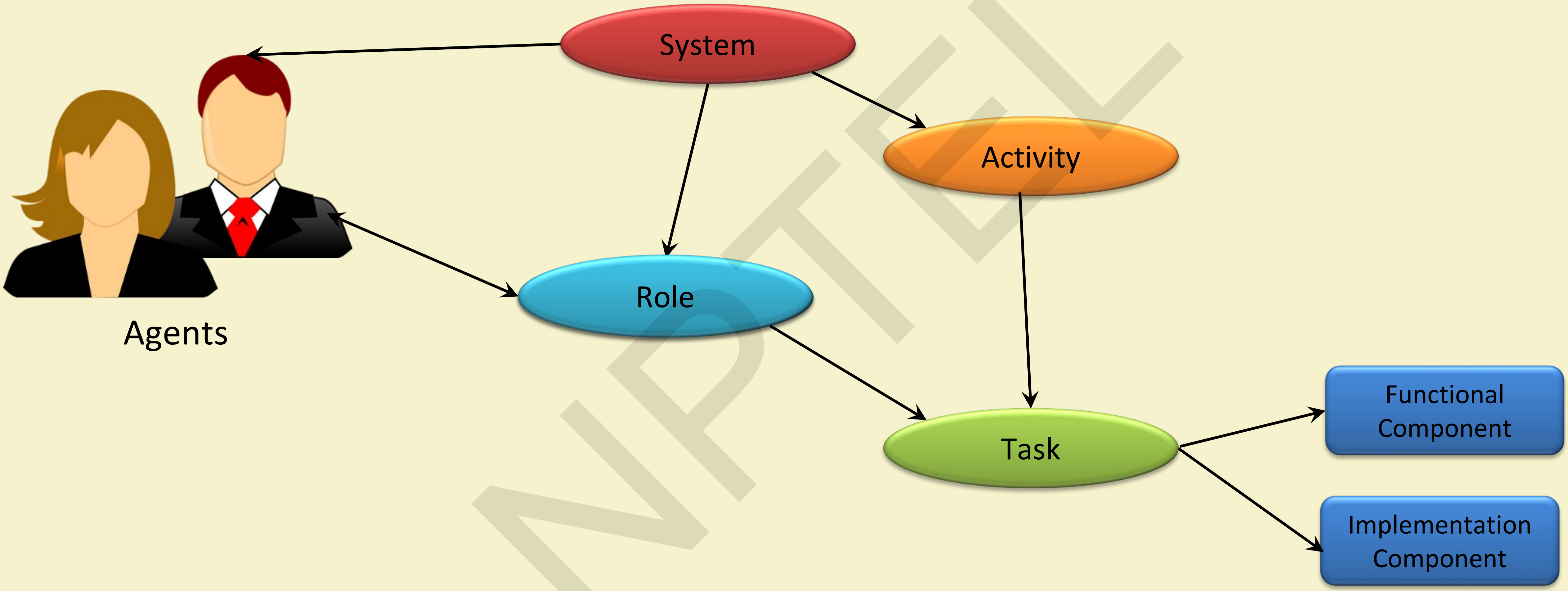
"IIoT Reference Architecture", IIoT World

Business Viewpoint (contd.)

- Fundamental capabilities are high-level specifications which are essential to complete business tasks.
  - Key objectives are basis for the identification of fundamental capabilities.
  - Capabilities are the ability of the organization to perform any function. They are specified independently.
  - Stakeholders obtain the fundamental capabilities from the objectives, which are necessary for a system.

"IIoT Reference Architecture", IIoT World

Usage Viewpoint



Concept taken from: "IIoT Reference Architecture", IIoT World

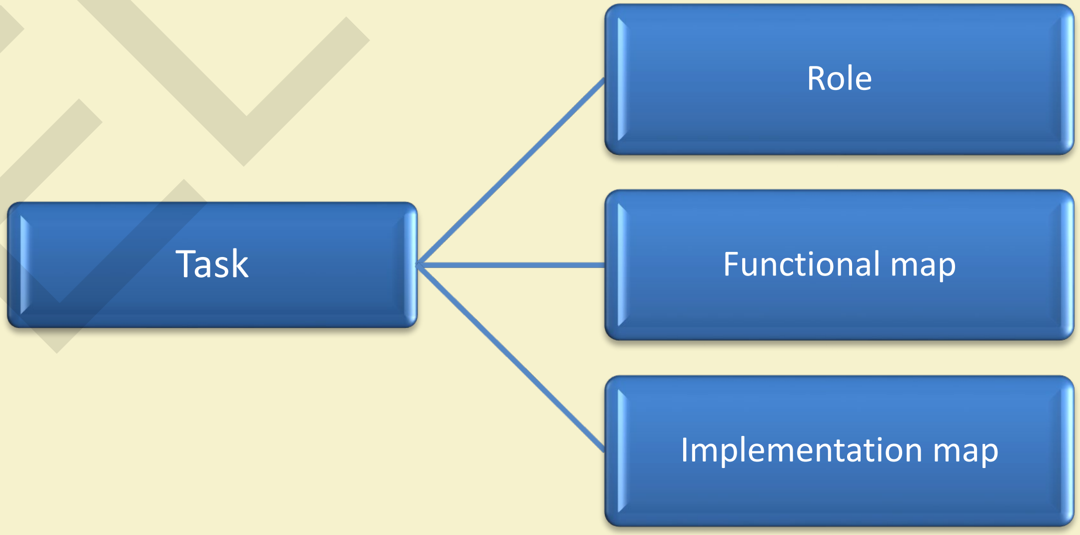
Usage Viewpoint (contd.)

- Usage viewpoint are related with the
  - key capabilities identified in the business viewpoint
  - activities that coordinate the different units of work.
- Task is
  - basic unit of work
  - carried out by a party assuming a role

Source: "IIoT Reference Architecture", IIoT World

Usage Viewpoint (contd.)

- Execution of a ***Task***
  - Role
  - Functional map: describes the functional component of the task maps.
  - Implementation map: depends on the execution of the task.



- Role
  - set of capacities assumed by an entity or organization
  - initiates or participates in the execution of tasks.

Source: "IIoT Reference Architecture", IIoT World

Usage Viewpoint (contd.)

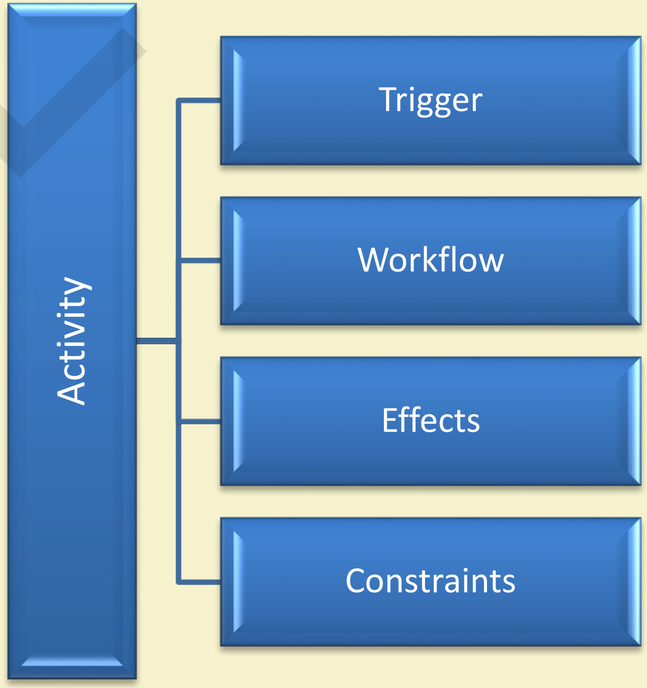
- Activity is
  - coordination of specific tasks
  - required to realize a well-defined usage of a system
  - executed repeatedly

- Activity has trigger, workflow, constraints, and effects

Source: “IIoT Reference Architecture”, IIoT World

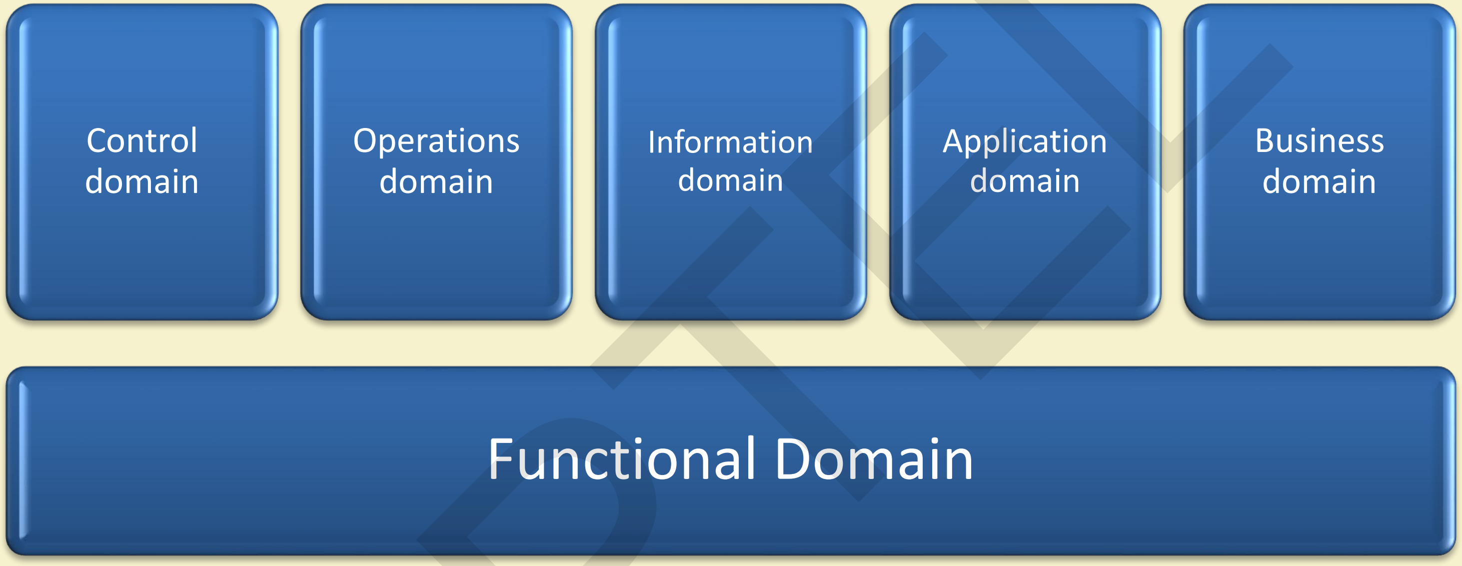
Usage Viewpoint (contd.)

- The elements of an *activity* are
  - **Trigger:** conditions under which the activity is initiated.
  - **Workflow:** sequential, parallel, conditional, iterative organization of tasks.
  - **Effect:** state of the IIoT system after successful completion of an activity.
  - **Constraints:** system characteristics which must be preserved during execution.



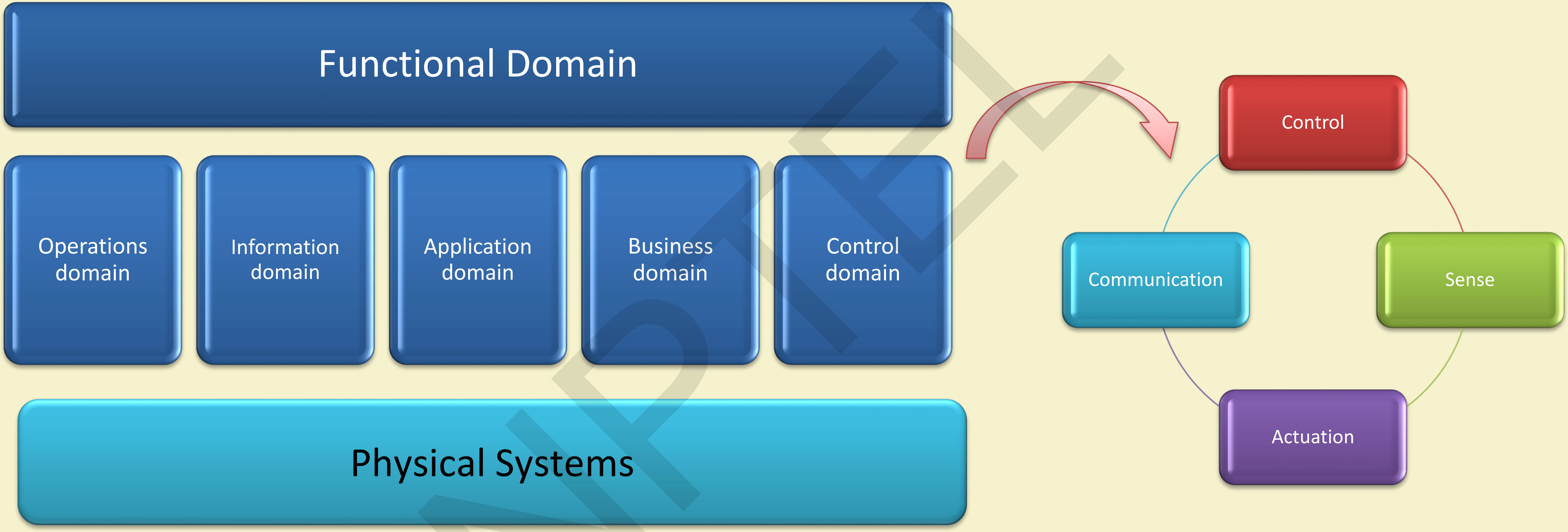
Source: "IIoT Reference Architecture", IIoT World

Functional Viewpoint



Source: "IIoT Reference Architecture", IIoT World

Functional Viewpoint (contd.)



Source: “IIoT Reference Architecture”, IIoT World

Functional Viewpoint (contd.)

- The control domain represents the set of functions performed by industrial control systems, which are as follows:
  - Sensing: Reading the data from sensor nodes.
  - Actuation: Writes data and control signals into an actuator.
  - Communication: Connects the sensors, actuators, gateways and other edge devices.

Source: "IIoT Reference Architecture", IIoT World

Functional Viewpoint (contd.)

- The <u>operations</u> domain represents the set of functions responsible for
  - Provisioning and deployment: Configure, track, register, and deploy assets online remotely, securely and at scale.
  - Management: Enables management of assets which is focused on the suite of management commands.

Source: "IIoT Reference Architecture", IIoT World

Functional Viewpoint (contd.)

- Prognostics: Acts as a predictive analytics engine of the IIoT systems.
- Monitoring and diagnostics: Responsible for real-time monitoring, and enables detection and prediction of occurrence of problems.
- Optimization: improves asset reliability and performance, reduces energy consumption, increases availability, and output in according to the assets used.

Source: “IIoT Reference Architecture”, IIoT World

Functional Viewpoint (contd.)

- The information domain represents the set of functions responsible for
  - assembling data from various domains, where data consists of
    - quality of data processing
    - syntactical transformation
    - semantic transformation
    - data persistence and storage
    - data distribution

Source: "IIoT Reference Architecture", IIoT World

Functional Viewpoint (contd.)

- The information domain represents the set of functions responsible for
  - assembling data from various domains
  - transforming
  - persisting
  - modelling/analysis of data

Source: “IIoT Reference Architecture”, IIoT World

Functional Viewpoint (contd.)

- The application domain represents the set of functions which implement application logic to realize specific business functions
  - Logics and Rules: Implements specific functions required for the use case.
  - APIs and UI: Enables an application exposes its functions as *APIs* for other applications to consume.

Source: "IIoT Reference Architecture", IIoT World

Functional Viewpoint (contd.)

- The business domain represents the set of functions which enables end-to-end operations of the IIoT systems by integrating them with traditional or new type of business functions which includes
  - supporting business processes
  - procedural activities.

Source: "IIoT Reference Architecture", IIoT World

Implementation Viewpoint

- The implementation viewpoint relates to the
  - technical representation of an IIoT system including interfaces, protocols, and behaviors
  - identification of system characteristics
  - general architecture of IIoT-its structure, distribution and the topology of interconnection of the components
  - Implementation map of the activities as recognized from usage viewpoint to the functional components, and from functional components to implementation components

Source: "IIoT Reference Architecture", IIoT World

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Key Enablers of Industrial IoT: Sensing-Part 1

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IIoT Features – Recap

- A network of billions of machines and devices, which are connected by communication technologies
- Smart machines and advanced analytics
- Detection of system/machine/product failure and downtime
- More concern about the improvement of efficiency, productivity, health, and safety of a system

Applications with Smart Sensors

Source: IIoT Application, Online: https://internetofthingsagenda.techtarget.com/definition/Industrial-Internet-of-Things-IIoT

IIoT Layer-wise Architecture

Idea Taken from: “Securing the Internet of Things: A Proposed Framework”, Cisco, Online: https://www.cisco.com/c/en/us/about/security-center/secure-iot-proposed-framework.html

Benefits of Sensor Usage in Industry

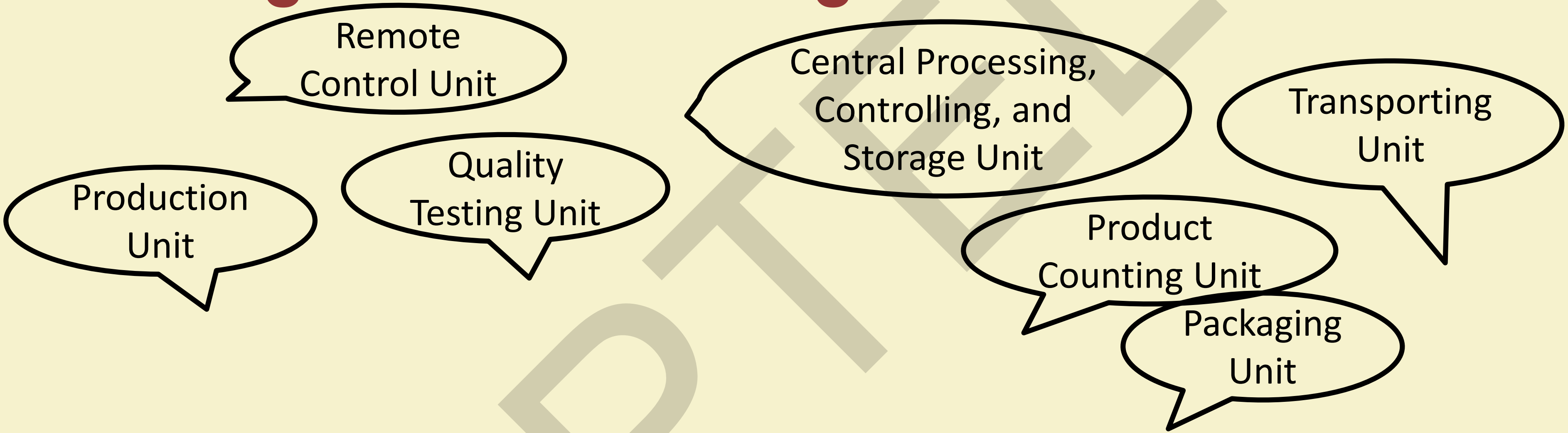
- Real-time monitoring
- Improving visibility
- Operational efficiency
- Increasing productivity
- Efficient quality management

Source: Online: https://www.newgenapps.com/blog/8-uses-applications-and-benefits-of-industrial-iot-in-manufacturing

Benefits of Sensor usage in Industry (Contd.)

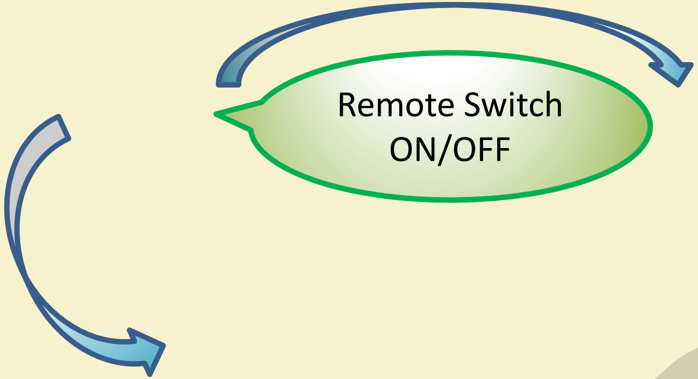
- Improving Safety
- Minimizing downtime
- Improving the prediction and prevention of system failure
- Remote diagnosis

Sensing for Manufacturing Process in IIoT



Idea taken from: Microsoft and IoT presented by Marlon Luz, Online: https://www.slideshare.net/marlonluz/microsoft-internet-of-things

Sensing for Manufacturing Process in IIoT (Contd.)



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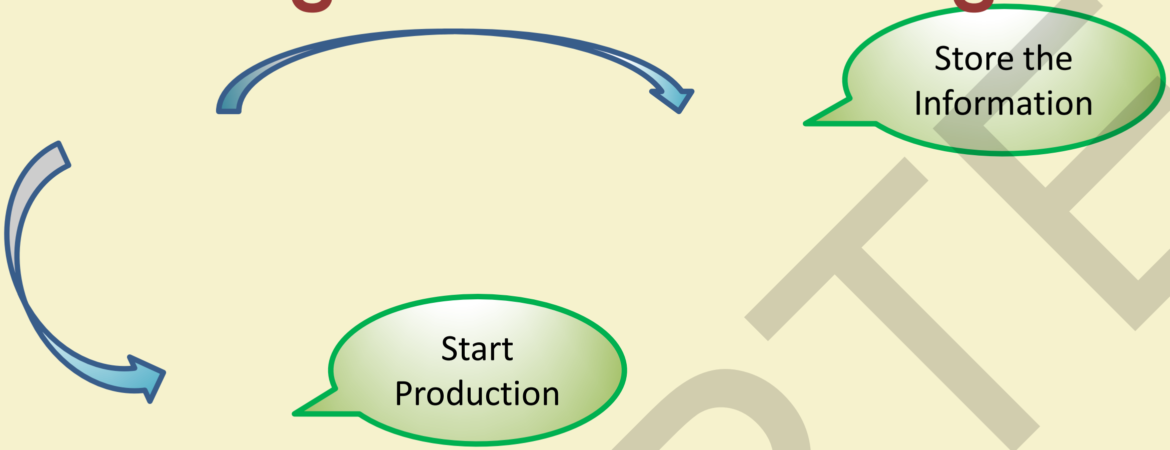
Sensing for Manufacturing Process in IIoT (Contd.)



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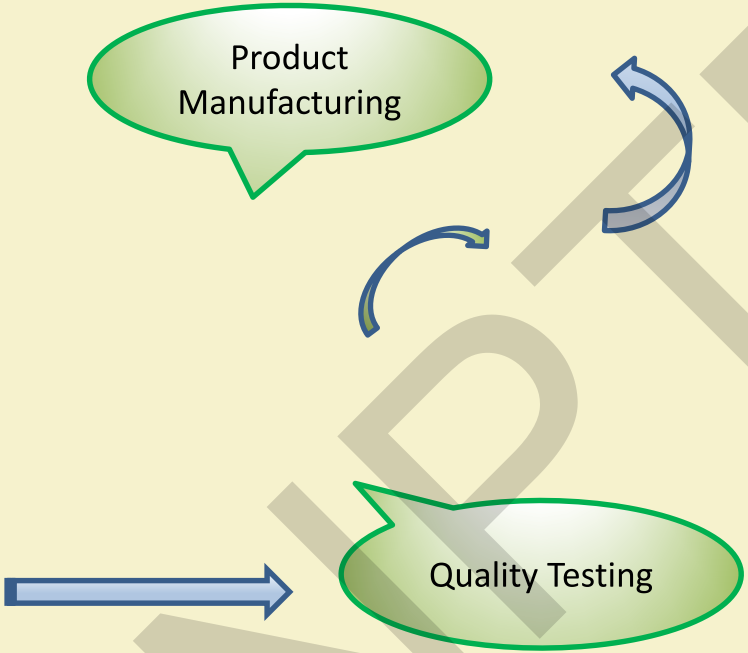
Sensing for Manufacturing Process in IIoT (Contd.)



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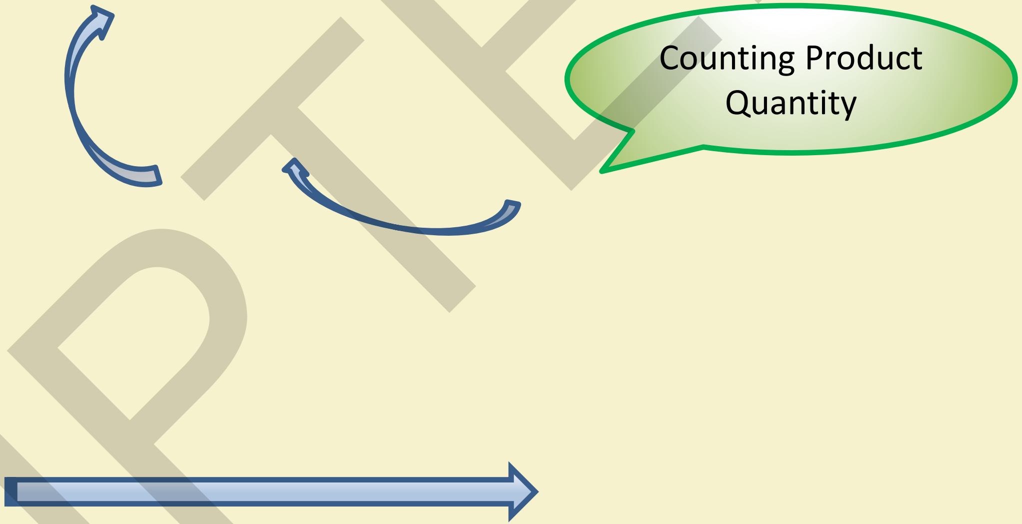
Sensing for Manufacturing Process in IIoT (Contd.)



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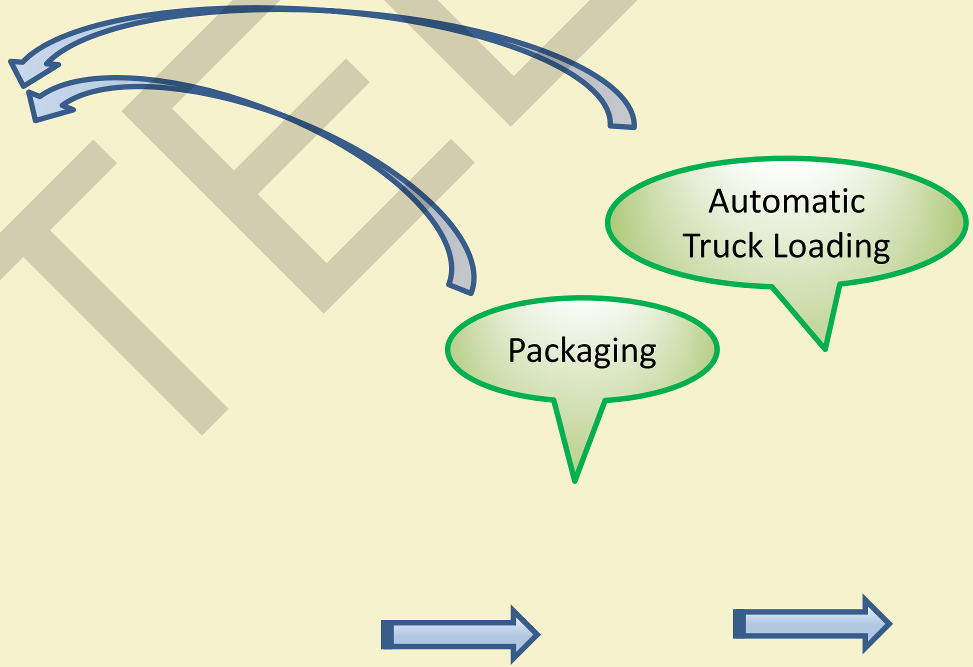

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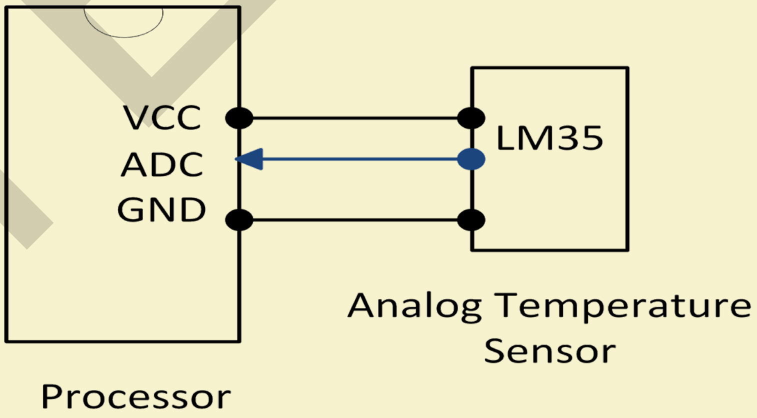
Sensing for Manufacturing Process in IIoT (Contd.)

Idea taken from: Microsoft and IoT presented by Marlon Luz, Online: https://www.slideshare.net/marlonluz/microsoft-internet-of-things

Block Diagram of a IoT Sensing Device

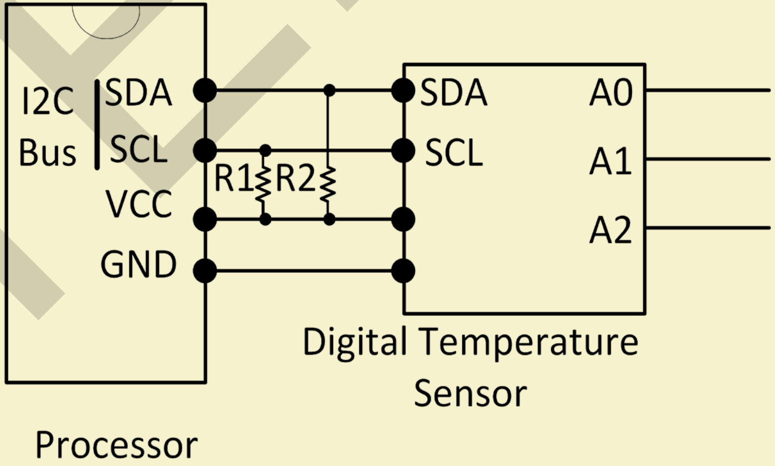
Temperature Sensor Interfacing Circuit

- Monitoring temperature of used devices in industrial applications
- LM 35 temperature sensor generates analog voltage
- The output voltage of LM 35 is linearly proportional to Celsius temperature



Temperature Sensor Interfacing Circuit (Contd.)

- Temperature sensor DS1621 is a digital sensor, which generates 9 bits temperature data.
- Operating voltage from 2.7 to 5.5 Volt
- User can define thermostatic settings
- The value of resistors R1 and R2 is from 4.7 to 10 KOhm



Temperature Sensor Interfacing Circuit (Contd.)

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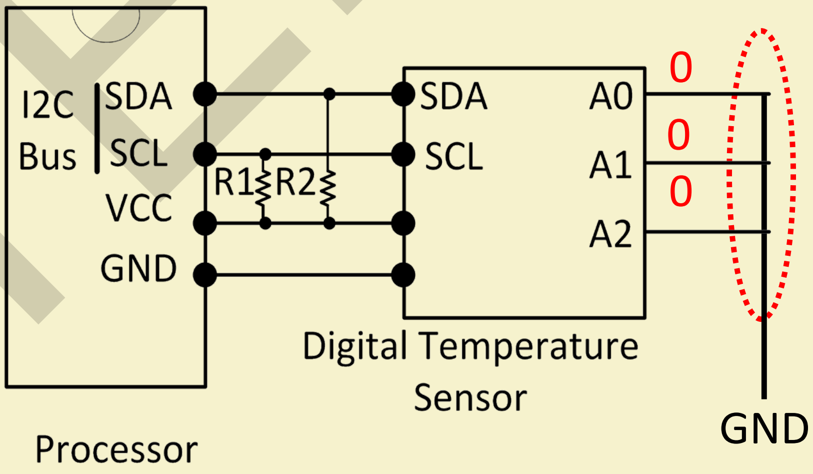

Temperature Sensor Interfacing Circuit (Contd.)

- Temperature sensor DS1621 is a digital sensor, which generates 9 bits temperature data.
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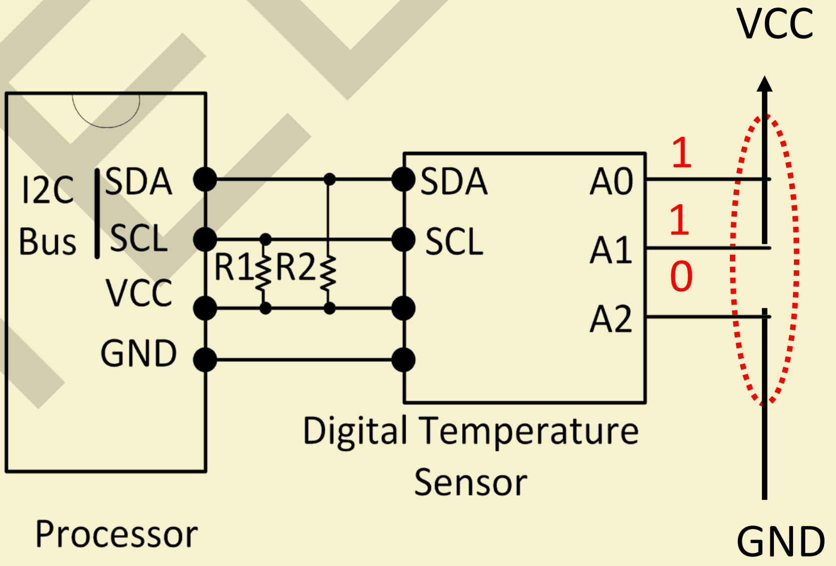
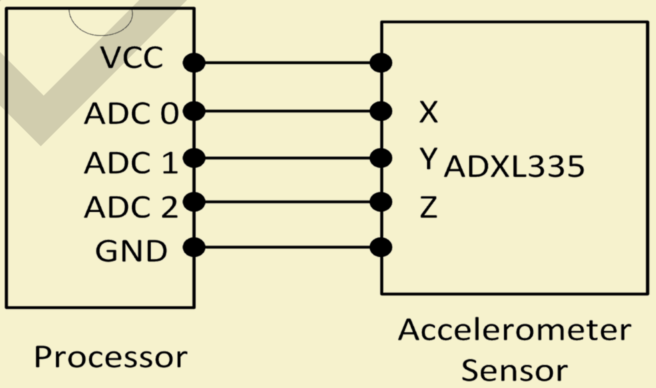
- The value of resistors R1 and R2 is from 4.7 to 10 KOhm



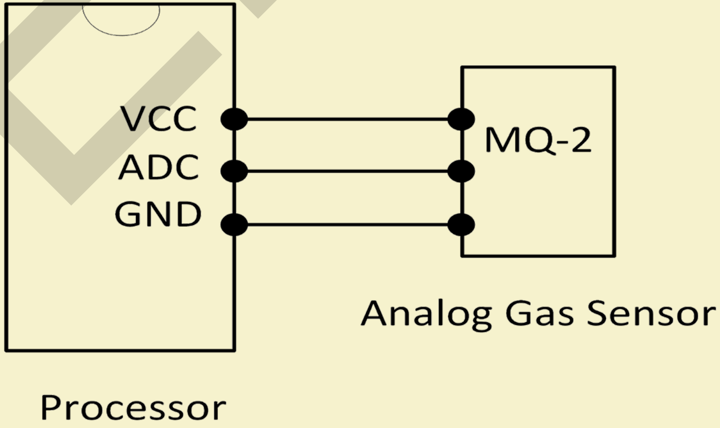
Accelerometer Sensor Interfacing Circuit

- Generates the magnitude and direction of the acceleration
- Accelerometer sensor ADXL335 provides 3 axes (X, Y, and Z) values in analog voltage



Gas Sensor Interfacing Circuit

- Measures and detects concentration of different gases
- Gas sensor MQ-2 provides the concentration of LPG, propane, and hydrogen in analog voltage



Sensors in IIoT Applications

- Temperature sensor
  - Monitoring temperature of used devices in industrial applications such as petrochemical, defense, aerospace, consumer electronics, and automotive
  - Used in some special types of application where a specific temperature is to be maintained, such as fabricate medical drugs and heat liquids.
- Magnetostrictive sensor
  - Measures and detects time-varying stresses or strains in ferromagnetic materials
  - Used for inspection of steel pipes, condition monitoring of machinery, and detection of vehicle safety

Sensors in IIoT Applications (Contd.)

- Torque sensor
  - Measures rotating torque
  - Used to measure the speed of rotation
- Pressure sensor
  - Used to measure pressure in Industrial and hydraulic systems
  - Measures different variables such as speed, water level, and gas/water flow

Sensors in IIoT Applications (Contd.)

- Vacuum sensor
  - Used to measure pressure below than atmospheric pressure
  - Used in different industrial applications such as chemical processing, detection, cathode ray tubes, gas turbine, and helium leak
- Acceleration sensor
  - Measures rate of change of velocity
  - Used to detect the magnitude and direction of the acceleration
  - Used in car electronics, ships, marine, and agricultural machines

Sensors in IIoT Applications (Contd.)

- Speed sensor
  - A measure of how fast
  - Basically measures speed which is determined by the travelling distance in a given time
  - Used in vehicle, diesel engine, engine-powered generator, anti-lock brake, printer, memory, engine-powered compressor
- PIR sensor
  - Detects infrared radiations coming from human body in its surrounding area
  - Used for automatic door open/close, human detection, lift lobby, common staircase, and shopping Mall

Sensors in IIoT Applications (Contd.)

- Image sensor
  - Used for distance measurement, pattern matching, color checking, structured lighting, and motion capture
  - Used in different applications such as 3D imaging, video/broadcast, space, security, automotive, biometrics, medical, and machine vision
- Ultrasonic sensor
  - Mainly uses for object detection, measuring distance, and dynamic body detection
  - Applications: Liquid level monitoring of tank, trash level monitoring, manufacturing process, automobile, and people detection for counting

Source: Camera Sensor’s Application, Online: http://www.cmosis.com/technology/applications/

Sensors in IIoT Applications (Contd.)

- Optical sensor
- Radiation sensor
- Level sensor
- Flow sensor
- Touch sensor
- Gas sensor

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Key Enablers of Industrial IoT: Sensing Part-2

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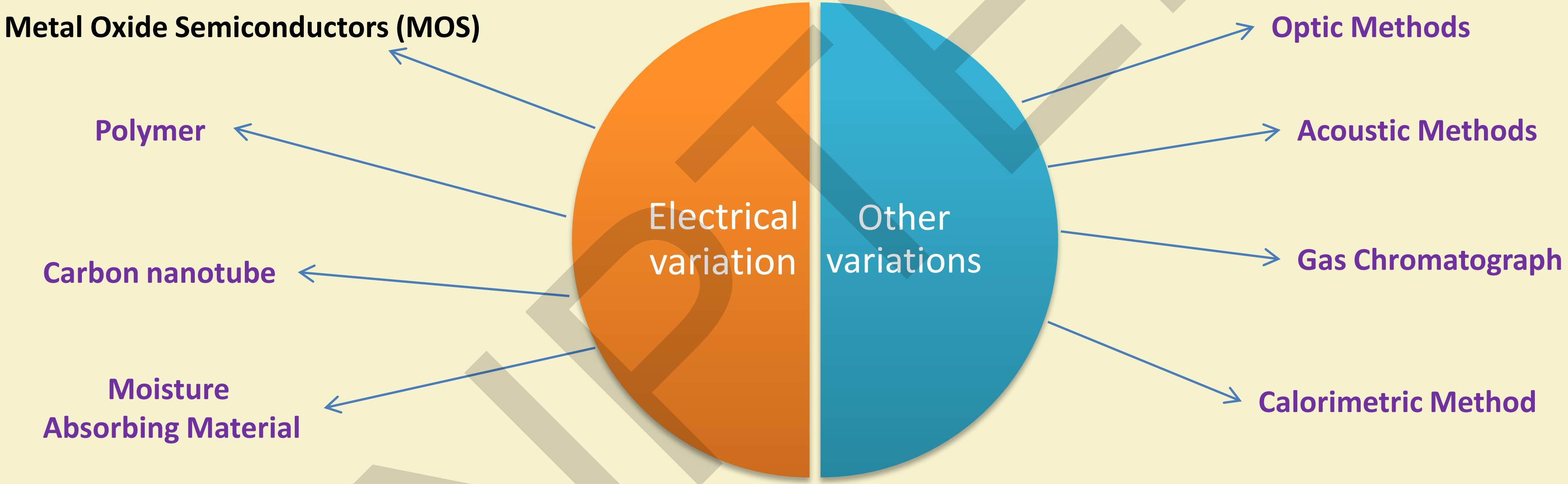
Introduction

- A <u>gas sensing system</u> plays a vital role for monitoring the concentration of flammable, combustible and toxic gases in the environment
- <u>Air quality monitoring and alert systems</u> with gas sensing units may be deployed to avoid risks of harmful exposure of gases in the environment

Gas Sensing Methods



Source: A Survey on Gas Sensing Technology, Sensors 2012

MOS Gas Sensor's Working Principle

- MOS Gas sensors are also called Chemi-Resistive Gas sensors
- Baseline Resistance: Resistance of the sensor material in **air** when not exposed to target gas
- Chemi-resistive gas sensors depend on the thermal energy for its operation which is supplied with an heater
- A particular temperature at which the sensor gives best response is called Optimum Temperature

Source: Electroceramics, Second Edition, A.J.Moulson,J.M.Herbert,Wiley

MOS Gas sensor working Principle(Contd.)

- Resistance changes when exposed to gas depending on the rise or fall in conductivity of the sensor material
- In n-type sensors, resistance decreases, and in p-type sensors, resistance increases with respect to the Baseline resistance when exposed to a reducing gas

Characterisics of Gas Sensor

- **Sensitivity**: It is the change in the output signal with respect to unit change in input (which is the target gas concentration).
- **Selectivity**: Ability to detect a particular gas in a mixture of different gases.
- **Stability**: This parameter determines the robustness in the gas sensing property of a gas sensor in a long time period when exposed to hostile ambience

Characteristics of Gas Sensor (Cond.)

- **Response time:** The time taken by the sensor to stabilize its response while sensing the target gas to reach some percent (80% or 90%) of the final value
- **Reversibility**: Whether the sensor resistance can return back to its base resistance value, if exposure to the target gas is stopped
- **Response Percent:** of a gas sensor is calculated by computing the percentage change in the resistance when exposed to target gas with respect to the resistance when not exposed.

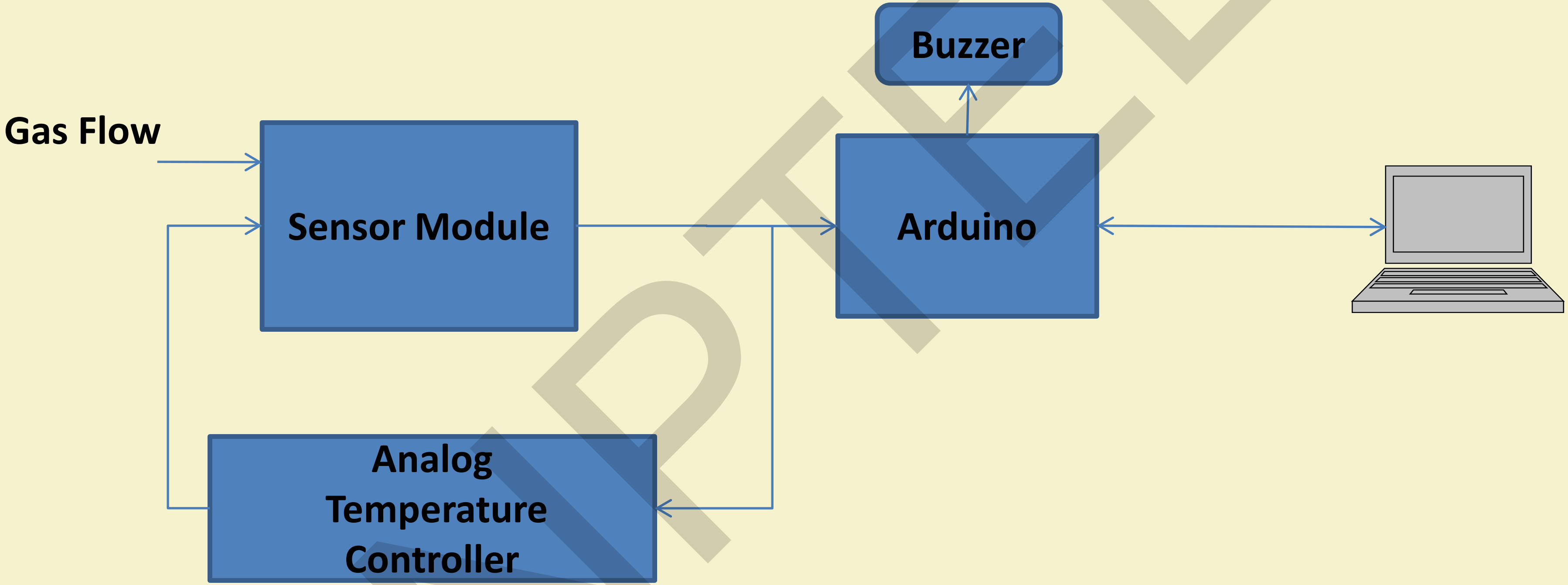
Applications of Gas sensors

- Air quality monitoring
- Leakage Detection of Toxic gases
- Manhole & Sewage Treatment
- Automotive Exhaust
- Alcohol Breath Test

A Demo on VOC Sensing

- **Introduction**
  - This gas sensing system is able to detect the presence of VOCs (Volatile Organic Compounds)
  - As soon as the gas sensors sense these gases, its resistance changes from its baseline resistance.
  - As the resistance changes, an alert is generated

Gas Sensing System



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Key Enablers of Industrial IoT: Connectivity-Part 1

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Industrial Communication

- Typical industrial communication requirements
  - Real-time
  - Very low duty-cycle
  - Very low latency
  - Very low jitter
- Industrial Communication majorly thrives on the following technologies:
  - Industrial Ethernet
    - Industrial Ethernet protocols for real-time control and automation.
    - Used in manufacturing processes dealing with clock synchronization and performance.
  - Fieldbus
    - A communication standard for Local Area Network (LAN) of field devices for industrial automation.
    - Used in manufacturing processes dealing with periodic I/O data transfer.

Industrial Communication (contd.)

- Industrial Ethernet
  - ModBus-TCP
  - EtherCat
  - EtherNet/IP
  - Profinet
  - TSN
- Fieldbus
  - Modbus-RTU
  - Profibus
  - Interbus
  - CC-Link
  - DeviceNet

Reference: Industrial Ethernet & Fieldbus solutions from KUNBUS.

ModBus-TCP

Introduction to ModBus-TCP

- A standard communication protocol used in industry, developed by Modicon Inc (Schneider Electric).
- It uses TCP/IP & Ethernet for data transmission between two compatible devices.
- The communicating system includes several devices:
  - Client-Server devices linked to a TCP/IP network
  - Interlinked devices – bridge or router or gateway
  - Serial line sub-network to grant links between client-server

Source: Modbus messaging on TCP/IP implementation guide.

Features of ModBus-TCP

- A standard date frame is embedded into a TCP frame.
- The protocol defines 2 units in the data frame: PDU (Protocol Data Unit) and ADU (Application Data Unit)

ADU

PDU

Additional Address	Function Code	Data

- ADU is identified by a header called MBAP.

Transaction Identifier (2 bytes)	Protocol Identifier (2 bytes)	Length (2 bytes)	Unit Identifier (1 byte)

(MODBUS Application Protocol header – 7 bytes)

Source: Swales, A. Open ModBus/TCP specification.

Features of ModBus-TCP (contd.)

- It is a connection-oriented protocol following the Client-Server architecture.
- Masters are the clients, whereas slaves are denoted as servers.
- The protocol supports up to 10 active connections/sockets at one time.

Source: Introduction to MODBUS TCP/IP.

EtherCat

Introduction to EtherCat

- EthernetCAT (Control Automation Technology) was developed by the ETG (EtherCAT Technology Group).
- It is based on IEC 61158 & IEC 61784 (international standards).
- It follows a <u>master-slave</u> architecture utilizing the standard IEEE 802.3.
- Application areas: <u>time-sensitive scenario</u> (due to high-speed of the system)

Source: Communication solutions for EtherCAT networks from KUNBUS.

Features of EtherCat

- Master and slave exchange data as PDO (process data objects)/telegram.
- Slaves follow multicast or broadcast communication initiated by the master.
- Every PDO contains a distinct address denoting several slaves.
- EtherCAT telegram = Process data + Header.
- Processing incurs a few nanoseconds delay for the telegrams.
- Each telegram utilizes memory up to 4 GB in size.

Source: Communication solutions for EtherCAT networks from KUNBUS.

Features of EtherCat (contd.)

- Data exchange provide low duty cycle time of <~100 µs and low jitter for better synchronization.
- Range of data transmission rate is ~200 Mbps
- Allow transmission range up to 100 m between the individual participants. (Using optical waveguides: up to 20 km).
- Utilizes CRC checksum for fault recognition (bit errors).
- Network topology – tree, star, line, ring, or hybrid.

Source: Communication solutions for EtherCAT networks from KUNBUS.

EtherNet/IP

Introduction to EtherNet/IP

- It is based on the standard Internet Protocol suite and IEEE 802.3.
- EtherNet/IP: CIP (Common Industrial Protocol) Over Ethernet.
- CIP: Unified communication architecture for industrial applications.
  - CIP is a media independent, connection-based, object oriented procedure intended for automation applications.
- It is constructed from layers used in DeviceNet and ControlNet.
- IIoT requires improved throughput and extensive approachability via CIP, which is offered by Ethernet.

Source: EtherNet/IP Quick Start for Vendors Handbook.

Communication Type

- EtherNet/IP defines two primary types of communications:
  - Explicit
    - Provide generic, multi-purpose transmission path between devices.
    - Message transfer is asynchronous.
    - Handles non time-critical information.
  - Implicit
    - Provide distinct and special-purpose transmission paths between a master and several clients.
    - Message transfer is continuous.
    - Handles real-time I/O data.

Source: Brooks, P. EtherNet/IP: Industrial Protocol White Paper.

Features of EtherNet/IP

- Based on active star topology.
- Easy set-up, operation, maintenance, and expansion.
- Handles large amount of information at speed of 10/100 Mbps.
- Maximum data rate up to 1500 bytes per packet.
- Mainly used with PCs, robots, I/O devices, and PLCs (Programmable Logic Controllers).

Source: EtherNet/IP Quick Start for Vendors Handbook.

Profinet

Introduction to Profinet

- Profinet (PROcess FIeld NETwork) is the standard for industrial Ethernet developed by Profibus & Profinet Int.
- The technology is based upon Ethernet/IP.
- Defines the communication channel between controller and distributed devices in the field.
- Basically used for process control and process measurement.

Source: PROFINET Unplugged – An introduction to PROFINET IO.

Communication Channel

- Uses three different communication channels:
  - Non-Real Time (NRT) – Used for non time-critical processes (acyclic read/write operations). Uses standard TCP/IP and UDP/IP to transmit data packets.
  - Real Time (RT) – Used for time-sensitive processes (cyclic data transfer and event-driven procedures). Utilized for optimized and high speed data exchange.
  - Isochronous Real Time (IRT) - Used for clock-synchronized communication. Suitable for motion control applications. Allows short cycle time (~250 μs).

Source: PROFINET. Siemens.

Time-Sensitive Networking (TSN)

Introduction to TSN

- It is an extension of Ethernet based on set of IEEE 802.1Q (virtual LAN) and 802.3 technology.
- It was developed to enable deterministic communication (predictive) for industries on standard Ethernet.
- This protocol is <u>time-aware</u> and distributes data over the bandwidth according to a schedule.
- It is centralized and <u>minimizes jitter</u> using <u>time scheduling</u> for real-time applications.

Source: Time-Sensitive Networking: A Technical Introduction. Cisco Public.

Features of TSN

- It supports cyclic data transfer.
- Provides pre-emption for packets with high priority.
- Network topologies: ring, chain, star, and hybrid topologies.
- Data rate is 100Mbit and 1Gbit for industrial applications.
- TSN offers IT/OT network convergence.
- The network and operation cost is minimized due to the convergence.

Source: TSN: Converging Networks for a Better Industrial IoT.

Modbus-RTU (Remote Terminal Unit)

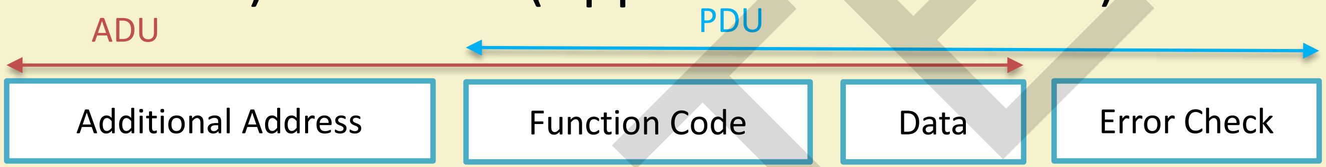
Introduction to Modbus-RTU

- It is a serial protocol (RS-232/485) that follows the Master and Slave architecture.
- It follows a request/response model.
- It is used for transmission of data signal from control/ instrumentation devices to the control unit.
- It is a messaging protocol intended for application layer.

Source: Modbus RTU Unplugged – An introduction to Modbus RTU Addressing, Function Codes and Modbus RTU Networking.

Features of Modbus-RTU

- The protocol defines 2 units in the data frame - PDU (Protocol Data Unit) and ADU (Application Data Unit)



- The client initiates the MODBUS transaction with a request.
- The format of a message request contains the address of the slave, the command (read/write register), the data, and error check.

Source: Modbus RTU Unplugged – An introduction to Modbus RTU Addressing, Function Codes and Modbus RTU Networking.

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Thank You!!

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Key Enablers of Industrial IoT: Connectivity-Part 2

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Profibus (Process field bus)

Introduction to Profibus

- It is based on the standard IEC 61158.
- It was first started in Germany in late 1980s and then used by Siemens.
- It is a field-bus technology that supports several protocols.
- It supports cyclic as well as acyclic data transmission, isochronous messaging, and alarm-handling.

Source: PROFIBUS Protocol. Smar.

Variants of Profibus

- There are 3 variants:
  - Profibus FMS (Fieldbus Message Specification)
    - Handles communication between PCs and Programmable Logic Controllers.
  - Profibus DP (Decentralized Peripherals)
    - The speed varies from 9.6Kbps to 12Mbps.
    - It uses RS485 balanced transmission.
    - It supports 32 devices at a time (up to 1900 m, up to 10 Km with 4 repeaters).
  - Profibus PA (Process Automation)
    - The speed is fixed at 31.2Kbps.
    - Uses Manchester Bus Power (MBP) for transmission (suits hazardous environment).

Source: PROFIBUS Protocol. Smar.

Features of Profibus

- It defines 2 layers:
  - Data link - accomplished over a FDL (Field bus Data Link).
  - Physical
- It uses bus topology where, the bus or central line is underwired all through the system.
- Buses using MBP supports transmission range up to 1900 meters and can support branches.
- MBP supports data as well as power transmission.

Source: PROFIBUS, PLC Manual; PROFIBUS Protocol. Smar.

Interbus

Introduction to Interbus

- It was developed by Phoenix Contact in 1987.
- It is based upon European Standard, EN 50254 as well as IEC 61158.
- It supports serial communication among control systems (PCs, PLCs) and spatially arranged I/O modules which connects to several sensors & actuators.
- Application areas: sensing-actuating application, machine & system production, and process engineering.

Source: Interbus Basics.

Features of Interbus

- Network topology: Active ring (Supports maximum 512 subscribers, and the last subscriber closes the ring.)
- Total bus length is 13 km. Length between two remote bus devices is 400m.
- Supports master/slave architecture, fixed telegram length, deterministic communication.
- Master & Slave forms a large and distributed shift register ring with master the starting-ending point, while slave as a part of it.
- Transmission rate: 500 kbps

Source: Interbus Basics

CC-Link (Control and Communication)

Introduction to CC-Link

- It is an open industrial network established by Mitsubishi Electric Corporation in 1997.
- It is based upon the standards EN 954 as well as IEC 61508 in the safety area (compatible to ISO 15693 & 14443).
- It enables devices from several manufacturers to communicate.
- Application areas: facilities management, manufacturing & production industries, process control & automation.

Source: CC-Link Protocol. Kunbus.

Variants of CC-Link

Standard CC-Link	CC-Link/LT	CC-Link Safety	CC-Link IE (Industrial Ethernet)
Facilitates transmission of information & control data.	Convenient for implementing sensors and actuators.	Based on CC-Link.	Enables operation, device monitoring & data transmission.
Transmission rate: 10 Mbps	Transmission rate: 2.5 Mbps	Transmission rate: 10 Mbps	Transmission rate: 1 Gbps
Transmission range: up to 1.2 km (RS485), expansible to 13.2 km using repeaters.	Transmission range: up to 500m	-	-
64 stations for every network.	64 stations for every network.	-	Available as fieldbus (254 stations per network) as well as a control network (120 stations per network)

Source: CC-Link Industrial Networks, Wikipedia

Features of CC-Link

- Allows variable communication speed of 2.5Mbps - 1Gbps.
- Maximum transmission distance up to 100 meters (Fieldbus) while 550 meters (Control).
- Operating frequency: 13.56 MHz (licenses global usage).
- Data transmission utilizes both duplex & single lines.
- Facilitates a deterministic communication.

Source: CC-Link Industrial Networks, Wikipedia

DeviceNet

Introduction to DeviceNet

- It is based up on the standard CAN (Controller Area Network) protocol.
- CAN standard is a serial protocol defining the communication of data link layer.
- It links industrial sensors & actuators with high-end devices (Programmable Logic Controllers).
- Application areas: safety devices, data exchange, and large I/O networks.

Source: DeviceNet Communication Manual.

Features of DeviceNet

- Data in CAN is conveyed via data frame: Identifier field (11 bit) and Data field (8 data bytes).
- Also has a remote frame (RTR) that only contains the identifier.
- CAN uses the CSMA/NBA channel access scheme (physical layer).
- It defines different sorts of telegrams (frames), error detecting scheme, and data validation.
- It uses linear network topology that permits the signal (shielded cable) and the power wiring (twisted-pair) in the same cable.

Source: DeviceNet Communication Manual.

Communication Infrastructure

- In IIoT and Industry 4.0 IoT deployments, the connectivity infrastructure can be classified as follows:
  - Wired Connectivity
    - DSL
    - Modem
    - PSTN
  - Wireless Connectivity
    - IEC-PAS 62601/WIA-PA
    - Satellite Connectivity
    - ISA 100
    - LPWAN

Note: ISA 100 is discussed in IoT Communication-Part II of this course.

DSL

Introduction to DSL

- DSL stands for “Digital Subscriber Line”.
- Aims at bringing high data rate to households and industries using the common telecommunication line.
- A DSL line can carry both data and voice signals.
- DSL may be categorized as Asymmetric DSL(ADSL) and Symmetric DSL(SDSL).
- ADSL supports a higher download speed compared to the upload speed.
- SDSL supports equal speed for both upload and download.

Features of DSL

- Supports simultaneous connection for voice and data communication.
- Basic DSL supports data rate between 1.544 Mbps and 8.448 Mbps for download service.
- Data is transmitted in its digital format, without any conversion to analog format.
- This digital transmission allows wide range of bandwidth for communication.
- The speed of the service decreases with the increasing distance of the user from the central office of the service provider.

MODEM

Introduction to MODEM

- MODEM is a short form of Modulator-Demodulator.
- A network hardware device to perform the modulation and demodulation of carrier signals with encoded data.
- Data is modulated into analog form at the transmitting side MODEM.
- The received analog data by the MODEM is transformed into digital form, called demodulation.

Types of MODEM

- On the basis of directional capacity:
  - Simplex: It offers data transmission in only one direction, from digital device to network or vice-versa.
  - Half duplex: It offers bi-directional data transmission but one at a time.
  - Duplex: Data transmission can take place in both directions, simultaneously
- On the basis of transmission mode:
  - Synchronous Mode: In this mode a continuous stream of bits of data can be handled but requires an external clock pulse.
  - Asynchronous Mode: In this mode data bytes with start and stop bits can be handled without any external clock signal.

PSTN

Introduction to PSTN

- PSTN stands for "Public Switched Telephone Network".
- It is considered as an aggregation of all the circuit switched networks across the world, used for public telecommunication.
- PSTN networks are also called POTS, Plain Old Telephone Systems.
- These network run on a regional, local, national and international scale using fiber optic cables, telephone connection lines, cellular communications or microwave transmission links.

Source: TSSN - Telephone Networks, Tutorialspoint.

IEC/PAS 62601: WIA-PA

Introduction to IEC/PAS 62601: WIA-PA

- WIA-PA stands for "Wireless Networks for Industrial Automation-Process Automation", is a wireless communication technology, primarily focused on Industrial IoT.
- It is a variation of IEEE 802.15 and IEC.
- Advantages:
  - It supports Adaptive Frequency Hopping (AFH).
  - Aggregation of data packets is done.
  - Variable routing methodologies and modes of application are available.

Source: Yu Chen. IEC 62601: Wireless Networks for Industrial Automation- Process Automation(WIA-PA).

Satellite Communication Technology

Introduction to Satellite Communication

- Satellite communication handles large number of devices providing long range data transmission with global coverage.
- Advantages:
  - Long range communication with global coverage.
  - Cost of transmission is independent of the geographical coverage region.
- Limitations:
  - Launching of satellite in space comes at a higher cost.
  - Propagation delay is more compared to other terrestrial methods.
  - Difficulty in repairs in case of any damage.

Source: Satellite Communication – Introduction, Tutorialspoint

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Key Enablers of Industrial IoT: Connectivity-Part 3

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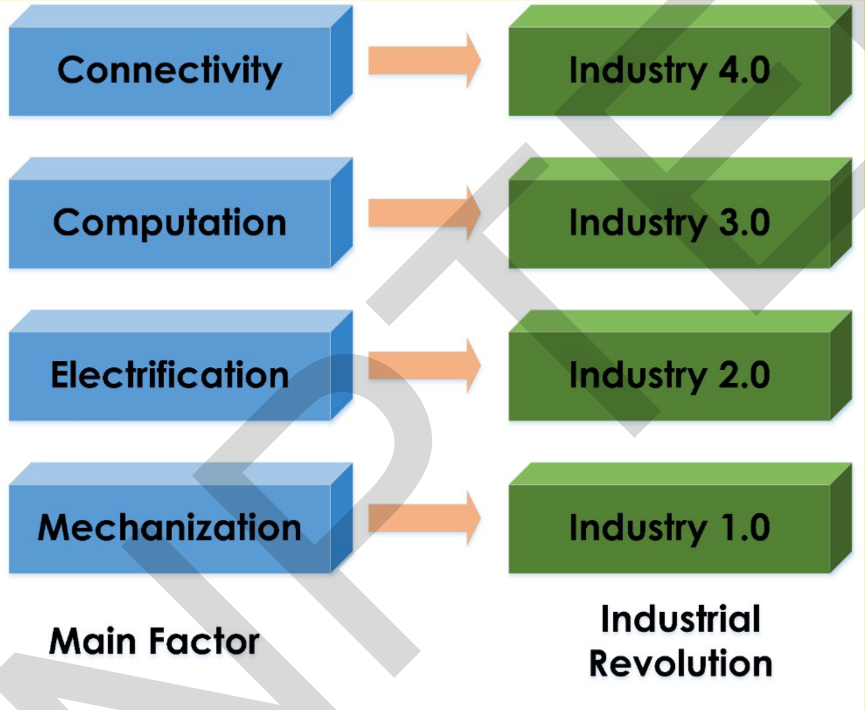
Introduction



Key Requirements

- Supports heterogeneity
  - Devices: Industrial robots, machineries, security cameras
  - Device-specific QoS parameters: delay, availability, reliability, throughput
- Unified connectivity
- Optimized service
- Dedicated network
- Low-latency communication
- Ultra-reliable communication

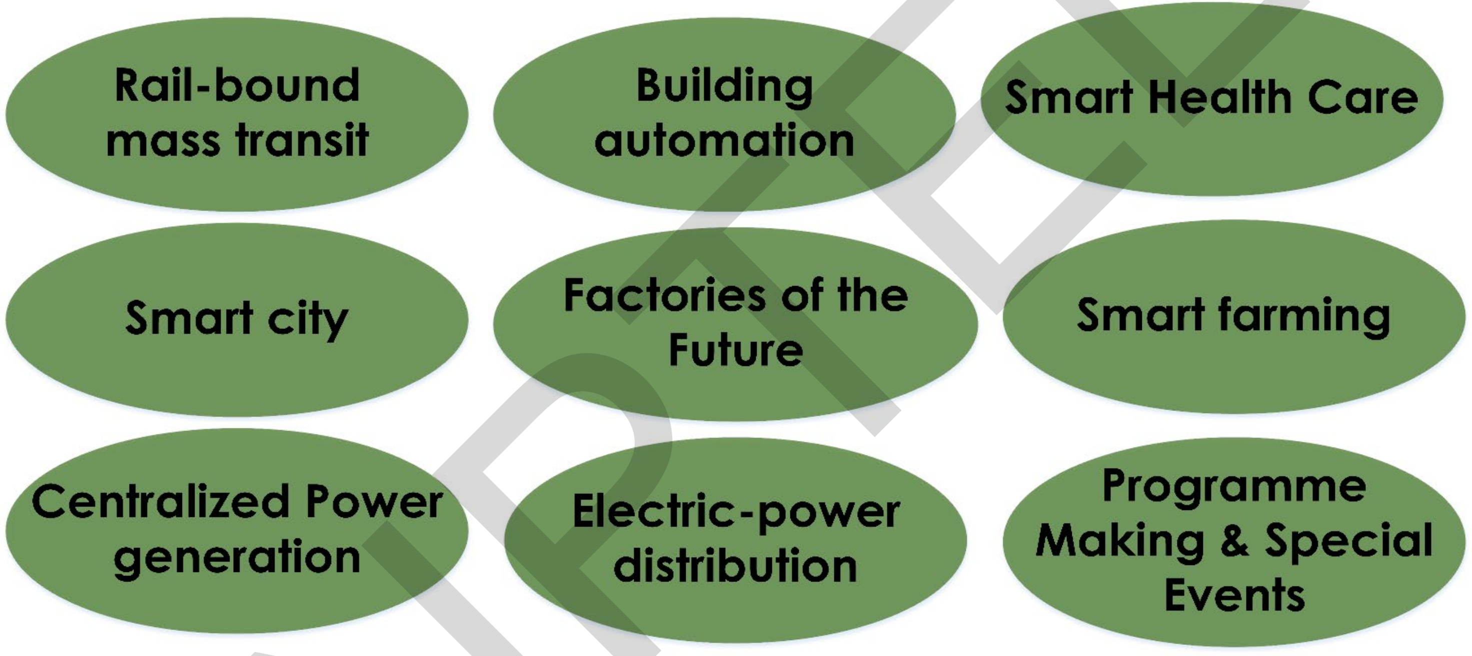
Source: G. Brown and M. Yavuz, "What Does 5G NR Bring to the Industrial IoT & the Factory of the Future? " Qualcomm (Producer), June 2018

Community Initiatives

- 3GPP
  - Study communication requirements specific to industries (Release 15)
  - "*Factories of the Future*" 5G usecase in (Release 16)
- 5G-ACIA
  - Unite OT industries, ICT industries and academia for enabling 5G for industries
- IEEE
  - Enabling Ethernet for Time Sensitive Network (TSN) - 802.1Q Ethernet

Source: G. Brownl and M. Yavuz, "What Does 5G NR Bring to the Industrial IoT & the Factory of the Future? " Qualcomm (Producer), June 2018

3GPP Release16 Usecases



Source: 3GPP Technical Report 22.804, “Study on Communication for Automation in Vertical domains”, 2018

Factories of the future

- Realization of heavy industries
  - Oil refineries
  - Mining
  - Manufacturing
  - Warehouses
- Systems in Interest
  - Motion Control
  - Robotics
  - Massive wireless sensor networks

Source: 3GPP Technical Report 22.804, "Study on Communication for Automation in Vertical domains", 2018

5G support for Private Network

- 5G new radio (NR)
  - Low band (<1 GHz)
  - Middle band (1-6 GHz)
  - High band (>24 GHz) millimeter wave
- Smallcell deployments
  - Femtocell
  - Picocell
  - Integrated WiFi
- Device-to-Device communication

Source: G. Brownl and M. Yavuz, "What Does 5G NR Bring to the Industrial IoT & the Factory of the Future? " Qualcomm (Producer), June 2018

5G -NR

5G-NR

- New air-interface proposed by 3GPP
- Aligned with ITU service categories
  - Enhanced mobile broadband (eMBB)
  - Massive machine-type communication (mMTC)
  - Ultra reliable low latency communication (uRLLC)
- Design objectives
  - Backward compatibility
  - Enabling versatile connections

Source: H. Ji et al., "Ultra-Reliable and Low-Latency Communications in 5G Downlink: Physical Layer Aspects," IEEE Wireless Communications, vol. 25, no. 3, pp. 124-130, JUNE 2018.

Smallcell Deployment

Smallcell Deployment

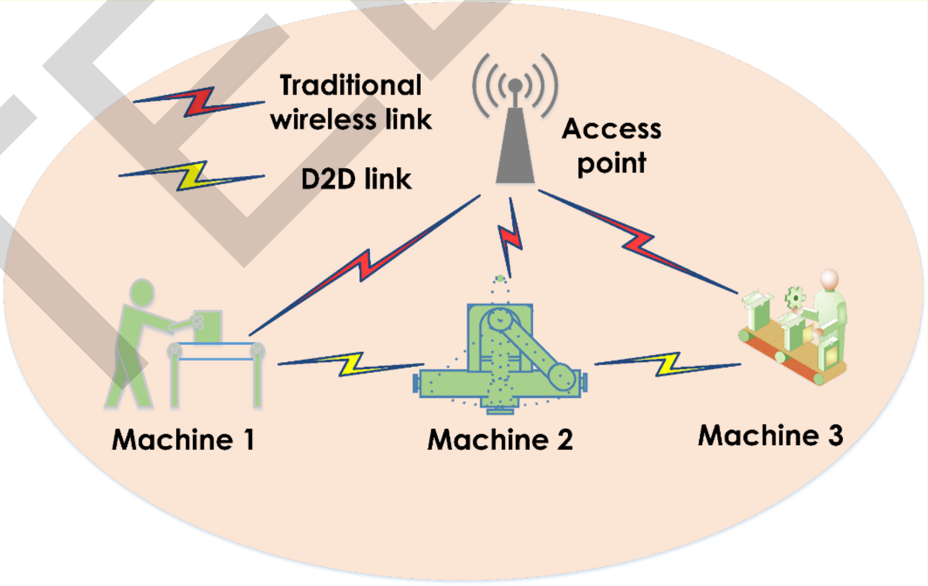
- Objectives
  - Alleviating burden on backhaul
  - Improving energy efficiency
  - Decreasing dead zones
- Operating frequency
  - Licensed spectrum
  - License-exempted spectrum

Source: A. Damnjanovic et al., "A survey on 3GPP heterogeneous networks," IEEE Wireless Communications, vol. 18, no. 3, pp. 10-21, 2011

Device-to-Device Communication

Device-to-Device Communication

- Objectives
  - Achieving low latency
  - Increasing throughput
  - Eliminating load core network
- Operating frequency
  - Inband deployment
    - Overlay, Underlay
  - Outband deployment
    - Controlled, Autonomous



Source: A. Asadi et al., "A Survey on Device-to-Device Communication in Cellular Networks," IEEE Communications Surveys & Tutorials, vol. 16, no. 4, pp. 1801-1819, Fourthquarter 2014.

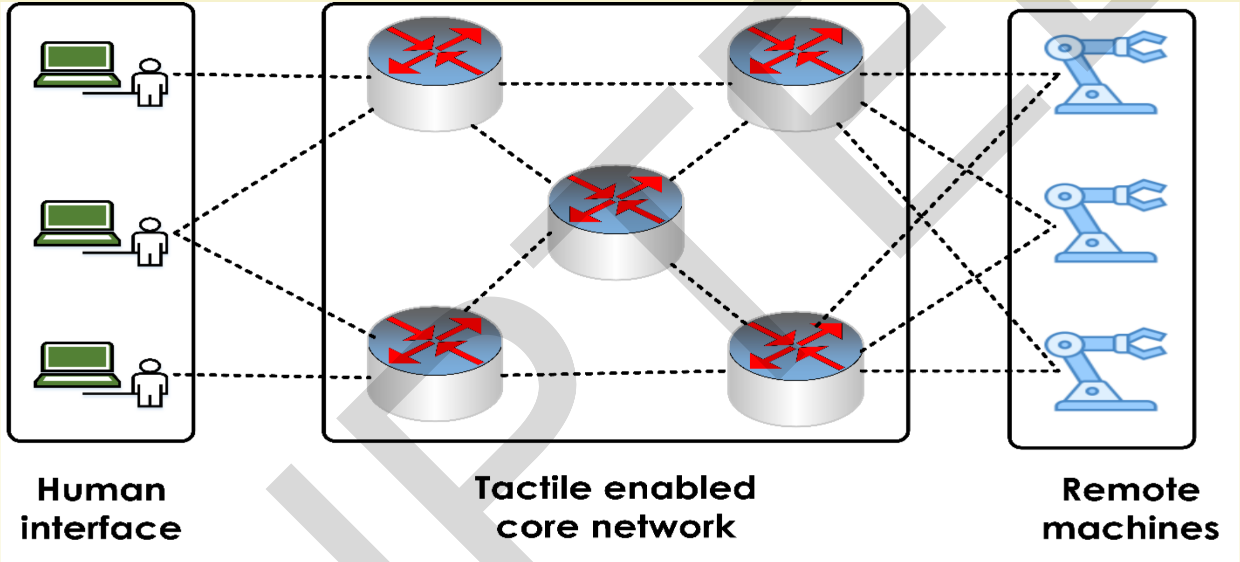
Tactile Internet

Introduction

- Real-time transmission of touch/sense and actuation
- Provides new facet to human-machine interaction
- Enables haptic communication
- Supports low end-to-end latency
    - < 1 ms round trip latency

Source: G. P. Fettweis, "The Tactile Internet: Applications and Challenges," in IEEE Vehicular Technology Magazine, vol. 9, no. 1, pp. 64-70, 2014.

Haptic communication architecture



Source: K. Antonakoglou, et al., "Towards Haptic Communications over the 5G Tactile Internet," in IEEE Communications Surveys & Tutorials. doi: 10.1109/COMST.2018.2851452

Requirements

- Ultra-responsive connectivity
  - Latency in the order of 1 ms
- Ultra-reliable connectivity
  - Ubiquitous connectivity and wide range coverage
- Security and privacy
- Tactile data
- Edge intelligence

Source: M. Simsek, et. al., "5G-Enabled Tactile Internet," in IEEE Journal on Selected Areas in Communications, vol. 34, no. 3, pp. 460-473, 2016.

Way to realizing tactile internet

- Software Defined Networking (SDN)
- Massive Multiple-Input and Multiple-Output (MIMO)
- Dual connectivity
- Mobile Edge Computing (MEC)
- Network Function Virtualization (NFV)

Source: K. Antonakoglou, et. al., "Towards Haptic Communications over the 5G Tactile Internet," in IEEE Communications Surveys & Tutorials. doi: 10.1109/COMST.2018.2851452

Applications

- Industry automation
- Autonomous driving
- Robotics
- Healthcare
- Virtual and augmented reality
- Gaming
- Unmanned autonomous system

Source: M. Simsek, et. al., "5G-Enabled Tactile Internet," in IEEE Journal on Selected Areas in Communications, vol. 34, no. 3, pp. 460-473, 2016.

uRLLC

Introduction

- Ultra-reliable Low Latency Communication
- Requirements:
  - Availability: 6-Nines (99.9999%)
  - End-to-End Latency : 1ms
  - Reliability: < 10^{-5} outage probability
  - Packet size: 32-200 B
  - Smaller transmission duration

Source: G. Pocovi et. al., "Achieving Ultra-Reliable Low-Latency Communications: Challenges and Envisioned System Enhancements," in IEEE Network, vol. 32, no. 2, pp. 8-15, 2018

Design Challenges

- Lacuna in traditional communication systems:
  - Primary objective: High throughput
  - Large latency (10 – 100 ms)
  - Large transmission time interval (TTI)
  - Large processing delay
  - Aggressive retransmission scheme
- Shorter TTI
  - Larger signal overhead
- Error prone channel
  - Decreases reliablity

Source: G. Pocovi et. al., "Achieving Ultra-Reliable Low-Latency Communications: Challenges and Envisioned System Enhancements," in IEEE Network, vol. 32, no. 2, pp. 8-15, 2018

Enabling Methods

- Shorter TTLs
  - Smaller slot length (micro scale)
  - Flexible transmission frame structure
  - Reducing Orthogonal Frequency Division Multiplexing **symbols** in TTL
  - Reducing symbol duration
  - Application: Mission-critical services

Source: G. Pocovi et. al., "Achieving Ultra-Reliable Low-Latency Communications: Challenges and Envisioned System Enhancements," in IEEE Network, vol. 32, no. 2, pp. 8-15, 2018

Enabling Methods (Contd..)

- Fast HARQ Retransmission scheme
  - Procedure: Predicting correctness of received symbol before decoding
  - Advantage: Reduces processing time
  - Disadvantage: False positive error
- Control channel enhancement methods:
  - CQI based Link adaptation
  - Compact downlink control information (DCI)

Source: G. Pocovi et. al., "Achieving Ultra-Reliable Low-Latency Communications: Challenges and Envisioned System Enhancements," in IEEE Network, vol. 32, no. 2, pp. 8-15, 2018

mmWave Communication

Introduction

- Frequency Spectrum : 30 – 300 GHz
  - mmWave for cellular communication: 30 – 100 GHz
  - Indoor communication : 57 – 64 GHz (Unlicensed band)
- Wave length : 1 - 10 mm
- Reduced element size
- MIMO based narrow beam formation

Source: G. Pocovi et. al., "Achieving Ultra-Reliable Low-Latency Communications: Challenges and Envisioned System Enhancements," in IEEE Network, vol. 32, no. 2, pp. 8-15, 2018

Enabling Methods

- Heterogeneous structure
  - Single macrocell with multiple smallcell
- Separate control and data channel
  - Control channel : microwave frequency (3G, 4G)
  - Data channel : mmWave frequency
- Dual mode smallcell

Source: G. Pocovi et. al., "Achieving Ultra-Reliable Low-Latency Communications: Challenges and Envisioned System Enhancements," in IEEE Network, vol. 32, no. 2, pp. 8-15, 2018

Disadvantages

- Need high-gain and high-directional antennas
- Signal blocking
- Suffer high penetration loss and shadowing
- Focused beam has very less chance to avoid blocking
- Low transmitting power due to maintain power amplifier efficiency

Source: J. G. Andrews, et. al. , "Modeling and Analyzing Millimeter Wave Cellular Systems," in IEEE Transactions on Communications, vol. 65, no. 1, pp. 403-430, 2017.

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9. J. G. Andrews, et. al. , "Modeling and Analyzing Millimeter Wave Cellular Systems," *IEEE Transactions on Communications*, vol. 65, no. 1, pp. 403-430, Jan. 2017

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Key Enablers of Industrial IoT: Connectivity – Part 4

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LPWAN

Introduction to LPWAN

- LPWAN stands for “Low Power Wide Area Network” is a wireless wide area network technology.
- Enables long range wireless communication among “things” at a low bit rate.
- It includes both standardized and proprietary solutions. Some of the technologies include LoRa, Sigfox's LPWAN.

LoRa and LoRaWAN

- LoRa, a short form for <u>Long Range</u>, incorporates a spread spectrum modulation technique based on chirp spread spectrum (CSS) technology.
- LoRa operates in the license-free sub-gigahertz radio frequency bands of 169 MHz, 433 MHz, 868 MHz (Europe) and 915 MHz (North America).
- LoRaWAN is the network in which LoRa operates and enables communication between devices.

Source: What is LoRa?.

SIGFOX

- The SIGFOX network and technology achieves low cost wide coverage for application domains with machine to machine networking and communication.
- The SIGFOX radio link operates in the unlicensed ISM radio bands.
- SIGFOX network give a performance of upto 140 messages per day with a payload of 12 bytes per message.
- The wireless throughput achieved is of up to 100 bits per second.

Source: *Ian Poole.* SIGFOX for M2M & IoT

Hands-On
(Industrial Environment Monitoring)

System Overview

- Sensor (DHT) and Communication Module (LoRa) interfaced with Processor (NodeMCU)
- Both transmitter and receiver module consists of a NodeMCU board connected to a LoRa module.
- Transmitter module has the sensor that monitors the temperature and humidity of the environment and sends the data to the receiver module.
- Receiver module responds according to the set condition.

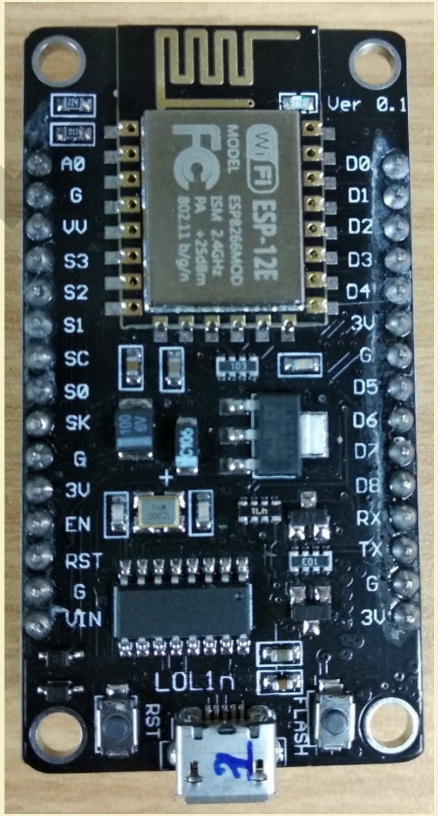
System Overview (contd.)

Requirements:

- NodeMCU
- LoRa
- DHT Sensor
- Jumper wires
- LED

NodeMCU

- This is an ESP-12 module and works with Arduino IDE.
- We can use other Arduino Boards as well.
- Pin configuration along with other documentation can be found here.

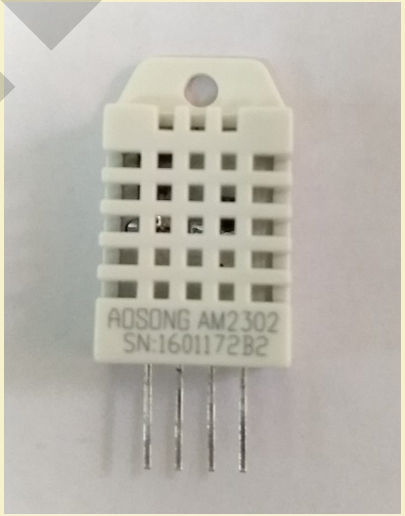


LoRa

- This is a LoRa transceiver module as discussed in the previous slides.
- It is used for long range wireless communication in industrial applications.

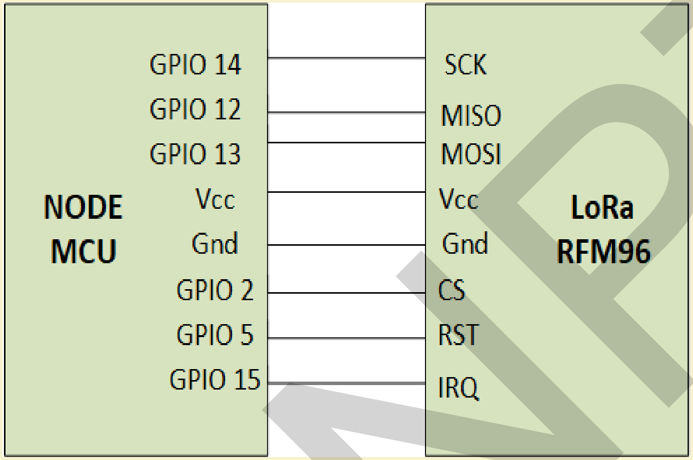
DHT Sensor

- Digital Humidity and Temperature (DHT) Sensor
- Pin Configuration (from left to right)
  - PIN 1- 3.3V-5V Power supply
  - PIN 2- Data
  - PIN 3- Null
  - PIN 4- Ground



Interfacing

- The connection between NodeMCU and LoRa is shown in the diagram.



Interfacing

- The connection between NodeMCU and DHT is shown in the diagram.
- NodeMCU ---- DHT
  - GPIO 4 – Data
  - 3V3 – Vcc
  - Gnd – Gnd

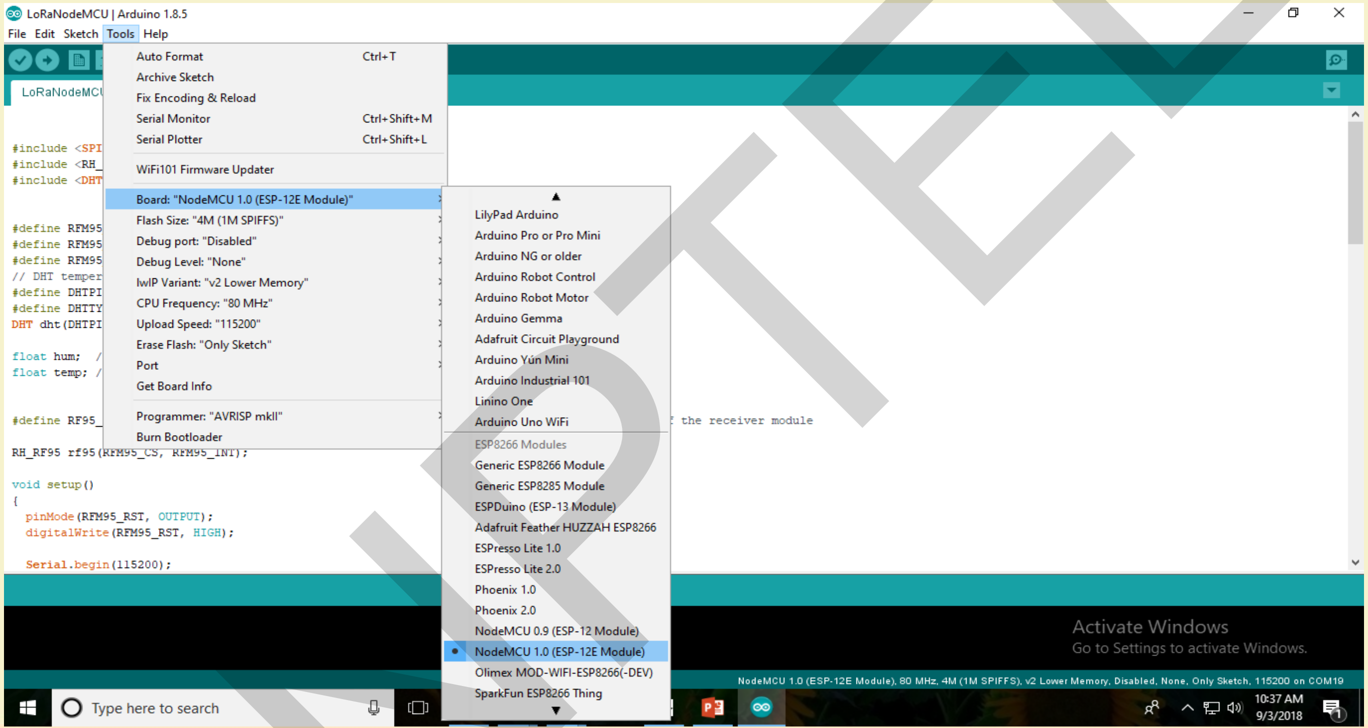
Pre-requisites

- Adafruit provides a library to work with the DHT22 sensor.
- To work with LoRa we use the Radiohead library which can be downloaded from the below URL.
  - https://learn.adafruit.com/radio-featherwing/using-the-rfm-9x-radio
- The initial connections have to be soldered in the LoRa module as mentioned in the URL provided above.

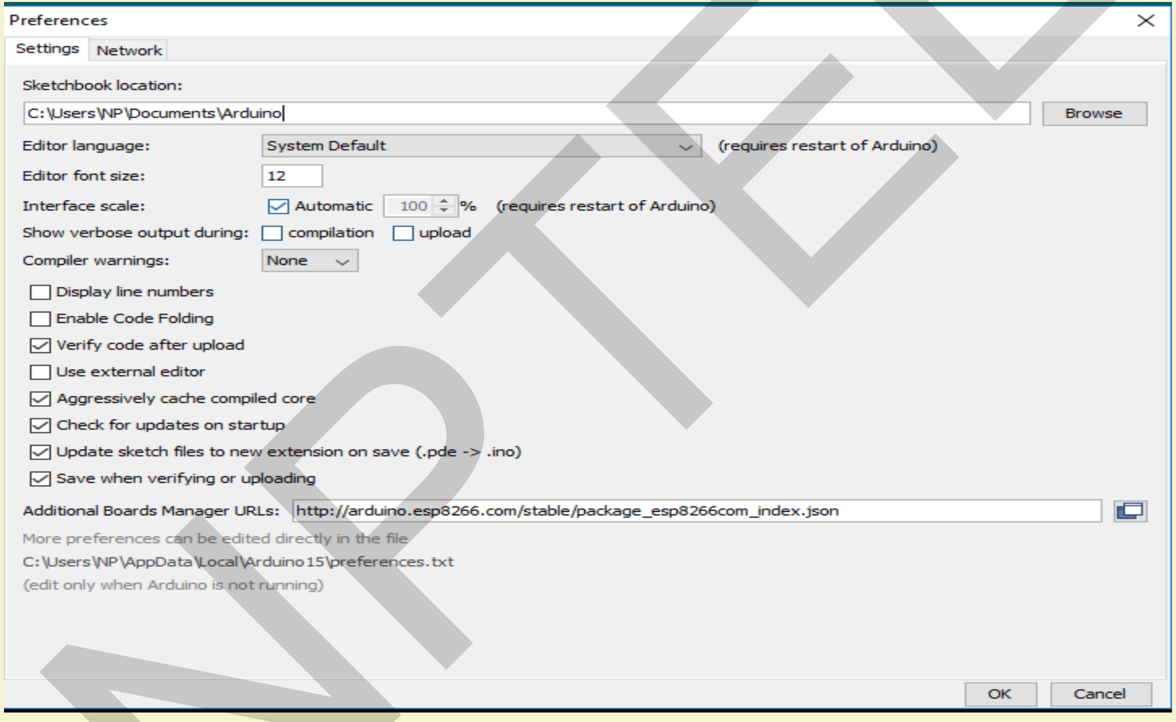
Pre-requisites (contd.)

- To add Node MCU board in the Arduino IDE, follow the below steps:
  - Arduino IDE >> File >> Preferences (Shortcut is CTRL + COMMA)>> Settings tab >> on Additional Board Manager URL side type this >>
  - http://arduino.esp8266.com/stable/package_esp8266com_index.json
  - click ok

Pre-requisites (contd.)



Pre-requisites (contd.)



Program: LoRa interfaced with NodeMCU

LoRaNodeMCUTx

```
#include <SPI.h>
#include <RH_RF95.h>
#include <DHT.h>

#define CS  2    // "E" D4
#define RST 5   // "D" D1
#define INT 15   // "B" D8
// DHT temperature and humidity sensor
#define DHTPIN 4     // Pin numbers in GPIO/D2
#define DHTTYPE DHT22   // DHT 22
DHT dht(DHTPIN, DHTTYPE);

float hum;  //Stores humidity value
float temp; //Stores temperature value


#define FREQ 915.0 // This can be changed to other frequency but should be same as that of the receiver module

RH_RF95 rf95(CS, INT);
```

- Here we declare the pins for connection with the CS, RST and IRQ pin of LoRa.
- The DHT data pin is mapped with the Node MCU pin.

Program: LoRa interfaced with NodeMCU(Tx)

```
//Reading data from the DHT sensor
hum = dht.readHumidity();
temp= dht.readTemperature();
String msgl= "Temp: ";
msgl += temp;
msgl += "C, Hum: ";
msgl += hum;
msgl += "%";
delay(1000); // Delay of 1 second before transmitting the data
Serial.println("Sending temperature and humidity");

//Send data to the receiver
char radiopacket[26];
msgl.toCharArray(radiopacket,26);
Serial.println(radiopacket);
delay(10);
rf95.send((uint8_t *)radiopacket, 26);
```

- The temperature and humidity value from the sensor is read and saved in a string.
- The data is sent to the receiver module in a character array with a delay of 1 second.

Program: LoRa interfaced with NodeMCU(Rx)

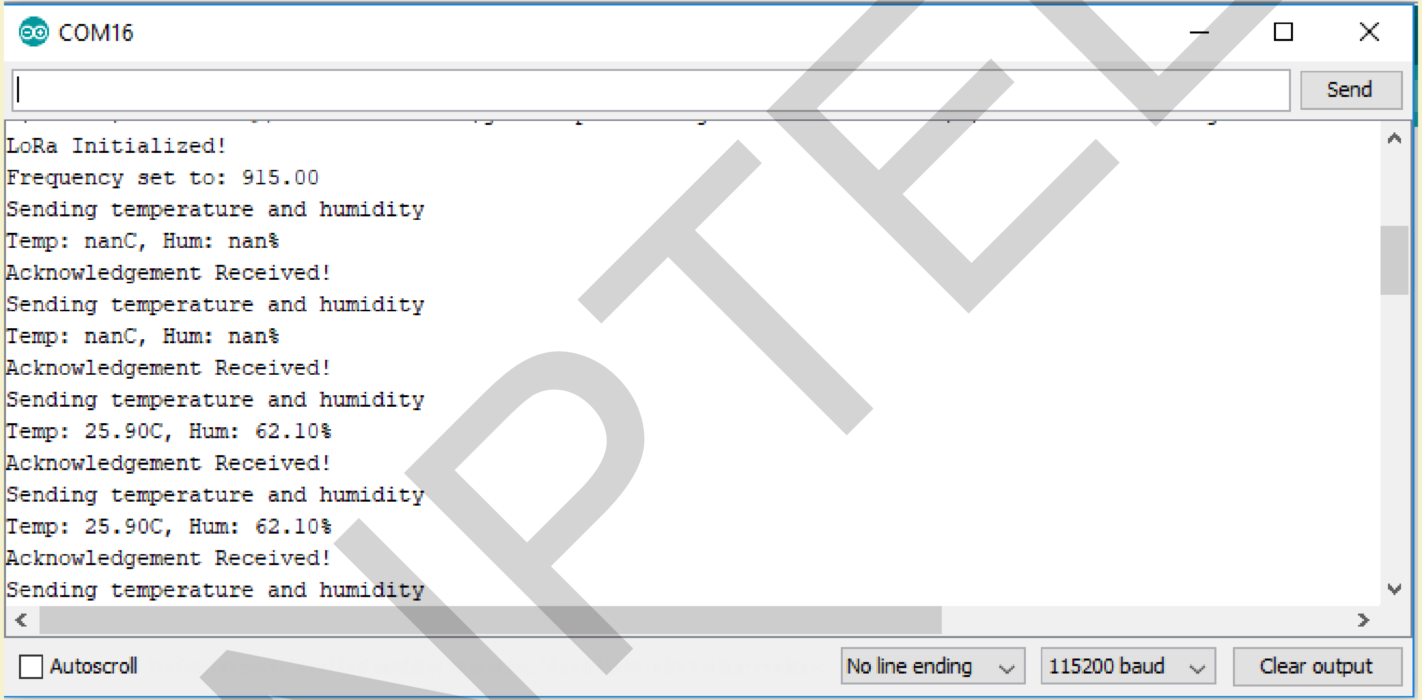
LoRaNodeMCURx

```
#include <SPI.h>
#include <RH_RF95.h>

#define CS  2    // "E"
#define RST 5   // "D"
#define INT 15   // "B"

#define FREQ 915.0

RH_RF95 rf95(CS, INT);

#define LED 4 //GPIO4- D2
```

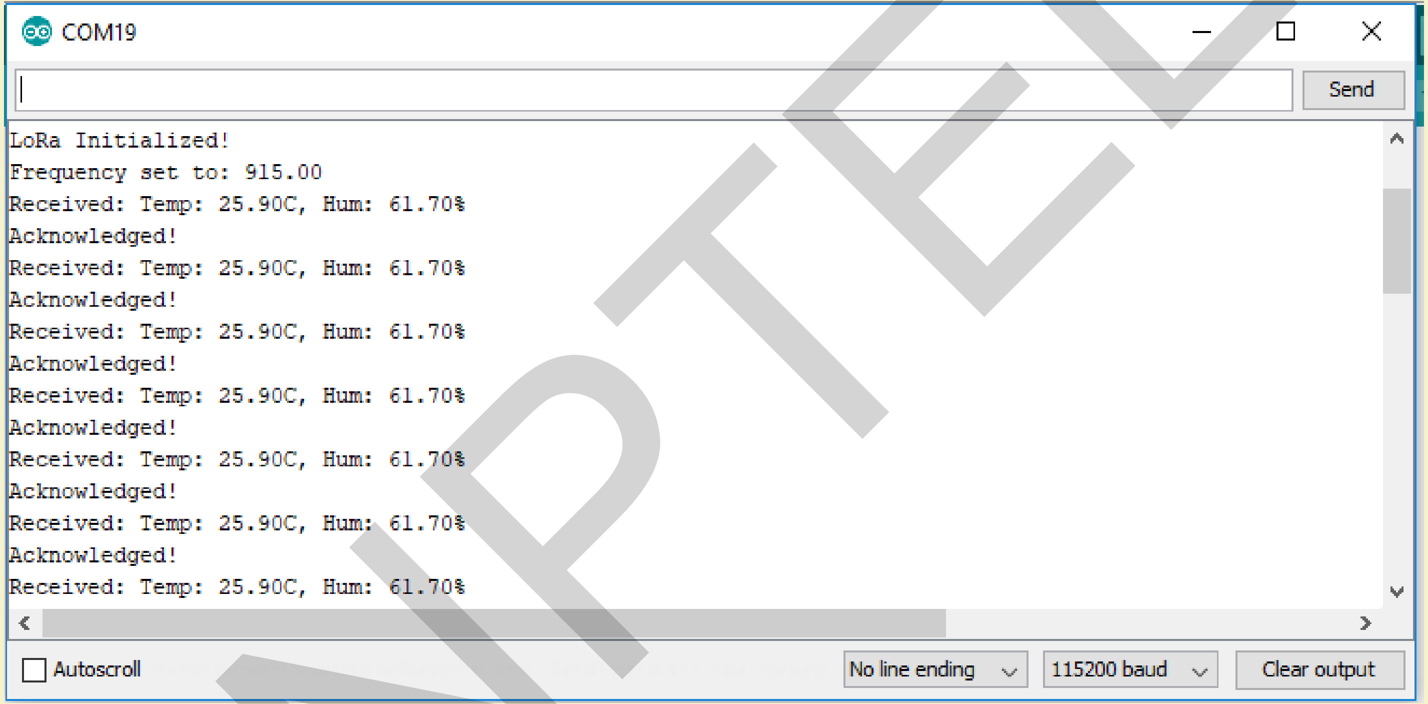
```
void loop()
{
  if (rf95.available())
  {
    uint8_t buf[RH_RF95_MAX_MESSAGE_LEN];
    uint8_t len = sizeof(buf);

    if (rf95.recv(buf, &len))
    {
      digitalWrite(LED, HIGH);
      Serial.print("Received: ");
      Serial.println((char*)buf);

      // Send a reply
      uint8_t data[] = "Data Received";
      rf95.send(data, sizeof(data));
      rf95.waitPacketSent();
      Serial.println("Acknowledged!");
      digitalWrite(LED, LOW);
```

- The data is received by the Receiver module.
- After successful reception, an acknowledgement message is sent to the sender module.
- Every time a message is received, the LED pin is set to HIGH.

Output from Tx Serial Monitor



Output from Rx Serial Monitor



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2. What is LoRa?. Online. URL: https://www.semtech.com/lora/what-is-lora

Tx Program: LoRa interfaced with NodeMCU

```
#include <SPI.h>
#include <RH_RF95.h>
#include <DHT.h>

#define CS  2    // "E" D4
#define RST 5   // "D" D1
#define INT 15   // "B" D8
// DHT temperature and humidity sensor
#define DHTPIN 4     // Pin numbers in
GPIO/D2
#define DHTTYPE DHT22   // DHT 22
DHT dht(DHTPIN, DHTTYPE);

float hum;  //Stores humidity value
float temp; //Stores temperature value

#define FREQ 915.0
//Can be changed to other freq but should be
same as that of the Rx

RH_RF95 rf95(CS, INT);

void setup()
{
  pinMode(RST, OUTPUT);
  digitalWrite(RST, HIGH);

  Serial.begin(115200);
  while (!Serial) {
    delay(1);
  }
  delay(100);
  Serial.println("LoRa Tx Node");

  // manual reset
  digitalWrite(RST, LOW);
  delay(10);
  digitalWrite(RST, HIGH);
  delay(10);

  while (!rf95.init()) {
    Serial.println("Initialization Failed!");
    while (1);
  }
  Serial.println("LoRa Initialized!");

  if (!rf95.setFrequency(FREQ)) {
    Serial.println("setFrequency failed");
    while (1);
  }
  Serial.print("Frequency set to: ");
Serial.println(FREQ);
  rf95.setTxPower(23, false);
}
```

Tx Program: LoRa interfaced with NodeMCU

```
void loop()
{
  //Reading data from the DHT sensor
  hum = dht.readHumidity();
  temp= dht.readTemperature();
  String msg1= "Temp: ";
  msg1 += temp;
  msg1 += "C, Hum: ";
  msg1 += hum;
  msg1 += "%";
  delay(1000); // Delay of 1 second before
transmitting the data
  Serial.println("Sending temperature and
humidity");

 //Send data to the receiver
  char radiopacket[26];
  msg1.toCharArray(radiopacket,26);
  Serial.println(radiopacket);
  delay(10);
  rf95.send((uint8_t *)radiopacket, 26);
  delay(10);
  rf95.waitPacketSent();
  uint8_t buf[RH_RF95_MAX_MESSAGE_LEN];
  uint8_t len = sizeof(buf);

 if (rf95.waitAvailableTimeout(1000))
  {
   if (rf95.recv(buf, &len))
   {
     Serial.print("Acknowledgement
Received!\n");
   }
   else
   {
     Serial.println("Receive failed\n");
   }
  }
  else
  {
   Serial.println("No Receiver Node Found!");
  }
}
```

Rx Program: LoRa interfaced with NodeMCU

```
#include <SPI.h>
#include <RH_RF95.h>

#define CS  2    // "E"
#define RST 5   // "D"
#define INT 15   // "B"

#define FREQ 915.0

RH_RF95 rf95(CS, INT);

#define LED 4 //GPIO4- D2

void setup()
{
  pinMode(LED, OUTPUT);
  pinMode(RST, OUTPUT);
  digitalWrite(RST, HIGH);

Serial.begin(115200);
while (!Serial) {
  delay(1);
}
delay(100);

Serial.println("LoRa Rx Node");
digitalWrite(RST, LOW);//Reset manually
delay(10);
digitalWrite(RST, HIGH);
delay(10);

while (!rf95.init()) {
  Serial.println("Initialization Failed!");
  while (1);
}
Serial.println("LoRa Initialized!");

if (!rf95.setFrequency(FREQ)) {
    Serial.println("setFrequency failed");
    while (1);
  }
  Serial.print("Frequency set to: ");
Serial.println(FREQ);

  rf95.setTxPower(23, false);
}
```

Rx Program: LoRa interfaced with NodeMCU

```
void loop()
{
  if (rf95.available())
  {
    uint8_t
buf[RH_RF95_MAX_MESSAGE_LEN];
    uint8_t len = sizeof(buf);

    if (rf95.recv(buf, &len))
    {
      digitalWrite(LED, HIGH);
      //RH_RF95::printBuffer("Received: ", buf,
len);
      Serial.print("Received: ");
      Serial.println((char*)buf);

      // Send a reply
      uint8_t data[] = "Data Received";
      rf95.send(data, sizeof(data));
      rf95.waitPacketSent();
      Serial.println("Acknowledged!");
      digitalWrite(LED, LOW);
    }
    else
    {
      Serial.println("Receive failed");
    }
  }
}
```

Thank You!!

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Key Enablers of Industrial IoT: Connectivity – Part 5

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Hands-On
(Zigbee Connectivity)

System Overview

- Basic connectivity model to enable data transfer between xbee modules is discussed. The hands-on focuses on the following areas:
  - Basic configuration of Xbee module
  - Introduction to basic communication between two Xbee modules using python programming language.

Zigbee

Introduction to Zigbee

- Zigbee is a communication protocol with its physical and MAC layer based on the IEEE 802.15.4.
- It is one of the well known standards for low power low data rate WPAN.
- Zigbee supports 3 topologies: Start, Tree and Mesh
- It is mostly used in home and industrial automation applications.
- The communication ranges varies between 10-100 meters depending on the device variant.

Introduction to Zigbee (Contd.)

- A Zigbee device can be any of the three types: 1) Coordinator 2) Router and 3) End device.
- A coordinator is the root of a the network and acts as a bridge between different networks.
- Router relays the information to other nodes in the network. It can also run small scale applications
- End devices are only responsible to connect to the parent node, no relaying of information is supported.

Source: Tarun Agarwal, ZigBee Wireless Technology Architecture and Applications

Zigbee and Xbee

- Zigbee is a mesh communication protocol based on the IEEE 802.15.4
- Xbee is the product that uses the Zigbee communication protocol for radio communication.
- Xbee is a product by Digi which comes in may variants.
- Digimesh is another protocol that works similar to Zigbee with additional desirable features.

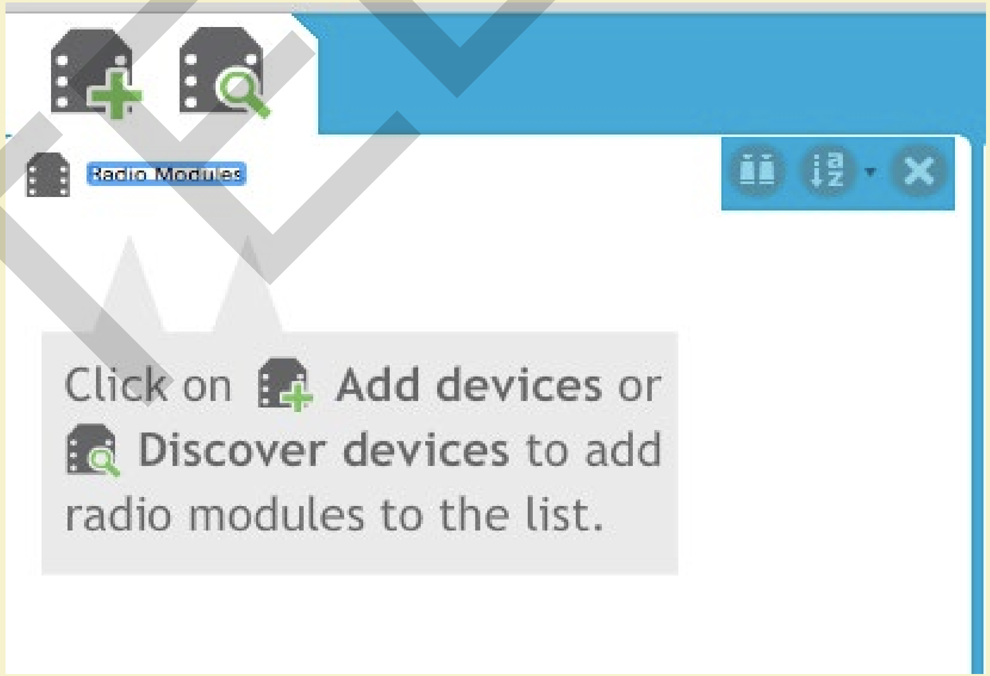
Source: ZigBee Vs. XBee: An Easy-To-Understand Comparison

Pre-requisites

- Install the xbee library
  - Pip install xbee
- Install XCTU software from here.
- XCTU will be used to configure the xbee modules before using them for communication.

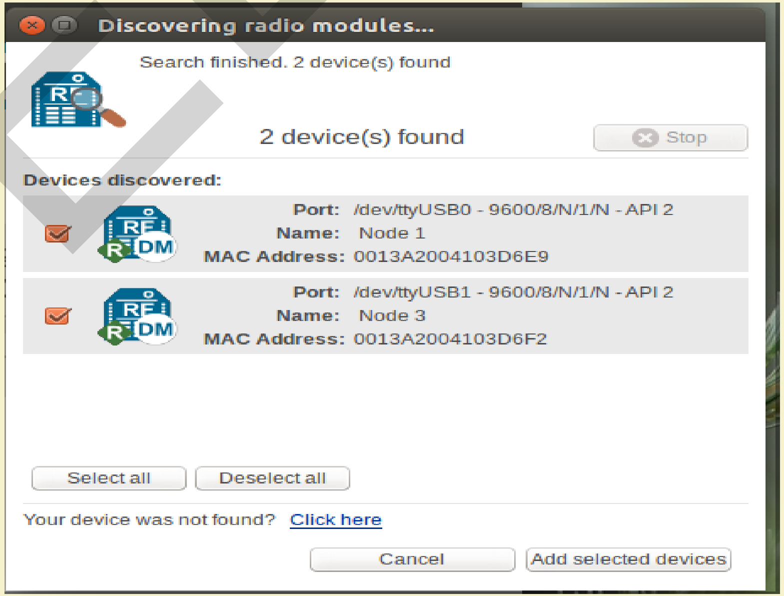
Xbee Configuration

- Open XCTU.
- Click on the discover button to discover the Xbee devices which are currently connected in the COM ports.



Xbee Configuration (cont.)

- After discovering the devices, identify the port id and the MAC address of the Xbee devices.
- Port id and MAC id are required for the communication.



Tx Program: Xbee Transmitter

```
from xbee import DigiMesh
import time
import serial
PORT = '/dev/ttyUSB1' #sender port id
BAUDRATE = 9600
ser = serial.Serial(PORT,BAUDRATE)
def send(ser, msg, addr64='000000000000FFFF'):
    xbee = DigiMesh(ser,escaped=True)
    if(ser.isOpen()==False) :
        ser.open()
    addr64 = bytearray.fromhex(addr64)
    xbee.tx(
        frame_id = b'\x00',
        dest_addr = addr64,
        data = msg.encode('utf8')
    )
msg=raw_input("Enter message:")
send(ser,msg)
```

- Importing the library files of DigiMesh protocol.
- Sender port id.
- dest_addr refers to destination address. The default target is to broadcast the message.

Rx Program: Xbee Receiver

```
from xbee import DigiMesh
import time
import serial
PORT = '/dev/ttyUSB0'
BAUDRATE = 9600
ser = serial.Serial(PORT,BAUDRATE)
xbee = DigiMesh(ser,escaped=True)
while True:
    try:
        response = xbee.wait_read_frame()
        if response['id']=='rx' :
            print(response['data'].decode('utf8'),)
    except KeyboardInterrupt:
        ser.close()
        break
```

- Importing the library files of DigiMesh protocol.
- Receiver port id.
- Waiting for receiving the data from sender.

Output Console for Transmitter

```
swan1@swan1-Inspiron-660s:~/XBEE_DEMO$ python sender.py
Enter message:Welcome to IIOT course
```

Output Console for Receiver

```
swan1@swan1-Inspiron-660s:~/XBEE_DEMO$ python receiver.py
(u'Welcome to IIOT course',)
```

References

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4. Glenn Schatz**.** April 15, 2016. ZigBee Vs. XBee: An Easy-To-Understand Comparison. Online. URL: https://www.link-labs.com/blog/zigbee-vs-xbee

Thank You!!

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Key Enablers of Industrial IoT: Processing-Part 1

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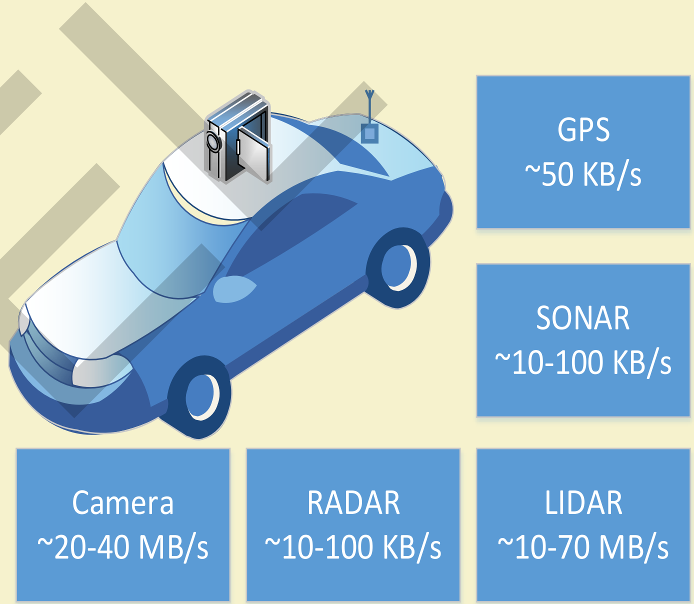
IIoT Processing: Necessity

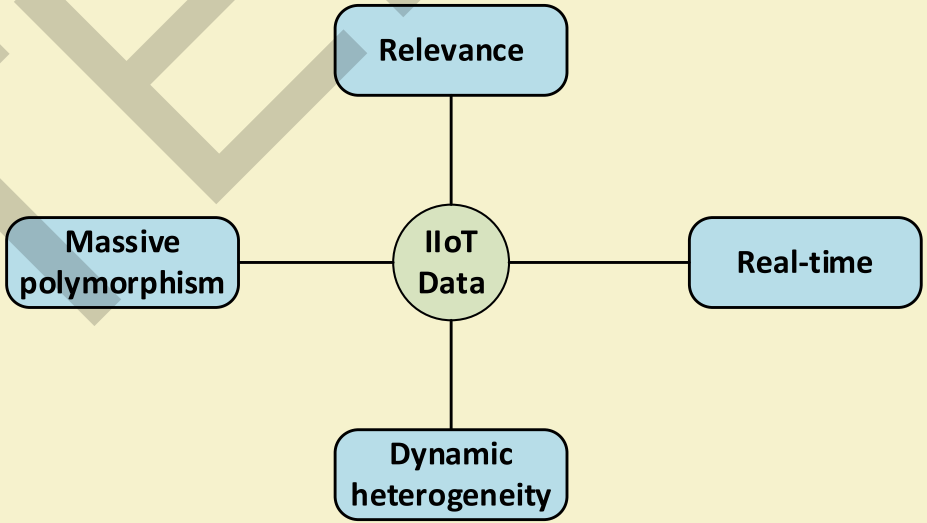
- Billions of connected devices
  - Cisco prediction of 50 billion connected devices by 2020
  - Autonomous cars generate ~100 MB data per second
  - Intermittent, unstructured, highly diverse data
  - Businesses do not need raw data deluge; need *insights* from data in real-time



Source: Self driving cars, Intel

IIoT Processing: Data characteristics

- Polymorphism
  - Heterogeneous sensors – pressure, vibration, sound
  - Different metrics, precision, formats
- Temporal/causal relationships in data
- Correlation in space, time and other dimensions



IIoT Processing: Challenges

- Complexity of data is increasing
  - Cyber Physical Systems (CPS)
  - Distributed connected applications
    - Need to interpret patterns
    - Accurate decisions with minimal latency
  - Analysis before storage
- Complex Event Processing (CEP)
  - Analyse and correlate event streams from different data sources

IIoT Processing: Complex Event processing (CEP)

- Rule-based engine
  - Extract <u>causal and temporal patterns</u> using predefined rules
  - Handles multiple data streams and correlates them to provide meaningful output
  - Can process data in near real-time

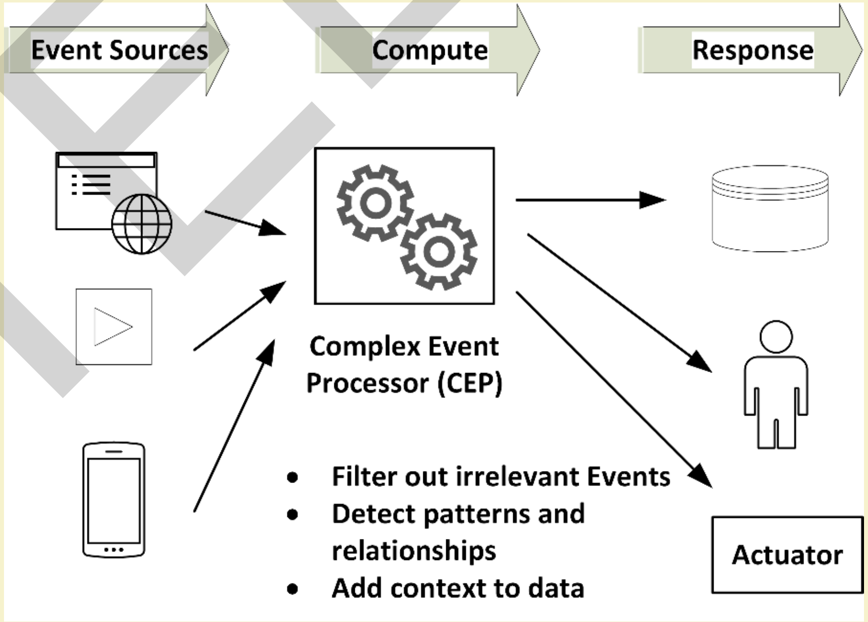
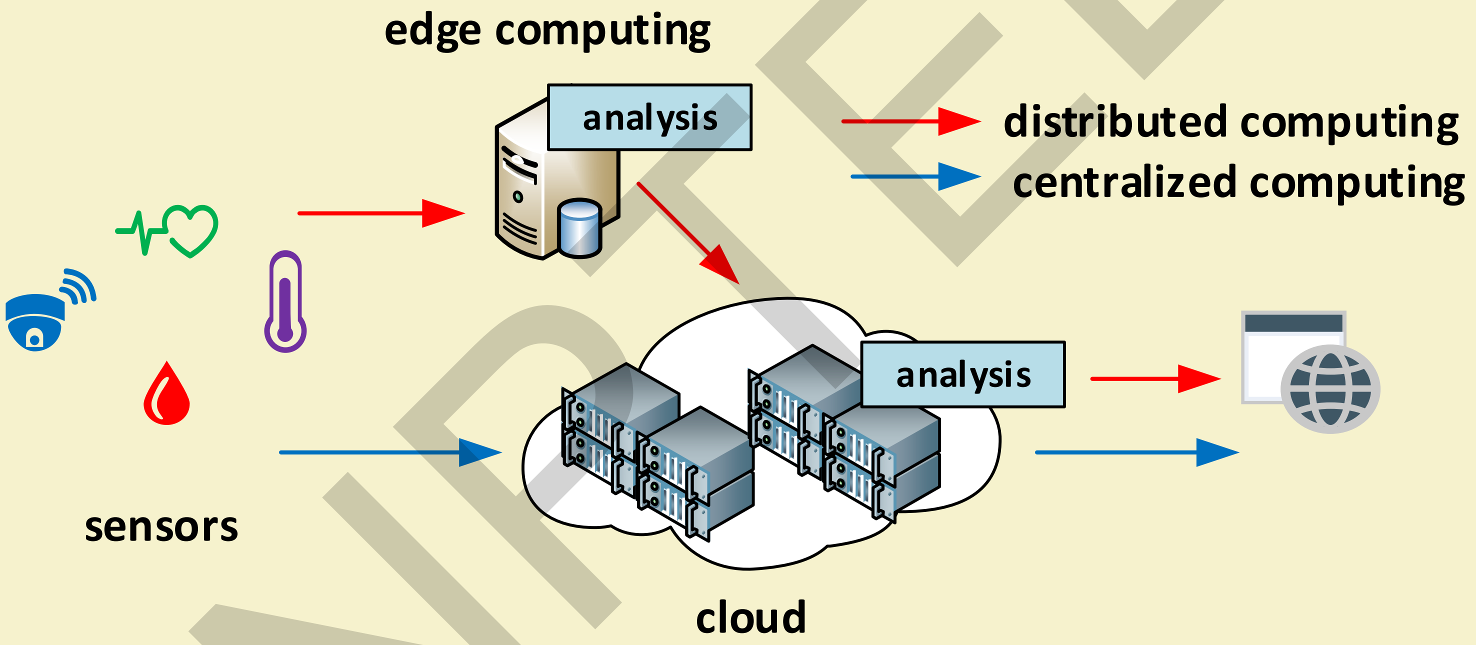


Figure: CEP Components

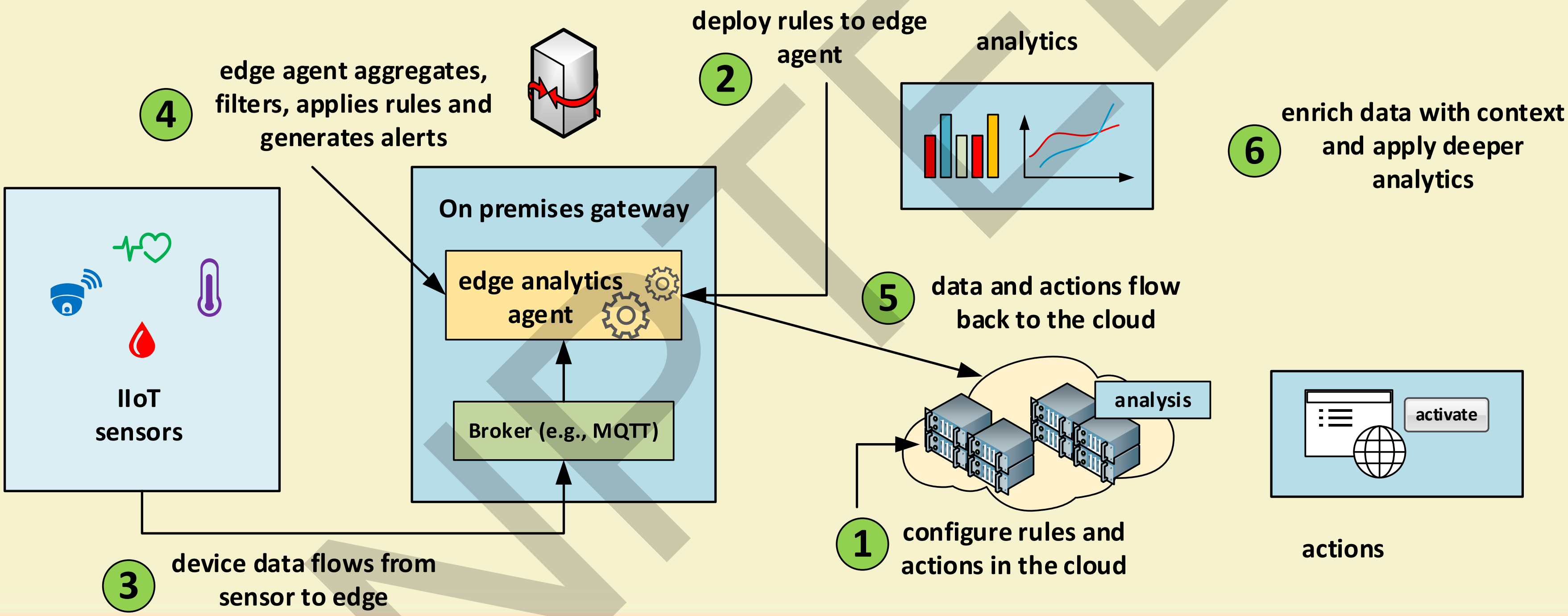
IIoT Processing: Types



IIoT Processing: Middleware

- Software layer between infrastructure layer and application layer
  - Provides services according to device functionality
  - Support for heterogeneity, security
  - Many middleware solutions are based on service-oriented architecture (SOA)

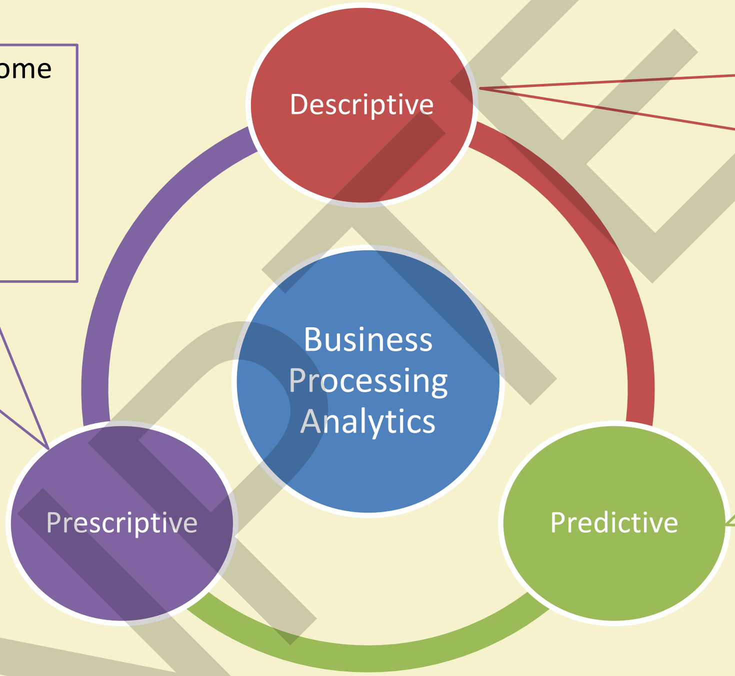
IIoT Processing: End to End



IIoT: Processing & Analytics

Questions: What already happened and currently happening
Enablers: Dashboard/Reports/Scorecards
Outcomes: Business questions & opportunities

Questions: What & why to perform some action
Enablers: Optimization/Simulation/ Decision models
Outcomes: Best possible business decision

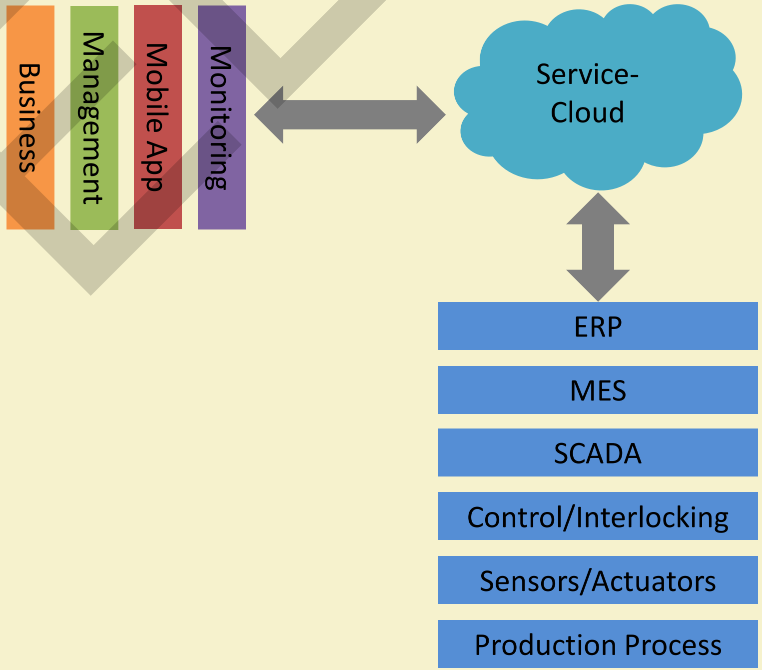


Questions: What will happen and why
Enablers: Data mining/Web mining/ predictions
Outcomes: Forecasting of future conditions

Source: Wang *et al.*, TENCON 2015

IIoT Processing: Supervisory Control & Management

- *Challenge*: Management of the huge number of heterogeneous devices in the SOA-based collaboration
- *Function*: Dynamic control & automation as per the business requirements
- Service-Cloud
  - Facilitates the remote supervisory control
  - Dynamic & rapid composition of multiple services
  - Virtualization of the automation hierarchy



Source: Colombo *et al.*, Springer 2014

MIDAS: IoT/M2M Platforms

- Modular, scalable & secure architecture
- Flexible design – facility for both on premise and cloud-based deployment
- Reliable data transfer with support for many existing protocols
- Provide a platform for custom application design
- Analytics platform:
  - Both runtime and batch analytics
  - Repository consists of pre-designed solutions

Source: MIDAS: IoT/M2M Platforms

IIoT Processing: On-going Research

- Content-aware processing
- Analytical energy model of IIoT
  - Relationship between transmission and processing energy costs
  - Exact expression of stochastic fluid model relating data correlation coefficient and computing types
- Results
  - Distributed computing is applicable for highly correlated data sources

Source: Zhou et al., 2018

IIoT Processing: On-going Research (cont.)

- Context-aware stream processing
- Limitation of current CEP systems
  - Manual threshold specification
  - Run-time update of threshold not possible
  - Not context-aware
- Proposed uCEP engine
  - Uses adaptive clustering techniques to dynamically detect boundaries between CEP values and find optimal rules
  - Extract causal and temporal patterns using adaptive rules

Source: Akbar et al., 2015

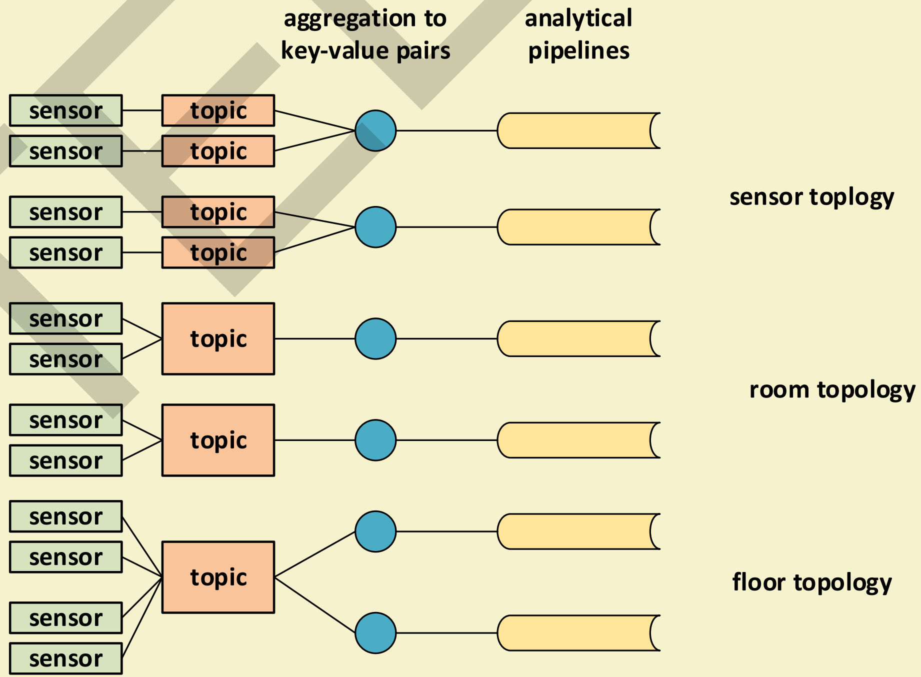
IIoT Processing: On-going Research (cont.)

- Processing topologies
  - Real-time IoT processing systems use message brokers (e.g. MQTT, Apache Kafka) and transfer them to analytical pipelines
  - Single message queue – not scalable, increased latency
  - Size of queue increases with increase in
    - Data volume
    - Number of sensors
    - Out of order data that needs more buffer space
  - Naive approach – Install more servers
    - Impractical
    - Existing server not fully utilized

Source: Dey et al., 2015

IIoT Processing: On-going Research (cont.)

- Producer phase
  - Similar across topologies
- Consumer phase
  - Extracts topic data and converts into key-value pairs
  - Workload increases from sensor to floor topology
- Modelling phase
  - Workload of room topology is reduced compared to sensor topology



Source: Dey et al., 2015

IIoT Processing: On-going Research (cont.)

- Semantic Rules Engine (SRE)
  - Rules Engine deployed at the gateways
    - high level concepts such as location and measurement type used for rule formation
  - Semantic engine to provide abstraction heterogeneity of devices
    - Business logic automatically implemented as low level rules
  - Leverage device metadata and enable retrieval of contextual data from devices

Source: Kaed et al., 2018

IIoT Processing: On-going Research (cont.)

- Big data analytics for maritime industry (Wang *et al.*, TENCON 2015)
  - Two-layer BDA-IIoT framework
    - Vessel BDA+IIoT
      - On-board, real-time & local processing
      - Limited resources
      - IIoT: Consists of *communication technologies, sensor/actuators, devices/machinery*
      - Vessel BDA: *CPU/GPU, Storage, Virtualization*
    - Land BDA
      - Remote high-power computing
      - Components: *CPU/GPU/ Cloud, Storage, Virtualization*

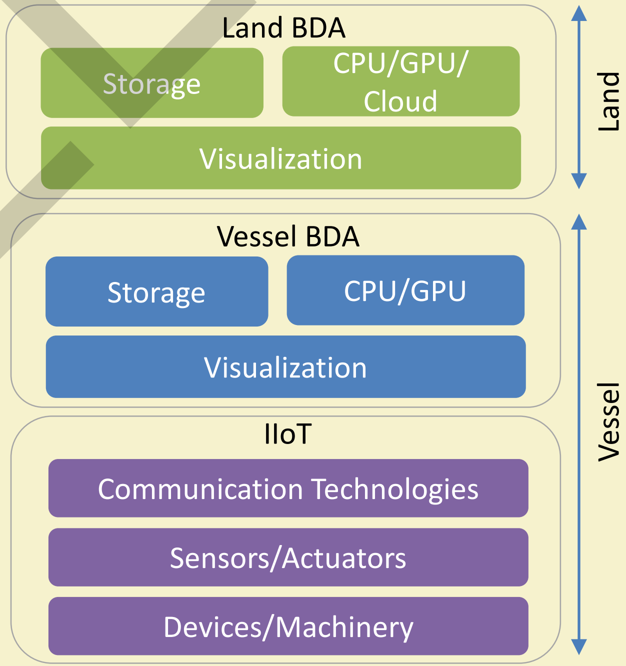
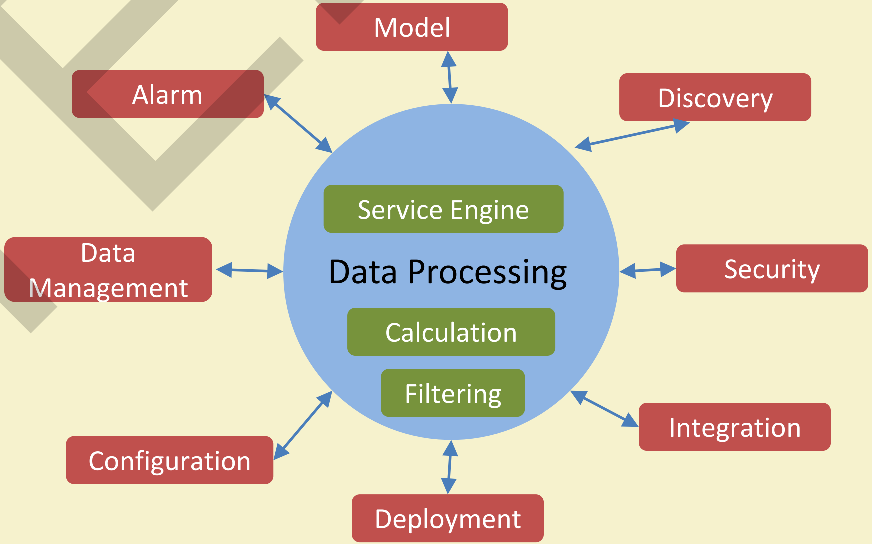


Fig: BDA-IIoT Framework

Source: Wang et al., 2015

IIoT Processing: On-going Research (cont.)

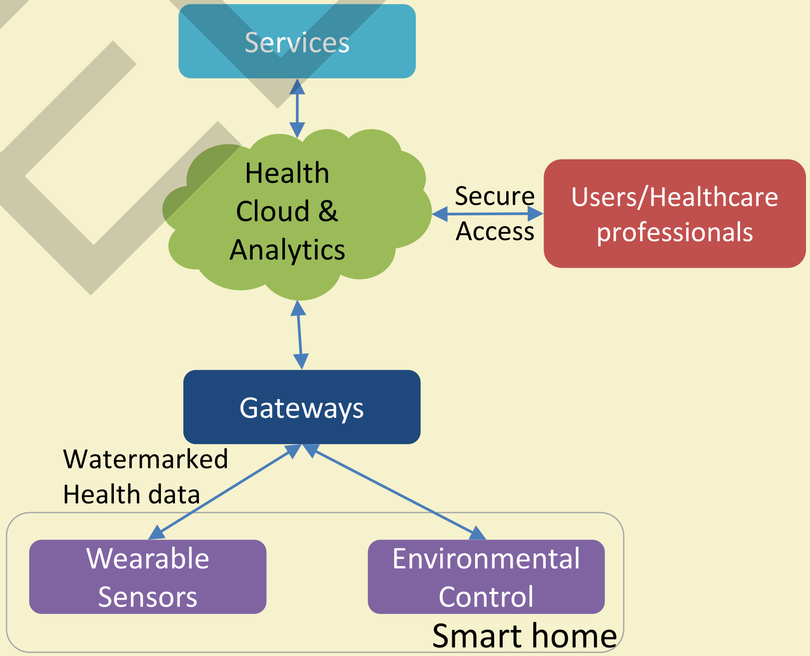
- Data Processing [Karnouskos *et al.*, 2014]
  - Functional group & block: In devices or in cloud
  - Services: Simple filtering to complex analytics
  - *Complex event processing (CEP)*: Real-time correlation & aggregation of event data
  - Rule-based deployment on incoming events
  - API-based facility to create, modify, or delete rules



Source: Karnouskos et al., 2014

IIoT Processing: On-going Research (cont.)

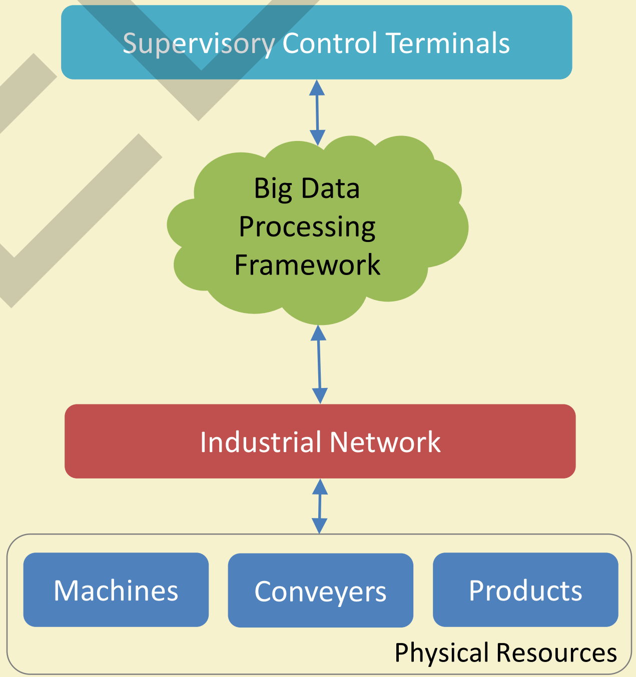
- HealthIIoT [Hossain et al., 2016]
  - Health data collected by sensor-equipped wearable devices
  - Cloud-based analytics for <u>clinical prediction</u>
  - Incorporates *watermarking* & *user identification* in the health data to enhance security
  - Cloud-based dynamic resource management & service provisioning
  - <u>Health condition monitoring</u> by in-loop healthcare professional



Source: Hossain et al., 2016

IIoT Processing: On-going Research (cont.)

- Self-organized Multi-agent System in Smart Factory [Wang et al., 2016]
  - Components: *cloud, industrial network, smart terminals*
  - Increased flexibility due to distributed cooperation and autonomous decision making framework
  - Self-organizing is achieved by intelligent negotiations between agents
  - Cloud-based big data processing framework assists the self-organization & supervisory control



Source: Wang et al., 2016

IIoT Processing: On-going Research (cont.)

- Line Information System Architecture (LISA) [Theorin et al. , 2017]
  - Event-driven information system
  - Loosely-coupled system with prototype-oriented information model
  - Components
    - *LISA events*: machine state change, occurrence of new information
    - *Message bus*: enterprise service bus with standard & structured framework for message routing
    - *Communication end-points*: interoperable communication for services
    - *Service end-points*: interoperable communication to standard interfaces

Source: Theorin et al., 2017

References

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Key Enablers of Industrial IoT: Processing-Part 2

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FarmBeats

- <u>Data-driven precision agriculture</u>
- *Challenges*: *Intra- & Inter-farm connectivity management*, *data collection* and *energy management*
- *Components*: Soil sensors, camera, UAVs, weather station, IoT gateway, IoT base station, cloud-services
- Suitable for large-scale long-term deployment
- Gateway incorporates weather-aware decisions & UAV flight planning

Source: Vasisht et al., 2017

FarmBeats (cont.)

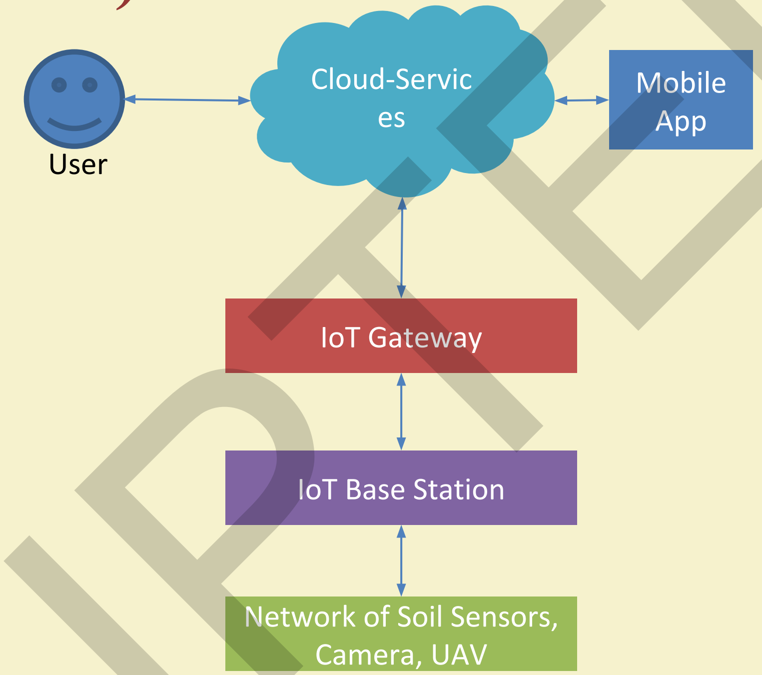

Fig: FarmBeats Architecture

Source: Vasisht et al., 2017

Smart Water Management Platform (SWAMP)

- Irrigation management for different types of crops & climate in different countries
- Services
  - *Entirely replicable services*: interaction with virtual entities, storage, analytics
  - *Fully customizable services*: water management & distribution
  - *Application specific services*: custom requirement specific & supports different architectures

Source: Kamienski et al., 2018

Smart Water Management Platform (SWAMP) (contd.)

- Components: *sensors, virtual entity, analytics & learning, data management, service management*
- SWAMP enables a smart management layer between the *water distribution network & farm-based irrigation system*

Source: Kamienski et al., 2018

SWAMP (cont.)

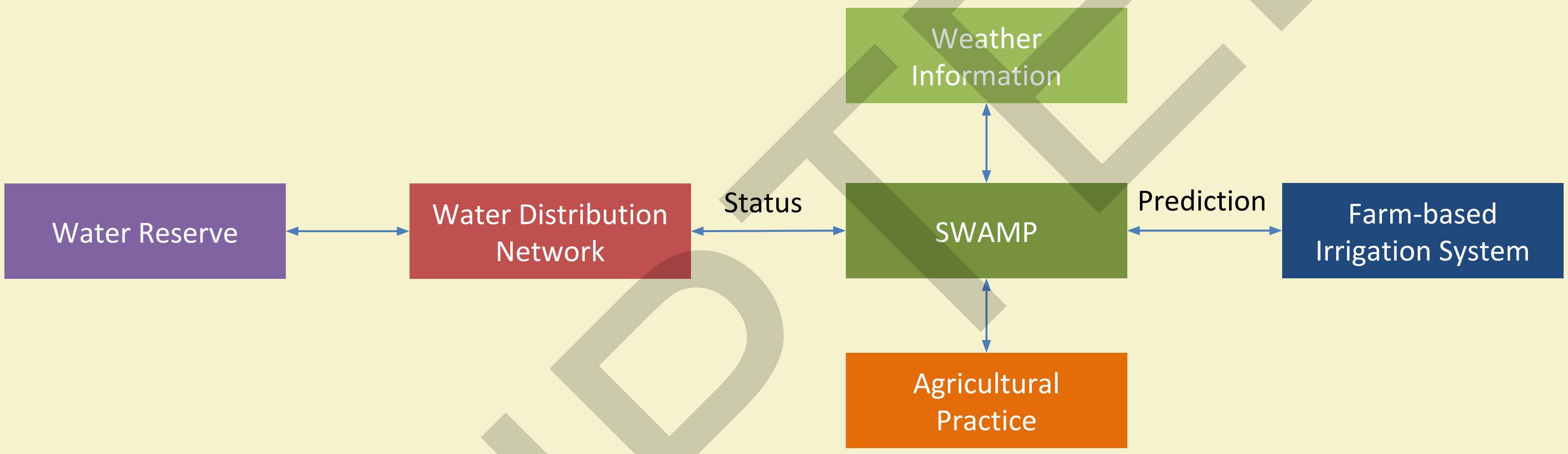

Fig: SWAMP Architecture

Source: Kamienski et al., 2018

AR Drones-based Precision Agriculture

- Precise fertilizer spray to the weeds
- Components: AR Drones, laptop, sprayer installed in a tractor
- The video processing module deployed in the laptop detects the weeds
- The precision sprayer installed in the tractor actuated according to the locations detected by the video processing module

Source: Cambra et al., 2018

AR Drones-based Precision Agriculture (cont.)

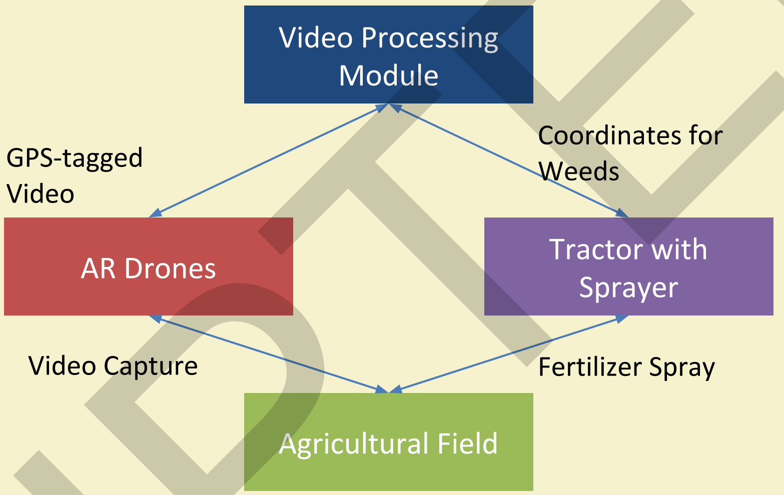

Fig: AR Drone-based Precision Agriculture

Source: Cambra et al., 2018

Vineyard Health Monitoring

- Challenge: Different variety of grape needs different climate conditions
- Real-time sensing and monitoring of vineyards
- Analytics to empower understanding of plant growth according to soil and climatic conditions
- Objective:
  - Increase yield, quality of grapes, with optimal use of water
  - Disease detection & control, optimal use of fertilizers

Source: SensorCloud by LORD MicroStrain

Vineyard Health Monitoring (cont.)

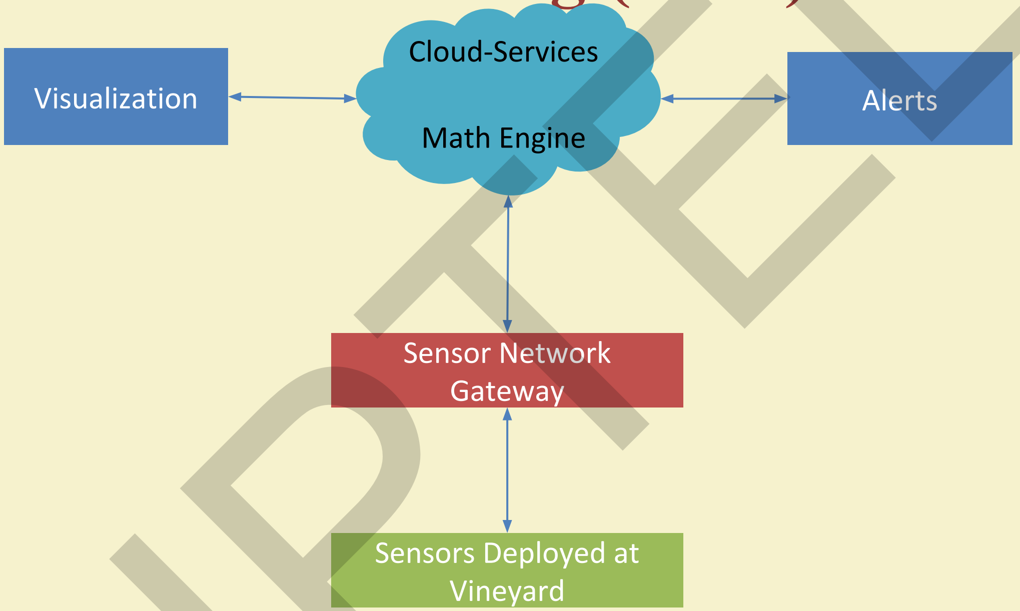

Fig: Vineyard Health Monitoring Framework

Source: SensorCloud by LORD MicroStrain

SmartSantander

- IoT-based smart city deployment platform for large-scale applications
- Design considerations –
  - experimentation realism
  - heterogeneity
  - scale
  - mobility
  - reliability
  - user involvement

Source: SensorCloud by LORD MicroStrain

SmartSantander (contd.)

- Components – IoT nodes, repeaters, and IoT gateways
- Architectural layers: *Authentication, Authorization and Accounting (AAA) subsystem*, *Testbed management subsystem (MSS)*, *Experimental support subsystem (ESS)*, and *Application support subsystem (ASS)*

Source: SensorCloud by LORD MicroStrain

SmartSantander (cont.)

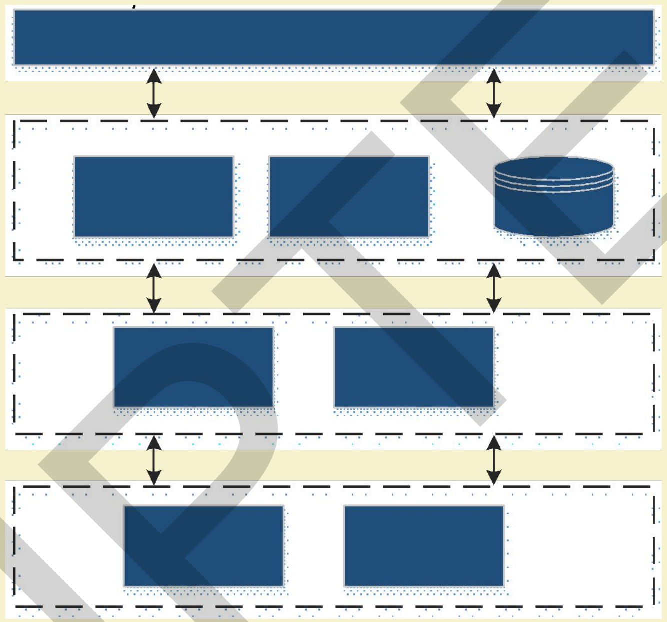

Fig: SmartSantander

Source: SensorCloud by LORD MicroStrain

iRobot-Factory: Cognitive Manufacturing

- Application of cognitive intelligence & edge computing for improved manufacturing
- Automation of the production line by information interaction & data fusion
- Components:
  - *Intelligent terminal*: Tasked with sensing user's emotion & request computing resources accordingly

Source: Hu et al., 2018

iRobot-Factory: Cognitive Manufacturing (contd.)

- *System Management*: Real-time analysis on collected data – emotion data, factory data
- *Edge Computing Node*: Enables low-latency response & decision system at the edge
- *Cognitive Engine*: Cloud-based high performance long-term data analytics using artificial intelligence techniques
- *Intelligent Device Unit*: The hardware assembler and manufacturing unit
- *Production Line Layer*: Production line sequencing with intelligent conveyer units

Source: Hu et al., 2018

iRobot-Factory (cont.)

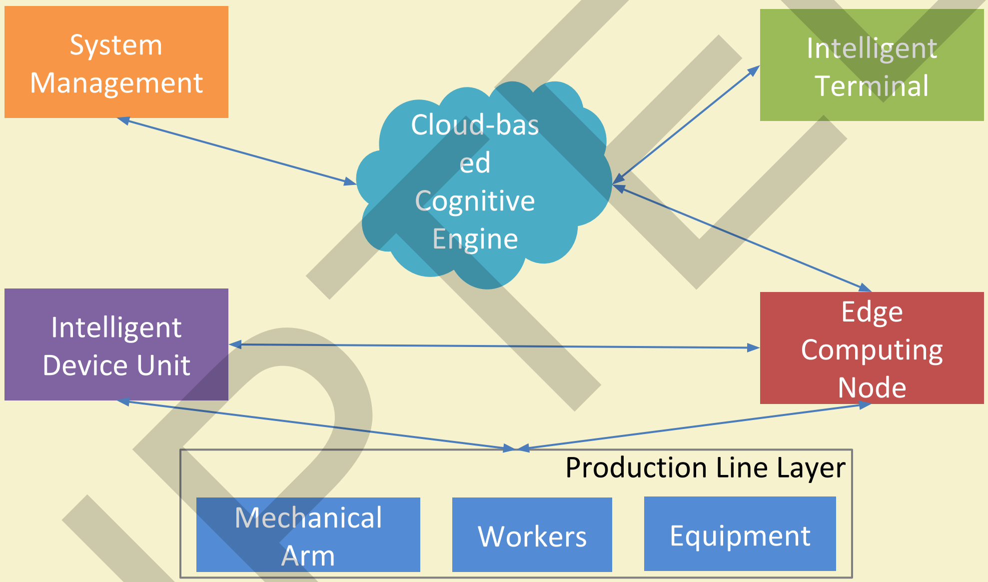

Fig: iRobot-Factory System Architecture

Source: Hu et al., 2018

Big Data Driven Smart Manufacturing

- Challenges: Existing investments, risk & regulation for new technology, lack of skill, mixed workplace
- Different phases of smart manufacturing
  - *Phase 1 - integration of data and contextual information*: gather data from sensors placed at different parts of the industry to have a contextual view
  - *Phase 2 – synthesis & analysis*: processing of data to build knowledge required for decision making
  - *Phase 3 – innovation in process & production*: using knowledge and intelligence to find new insight and use it for future innovation

Source: Donovan et al., 2015

Big Data Driven Smart Manufacturing (cont.)

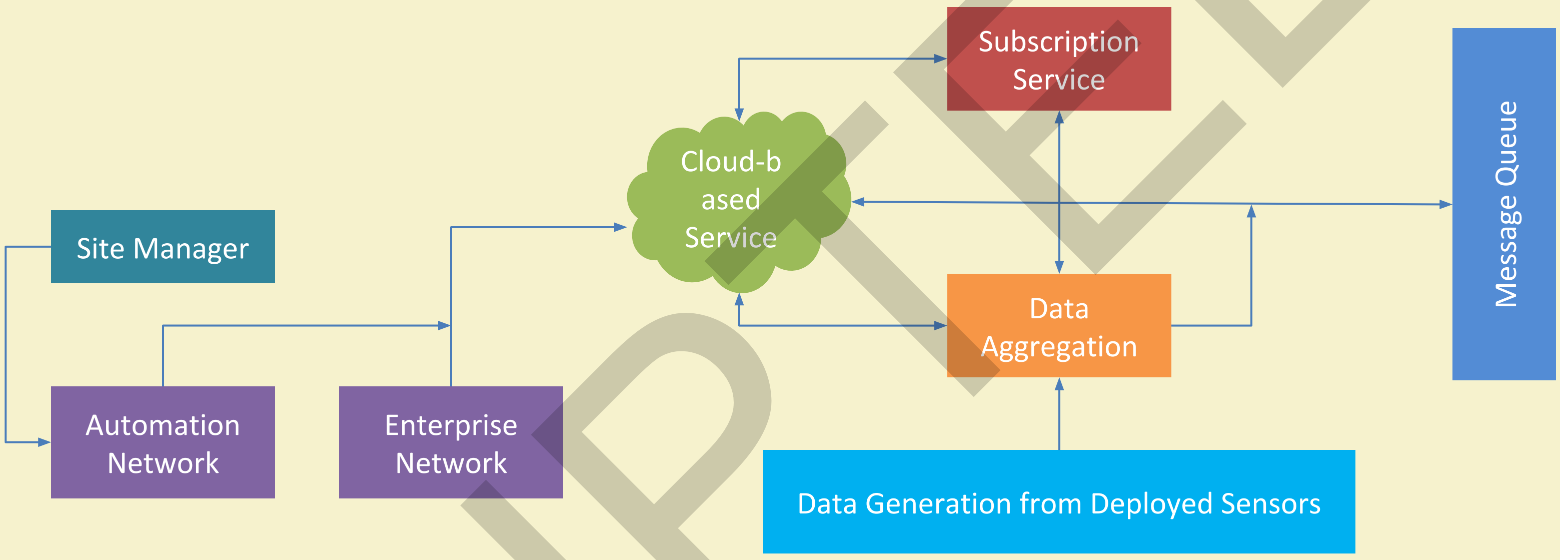

Fig: Architecture for Big Data Processing in Smart Manufacturing

Source: Donovan et al., 2015

Smart Warehousing

- REST-based framework
- Data collection module:
  - Uniquely identifiable objects with RFID tags, sensors
  - Database for storing the information
  - Authenticated & secure access
- Administrative module:
  - Organize & process data, decision making
  - Generating & controlling the events in real-time
  - Dynamic operational parameters & history-based decision making

Source: Jabbar et al., 2016

Smart Warehousing (cont.)

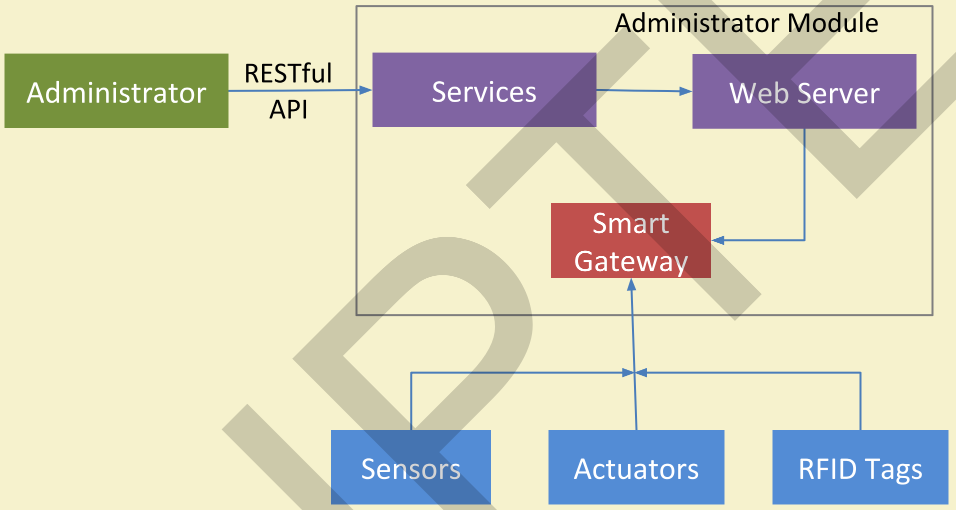

Fig: System Architecture for Smart Warehousing

Source: Jabbar et al., 2016

Industrial Manufacturing

- Cloud computing & IoT services-based
- User entities:
  - *Providers:* service offering organization
  - *Consumers:* service subscribers
  - *Operators:* middle-man, who provisions the services

Source: Tao et al., 2014

Industrial Manufacturing (contd.)

- Workflow:
  - Phase 1: collection of the service offerings & infrastructure
  - Phase 2: virtualization, allocation & management of services
  - Phase 3: on-demand service provisioning
- Layers: (bottom) IoT layer, (middle) Service layer, (top) Application layer, (cross-layer) bottom support layer (knowledge, cloud security, wider internet)

Source: Tao et al., 2014

Industrial Manufacturing (cont.)

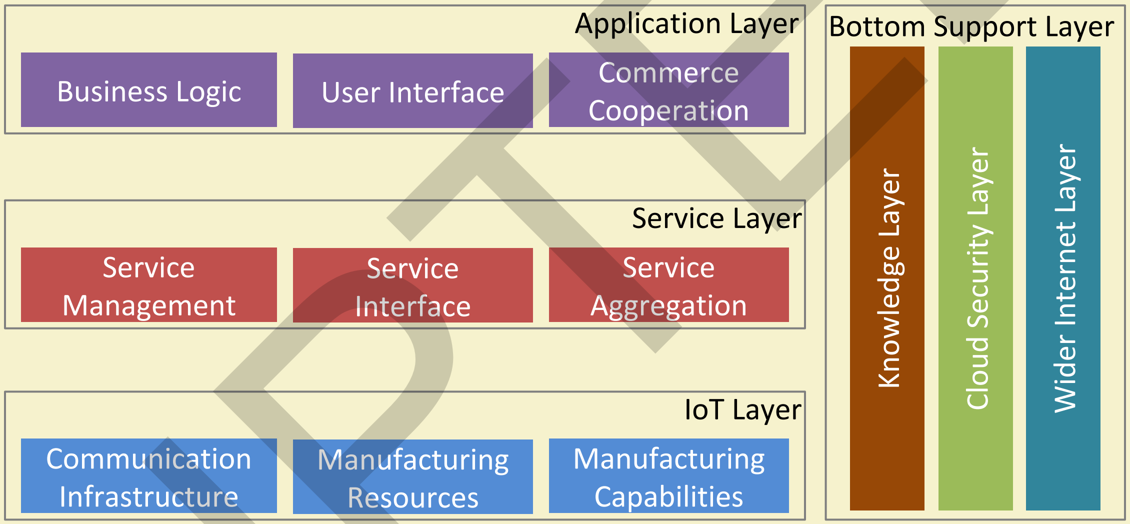

Fig: System Architecture for Industrial Manufacturing

Source: Tao et al., 2014

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Thank You!!

Industrial Rechargeable Sensor Networks

- Novel application of wireless charging for industry
- Proactive algorithm for grid-based routing as well as charging
- Routing protocol
  - Considers the characteristics of the charger
  - Energy balance is achieved *locally*
- *Global* balance of energy:
  - Considers the energy consumption rates of surrounding nodes
  - Different charging points are allocated different slots

Source: Han et al., 2016

Industrial Rechargeable Sensor Networks (cont.)

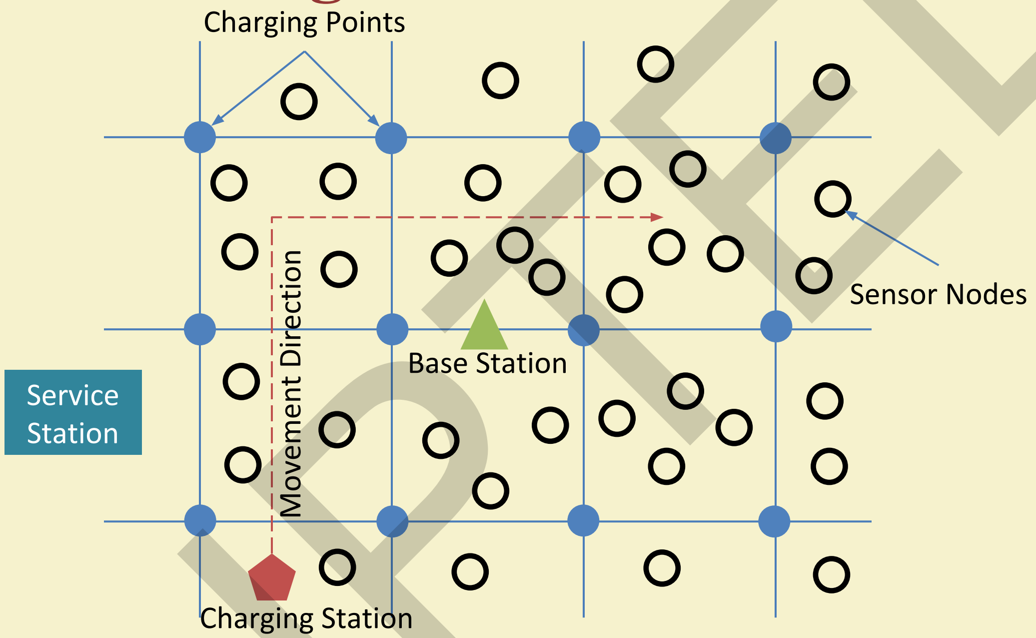

Fig: Industrial Rechargeable Sensor Network Deployment

Source: Han et al., 2016

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IIoT Process Control

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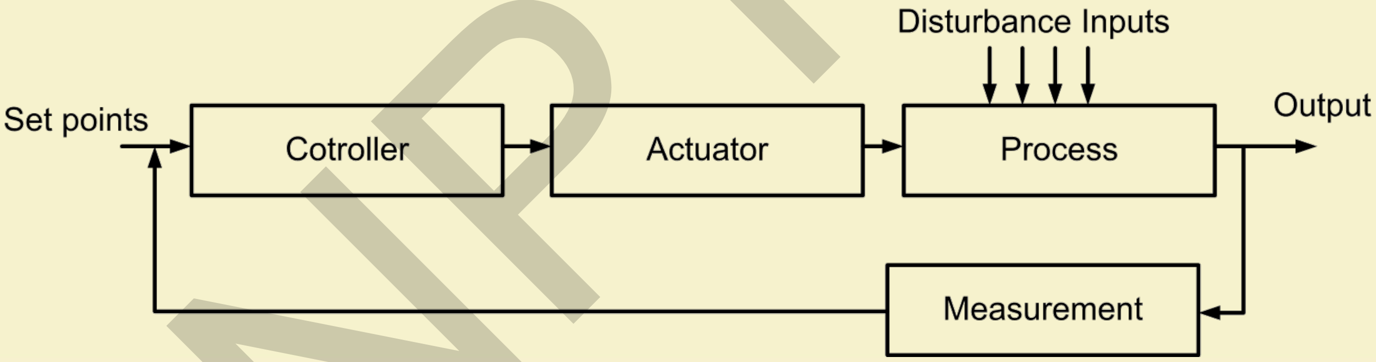
What are Industrial Control Systems?

- Different types of electro-mechanical instruments and the associated systems used in industries to control various industrial units or *processes*
- Comprise of four major components:
  - Process Variables - Values of process parameters measured using devices such as sensors
  - Set Points - Standard values of the process parameters for controlled operation of the process

What are Industrial Control Systems? (Contd.)

- Controllers – For taking action decisions based on comparison of process variables with set points
- Manipulating Variables – Process variables modified based on controller decisions to manipulate the process



Control Loops

- Fundamental element of industrial control systems for automatic control of industrial process variables
- Two types:
  - Open Loop Control – Control decision independent of process variable
  - Closed Loop / Feedback Control – Control decision depends on the measured value of process variable

Types of Industrial Control Systems

- Programmable Logic Controllers (PLCs)
- Distributed Control Systems (DCS)
- Supervisory control and Data Acquisition (SCADA)

Programmable Logic Controllers (PLCs)

- An industrial control system based on programming logic capable of –
  - Monitoring the industrial processes
  - Taking control actions based on some predefined computer program
- Comprises of a processor unit, memory unit, power supply and communication modules
- Used in assembly lines and robotic manufacturing devices

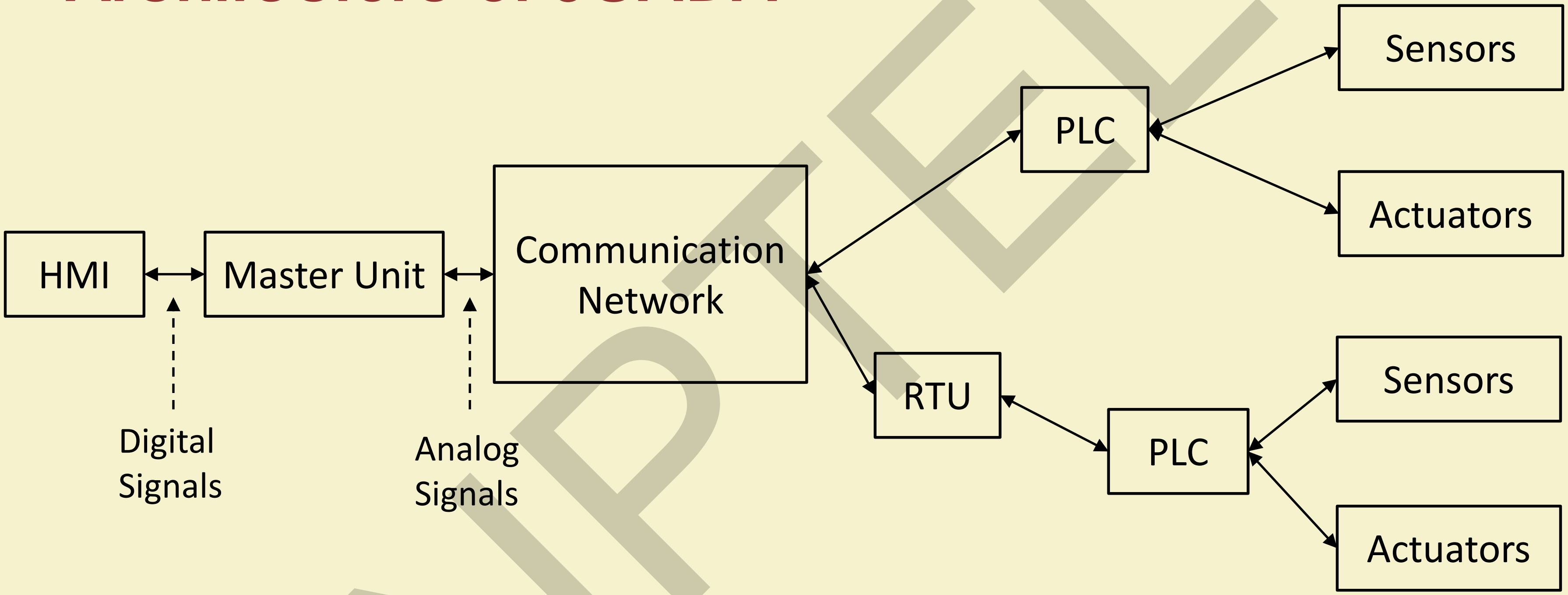
Distributed Control Systems (DCS)

- Specially designed control systems used to control highly distributed plants having huge number of control loops
- Improved reliability due to distributed control
- Main components are –
  - Central supervisory controller
  - Distributed controllers
  - Field devices such as sensors and actuators
  - High-speed communication network

Supervisory control and Data Acquisition (SCADA)

- Industrial process automation system used in automatic traffic management, water distribution, electric power grids, etc
- Main components are:
  - Sensors and Control Relays
  - Remote Telemetry Units (RTUs)
  - SCADA master units
  - Human-Machine Interface (HMI)
  - Communication Infrastructures

Architecture of SCADA



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IIoT Analytics and Data Management: Introduction

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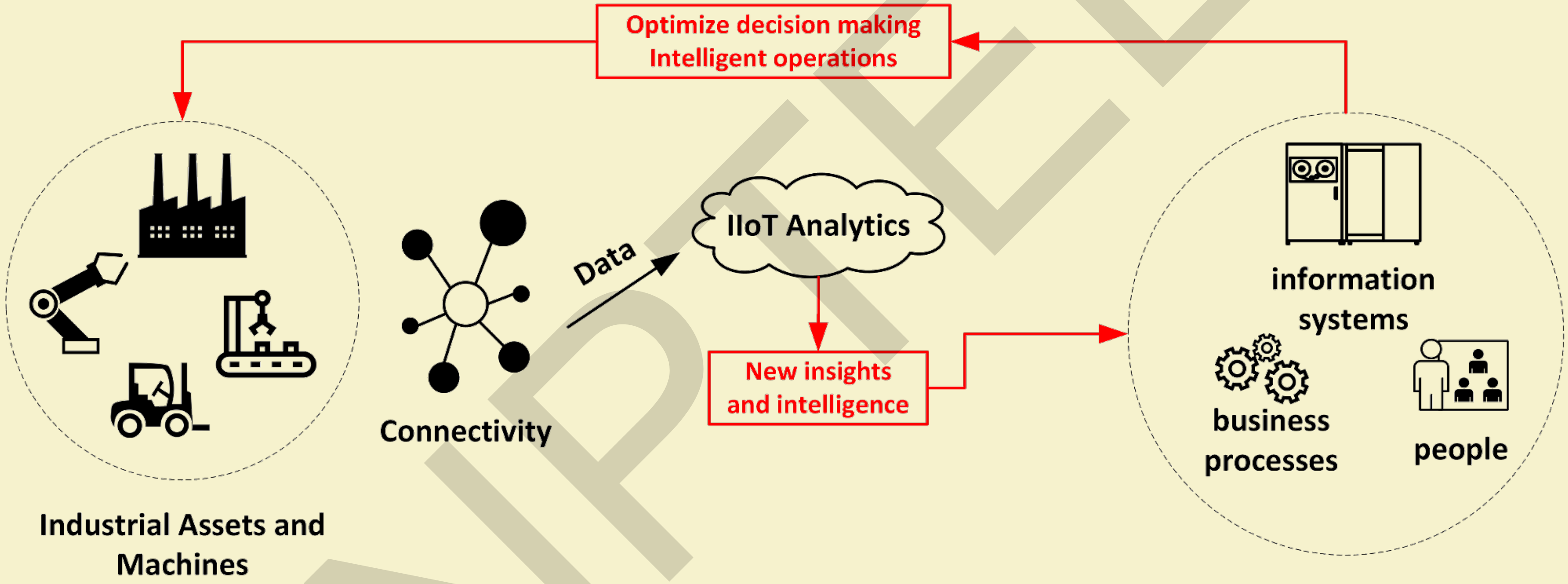
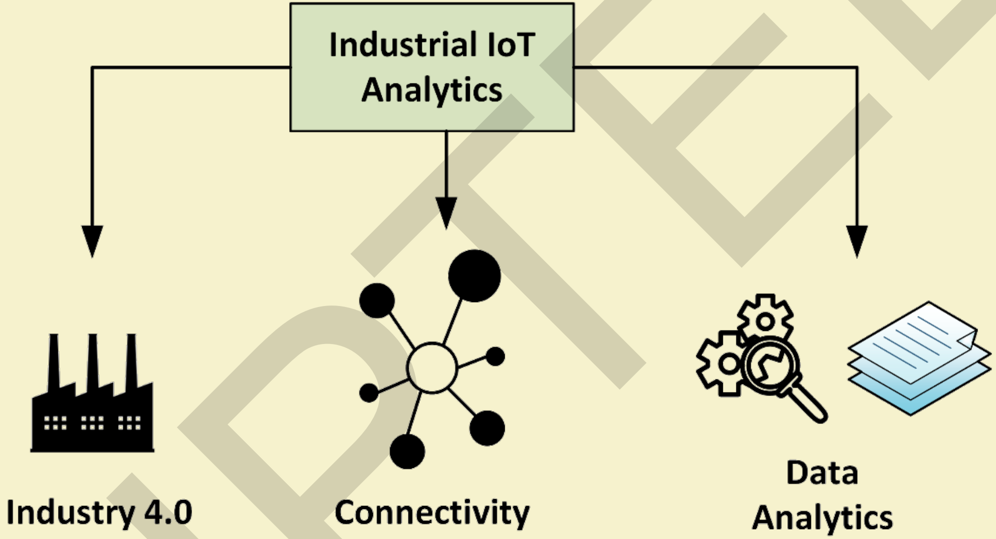
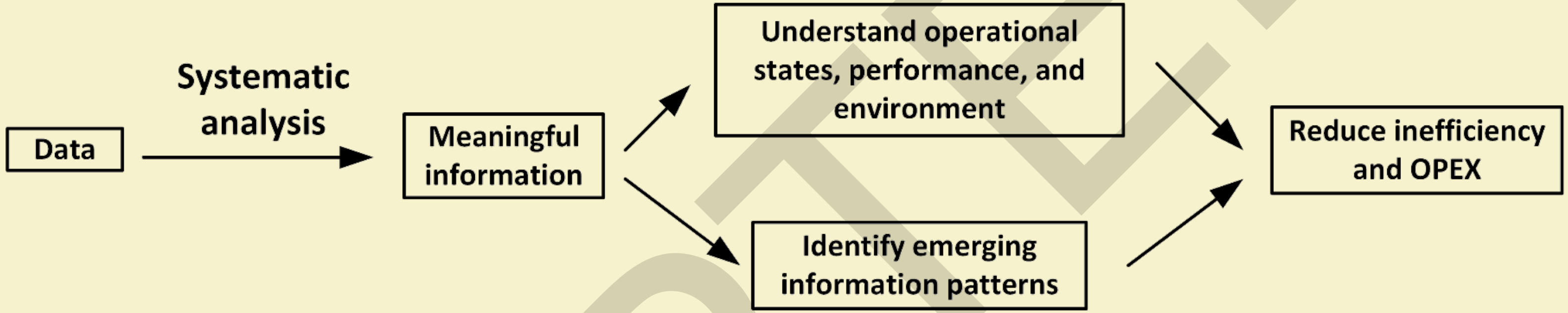
IIoT Analytics : Necessity



IIoT Analytics : Definition

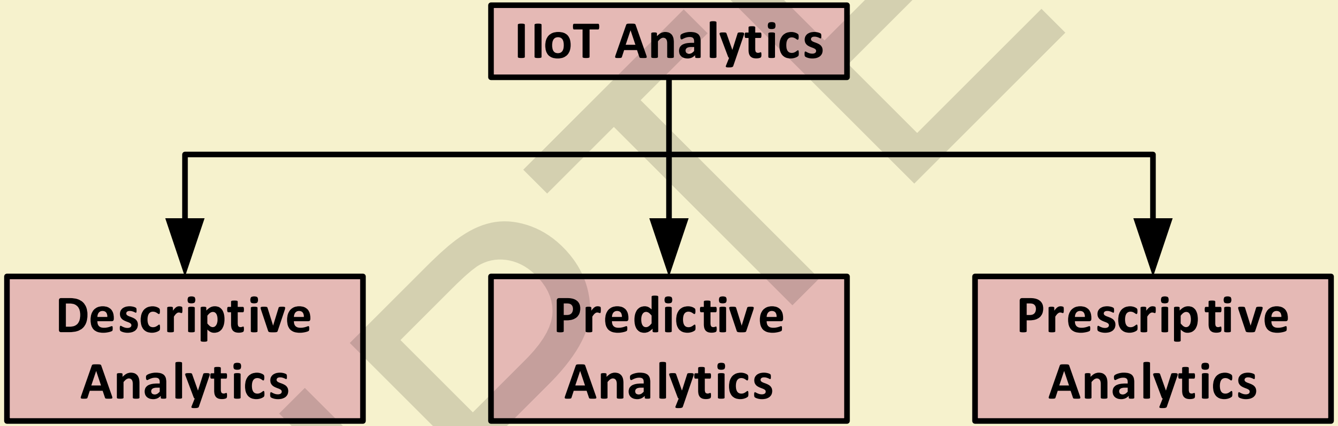


IIoT Analytics : Definition (cont.)

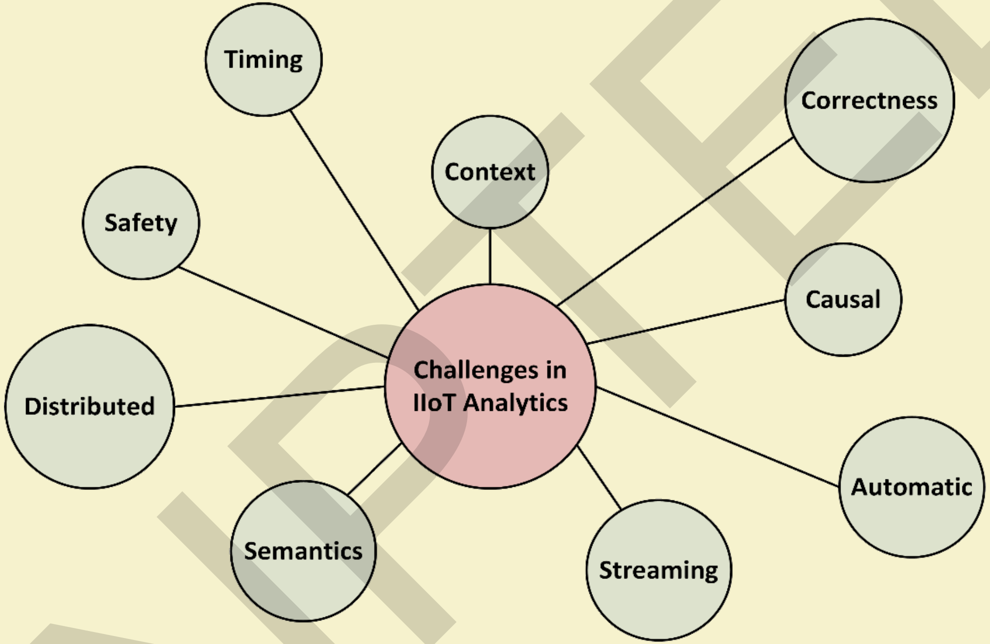


- Dynamic operations optimization
- Prognostic maintenance
- Real-time data analysis

IIoT Analytics : Types



IIoT Analytics : Challenges



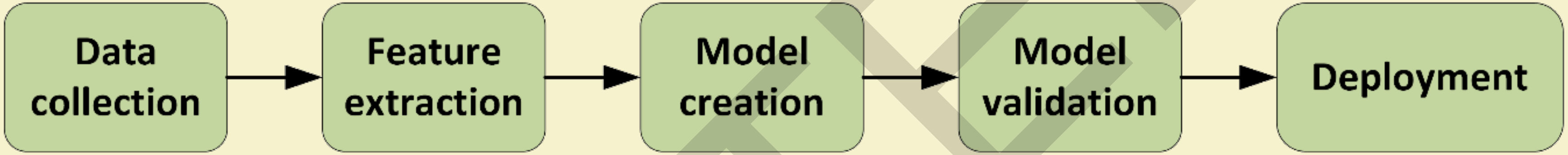
IIoT Analytics: Data Science

- Big Data Analytics
  - Volume, velocity, variability, veracity, variety
  - Industrial automation, system health monitoring, predictive maintenance, remote monitoring

- Artificial Intelligence
  - Deep Learning (DL)
  - Machine Learning (ML)

  Instead of physics-based models, ML and DL enable a data-driven system modelling approach.

IIoT Analytics: Machine Learning



- May be *supervised* or *unsupervised*
  - **Feature extraction:** Convert raw data to information that relates to the physical state of the asset.
  - **Supervised algorithms** are useful when it is feasible to acquire training data for the different states (or classes) that need to be modeled.
  - **Unsupervised** methods do not use labeled data. These algorithms find structure in the input data on its own.

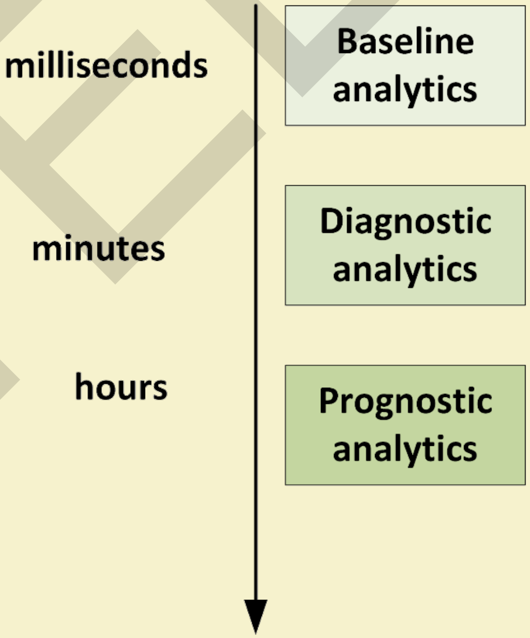
IIoT Analytics: Deep Learning

Data collection → Model creation → Model validation → Deployment

- Feature engineering is absent
  - Raw data from sensors is directly fed into deep learning algorithms
  - Learns features automatically without manually specifying them
  - Largely based on <u>neural networks</u>
  - Require large amount of computation power (GPU servers)
  - Gaining popularity due to advances in computing

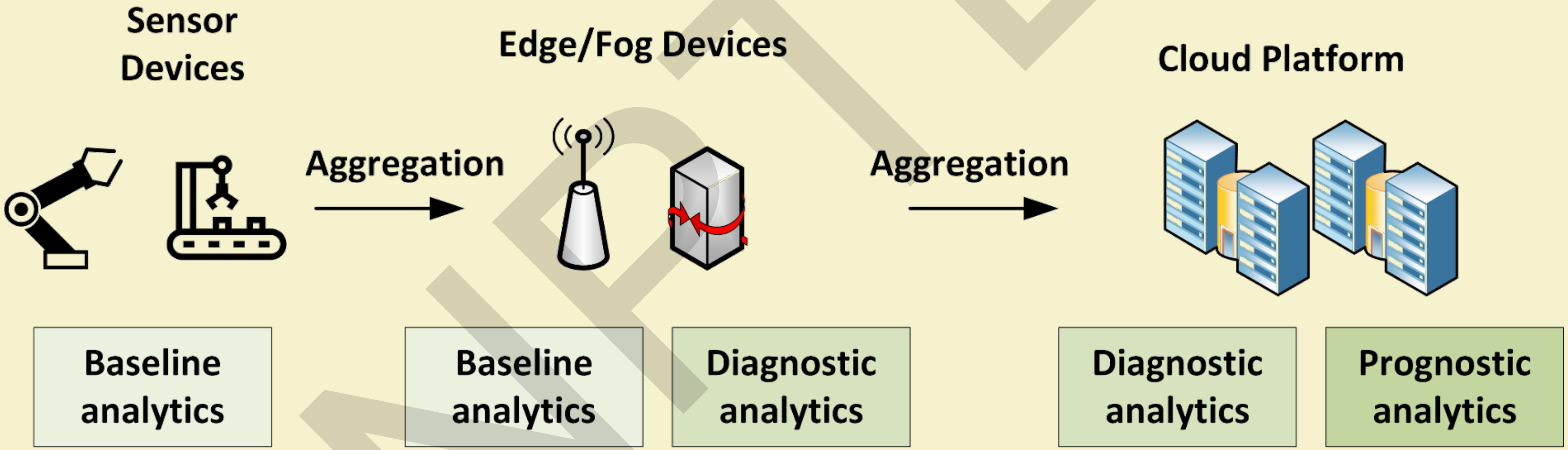
IIoT Analytics: Timescales

- Baseline analytics (ms)
  - Detect irregular behavior of asset quickly
- Diagnostic analytics (min)
  - Identify root cause of anomaly
- Prognostic analytics (hrs)
  - Inform about remaining useful life of an asset



IIoT Analytics: Deployment

- Deployment of analytics typically consists of three steps:
  - *train* a (predictive) analytics model
  - *test and validate* the model on previously unseen data
  - *deploy* the model to make predictions on real (streaming) data.



IIoT Analytics: Real-time

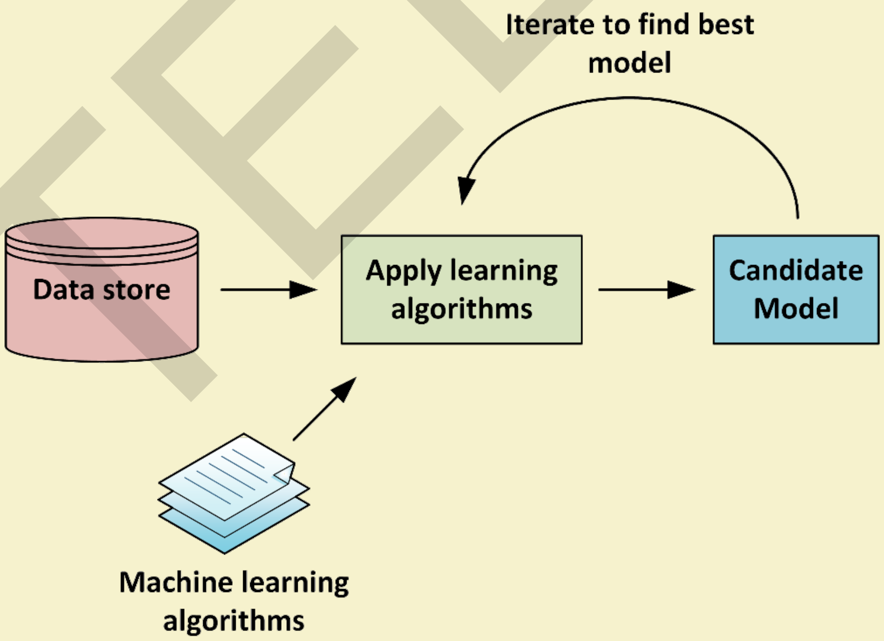
- Streaming real-time analytics
  - Most often used for IoT processing
  - Take action immediately on some event with the source
    - Send out alert on temperature sensor reaching a threshold
    - Send out notification about low tire pressure in smart car
  - Generating instant alerts requires stream processing. Process events in real-time to match a predefined set of rules
  - Edge processing, data aggregation and down-sampling
  - Complex Event Processing software such as Apache Storm, Esper etc may be used.

IIoT Analytics: Batch Processing

- Batch-oriented analytics
  - Improve accuracy of the streaming layer analytics
  - Useful for <u>long-term statistics</u>
    - Average temperature in room for last month
    - Power usage of house in last year
  - Distributed analytics: Batch processing can be used to get a better overall picture by aggregating data sources from <u>geo-distributed sources</u>.
  - Software such as Apache Hadoop and Apache Spark may be used

IIoT Analytics: Model Building

- Anomaly detection (e.g., Gaussian Mixture Model)
- Classification (e.g., Support Vector Machine)
- Regression (e.g., Bayes Regression)



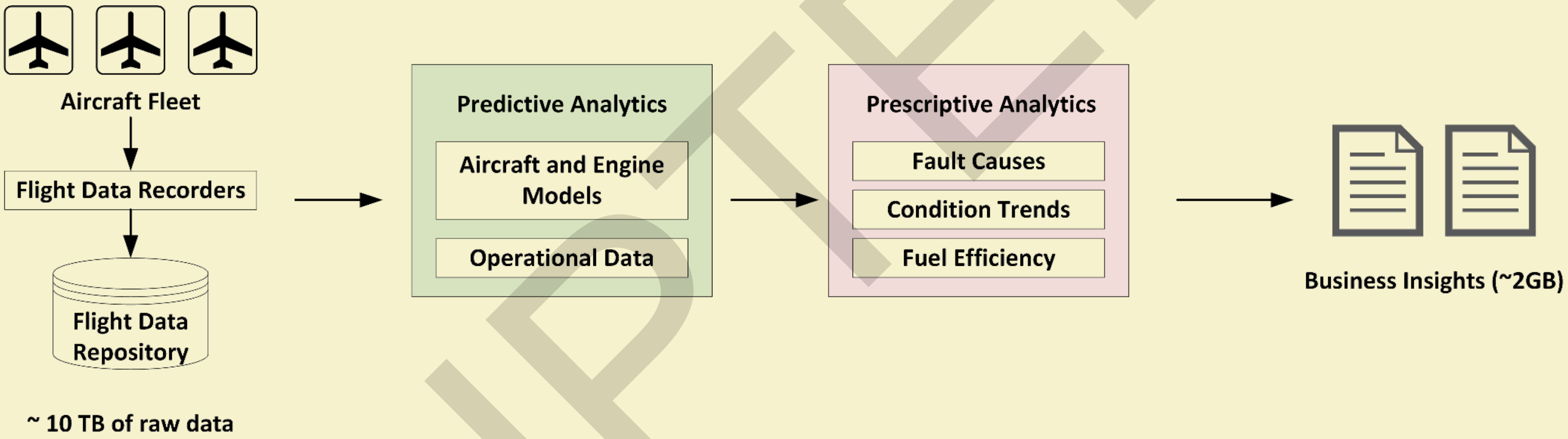
IIoT Analytics: Value Drivers

- New revenue streams
  - Upgrading existing products
  - Changing the business model
  - Creating new business models
- Reduce costs
  - Data-driven process optimization
  - Data-driven process automation
  - Data-driven product optimization

IIoT Analytics: Applications across the value chain

- R&D: Analyze product usage characteristics and feed back generated data to improve the product in the next cycle
- Manufacturing / Operations
  - Predictive maintenance
  - Decision support systems for industrial processes
  - Optimizing machine parameters: Correlated cause and effect parameters such as machine speed
- Logistics / Supply chain
  - Supply chain optimization: forecast shortages, reduce overall inventory levels etc
  - Fleet management: optimize to reduce transportation and fuel cost
- Marketing and Sales: Propose suitable upgrades as per user behavior

IIoT Analytics: Aircraft Example



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Thank You!!

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IIoT Analytics and Data Management: Machine Learning and Data Science – Part 1

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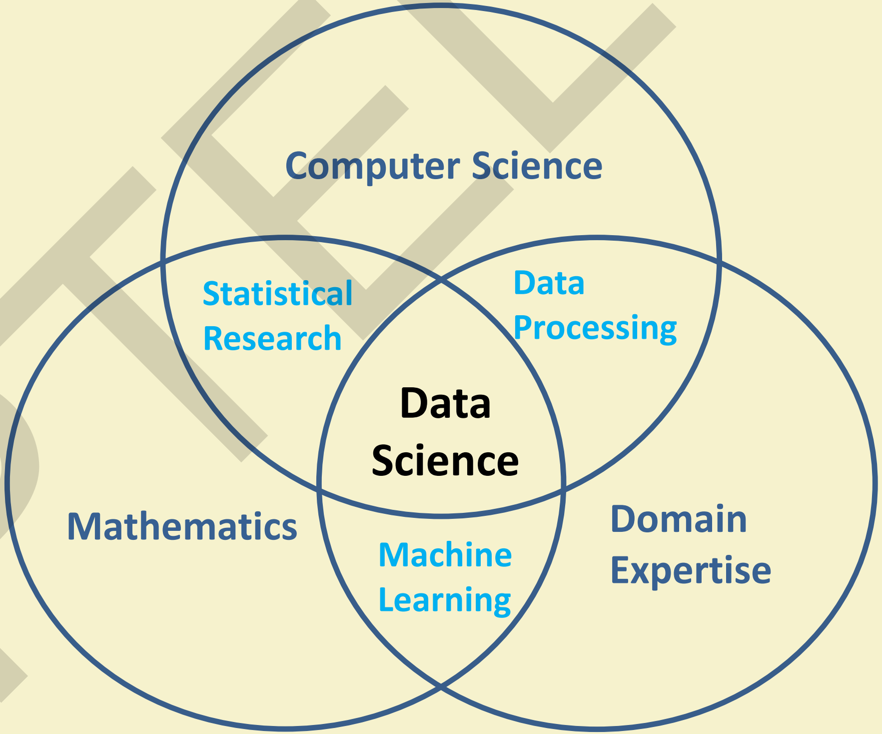
Basics of Machine Learning

What is Machine Learning?

Machine learning is a subset of Artificial Intelligence which enables machines to make decisions based on their <u>experience</u> rather than being explicitly programmed.

Source: Google Cloud AI Adventures, figure redrawn from URL:https://towardsdatascience.com/what-is-machine-learning-8c6871016736

What is Data Science?



Source: Quora
URL: https://www.quora.com/What-is-data-science

Machine Learning

Using data to answer questions

Training

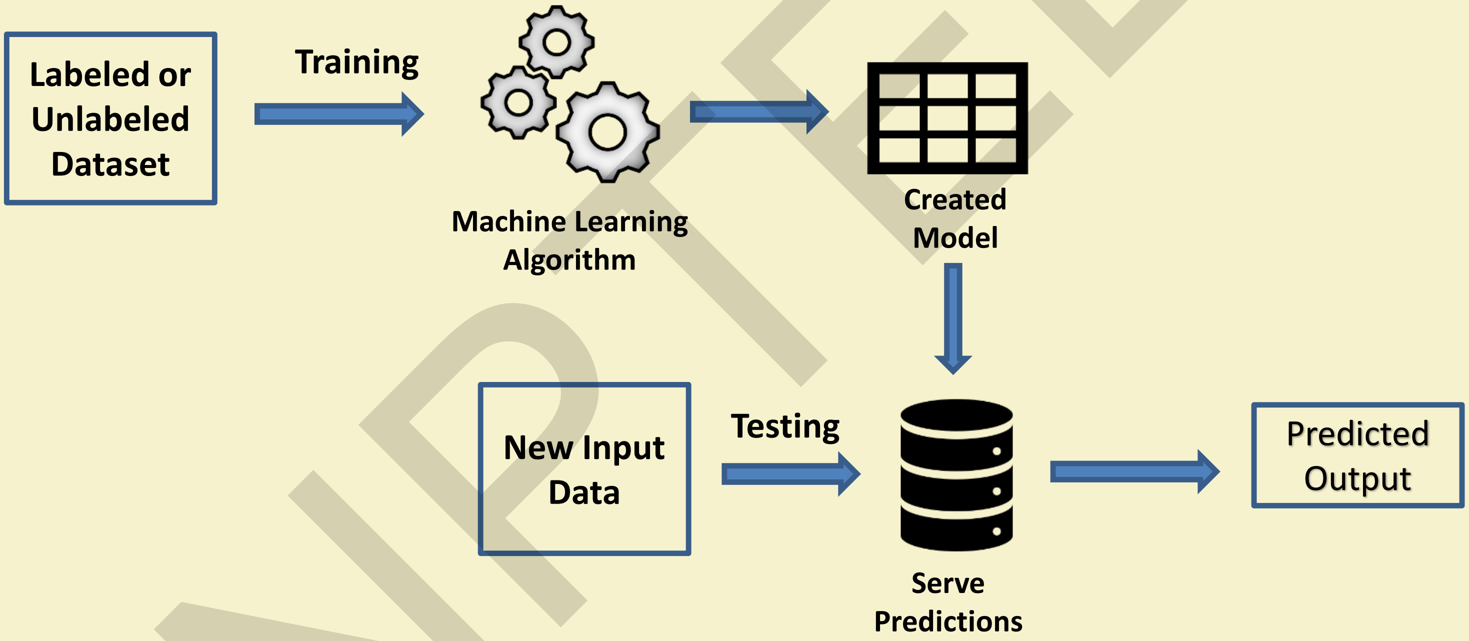
Using Data

Prediction

Answer questions

Source: Google Cloud AI Adventures, figure redrawn from URL:https://towardsdatascience.com/what-is-machine-learning-8c6871016736

How Machine Learning works?



Source: Google Cloud AI Adventures, figure redrawn from URL:https://towardsdatascience.com/what-is-machine-learning-8c6871016736

Types of Machine Learning Algorithms

Machine Learning

1. Unsupervised Learning
2. Supervised Learning
3. Reinforcement Learning

1. Unsupervised Learning

This machine learning technique is used to identify similar groups of data, coined as clustering. The segregation of data is performed on unlabeled dataset, based on the inner structure of the data without looking into the specific outcome.

Clustering

- **Hard Clustering** — Data points belong to completely one cluster. Ex. **K-Means**
- **Soft Clustering** — Data points may belong to more than one cluster. Ex. **Fuzzy c-Means**

Source: analyticsvidhya website URL: https://www.analyticsvidhya.com/blog/2016/11/an-introduction-to-clustering-and-different-methods-of-clustering/

Difference between K-Means and Fuzzy c-Means Algorithm

K-Means

1. One data point may belong to only one cluster

2. K-Means may not be as fast as FCM

Fuzzy c-Means

1. One data point may belong to more than one cluster

2. FCM is extremely faster than K-Means

2. Supervised Learning Algorithm

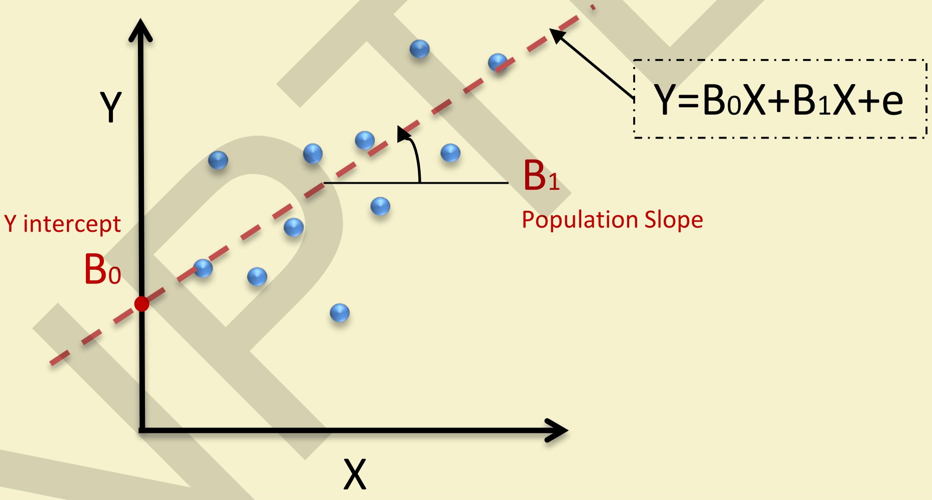
It is used to <u>classify</u> the dataset by <u>learning the mapping function</u> from the labeled dataset.

Supervised Learning

- **Regression** — When the <u>output variable is a real number</u> such as dollars or weight
- **Classification** — When the <u>output variable is a category</u> such as red or blue

Regression : Linear Regression

It is supervised learning problem which learns a linear function from the given instances of X (independent variable) and Y (dependent variable) values, so that it can predict Y for an unknown X.



Classification: Decision Tree

- Tree-based machine learning algorithm used for classification
- Non-linear function with two types of nodes: decision nodes and leaf nodes
- ***Decision node*** is used to test or decide the outcome based on some value of an attribute
- ***Leaf node*** denotes the classification of an example

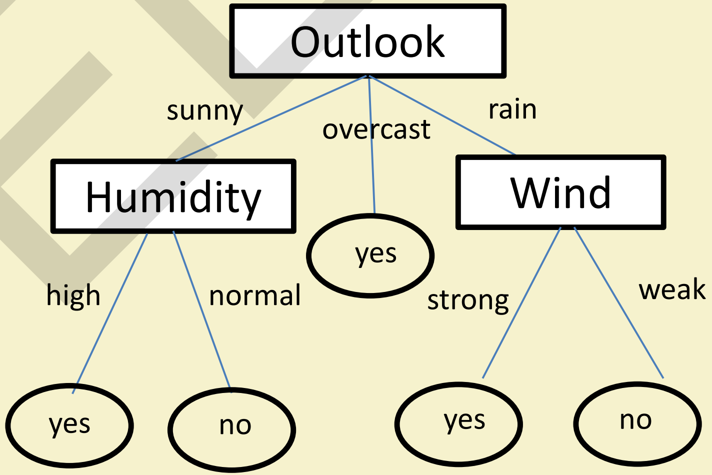
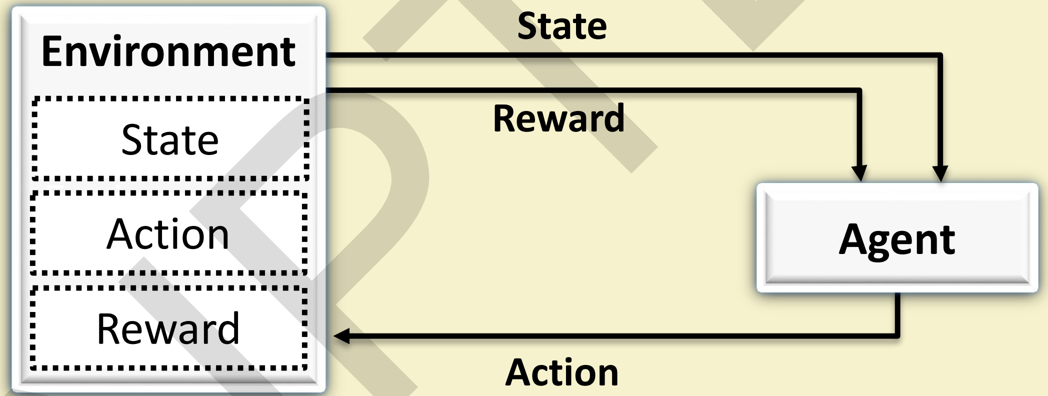


Figure redrawn from URL: https://nullpointerexception1.wordpress.com/2017/12/16/a-tutorial-to-understand-decision-tree-id3-learning-algorithm/

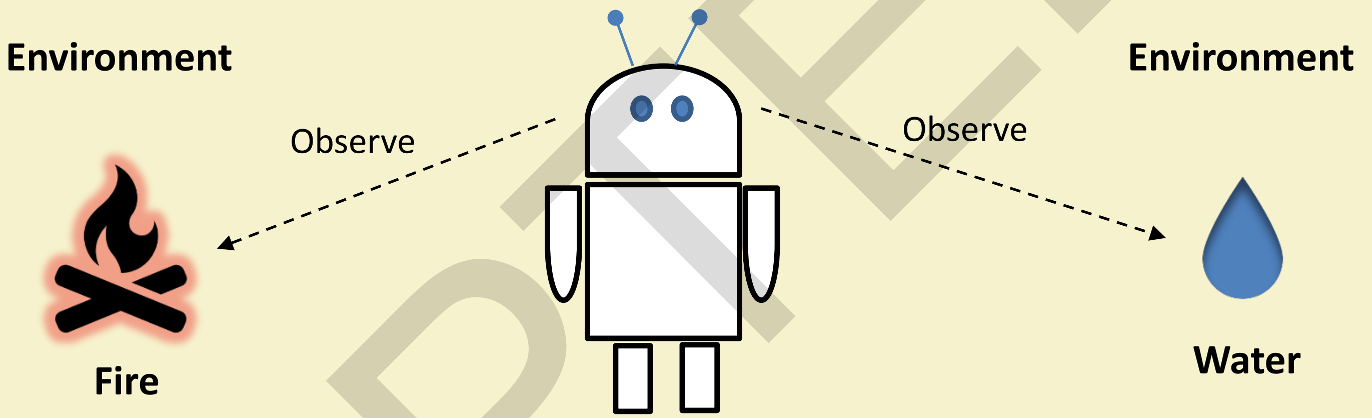
3. Reinforcement Learning Algorithm

It is a machine learning algorithm which enables machines to improve its performance by automatically learning the ideal behaviors for a specific environment.



Source: *"Learn Unity ML-Agents – Fundamentals of Unity Machine Learning"* by Micheal Lanham

RL – An Analogy



Differences between RL and Supervised Learning

Reinforcement Learning

1. There is no external supervisor to guide the agent.

2. No problem faced during the circumstances. The agent has many combinations of subtasks to achieve the objective.

3. There is a reward function which acts as a feedback to the agent.

Super-vised Learning

1. Here agent is guided by an external supervisor who has the knowledge of the environment.

2. Problem faced during the circumstances. The agent has many combinations of subtasks to achieve the objective.

3. There is no reward function.

Source: Analytics Vidhya URL:https://www.analyticsvidhya.com/blog/2017/01/introduction-to-reinforcement-learning-implementation/

Difference between RL and Unsupervised Learning

Reinforcement Learning

1. There is a <u>mapping</u> between input and output.
2. It builds a <u>knowledge graph</u> from the constant feedbacks of the corresponding actions.

Unsupervised Learning

1. There is <u>no mapping</u> between input and output.
2. It finds the <u>underlying pattern</u>.

Source: Analytics Vidhya URL:https://www.analyticsvidhya.com/blog/2017/01/introduction-to-reinforcement-learning-implementation/

Integration of Machine Learning with IIoT

Various industries utilizing IIoT with Machine Learning

- Health care
- Retail
- Finance
- Travel
- Social media

Applications of IIoT with Machine Learning (Contd...)

- Pfizer exploits IBM Watson for drug discovery
- Genentech provide personalized treatment for patients

Healthcare

Source: Top 10 Industrial Applications of Machine Learning
URL: https://www.dezyre.com/article/top-10-industrial-applications-of-machine-learning/364

Applications of IIoT with Machine Learning (Contdâ¦)

- Fraud detection
- Targeting focused account holders

Finance

Source: Top 10 Industrial Applications of Machine Learning
URL: https://www.dezyre.com/article/top-10-industrial-applications-of-machine-learning/364

Applications of IIoT with Machine Learning (Contd…)

- Product recommendation
- Improved customer service

Retail

Source: Top 10 Industrial Applications of Machine Learning
URL: https://www.dezyre.com/article/top-10-industrial-applications-of-machine-learning/364

Applications of IIoT with Machine Learning (Contd…)

- Dynamic price setup
- Sentiment analysis to act as trip advisor

Travel

Source: Top 10 Industrial Applications of Machine Learning
URL: https://www.dezyre.com/article/top-10-industrial-applications-of-machine-learning/364

Applications of IIoT with Machine Learning (Contd…)

- Facebook uses ANN for tagging faces
- LinkedIn uses machine learning technology for suggesting job

Social media

Source: Top 10 Industrial Applications of Machine Learning
URL: https://www.dezyre.com/article/top-10-industrial-applications-of-machine-learning/364

Instances of IIoT with Machine learning

ThingWorx platform

- Perform complex analytical process
- Deliver real-time perception
- Ability of condition monitoring
- Ability of predictive analytics and recommendation

Source: Deliver Industrial IoT Analytics with ThingWorx
URL: https://www.ptc.com/en/products/iot/thingworx-platform/analyze

Instances of IIoT with Machine learning (Contd…)

Toumetis ➡

- Help oil and gas engineers to access real time data and predict anomalies
- Making more advanced smart home automation

Source: Toumetis URL: https://toumetis.com

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[6] Top 10 Industrial Applications of Machine Learning
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[8] Deliver Industrial IoT Analytics with ThingWorx
URL: https://www.ptc.com/en/products/iot/thingworx-platform/analyze

Thank You!!

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IIoT Analytics and Data Management: Machine Learning and Data Science – Part 2

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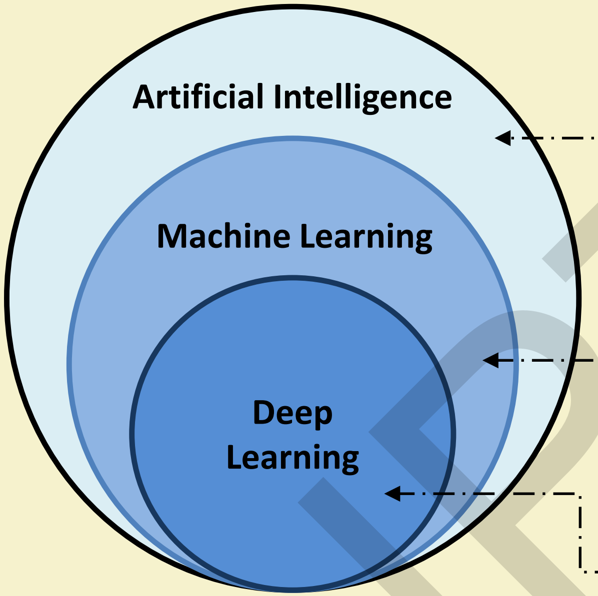
AI vs Machine learning vs Deep learning



Artificial Intelligence

Making of intelligent machines which take decisions on its own without being explicitly programmed

Machine Learning

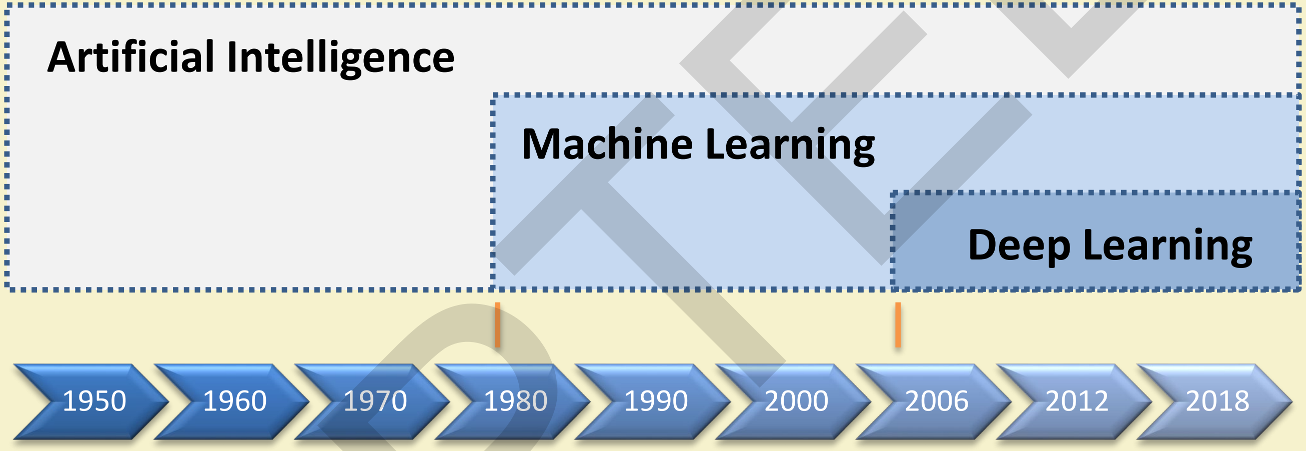
Subset of AI which can learn automatically from the object features

Deep Learning

Subset of machine learning which can learn automatically by finding the features of the object on its own

Source Edureka website
URL: https://www.edureka.co/blog/what-is-deep-learning

Timeline



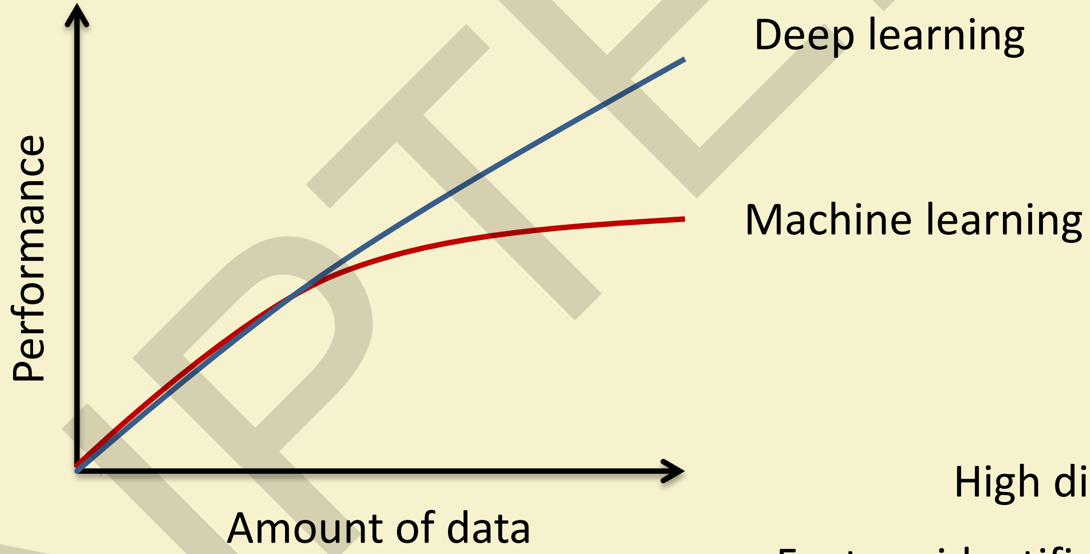
Source Edureka website
URL: https://www.edureka.co/blog/what-is-deep-learning

Limitations of Machine learning

1. ML algorithms are not useful for high dimensional data
2. Features have to be explicitly mentioned

Solution
Deep Learning

Limitations of Machine learning (cont..)



High dimensional data

Feature identification/extraction

Source Edureka website
Figure redrawn from URL: https://www.edureka.co/blog/what-is-deep-learning

Deep Learning

- It is a subfield of machine learning, capable to learn the right features by its own, basically mimics the working function of billions of neurons in our brain.

- Deep learning learns features by own
- Deep learning gives better performance like accuracy, when the amount of data is huge

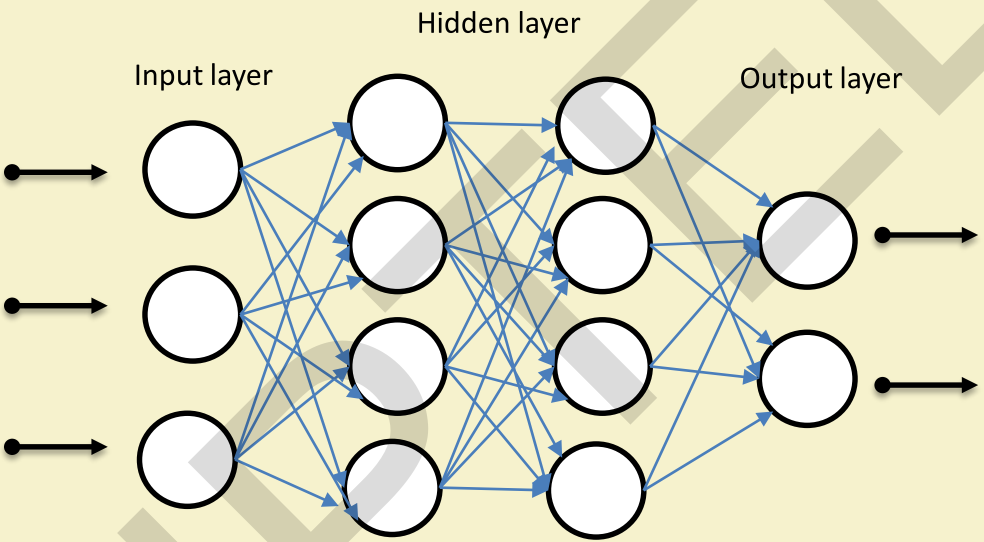
How it works

Deep learning : **deep neural network**

- Signals travel between neurons in artificial neural network
- In neural network, each neuron is assigned with weightage value
- A high weighted neuron exerts more effect on next layer than others
- Final layer combines all weighted inputs to emerge with a result

Source: Mathworks website
URL: https://in.mathworks.com/discovery/deep-learning.html

How it works (cont..)



Deep refers to number of hidden layers, deep network can have up to 150 hidden layers

Source: Mathworks website Figure redrawn from URL: https://in.mathworks.com/discovery/deep-learning.html

Understanding analogies of Deep Learning

Let we want to recognize an *apple,*

- First check *shape* if **Yes**
- Then check *color* if **Yes**
- Then check its *taste* if **Yes**

Apple ✓

So it is a **nested hierarchy of concept**

Deep learning also follows the concept of nested hierarchy, it breaks the complex task into simple tasks

Difference between machine learning and deep learning

- Deep learning is an “end-to-end learning”, which <u>extracts features on its own</u>. On the contrary, in machine learning <u>features are to be explicitly mentioned</u>.

- In deep learning performance level often improves as the size of the data increases, whereas in machine learning, shallow learning converges

Source: Mathworks website
URL: https://in.mathworks.com/discovery/deep-learning.html

Deep learning in IIoT

Impacts of deep learning in IIoT

IIoT ✕ Deep learning

Improve speed

Improve accuracy

- ➢ For optimization of manufacturing lines in factories
- ➢ For stable operations of energy and transportation system
- ➢ For system shutdown in emergency

Reason for usefulness of deep learning in IIoT

The most important reasons that have made deep learning so useful recently are:

- Requires **large amount of labeled data**
- Requires **high end computational power**

Source: Mathworks website
URL: https://in.mathworks.com/discovery/deep-learning.html

Critical requirements of deep leaning in IIoT

The important factors required by deep learning methods in IIoT for solving critical issues

- Large ***Quantity*** of data

- High ***Quality*** and accuracy of reliable data

Source: TOSHIBA website
URL: https://www.toshiba-sol.co.jp/en/articles/tsoul/20/001.htm

Values provided by deep learning in IIoT

Three values provided by deep learning to customers in various business segments

1. **Identification or recognition using cameras, sensors etc**
2. **Prediction/ Inference of human behavior**
3. **Autonomous decision control**

Source: TOSHIBA website
URL: https://www.toshiba-sol.co.jp/en/articles/tsoul/20/001.html

Deep learning as strength of technology

TOSHIBA is using **Collaborative Distributed Deep Learning** technology between edge and cloud

Learning process is performed in cloud for high processing

Inference process is conducted in edge for real time processing

Source: TOSHIBA website
URL: https://www.toshiba-sol.co.jp/en/articles/tsoul/20/001.html

Deep learning as strength of technology (Contd...)

TOSHIBA →

- Improve yield and productivity in semiconductor factory
- Adopted drone navigation control system to find damage in power transmission line
- Predict behavior of workers in warehouses through wearable devices
- Forecasting power generation in solar power system

Source: TOSHIBA website
URL: https://www.toshiba-sol.co.jp/en/articles/tsoul/20/001.html

Deep learning as strength of technology (Contd…)

- **H2O** platform utilizes deep learning platform
- **Intel's** innovation **Nervana**, a deep learning processor
- **Zebra medical vision** systems is applying deep learning techniques

URL: https://www.h2o.ai/, https://ai.intel.com/, https://www.zebra-med.com/

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[6] TOSHIBA, URL:https://www.toshiba-sol.co.jp/en/articles/tsoul/20/001.html

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IIoT Analytics and Data Management: Cloud Computing in IIoT – Part 1

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Introduction

- IIoT support for Industry 4.0
  - Sensing
  - Communication
  - Computing
  - Networking
- Achieves digitization in manufacturing and production process

Source: "Industry 4.0: The Industrial Internet of Things", Apress, 2016

IIoT and Big Data

- Digitization Process
  - Data acquisition
  - Asset management
  - Resource management
  - Knowledge management
- Bulk amount of data due to the time series data streams from end devices

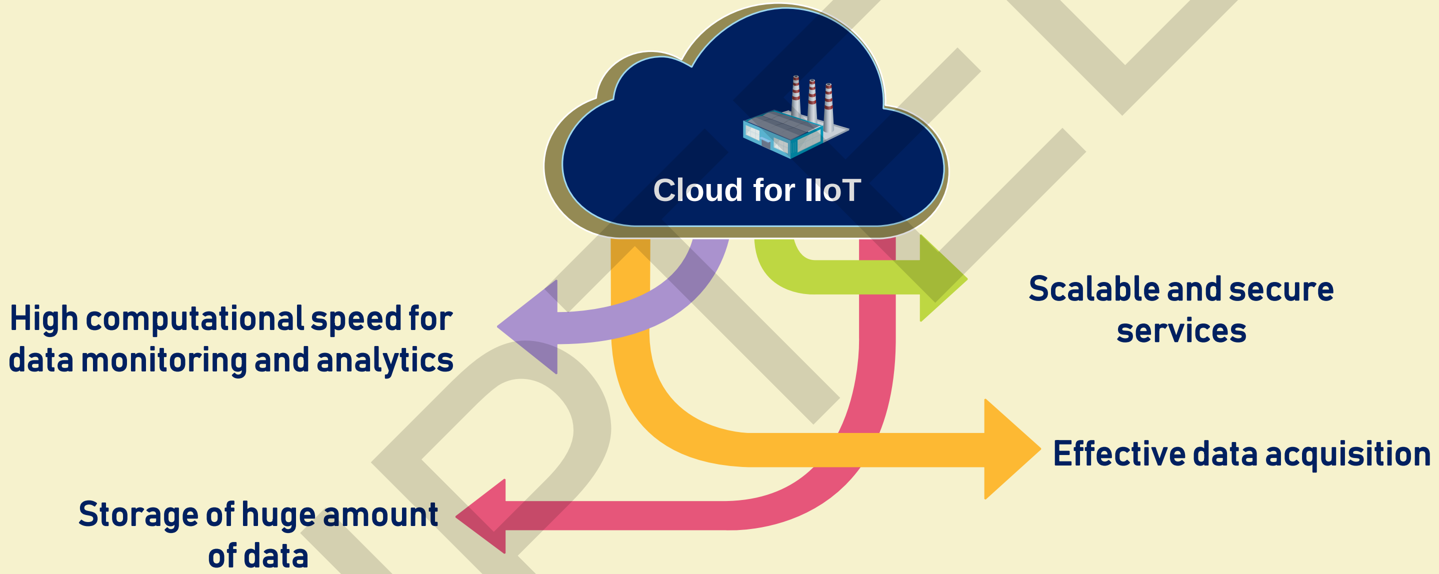
Source: "Industry 4.0: The Industrial Internet of Things", Apress, 2016

Need for Cloud

- Major concern to handle huge amount of data
- Nature of data
  - Unorganized
  - M2M sensor data
  - From heterogeneous big number of devices
  - Varying data quality

Source: "Industry 4.0: The Industrial Internet of Things", Apress, 2016

Need for Cloud (Contd.)



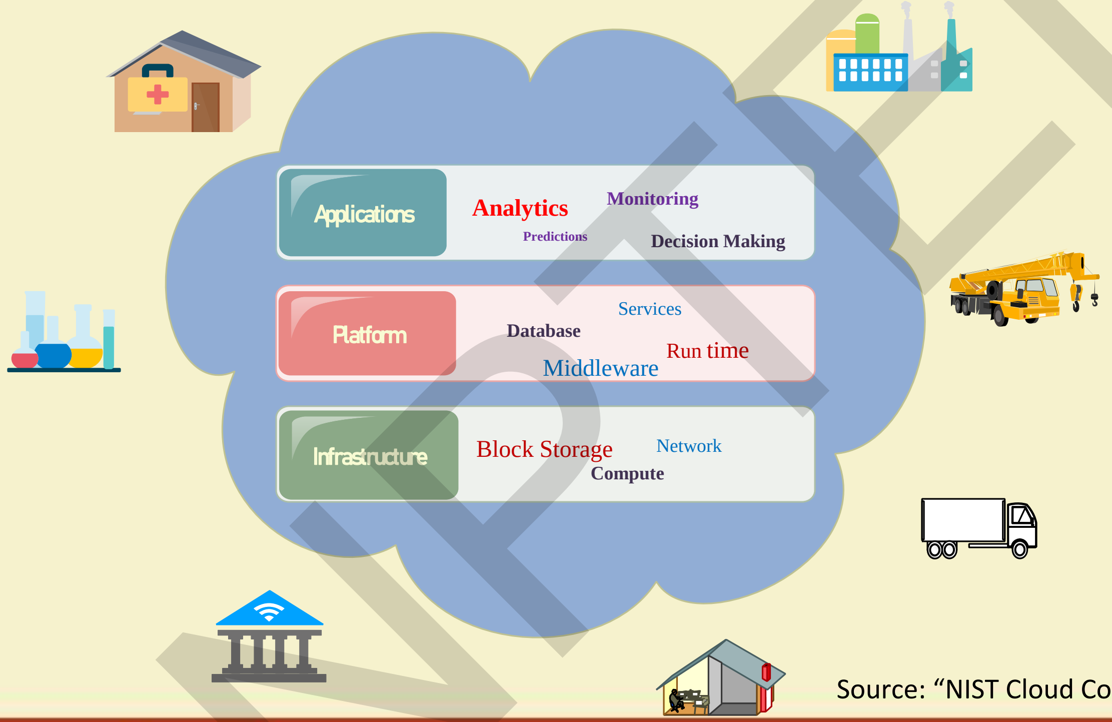
Source: “Industry 4.0: The Industrial Internet of Things”, Apress, 2016

Cloud Computing – Basics

- Suitable for its scientific and business adaptability
- Fulfills the need of what, when and where solutions
- Secure storage and access
- Supports a coherent, expandable and coordinated business model
- Supports mobile devices

Source: "NIST Cloud Computing Reference Architecture", NIST

Cloud Computing



Source: "NIST Cloud Computing Reference Architecture", NIST

Cloud Computing in IIoT: Services

- Three types of services: SaaS, PaaS and IaaS
- Software-as-a-Service (SaaS)
  - Industrial applications with web or program Interface
  - Subscribe-and-use feature to industry clients with final product
  - Everything managed by the service provider
  - Ex: Industrial Machinery Catalyst from Siemens is a SaaS for industrial use

Source: "NIST Cloud Computing Reference Architecture", NIST

Cloud Computing in IIoT: Services

- Platform-as-a-Service (PaaS)
  - Allows industries for self-development of applications
  - Clients have control over the application and the configuration environment
  - EX: Predix (GE), Sentience (Honeywell), and MindSphere (Siemens) are some industrial PaaS providers
  - Software firms like Cumulocity, Bosch IoT, and Carriots offer PaaS for IoT industries

Source: "NIST Cloud Computing Reference Architecture", NIST

Cloud Computing in IIoT: Services

- Infrastructure-as-a-Service (IaaS)
  - Access to the servers, network and storage and provisioning
  - Clients can use cloud to operate a virtual data center
  - Used to deploy PaaS and SaaS
  - Ex: Microsoft Azure, Google Compute Engine, IBM SmartCloud Enterprise, Rackspace Open Cloud, Amazon Web Services (AWS), etc.

Source: “NIST Cloud Computing Reference Architecture”, NIST

Cloud Computing in IIoT: Deployment Models

- Cloud set-up for use of any person or industry
- Virtualized resources are publicly shared
- Examples: Google Compute Engine, Amazon Web Service (AWS), Microsoft Azure, etc.

Public

- Cloud set-up for a single organization
- Virtualized resources are shared with the client only
- managed by the client itself or a third party
- Highly Secure

Private

- Cloud set-up by two or more unique cloud set-up (private or public)
- Designed to have advantages of both private and public
- Flexibility for data and applications movement between private and public clouds

Hybrid

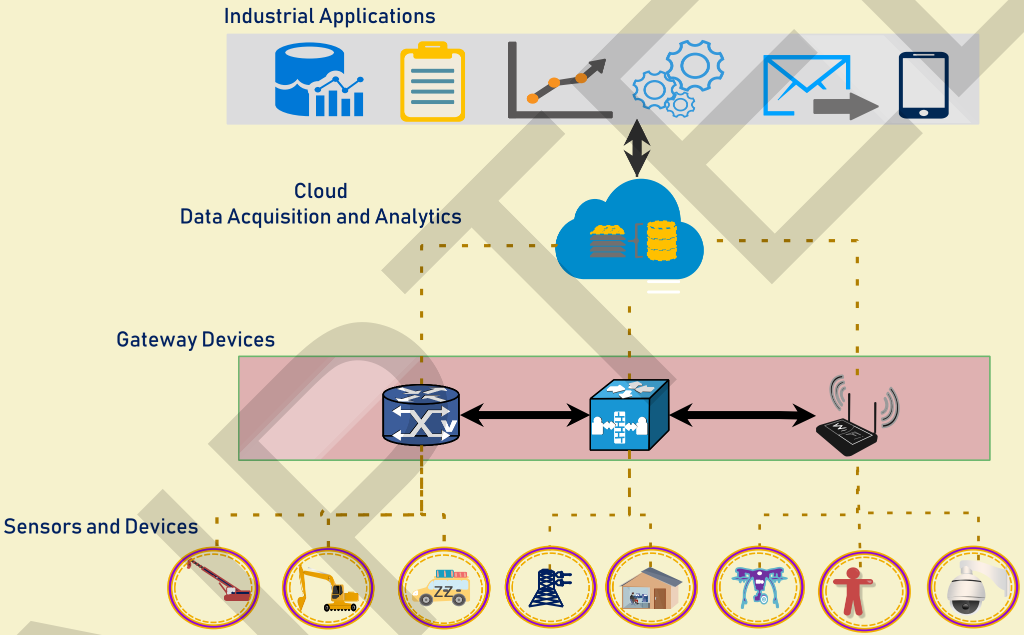
Source: "NIST Cloud Computing Reference Architecture", NIST

Cloud Computing in IIoT: End-users

- End-users are the industries who actually avail the cloud services
- Services differ form firm to firm based on their products and services
- Domain of use for IIoT lies in many areas like Healthcare, Transportation, Manufacturing plants, Refineries, Mining, Marine and many more.

Source: "Industry 4.0: The Industrial Internet of Things", Apress, 2016

Cloud-Based IIoT Architecture



Source: Gubbi et al., 2013

Cloud Computing in IIoT

- Industrial big data storage
- Heavy weight algorithms for data analytics
- Prediction of failures before occurrences
- Device provisioning and configuration remotely
- Real-time device monitoring
- Data privacy and security

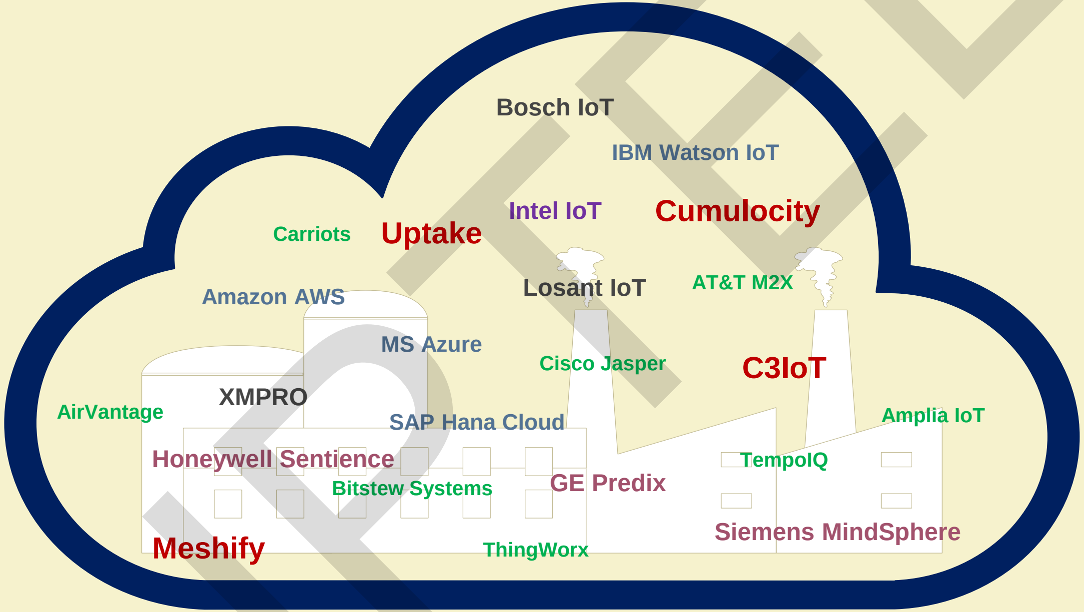
Source: “Industry 4.0: The Industrial Internet of Things”, Apress, 2016

Consumer vs. Industrial IoT Cloud Platforms

- Consumer IoT cloud platform
  - Very specific applications for end users
  - Modest security
  - Cost sensitive
- Industrial IoT cloud Platform
  - Large number of data points
  - QoS
  - Robust security
  - Return on investment (ROI) sensitive

Source: "The Future of Industrial IoT", Industrial Internet Consortium

Industrial Cloud Platform Providers



Source: "The List of Industrial Cloud Platform Providers", Element 14

Industrial Cloud Platform Providers: Our Discussion

- By industrial companies
  - GE Predix
  - Siemens MindSphere
  - Honeywell
- By Software development firms
  - C3 IoT
  - Uptake
  - Meshify

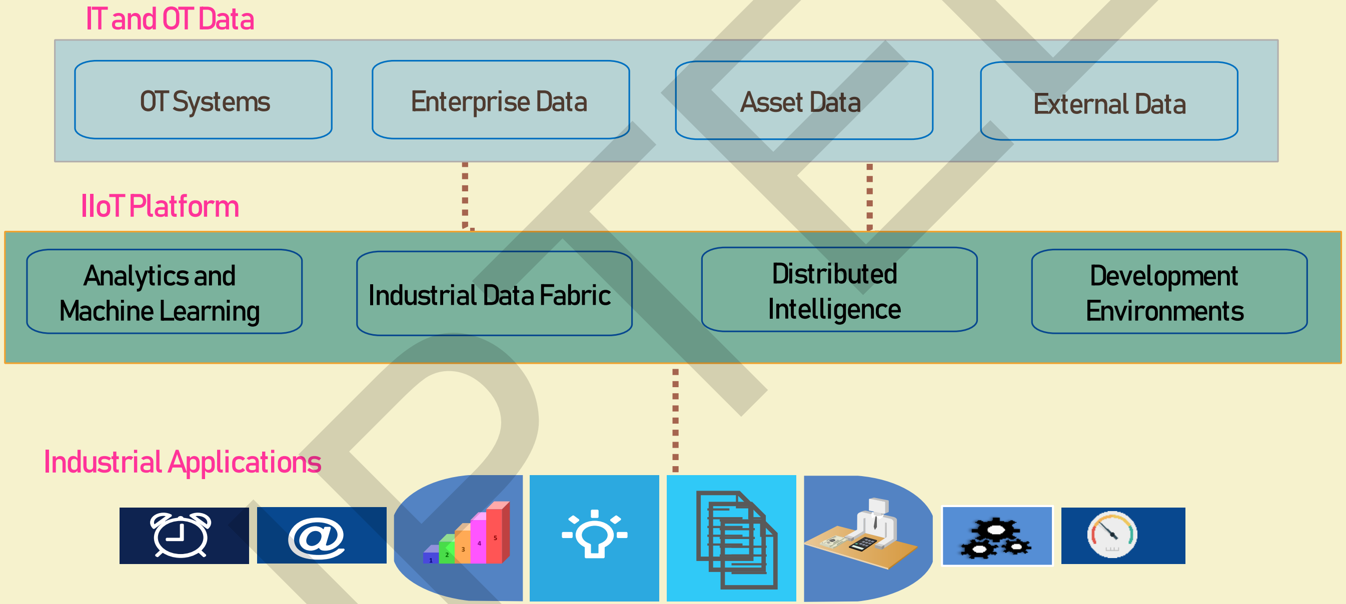
Source: "Will There Be A Dominant IIoT Cloud Platform?", Element 14

Predix

- Platform-as-a-service
- Tracking, management and enhancement of capital
- Defines the organization of the system and subassemblies components of services
- Enables differentiated functionalities of applications
- Digital Twin Technology for learning, estimating, optimizing and representation of assets

Source: “Industrial Capabilities of Predix”, Predix

Predix (Contd.)



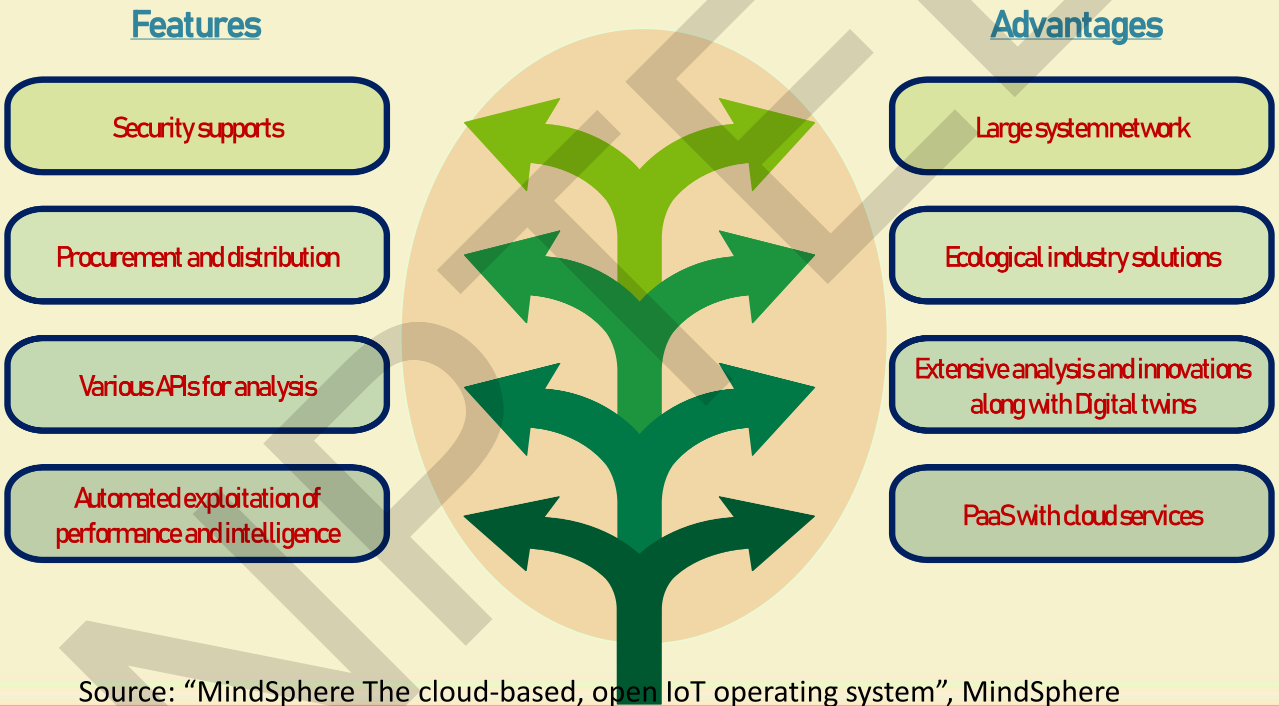
Source: "Industrial Capabilities of Predix", Predix

MindSphere

- Cloud-based operating system platform for IoT
- Open platform-as-a-service in addition to AWS cloud service
- Brings together IoT data from product, factory, machine and system to exploit the its prosperity
- Enterprise oriented solutions

Source: “MindSphere The cloud-based, open IoT operating system”, MindSphere

MindSphere (Contd.)



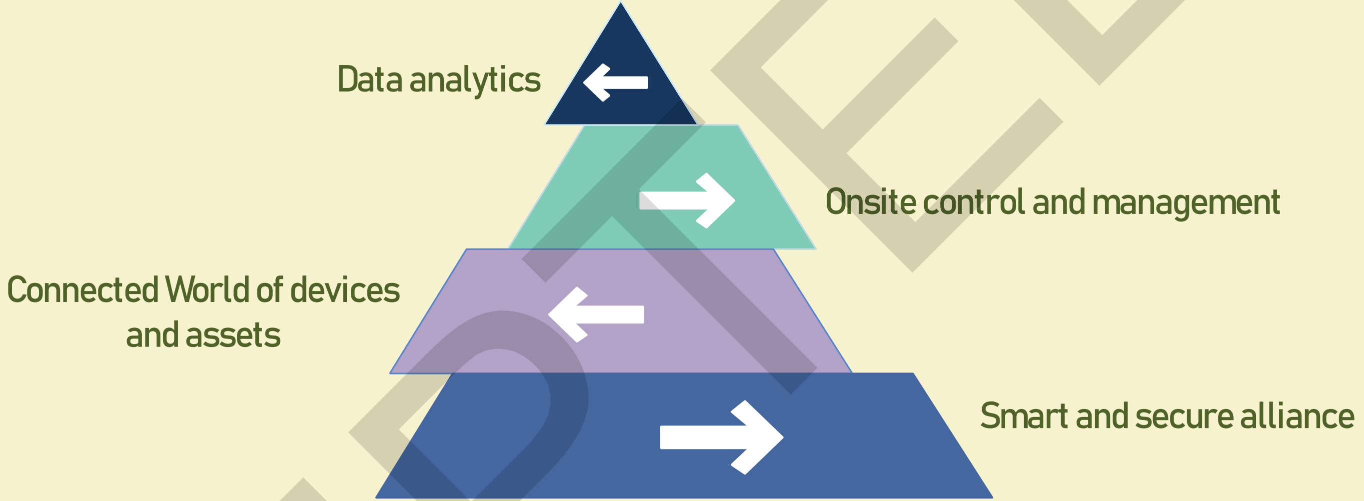
Source: "MindSphere The cloud-based, open IoT operating system", MindSphere

Honeywell

- Cloud software service for performance optimization
- Deeper insights of processes, driving agents and design skills
- Efficient solution for oil and gas industries
- Secure, scalable and standards-based platform
- Supports for SaaS business models

Source: “Honeywell Industrial Internet of things-Cloud Software”, Honeywell

Honeywell (Contd.)



Source: “Honeywell Industrial Internet of things-Cloud Software”, Honeywell

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Thank You!!

IIoT Analytics and Data Management: Cloud Computing in IIoT – Part 2

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Industrial Cloud Platforms Providers: Our Discussion

- By industrial companies
  - GE Predix
  - Siemens MindSphere
  - Honeywell
- By Software development firms
  - C3 IoT
  - Uptake
  - Meshify

Source: “Will There Be A Dominant IIoT Cloud Platform?”, Element 14

C3 IoT

- Platform offers services including analysis and prediction
- Secure framework: authentication and authorization
- Artificial Intelligence powered analytical tools
- C3 Data Lake: Storage service for unstructured data in RESTful format

Source: “C3IoT: Products + Services Overview”

C3 IoT (Contd.)

- C3 IoT Platform tools
  - Data Integrator
  - IDE
  - Data Explorer
  - Analytics Designer
  - Ex Machina
  - Data Science Notebook
  - Type Designer

- C3 IoT SaaS Products
  - Predictive Maintenance
  - Inventory Optimization
  - Supply Network
  - Energy Management
  - Fraud Detection
  - Sensor Health

Source: “C3IoT: Products + Services Overview”

Uptake

- Enterprise solutions equipped with latest technologies to provide high value low cost
- Identifying the strength and goals of business through trade discussions
- Smarter ways of achieving the goal

Source: "Predictive Analytics Solutions for Global Industry l Uptake", Uptake Digital

Uptake (Contd.)

Better resource utilization

- Effective cost computations
- Avoid replications
- Growth in production

Technological supports

- Build constant revenue flow for subscribed user services
- Automation and technological advancements
- Ease of buy and sell process

Customer satisfaction

- Secure services
- Smarter storage solutions
- Compliance with legal rules and regulations

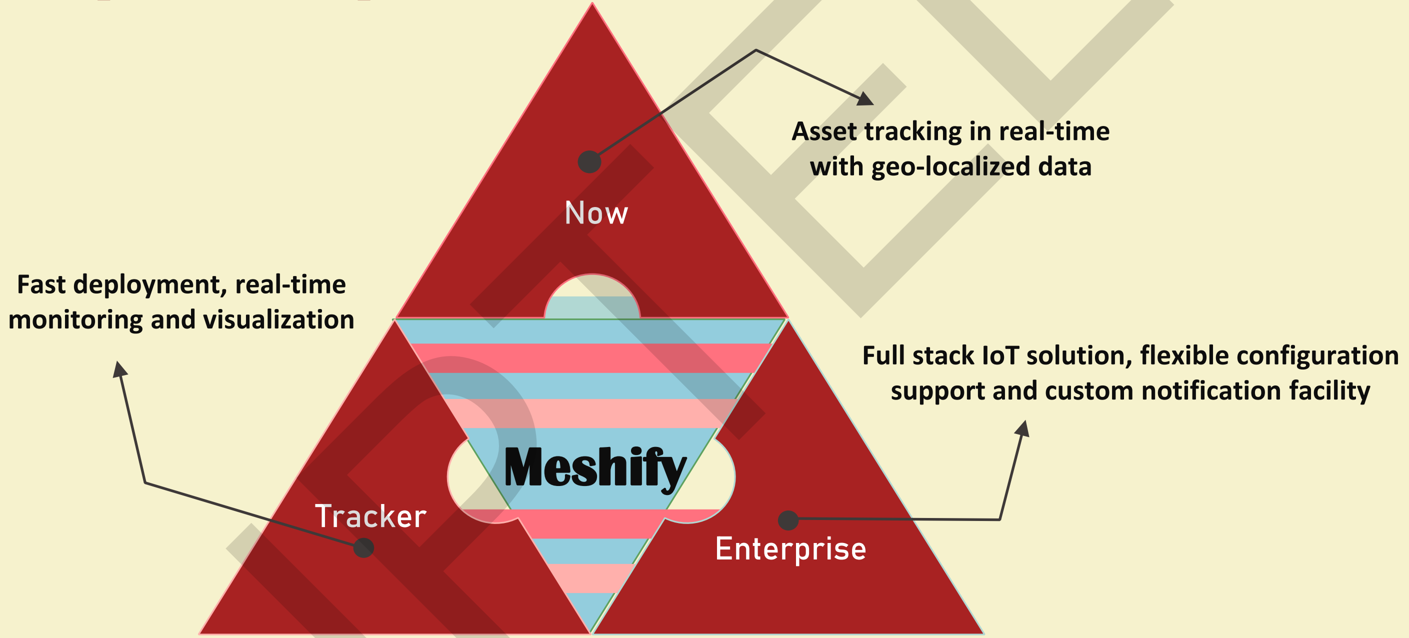
Source: "Predictive Analytics Solutions for Global Industry l Uptake", Uptake Digital

Meshify

- Provides industrial IoT platform
- Faster development and deployment processes
- Real-time monitoring
- Low-cost solutions
- Solutions:
  - Now
  - Tracker
  - Enterprise

Source: “Meshify - Complete IoT Solution”, Meshify

Meshify (Contd.)



Source: “Meshify - Complete IoT Solution”, Meshify

Cloud-Platform for Device Management

- Need for device management:
  - Increase in number of devices makes an IIoT ecosystem more complex
  - Not deploy and forget scenario for installed devices
  - Change in standards and services
  - Replacement of faulty devices
  - Security requirement
- Device management is dependent on few other functionalities
- Better way to keep device management service at cloud

Source: “Fundamentals of IoT device management”, IoT Design

Cloud-Platform for Device Management

- Features that cloud platform provider should offer for device management:
  - Provisioning and authentication
  - Fault diagnosis and monitoring
  - Updates, security patches and maintenance
  - Configuration and control
  - Device decommission

Source: “Fundamentals of IoT device management”, IoT Design

Cloud-Platform for Device Management

- Example of cloud platform providers with device management facility:
  - Bosch IoT Remote Manager
  - AWS's IoT Device Management
  - Verismic's Cloud Management Suite
  - ICP DAS's IoTstar
  - Software AG's Cumulocity

Service Level Agreement (SLA) for IIoT

- Many IIoT applications are real-time and include safety measures
- Framework should achieve the goals as per plan
- Services should be as per the agreement with cloud provider
- A SLA helps the cloud provider in promising the deliverables
- SLA helps the industrial client to check what and how good the cloud provider gives service

Source: Papadopoulos et al. , 2017

Characteristics of a Good SLA

Source: Sturm et al., 2000

Current Status and Future of SLAs in IIoT

- SLA complied cloud service in IIoT is at infant stage for following reasons:
  - Quality of services offered has interdependencies
  - Methodologies and frameworks of IIoT are not well developed
  - Life cycle management of an SLA in industrial context is not clear
  - Lack of SLA enforcement policies for both provider and consumer
- SLA support for IIoT is crucial along with business models
- Future IIoT needs a standardization of SLA and its management

Source: Papadopoulos et al. , 2017

Choosing the Right Cloud Vendor for IIoT

- Cloud is the heart of an IIoT ecosystem and choosing the correct platform is crucial
- Market of Many cloud vendors available with similar services
- A proper checklist of needs and cross checking with services from vendors

Source: "Top 10 selection criteria to choose your IoT platform", IOTIFY

Choosing the Right Cloud Vendor for IIoT

- Points to consider:
  - Scalability support
  - Bandwidth requirement
  - Communication protocols
  - Security
  - Interoperability
  - Edge Intelligence feature
  - Infrastructure management

Source: "Top 10 selection criteria to choose your IoT platform", IOTIFY

Limitations in Cloud-Based Approach

- Volume, velocity and variety
- Higher latency
- Bandwidth requirement for huge data volume
- Reliability for the big network
- Need for scalable security

Source: "Introduction to Edge Computing in IIoT", Industrial Internet Consortium

Centralized vs. Decentralized Approach

- Cloud based centralized approach suffers from many limitations
- Decentralized approach decreases the load at cloud
- Real-time operations feasibility
- More scalable IIoT network and features
- Greater mobility support

Source: "Today's Centralized Cloud And The Emerging Decentralized Edge", Forbes

Industry 4.0 Objectives

- Robust solutions
- Higher production
- Better Customer satisfaction
- Expanded security
- Better performance
- Entire world of industry at one place

Source: “Industry 4.0: The Industrial Internet of Things”, Apress, 2016

Industry 4.0 Requirements from IIoT

- Aims to achieve greater production, optimized decisions, efficiency and availability
- Deeper insights of analysis and prediction
- Establishing a connected world of machines, systems, products and environments
- Collection of data from each sector and performing analytics to exploit the wealth at its best

Source: “Industry 4.0: The Industrial Internet of Things”, Apress, 2016

Solution

- A Decentralized or distributed approach along with cloud
- Handling time-sensitive data
- Immediate action and quick response
- Delay in proper action at proper time may create hazardous situation
- Thus, Fog emerges to be a solution

Source: “Introduction to Edge Computing in IIoT”, Industrial Internet Consortium

Fog Computing

- An added layer between the edge and the cloud layer
- Not a replacement but an addition to cloud
- Identify useful data thus reducing the amount of raw data sent to cloud
- Increased scalability with reduced traffic

Source: Bonomi et al., 2014

Fog Computing (Contd.)

- Intelligent devices deployed at edge
- Intelligent compute devices known as fog nodes
- Intelligent in providing services like filtering, aggregation and translation
- Distributed at one level, centralized on the other

Source: Bonomi et al., 2014

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Thank You!!

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Analytics and Data Management: Fog Computing in IIoT

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Why Fog Computing for IIoT?

- Consistent release of data from sensors and machines
- Data may be critical as well as time-sensitive
- Need for immediate action and quick response
- Delay in proper action at proper time may create hazardous situation
- Major challenge is to handle the diversity: different protocols, different data syntax, different data source

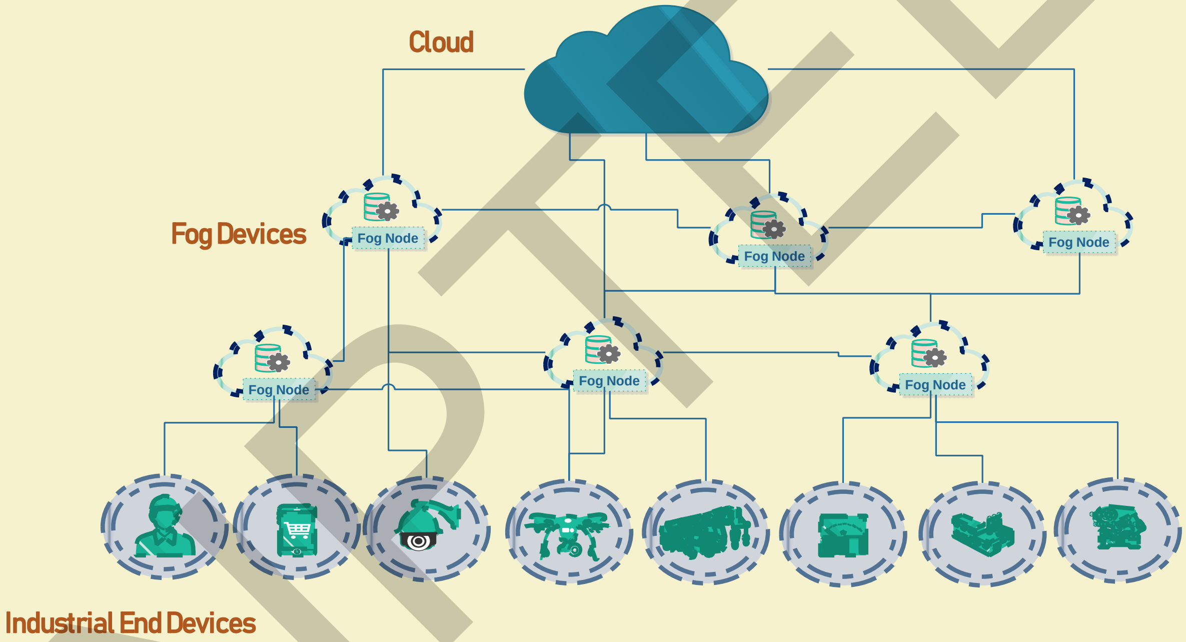
Source: Mohammad et al., 2018

Why Fog Computing for IIoT?

- Goal is to address the weaknesses of industrial automation
- Enabling new functionalities along with additional features
- Process control analytics
- Enriching the current functionalities

Source: Mohammad et al., 2018

Fog Computing Architecture for IIoT



Source: Mohammad et al., 2018

Fog Computing for Industrial Analytics

- Machine, process and data analysis in industries
- Advanced ways for optimized decision making and intelligent operations
- Achieving a new level of functioning and production in the system along with social values
- Classification can be done based on the place and function performed during analysis

Source: “Introduction to Edge Computing in IIoT”, Industrial Internet Consortium

Fog Computing for Industrial Analytics

- Support to algorithms at edge for real time control
- Additionally, high bandwidth communication and big data computations allows analysis on streaming data at cloud
- Prevention from unnecessary noisy big data crowd at cloud with prior filtration at edge

Source: “Introduction to Edge Computing in IIoT”, Industrial Internet Consortium

Fog Enabled IIoT

- Real-time monitoring and visualization
- End to end security
- Scalable and flexible
- Reduced overall cost
- Novel trading ideas

Source: “Fog Computing pioneers”, Nebbiolo Technologies

Use Cases

Use Cases

- Mining
- Smart Grid and Power
- Transportation
- Oil and Gas Industry

Source: Mohammad et al., 2018

Use Case - Mining

- Risky Environment
- IIoT may increase productivity and minimize over expenses
- Prediction and analysis of machines using IIoT reduces the operational cost
- Identifying the failure before it actually occurs
- Processing at fog nodes will increase accuracy

Source: Mohammad et al., 2018

Use Case - Smart Grid and Power Industry

- Dynamic demand of appliances
- Bi-directional communication between the consumer and supplier
- Power supply is provided from micro-grids, local distribution companies
- Advanced metering infrastructure for bi-directional communication

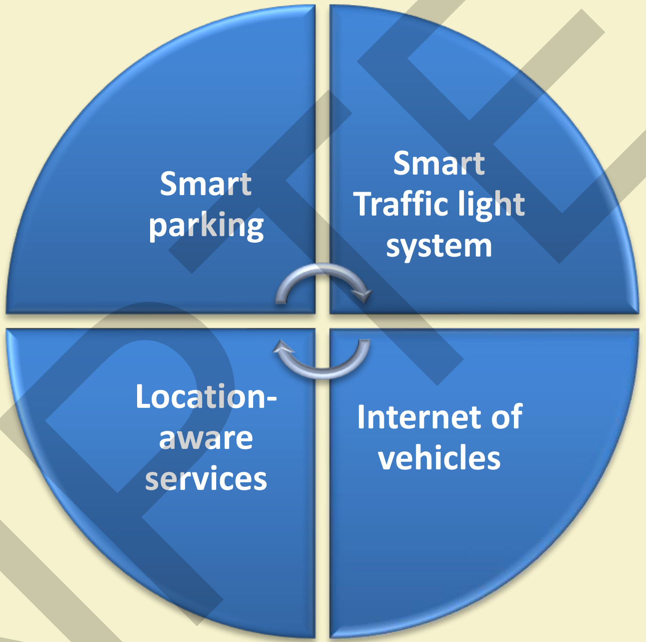
Source: Mohammad et al., 2018

Use Case - Smart Grid and Power Industry

- Continuous data exchange becomes a need
- Proper data communication is required
- Fog computing solves the issue

Source: Mohammad et al., 2018

Use Case - Transportation



Source: Mohammad et al., 2018

Use Case – Oil and Gas Industry

- Offering real-time advanced operation
- Detection of unusual events
- Step by step automation
- Real-time computation, control and management
- Support to scalability and adaptability

Source: "Fog Computing pioneers", Nebbiolo Technologies

IIoT Solutions using Fog

- Advanced hardware and software feature
  - Virtualization
  - Automation
  - Communication
  - Analysis
  - Prediction

Source: “Fog Computing pioneers”, Nebbiolo Technologies

IIoT Solutions using Fog (Contd.)

- Asset management
  - Compliant cloud-fog analytics
  - Remotely managed machines
  - Energy management
  - Effective production
  - Quality with quantity

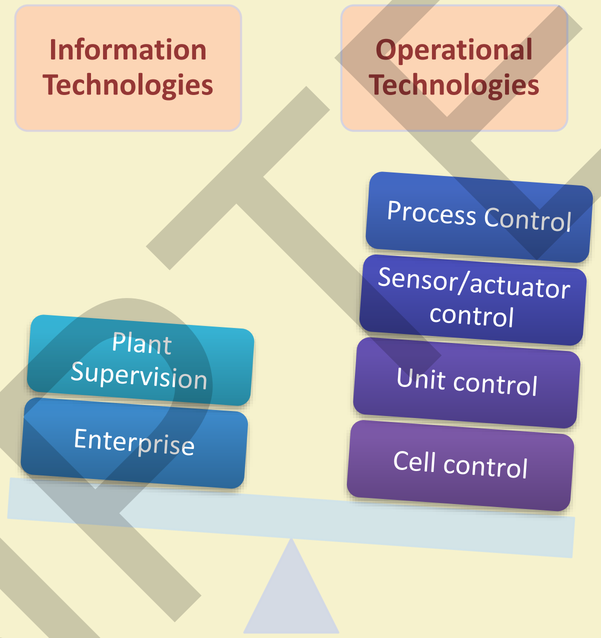
Source: "Fog Computing pioneers", Nebbiolo Technologies

IIoT Solutions using Fog (Contd.)

- Futuristic monitoring and control system for industries
  - A platform for workload (real-time/non real-time) merging
  - Robust platform facilitating secure co-existence
  - Advanced fog-based control of IoT end points and sensors

Source: “Fog Computing pioneers”, Nebbiolo Technologies

Factors affecting Business



Source: “Fog Computing pioneers”, Nebbiolo Technologies

Fog platform Providers

- FogHorn
- Nebbiolo Technologies
- Crosser
- Sonm

FogHorn

- Edge network solution for quicker processing, analysing and responding
- Intelligent software platform for enabling edge computing
- Achieves efficient operation in lower cost
- Analysis and prediction on edge

Source: “Edge Intelligence software for IIoT”, FogHorn Systems

Nebbiolo Technologies

- Bringing together IT and OT for real-time services
- Connecting the modern IT with future OT
- Optimized solution with smarter decision making capability in lower cost
- Products: fogOS, fogNode, fogSM

Source: "Fog Computing pioneers", Nebbiolo Technologies

Crosser

- Edge node software solution for asset data
- Supports any protocol, any PLC and any hardware
- Compute, Process and analyse wherever the requirement
- Real-time response to streaming IoT data
- Easy visual interfaces

Source: “Crosser Edge Computing Software”, Crosser

Sonm

- Distributed cloud services with fog as backend
- Either provide your hardware services or use third-party facility
- Current solutions
  - Blockchain infrastructure
  - Video streaming
  - Machine learning
  - Video rendering

Source: “SONM: Decentralized Fog Computing Platform”, Sonm

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[1] A. Mohammad, S. Zeadally, and K. A. Harras, “Deploying Fog Computing in Industrial Internet of Things and Industry 4.0”, *IEEE Transactions on Industrial Informatics*, 2018. **DOI:** 10.1109/TII.2018.2855198.

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IIoT Analytics and Data Management: Tutorial for R & Julia Programming

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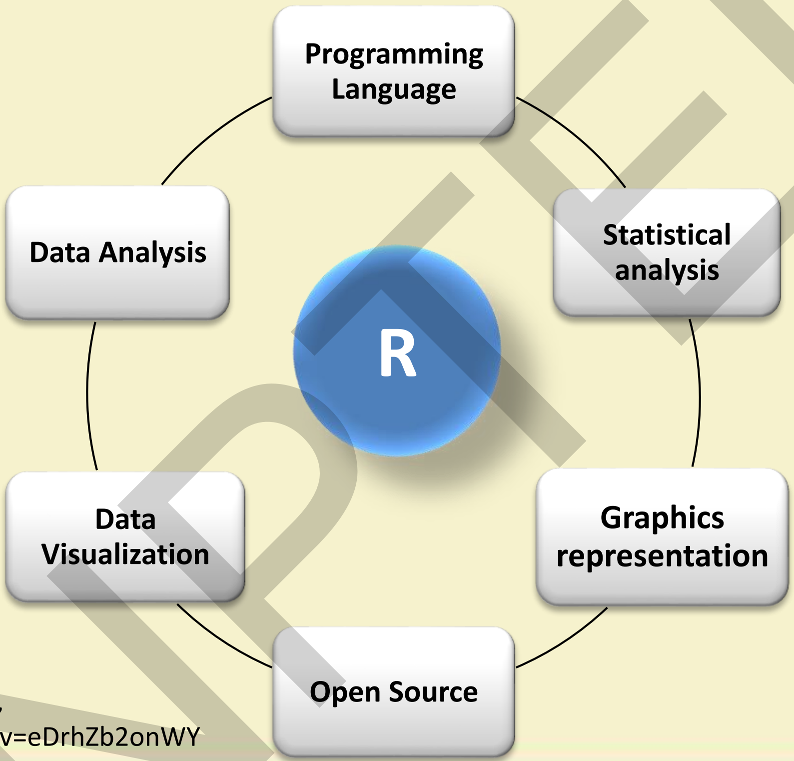
R Programming

What is R tool ?



Source: R tutorial for beginners, Edureka,
URL: https://www.youtube.com/watch?v=eDrhZb2onWY

Fundamental concept of R

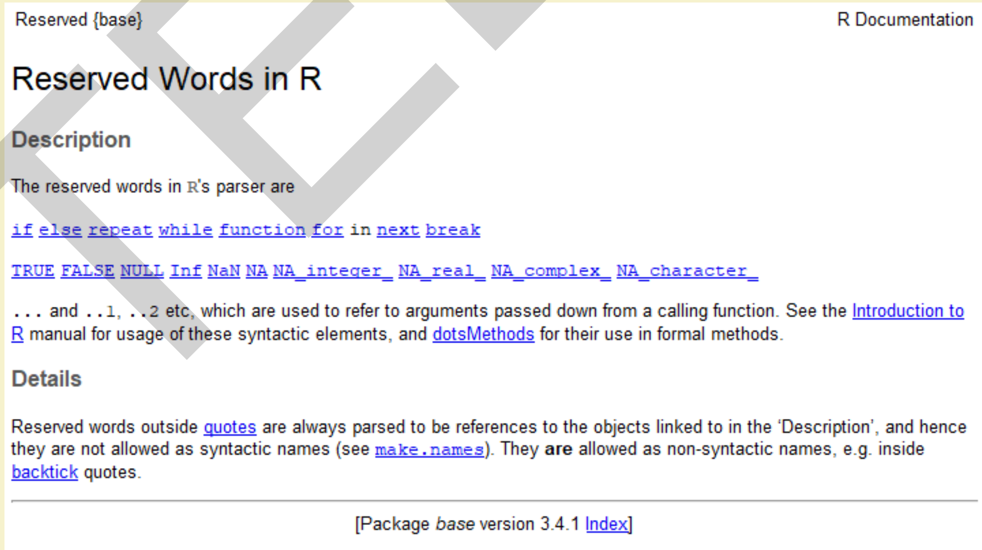
- Reserved words in R
- Variables in R
- R Operators
- R Data Types

Here all codes are run in RStudio Version 1.1.456 – © 2009-2018 RStudio, Inc in Windows 10

Reserved words in R

Words having special meaning and cannot be used as variable name, function name etc.

> ?reserved
or,
> help(reserved)


Reserved {base} R Documentation

Reserved Words in R

Description

The reserved words in R's parser are

`if` `else` `repeat` `while` `function` `for` in `next` `break`

`TRUE` `FALSE` `NULL` `Inf` `NaN` `NA` `NA_integer_` `NA_real_` `NA_complex_` `NA_character_`

`...` and `..1`, `..2` etc, which are used to refer to arguments passed down from a calling function. See the Introduction to R manual for usage of these syntactic elements, and dotsMethods for their use in formal methods.

Details

Reserved words outside quotes are always parsed to be references to the objects linked to in the 'Description', and hence they are not allowed as syntactic names (see `make.names`). They **are** allowed as non-syntactic names, e.g. inside backtick quotes.

[Package *base* version 3.4.1 Index]

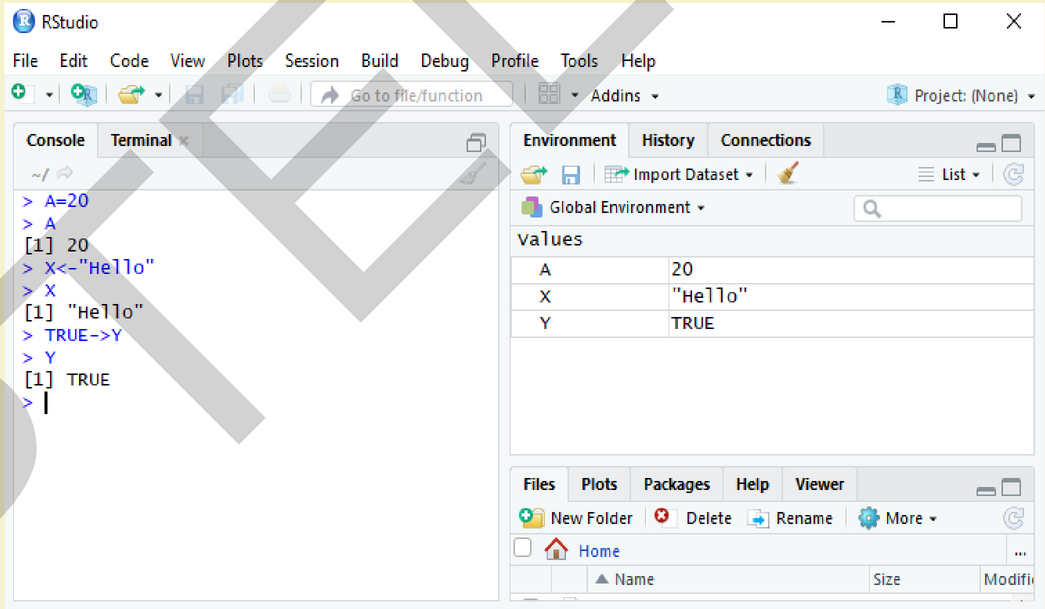
Source: R tutorial for beginners, Edureka,
URL: https://www.youtube.com/watch?v=eDrhZb2onWY

Figure is taken from RStudio Version 1.1.456 – © 2009-2018 RStudio, Inc.

Variables in R

- Declaration of variable do not need to specify the datatype
- Declaration of variables can be performed in three ways,

A=20;
X<-"Hello"
TRUE->Y



Source: R tutorial for beginners, Edureka,
URL: https://www.youtube.com/watch?v=eDrhZb2onWY

Figure is taken from RStudio Version 1.1.456 – © 2009-2018 RStudio, Inc.

R operators

1. Arithmetic Operators:

Arithmetic Operators	Purpose
+	Add two operators or unary plus
-	Subtract two operators or unary minus
*	Multiply two operators
/	Divide two operators
^	Left operand raised to the power of right
%%	Remainder of division
%/%	Divisions results in whole number adjusted to the left in the number line

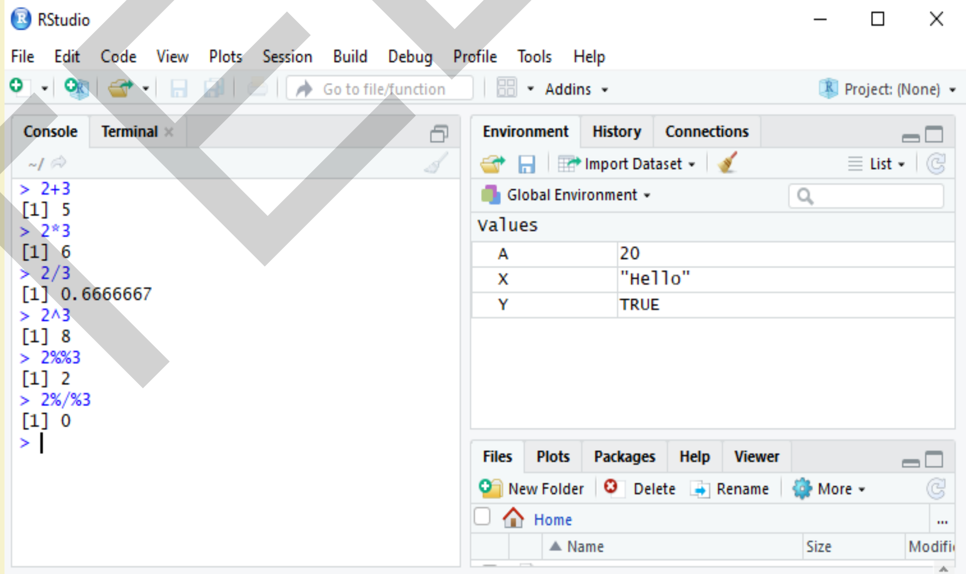


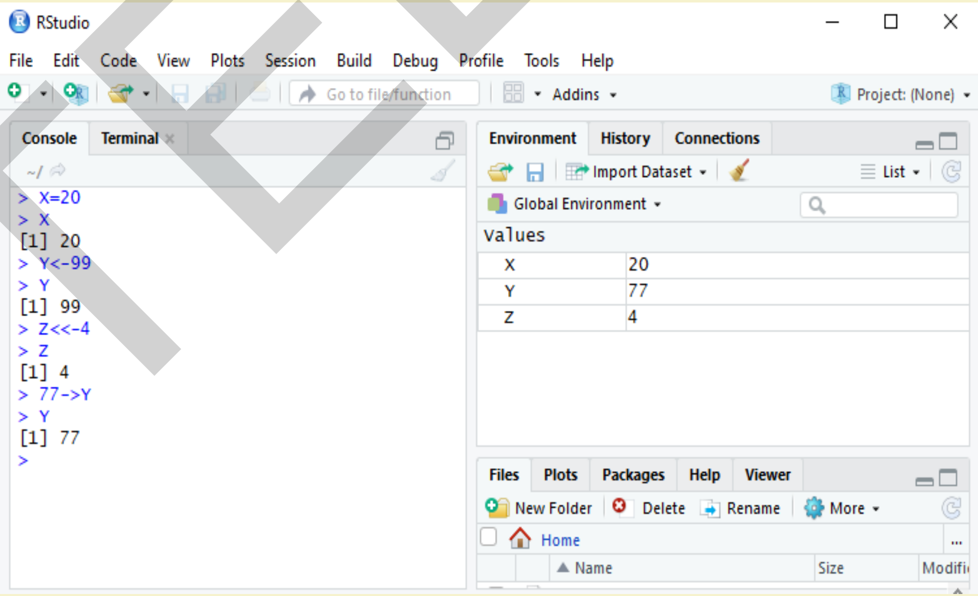
Figure is taken from RStudio Version 1.1.456 – © 2009-2018 RStudio, Inc.

Source: R tutorial for beginners, Edureka,
URL: https://www.youtube.com/watch?v=eDrhZb2onWY

R operators (Contd..)

2. Assignment Operators:

Assignment Operators	Purpose
=	variable= right operand
<-	variable<-right operand
<<-	variable<<-right operand
->	left operand->variable



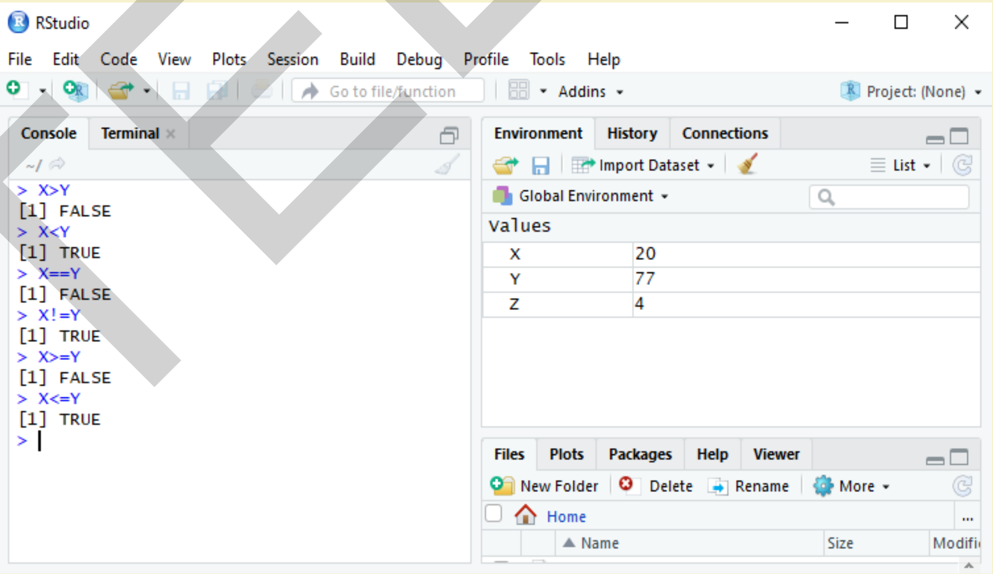
Source: R tutorial for beginners, Edureka,
URL: https://www.youtube.com/watch?v=eDrhZb2onWY

Figure is taken from RStudio Version 1.1.456 – © 2009-2018 RStudio, Inc.

R operators (Contd..)

3. Relational Operators:

Relational Operators	Purpose
>	Greater than operator
<	Less than operator
==	Equal to operator
!=	Not equal to operator
>=	Greater than and equal to
<=	Less than and equal to



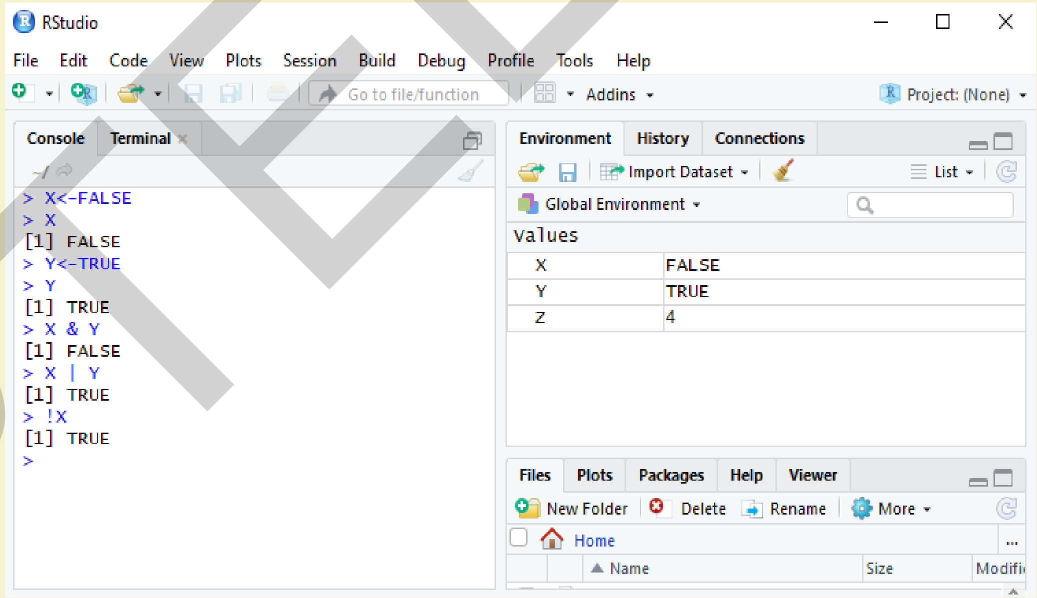
Source: R tutorial for beginners, Edureka,
URL: https://www.youtube.com/watch?v=eDrhZb2onWY

Figure is taken from RStudio Version 1.1.456 – © 2009-2018 RStudio, Inc.

R operators (Contd..)

4. Logical Operators:

Relational Operators	Purpose
&	AND operator
|	OR operator
!	NOT operator



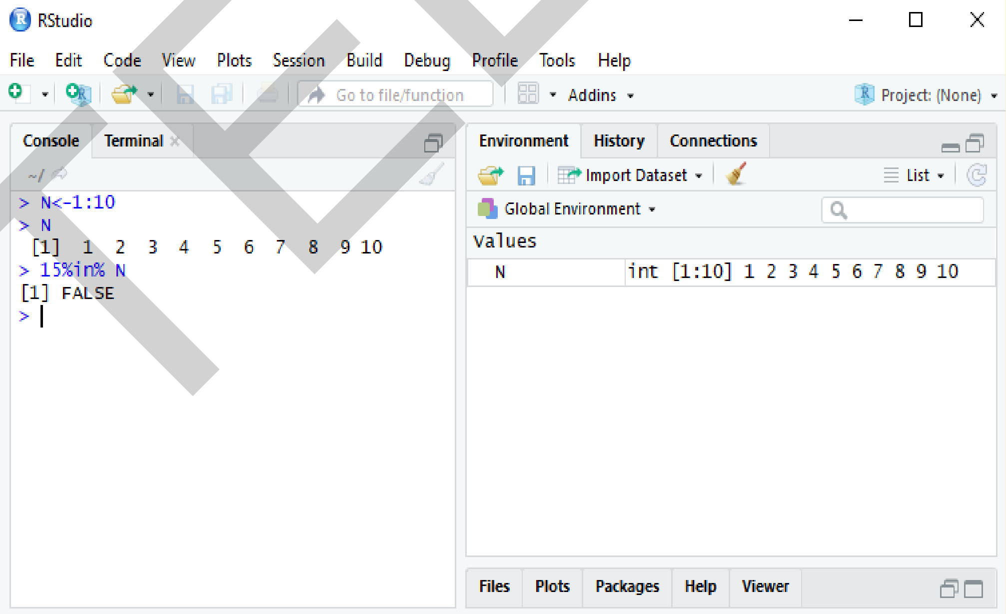
Source: R tutorial for beginners, Edureka,
URL: https://www.youtube.com/watch?v=eDrhZb2onWY

Figure is taken from RStudio Version 1.1.456 – © 2009-2018 RStudio, Inc.

R operators (Contd..)

5. Special Operators

Relational Operators	Purpose
:	Creates series of numbers for a vector
%in%	To check an element belongs to vector

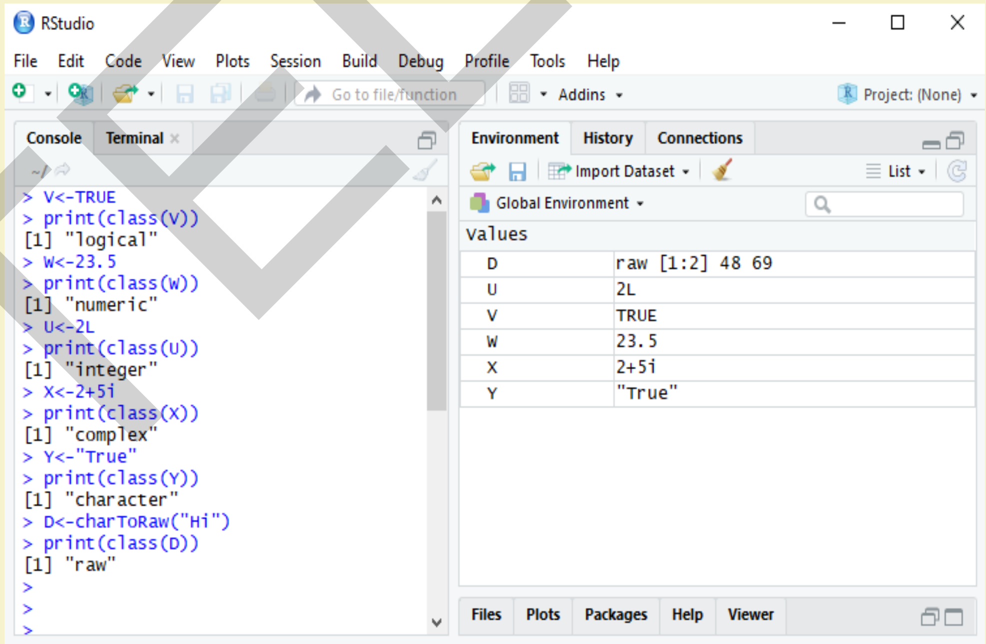


Source: R tutorial for beginners, Edureka,
URL: https://www.youtube.com/watch?v=eDrhZb2onWY

Figure is taken from RStudio Version 1.1.456 – © 2009-2018 RStudio, Inc.

R Data Types

- Unlike other programming languages like C and java, the variables are not declared as some data types in R
- Variables are assigned with R-objects and the data type of the R-object becomes the data type of variable
- Different objects are **Vectors, Lists, Matrices, Arrays, Factors, Data Frames**
- Different data types are **Logical, Numeric, Integer, Complex, Character, Raw**



Source: R tutorial for beginners, Edureka,
URL: https://www.youtube.com/watch?v=eDrhZb2onWY

Figure is taken from RStudio Version 1.1.456 – © 2009-2018 RStudio, Inc.

R Data Types (Contd..)

- Vectors

```
> apple<-c('red', 'green’, 'yellow’)
> print(apple)
[1] "red" "green" "yellow"
```

- Arrays

```
a<-array(c('green','yellow'),dim=c(3,3,2))
> print(a)
 , , 1

     [,1] [,2] [,3]
[1,] "green" "yellow" "green"
[2,] "yellow" "green" "yellow"
[3,] "green" "yellow" "green“

 , , 2
 [,1] [,2] [,3]
 [1,] "yellow" "green" "yellow“
 [2,] "green" "yellow" "green“
 [3,] "yellow" "green" "yellow"
```

- Matrices

```
> Mat=matrix(c('a','b','c','d','e','f'), nrow=2,
ncol=3, byrow=TRUE)
> print(Mat)
    [,1] [,2] [,3]
[1,] "a" "b" "c"
[2,] "d" "e" "f"
```

- Lists

```
> list1<-list(c(2,5,3),21.3,sin)
> print(list1)
[[1]] [1] 2 5 3
[[2]] [1] 21.3
[[3]] function (x) .Primitive("sin")
```

Source: R tutorial for beginners, Edureka,
URL: https://www.youtube.com/watch?v=eDrhZb2onWY

Figures are taken from Rstudio Version 1.1.456 – © 2009-2018 RStudio, Inc.

Important machine learning packages of R

Packages	Functions
1. **e1071**	Fuzzy clustering, support vector machine, naïve bayes classifier etc
1. **rpart**	Regression tree etc
1. **nnet**	Feed forward neural network etc
1. **randomForest**	Random forests for classification and regression
1. **igraph**	Network analysis tools
1. **caret**	Functions for creating predictive models

Execution of machine learning

- Install caret package using,

```
install.packages("caret", dependencies=c("Depends", "Suggests"))
```

or

```
install.packages("caret")
```

- 2. Load the packages using,

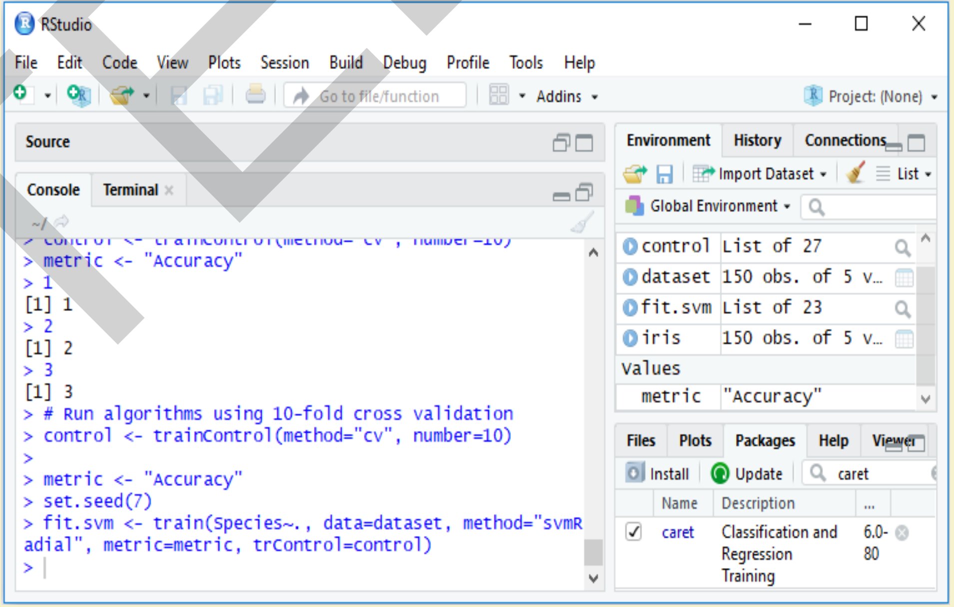
```
> library(caret)
```

- 3. Load data using

```
> data("iris")
```

- 4. Rename the dataset

```
> dataset <- iris
```



Source: Your First Machine Learning Project in R Step-By-Step
URL: https://machinelearningmastery.com/machine-learning-in-r-step-by-step/

Execution of machine learning (contd…)

- 10 fold cross validation to estimate accuracy

```
> # Run algorithms using 10-fold cross validation
> control <- trainControl(method="cv", number=10)
>
> metric <- "Accuracy"
```

- Support vector machine with linear kernel

```
> set.seed(7)
> fit.svm <- train(Species~., data=dataset, method="svmRadial", metric=metric, trControl=control)
```

Source: Your First Machine Learning Project in R Step-By-Step
URL: https://machinelearningmastery.com/machine-learning-in-r-step-by-step/

Julia Programming

Why Julia programming?

Julia merges python's benefits with c's performance

- Open source
- Distributed computation and parallelism possible
- Support efficiently Unicode
- Call c functions directly

Source: Julia tutorial URL:http://codebasicshub.com/
Source: Julia 1.0 Documentation URL: https://docs.julialang.org/en/stable/

Basics of Julia programming

➢ Use println() is used to print

```
In [1]: println("I'm excited to learn Julia!")
        I'm excited to learn Julia!
```

➢ Variables can be assigned without defining the type

```
In [2]: my_answer = 42
        typeof(my_answer)
Out[2]: Int64

In [4]: my_pi = 3.14159
        typeof(my_pi)
Out[4]: Float64
```

➢ Basic math

```
In [5]: sum = 3 + 7
Out[5]: 10

In [6]: difference = 10 - 3
Out[6]: 7

In [7]: product = 20 * 5
Out[7]: 100

In [8]: quotient = 100 / 10
Out[8]: 10.0

In [9]: power = 10 ^ 2
Out[9]: 100

In [10]: modulus = 101 % 2
Out[10]: 1
```

codes are run in browser on JuliaBox.com
https://www.juliabox.com/notebook/notebooks/tutorials/intro-to-julia/03.%20Data%20structures.ipynb

Basics of Julia programming (Contd...)

- Assigning string

```
In [1]: s1 = "I am a string."
Out[1]: "I am a string."
```

- Use of $ sign for string interpolation

```
In [3]: name = "Jane"
        num_fingers = 10
        num_toes = 10
Out[3]: 10

In [4]: println("Hello, my name is $name.")
        println("I have $num_fingers fingers and $num_toes toes.")

        Hello, my name is Jane.
        I have 10 fingers and 10 toes.
```

- String concatenation

```
In [5]: s3 = "How many cats ";
        s4 = "is too many cats?";

In [6]: string(s3, s4)
Out[6]: "How many cats is too many cats?"
```

codes are run in browser on JuliaBox.com
https://www.juliabox.com/notebook/notebooks/tutorials/intro-to-julia/03.%20Data%20structures.ipynb

Basics of Julia programming (Contd...)

- Data structures

1. Tuples

```
In [1]: myfavoriteanimals = ("penguins", "cats", "sugargliders")
Out[1]: ("penguins", "cats", "sugargliders")
```

We can index into this tuple,

```
In [2]: myfavoriteanimals[1]
Out[2]: "penguins"
```

but since tuples are immutable, we can't update it

```
In [3]: myfavoriteanimals[1] = "otters"
MethodError: no method matching setindex!(::Tuple{String,String,String}, ::String, ::Int64)
```

codes are run in browser on JuliaBox.com
https://www.juliabox.com/notebook/notebooks/tutorials/intro-to-julia/03.%20Data%20structures.ipynb

Basics of Julia programming (Contd...)

2. Dictionary

- Dict() is used for creating dictionaries

```
In [4]: myphonebook = Dict("Jenny" => "867-5309", "Ghostbusters" => "555-2368")

Out[4]: Dict{String,String} with 2 entries:
          "Jenny"        => "867-5309"
          "Ghostbusters" => "555-2368"
```

- Show a particular instance

```
In [5]: myphonebook["Jenny"]

Out[5]: "867-5309"
```

codes are run in browser on JuliaBox.com
https://www.juliabox.com/notebook/notebooks/tutorials/intro-to-julia/03.%20Data%20structures.ipynb

Basics of Julia programming (Contd…)

3. Arrays

```
In [6]: myfriends = ["Ted", "Robyn", "Barney", "Lily", "Marshall"]

Out[6]: 5-element Array{String,1}:
         "Ted"
         "Robyn"
         "Barney"
         "Lily"
         "Marshall"
```

```
In [7]: fibonacci = [1, 1, 2, 3, 5, 8, 13]

Out[7]: 7-element Array{Int64,1}:
          1
          1
          2
          3
          5
          8
         13
```

codes are run in browser on JuliaBox.com
https://www.juliabox.com/notebook/notebooks/tutorials/intro-to-julia/03.%20Data%20structures.ipynb

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[4] : codes are run in browser on JuliaBox.com
https://www.juliabox.com/notebook/notebooks/tutorials/intro-to-julia/03.%20Data%20structures.ipynb

Thank You!!

IIoT Analytics and Data Management: Data Management with Hadoop

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What is Data Management

- Data Management
  - Ensures that research data is stored, archived or disposed off in a safe and secure manner during and after the conclusion of a research project
  - Includes the development of policies and procedures to manage data handled electronically as well as through non-electronic means

- In recent days, most industrial data –
  - Big Data
    - Due to heavy traffic generated by IoT devices
    - Huge amount of data generated by the deployed sensors

Data Management: Technologies

- Cloud computing
  - Essential characteristics according to NIST
    - On-demand self service
    - Broad network access
    - Resource pooling
    - Rapid elasticity
    - Measured service
  - Basic service models provided by cloud computing
    - Infrastructure-as-a-Service (IaaS)
    - Platform-as-a-Service (PaaS)
    - Software-as-a-Service (SaaS)

Data Management: Technologies (Contd.)

- Internet of Things (IoT) and Big Data
  - According to Techopedia, IoT *"describes a future where every day physical objects will be connected to the internet and will be able to identify themselves to other devices."*
  - Sensors embedded into various devices and machines and deployed into fields.
  - Sensors transmit sensed data to remote servers via Internet.
  - Continuous data acquisition from mobile equipment, transportation facilities, public facilities, and home appliances

Data Management: Technologies (Contd.)

- Data handling at data centers
  - Storing, managing, and organizing data.
  - Estimates and provides necessary processing capacity.
  - Provides sufficient network infrastructure.
  - Effectively manages energy consumption.
  - Replicates data to keep backup.
  - Develop business oriented strategic solutions from big data.
  - Helps business personnel to analyze existing data.
  - Discovers problems in business operations.

Data Management: Process

Generation → Acquisition → Storage → Analysis

Generation

- Enterprise data
- IoT data
- Bio-medical data
- Other data

Acquisition

- Data collection
- Data transportation
- Data pre-processing

Storage

- Hadoop
- MapReduce
- NoSQL databases

Analysis

- Bloom filter
- Parallel computing
- Hashing and indexing

Data Sources

- Enterprise data
  - Online trading and analysis data.
  - Production and inventory data.
  - Sales and other financial data.
- IoT data
  - Data from industry, agriculture, traffic, transportation
  - Medical- care data,
  - Data from public departments, and families.
- Bio-medical data
  - Masses of data generated by gene sequencing.
  - Data from medical clinics and medical R&Ds.
- Other fields
  - Fields such as – computational biology, astronomy, nuclear research etc

Data Acquisition

- Data collection
  - Log files or record files that are automatically generated by data sources to record activities for further analysis.
  - Sensory data such as sound wave, voice, vibration, automobile, chemical, current, weather, pressure, temperature etc.
  - Complex and variety of data collection through mobile devices. E.g. – geographical location, 2D barcodes, pictures, videos etc.

Data Acquisition

- Data transmission
  - After collecting data, it will be transferred to storage system for further processing and analysis of the data.
  - Data transmission can be categorized as – <u>Inter-DCN</u> transmission and <u>Intra-DCN</u> transmission.

Data Acquisition (Contd.)

- Data pre-processing
  - Collected datasets suffer from noise, redundancy, inconsistency etc.
  - Pre-processing of relational data mainly follows – integration, cleaning, and redundancy mitigation
  - Integration is combining data from various sources and provides users with a uniform view of data.
  - Cleaning is identifying inaccurate, incomplete, or unreasonable data, and then modifying or deleting such data.
  - Redundancy mitigation is eliminating data repetition through detection, filtering and compression of data to avoid unnecessary transmission.

Data Storage

- Databases
  - Emergence of non-traditional relational databases (NoSQL) in order to deal with the characteristics that big data possess.
  - Three main NoSQL databases – Key-value databases, column-oriented databases, and document-oriented databases.

Data Storage (Contd.)

- File system
  - Distributed file systems that store massive data and ensure – consistency, availability, and fault tolerance of data.
  - GFS is a notable example of distributed file system that supports large-scale file system, though it's performance is limited in case of small files
  - Hadoop Distributed File System (HDFS) and Kosmosfs are other notable file systems, derived from the open source codes of GFS.

Industrial Data Management

- Incorporates data generated during
  - Manufacturing plants
  - Processing plants
- Management done in entire value chain
- Data availability is ensured
- Enables decision making process easier

Industrial Data Management: Advantages

- Production data of your plant is available
  - Raw material consumption
  - Production specifications
  - Energy Consumption
  - Plant utilization
  - Diagnostic information
- Enabling automated process

Data Management Using Hadoop

What is Hadoop

- Hadoop
  - Software framework for distributed processing of large datasets across large clusters of computers
  - Open-source implementation for Google File System (GFS) and MapReduce
  - MapReduce and Hadoop Distributed File System (HDFS) components originally derived respectively from Google's MapReduce and GFS.

Building Blocks of Hadoop

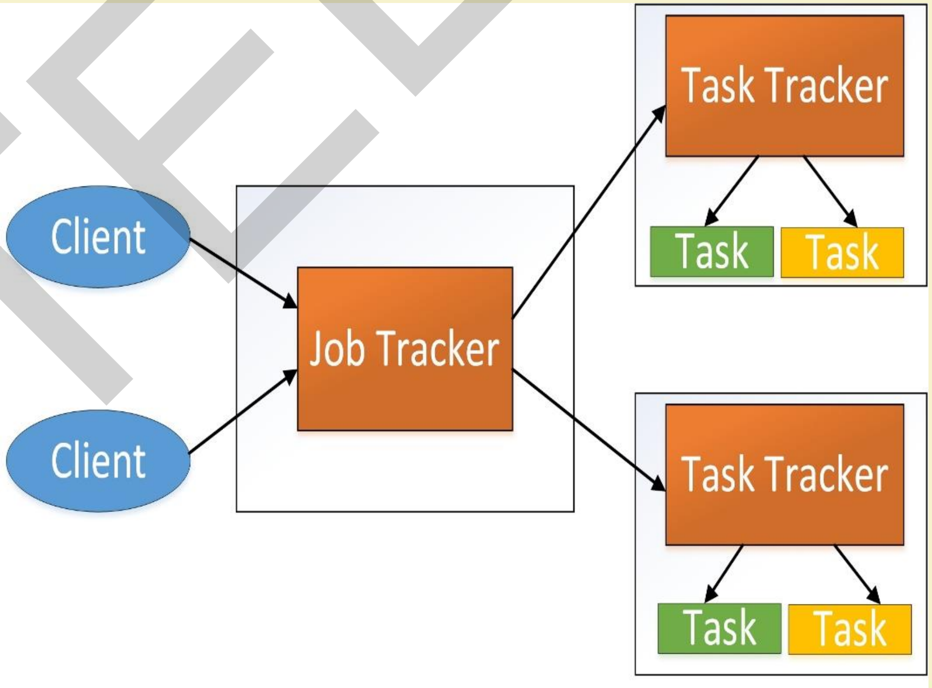
- Hadoop Common
  - A module containing the utilities that support the other Hadoop components
- Hadoop Distributed File System (HDFS)
  - Provides reliable data storage and access across the nodes
  - Rapid data transfer among the nodes
  - Fault tolerant

Building Blocks of Hadoop (Contd.)

- MapReduce
  - Framework for applications that process large amount of datasets in parallel
- Yet Another Resource Negotiator (YARN)
  - Next-generation MapReduce
  - Assigns CPU, memory and storage to applications running on a Hadoop cluster.

Hadoop Distributed File System (HDFS)

- Centralized node
  - Namenode
  - Maintains metadata info about files
- Distributed node
  - Datanode
  - Store the actual data
  - Files are divided into blocks
  - Each block is replicated

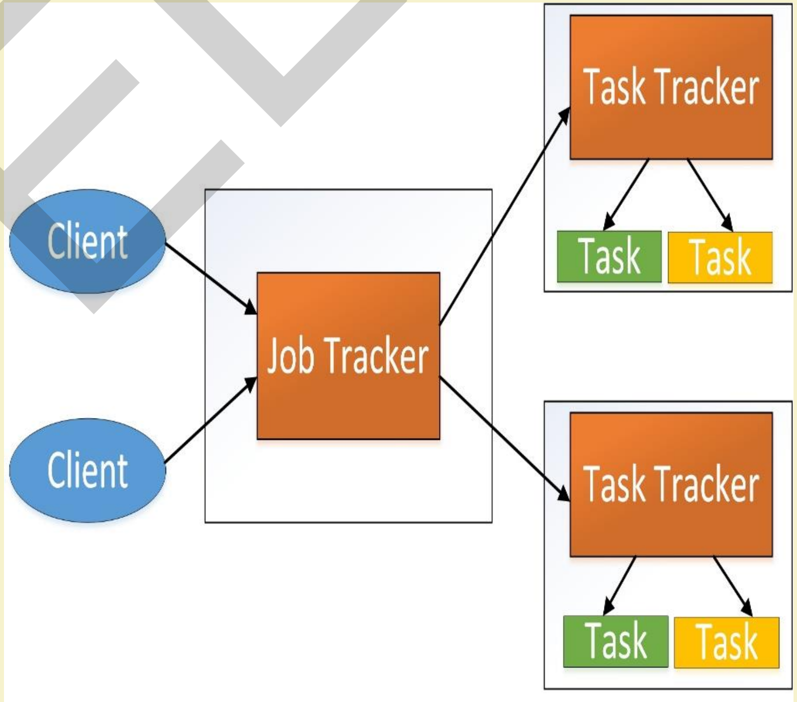


Name and Data Nodes

- Name Node
  - Stores filesystem metadata.
  - Maintains two in-memory tables, to map the datanodes to the blocks, and vice versa
- Data Node
  - Stores actual data
  - Can talk to each other to rebalance and replicate data
  - Update the namenode with the block information periodically
  - Before updating, datanodes verify the checksums

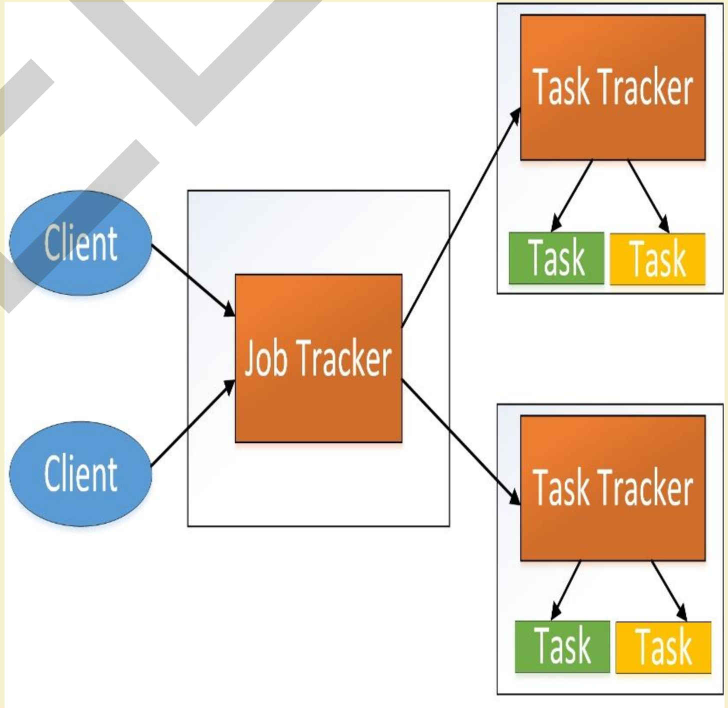
Job and Task Trackers

- Job Tracker
  - Runs with the Name Node
  - Receives the user's job
  - Decides on how many tasks will run (number of mappers)
  - Decides on where to run each mapper (concept of locality)
- Task Tracker
  - Runs on each Data Node
  - Receives the task from Job Tracker
  - Always in communication with the Job Tracker reporting progress



Hadoop Master/Slave Architecture

- Master
  - Executes operations like opening, closing, and renaming files and directories
  - Determines the mapping of blocks to Data Nodes
- Slave
  - Serves read and write requests from the file system's clients
  - Performs block creation, deletion, and replication as instructed by the Name Node

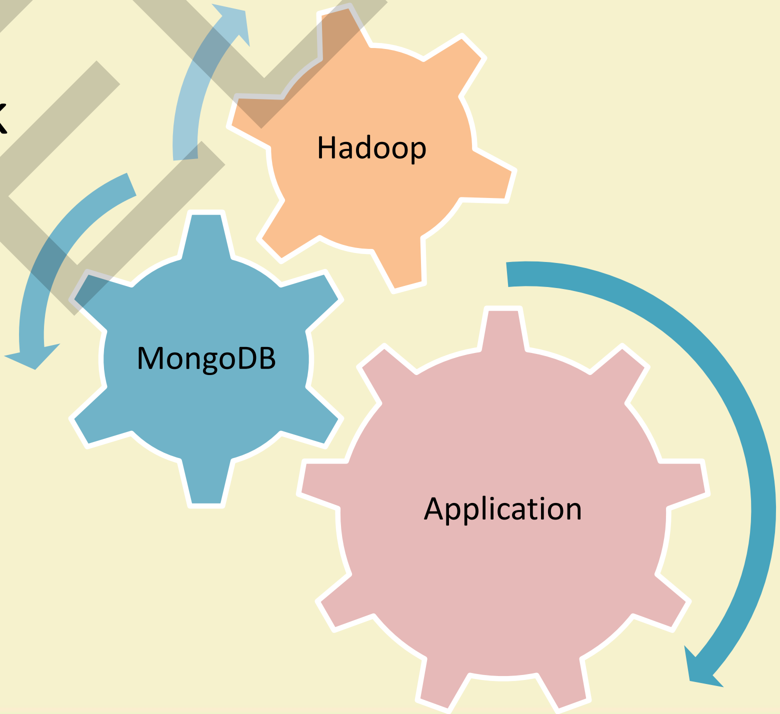


MongoDB in Data Management

- Uses Relational Database
- Ensures
  - Performance
  - Scalability
  - Availability
- Creates a similar view of data across the enterprise

MongoDB with Hadoop

- ➢ Hadoop adds a powerful framework to MongoDB for complex analytics
- ➢ Applications:
  - ➢ Batch Aggregation
  - ➢ Data Warehouse
  - ➢ ETL Data



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Thank You!!

IIoT Analytics and Data Management: Data Center Networks

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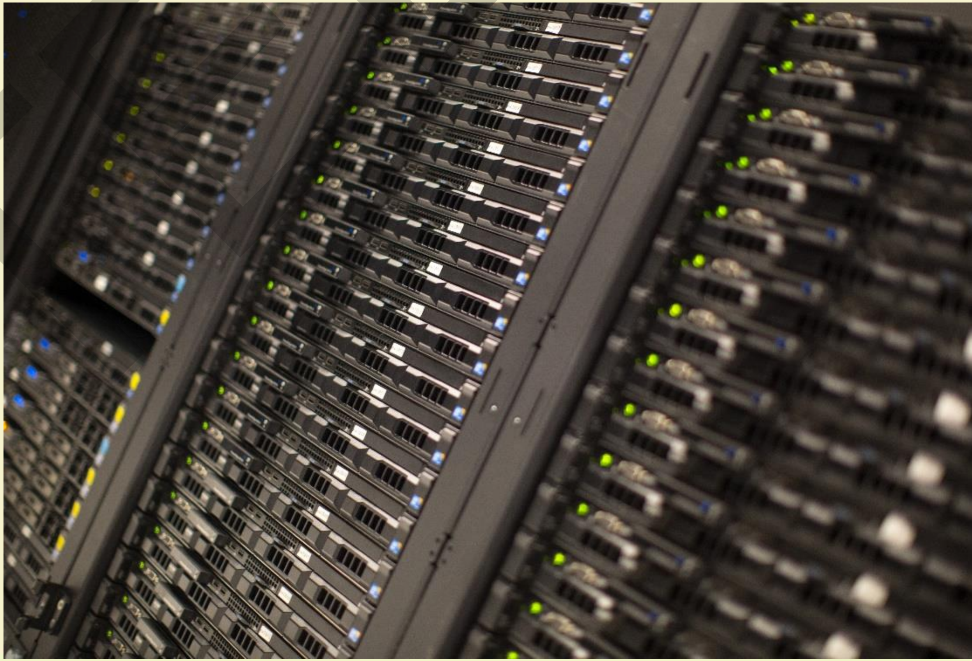
What is Data Center Networks

- Data Center
  - Composed of networked computers and storage
  - Core of an organization's information system
- Data center networks
  - Interconnects the different data center resources such as computational, storage, network entities
  - Accommodates different data centers having varying dataload

Data Center (Example)

- Wikimedia Foundation



Source: **Wikimedia Foundation Servers 2015-90.jpg**, VGrigas (WMF), Published date: **21 July 2015**, Online: **https://commons.wikimedia.org/wiki/File:Wikimedia_Foundation_Servers_2015-90.jpg**

Data Center Network: Properties

- Stable
- Secure
- Reliable
- Supports networking requirements
- Scalable
- Agility (any service on any server at any time)

Data Center Network: Requirements

- <u>VM migration without changing IP address</u>
- <u>No need to configure switch</u> before deployment
- Path should be available among the end-users to communicate
- Fast <u>detection of failure</u>
- Efficient <u>repair of failure</u>

Data Center Applications

- Outward facing applications
  - Serving web pages to users
- Internal computational applications
  - MapReduce for web indexing
- Running multiple concurrent services

Data Center Network: Topology

- Three-tier DCN
- Fat Tree DCN
- Dcell
- BCube

Data Center Network: Topology (Contd.)

- Three-Tier DCN
  - Multi-rooted tree based network topology
  - Three layers of network switches
    - Edge
    - Aggregate
    - Core
  - Disadvantages:
    - Scalability, fault tolerance, energy efficiency, and cross-sectional bandwidth

Data Center Network: Topology (Contd.)

- Fat-Tree DCN
  - Inter connects K-ary Fat tree
  - Three-tier topology
    - Edge, Aggregation, Core
  - Pod at edge tier consists of $(k/2)^2$ servers and (k/2) k-port switches
  - Each edge switch connects to (k/2) servers and (k/2) aggregation switches
  - Each aggregation switch connects to (k/2) edge and (k/2) core switches
  - $(k/2)^2$ core switches, each of which connects to k pods

Data Center Network: Topology (Contd.)

- DCell
  - Uses a recursively-defined structure to interconnect server
  - Server is connected to several other servers and a mini-switch via communication links
  - Low-level DCells form a fully-connected graph
  - Fault tolerant
  - No single point of failure

Data Center Network: Topology (Contd.)

- BCube
  - Server-centric approach, rather than the switch-oriented practice
  - Places intelligence on modular data center (MDC) servers
  - Provides multiple parallel short paths between any pair of server
  - Constructs edge-disjoint complete graphs
  - Forms multiple edge-disjoint server spanning tree
  - Runs a source routing protocol called BSR (Bcube Source Routing)

Data Center Network: Technology

- Networking equipment
  - Routers
  - Switches
  - Modems
- Network cabling
  - LAN/WAN
  - Network interface cabling

Data Center Network: Technology (Contd.)

- Network addressing scheme
  - IPV4
  - IPV6
- Network security
  - Security protocols or encryption algorithms
  - Firewalls
- Internet connectivity
  - Satellite, wireless, optical

Data Center Network: Challenges

- Scalability
- Poor server-to-server Connectivity
- Static resource assignment
- Resource Fragmentation
- Fault-tolerance

Data Center and IIoT: Challenges

- Data
- Security
- Consumer Privacy
- High Availability
- Storage Management
- Data Center Network

Data and IIoT: Challenges

- Generates a substantial amount of data
- Continuously learn about the end-user and industrial appliances
- Storage
  - Consumer Driven
  - Enterprise driven

Security and IIoT: Challenges

- Connects a large number of assets or device
- Communicate automatically
- Increase in digitization and automation of devices
- Devices are spread across different areas
- Absence of a secure and properly encrypted network

Consumer Privacy and IIoT: Challenges

- Presence of several IoT connected things
- Vast amounts of data
- Information on users' personal use of devices
- Personal information generated by the devices serves as the key to bringing improved services
- Improve management of IoT devices at industries

High Availability and IIoT: Challenges

- Innumerable devices are connected
- Generated big data
- Increase in the complexity of security management
- Impact due to security challenges
- Real-time business process
- Personal data safety

Storage Management and IIoT: Challenges

- Increase in demand of storage capacity
- Large amounts of data generated by connected devices
- Cost efficient storage for IoT devices

Data Center Network and IIoT: Challenges

- Support for bandwidth requirements
- Drastic change in bandwidth pattern
- Bulk amount of small messages having sensor data
- Requirement for increase in inbound data center bandwidth

Software-Defined Data Center for IIoT

- Software defined data center
  - Virtualized data storage
  - Data center as a service
- Abstracted from hardware
  - Deployment
  - Operation
  - Provisioning
  - Configuration

Software-Defined Data Center: Components

- Network virtualization
- Storage virtualization
- Server virtualization
- Business logic layer

Software-Defined Data Center: Advantages

- Separation of control and data panel
- Agility
- Elasticity
- Scalability
- Cloud Computing
- Programmable infrastructural and workload management

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Advanced Technologies:
Software-Defined Networking (SDN) in IIoT – Part 1

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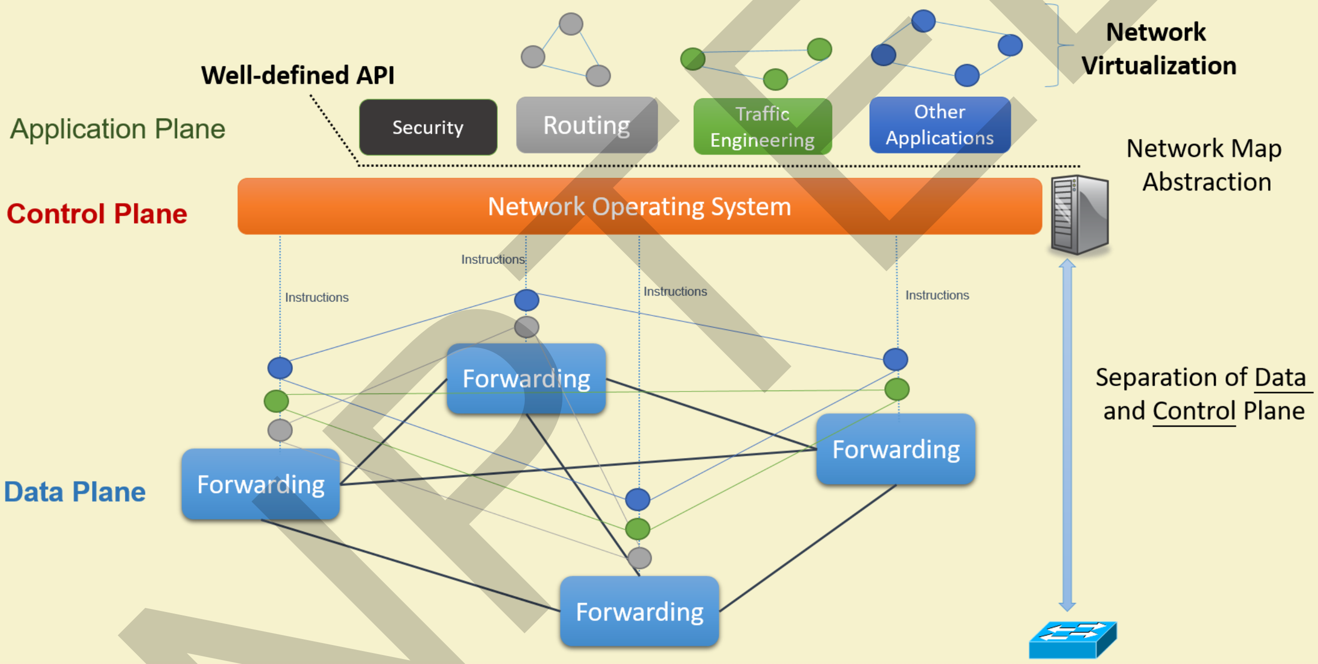
Software-Defined Network (SDN)

- What is SDN?
  - Restructuring the current network infrastructure for improved network management.
  - It is not a new technology – rather reshaping the current network architecture.
  - Control and data planes are decoupled from the traditional forwarding devices.

SDN Architecture



SDN Components/Attributes

- Application programming interfaces (APIs)
- Controller
- Forwarding devices
- Protocol – OpenFlow
- Applications

SDN Aspects

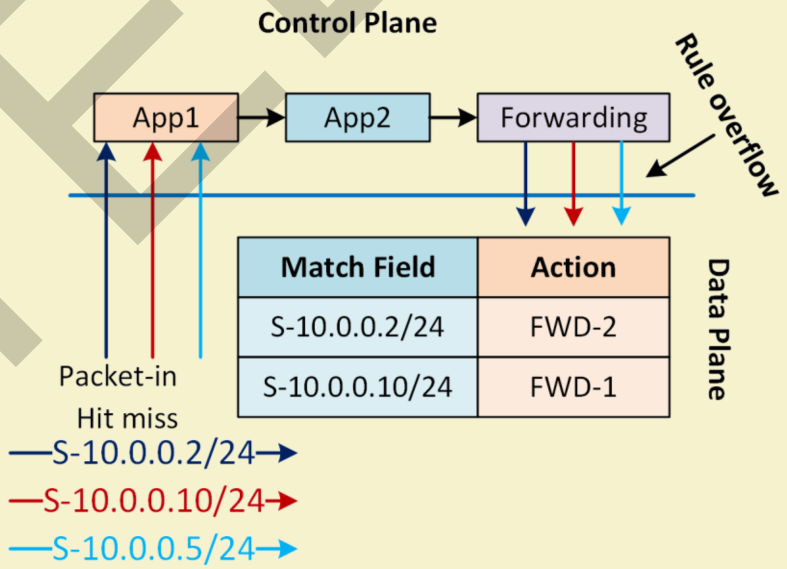
- Rule Placement
- Controller Placement
- Security

Rule Placement

- Forwarding devices forward an incoming traffic based on the control logic defined by the SDN controller.
- The control logic is placed at the devices in the form of flow-rule.
- Ternary content addressable memory (TCAM) available at the devices is used to place the flow-rules.
- TCAM is limited – limited number of flow-rules can be placed.

Rule Placement (contd.)

- Flow-rule for first two flows are inserted.
- Rule for third incoming flow cannot be inserted due to rule capacity constraint.
- How to accommodate the new flow?
  - Existing rule may be deleted
  - Two rules may be combined (wildcard) to make them one rule



Controller Placement

- How many controllers required?
- What should be there placement – flat, hierarchical, etc.
- What about fault-tolerance – backup controller?

Security

- Firewall
- DoS attack
- Reliable and secure connection between SDN controller and forwarding devices
  - Currently, TCP with TLS is used for communication between controller and forwarding devices.

SDN Applications I

- Network management – backbone Internet
- Traffic Engineering (Katta et al., 2016)
- Load Balancing (Qiao et al., 2016)
- Dynamic access control between user and access points (Suresh et al., 2012)
- Mobility Management (Li et al., 2014; Bera et al., 2016)

SDN Applications II

- WSN Management (Galluccio et al., 2015; Bera et al., 2016)
- IoT Applications (Bera et al., 2017)
- IIoT Applications (Wan et al., 2016)

Software-Defined IIoT (SDIIoT)

- Challenges/Requirements in IIoT network:
  - Network Segmentation
  - Policy-based data forwarding
  - Remote control of devices' functionalities
  - Security

Network Segmentation

- Data from IIoT system is typically follows UDP service.
- Streaming the UDP data over TCP/IP may reduce network performance.
- If want to use the same/common network for all applications, network architecture and forwarding policies need to be changed.

- SDN is capable of address such issues by separating control and data planes from the traditional forwarding devices.

Policy-based Data Forwarding

- Several sensors/actuators would be placed to monitor/actuate real-time status of industrial equipment.
- Forwarding policies may need to change dynamically depending on real-time situation.
- For example, temperature data may have higher priority compared to humidity, and vice-versa, in different time periods. How to meet such requirements dynamically?
- Rule-based forwarding policies in SDN would be capable of meeting such requirements of IIoT.

Remote Control of Devices’ Functionalities

- A device with multiple sensors may be planted in an industrial component to monitor different parameters simultaneously or according to requirements.
- The system should be capable of controlling the sensor-device’s functionality remotely to meet requirements.
- Software-defined approach is capable of achieving such requirements.

Security

- Securing the network and device is another important aspect.
- Flow-based forwarding in SDN is capable of preventing DoS attacks.
- Customized middleware is also useful for improved security in IIoT network.

SDIIoT Advantages

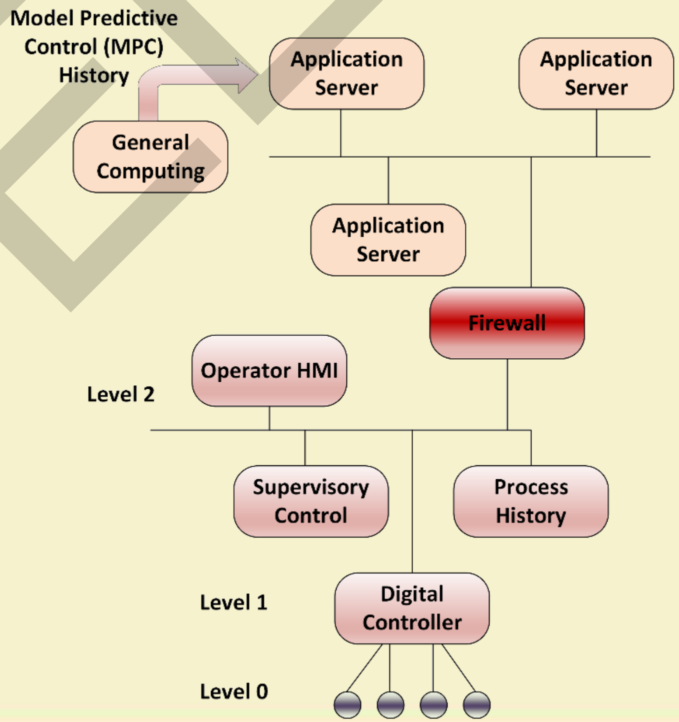
- Low-latency virtualization of VMs
  - Dynamic capacity adjustment based on demand
  - Easy migration of VMs using software-defined policies
- Deterministic networking
  - Logically centralized view of the network
  - Rule-based forwarding enables deterministic forwarding of traffic over network – so that events are processed in order

- High availability
  - Fault-tolerance feature of SDN would help IIoT system to enable new servers or software to deal with faults
  - Carrier grade telecommunication NFV is capable of meeting such requirements
- Robust security
  - Centralized view of the devices and events provides improved security
  - Each component of IIoT system would be monitored – which will help us to prevent unwanted access of the system

- Up-to-date applications
  - The open architecture of devices enables administrators to run up-to-date applications
  - Cost-effective, reliable, and secure management is possible by using the up-to-date applications

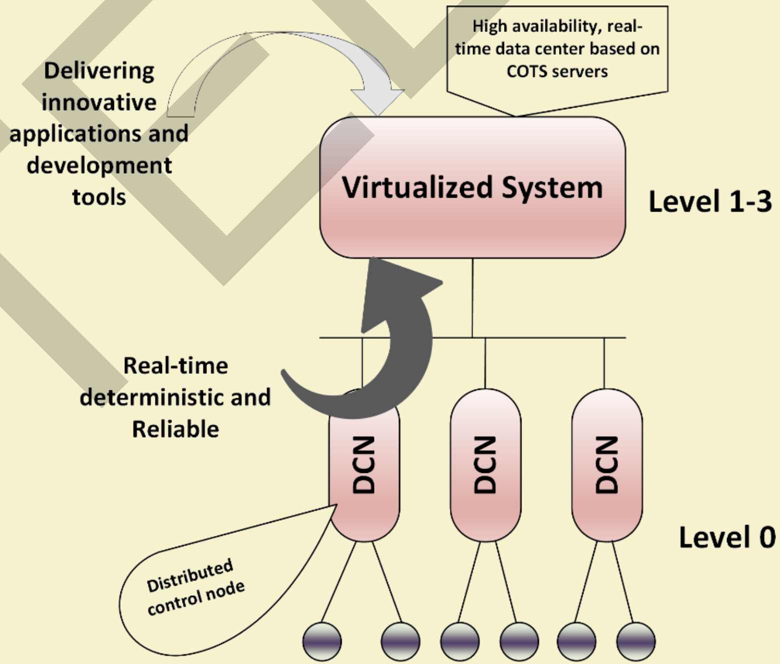
Current Practice: Automation

- ➢ Level 0 – Sensors
- ➢ Level 1 – Digital controllers
- ➢ Level 2 – Supervisory control



Software-Defined Automation

- ➢ Virtualized platform
- ➢ Dynamic, real-time control of systems



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Advanced Technologies: Software-Defined Networking (SDN) in IIoT – Part 2

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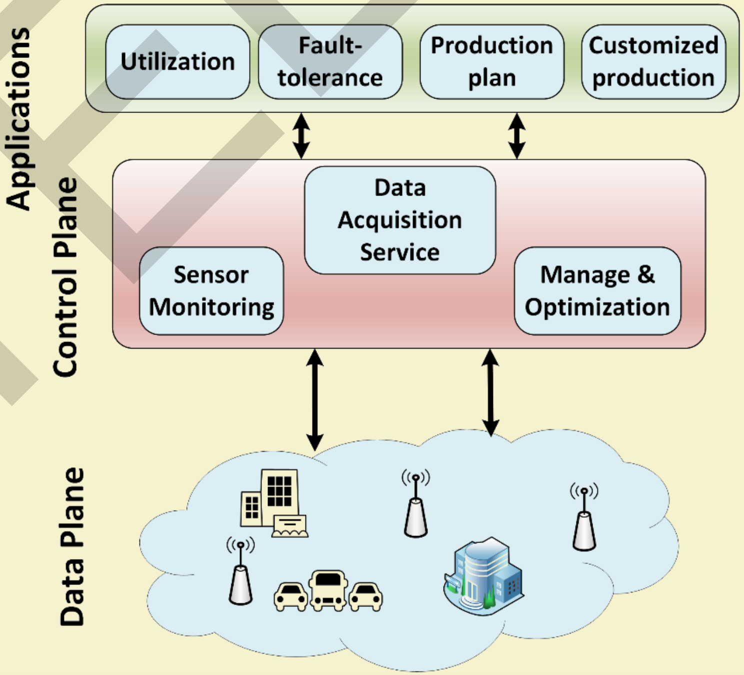
SDIIoT Architecture

- SDIIoT – WSN
- SDIIoT – Public Networks
- SDIIoT – Industrial Cloud
- SDIIoT – Industrial bus & network

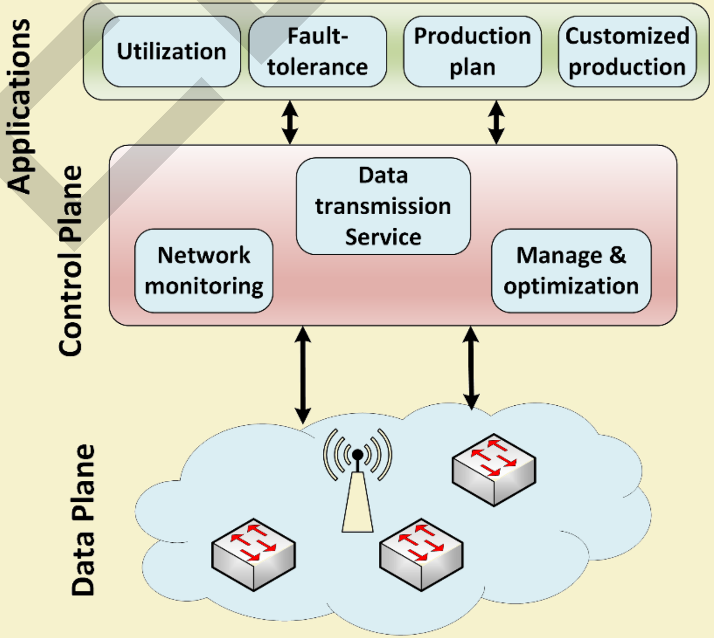
SDIIoT Architecture - WSN

- Software-defined WSN platform in the context of industry 4.0



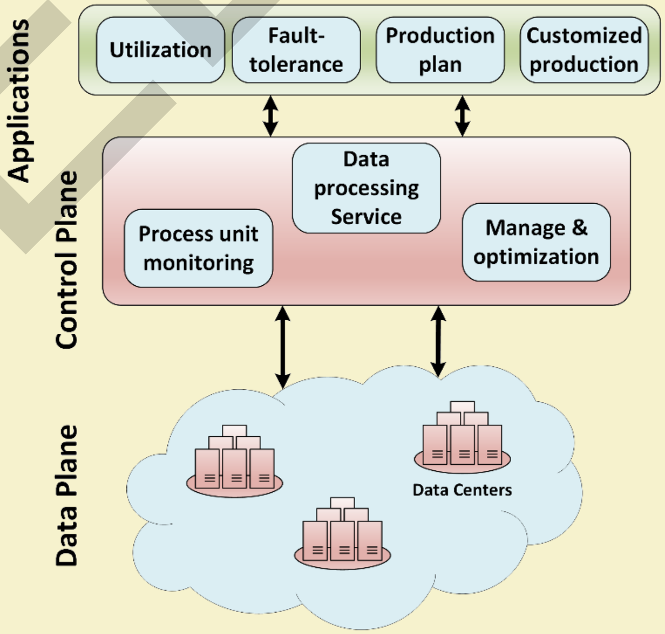
SDIIoT Architecture – Public Networks

- Public network consists of switches, routers, and access network.
- Network monitoring, management and optimization are done at the control plane.



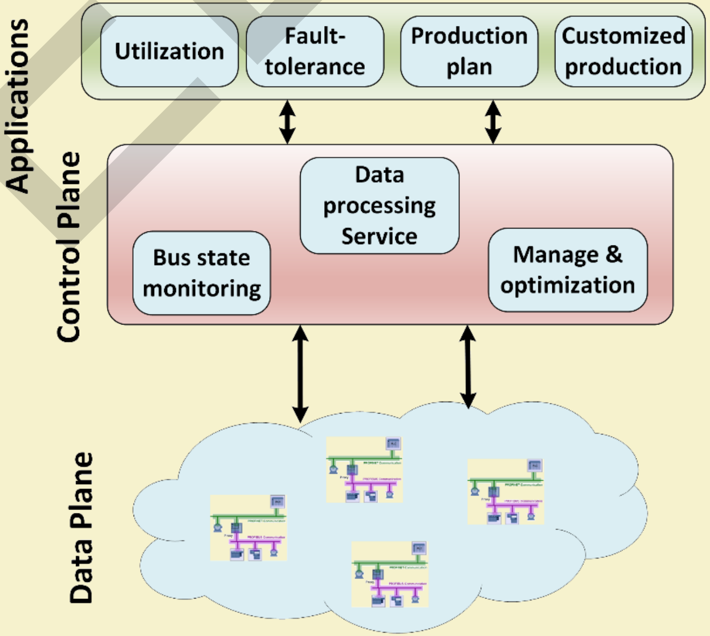
SDIIoT Architecture – Industrial Cloud

- Focuses on data center network.
- Data processing is done at this stage.



SDIIoT Architecture – Industrial Bus & Network

- It includes bus network.
- Monitoring of bus network is done.



Software-Defined 6TiSCH IIoT

- Time scheduled channel hoping (TSCH)
  - Deterministic communication
  - Efficient resource allocation in constrained networks (e.g., IoT and IIoT)
- IETF 6TiSCH is introduced to achieve the objectives

Challenges: SDN in 6TiSCH

- Unreliable link – low power and lossy network
- Control overhead due to message exchange between SDN controller and devices
- Increased jitter

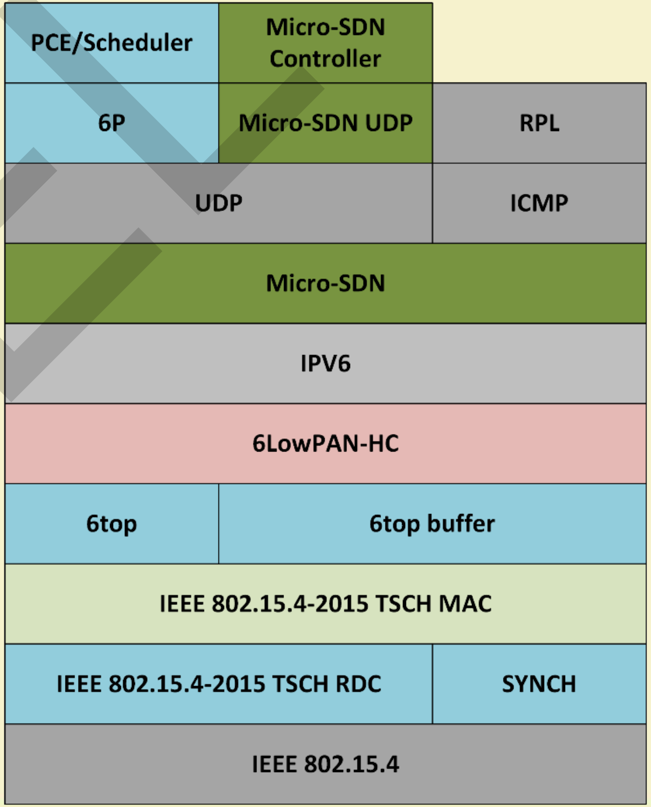
Software-Defined 6TiSCH*

- Slicing mechanism is proposed in Layer-2
- Dedicated forwarding paths across 6TiSCH network
- Slicing mechanism isolates the control overhead
- Allows deterministic and low-latency SDN controller communication
- Advantages of SDN is utilized, while minimizing the associated control overhead

*Baddeley et al., '17

SD-6TiSCH Protocol Stack

- μSDN incorporates features for minimizing controller overhead
- Integrated with the Contiki IEEE 802.15.4-2015 stack



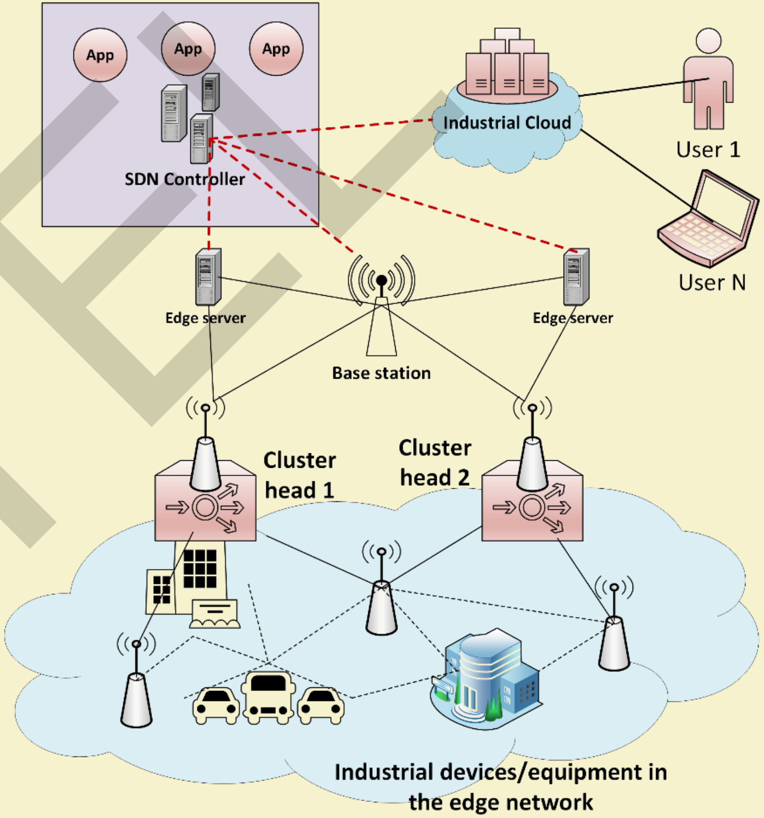
SD Edge Computing for IIoT*

- Adaptive transmission architecture with SDN and EC is proposed for IIoT
- Data stream is divided into two categories:
  - Ordinary data stream
  - Emergent data stream
- Emergent stream is served by finding paths which meet requirements based on a coarse-grained transmission path algorithm

*Li et al., '18

SD-Edge IIoT Architecture

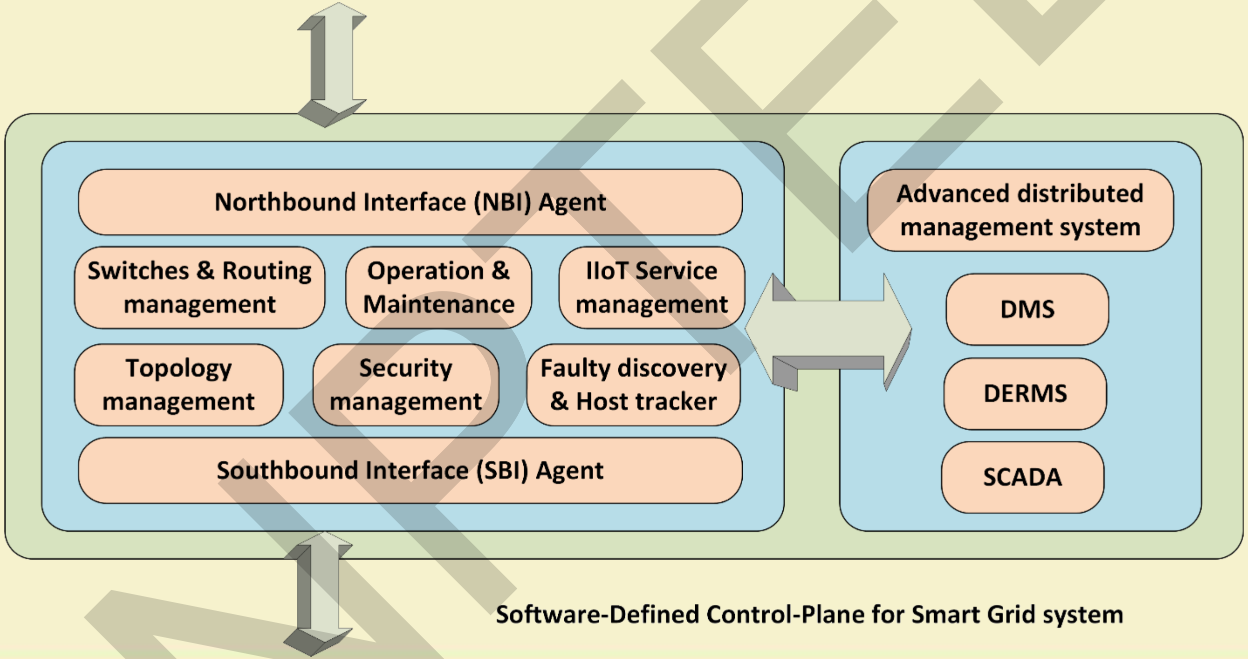
- Cluster head
- Industrial cloud
- Edge network
- SDN controller
- Devices/equipment
- Applications



Software-Defined Control Plane for Smart Grid*

- Smart grid monitoring system using a centralized controller
- Distribution management system (DMS)
- Distributed energy resource management system (DERMS)
- Supervisory control and data acquisition (SCADA)
- Presence of APIs at both ends – distribution side and generation side

*Al-Rubaye et al., ’17



Software-Defined Control-Plane for Smart Grid system

Challenges and Opportunities

- Absence of SDN protocol (like OpenFlow) for low power & lossy network
  - New protocol for enabling interaction between SDN controller and resource constrained devices may be proposed
  - Restructure of controller architecture and placement?
  - Do we need IoT middleware in software-defined IIoT system?

Challenges and Opportunities (contd.)

- Fog node/access devices play important role to provide emergent services (delay-constrained)
  - Can we utilize fog nodes as SDN controller?
  - What about the fault-tolerance of fog nodes?
  - Distributed/semi-distributed/fully centralized architecture?

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Thank You!!

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Advanced Technologies: Security in IIoT – Part 1

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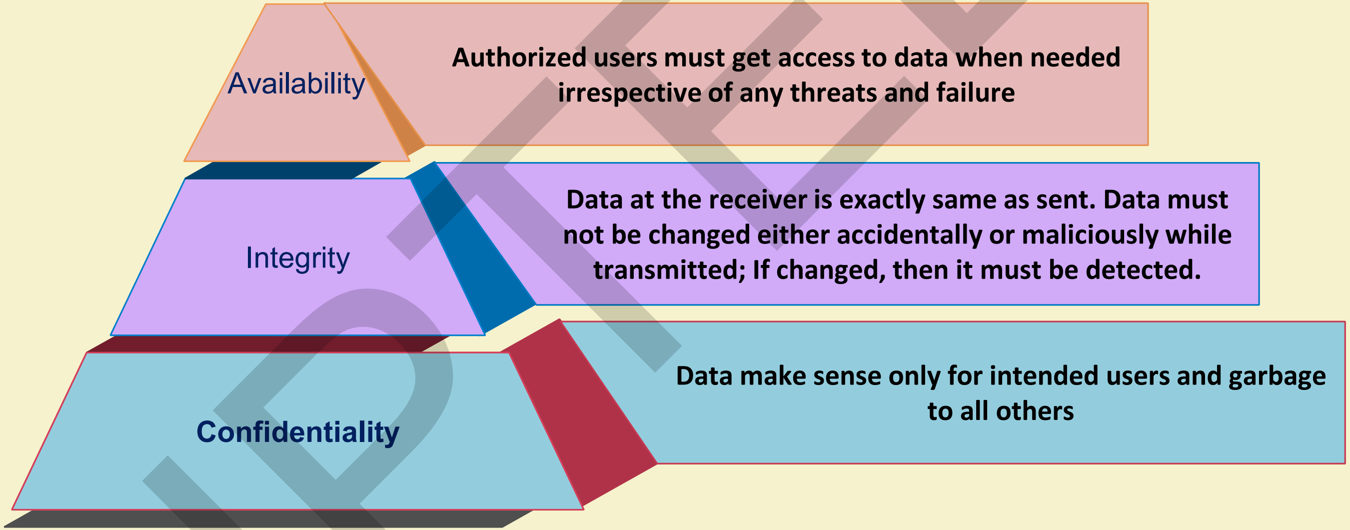
Need for IIoT Security

- Network of resource-constrained devices with low-bandwidth channels
- Devices with heterogeneous storage and processing capability
- Exposed to large attack surface
- Threats from hazards, device malfunctions and human errors
- Risks of Industrial accidents, disclosure of sensitive data and interrupted operations

Source: "Industrial Internet of Things Volume G4: Security Framework", Industrial Internet Consortium

Basic Security Goals

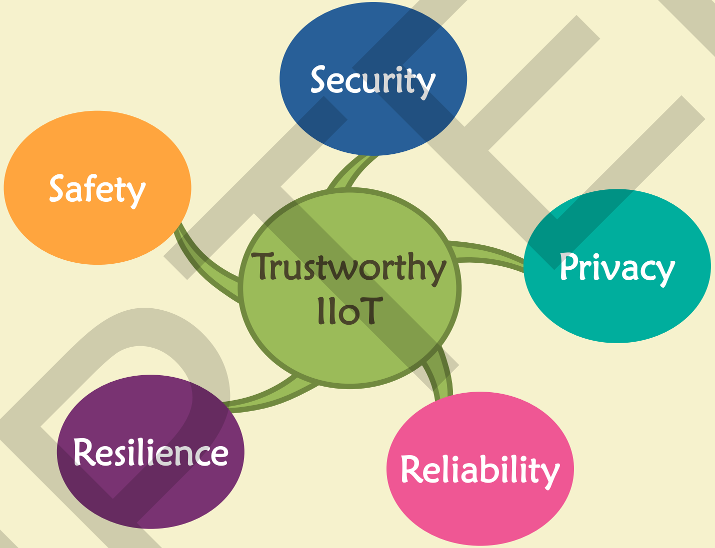


Source: “An Introduction to Information Security”, NIST

Trustworthy IIoT

Safe operations of device and people without any risks and injury

Ability of the system to function correctly on dynamic adversarial conditions



Protecting the system from Unauthorized access, modification and destruction

Restriction on data access - who can access and by whom it can be disclosed

Ability of the system to perform under stated conditions correctly for the specified time period

Source: “Industrial Internet of Things Volume G4: Security Framework”, Industrial Internet Consortium

Security In IIoT: Distinguished Aspects

- IIoT brings Information Technology (IT) and Operational Technology (OT) together
- Traditional security techniques working independently for IT and OT are no more applicable
- Simply integrating features from IT and OT is not possible
- Information security and device security
- Inadequate regulatory framework and standards.

Source: "Industrial Internet of Things Volume G4: Security Framework", Industrial Internet Consortium

IT and OT Security Requirement

- Current security architectures are mostly IT-centric
- Security assumptions for client-server model with well known communication protocols such as IP, TCP and HTTP.
- Assumes some well-known attacks and attack models
- OT systems only deploy legacy physical security protections
- Out-dated security protection for isolated OT networks
- Security for OT integrated with IT components ignored

Source: "Industrial Internet of Things Volume G4: Security Framework", Industrial Internet Consortium

Cloud Complied IIoT Security Requirement

- OT infrastructure is controlled and managed at external networked cloud
- Data from thousands of devices stored in cloud
- Third-party services with trust-boundaries for security and privacy
- Safeguarding the control systems from incoming cloud information flow

Source: "Industrial Internet of Things Volume G4: Security Framework", Industrial Internet Consortium

IIoT Security Risk Management

01 Avoiding risks

02 Mitigating risks

03 Outsourcing risks

04 Accepting risks

05 Balancing residual risks

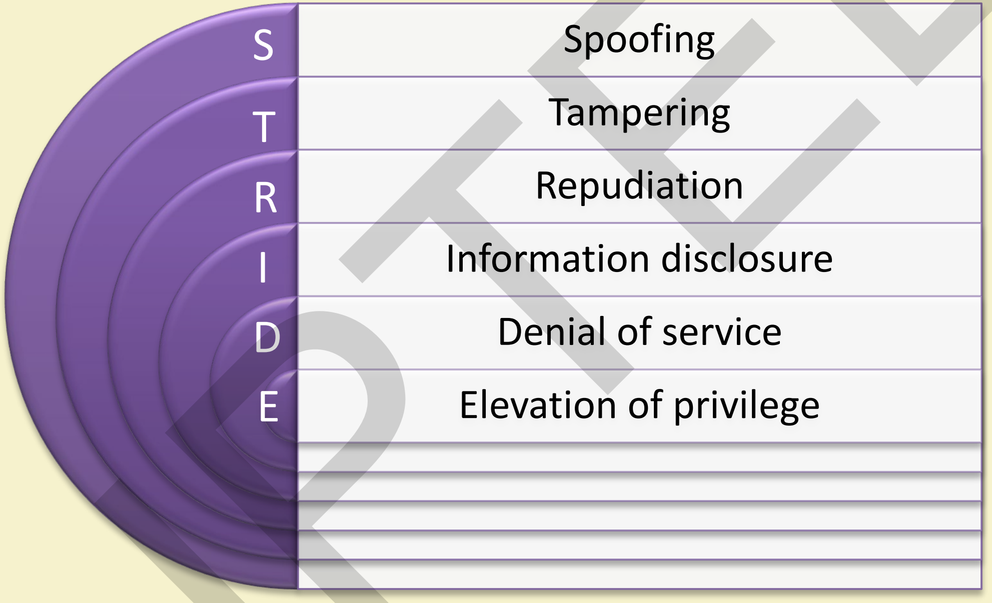
Source: “Industrial Internet of Things Volume G4: Security Framework”, Industrial Internet Consortium

Classes of Attackers

- Outsourced firms
- Hardware vendors
- Third-party service providers like cloud vendors
- Internal unethical employees
- Organized crime groups

Source: "The who and how of cyber-attacks: types of attackers and their methods", Out-law

STRIDE Threat Model



Source: “IoT Security Architecture | Microsoft Docs", Microsoft Azure

IIoT Attack Surface

Application

- Data stores
- Interfaces
- Application software

Network

- Gateway devices
- Local intelligent devices
- Routers

Physical

- Sensors and actuators
- Industrial process control devices

Source: “IoT Attack Surface Areas”, OWASP

IIoT Attack Vectors: Application Layer

- Data spoofing
- SQL injection
- DoS or DDoS
- Replay attack
- Resource exemption
- Reversal attack

Source: IoT Attack Surface Areas", OWASP

IIoT Attack Vectors: Network Layer

- Traffic flooding
- Man-in-the-middle attack
- Misrouting
- Packet sniffing
- Resource exemption

Source: IoT Attack Surface Areas", OWASP

IIoT Attack Vectors: Physical Layer

- Impersonation attack
- Jamming attack
- Device tampering

Source: IoT Attack Surface Areas", OWASP

Trustworthiness Management

Security measures adaption

Quick response to security threats

Coordination between organizations for early threat identification

Source: “Industrial Internet of Things Volume G4: Security Framework”, Industrial Internet Consortium

Trust Permeation in IIoT

- Hierarchical trust flow with in the IIoT system
- IIoT system consists of many units: design, development, manufacturing, logistics, etc.
- Trust permeation deals with trust establishment in all the components through the entire life cycle
- Device integrity and trustful chain of the devices make the whole system a secure one

Source: "Industrial Internet of Things Volume G4: Security Framework", Industrial Internet Consortium

Trust Flow in IIoT System

System Owner

Specify the system and operational requirements

System Builders

Specify trust requirements component builders

Validate and integrate the trust components

Component Builders

Build and deliver devices with specified trust requirements

Source: "Industrial Internet of Things Volume G4: Security Framework", Industrial Internet Consortium

Trust Functionalities: System Owner

- Every trust components are realized by the system owner
- The owner always ensures :
  - Trust requirements are met
  - The system works against the threats
  - Security patches and updates are implemented timely
  - Security risks are evaluated for further modifications

Source: "Industrial Internet of Things Volume G4: Security Framework", Industrial Internet Consortium

Trust Functionalities: System Builder

- Feasibility of user requirement as per regulatory standards
- Design of a cost-efficient trustworthy system
- Trust requirements for every component and subcomponents
- Tests and certifications for component builder products
- Timely trust verification of devices and services

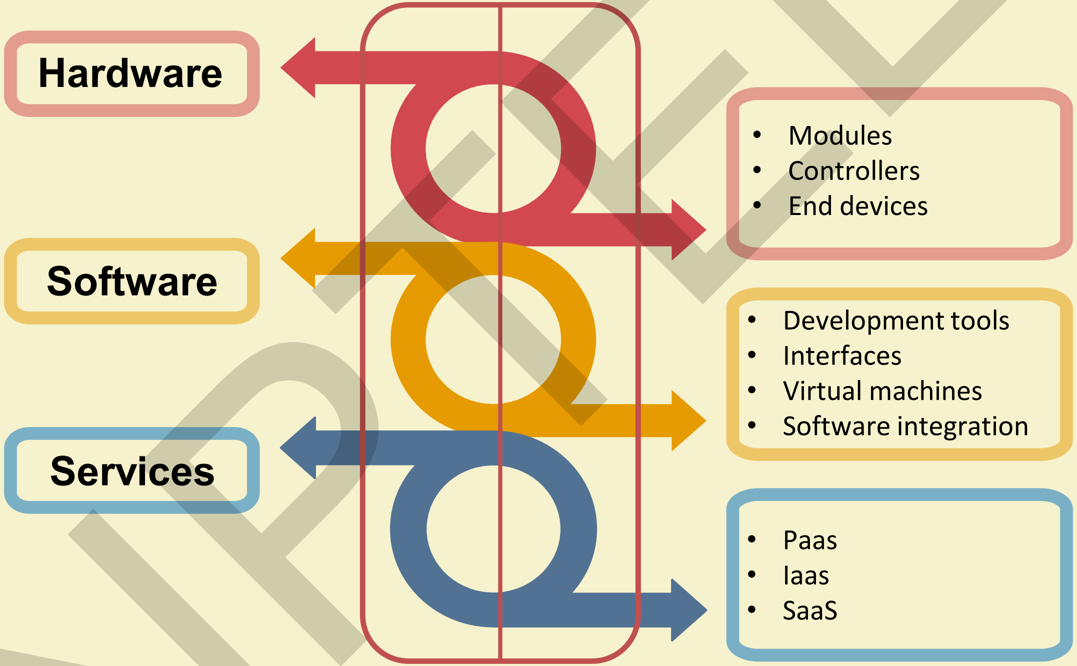
Source: "Industrial Internet of Things Volume G4: Security Framework", Industrial Internet Consortium

Trust Functionalities: Component Builder

- Hardware developers include trust requirements to devices and ensure trust compatibility with other components
- Software developers ensure security requirements with hardware compatibility and support for future updates
- Trust support for hardware or software replacements
- Trust support for different services

Source: "Industrial Internet of Things Volume G4: Security Framework", Industrial Internet Consortium

Trust Functionalities: Component Builder (Contd.)



Source: "Industrial Internet of Things Volume G4: Security Framework", Industrial Internet Consortium

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Advanced Technologies: Security in IIoT – Part 2

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Security requirements for IIoT

- End-to-end security is the primary requirement of IIoT
- Both horizontal and vertical security are important
- Security of the whole system depends:
  - Security of deployed devices
  - Communication security
  - Data protection
  - Security management

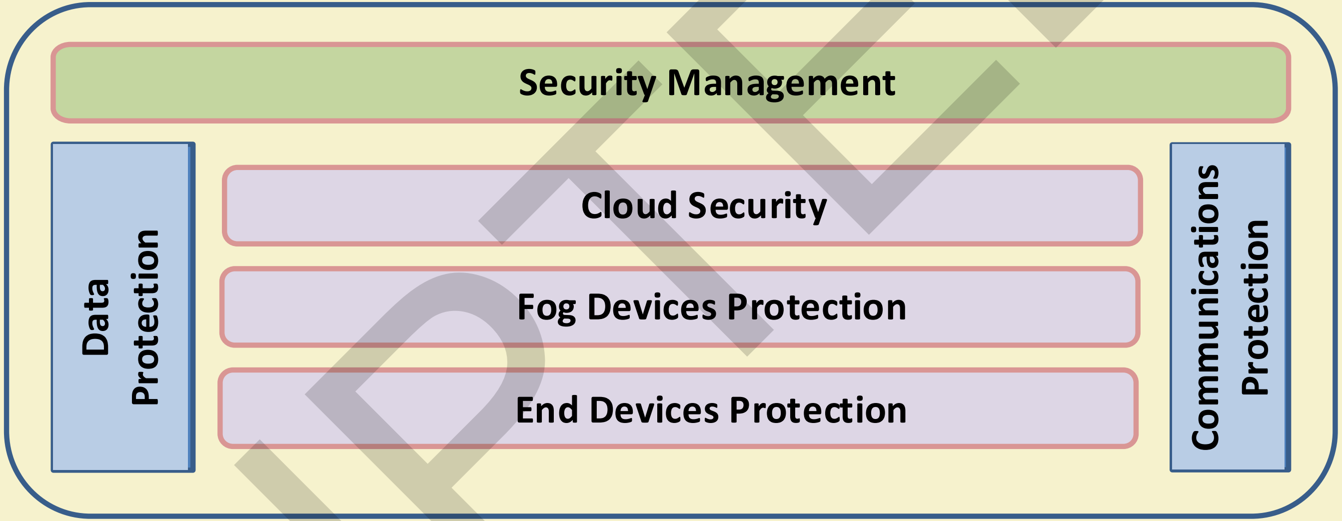
Source: “Industrial Internet of Things Volume G4: Security Framework”, Industrial Internet Consortium

Security Framework for IIoT

- Every industrial application of IoT must have a security framework with its own requirements and solutions
- The framework should address:
  - Different security issues in IIoT
  - Trustworthy IIoT System
  - Major security building blocks of IIoT
  - Techniques for securing each independent block and secure integration

Source: “Industrial Internet of Things Volume G4: Security Framework”, Industrial Internet Consortium

IIoT Security Building Blocks:



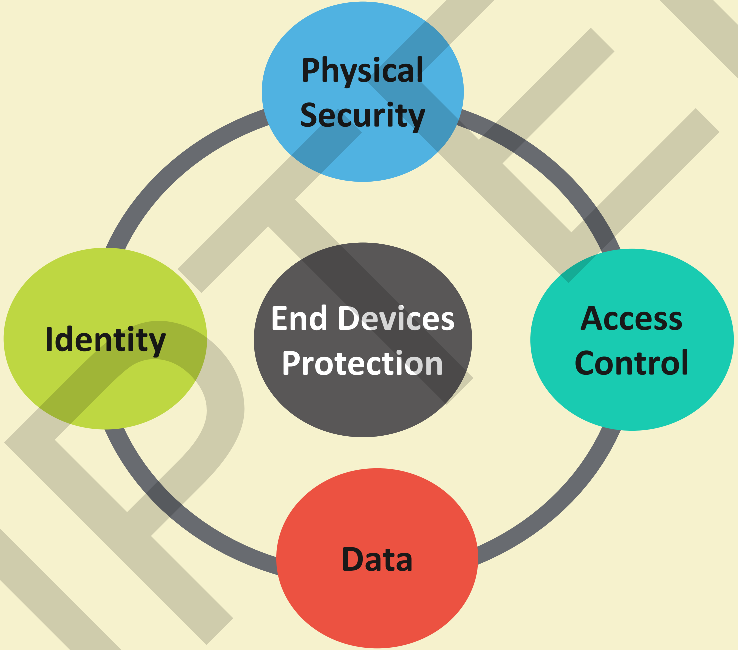
Source: "Industrial Internet of Things Volume G4: Security Framework", Industrial Internet Consortium and "Security for the Industrial Internet of Things", Accenture

End Devices Protection - Challenges

- Devices: sensors, actuators, machines and many small embedded devices
- Resource constrained
- Many devices are mobile
- Heterogeneous
- No support for standard cryptographic protocols

Source: “Security for the Industrial Internet of Things”, Accenture

End Devices Protection - Requirement



Source: “Industrial Internet of Things Volume G4: Security Framework”, Industrial Internet Consortium

End Devices Protection - Solutions

- Lightweight cryptographic protocols
  - Energy efficient authentication
  - Lightweight symmetric key cryptography
- IDS and behavior analysis at upper layer devices
  - Malicious behavior detection
  - Abnormal data traffic detection
  - Mitigation using proper actuation unit and signals

Source: Pacheco et al., 2017 and
"Lightweight Cryptography for the Internet of Things", Sony Corporation

Fog Devices Protection

- Devices deployed near to end devices capable of notable computing and storage
- Requirements are same as end devices
- Standard cryptographic protocols for:
  - Authentication between fog devices
  - Authentication between fog devices and cloud
- Lightweight cryptography for security between for authenticating end devices

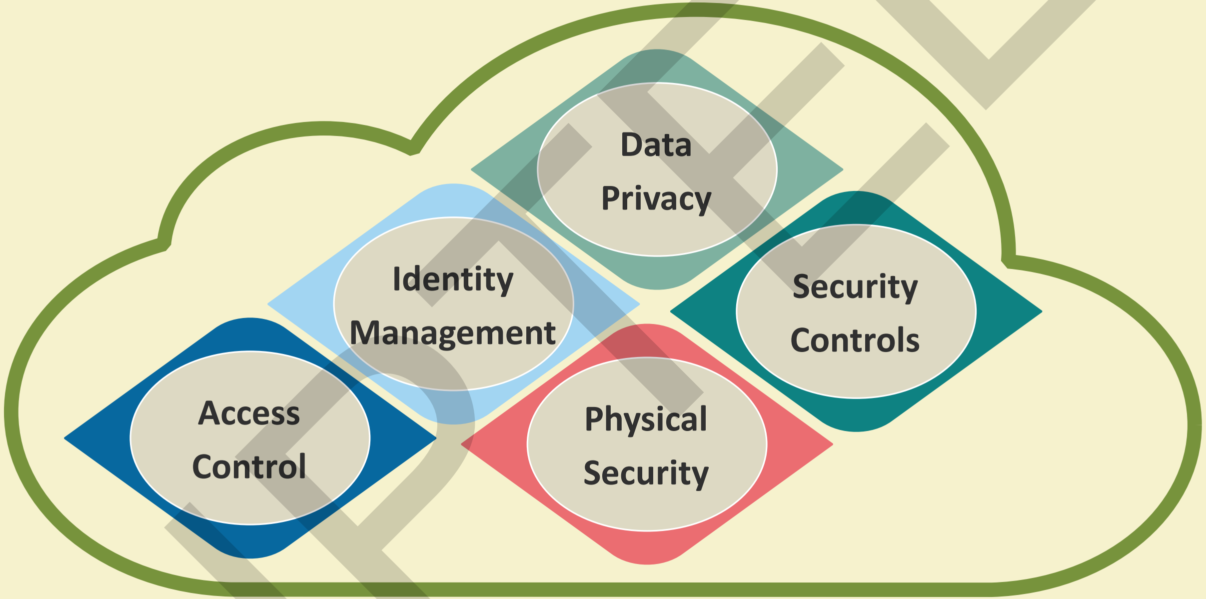
Source: Pacheco et al., 2017

Cloud Security

- Cloud is the data and control hub of the IIoT system
- Security requirement for :
  - Data protection
  - Applications
  - Cloud infrastructure
  - Limiting the service provider access
  - Access control for cloud resources

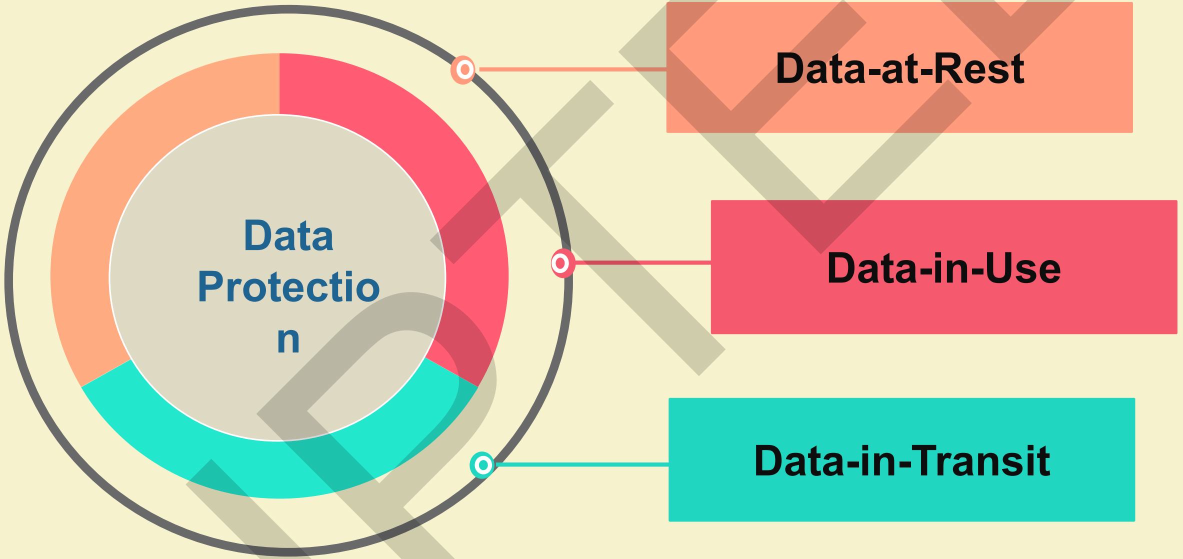
Source: “Cloud computing security”, Wikipedia

Cloud Security



Source: "Cloud computing security", Wikipedia,

Data Protection



Source: “Industrial Internet of Things Volume G4: Security Framework”, Industrial Internet Consortium

Data Protection

- The most sensitive part of IIoT is data
- Different data sources and types with their own lifecycle, risks and security challenges
- Data protection includes:
  - Confidentiality
  - Integrity
  - Availability

Source: “An Introduction to Information Security”, NIST

Communications Protection

- Secure exchange of information between IIoT devices
- Different security risk: sensor data, commands, actuation signals, log reports, configuration messages, etc.
- IIoT traffic and data formats are different from core network
- Protection involves:
  - Communication with devices at the same layer
  - Communication with devices at upper or lower layer

Source: Pacheco et al., 2017

Communications Protection Techniques

- Network access control
- Security gateways
- Network firewalls
- Cryptographic protocols with:
  - Strong mutual authentication
  - Authorization mechanism
  - Data ciphering

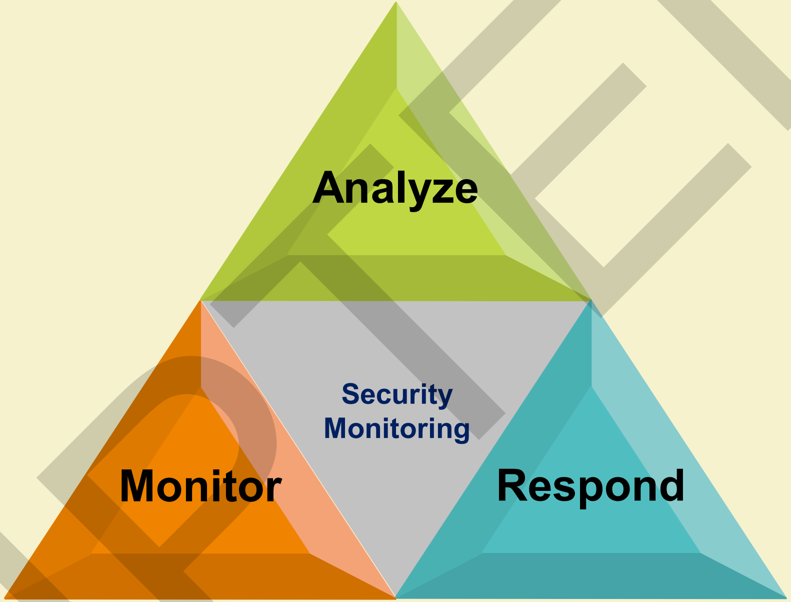
Source: Pacheco et al., 2017

Security Management

- Deals with configurations, periodic updates and managing the security controls
- An active unit, functions from establishment to end of entire IIoT system
- Prevention, detection, analysis and mitigation of security risks
- Performs security monitoring, policy management and updates over time as per standards

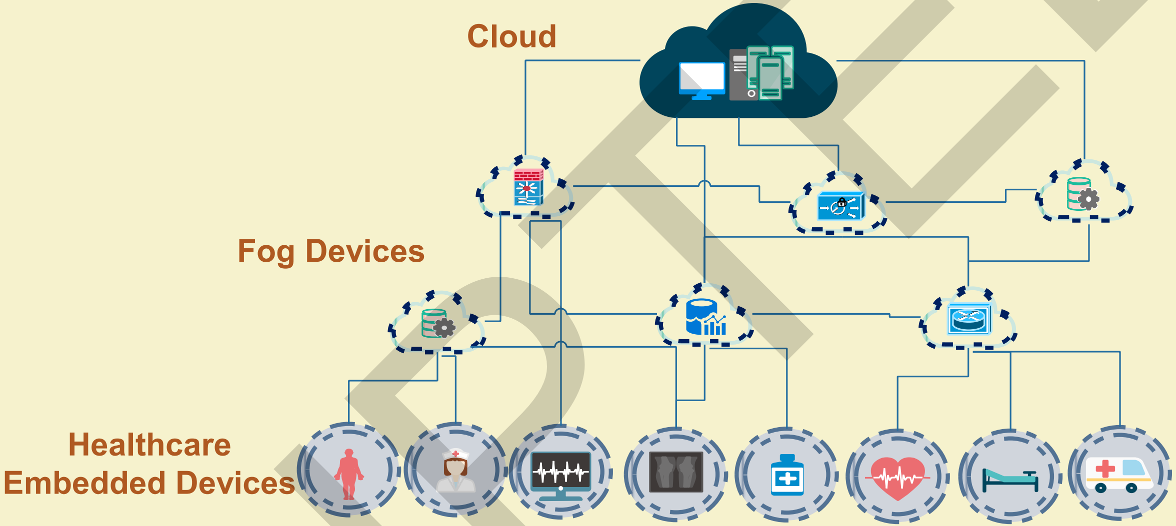
Source: "Industrial Internet of Things Volume G4: Security Framework", Industrial Internet Consortium

Security Monitoring



Source: “Industrial Internet of Things Volume G4: Security Framework”, Industrial Internet Consortium

Use Case – Healthcare Industry



Source: Al-Joboury et al., 2017

Security in Healthcare IoT

- Devices security:
  - Protection of healthcare embedded devices
  - Protection of fog devices - gateways, processing units, data hubs
  - Cloud security
- Communications Security:
  - Healthcare devices - Fog devices (Lightweight cryptography)
  - Fog devices - Fog devices (Cryptography, Firewalls, Security gateways)
  - Fog devices - cloud (Cryptography, Security applications)

Source: Pacheco et al., 2017

Security in Healthcare IoT (Contd.)

- Data Protection:
  - Device data protection (Password, Signatures, Digital certificates)
  - Communication data (data ciphering and hashing)
  - Data at cloud (Access control lists, Signatures, Digital certificates)
- Security Management:
  - Global security handling at cloud
  - SDN-based security management and monitoring

Source: Pacheco et al., 2017 and Flauzac et al., 2017

Regulatory Standards for IIoT Security

- A security standard helps in achieving a common level of security in industries
- Standards help for manufacturers and vendors to offer services at different level of security
- For IIoT, security standards should include requirements of IT and OT
- Till date, there is no security standards specific to IIoT

Source: "Industrial Internet of Things Volume G4: Security Framework", Industrial Internet Consortium

Standards Related to IIoT Security

IT Security

- ISO/IEC 154083: Common Criteria for Information Technology Security Evaluation
- ISO series of standards for privacy, framework and regulations
- ISO 27017, NIST SP 800-144, ENISA standard: Cloud security standards
- Common criteria and Federal Information Processing Standard (FIPS)

OT Security

- IEC 62443: Industrial automation and control systems security
- NIST SP 800-82: Security in Industrial Control Systems
- NERC-CIP: Critical infrastructure protection
- IEEE 1686: Standard for Intelligent Electronic Devices Cyber Security Capabilities
- NISTIR 7628: Guidelines for Smart Grid Cyber Security

Source: “Industrial Internet of Things Volume G4: Security Framework”, Industrial Internet Consortium

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Thank You!!

IIoT Applications: Factories and Assembly Line

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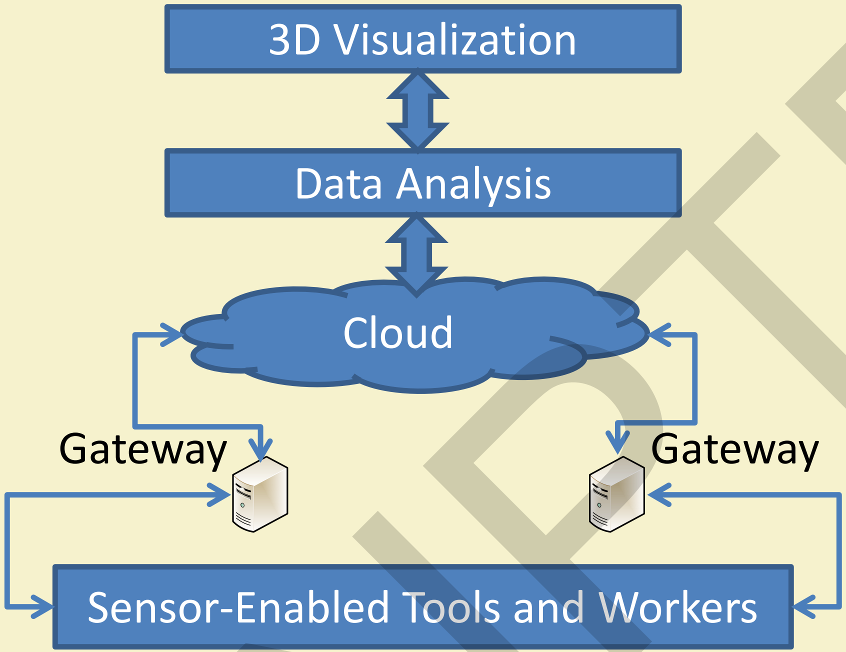
Traditional Manufacturing vs. Smart Manufacturing

- Challenges in Traditional Manufacturing
  - Unavailability of real-time data
  - Unbalanced workload
  - Longer changeover time
  - Extended production time

Smart Factory and Assembly Line

- **Smart Factory** involves machinery and equipment which improve processes through self-optimization and automation.
- Benefits of **Smart Factory**:
  - Supply of real-time data
  - Data analysis and quality control
  - Reduced changeover time
  - Reduced production time
  - Flexibility and easy management

Smart Factory



Overview of a Smart Factory

Features of a Smart Factory

- Connected
  - Continuous real-time data
- Optimized
  - Minimum manual intervention
- Transparent
  - Live metrics for quick decision
- Proactive
  - Prediction of future outcomes for taking preventive actions
- Agile
  - Flexibility and adaptability

Source: https://www2.deloitte.com/insights/us/en/focus/industry-4-0/smart-factory-connected-manufacturing.html

Smart Factory Applications: Airbus – Factory of the Future

- A European aircraft manufacturer
- Applies IoT technologies for production
- Collecting data on flights to improve in-flight experience
- Workers on factory floor use IoT-enabled devices
- Launched digital manufacturing initiative - Factory of the Future

Airbus: Factory of the Future

- Digital tracking and monitoring technology
- Tools and machines with integrated sensors
- Smart wearables
  - Industrial smart glasses
- 3D Real-time visualization of production process
- Deployed on the A330 and A350 final assembly lines in Toulouse
- Deployed for the A400M wing assembly operations in the UK

Smart Factory Applications: Kuka – IoT-Enabled Factory

- A German robotics maker
- Built an IoT-enabled factory
- The factory has hundreds robots
- Robots are connected with a private cloud
- 800 cars are produced per day

Smart Factory Applications: DeWalt – Construction Internet of Things

- A tool manufacturer
- Launched **Construction Internet of Things** initiative
  - Uses IoT Platform and Wi-Fi mesh network
  - Tracks workers and equipment
  - Monitors sites as large as an NFL football stadium

Smart Factory Applications: ABB - YuMi

- A power and robotics firm
- Operates across five continents
- Monitors robots via connected sensors
- Preventive maintenance
- YuMi Model
  - An initiative for collaboration between robots and humans

Smart Factory Applications: Amazon – Robotic Shelves

- An e-commerce company
- Uses robotic shelves
  - Robots carry and rearrange shelves
  - Automated product search
    - Robots locate and bring shelves to workers
- In 2014, the operating cost was cut down by 20% after using robotic shelves

Smart Factory Applications: Caterpillar – AR App

- A heavy-equipment maker
- Uses Augmented Reality (AR) with IoT
- AR app generates end-to-end view of the factory floor
- Machine operators detect need for tool replacement after viewing the end-to-end view
- AR app sends instructions for tool replacement

Caterpillar: IoT-Driven Ship Maintenance

- The marine division uses shipboard sensors to perform **Predictive Maintenance Analytics**
- The sensors monitor generators, engines, GPS, air conditioning systems and fuel meters.
- Analysis of the sensed data provides some useful insights
  - The power usage of refrigerated containers is linked with fuel meter readings
  - The cost of hull cleaning is correlated to performance enhancement
  - Optimized cleaning schedule saves up to $400,000 per ship

Caterpillar: Predictive Maintenance Analytics

- A machine learning technique
- Uses R, Python, and Weka
- Easier fault-correction
- Reduced downtime
- Increase profitability

Smart Factory Applications: Fanuc – Zero Downtime System

- A robotic maker
- Uses predictive maintenance to reduce downtime
- Cloud-based analytics with in-built sensors
- Predicts component failure
- The Zero Downtime (ZDT) system is the winner of the GM Supplier of the Year Innovation Award 2016

Smart Factory Applications: Gehring – Connected Manufacturing

- Makes honing machines
- Uses cloud-based analytics
- Sends real-time data of new machines to customers to confirm requirements before order placement
- Optimizes productivity

Smart Factory Applications: Hitachi - Lumada

- Offers IoT platform – Lumada
- Five layers
  - Edge
  - Core
  - Analytics
  - Studio
  - Foundry

Smart Factory Applications: Maersk – Intelligent Shipping

- A container shipping company
- Tracks assets and fuel consumption using sensors
- Uses IoT for preserving refrigerated containers
- Uses blockchain technology for supply chain optimization

Smart Factory Applications: Magna Steyr – Smart Packaging

- An automotive manufacturer
- Uses IoT for tracking assets including tools and vehicle parts
- Smart packaging
  - Bluetooth-enabled packaging
  - Tracks components in warehouses
- Employees use wearable technologies

Magna Steyr: Driverless Transport System

- Digital factory
  - A virtual image of entire factory is created
  - Virtual image provides real-time control and detects anomaly
- 3D map of digital factory
  - Driverless transport vehicles follow the 3D map to move parts along the assembly line
- IoT-based predictive maintenance
  - Data sensed by driverless transport vehicles are analyzed in cloud to detect deviations

Smart Factory Applications: North Star BlueScope Steel – IoT for Worker Safety

- A major supplier in steel industry
- Attached wearables to helmets and wristbands
- Wearables send health parameters to supervisors
- Supervisors give break to overloaded workers
- Sensors monitor environmental parameters to detect radiation and toxic gases

Some Other Smart Factory Applications

- Rio Tinto: IoT for mining
  - Driverless trucks and trains to pull ore from mining sites
  - Autonomous drill technology
- Real-Time Innovations: microgrid technology
  - Divides a power grid in to multiple distributed microgrids
- Bosch: Track and Trace Testbed
  - Locates handtools and shows specific requirements for each tool
  - Save labour and reduces errors

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IIoT Applications: Food Industry

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IoT and Food Industry

- Sensing layer
  - Networked sensors monitor food quality along the supply chain
  - WSNs monitor environmental conditions
- Communication layer
  - Stakeholders access supply chain data
- Application layer
  - Applications for farmers, retailers, government, analysts, and consumers

IoT and Food Industry: The Future

- Sensors monitor humidity, temperature, and composition of food products
- Real-time data analysis
- Easier process control and increased food safety
- A rice packet can be traced back to the paddy field

Impacts of IoT in Food Industry

- Efficient production line
  - IoT monitors equipment performance
  - Detects anomaly in production line
  - Real-time solutions by predictive maintenance
- Food safety
  - Temperature tacking sensors
  - Automated Hazard Analysis and Critical Control Points (HACCP) checklists

Impacts of IoT in Food Industry

- Transparency of the supply chain
  - Availability of real-time data about products
  - Easier to find inefficiencies
  - Easier to meet food safety regulations
- Less wastage
  - Analysis of real-time information of food products reduce food wastage

Applications of IoT in Food Industry: On the Farm

- Sensors monitor weather, crop maturity, and presence of insects
- Soil moisture sensors optimize irrigation and fertilization

Applications of IoT in Food Industry: In the Livestock Barns

- Sensors monitor health parameters of animals
- Automated feeding cycles
- Diet control
- Automated temperature control in brooding barns and hatchery

Applications of IoT in Food Industry: On Equipment

- GPS tracking
- Drone-assisted field monitoring

Applications of IoT in Food Industry: For Maintenance

- Embedded sensors monitor machine performance
- Early detection of warning signs
- Smart maintenance extends equipment lifetime

Applications of IoT in Food Industry: To Improve Margins

- Predictive analysis
- Spotting early warning signs
- Well informed decisions
- Profit maximization

Applications of IoT in Food Industry: For the Consumer

- SmartLabel
  - An initiative by the Grocery Manufacturers Associations (GMA)
  - Uses QR code to provide product related information to consumers
  - Provides ingredient details, allergens exposure, nutrition value, and many more

Applications of IoT in Food Industry: About the Product

- Consumers scan QR code to access product information
- Product information includes nutrition, ingredients, allergens, third-party certifications, social compliance programs, usage instructions, advisories & safe handling instructions, etc.

Applications of IoT in Food Industry: In the Factory

- Connected processes and workers
- Insights gained from IoT technology help to improve quality
- Reduction in time to market (TTM)

Applications of IoT in Food Industry: About Compliance and Safety

- IoT insights help to identify and isolate unsafe food
- Timely action for food quality and safety issues
- Increases confidence of food manufacturers

Applications of IoT in Food Industry: For Empowering the Workers

- Safety glasses and other wearables
- Increases productivity and efficiency

IoT Solutions for Food Industry: CityCrop – Intelligent Indoor Garden

- Provides intelligent indoor garden to grow fruits, herbs, vegetables, greens, and edible flowers
- Climate control
- Live monitoring
- Smart notifications
- Plant doctor

IoT Solutions for Food Industry: Diagenetix - BioRanger

- Detects the presence of microbial disease in food
- BioRanger
  - A small handheld device
  - Connects with android app
  - Instantly detects pathogens in food

IoT Solutions for Food Industry: Eskesso – The Cooking Sorcery

- Wifi-connected smart cooking device
- Easy monitoring of cooking status via smartphone app
- Smart cooking
  - By placing food packet and Eskesso device in a pot of water, selecting the recipe and starting via smartphone app

IoT Solutions for Food Industry: Culinary Science Industries – Flavor Matrix

- Infuses foods and beverages with unique flavors
- Collects data on food ingredients
- Collects user data
- Uses machine learning and data analysis to enhance flavor of dishes and provide user specific food and beverage pairing

IoT Solutions for Food Industry: Intellicup – Smart Cups

- Smart beverage vending
- Reduces waiting time and increases profit at beverage shops
- IoT-enabled cups
  - Integrated NFC chip at the cup base
  - Connects cups to mobile banking platform and IntelliHead – a modular dispensing unit
  - NFC chips connects each user to a cup
  - Cups are reusable and made with biodegradable material

IoT Solutions for Food Industry: Intellicup – Smart Cups

- How the smart cups work
  - Separate apps for merchants and customers
  - Customers create Intellicup accounts using the app
  - Transferring fund to e-wallets
  - Linking cup to the e-wallet by scanning a QR code via the app
  - Docking the cup on the dispensing unit (Intellihead)
  - Customers enjoy the beverage

Some Other IoT Solutions for Food Industry

- Spinn Inc.: smart coffee brewing machines
  - Connects coffee brewing machines with Amazon Echo
  - Auto-order feature
- FarmShelf: smart indoor farming
  - IoT-enabled climate control for growing crops
  - Automatic notification regarding crop status

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IIoT Applications: Healthcare

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Introduction

- Earlier so many people died due to lack of health care.
- People forget about their health due to busy life.
- IIoT makes the healthcare easier.
- IIoT based healthcare service is cheapest.
- ECG, blood pressure, glucose level, and temperature can be monitored from patient's home.
- If any critical conditions are there, it sends alert.

Healthcare Challenges

- Populations are ageing all over the world
- Different diseases are increasing
- Expenditure of hospitals and medical clinic are increasing

Largest Age Group

- Populations are growing older
  - Between 2017 to 2050, person's aged 60 years or over is expected to increase more than double.
  - In 1980, there were 382 million older person all over the world.
  - In 2050, it is expected to be 2.1 billion older person worldwide.

- Telecare applications, smart home or telemedicine helps older people to live safely.

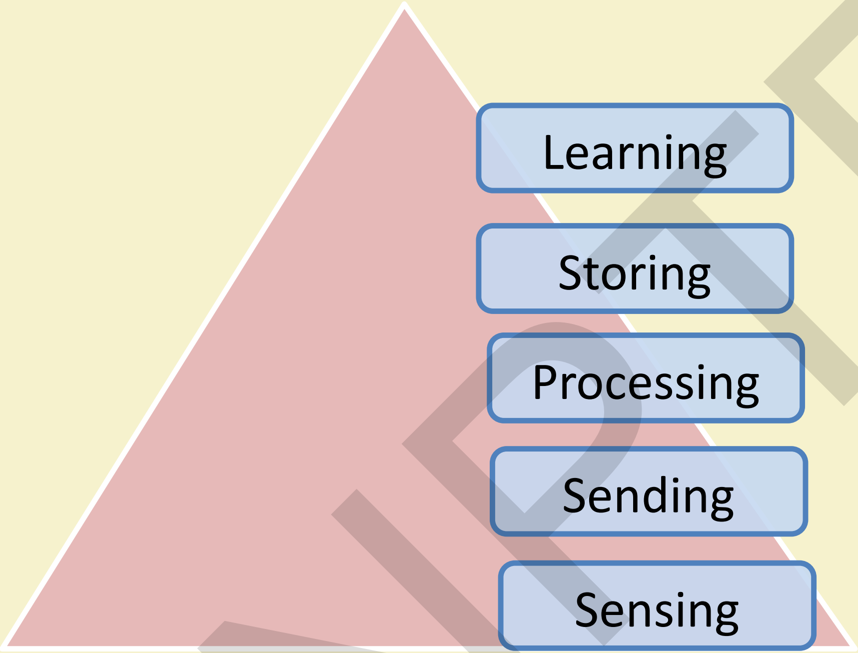
Increase of Diseases

- Different diseases are increasing.
- Telecare applications, smart home or telemedicine helps older people to live safely.
- Continuous monitoring of patient’s health reduces hospitalizing.
- Sensors collects blood pressure, respiration, pulse rate, heart rate, and weight. It triggers alarm, if any abnormal situation is there

Reduce the Expenditure

- IIoT based healthcare device
  - Different wearable healthcare devices which reduce the cost of checkup.
- Remote monitoring
  - Patient’s health condition can be monitored by sensors, which reduce the cost.
- In hospitals, smart beds can send notification about patient’s activity.

IIoT Healthcare Architecture



Source: Nguyen et. all, “A Review on IoT Healthcare Monitoring Applications and a Vision for Transforming Sensor Data into Real-time Clinical Feedback”, in Proc. 21st Comp. Supported Cooperative Work in Design, IEEE, 2017

Benefits of IIoT in Healthcare

- Monitor patient's health condition remotely.
- Hospital staff can predict the arrival of a patient in PACU.
- Hygiene monitoring system can detect the cleanliness of hand.
- Medical staff can provide quality medical service with small budget using IIoT.

IIoT Based Electrocardiogram Monitor

- Wireless ECG monitor.
- Bio signals are collected by ECG sensors.
- The collected data are sent to the cloud.
- Medical staffs can analyze the health related data in real time.
- QardioCore is an example of wireless ECG monitoring device.

IIoT Based Glucose Level Monitor

- Diabetes is metabolic disease, glucose level is high.
- Monitoring the glucose level helps meal planning, physical activity, medication.
- Glucose sensor devices are used to check the glucose level.
- It notifies the doctors and patients if any abnormal situation occur.
- Dexcom develops continuous glucose monitoring devices.

IIoT Based Blood Pressure Monitor

- Using IIoT device, the patient's blood pressure is measured and compared with the other blood pressure.
- Doctors can monitor patient's blood pressure in real time.
- Medicines can be prescribed based on this.
- iHealth BP5 is IoT based blood monitoring system.

IIoT Based Body Temperature Monitor

- Wearable sensor to continuous monitoring human body temperature
- It measures skin temperature
- The WBAN is used to connect to gateway
- Kinsa smart thermometer is IoT based body temperature monitoring devices

IIoT Based Oxygen Saturation Monitor

- Oxygen saturation= ratio of oxyhemoglobin to total hemoglobin
- Pulse Oxiometry measures the oxygen saturation.
- IoT is integrated with Pulse Oxiometry.
- Bluetooth is used for connectivity.
- Low cost device to remotely monitor patient's health.

IIoT Based Contact Lenses

- The IIoT based smart contact lense support WiFi signal, conneted with smart phone.
- It consists of micro camera, sensors.
- Sugar level can be measured by tears. Smart contact lenses can monitor the sugar level.
- It can monitors human health conditions.
- It can detect various diseases, if any abnormal situation is found.

IIoT Based Asthma Treatment

- Asthma is lifelong disease, can be controlled, not cured.
- Inhaler is commonly used to give proper dose of drugs.
- Smart Inhaler can keep track via GPS.
- ADAMM Intelligent Asthma Monitoring device.
- Wearable device, connected with Bluetooth or WiFi.
- From the body temperature, cough rate, heart rate, it predicts pre symptoms of asthma attack.

Smartphone :Healthcare Solution

- Electronic devices consist of sensors, which are supported by smartphone
- Smartphone is used to monitor the health of user and detect diseases.
- Smartphone's healthcare app provides low cost healthcare service.
  - Diagnostic apps detect patient's health condition.
  - Medical communication apps connect patients with hospitals.
  - Medical education apps provide tutorials.

Smartphone Based Healthcare App

- Health Assistant: Keeps track of health condition
- Google Fit: Keeps track of different physical activity
- ECG Self Monitoring: Serves as ECG device, based on "ECG Self Check" software.
- Instant Heart Rate: Measures heart rate using smartphone's camera
- Fingerprint Thermometer: Determine body temperature from the fingureprint

IIoT Healthcare Technology

- Cloud computing: Provide facilities to shared resources.
- Big data: Includes heath data generated from sensor nodes.
- Networks: WBAN, 6LoWPAN, WSN are part of IIoT based healthcare.
- Ambient intelligence: It involves continuous learning and analyze based on the learning.

IIoT Healthcare Security Requirement

- Confidentiality: It ensures medical data is not accessible by unauthorized users.
- Integrity: It ensures medical data is not altered by any third party.
- Authentication: It ensures the identity from which the data is coming.
- Availability: It ensures the accessibility of data to valid users

IoT Healthcare Challenges

- Less computational capability, not able to perform expensive operations.
- Less on device memory.
- Energy limitation, sensor has low power battery.
- Not static, mobile devices. Designing mobile enabled algorithms are challenge.
- Designing scalable algorithm without compromising security is challenge.

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IIoT Applications: Power Plants

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Introduction

- Data collected from IIoT enabled devices increase productivity and efficiency.
- Using IIoT, the equipment can be monitored remotely.
- Sensors collect data and sends to cloud.
- Different machine learning and artificial intelligence based algorithms are used to analyze the data.

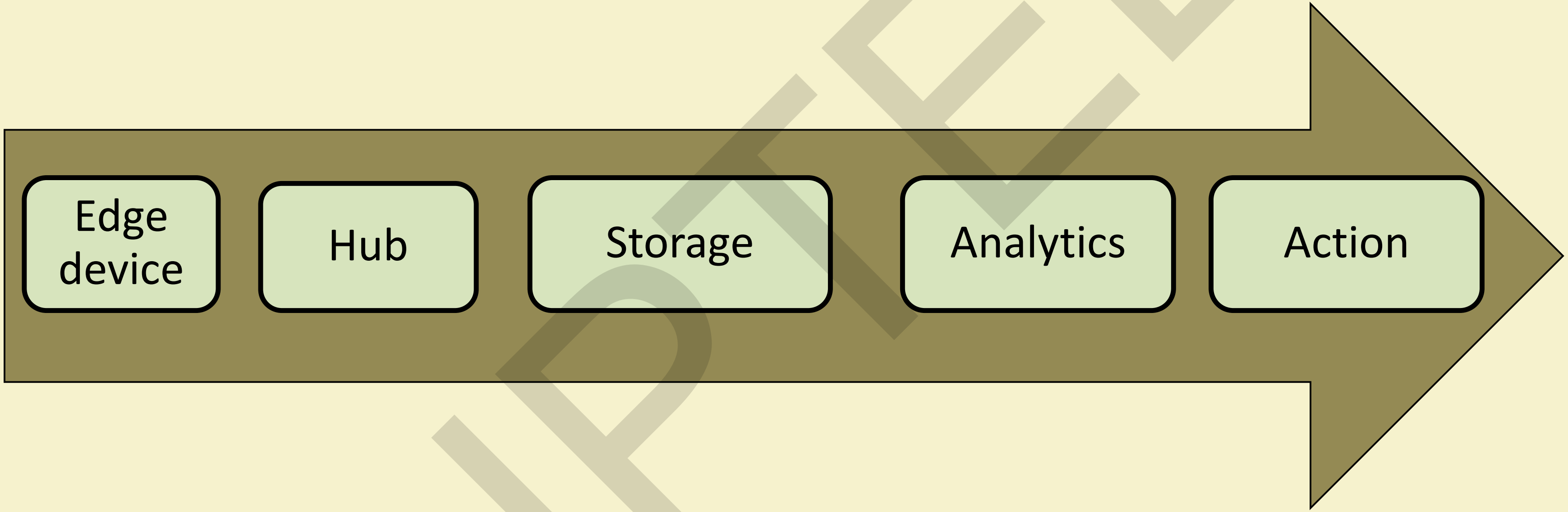
Drivers of IIoT in Power Plant

- Low cost powerful chips
  - WiFi chip, cameras, sensors, accelerometers are used.
- Standardization with IPV6
  - 3G, 4G, 5G networks are used, the devices are standardized with TCP/IP and IPV6 protocol.
- Standardization with software technology
  - Use of artificial intelligence algorithms, and cloud computing software makes it easier.

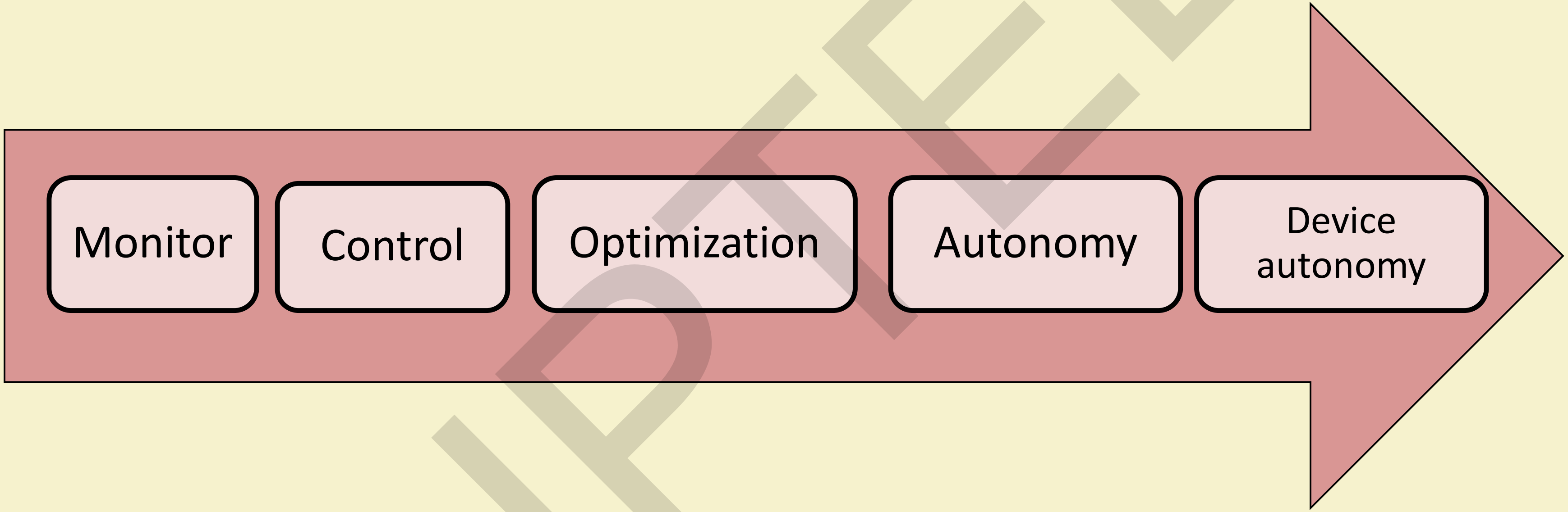
Digital Power Plant Benefits

- Increase efficiency
  - Smart grid- automated devices increases efficiency and reduces manpower.
- Reduce cost
  - Automated devices- no need of money for manpower, fuel, maintenance.
- Improves performance
  - Turbine's performance improvement, remote monitoring.
- Reduce energy demands
  - Helps users to learn how to use energy in real time.

Architecture



IIoT Maturity Model



Communication Network

- Home area network
  - Covers in-home IoT devices. Wireless: Zigbee, 6LowPan
- Neighborhood area network
  - Distribution domain networks. Data collected from smart devices and sent to gateways.
- Field area network
  - Distribution domain networks. It includes controller, regulators, and data collector. Wireless: WiMAX, 3G, 4G. Wired: Eathernet.
- Wide area network

Smart Grid in Power System

Information flow	Wide area network	Neighborhood area network	Home area network
Power flow	Generation	Transmission	Distribution and consumption
Power system	Step up transformer	Step down transformer	Gateway

IIoT in Power Plants Applications

- Digital twins
  - Considered as virtual power plant, reduce fuel and energy consumption by incorporating data.
- Supply chain management
  - Sensors monitor product condition and optimize delivery time.
- Smart pumping
  - Combined with sensors and software. Automated flow control.

IIoT in Power Plants Applications

- Smart boiler
  - Customer can control it by mobile application
  - Energy efficient usage
  - Automatically reports if any defects are there
- Smart water monitoring
  - Detect flow of water and volume of water of a pipe in a time period.
  - Sends data to cloud storage.
  - Saves wastage of water.

IIoT in Power Plants Applications

- Smart metering
  - Important element of smart grid
  - IoT reduces operational costs as operations are remotely managed.
  - Reduces the chance of energy loss.
- Building automation
  - Monitors the building remotely.
  - Elevators, lighting systems, and other electronic systems are connected through internet.

Supervisory Control And Data Acquisition (SCDA)

- Software and hardware allows organization to process locally or remotely.
- Sensors gather real time data.
- Programmable logic controller or remote terminal units communicate with different objects and route the data to SCDA software.
- SCDA software processes the data. Then users analyze the data to make decision.

Advanced Metering Infrastructure(AMI)

- It comprises whole infrastructure- smart meters, communication networks.
- Smart meters: collect information about energy, water etc. Transmits the data to network.
- Communication network: Broadband over PowerLine, Fixed radio frequency are used.
- Meter data acquisition system: gathers data from smart meters
- Meter data management system: analyze the data.

IIoT in Electricity Sector

- Efficient power grid system
  - Collect data from sensors
  - Use the data to manage resources
  - Optimization, stakeholders take decision about power usage.

- Data collected from sensors can easily predict if any failure in grid.
- Predict earlier if any accident is going to happen.

IIoT in Water Sector

- Saves water using smart sensors.
- IoT sensors track water pressure, water quality etc.
- The gathered data is sent to utility company to analyze the data.
- It gives public useful information about how to stop wastage of water.
- It also predicts the water leakage.

IIoT in Wind Energy Sector

- In wind energy sector, large turbines are used. The factories also locate at remote location, It is hard to maintain.
- With IoT, the local control system can adjust switches and software.
- The remote location of farm is not an issue with IoT.
- IoT can predict any issues of turbines easily and it can be addressed earlier before any large scale damage.

IIoT in Solar Energy Sector

- In IoT based solar energy sector, sensors monitor their performances from the control panel.
- The gathered data is sent to cloud server to analyze.
- IoT helps to understand the problem of device whether it is hardware related problem or network related problem.
- IoT helps to detect any problem in real time.
- IoT can manage the largest solar grid.

Challenges of IIoT in Power Plant

- Security issues
  - Privacy issues, chances of denial of service attack.
- Low power devices
  - IoT devices are resource constrained devices, battery powered devices.
- Scalability issues
  - Number of devices are increasing, Increase of data bandwidth.

Challenges of IIoT in Power Plant

- Determinism of network
  - Using cloud makes the process delay about 200 msec or more.
- Poorly designed
  - Most of the devices are poorly designed as different protocols are used.
  - It lacks of standard authentication for the edge devices.

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Thank You!!

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IIoT Applications: Inventory Management & Quality Control

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Inventory Management

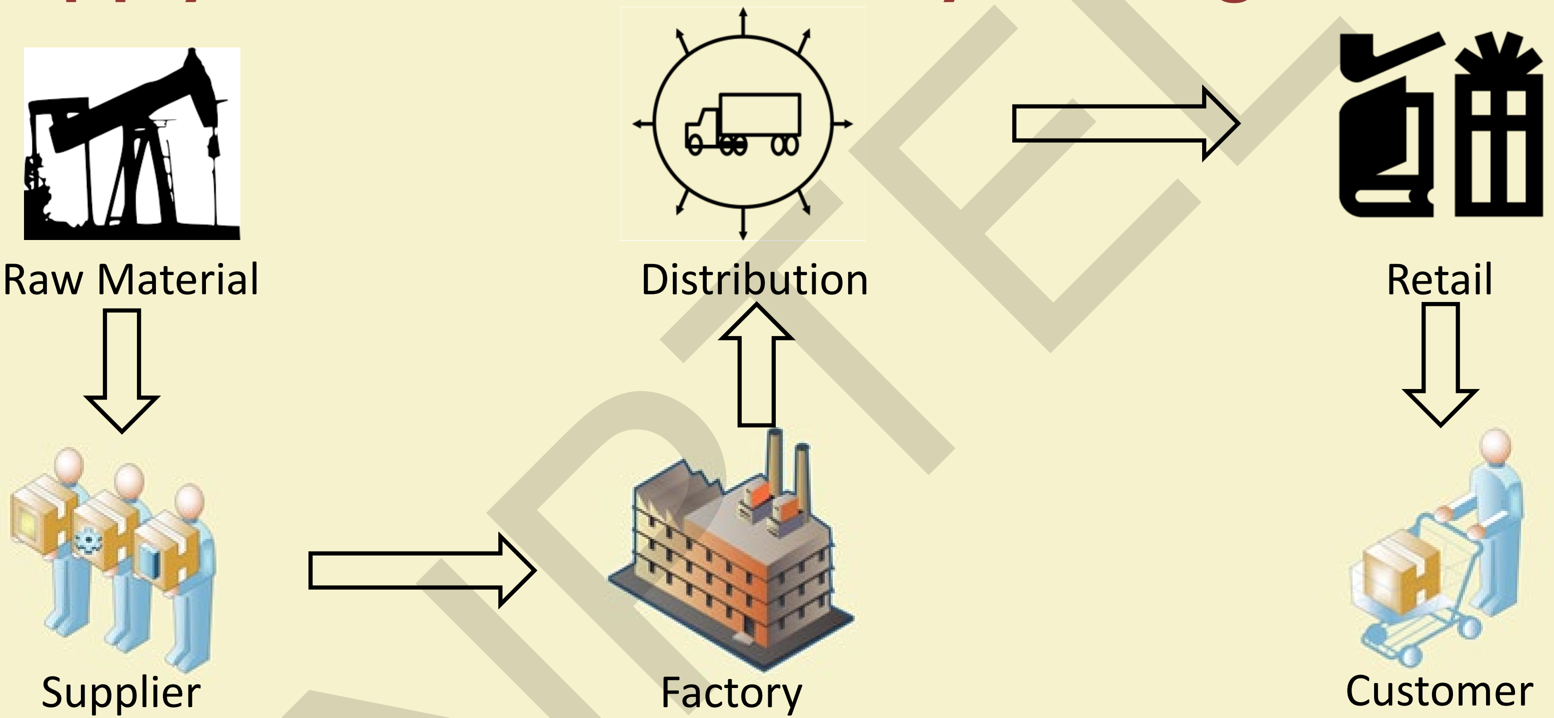
- Inventory

  "a usable but idle resource having some economic value"

  [P. Vrat, Materials Management]

- Inventory Management
  - Activities entailing management of inventory such as:
    - Controlling, overseeing and ordering
    - Storage
    - Determine supply for sale

Supply Chain and Inventory Management



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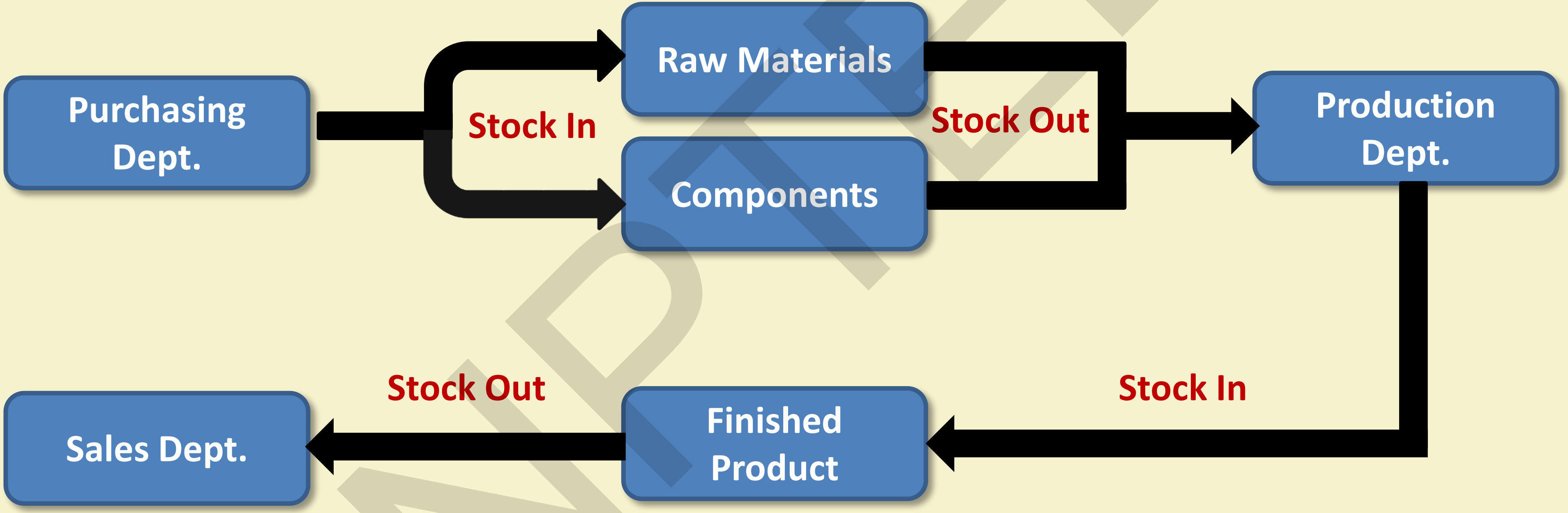
Inventory Management and IIoT



Functions of Inventory Management

- Meet anticipated demand
- Smoothen the production requirement procedure
- Decouple components of the production-distribution system
- Protection against stock outs
- Proper order cycles
- Hedge against price increases or to take advantage of quantity discounts
- Smoothen the flow of operations

Requirements for Effective Inventory Management

- Keep track of the inventory
- Forecast of demand
- Manage lead times and lead time variability
- Estimate inventory holding costs, ordering costs, and shortage costs
- Classification of inventories

Quality Control

- *"system of routine technical activities, to measure and control the quality of the inventory as it is being developed"*

  [IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories]
- Internally maintained by the management to provide product satisfaction to the customers

Objectives:

- Routine and consistent checks
- Ensure data integrity, correctness, and completeness
- Rectify errors and omissions
- Document and archive inventory material and record all QC activities

Radio Frequency Identification Devices (RFID) tags

- Used in an identification system
- Uses Radio waves for communication
- RFID Tagging system consists of:
  - The RFID tag
  - Read/write device
  - Host System
- Two types:
  - Active RFID tags
  - Passive RFID tags
- Finds scope in data collection, processing, and transmission applications

https://c1.staticflickr.com/4/3856/14891130616_d155bbf0cd_b.jpgt

Passive RFID Tags

- No internal power source
- Relies on ***backscattering***
- Wait for a signal from an RFID reader
- Powered by electromagnetic energy from this signal
- Have shorter range than Active RFID tags
- Small in size and thickness

Active RFID Tags

- Battery powered
- Broadcasts information signal in the form of a ***beacons***
- Have longer range and memory than passive RFID tags
- Bulky and expensive as compared to passive RFID tags

Semi-Passive tags

- Has an onboard battery to power the IC
- But no active transmitter
- Relies on ***backscattering***
- Does not depend on signals from reader for power
- Does not create additional noise

RFID tags over Barcodes

- Barcodes are printed on paper and plastic which makes them vulnerable
- Barcodes need to be on Line of Sight of the readers
- Only one barcode can be read at a time
- Barcodes have less security and hence can be forged
- Barcodes cannot contain any added information

Applications

- Identification of products
- Added information along with ID
- Comprehensive visibility
- Built in GPS
- Warehouse management

Applications (contd.)

- Added information along with ID:
  - Current storage temperature
  - Weather condition
  - Damage (if any)
  - etc

Applications (contd.)

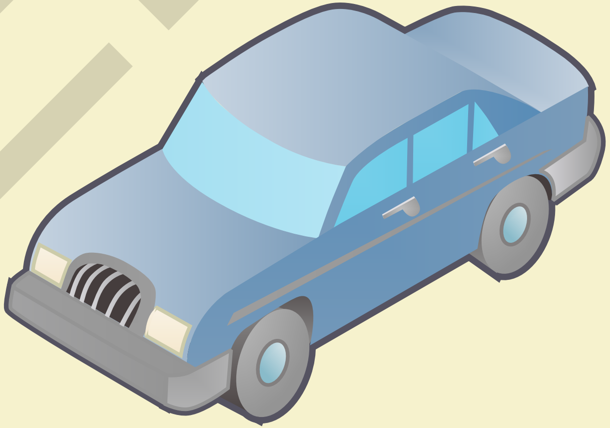
- Comprehensive Visibility
  - Inventory levels
  - Expiration dates
  - Item location
  - Forecast demand
  - etc

Applications (contd.)

- Warehouse management
  - Shrink, Shortage, Overstock of commodities
  - Identification of efficient areas based on demand

Applications (contd.)

- Similarly in transportation modes
  - Track time and place of congestion
  - Compute delay and alternate routes
  - Commute with efficient time and mode



Problems that can be eliminated

- Data inconsistency
- Staff training expenses
- Human errors
- Data scattering
- Lapse in security
- Slow operation
- Other hidden costs

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IIoT Applications: Plant Security and Safety

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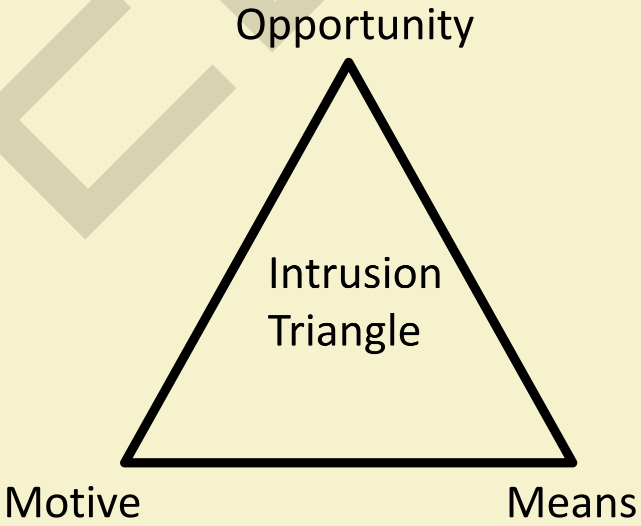
Plant Security and Safety

"freedom from risk or danger; safety"

[The American Heritage Dictionary]

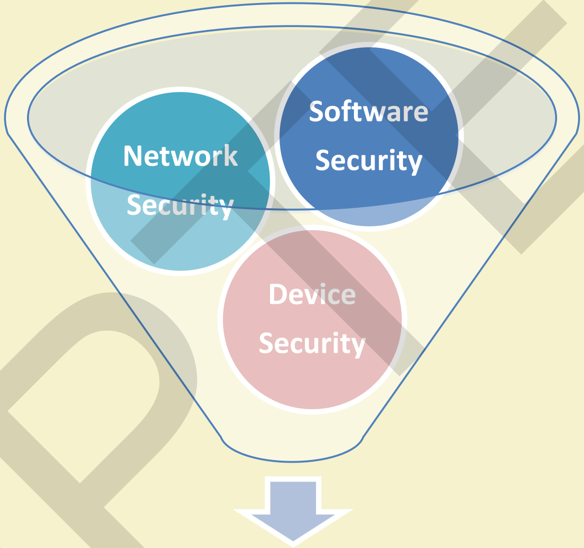


Plant Safety

- Health and well being of the industry as a whole
- Hazards in a plant are catastrophic
- Aim: Protection of human and plant resources

https://pixabay.com/en/helmet-engineer-hard-hat-hardhat-35053/

Plant Security and Safety



Plant Security and Safety

Need for Software Security

- Steal valuable information
- Unauthorized monitoring of sensitive content
- Corrupt behavior of software
- Denial of Service (DoS) attacks
- Overflows, Overrides and Overwrites
- Padding

Software Security

Integrity

- Assurance of an uncorrupted data
- Correct functioning even under malicious attack
- Maintain consistency, accuracy, and trustworthiness of data over its entire life cycle
- Assurance that data is not altered by unauthorized people

Authentication

- Identification of user
- Verification of credentials entered (local or remote)
- Access control based on these credentials
- Protection of resources

Availability

- Ratio of time of functioning to the total time
- Extent to which the software continues functioning when a component or set of components fail
- Strong relation between availability and reliability

Requirements

- Good programming techniques
- Install good firewalls
- Detect intrusions
- Good preventive measures

Network Security

- Maintain usability and integrity of network and data
- Management of access to the network
- Both hardware and software
- Protection against variety of threats

Types of Network Security

- Access control
  - Provide access based on user identity
- Antivirus and antimalware software
  - Scan for malware detection and prevention
- Application security
  - Protection of software after creation

Types of Network Security (contd.)

- Behavioral analytics
  - Detection of abnormal behavior by the network
- Data loss prevention
  - Prevention of unauthorized sharing of sensitive data
- Email security
  - Protection against phishing attacks

Types of Network Security (contd.)

- Firewalls
  - Barrier between trusted internal network and the external networks
- Intrusion prevention systems
  - Detection and blocking attacks
- Mobile device security
  - Device level security

Types of Network Security (contd.)

- Network segmentation
  - Divide the network into smaller parts and enforce security policies explicitly
- Security information and event management
  - Gather information for security staff to identify and respond to threats
- Virtual Private Network (VPN)
  - Encrypt connection from an endpoint to a network

Device Security

- Protection of sensitive information stored on and transmitted by portable devices
- Portable devices:
  - Smart phones
  - Tablets
  - Laptops
  - Other mobile devices

Components

- Endpoint security
  - Monitoring of mobile devices (files and processes) that access a network
- Virtual Private Network (VPN)
  - Encrypt connection from a mobile device to a network
- Secure web gateway
  - Identification of an attack on one location and prevention of the same at other locations (integration of security with the cloud)

Components (contd.)

- Email security
  - Protection against phishing attacks
- Cloud access security broker
  - Securing the tasks being performed on the cloud

Virtual Reality (VR)

- Computer generated interactive environment
- Transpose the user
- Isolate the user from the current world
- Example: Oculus Rift, Samsung Gear VR, Google Cardboard

Augmented Reality (AR)

- Enhanced reality (adds a digital layer over the real world)
- Does not isolate the user to a different world
- Can add details to things a user tries to examine (can be used by retailers to sell their products)
- Examples:
  - Bus stop prank by Pepsi Max
  - Pokémon Go

Risks (AR/VR)

- Prone to attacks by hackers
- Compromised content on the screen
- Intellectual Property (IP) rights
- Privacy and Security issues
- Risks pertaining to user's health

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IIoT Applications: Facility Management

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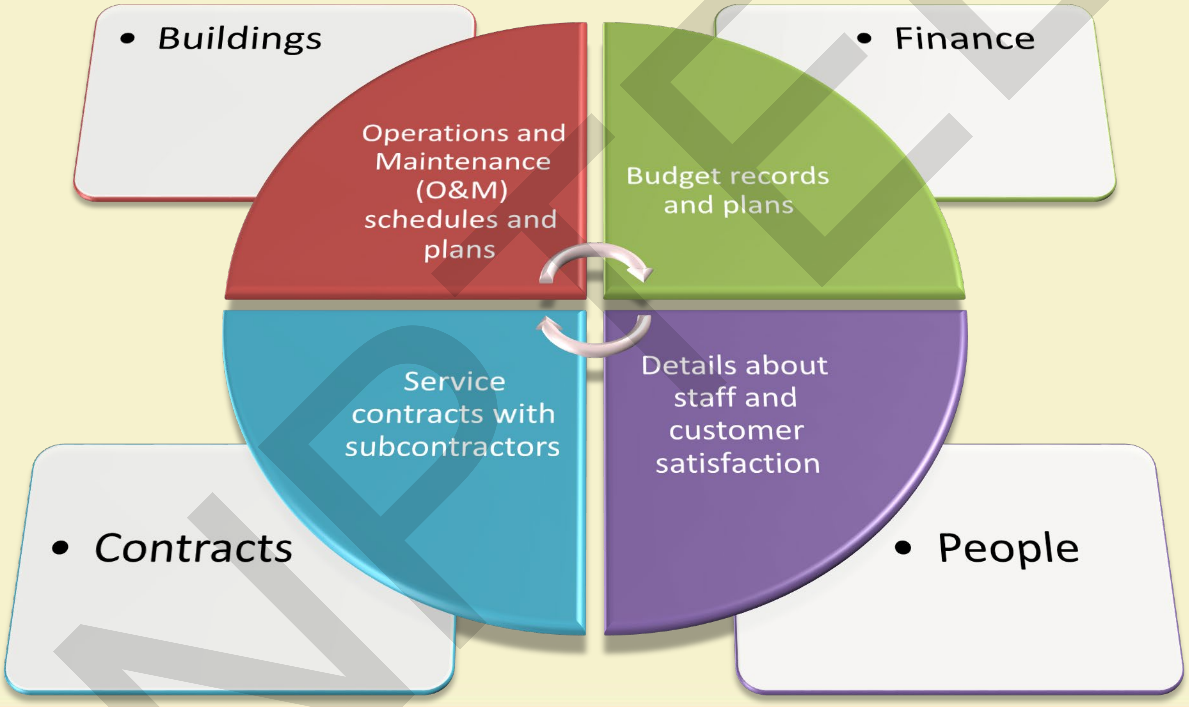
Facility Management

“guiding and managing the operations and maintenance of buildings, precincts and community infrastructure on behalf of property owners”

[Facilities Management Good Practice Guide]

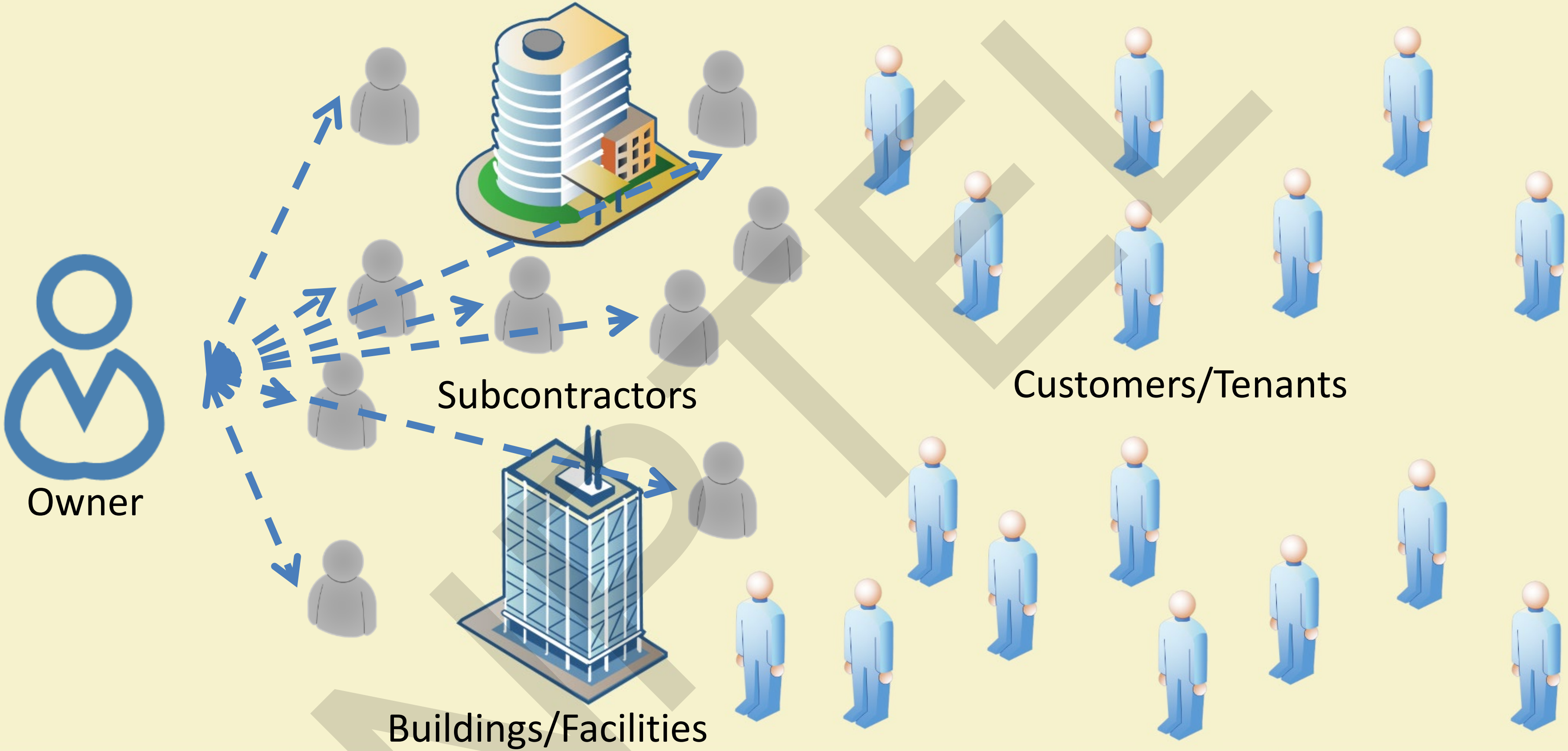
Facility Management



Facility Management

- Support services for organizations
- Integrates people, place and process
- Improve quality of working environment
- Improve productivity

Closely related to the operations conducted in a building


Owner
Subcontractors
Customers/Tenants
Buildings/Facilities

Scope of IoT in Facility Management

- Accessing new insights:
  - Gather data, reduce power consumption
- Implementing new technology:
  - Implementing new technology like Li-Fi (Light Fidelity) and data security
- Addressing cost barrier:
  - Increases operating efficiency and reduce maintenance cost

Support Services

- Finance
  - Planning and reviewing of budget
- Information Technology
  - Improve the ability to co-ordinate among the installed devices
- Human Resources
  - Improve the quality of workforce and the environment

Support Services (contd.)

- Administrative Support
  - Monitoring, gathering, disseminating relevant information and take decisions
- Marketing
  - Research potential customers
- Knowledge
- Business Development
  - Overall growth of business

Key Idea

- Comprehensive detail of every machine
  - Faults, history, usage and modifications
- Data consistency
- Harmonized decisions

Real Power

- Predict events before they occur
- Measures to prevent predicted hazards

Need for Big Data and advanced analytics to analyze them

Optimization

- Optimized usage of resources:
  - Manpower
  - Assets
  - Technology
  - Cost-effectiveness

Challenges

- Cost management
  - Balancing the quality of the facility and its budget
- Ageing inventory
  - Need for proactive preventive and maintenance procedures
- Changing regulatory and compliance standards
  - Need for improvement and new ways to stand out from competitors
- Security Management
  - Security against breaches and threats

IoT Application in Facility Management

- Lighting
- Refrigeration
- Smart Meters
- Fire Suppression Systems
- Appliances with Embedded Sensors/Software

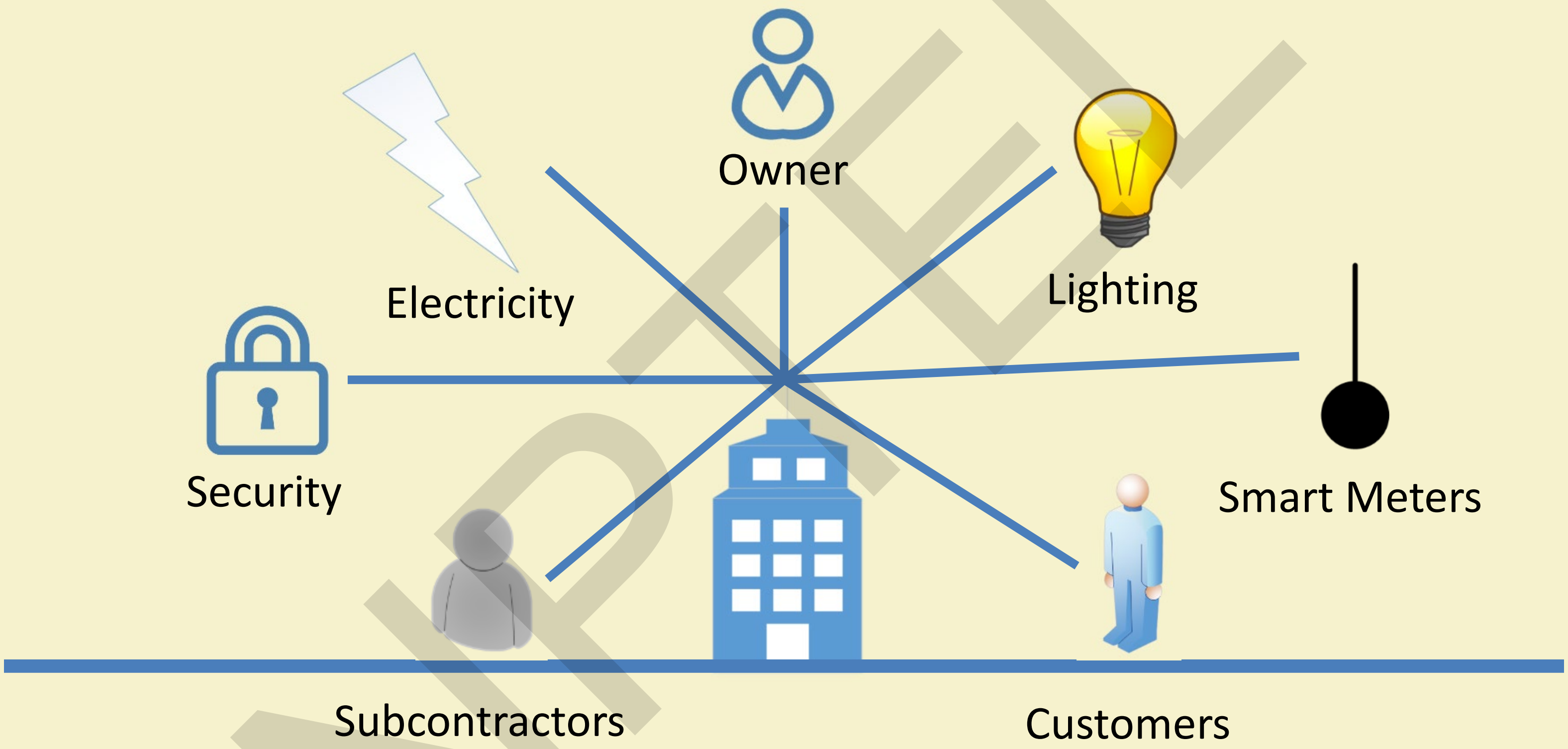
IoT Application in Facility Management (Contd..)

- Security and Safety Alarms
  - Monitor alarms, smoke detector, other life safety systems remotely
  - Real time information about emergency
- Central Heating Ventilation and Air-Conditioning (HVAC)

  "we will start to see an ecosystem of tools and services develop that will make the HVAC system more efficient and easier to operate," Dan McJacobson, McGuire Engineers

IoT Application in Facility Management (Contd..)

- Room Reservation and Scheduling
  - Checking real time status of meeting rooms and avoid double-booking
- Monitoring Stock and Usage of Supplies
  - Monitor usage of restrooms
  - Efficient supply management
  - Water management
  - Monitor transmission lines and pipes


Owner
Electricity
Lighting
Security
Smart Meters
Subcontractors
Customers

Analytics in Facility Management (contd..)

- Managing Energy Consumption
- Data-driven Decision-making
- Operational Cost-optimization
- Remote Monitoring of Facilities
- Determining the Exact Square-foot Utilization of Office Space

Benefits

- Improve customer experience
- Prevent unauthorized access
- Real-time tracking
- The ability to do more with less

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Thank You!!

IIoT Applications: Oil, Chemical and Pharmaceutical Industry

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IoT and the Industry

- Industries add extensive value by integrating IoT strategies for transforming the business
- Industries need to become more efficient and reliable
- Maximize profit by the predictions
- IoT cloud slash cost

IoT in Oil and Gas Industry

Oil and Gas Industry

"lies not in helping oil and gas companies directly manage their existing assets, supply chains or customer relationships–rather, IoT technology creates an entirely new asset: information about these elements of their business," Deloitte

Oil and Gas Industry Work-flow

Apply predictive analytics → Deploy IoT solutions in different locations → Generate on-premises simulated data → Data analysis by extraction, transform and load process → Data moves to a cloud-based analytics platform → Accurately identify the require maintenance

Reference: https://blog.equinix.com/blog/2017/12/06/how-the-oil-and-gas-industry-is-powered-by-the-iot-machine-learning-and-cloud/

Machine learning and cloud services

- Examine current state architecture
- Identifies specific data types
- Find assumptions and constraints of data types
- Identifies machine learning algorithm
- Identifies cloud platform
- Analyze and evaluate data
- Provides a top-down review
- Illustrates context, limitations and solutions
- Creates a roadmap

Improve operational Excellence

- Predictive maintenance
- Location Intelligence
- Pipeline and equipment monitoring
- Monitor
  - Sensor integration
  - Real time machines
  - Fleet operations

Reference: https://dzone.com/articles/usage-of-iot-in-oils-and-gas

IoT increases customer loyalty

- Connects business and car
- Smart application
- Energy consumption profiles

Reference: https://www.allerin.com/blog/whats-iot-doing-in-oil-gas

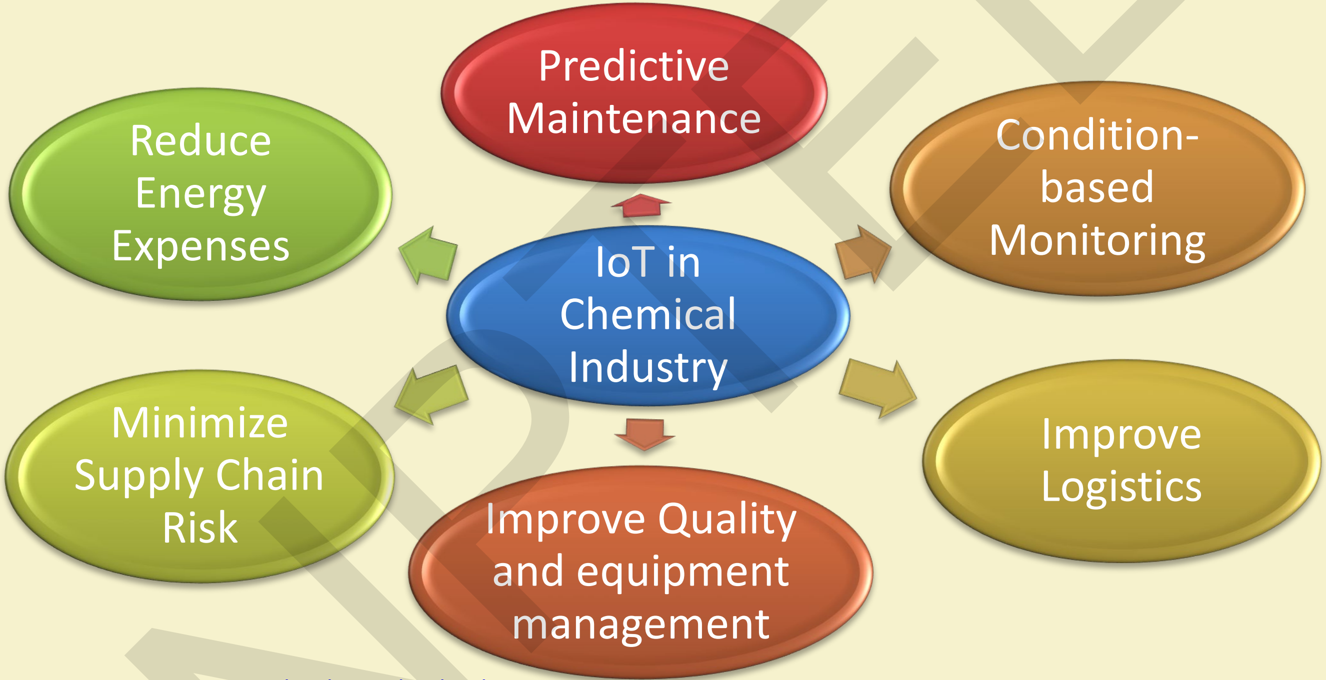
ee

Benefits of using IoT in Oil and Gas Industries

- Increase production efficiency
- Save cost and time
- Improve asset maintenance
- Enhance
  - Production
  - Work safety
  - Supply chain planning

IoT in Chemical Industry

IoT helps in Chemical Industry



References: https://www.digitalistmag.com/iot/2016/05/12/chemical-industry-4-opportunities-provided-by-internet-of-things-04196654
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Predictive maintenance

- Address real time issues
- Reduce equipment breakdown
- Efficient and effective maintenance
- improve quality by efficient IoT analytics programs
- improve service

Condition-based monitoring

- Predict quality by continuous monitoring
- Water, nutrients, and pesticides analysis
- Analytics predict weather and its impact on farming
- Adjust the amount of required material
- Pricing model with the profit margin

Improve Logistics

- Ensure product location through sensors or RFID tags
- Track assets to prevent loss
- Detection of contamination or attacks
- Alert notification
- Warehouse monitoring

Reduce Energy Expenses

- Energy usage and regulatory control
- Analyze real time data
- Improve
  - Usage pattern
  - Inefficiency

Minimize Supply Chain Risk

- Chemical manufacturers can response immediately to the required process
- Real-time monitor in supply chain:
  - Equipment
  - Material
  - Process
  - Environment
  - Workers

IoT in Pharmaceutical Industry

Use of IoT sensors in Pharmaceutical Industry

- Deployed in production areas
- Access huge data of different manufacturing departments
- Real time monitoring
- Able to control the areas remotely
- Proper utilization of equipment
- Reduce
  - Production cost
  - Wastage

IoT Application in Pharmaceutical Industry

- Examine drugs
- Detect:
  - Adverse Drugs Reaction (ADR)
  - Effects of pharmaceutical excipients
  - Allergies
  - Other complications

IoT Application in pharmaceutical Industry (Contd..)

- Quality control by real-time monitoring
- Safe and secure drug delivery
- Deploy to connect different technologies:
  - Manufacturing
  - Monitoring
  - Controlling
  - Distribution

Improve logistics

- Track the movement of pharmaceutical goods
- Improve warehousing
- Optimize routing
- Maintenance of machines and equipment
- Inspects the maintenance of medicine and vaccines

Reference: https://www.entrepreneur.com/article/305272

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IIoT Applications: UAVs in Industries

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UAVs are Connected to IoT

- Deployable to various locations
- Capable of conveying adaptable payloads
- Measure the required data from different locations
- Re-programmable

Source: Why Drones Are the Future of the Internet of Things, Skylogic Research Drone Analyst

UAVs Applications in Industry

- UAVs gather integration of the measurements using IoT sensors
- UAVs have an end-to-end connection via wireless, from user to controller
- Communicates directly to an industrial control system such as the SCADA
- UAVs are capable of taking aerial imagery, visual imagery, thermal imagery and also radio-frequency imagery of factory stations and substations.

Source: Drones for Industrial Applications, Plant Automation Technology

UAVs Technology Generations:

First Generation	Fundamental Remote Control UAVs of different forms
Second Generation	Static design, fixing camera mount, still photography, video recording, and manual steering control
Third Generation	added two-axis gimbals, essential safety models. HD video, assisted guiding
Fourth Generation	Transformable designs, 1080 HD video or higher value instrumentation, three-axis gimbals, improved safety modes, autopilot modes.
Fifth Generation	Transformable designs with 360° gimbals, high quality video or higher-value instrumentation, improved piloting modes.
Sixth Generation	improved safety and regulatory, platform and payload adaptability, automated safety modes, intelligent piloting models and full autonomy, airspace awareness.
Seventh Generation	enhanced intelligent piloting models and full autonomy, full airspace awareness, auto action (takeoff, land, and mission execution)

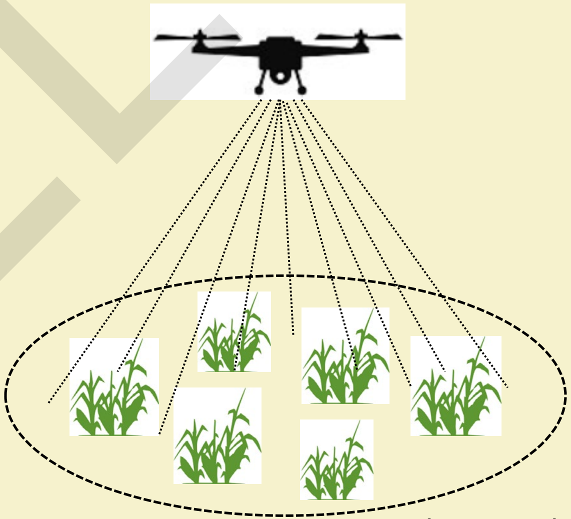
Source: Drones Racing up the Industrial Futures, The IoT Magazine

Application Fields

- Agriculture
- Construction Sites
- Mining
- Energy Management
- Telecommunication
- Delivery / Healthcare
- Oil and Gas
- Warehousing and Inventory
- Forestry
- Entertainment

Application in Agriculture

- Increase effective yields:
  Precisely estimate the field characteristics
- Save time:
  Help farmers in scouting their crops
- Optimized inputs:
  Optimize use of seed, fertilizer, water
- Crop health monitoring:
  - Fertilization dispersal to different areas as per needed
  - Monitor crop stress factors (like over fertilization or drought)



Source: Use cases: The many IoT applications of drones, RCR Wireless News

Application in Agriculture (Contd..)

- Other information:
  - Find the field borders for flight pattern
  - Soil quality, plant counting, plots size
- Low-cost camera platform :
  - Integrated software covers maximum areas of growing yields
  - Take effective images by planning their flight path
  - High quality and high precision real time images

Source: Six Ways Drones Are Revolutionizing Agriculture, MIT Technology Review

Application in Construction Sites

- Survey:
  - Quick survey of required job areas
  - Build maps
- Monitoring job sites:

  Monitor progress, works, and safety standards
- Inspecting structures:
  - Take continuous complex readings instead of lots of workers and heavy softwares
  - Inspect infrastructures and constructing roadways and forest roads

Construction Sites Monitoring

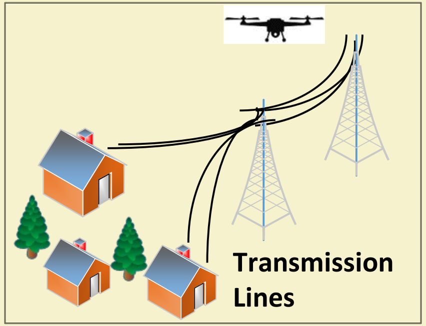
Source: Use cases: The many IoT applications of drones, RCR Wireless News
Image source: “building the lift construction site”, PhotoMIX-Company/ Creative Common CC0/, Online: https://pixabay.com/en/building-the-lift-construction-site-1804030/

Application in Construction Sites(Contd..)

- Showing clients progress:

  Show clients work progress when they are far away from job sites
- Require less time, save energy and money
- Monitor shoreline erosion

Energy Management



Solar Panels Monitoring

- Inspections without climbing power poles
- No need to get close to dangerous wires
- Observe miles of transmission lines in a single flight
- Damage from storms
- Inspect large boiler at power plants
- Monitor solar panels of the farms
- Inspect of wind turbines
- Inspect bridges, dams

Source: Top 5 Industrial Applications For Drones, OpTo Blog
Image source: “solar roof panels farm house shed”, RosiePosie/ Creative Common CC0/,
Online: https://pixabay.com/en/solar-roof-panels-farm-house-shed-776563/

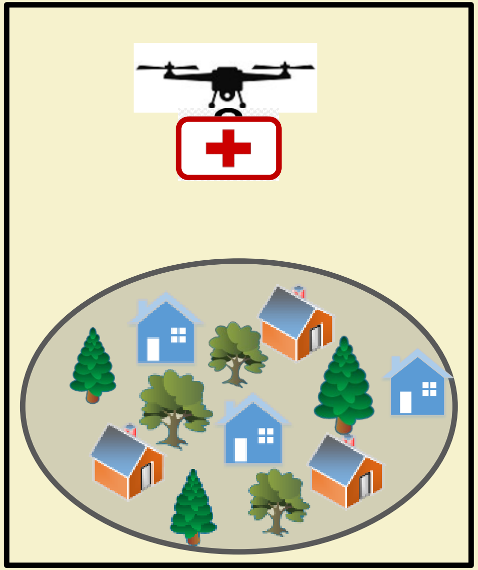
Application in Mining

- Regular surface survey for optimized blast design
- Identify misfire and wall damage
- Manage stockpiles
- Helps in grading control
- Site exploration
- Safety and surveillance

Mining Sites Survey

Source: Top 5 Industrial Applications For Drones, OpTo Blog
Image source: “open pit mining carbon coal mining”, herbert2512/ Creative Common CC0/, Online: https://pixabay.com/en/open-pit-mining-carbon-coal-mining-3559209/

Application in Delivery and Helthcare

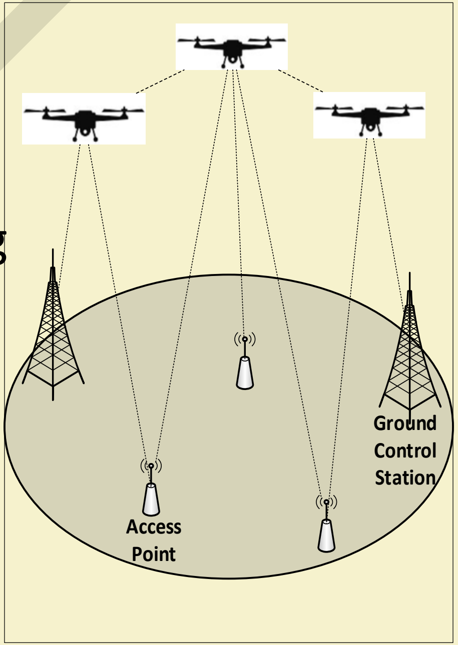


Healthcare Delivery

- ➢Delivery of medicines, vaccines, defibrillators, snake bite serum
- ➢Delivery to the hospitals and remote areas
- ➢Transport blood samples to laboratories for testing crucial diseases
- ➢Research is being done on drones with manipulator arms that can help the senior population

Application in Telecommunication

- Tower inspection by UAVs:
  - Monitor towers from any angle and height
  - Maintenance and repairing by continuous monitoring
- Deployed on demand
- Re-deployed with changing purposes
- Testing networks:
  - Network coverage and stability
  - Covers wide areas with less cost



Application in Telecommunication (Contd..)

- Broadcasting live events
- Provides internet services in rural areas
- Increase work safety

Application in Oil and Gas

- Data collection:

  Collect videos and thermal imagery of oil and gas fields, fed to the industry for analyze

- Pipeline monitoring:
  - Detect leakage of oil and gas pipelines
  - Oil spill detection and damage assessment

Application in Oil and Gas

- Construction planning:

  Information gathered by elevation mapping, watershed analysis

- Reduce manpower requirement and increase safety:

  No need of industrial mountaineering with risk and high cost

- Monitoring work progress
- Tracking asset usage

Application in Warehousing and Inventory

- Scans a huge number of items in a warehouse
- Check the missing items
- Monitor full inventory in a day

Application in Forestry

- Forestry survey:

  Show information about the forest species including the humans around the forest

- Precision forestry and canopy mapping:

  Measurement of canopy height, density and volume estimation

- Wildland fires tracking
- Protecting endangered species
- Save time, manpower and resources

Application in Forestry (Contd..)

- Forest management:
  - Manage forest plantations and evenly distribute seedlings sprinkling fertilizer
  - Control forest density
- 3D mapping of carbon storage in the forest:
  - Measure the carbon storage in biomass by remote sensing
- Resist deforestation and increase security

Application in Entertainment

- Cheaper and exciting:
  - UAV-based light displays are cheaper and more exciting than traditional firework display
  - Entertains as a flying light show
  - Controlled by single computer that consumes manpower
  - Reusable
- Film industries for capturing frames in a cost effective way

Source: Drones as Entertainment: what's ahead for this emerging application?, Unmanned Systems source

Shipping and Delivery

- Shipping and delivery by drone in different companies
- Save manpower and resources
- Save time by avoiding unnecessary road traffic

Source: 10 stunning applications of drone technology, Allerin

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Thank You!!

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Case Studies for Industry 4.0 & IIoT

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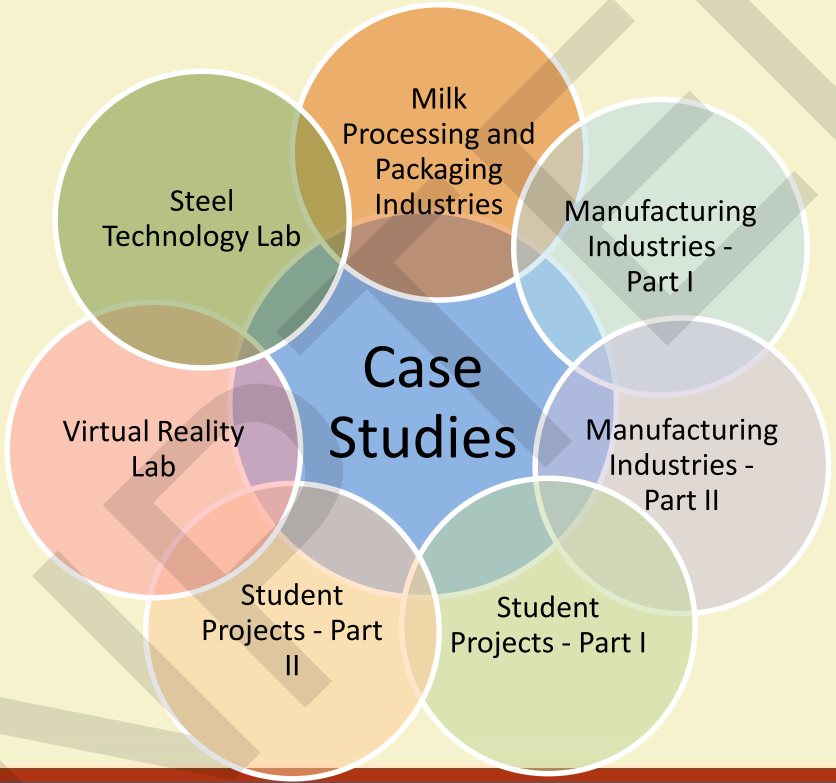
Why are Case studies necessary?

- Case studies provide in-depth knowledge and clarity of concepts regarding the research topic.
- Case study
  - enables a researcher to closely examine the data
  - within a specific context
  - follows certain procedures
  - provides quantitative and qualitative analysis of the data

Why are Case studies necessary? (contd.)

- Case studies explore and investigate real-life phenomenon through detailed analysis of related events.
- Generally, in a case study, a small geographical area or a very limited number of individuals, are selected as the subject matter.

Different Case Studies



Points to ponder … (for all case studies)

- Transformation of existing processes for Industry 4.0 adoption
- Assessment of existing processes
- Target objectives
- Transformation project management … setting objectives, schedule, budget
- Sensors, actuators, networks, interoperability, automated fault detection & maintenance, feedback control,

Points to ponder … (for all case studies)

- Sensors, actuators, networks, interoperability
- automated fault detection & maintenance
- feedback control
- analysis of data (real time & non-real time)
- reduction of health hazards of workers
- improvement in overall efficiency

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Industry 4.0 and Industrial Internet of Things

Thank You!!