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Basics of Industrial IoT: Industrial Processes – Part 2

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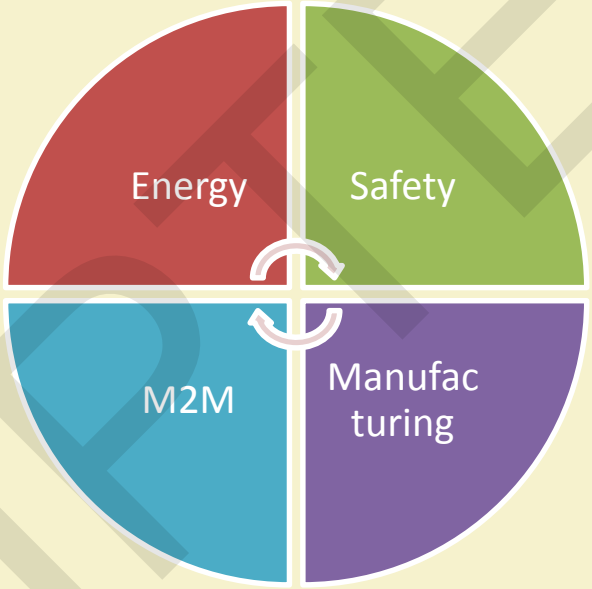
Industry 4.0 – Different Sectors

- 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

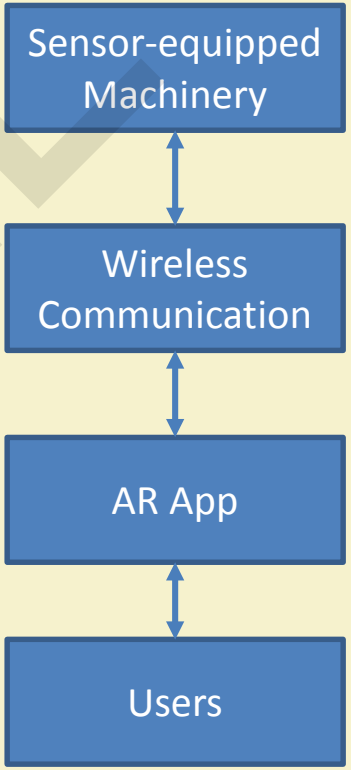
- Supply chain automation
- Logistics
- Motion control
- Storage & parking

- 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

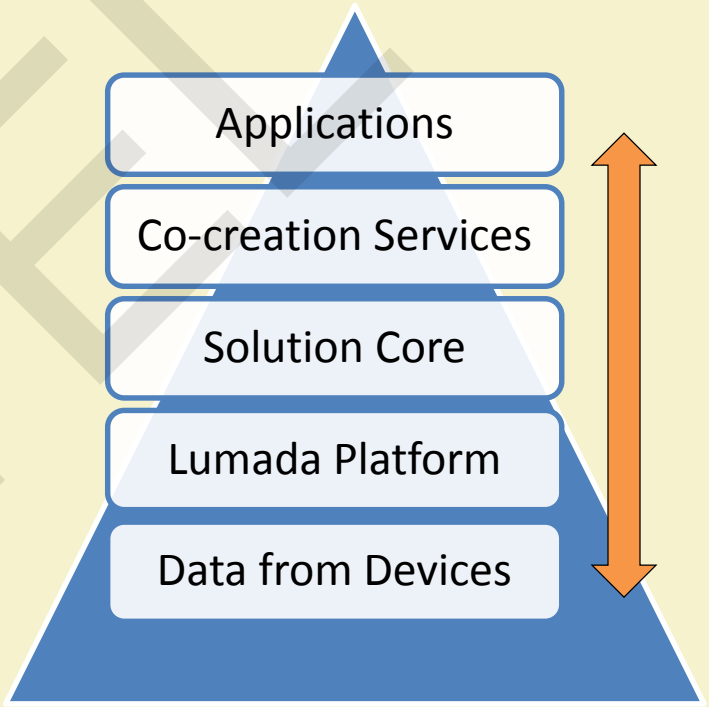


Figure: Hitachi IIoT platform hierarchy

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

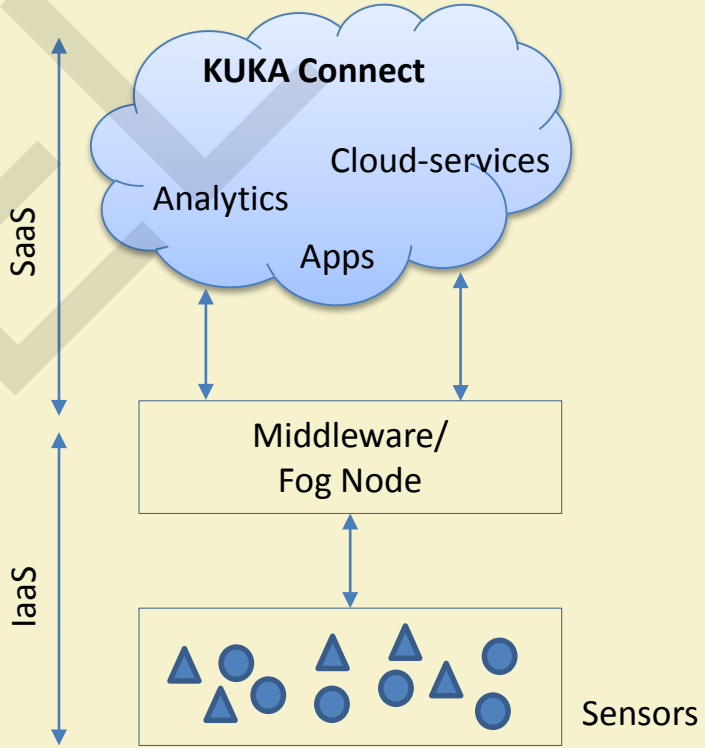
Bosch: Track & Trace Innovation

- 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

- Connected robotics system for super-fast manufacturing
- 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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Thank You!!

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Business Models and Reference Architecture for IIoT

Business Models – Part 1

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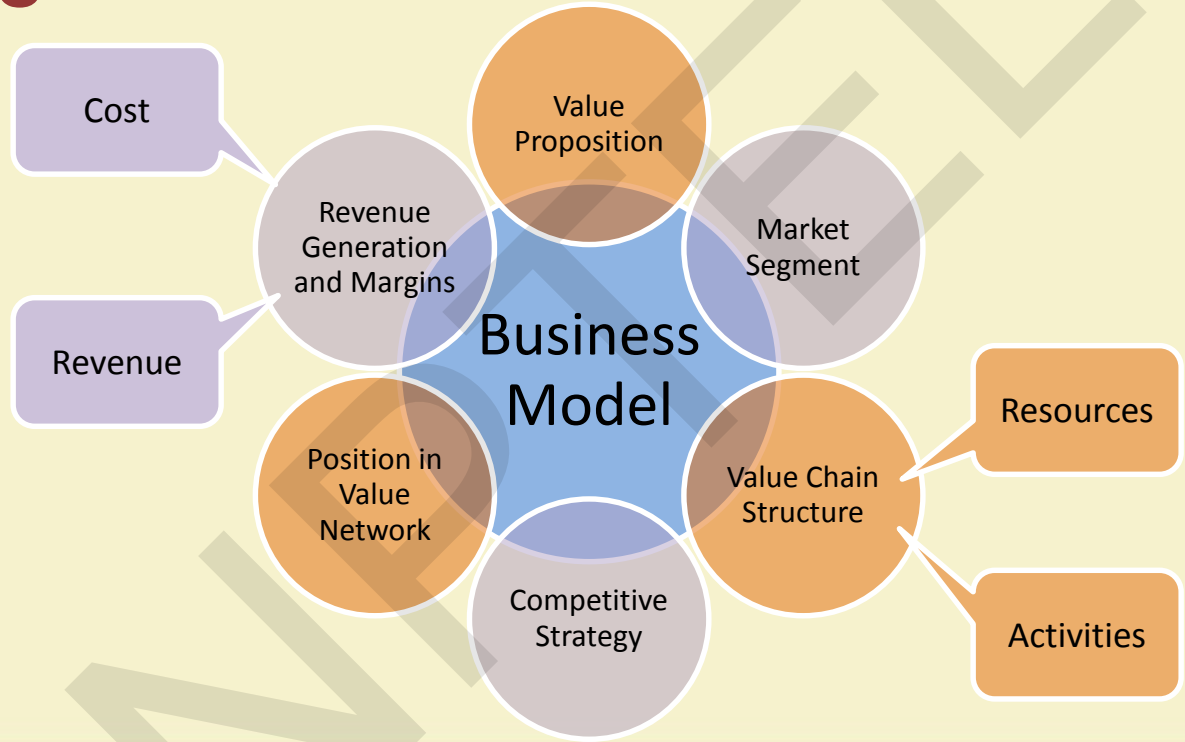
What is a Business Model?

- *"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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Thank You!!

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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

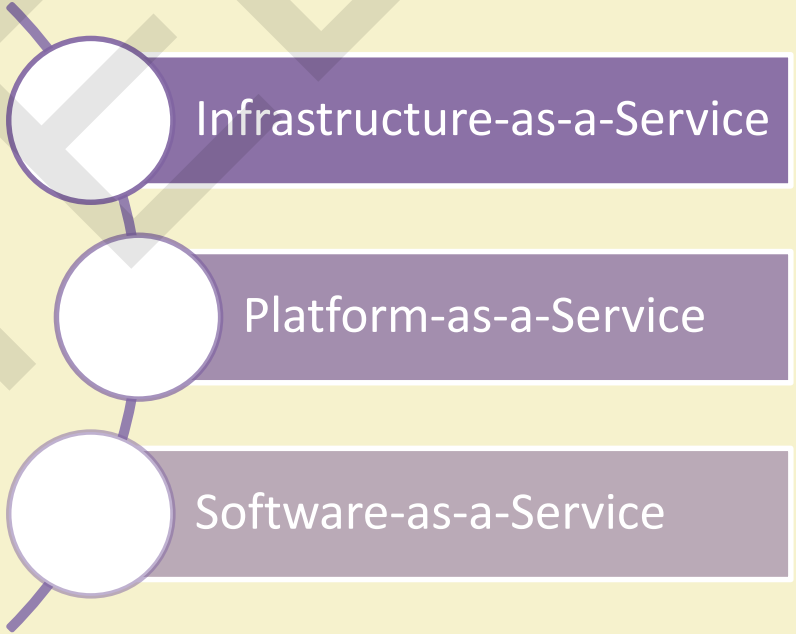
- Value proposition
- Value capturing mechanism
- Value network
- Value communication

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



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

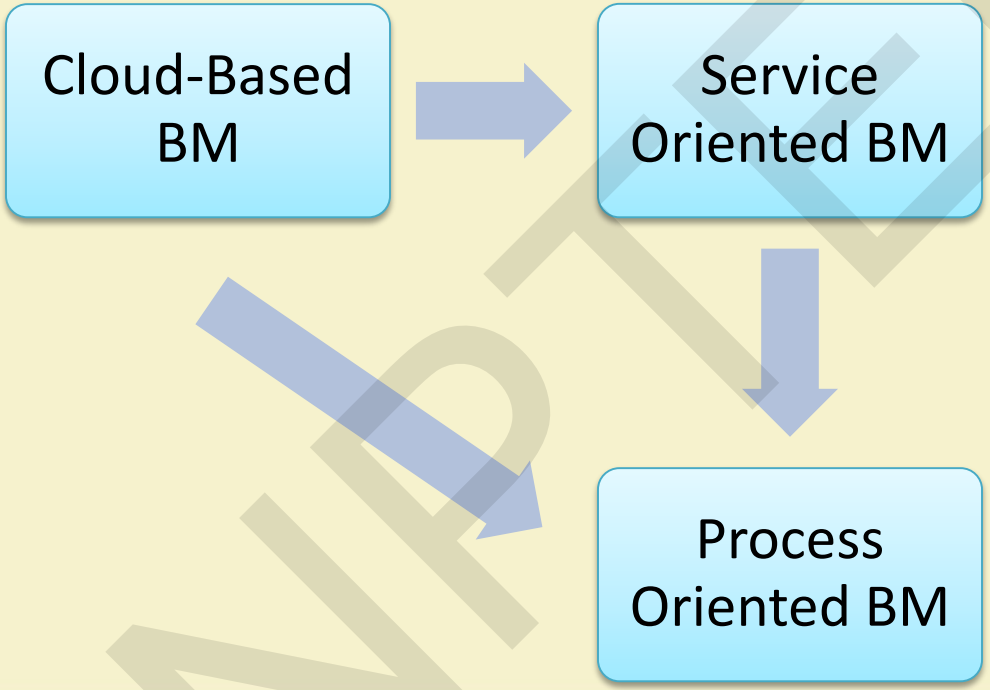
Process Oriented Business Model (Contd.)

- 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



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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Business Models and Reference Architecture for IIoT

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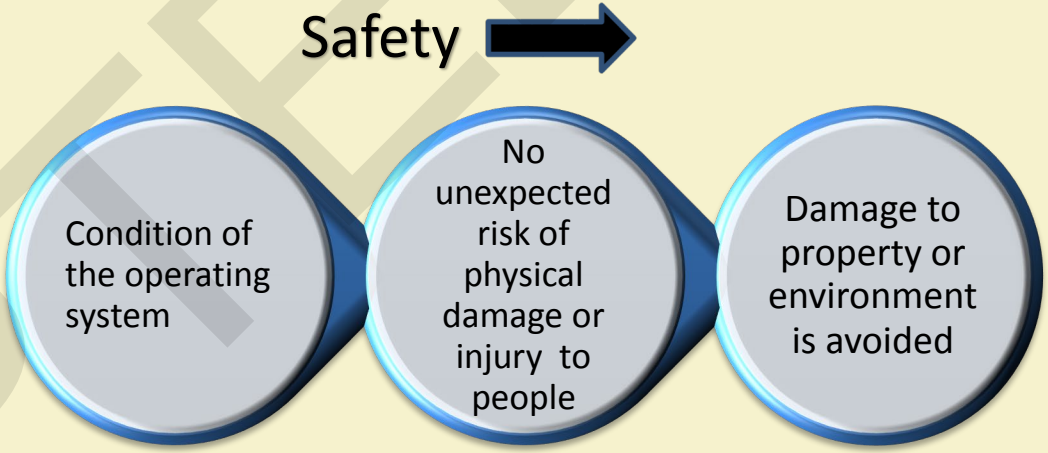
IIRA - Introduction

- 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

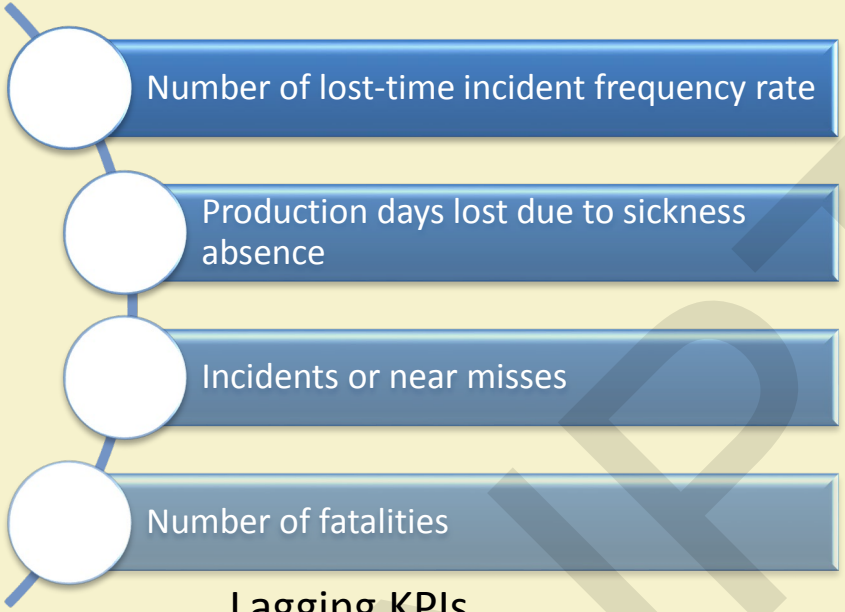
Source: “Performance Indicators”, Oshkiwi
“KPIs”, Beyondlean

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

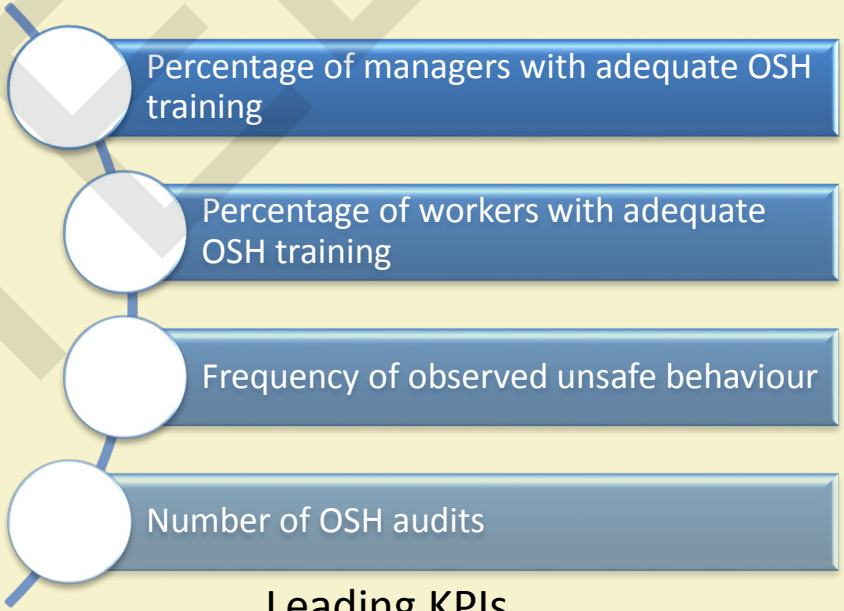
- Based on the leading and lagging OSH indicators, KPIs are also categorized into
  - **Leading KPI** is mainly used to predict the economy. It is
    - input-oriented, and
    - hard to measure.
  - **Lagging KPI** is a technical indicator which changes after the economy has begun. It is
    - output-oriented,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



Leading KPIs

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.

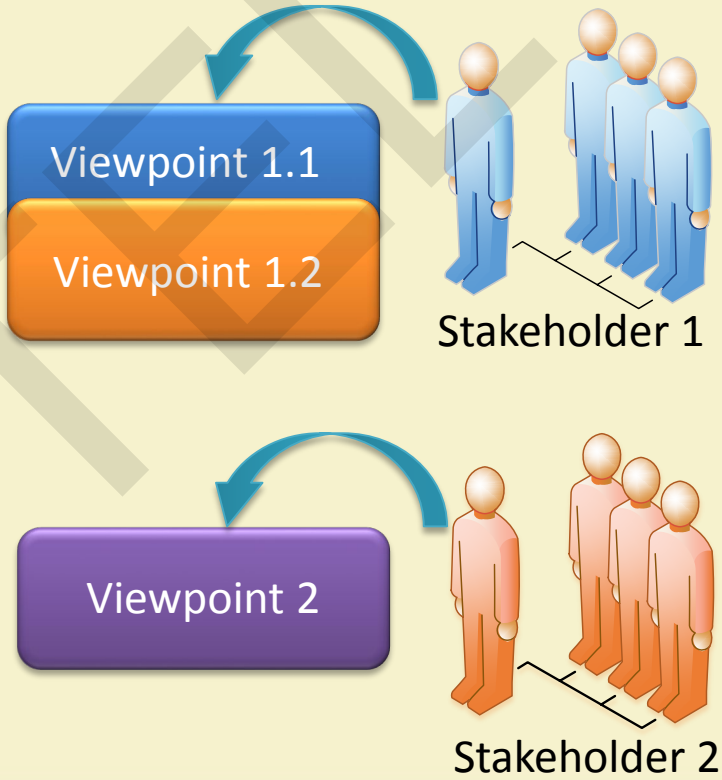
Source: "Test Beds", IIConsortium

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.

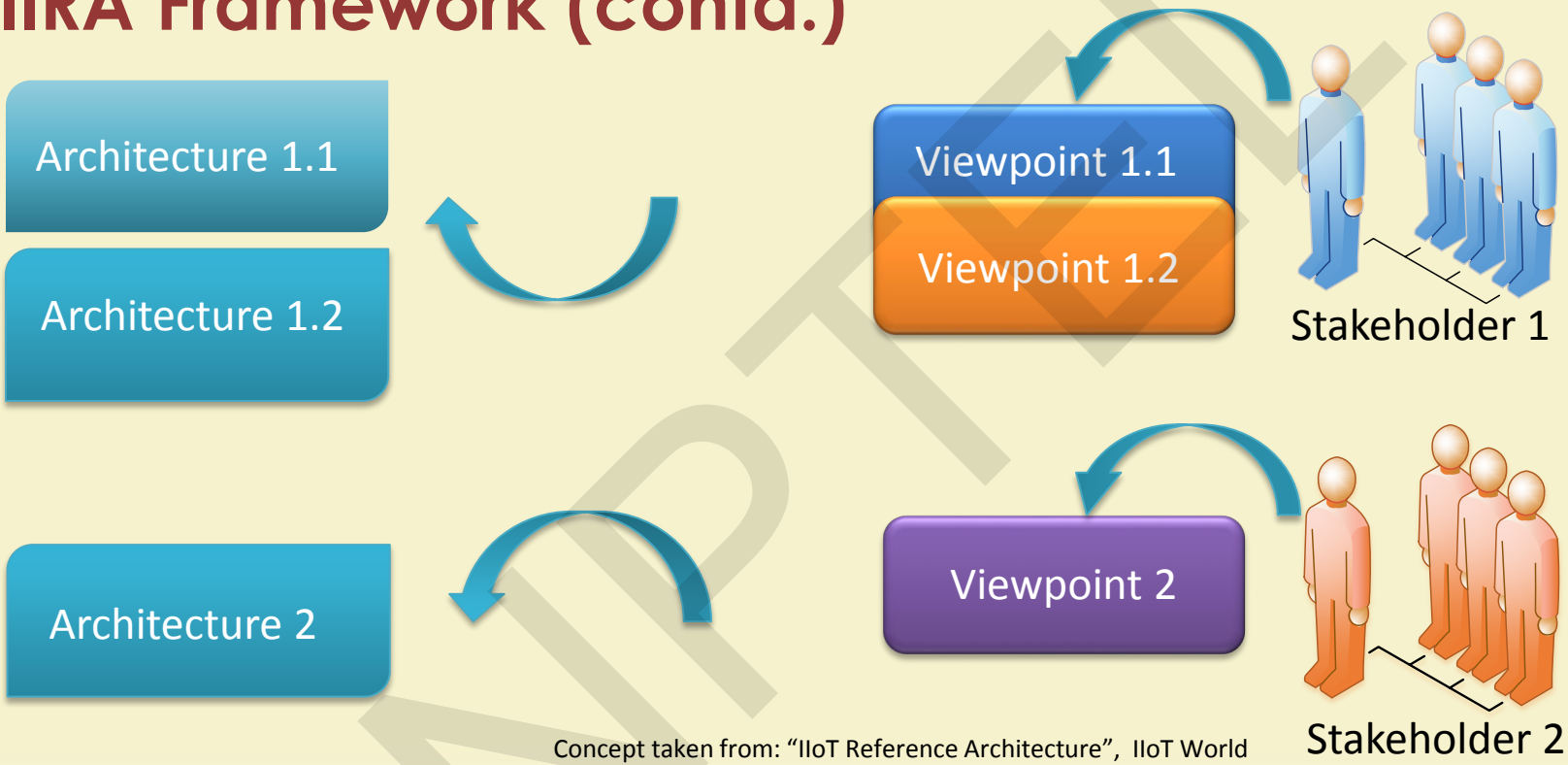
Source: "IIoT Reference Architecture", IIoT World

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.

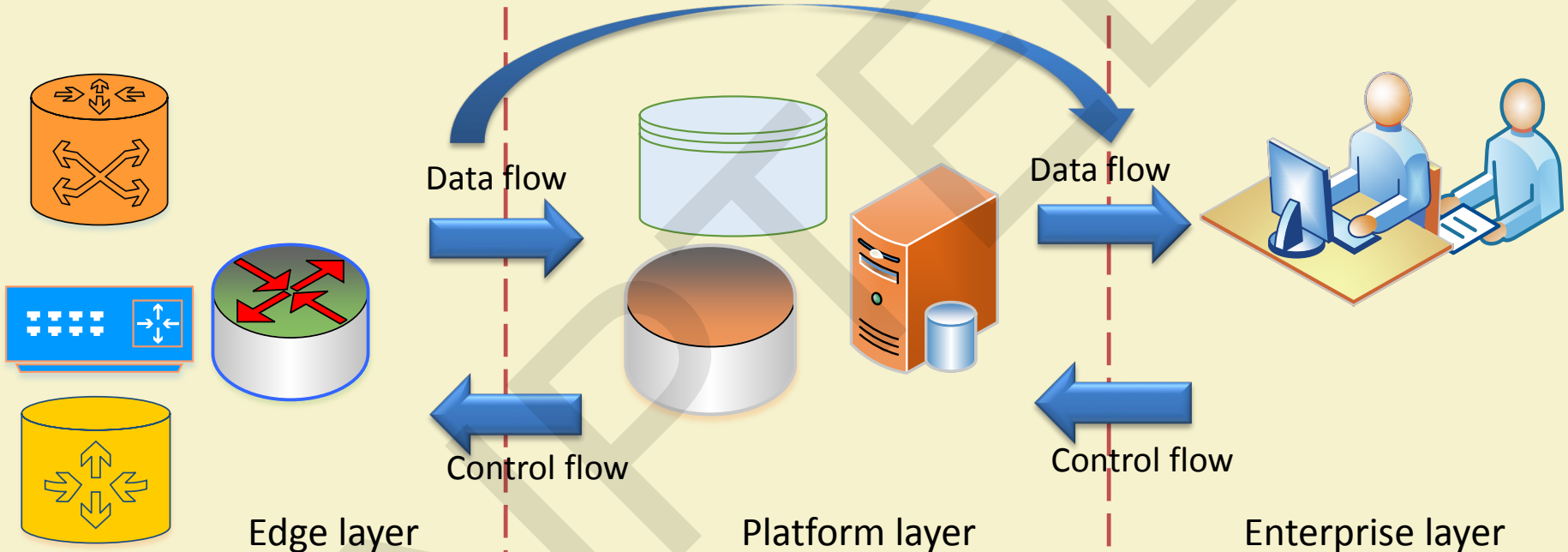
Source: "IIoT Reference Architecture", IIoT World

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.

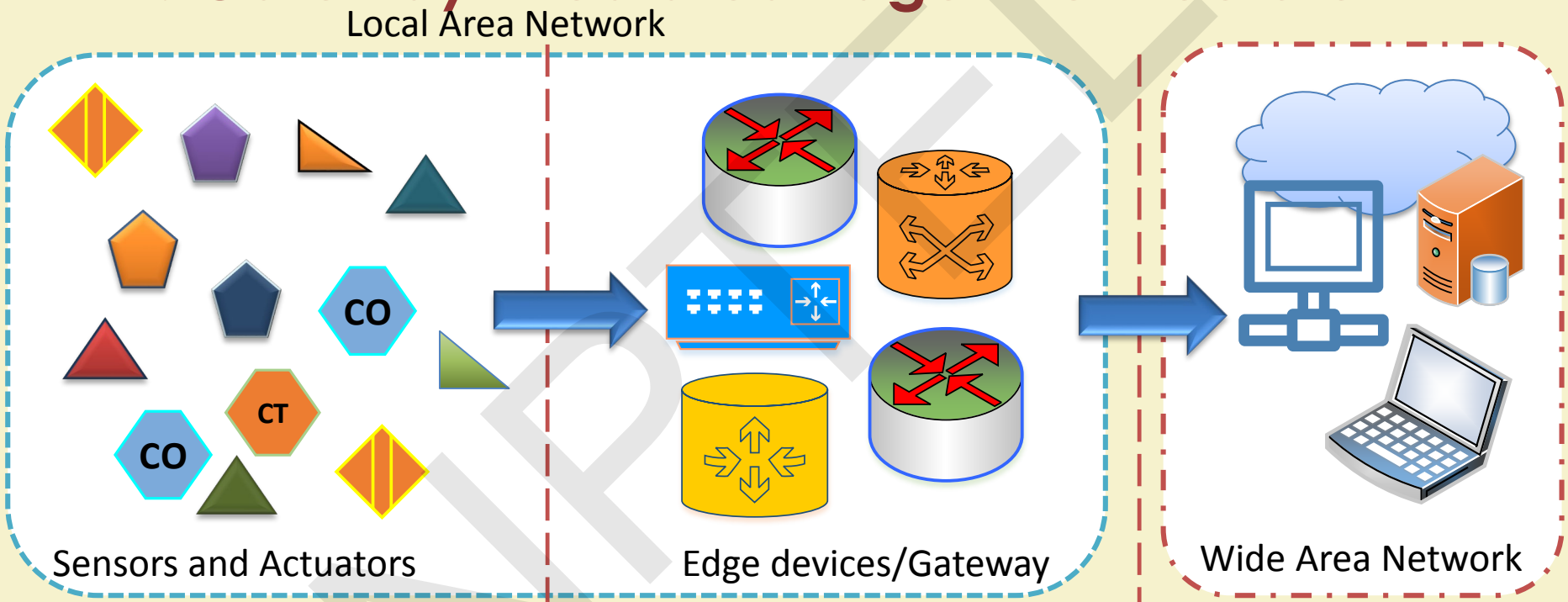
Source: "IIoT Reference Architecture", IIoT World

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

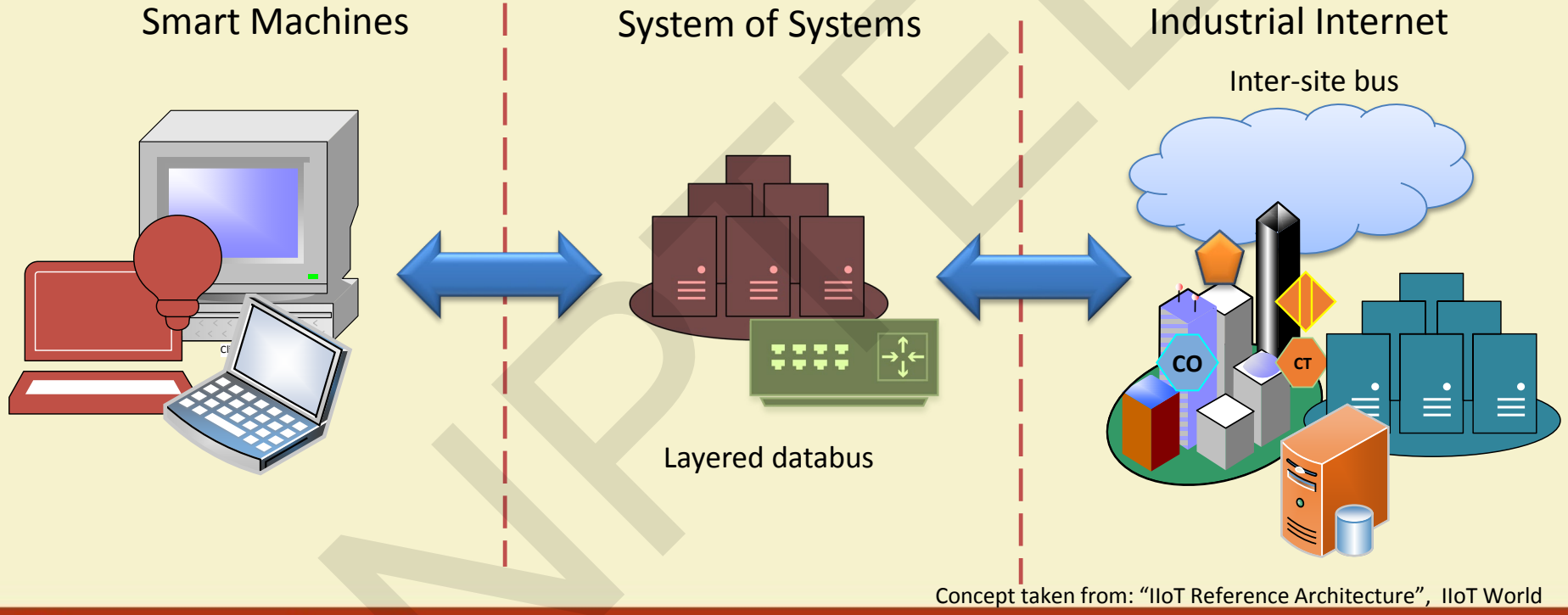
Source: "IIoT Reference Architecture", IIoT World

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

References

[1] Anthea Zacharatos and Julian Barling, Roderick D. Iverson, “High-Performance Work Systems and Occupational Safety”, Journal of Applied Psychology, 2005, Vol. 90, No. 1, 77–93.

[2] http://iiot-world.com/connected-industry/iic-industrial-iot-reference-architecture/

[3] https://www.networkworld.com/article/3243928/internet-of-things/what-is-the-industrial-iot-and-why-the-stakes-are-so-high.html

[4] P A Wordworth, “A Reference Architecture for Enterprise Architecture”.

[5] William Ulrich, “Business Architecture: The Art and Practice of Business Transformation”.

[6] Graham Meaden and Jonathan Whelan, “Business Architecture: A Practical Guide”.

Thank You!!

IIT KHARAGPUR

NPTEL ONLINE CERTIFICATION COURSES

Business Models and Reference Architecture for IIoT

Reference Architecture – Part 2

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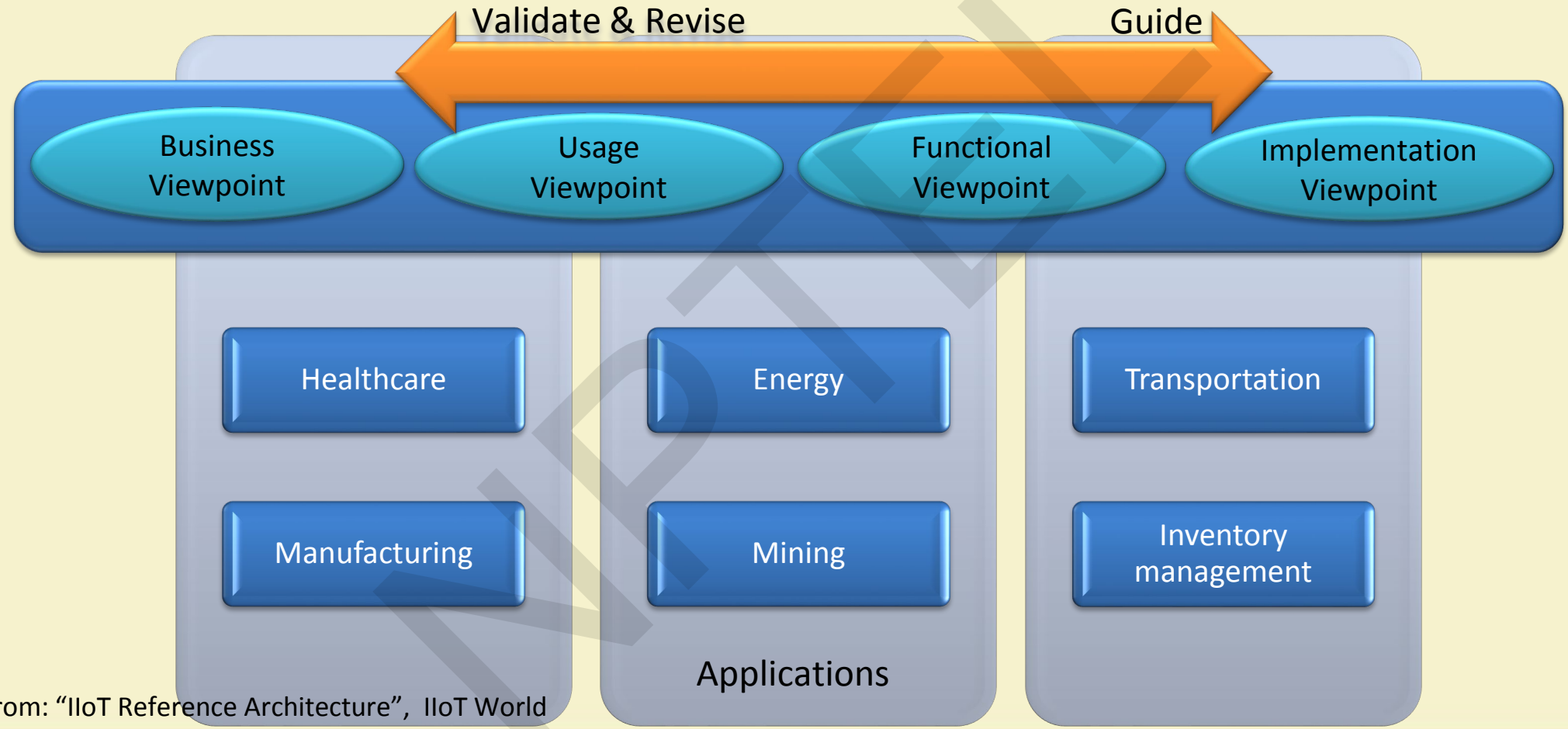
IIRA Viewpoints

- 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

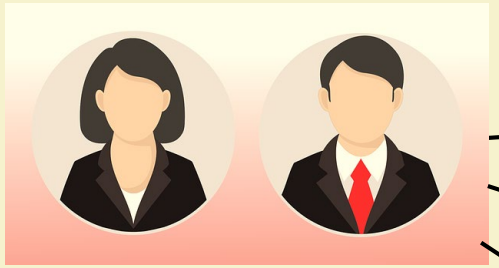
"IIoT Reference Architecture", IIoT World

IIRA Viewpoints (contd.)



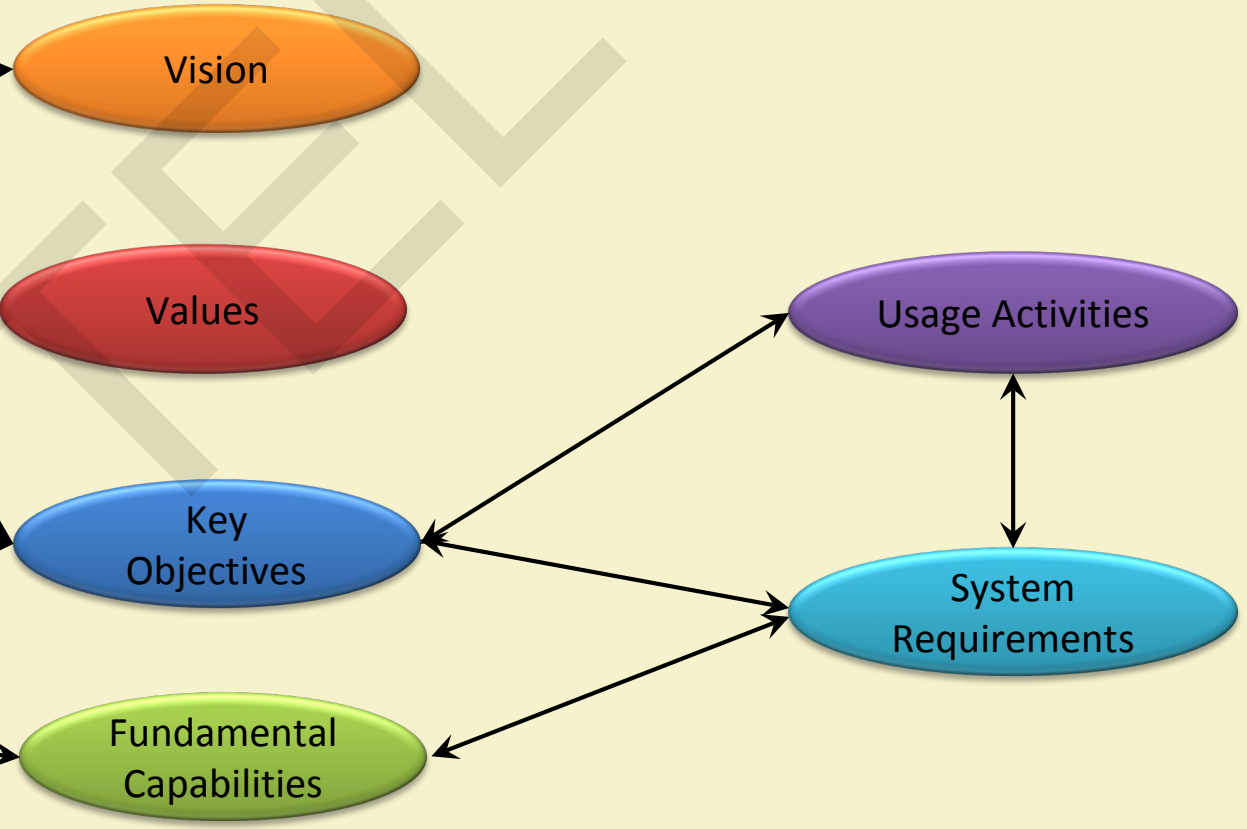
Concept taken from: "IIoT Reference Architecture", IIoT World

Business Viewpoint



Business Decision Makers

System Engineers



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.

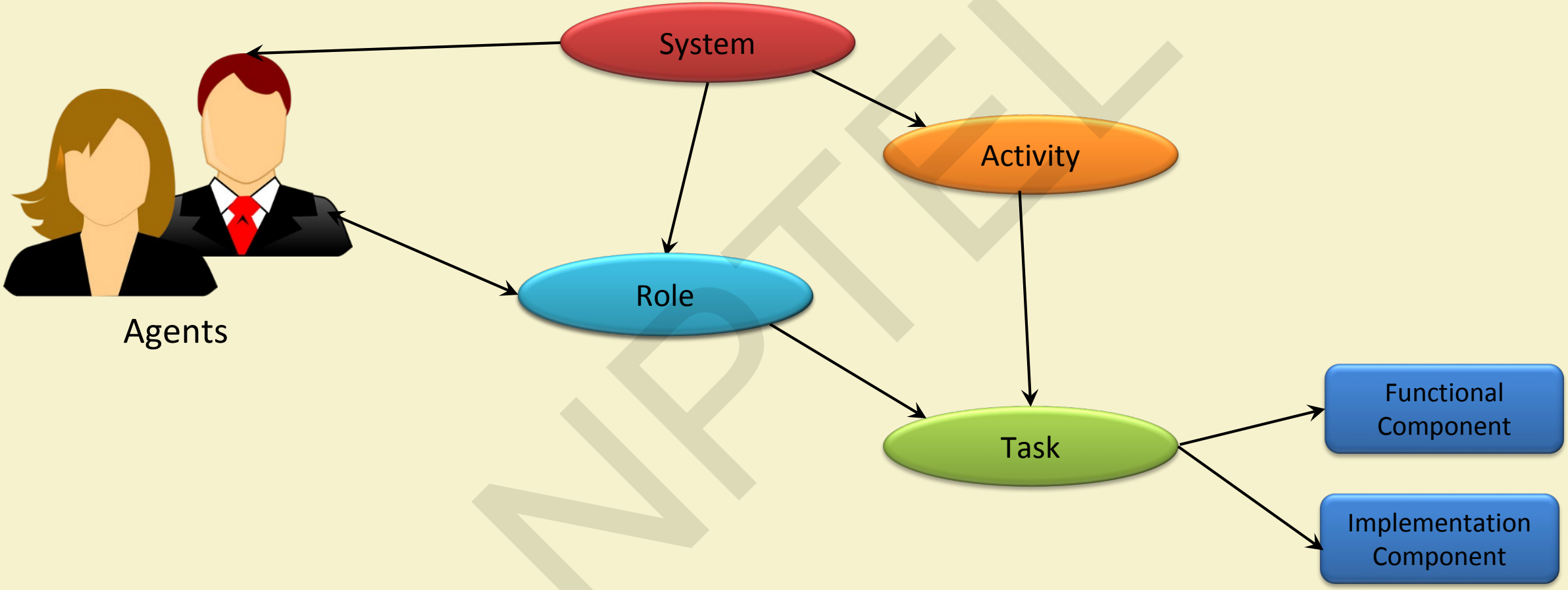
"IIoT Reference Architecture", IIoT World

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

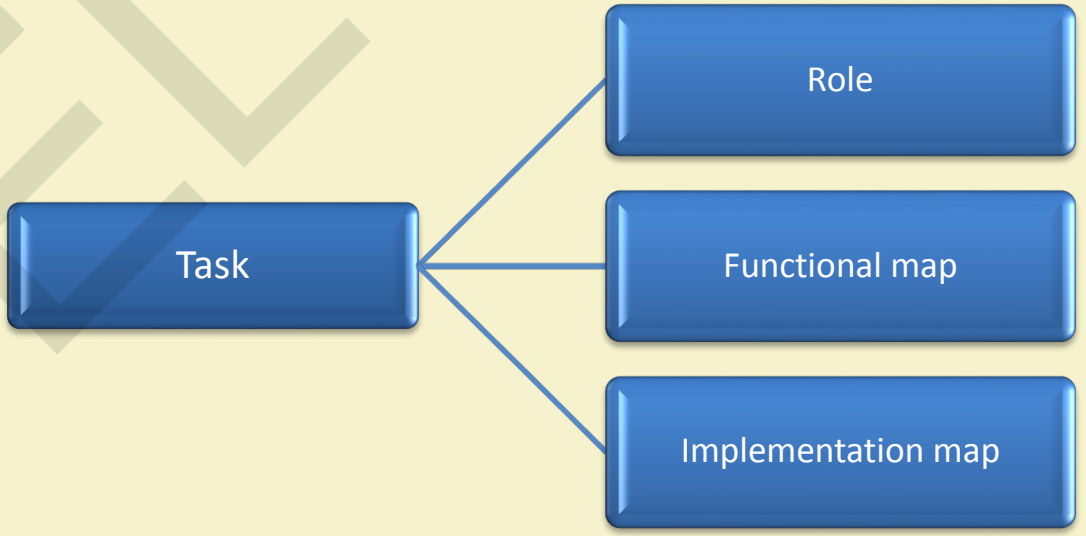
Usage Viewpoint (contd.)

- 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.)

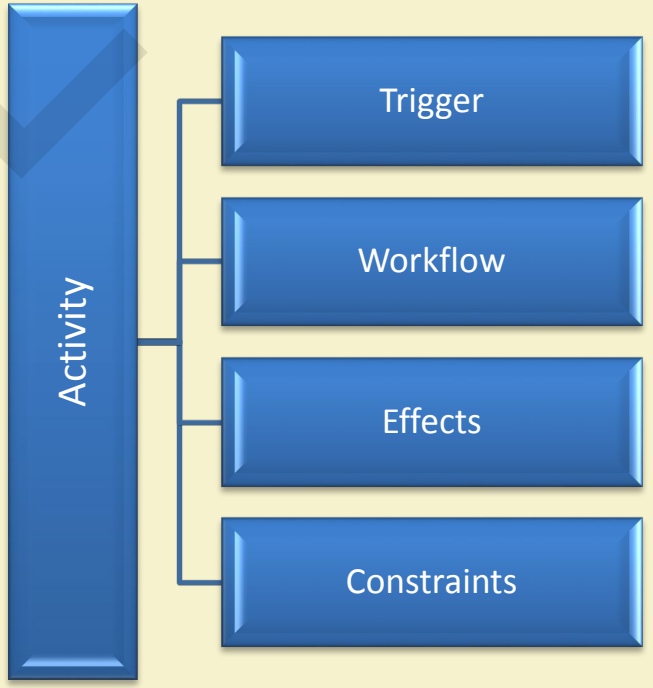
- Activity is
  - coordination of specific tasks
  - required to realize a well-defined usage of a system
  - executed repeatedly

- Activity has trigger, workflow, constraints, and effects

Source: "IIoT Reference Architecture", IIoT World

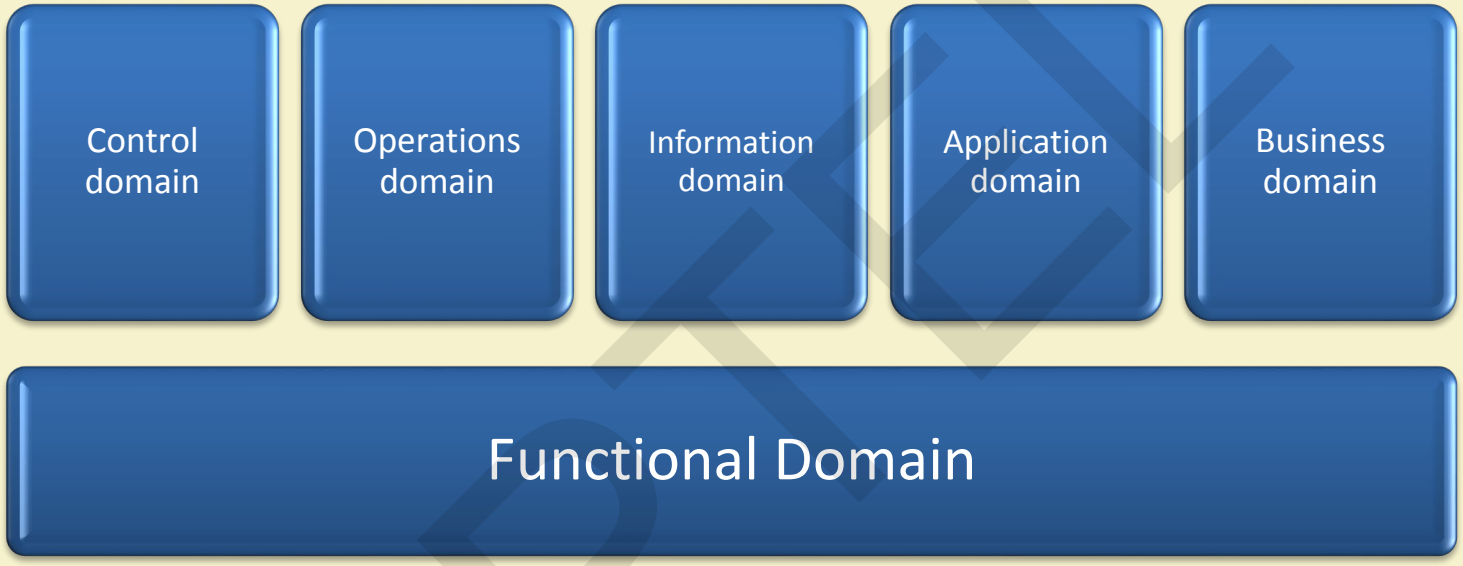
Usage Viewpoint (contd.)

- 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.



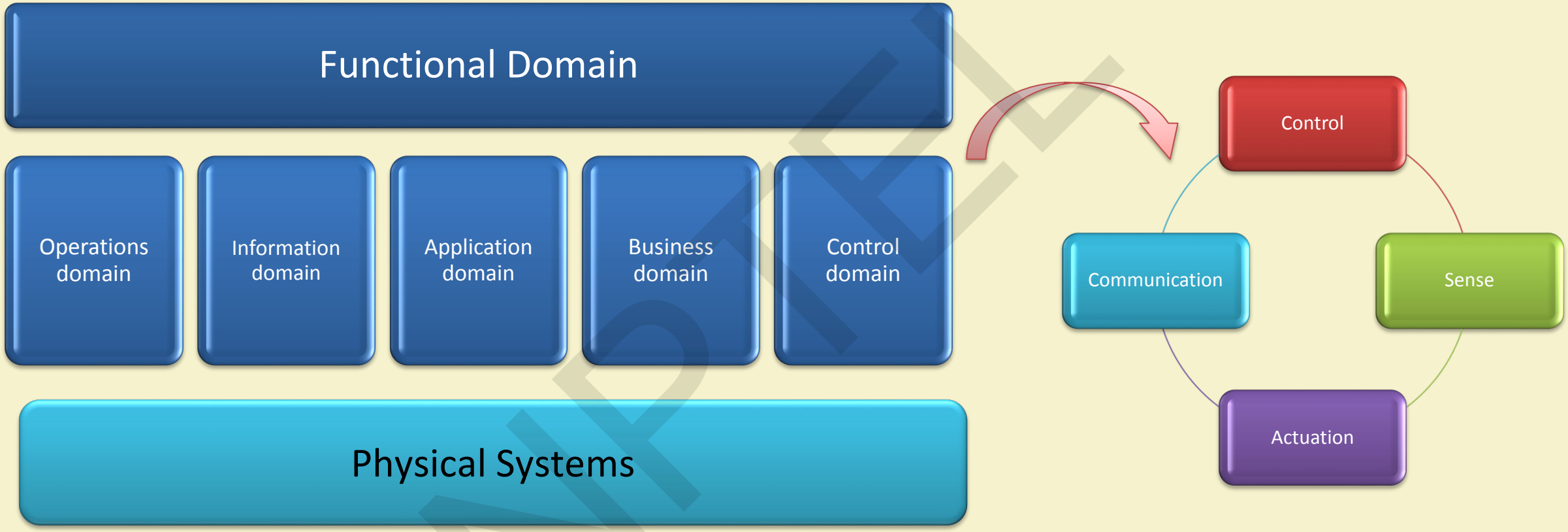
Source: "IIoT Reference Architecture", IIoT World

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 operations 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 *API*s 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

References

[1]http://iiot-world.com/connected-industry/iic-industrial-iot-reference-architecture/

[2] https://www.networkworld.com/article/3243928/internet-of-things/what-is-the-industrial-iot-and-why-the-stakes-are-so-high.html

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[4] https://www.intel.in/content/www/in/en/internet-of-things/white-papers/iot-platform-reference-architecture-paper.html

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