Challenges of Integrating Ubiquitous Industrial Internet-of-Thing (IIoT) in Enablement of Multiple Clouds

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Overview

Industrial Internet-of-Things and Heterogeneous Clouds

Wipro Ltd. → Connected Enterprise Services

Wipro Ltd

- **173000+ workforce** serving clients in 175+ cities across 6 continents
- **55+ dedicated emerging technologies** 'Center of Excellence'
- **Trusted partner** of choice for global businesses

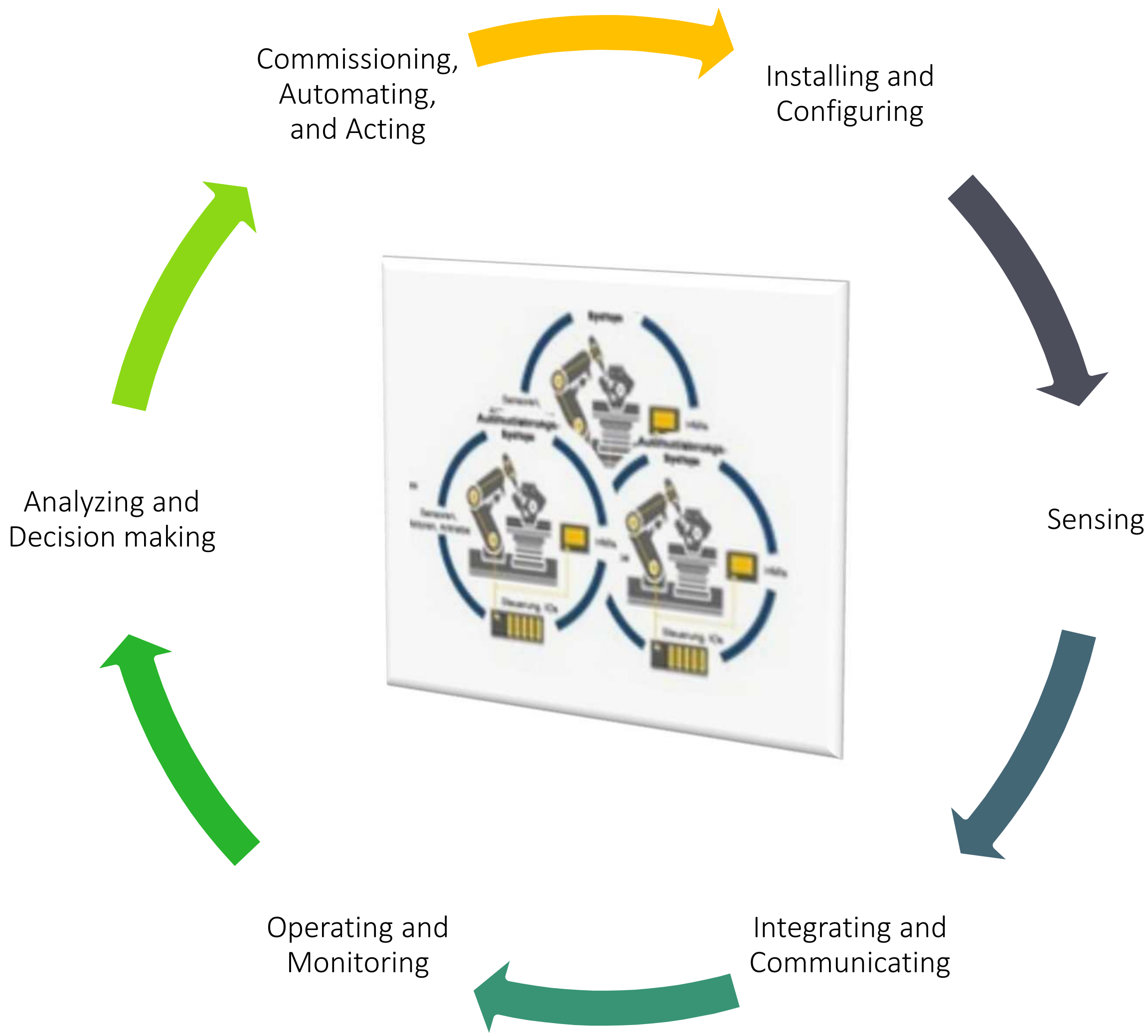
Connected Enterprise Services

- **Connected customer experience** and integrated enterprise
- Elevating the brand and connecting to the communities where the business operates
- Integration competency center
- **200+ customers** and $900M+ revenue

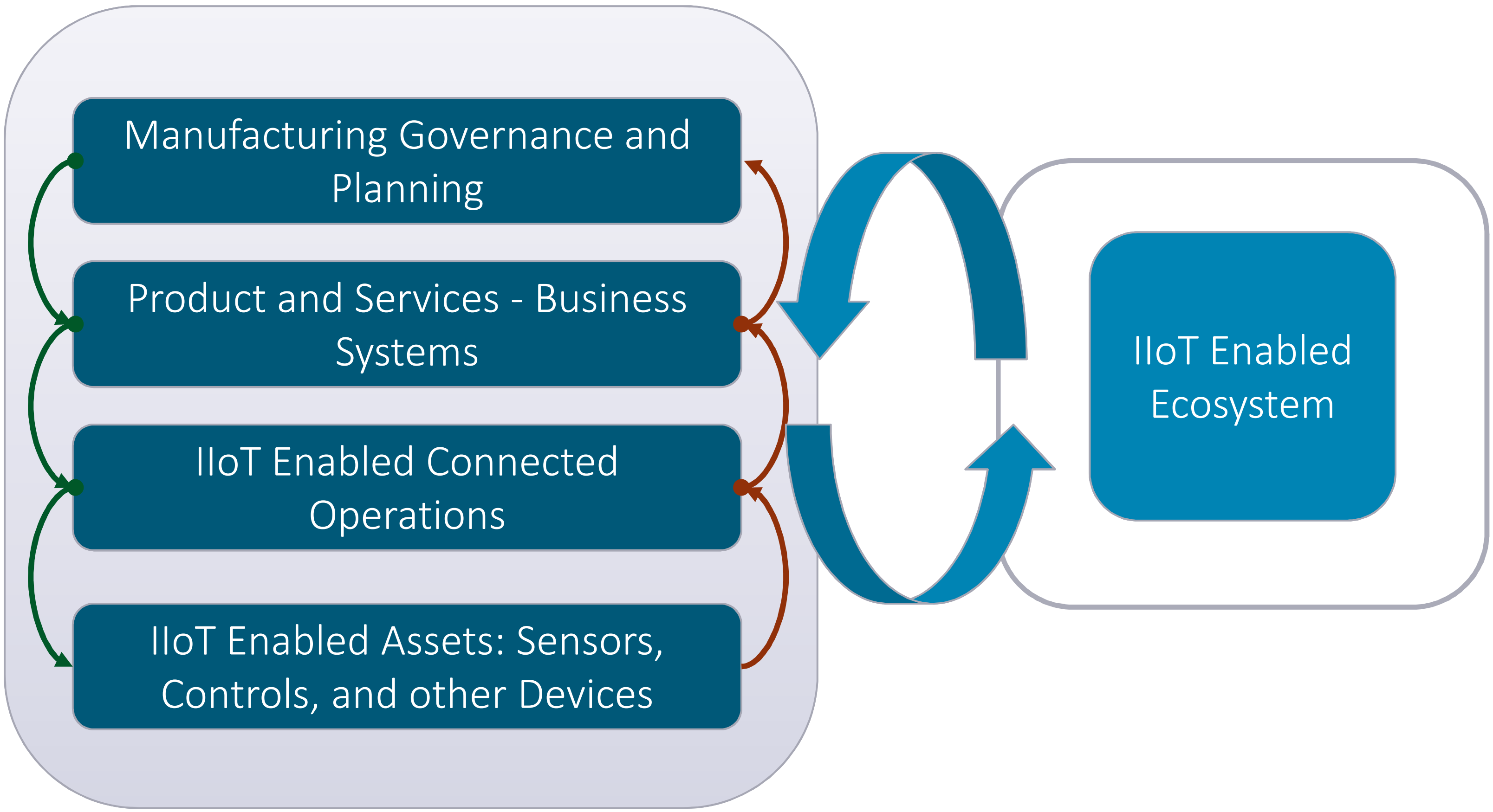
Vikas Shah

- **20+ Years** of IT experiences in diversified technologies and verticals
- **22+ Publications and 6 Patents pending** in digital technologies and real-time enterprises
- CES architecture **consulting** to pre-sales enablement and workshops

Lifecycle of Industrial Internet-of-Things



IIoT – Smart Connected Ecosystem Evolution



IIoT Solutioning and Product Paradigms

Functional

- Connectivity – devices, data transports, event processing, and security
- Cloud integration – Private, Public, and Hybrid. IaaS, SaaS, and PaaS
- Application development – IDE, Workflows, Social, Mobile, Search, and Controls
- Big data analytics
- Automation

Operational

- Different levels of maturity and standards
- Diversified data types
- Heterogeneous infrastructure
- Time binding operations
- Environmental impact

Executional

- Asset visibility, reliability, and predictive maintenance
- Utilization visibility and benchmarking
- Traceability and serialization
- Flexible operations
- Environmental health and safety

IIoT Expectations and Presence

Industry Verticals

- Manufacturing
- Healthcare
- Retail
- Agriculture
- Wearable
- Utility
- Workforce MGMT
- Fleet
- Energy Efficiency
- Smart Building
- Security

Predictive & Prescriptive

Unified view of the devices participation to provide decision making capabilities during each phase of IIoT lifecycle
Continuous improvement to provide predictive + prescriptive event derivation
Capitalize on a new revenue stream while ensuring higher service quality

Analytics

Continuously analyzing real-time equipment sensor data through deep learning algorithms
Cognitively utilize internal and external data sources to co-operate decision making process
Evolve analytics based on new conditions including environment and economic data

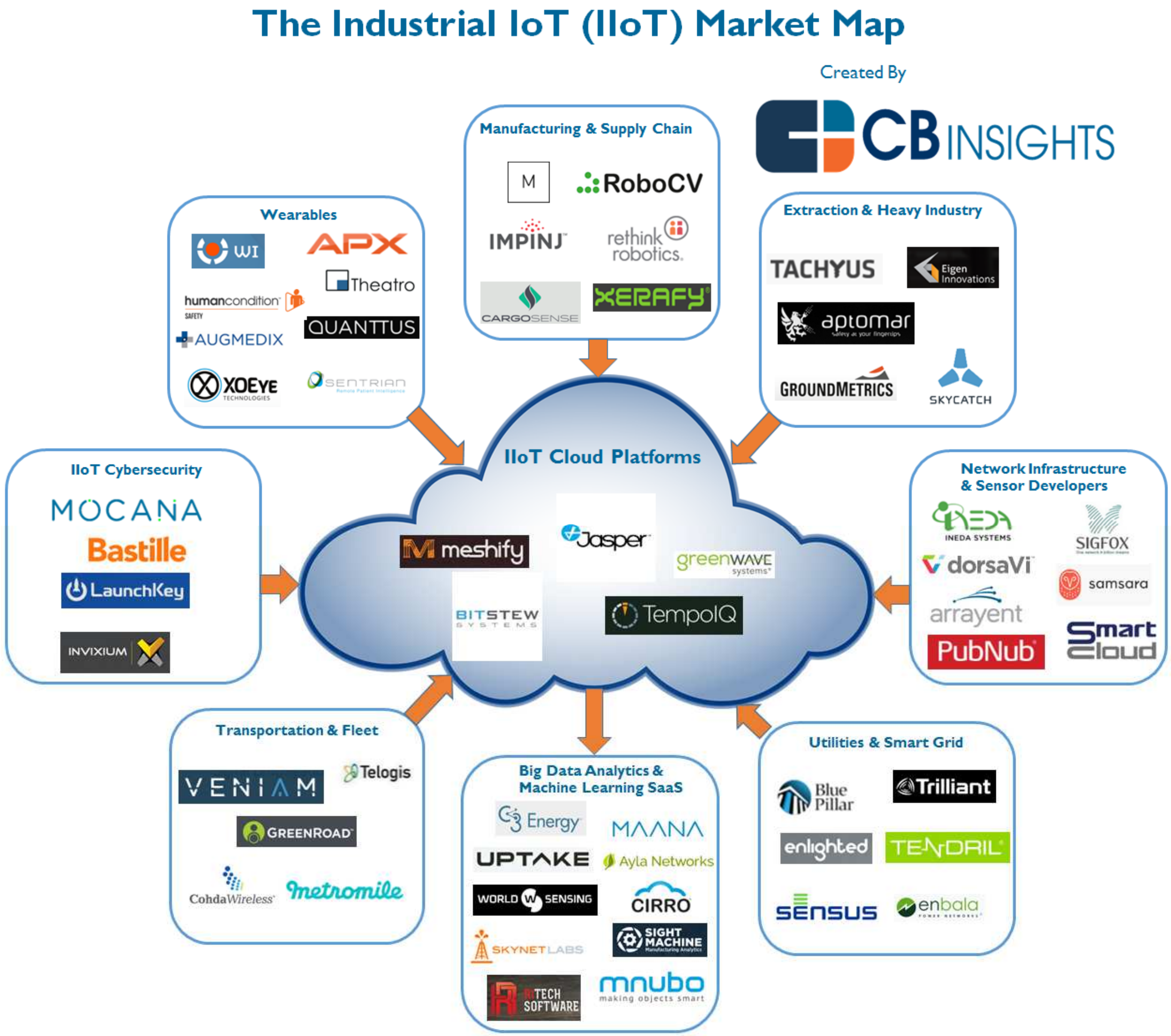
Monitoring

Collection, analysis and usage of data generated in industrial operations and throughout the entire product lifecycle
Ensure performance and availability utilizing real-time sensor data for condition monitoring
Granular visibility of the relevant data for sensors, equipment, plants, and infrastructure

Automation

Automating events across the IIoT ecosystem of devices in publish/subscribe model
Act upon in conjunction of all types of SLAs and their inter/intra-relationship
Eliminate manual interventions and faults implementing intelligently switching to alternate path or variations

CB Insight View of IIoT Transformation



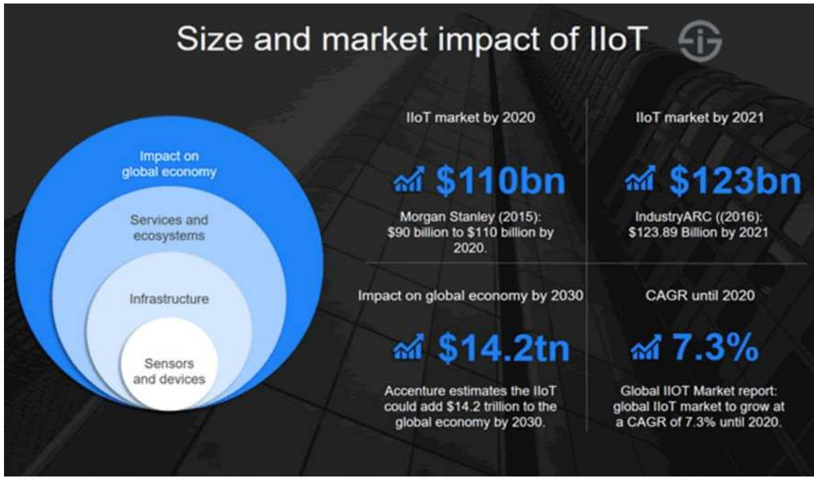
Primary Concerns

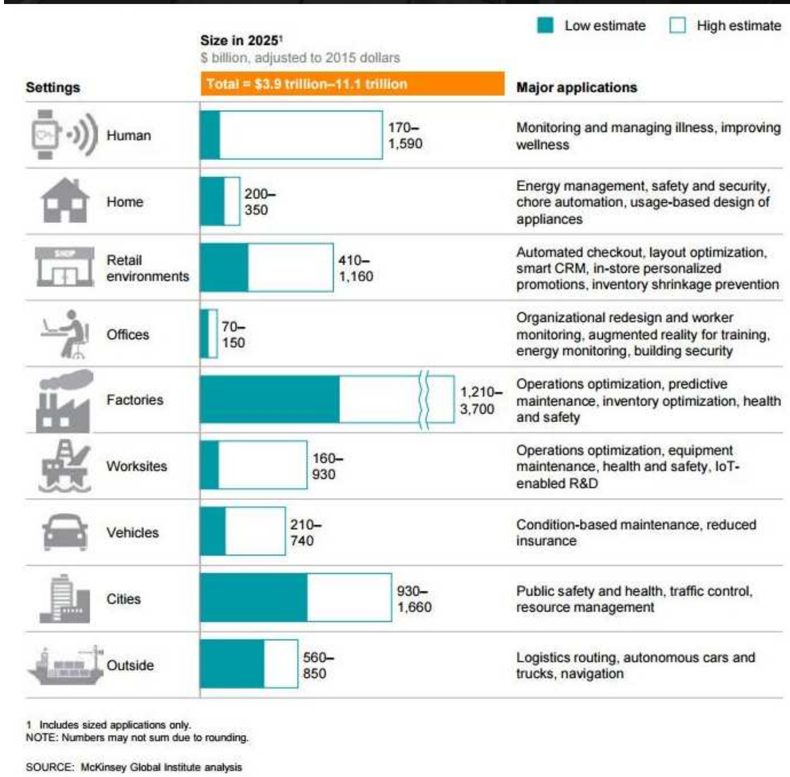
Integrating IIoT in Growing Paradigms of Heterogeneous Clouds

Challenges of IIoT in Heterogeneous Clouds (HCs)

- Different resource constraints of IIoT devices to be recognized at the edge of HC (Example: processing strength and integrity)
- Today's HCs formulated are dynamic as network conditions can change rapidly
- Large spread on device capabilities to be recognized, additionally there are sources and sinks of information across IIoT ecosystem
- HCs and mashup of IIoT applicability are largely unstructured. They can vary rapidly based on the published APIs, specific vertical, and their overlap
- Associations of edge users and their roles to IIoT in context of HC that facilitates publishing custom IIoT APIs by the edge users (or participants of HCs)
- Monitor socio economical concerns and impacts across the IIoT Cloud and respective events

Key Influencing Factors





Factors

- IIoT channels and integration between the verticals
- High performing IIoT devices are deployed and advanced
- HC vendor landscape is being reshaped and increased integrity among them
- IIoT application development to leverage ‘Fit to purpose’.
- Rich set of analytics, inbuilt intelligence, and automation techniques

Illustration: Usecase of IIoT in HC

Globalization: End-to-end Supply-chain of Shoes' Manufacturing

- Raw material distribution
  - Raw material types: Leather, wood, adhesive, color, packaging material, color, nails, and fitting & decorative items
  - Suppliers: India and most of the south Asian countries
- Manufacturing plant locations: China, Mexico, and other parts of South America
- Transportation: Ship mode, Airplane mode, and Ground mode.
- Distribution: USA
- Retail: All across the world including cities of developed countries
- Recycling of recalled products and wastage: Africa and most of the underdeveloped countries

Smart Manufacturing Plant Events

Event 1 (E1): Order Manufacturing of 10,000 shoes of type “X” [Initiation Event from Supplier Cloud to Vendor Cloud]

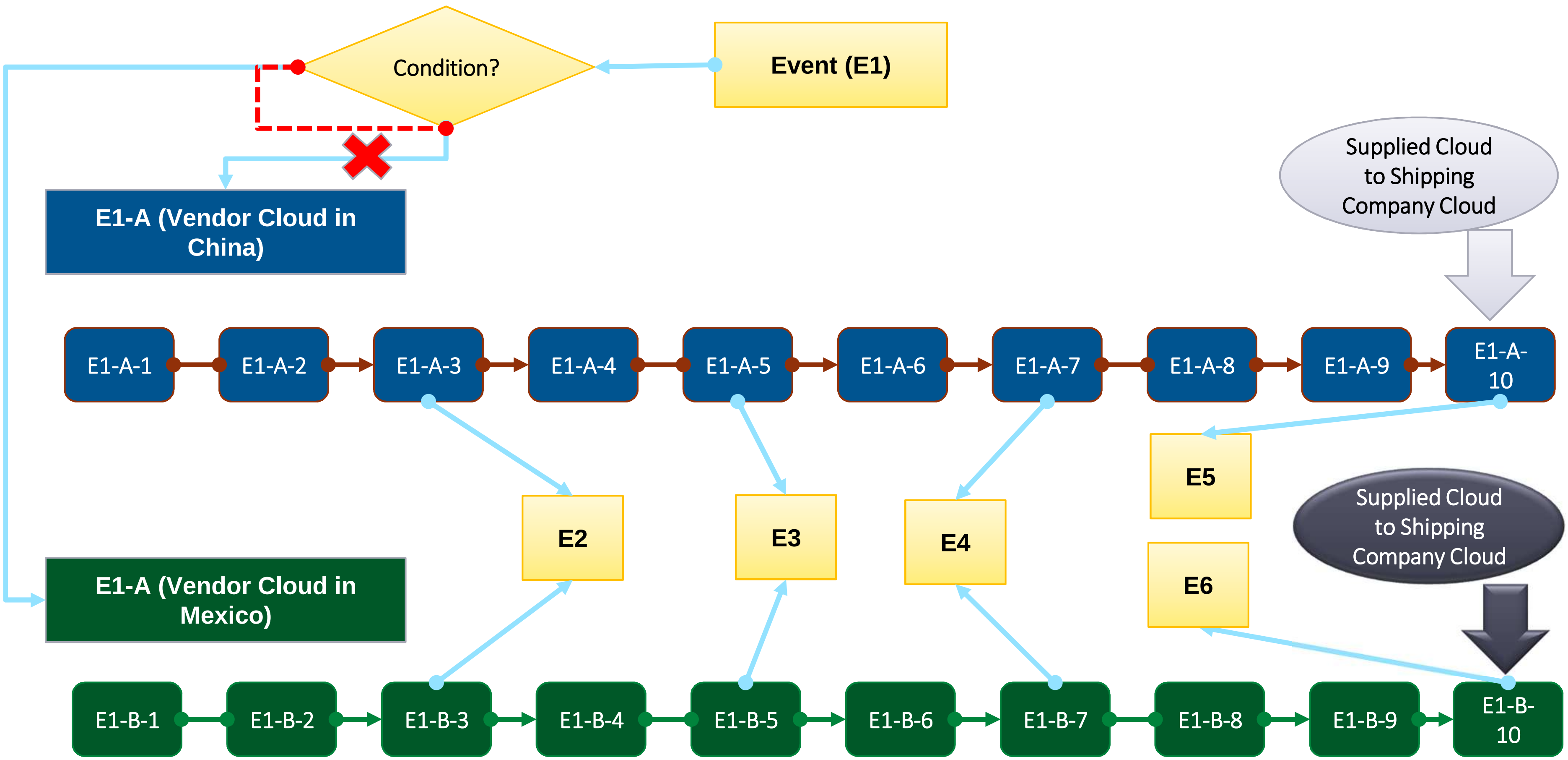
E1-A: Assign Company “C” in China [Conditions Vendor Cloud]

- E1-A-1: Transition to Company “C” Cloud to set Manufacturing Initiation
- E1-A-2: Identify start and completion dates
- E1-A-3: Set configuration, controls, and status of devices for manufacturing product [Event Hierarchy “E2”]
- E1-A-4: Run manufacturing process from 8:00AM to 5:00PM [Supplier Cloud to Vendor Cloud Collaborative Event]
- E1-A-5: Track government (China) regulations to operate devices [Event Hierarchy “E3”: eGov of China Cloud to Vendor Cloud event Hierarchy]
- E1-A-6: Monitor devices for accuracy and fault based on standards defined by the vendors [Conditions: to Vendor Cloud in correlation to Supplier Cloud]
- E1-A-7: Identify fault [Event Hierarchy “E4” for Fault type {F1, F9, F12}]
- E1-A-8: Completion of the manufacturing process [Vendor Cloud Event]
- E1-A-9: Confirmation of completion [Vendor cloud to Supplier Cloud Event]
- E1-A-10: Assign to Ship Company “S” [Event Hierarchy “E5”: Supplier Cloud to Shipping Company Cloud Collaboration Event]

Variation due to Diversified Conditions

E1-B: Assign to Company “M” in Mexico

- E1-B-5: Track government (Mexico) regulations to operate devices [Event Hierarchy “E3”]
- E1-B-10: Assign Airline “A” [Event Hierarchy “E6”]



Selection of Condition in Diversification

Selection between Event 1-A and 1-B depends on the numerous factors as described below. Which one will take higher precedence?

- environmental condition associated with China and Mexico (from eGovt Cloud associated with devices defined in icGMM),
- contractual agreements of maximum limit set (from Siebel Cloud on contracts),
- condition of the machines and devices (from provider’s private cloud),
- cost of manufacturing based on present currency value (from supplier’s cloud),
- present labor conditions of different vendors (public cloud), and
- transportation related environmental impact (environment agencies’ cloud)

IIoT integration under the influence of HC

Types of Issues

- Advancements in connectivity and convergence due to potentials of newly introduced IIoT devices
- Upcoming regulatory and legality of IIoT technologies in assertion of globalization (Industry 4.0 and P2413)
- Desired level of intelligence and accuracies for specific industry vertical and goals
- Operational agility when introducing new paradigms of either existing Cloud or new Cloud environment
- Requirement of upgrades and changes required due to changing dynamics of IIoT ecosystem including device level agreements

Approaching Resolution

- Analyzing operational requirements, including need for flexibility and expandability between IT and OT
- Close integration between IIOT, HC, and Edge Users
- Agreement between suppliers and end users; and between plant engineers, process engineers, and data scientists when developing and implementing solutions
- Consideration of how the IIoT solution will be maintained and fine-tuned over time under the influence of HCs
- Ability to adapt to new business logic
- Addressing cybersecurity including secure and robust interfaces
- Clear definition of the SLAs between IIoT and HC and integrity with actual business level KPIs

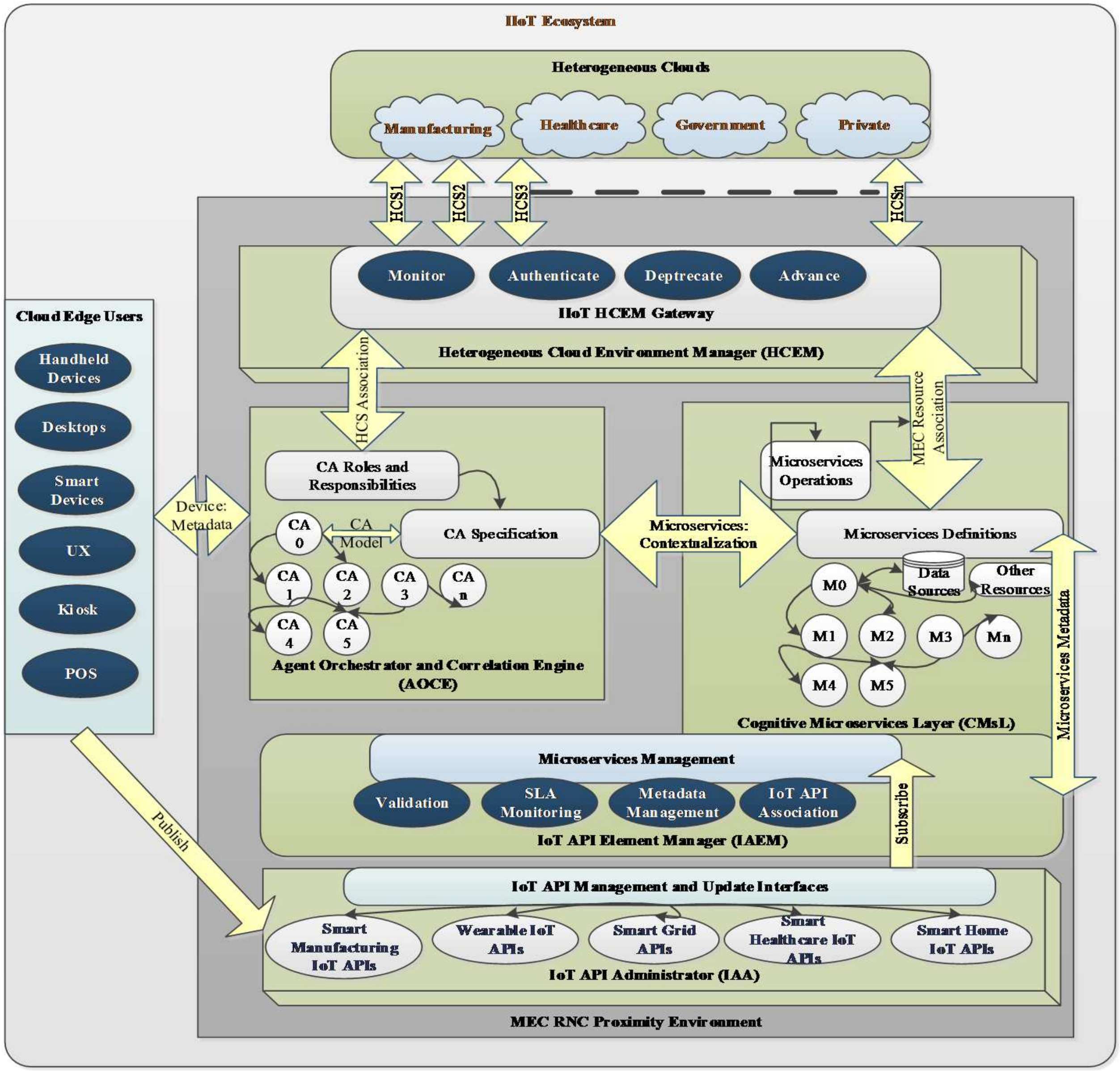
Ubiquitous IIoT Framework in Heterogeneous Clouds

Components and their Extensibilities

Factors to Consider

- How IIoT applications are architected, deployed, and managed in the vicinity of the heterogeneous clouds?
- What aspects are required to be modeled for maintaining the integrity between IIoT, devices, and Cloud edge users?
- How to represent the IIoT operational correlations with heterogeneous clouds and decision capabilities in presence of distributed intelligence?
- How to combine distributed IIoT application logic to generate coherent services at the edge?
- The level of manual interventions necessary to perform functions of IIoT?

Ubiquitous IIoT Framework for Heterogeneous Clouds



Layered Approach

- **Heterogeneous Cloud Environment Manager (HCEM)**: The primary responsibilities of HCEM is to perform gateway for multiple clouds to be participate in IIoT ecosystem.
- **Agent Orchestrator and Correlation Engine (AOCE)**: AOCE constitutes the modeling capabilities for the agent specification, the formalization of agent roles and responsibilities, and defines relationship with the specific set of cloud services.
- **Cognitive Microservices Layer (CMsL)**: CMsL is primarily responsible for composition of the agents identified and modeled in AOCE with either new or developed set of Microservices. It leverages IIoT APIs specific knowledge management and decision tree to provide context to the agents.
- **IIoT API Element Manager (IAEM)**: IAEM is responsible for configuring the services running on the CMsL associating IIoT APIs. Metadata are managed within IAEM.
- **IIoT API Administrator (IAA)**: IAA is responsible for introducing, managing, monitoring, and deprecating IIoT APIs. IoT APIs are published by numerous users or participants of heterogeneous Clouds.

Architecture Principles

- IIoT vertically layered two pass cognitive agent architecture and dynamic control process of the agent
- Layered architecture needs to place Microservices with various degrees of abstraction and complexity of events of HCs
- Every layer uses the operations primitives of the lower layer to achieve its goals
- Both, the CAs and Microservices, are multi-layered
- The definition of artifacts are bottom-up, that is specific IIoT API receives control over a functionalities only when this exceeds the capabilities of the layer beyond
- Every CA consists of two functionalities:

  \- scenario recognition and goal activation

  \- planning and scheduling module

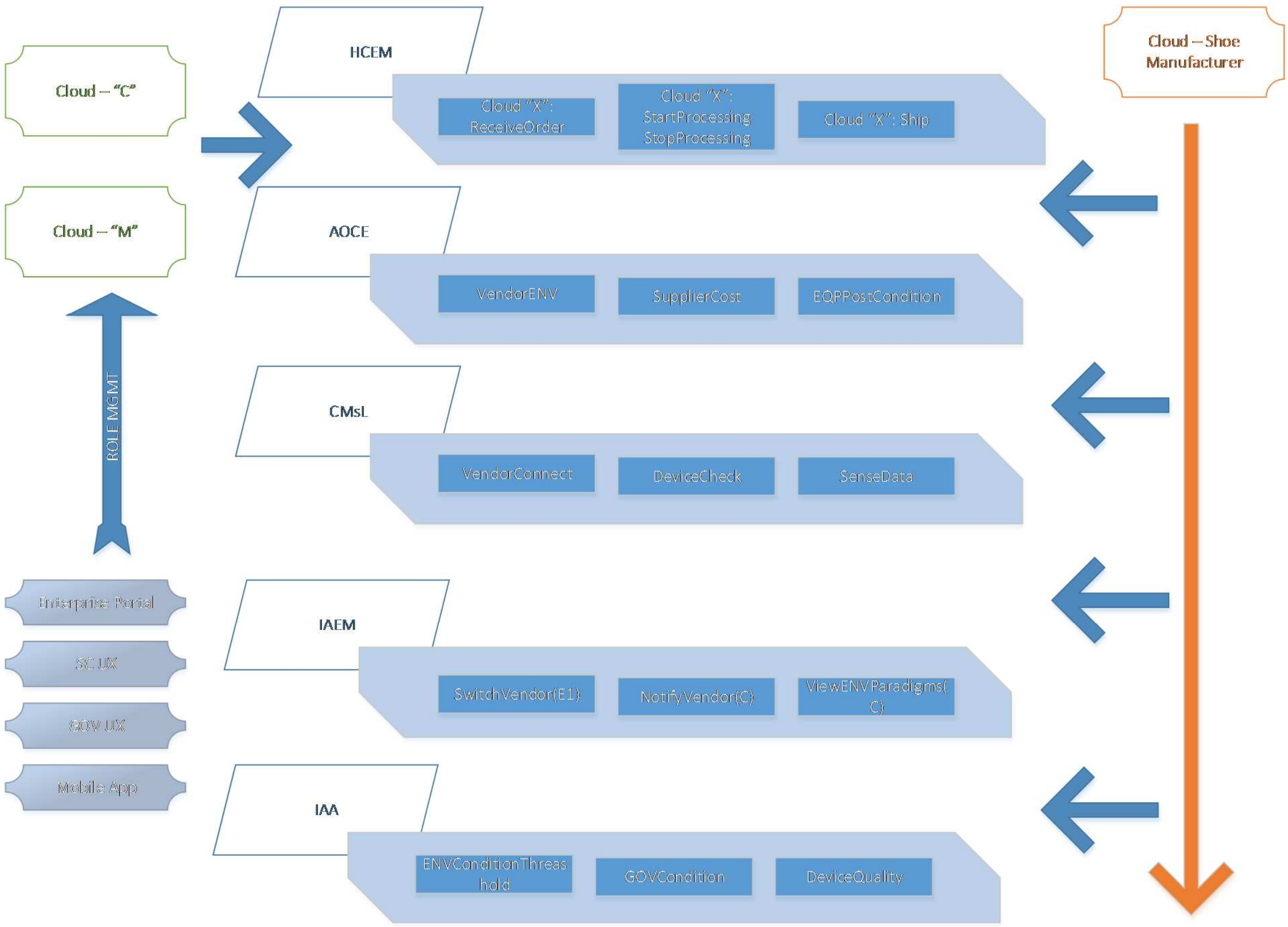
Advantages

- Technology Competitiveness
- Dynamic Changes
- Streamlining Deployment
- Governance
- Intelligence
- Integrity
- Agility
- Operational Visibility

Implication of Ubiquitous IIoT in HCs

- Flexibility and adaptability in the management and deployment of workflows of HCs
- Eliminates the need for new IIoT APIs due to changing requirements of users or devices
- Introduces an intrinsic competitive environment for IIoT ecosystem
- Features decentralization allowing abstraction to HCs and system resources
- CA have self-properties and allow the direct manipulation of the devices and their APIs
- Distributed information processing closer to actual data sources in HCs
- Transmits execution state from devices to APIs in HC
- Dynamic reuse of hardware components
- Monitoring, alerting, and dynamic changes based on runtime behavior and conditions

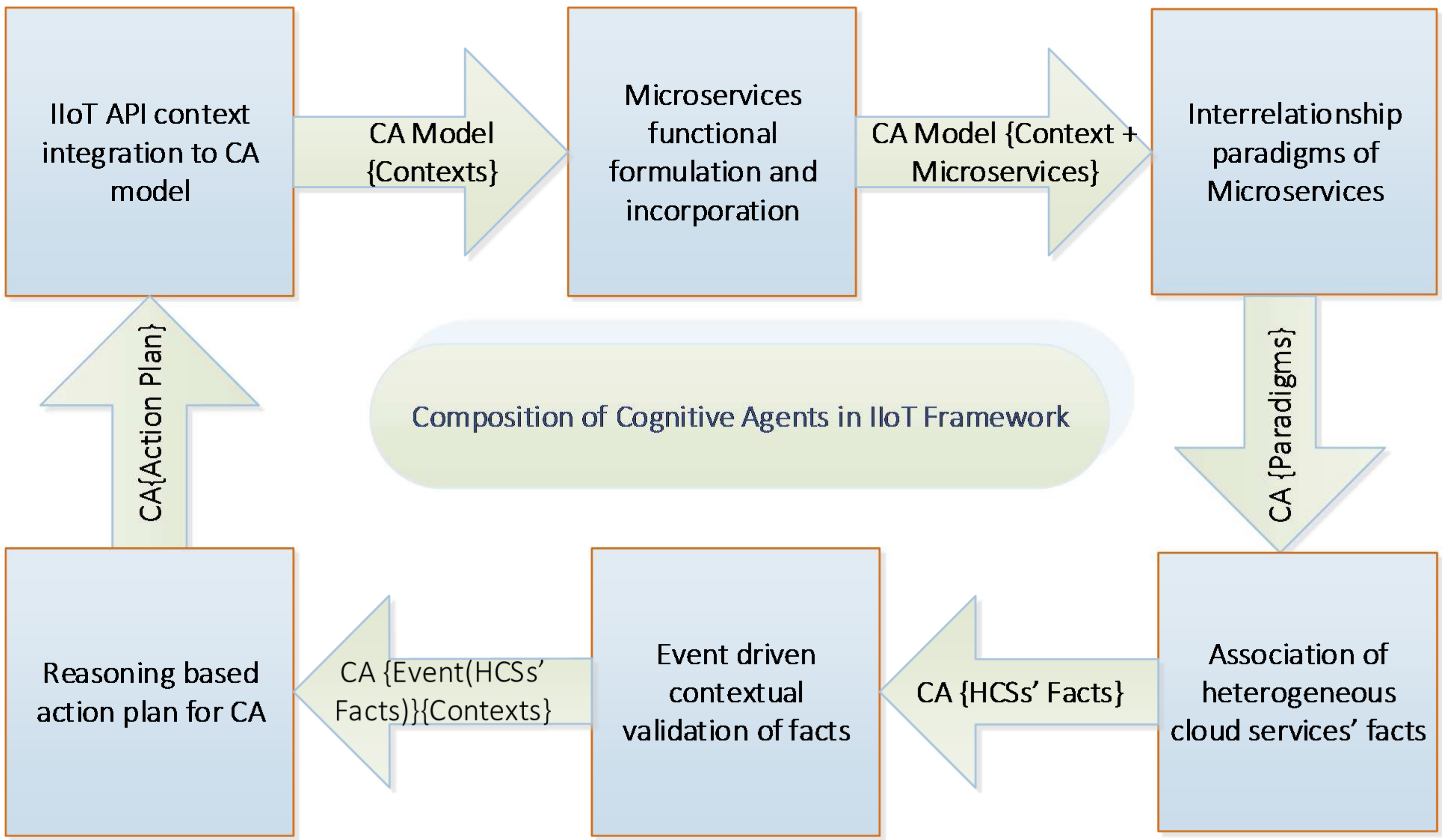
Usecase View after implying Framework



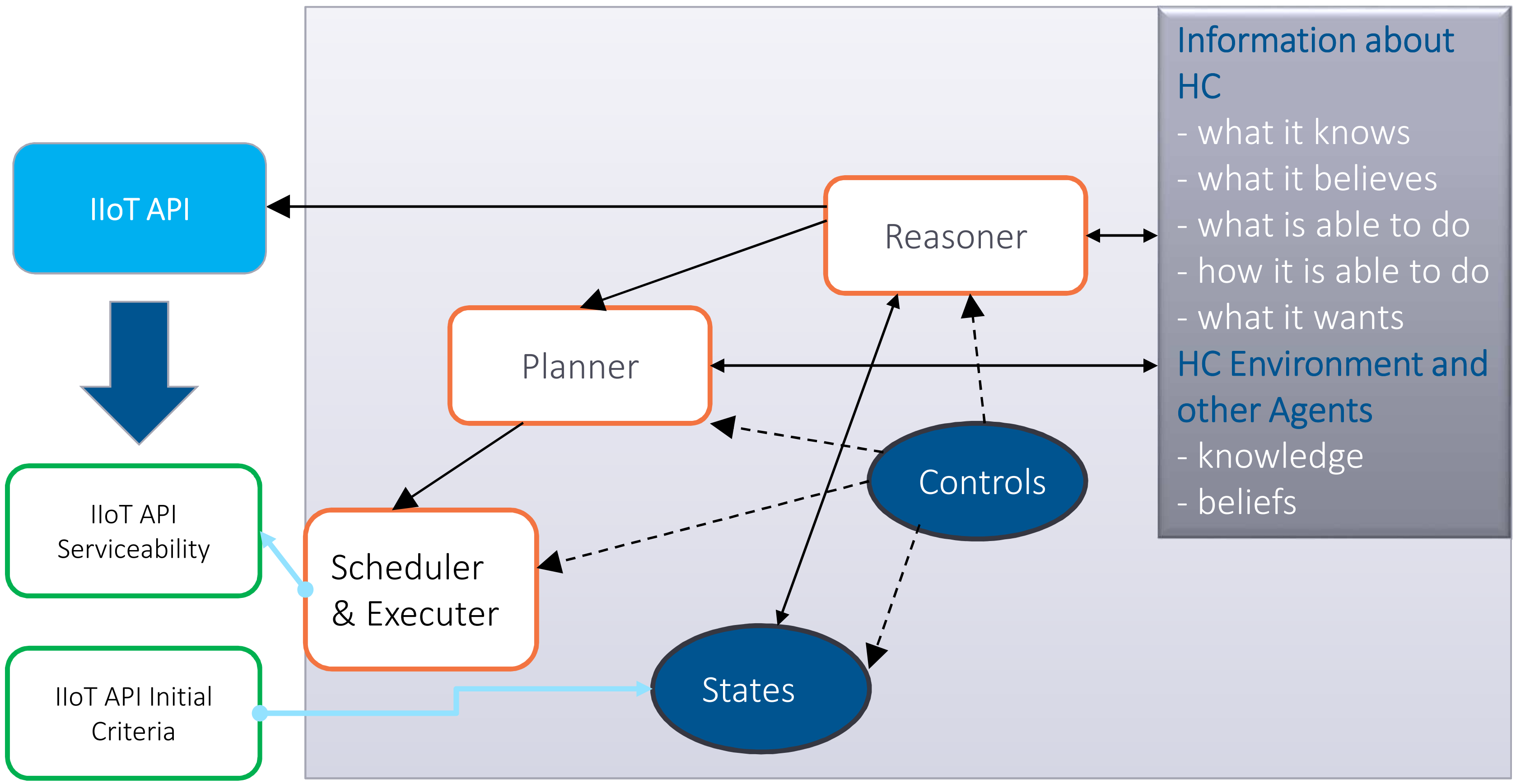
Cognitive Agents of IIoT Ecosystem

Modeling, Implementing, and Classification

Modeling CA for IIoT Framework



General IIoT Multiple Cognitive Agents Architecture

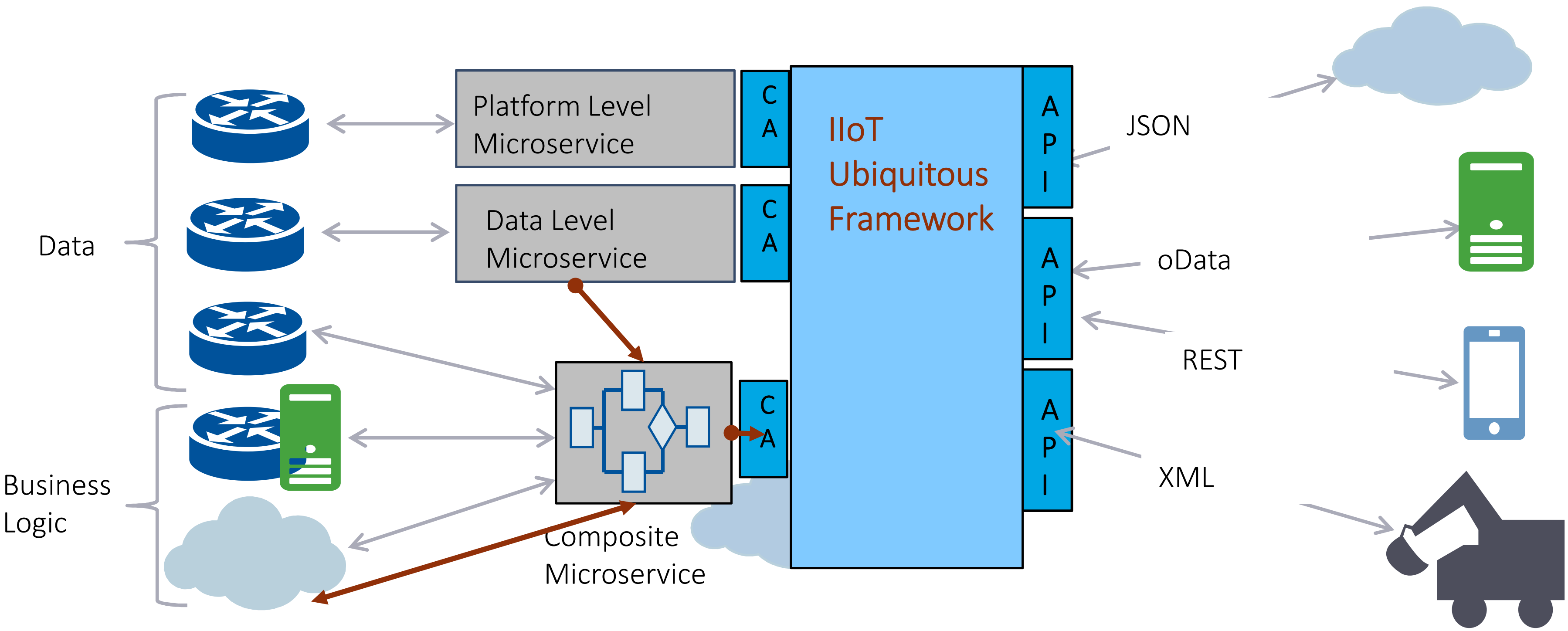


Classification of Cognitive Agents (CAs)

The classification emphasizes to precisely representing the characteristics of the IIoT services to CAs with respective to the contexts of heterogeneous clouds

- Cloud Service Subscriber CA (CSS)
- Information Distribution CA (ID)
- Microservices Deployment and Migration CA (MDM)
- Edge User Access CA (EUA)
- API Control CA (AC)
- Edge Interaction CA (EI)
- IIoT API Regulatory CA (AR)
- Resource Reconfiguration CA (RR)
- Resource Utility CA (RU)
- Proactive Enablement of API CA (PEA)
- Operational Response CA (OPR)

Key Enablers of Microservices' Implementation



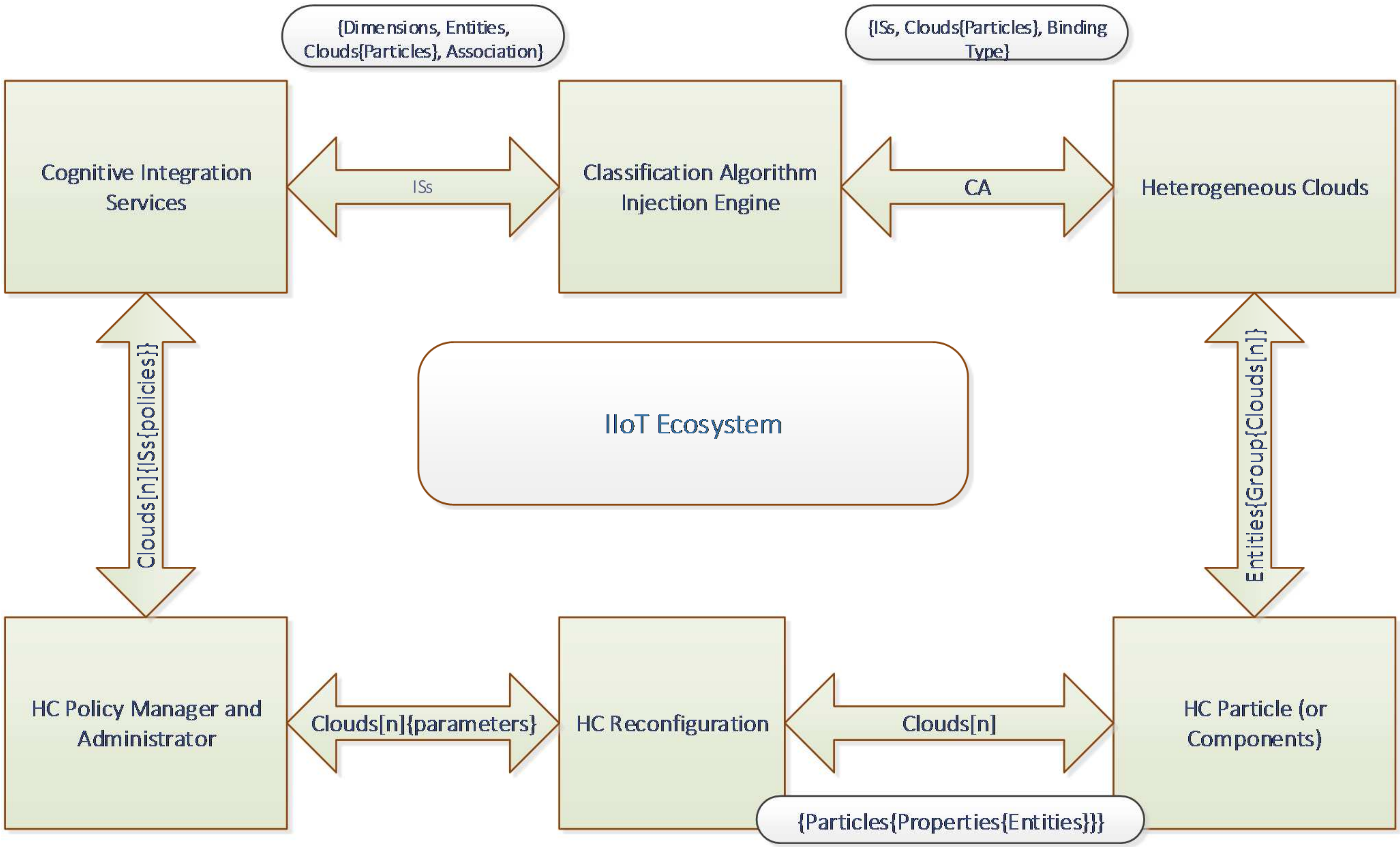
Microservices at Scale of CAs

- Derive device layer SLAs within the modeling paradigms of Microservices: Response time, Latency, Availability, and Durability of associated data
- Standardizing integrity of Composite Micoservices and right level of isolation to reduce erroneous execution: Define alternate paths and error conditions
- Consistent behavioral modeling when defining Microservice’s operations in presence of diversified scenarios pertaining to cognitive logic
- Streamline degrade and upgrade of Microservices’ functionalities based on demand of digital technologies in collaboration with allied business operation
- Utilize dynamic service registries to describe, discover, publish, subscribe, version, and monitor Microservices
- Imply performance optimization techniques in consideration of physical resources utilized during execution of Microservice’s operations

Continuous Integration and Evaluation

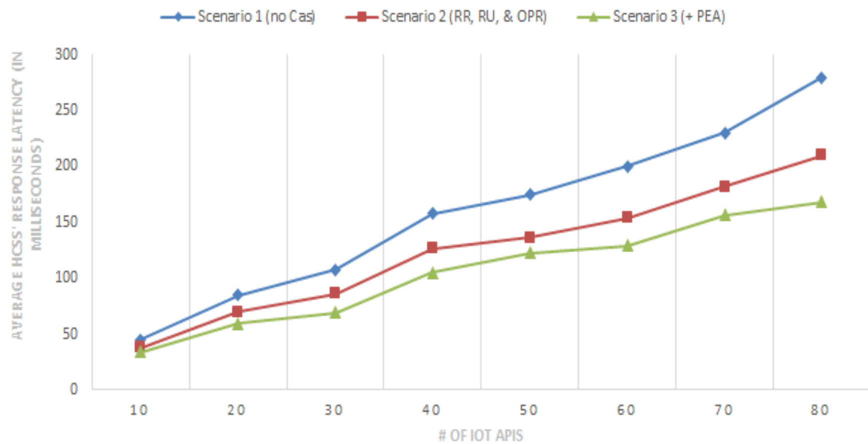
CA Classification Injection and IIoT Maturity Model

Continuous Integration of CAs to HCs

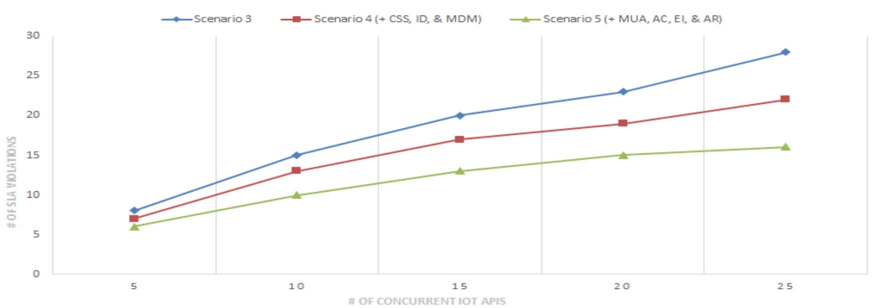


Scenario based IIoT Metrics in adherence to CA Classification

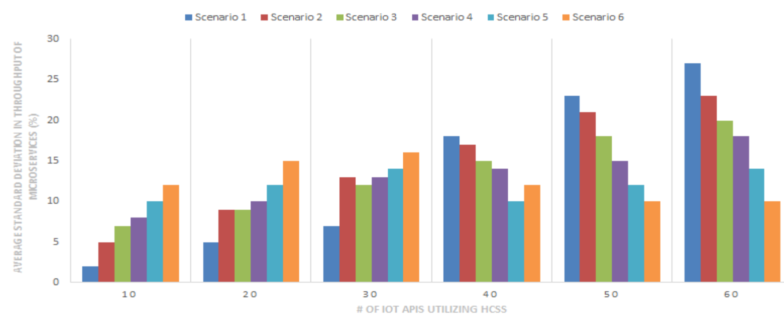
HCs’ response latency and number of IIoT APIs



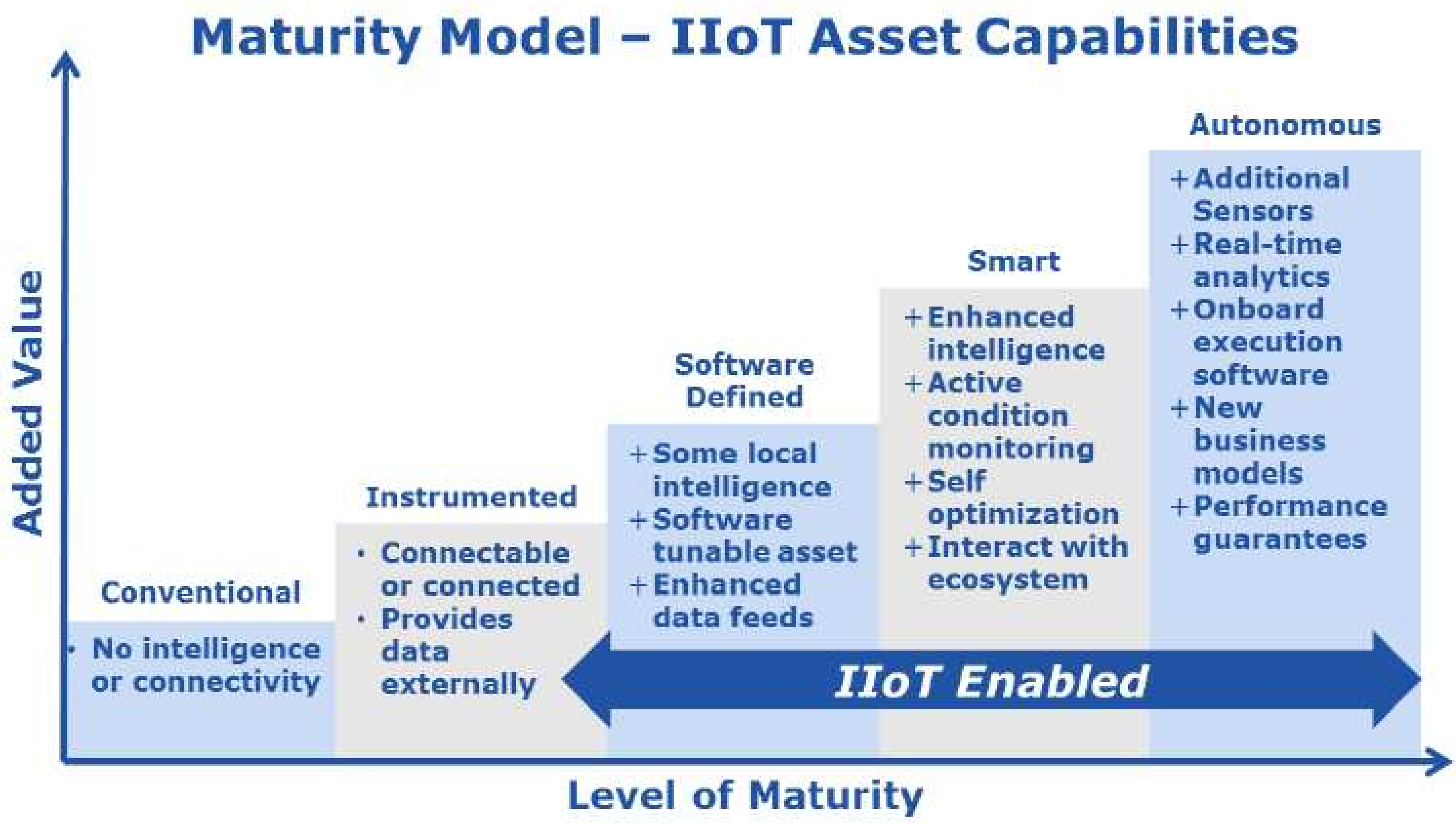
SLA violations and number of concurrent IIoT APIs



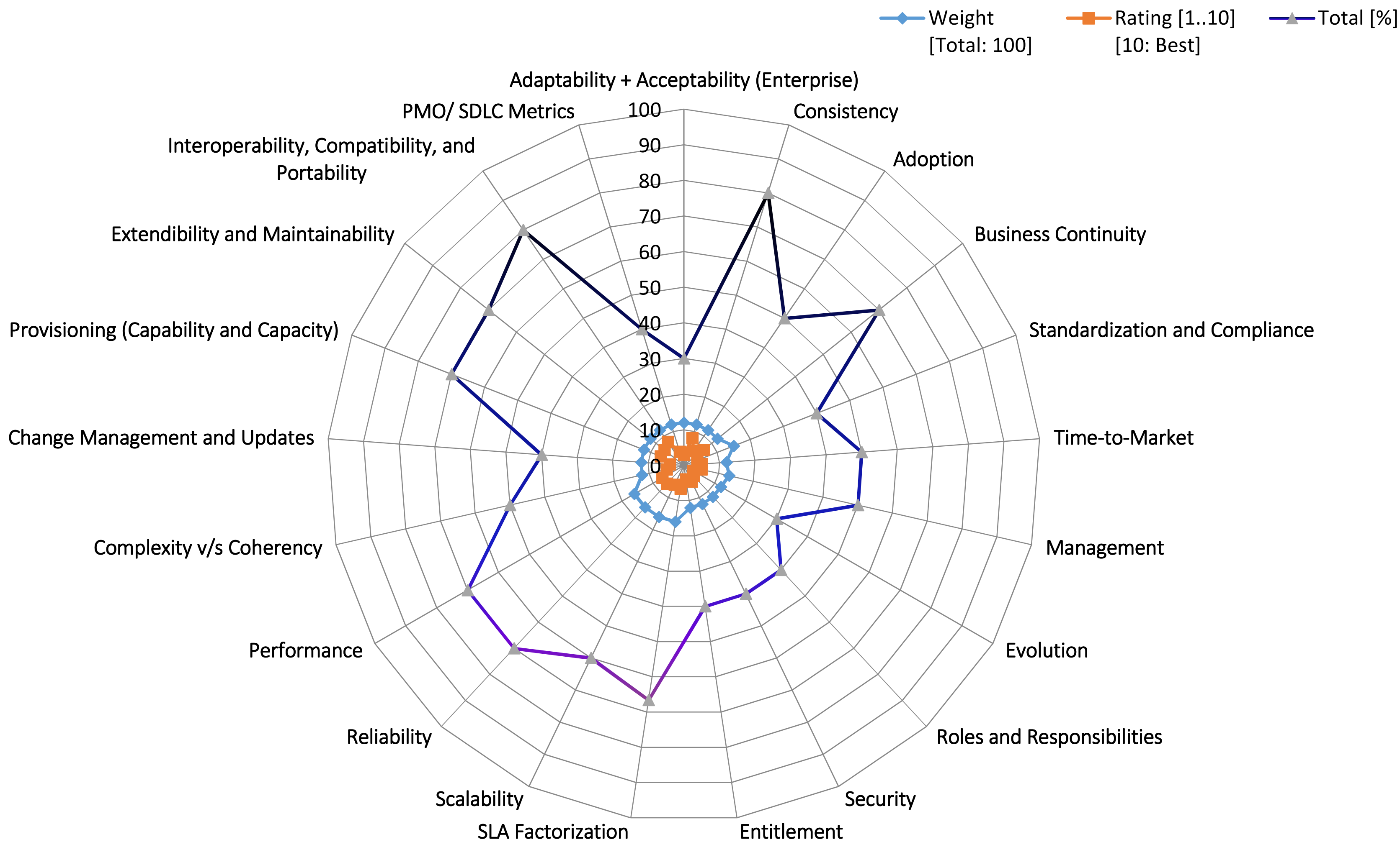
Average standard deviation in throughput of the Microservices and IIoT APIs utilizing HCs



IIoT Maturity Model based Evaluation



Leverage Rating based Evaluation Graph



Observations and Trends

IIoT Focus Areas

Key Observations

- Industrial device-level connectivity remains one of the most fragmented interface areas for IIoT, with many proprietary and/or de facto standard protocols in use to communicate with HCs
- IIoT will play an important role across the entire lifecycle of an industrial plant; from initial design and engineering during the upfront, capital expenditure-based project stage, through the much longer operational expenditure-based operations and maintenance lifecycle phase, where value is achieved from industrial assets
- Analytics combined with focused, structured data sets enables systematic and adaptive approaches for IIoT APIs under HCs
- IIoT with intelligence enables proactive maintenance increases offerings to pursue HC integration specific to configurable dimensions including specific industry verticle
- Ubiquitous framework provides consistent and continuous operational excellence across HCs

Trends

Technology Trends

- Smart sensors and controllers
  - Equipment-mounted sensors (temperature, pressure, vibration, etc.)
  - Soft sensors
  - Process variable transmitters
  - Analytical transmitters
  - HMIs
  - Mobility devices (smartphones, tablets, etc.)
  - Smart positioners and drives
- Industry specific API proliferation
- IIoT Application/data integration convergence
- Prepackaged devices and plant level automation
- Internet of Everything - Over 30 billion objects will be connected by 2020

Vendors' Landscape

- Facilitating visibility in operations through open ended monitoring tools
- Enabling predictive maintenance for integrated IIoT ecosystem
- Proactive IIoT asset management platforms, tools, and approaches
- Subscription based intelligence and knowledge in Clouds from diversified vendors
- Gathering and analyzing data to transform Big Data into actionable intelligence irrespective of the specific industry segment

Conclusions and Key References

Current R & D and Industrialization

Conclusions

- ✓ HC computing is quickly becoming a dominant to ubiquitously managing computational resources across multiple aspects of IIoT.
- ✓ IoT devices and their corresponding APIs are predominantly taking advantages of cloud computing.
- ✓ The challenge is in architecting the future of connected IIoT ecosystem that should capable of simplifying the integration between HCs, IIoT APIs that are published or subscribed by edge users, and edge users' devices or services.
- ✓ Core concepts and design principles of Microservices to develop ubiquitous IIoT framework to constitute relationship between IIoT APIs and HCs provides desired level of extendibility and governance
- ✓ An affirmative approach to compose (or model) and classify CAs within the framework based on characteristics and functionalities of inherent IIoT devices and representative data sets are essential

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