# Edge Computing & Blockchains for Industrial Automation





John Kaldis (jkaldis@ait.gr) Athens Information Technology



#### FAR-EDGE Joint effort of global leaders in manufacturing and IoT towards adoption of virtualized Factory Automation Whirlpool Focuses on Cloud and Edge Computing for Manufacturing ENGINEERING Decentralization of control RAMI 4.0 & Industrial Internet standards SIEMENS Expected Outcomes VOLVO THE *en* group • Reduced Time to deploy new automation concepts and technologies Better Exploitation of Data University of Applied Sciences and Art Increase automation in factories SUPSI

- Improve process agility
- Enable factory collaboration
- RAMI Compliant Implementation

# **Flexible Decentralized Factory Automation**



POLITECNICO **DI MILANO** 

**smart**Factory<sup>KL</sup>



#### The FAR EDGE Reference Architecture

The Blockchain Ledger Tier

### Next Generation Access Control (NGAC) for Industrial IoT

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# 1. The FAR EDGE Reference Architecture

# Generic REFERENCE ARCHITECTURES

A reference architecture (RA) is a SYNTHESIS of BEST PRACTICES based on successful past experience

Not targeting any specific application, domain, industry or even sector

- FAR-EDGE Reference Architecture is inspired from
  - Reference Architectural Model for Industrie 4.0 (RAMI 4.0)
  - Industrial Internet Reference Architecture (IIRA)
  - OpenFog



# IIRA 3-Tiers Pattern + Functional Viewpoint



The Industrial Internet Reference Architecture (IIRA) developed by the Industrial Internet Consortium (IIC), a global community of organizations (>250 members, including IBM, Intel, Cisco, Samsung, Huawei, Microsoft, Oracle, SAP, Boeing, Siemens, Bosch and General Electric). First published in 2015 and since evolved into version 1.8 (Jan 2017)

# RAMI 4.0 & Industrie 4.0 Components







# OpenFog RA



OpenFog Consortium. A public-private initiative, born in 2015 and shares similarities to the IIC: Big players like IBM, Microsoft, Intel and Cisco as their founding members, both the use the ISO/IEC/IEEE 42010:2011 international standard for communicating architecture descriptions to stakeholders

# FAR-EDGE Reference Architecture

- Functional Domains: Tiers: Field, Edge, Ledger, Cloud
  - $\circ$  Automation

 $\circ$  Analytics

- $\circ$  Simulation
- Crosscutting Functions:
  - o Management
  - o Security
  - Digital Models
  - Field Abstraction & Data Routing





# **Functional Viewpoint**

#### **Automation Domain**

 Functionalities supporting automated control and automated configuration of physical production processes

#### **Analytics Domain**

 Functionalities gathering and processing Field data for a better understanding of production processes-Factory focused BI

#### **Simulation Domain**

- *simulating the behaviour* of physical *production processes*
- optimization / testing **what-if scenarios** without impacting regular shop activities



# Crosscutting (XC) Functions



#### Management

 Low-level functions for monitoring and commissioning/decommissioning of individual system modules

#### Security

 Functions securing the system against the unruly behavior of its user and of connected systems

#### **Digital Models**

 management of digital models and their synchronization with the real-world entities they represent

#### **Field Abstraction & Data Routing**

 ensure the connectivity of business logic (Functional Domains) to the Field, abstracting away the technical details

# Structural Viewpoint



2 classes of concepts for describing the structure of a system: Scopes and Tiers. Inspired by OpenFog RA but FAR-EDGE Tiers are industry-oriented

Scopes define a coarse mapping of system elements (machinery, Field devices, workstations, SCADA-MES systems, and software running in the factory data centre.

Tiers provide more insight into the relationship between system components.

# **COMPONENTS AND ENABLERS**



# FAR-EDGE : High-level design



### Existing Industry 4.0 Standards & FAR-EDGE Reuse/Extension

- Hierarchy Levels:
  - IEC 62264 (implemented by B2MML)
- Engineering:
  - $\circ$  AutomationML
    - IEC 62424 (CAEX)
    - IEC 61131 (PLC Open XML)
    - ISO/PAS 17506 (COLLADA)
- Communication Layer:
  OPC UA





# 2. The Blockchain Ledger

# Ledger Tier



This is where the full potential of edge computing is unleashed

### Ledger Tier



#### Key Innovation of Far Edge Project

distributed ledger and smart contract patterns

truly distributed process logic without any centralized service being in charge

> No constraints of Deployment

### Hyperledger-fabric

• Permissioned not public

#### Selected because

- factories want private Blockchains
- performance according to benchmarks.
- Generally in the ledger tier we perform distributed process synchronization

# Hyperledger-fabric





- Validators evaluate the effect of a transaction and reach consensus over the new version of the ledger
- Ledger = total order of transactions + hash (global state)
- · Pluggable consensus protocol, currently PBFT & Sieve

### Ledger Tier: Distributed Ledger [Enabler] 1

- Transactional ledger Foundation of the Tier
- Replicated on all PNs and automatically kept insync across all instances
- Stores and maintains shared state of distributed processes i.e. global variables and complex data structures running on any Tier
- State secured by cryptographic techniques
- Records modification through system-wide
  unanimous consensus

### Ledger Tier: Distributed Ledger [Enabler] 2

- Majority consensus of PNs for record creation
- Validity of transactions defined by consensus
- Smart contract i.e., executable code implementing deterministic algorithm deployed on the ledger.
- Decentralized Coordination and dynamically (re)definable
- Ideal clients: frequent reads infrequent writes
- Only highly valuable data should be persisted on the Ledger Tier

# Role of Distributed Ledger in FAR-EDGE (Blockcha





# 3. Next Generation Access Control for Industrial IoT

# **Applying NGAC to FAR-EDGE**

We have chosen to apply an emerging standard known as Next Generation Access Control (NGAC)

- NGAC is a flexible and expressive approach to specifying and enforcing a wide variety of policies over distributed systems.
- NGAC enables diverse access control policies to be simultaneously defined and enforced either independently or in combinations.
- In NGAC the policy is completely separate from the enforcement mechanism.
- A reference implementation known as the "Policy Machine" (PM) is publicly available

# Applying IISF to FAR-EDGE architecture

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The Industrial Internet Security Framework (IISF) is one of the products of the Industrial Internet Consortium to create a broad industry consensus on how to secure Industrial Internet of Things (IIoT) systems.

The IISF builds on the Industrial Internet Reference Architecture (IIRA) The Open Group, is a members of the FAR-EDGE consortium, a member of the Industrial Internet Consortium (IIC) and has active members who serve on the IIC standards authoring teams

- IIRA has previously been referenced and applied in the FAR-EDGE Architecture
- The IISF will be used as a reference and the FAR-EDGE Security Framework and patterned after the IIC's model



IISF security functions to FAR-EDGE RA and PS

- Endpoint protection
- Communications and connectivity protection
- Security monitoring and analysis
- Security configuration and management
- Data protection Security





### 4. Use Cases

### The FAR-EDGE Way





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# FAR-EDGE Pilots (Volvo)

Wheel alignment station (WAS) in Goteborg

- Each single truck requires a specific configuration (i.e., rotation angle and torque) of a nut driver tool
- The tool supports remote configuration, but is not connected to the workstation control system: setting is done manually for each work item
  - Problem #1 (UC enhancement): error prone

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 Problem #2 (UC expansion): Volvo needs to deploy a great number of WAS equipment all over the world (e.g., at service shops) and each deployment requires a substantial configuration and training effort on site





# FAR-EDGE Pilots (Volvo)



FAR-EDGE experimentation

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- Automate the nut driver tool configuration
- Encapsulate the entire WAS as an autonomous module with embedded intelligence, so that:
  - It will still not require a persistent data connection to the Factory systems (don't introduce a soft spot)
  - It may be packaged and deployed anywhere in the world with minimal effort





Conveyor sorter in Melano

- Items dispatched to delivery from the assembly line travel along a conveyor belt and need to be routed to a number of exit bays according to product type, bay capacity and forklift capability
- Problem #1 (UC enhancement): the input to the sorting algorithm is the production plan, not the current situation, which depends on the actual production and on external variables (forklift)
- Problem #2 (UC expansion): the conveyor layout is static and very difficult to adapt to significant changes in production



# FAR-EDGE Pilots (Whirlpool)

#### FAR-EDGE experimentation

- Implement a sorting algorithm which gets input from existing sensors that identify product items along the conveyor belt
- Make each exit bay an autonomous system that:
  - Is aware of its own pains and needs (requires new sensors and an embedded controller)
  - Can negotiate with a Factory-level smart contract (blockchain) the items to be received
  - May be hot swapped at need (i.e., switched on/off, added/removed without any discontinuity)





### FAR-EDGE Deployment @ WHIRLPOOL



FAR**edga** 

### **FAR-EDGE Pilots (Smart Factory)**

- Test the full fledged functionality of FAR-EDGE solution and validate the following enablers:
  - $\circ$  Automation
  - o Analytics
  - o Real to Digital Synchronization
  - o Simulation
  - Ledger Services











• Site: http://www.faredge.eu/

Ecosystem Portal: <u>https://www.edge4industry.eu/</u>

• GitHub: <u>https://github.com/far-edge</u>



# https://www.edge4industry.eu/