# Intelligence Orchestration

## Empowering IoT beyond microservices

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Ericsson Research

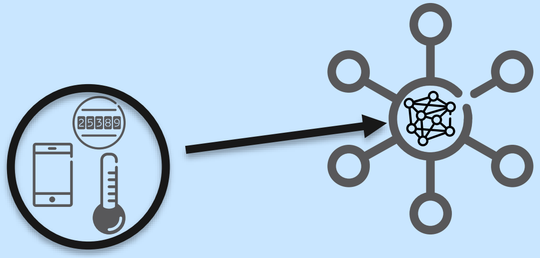
2022-06-23

# Automation and Distributed Intelligence

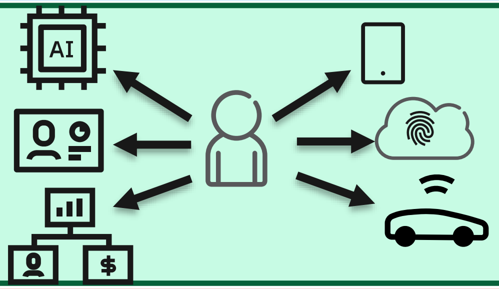
Some aspects to considerate

# Current and future challenges of smart automation

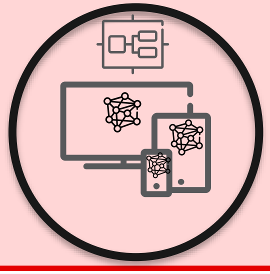
**Scalability**
73 ZB of IoT produced data by 2025 ( 17 ZB in 2019)
Cloud will consume a lot of the data for analytics (but it won't be able to cope with all)



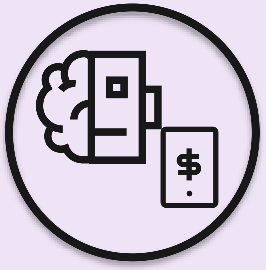
**Privacy**
Regulatory frameworks
End user agreements
Data governance (who owns the data?)



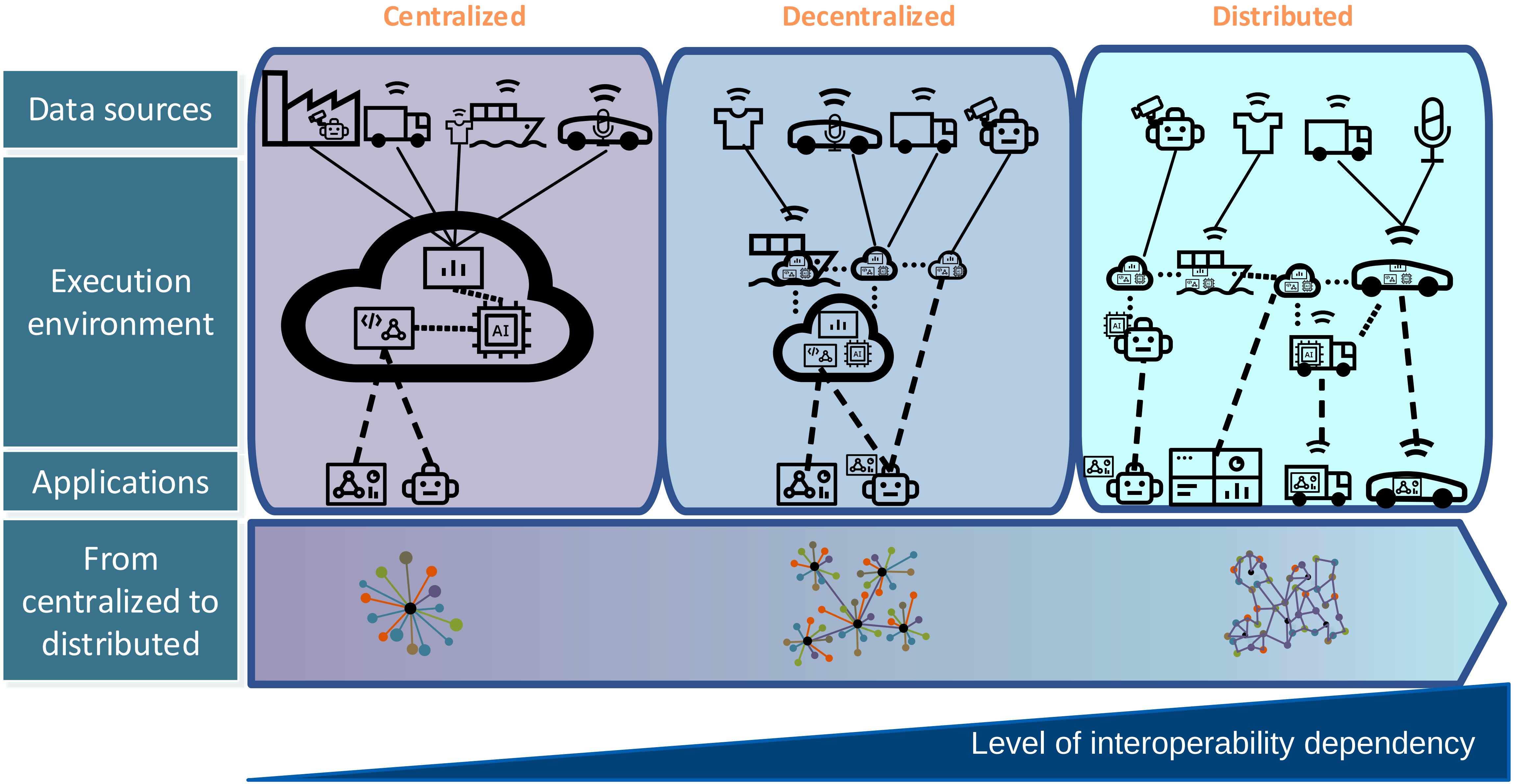
**Fragmentation**
Cheaper acceleration hardware
Everything that benefit from intelligence will be intelligent



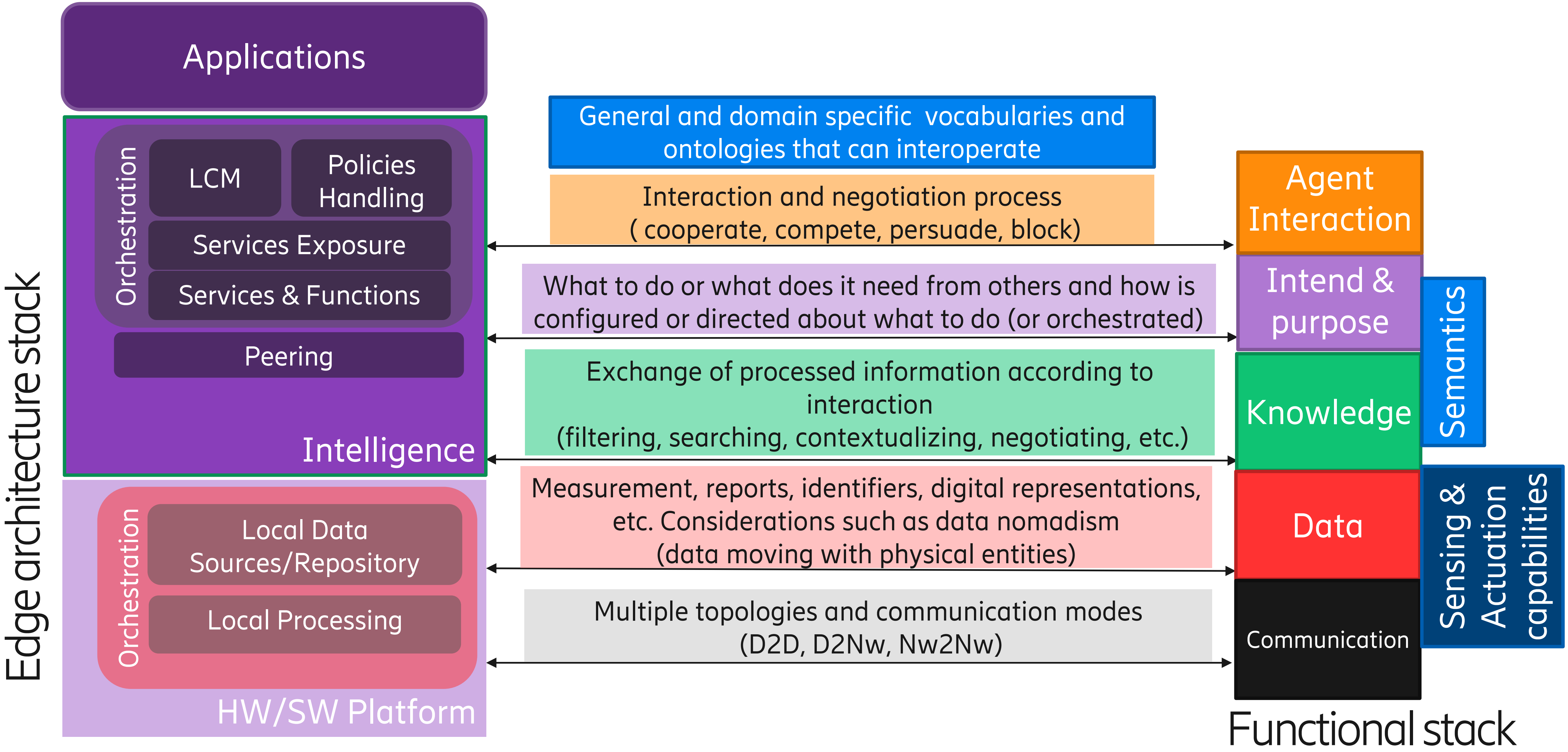
**Monetization & business models**
Intelligence as a commodity
Intelligence specialization vs. generalization
Intelligence life cycle management



# Centralized vs. Distributed Computing Architectures



# Edge-Intelligence Computing Stacks Mapping



Edge architecture stack

Applications

Intelligence

Orchestration

LCM

Policies Handling

Services Exposure

Services & Functions

Peering

HW/SW Platform

Orchestration

Local Data Sources/Repository

Local Processing

General and domain specific vocabularies and ontologies that can interoperate

Interaction and negotiation process ( cooperate, compete, persuade, block)

What to do or what does it need from others and how is configured or directed about what to do (or orchestrated)

Exchange of processed information according to interaction (filtering, searching, contextualizing, negotiating, etc.)

Measurement, reports, identifiers, digital representations, etc. Considerations such as data nomadism (data moving with physical entities)

Multiple topologies and communication modes (D2D, D2Nw, Nw2Nw)

Functional stack

Agent Interaction

Intend & purpose

Knowledge

Data

Communication

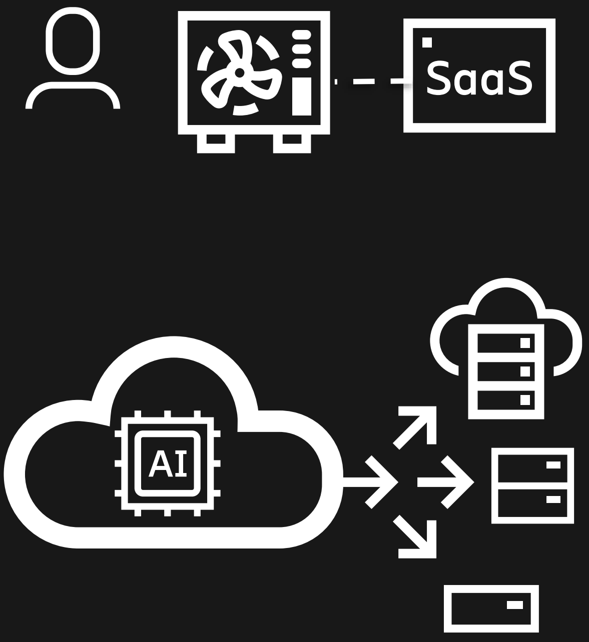
Semantics

Sensing & Actuation capabilities

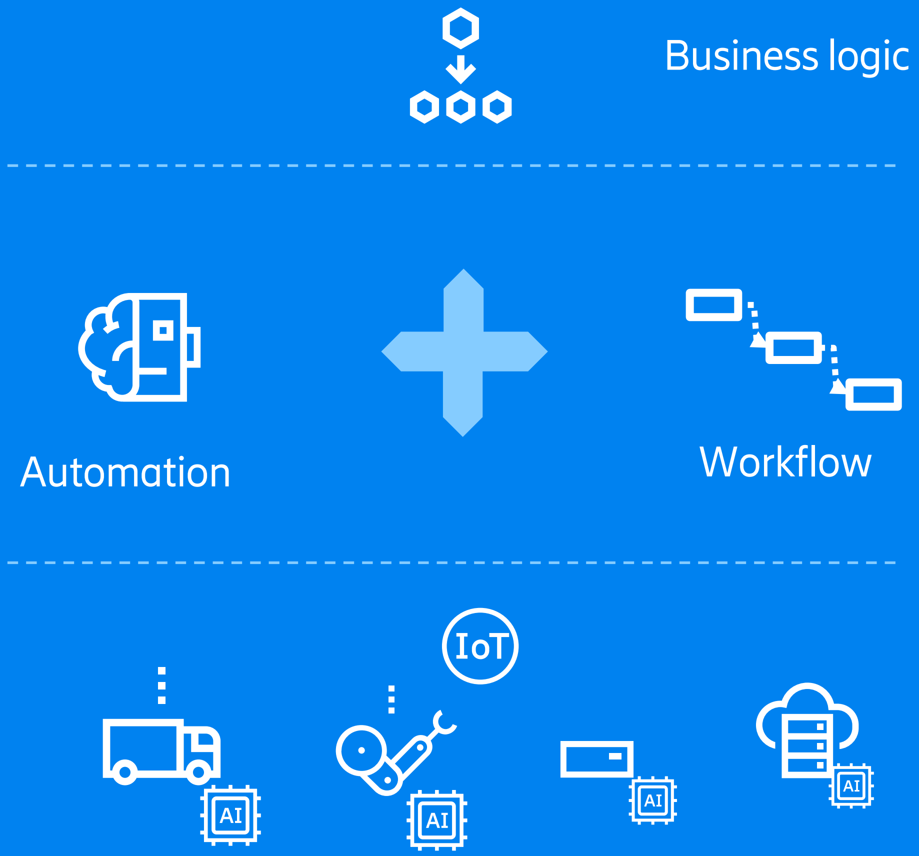
# What intelligence orchestration implies?

Making intelligent things work together

## From regular cloud and edge orchestration which focuses on deployment



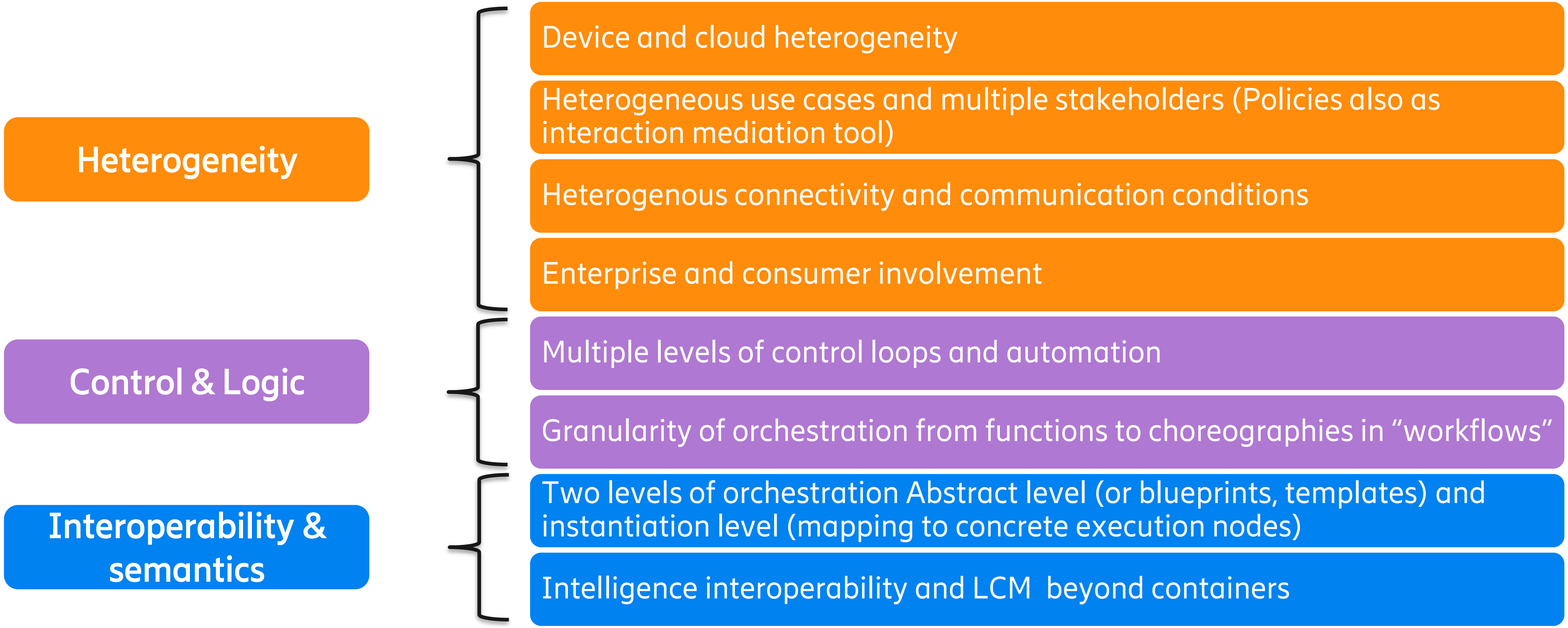
## … to intelligence orchestration which focuses on processes


Business logic

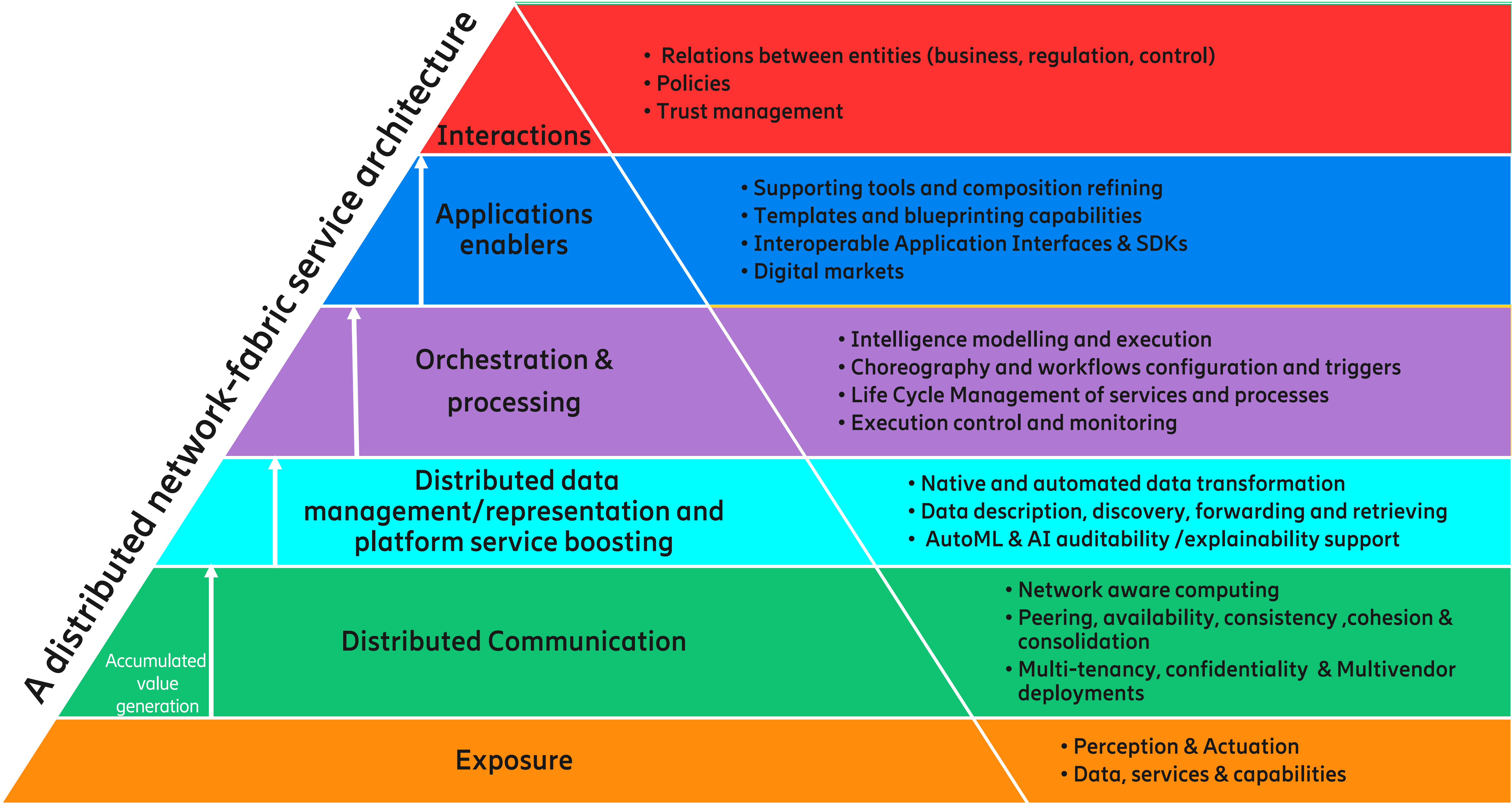
Automation

Workflow

# Challenges and characteristics of IoT intelligence orchestration



- **Heterogeneity**
  - Device and cloud heterogeneity
  - Heterogeneous use cases and multiple stakeholders (Policies also as interaction mediation tool)
  - Heterogenous connectivity and communication conditions
  - Enterprise and consumer involvement
- **Control & Logic**
  - Multiple levels of control loops and automation
  - Granularity of orchestration from functions to choreographies in “workflows”
- **Interoperability & semantics**
  - Two levels of orchestration Abstract level (or blueprints, templates) and instantiation level (mapping to concrete execution nodes)
  - Intelligence interoperability and LCM  beyond containers



A distributed network-fabric service architecture

**Interactions**

- Relations between entities (business, regulation, control)
- Policies
- Trust management

**Applications enablers**

- Supporting tools and composition refining
- Templates and blueprinting capabilities
- Interoperable Application Interfaces & SDKs
- Digital markets

**Orchestration & processing**

- Intelligence modelling and execution
- Choreography and workflows configuration and triggers
- Life Cycle Management of services and processes
- Execution control and monitoring

**Distributed data management/representation and platform service boosting**

- Native and automated data transformation
- Data description, discovery, forwarding and retrieving
- AutoML & AI auditability /explainability support

**Distributed Communication**

- Network aware computing
- Peering, availability, consistency ,cohesion & consolidation
- Multi-tenancy, confidentiality & Multivendor deployments

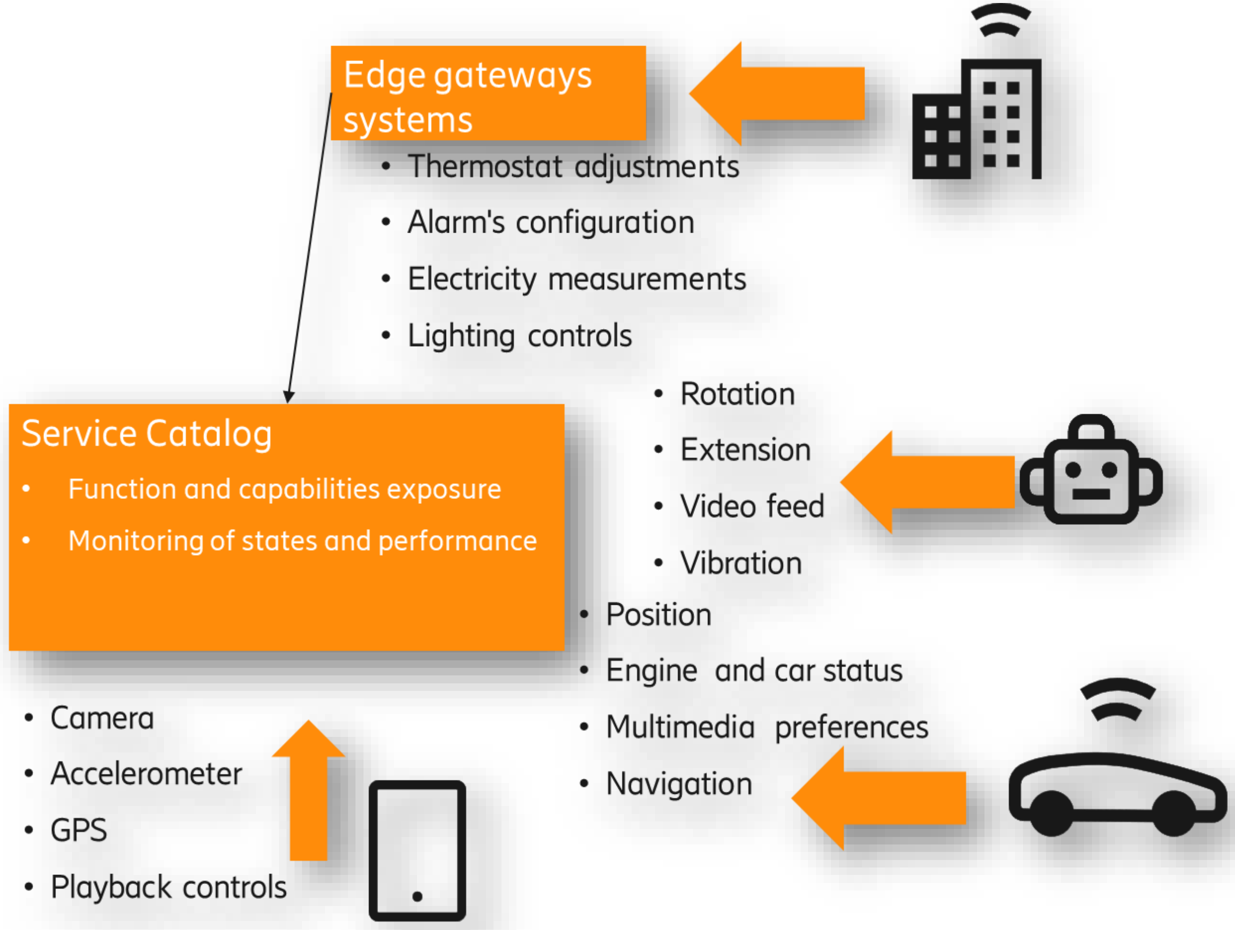
**Exposure**

- Perception & Actuation
- Data, services & capabilities

# Service Exposure

**Capabilities required**

- Distributed Service Registry (dynamic registration /de-registration)
- Services Discovery Mechanism
- Services Life Cycle Management
- Capabilities management → devices characteristics, Software dependencies



Edge gateways systems

- Thermostat adjustments
- Alarm's configuration
- Electricity measurements
- Lighting controls

Service Catalog

- Function and capabilities exposure
- Monitoring of states and performance

- Rotation
- Extension
- Video feed
- Vibration

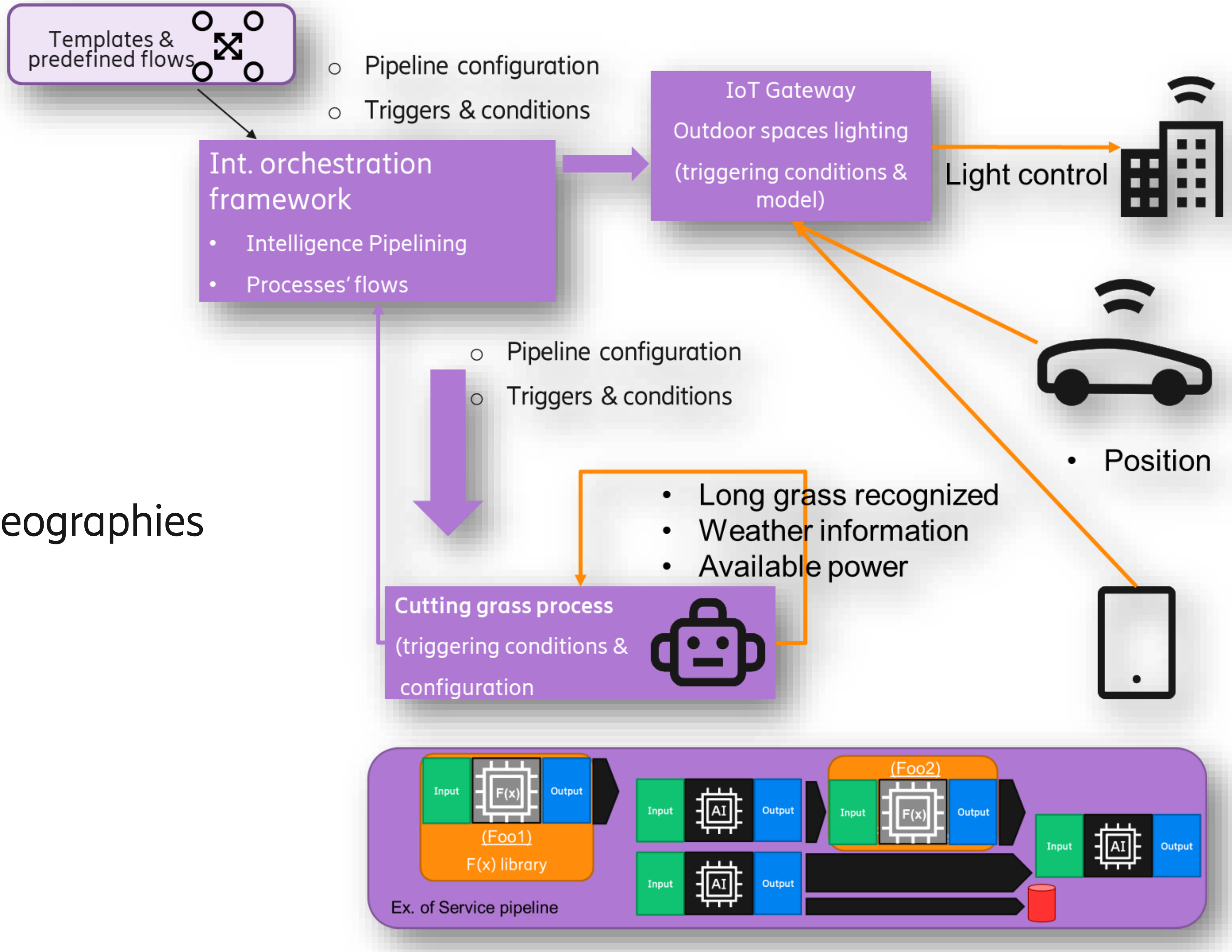
- Position
- Engine and car status
- Multimedia preferences
- Navigation

- Camera
- Accelerometer
- GPS
- Playback controls

# Workflows and processes (Intelligence Pipeline)

**Requirements:**

- Intelligence Pipeline definition
- Function trigger definition
- Observability Monitoring configuration
- Workflow composability
- Multitenancy and share access → Choreographies
- Workflow security and privacy
- Stateful vs stateless workflows



Templates & predefined flows

- Pipeline configuration
- Triggers & conditions

Int. orchestration framework

- Intelligence Pipelining
- Processes' flows

IoT Gateway

Outdoor spaces lighting

(triggering conditions & model)

Light control

- Position

- Pipeline configuration
- Triggers & conditions

- Long grass recognized
- Weather information
- Available power

Cutting grass process

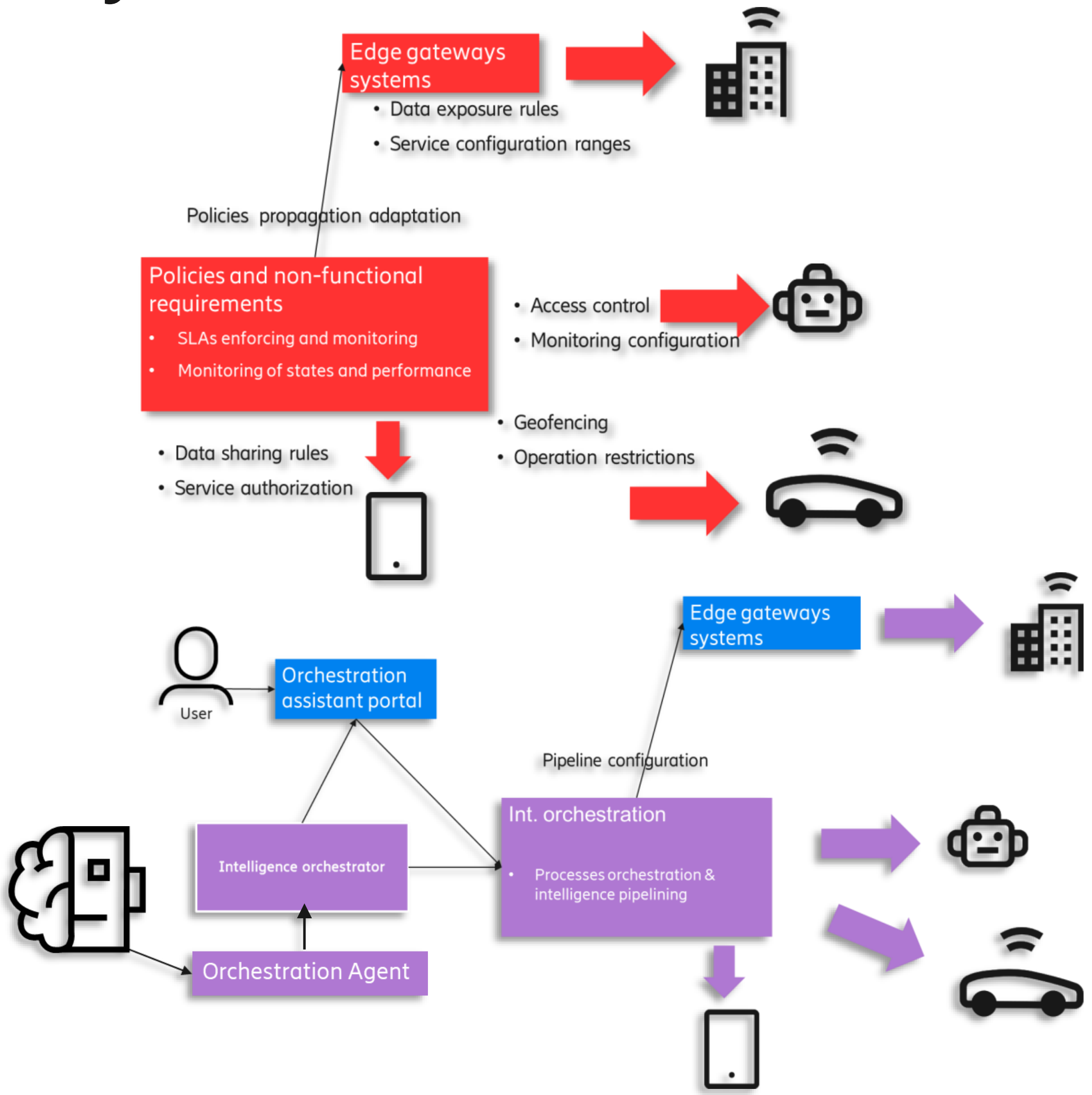
(triggering conditions & configuration

Ex. of Service pipeline

# Ubiquitous policies and deployments

**Requirements:**

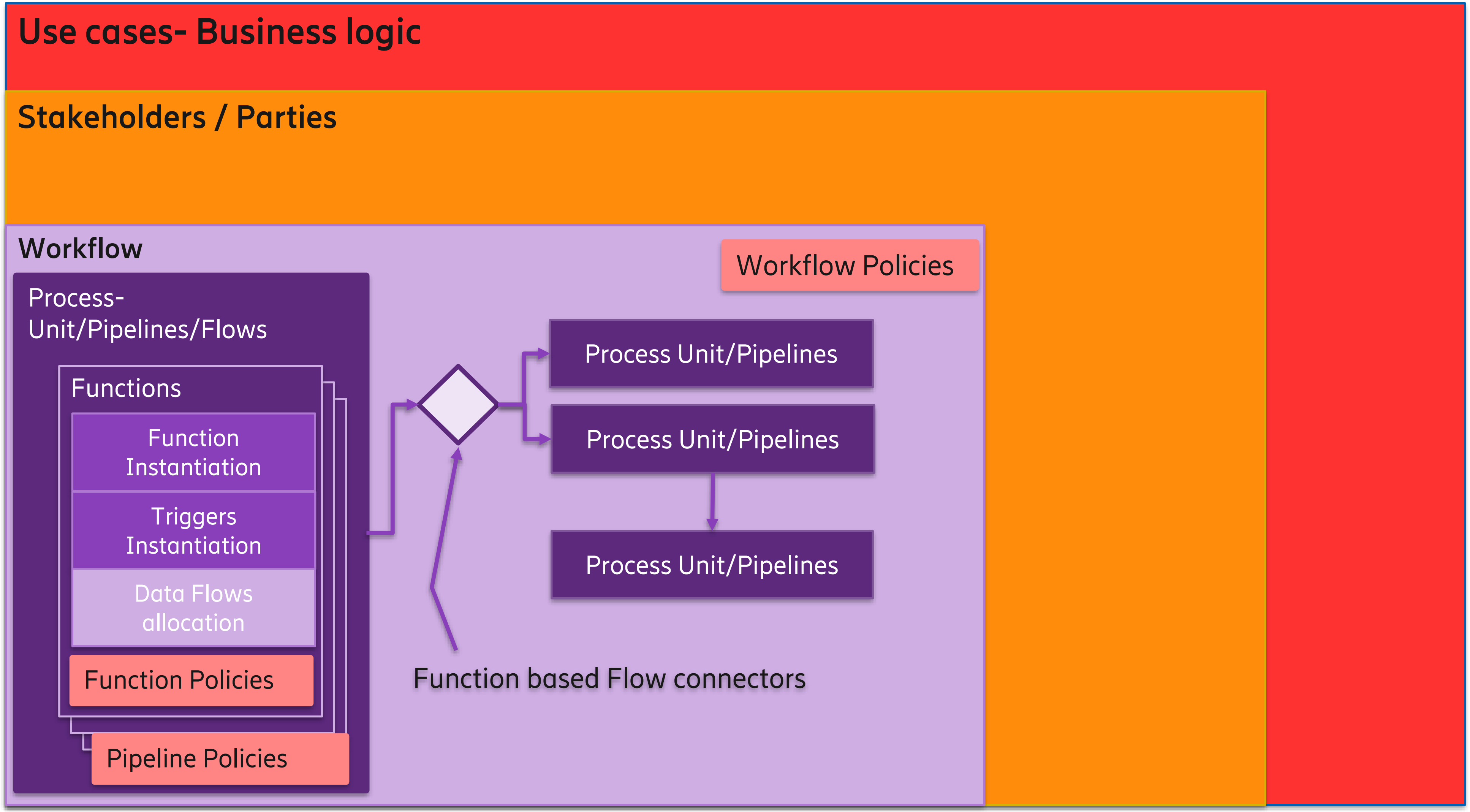
- Orchestrator engine
- Local orchestration instantiation
- Portability
- Description language(s)(e.g., BPMN, TOSCA)
- Automated orchestration (Reasoner)


Edge gateways systems
Data exposure rules
Service configuration ranges
Policies propagation adaptation
Policies and non-functional requirements
SLAs enforcing and monitoring
Monitoring of states and performance
Access control
Monitoring configuration
Geofencing
Operation restrictions
Data sharing rules
Service authorization
Edge gateways systems
User
Orchestration assistant portal
Pipeline configuration
Int. orchestration
Processes orchestration & intelligence pipelining
Intelligence orchestrator
Orchestration Agent

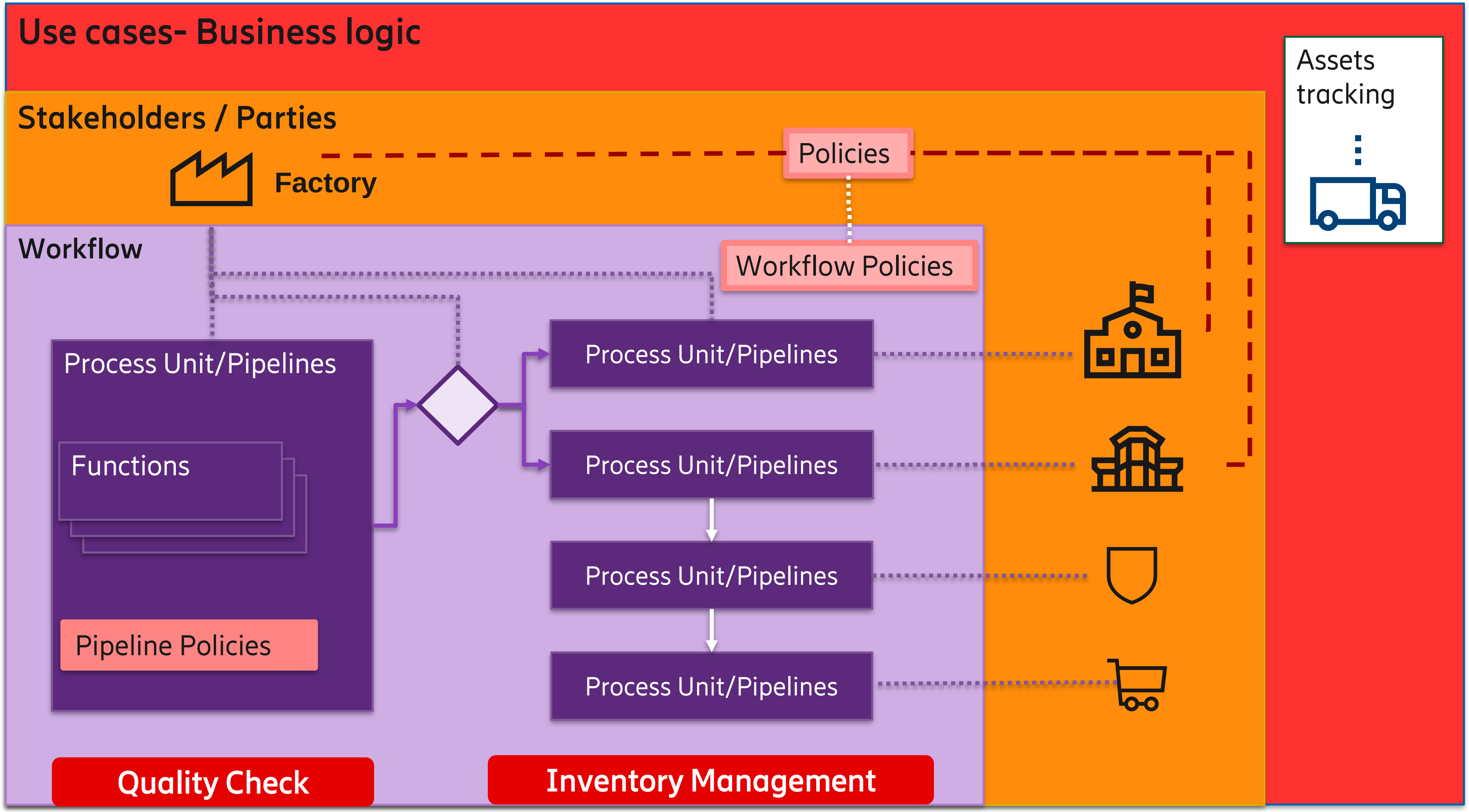
# A framework for orchestrating AI for IoT & AIoT

A Functional Architecture proposal

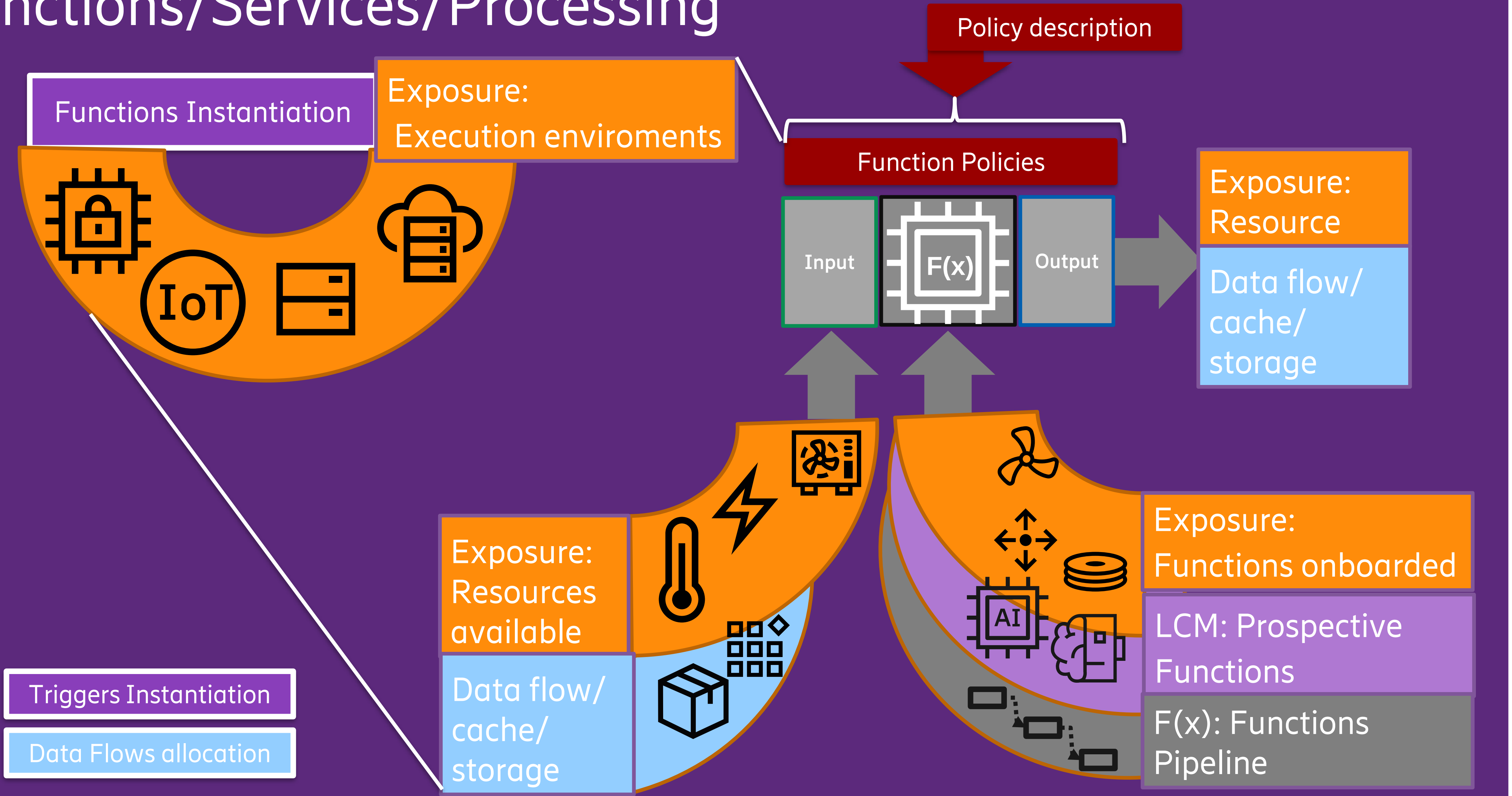
# Workflows: Mapping business logic to deployments



# Defining a workflow:  The context



# Functions/Services/Processing



Policy description

Functions Instantiation

Exposure: Execution enviroments

Function Policies

Input

Output

Exposure: Resource

Data flow/ cache/ storage

Exposure: Resources available

Data flow/ cache/ storage

Exposure: Functions onboarded

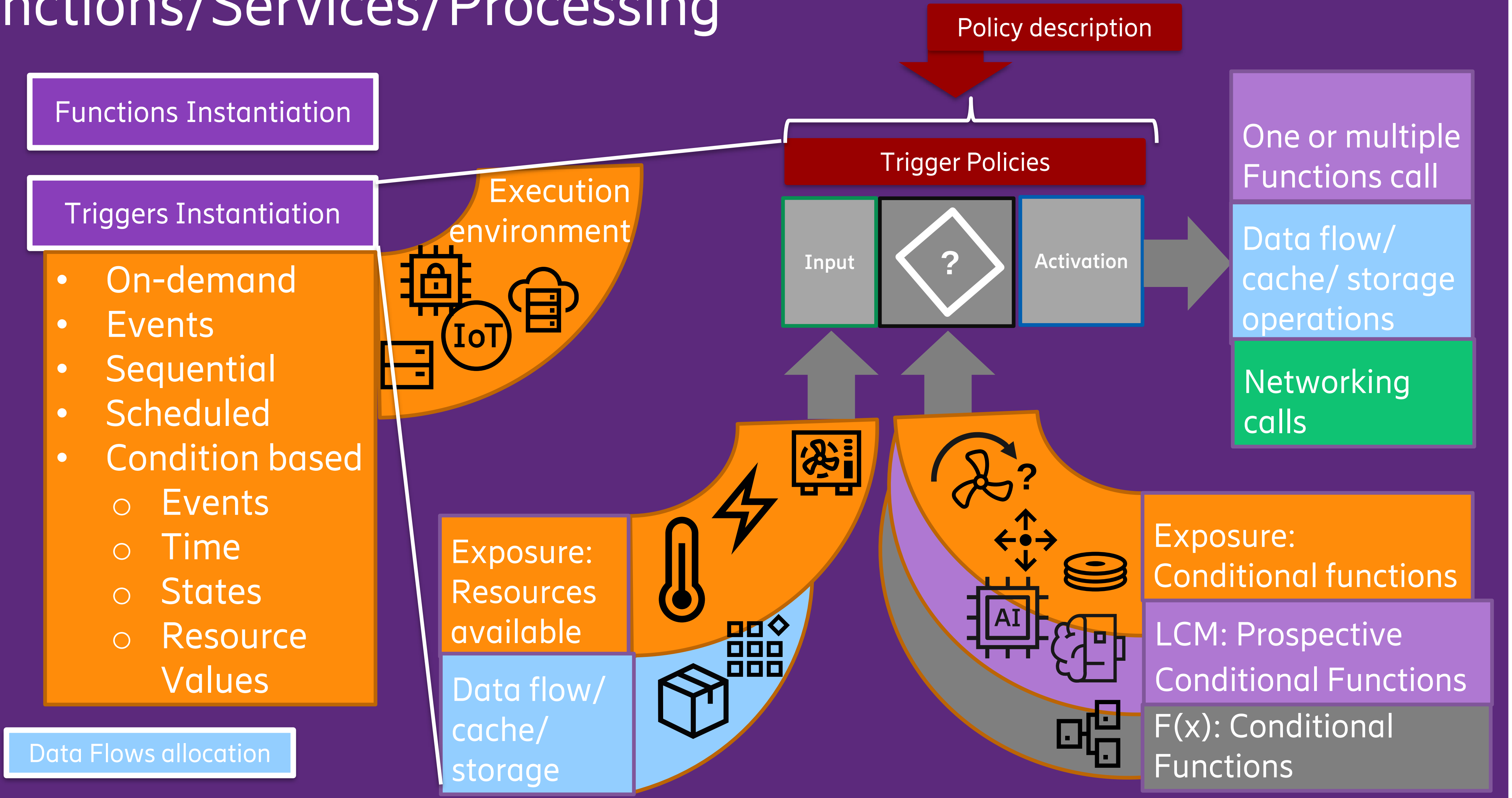
LCM: Prospective Functions

F(x): Functions Pipeline

Triggers Instantiation

Data Flows allocation

# Functions/Services/Processing



Functions Instantiation

Triggers Instantiation

- On-demand
- Events
- Sequential
- Scheduled
- Condition based
  - Events
  - Time
  - States
  - Resource Values

Data Flows allocation

Execution environment

Policy description

Trigger Policies

Input

?

Activation

One or multiple Functions call

Data flow/ cache/ storage operations

Networking calls

Exposure: Resources available

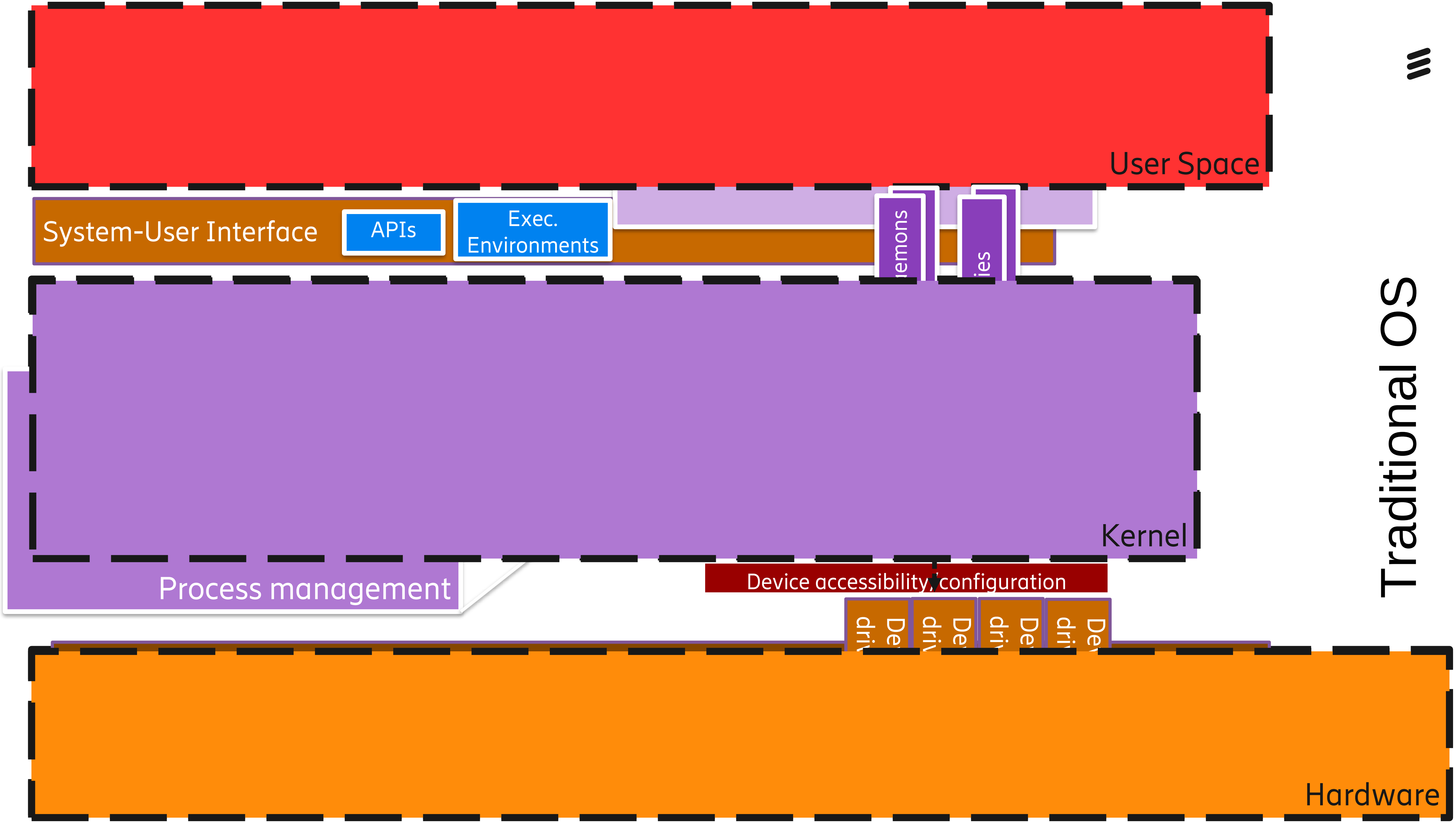
Data flow/ cache/ storage

Exposure: Conditional functions

LCM: Prospective Conditional Functions

F(x): Conditional Functions

# Traditional OS



User Space

System-User Interface

APIs

Exec. Environments

emons

ies

Kernel

Process management

Device accessibility/configuration

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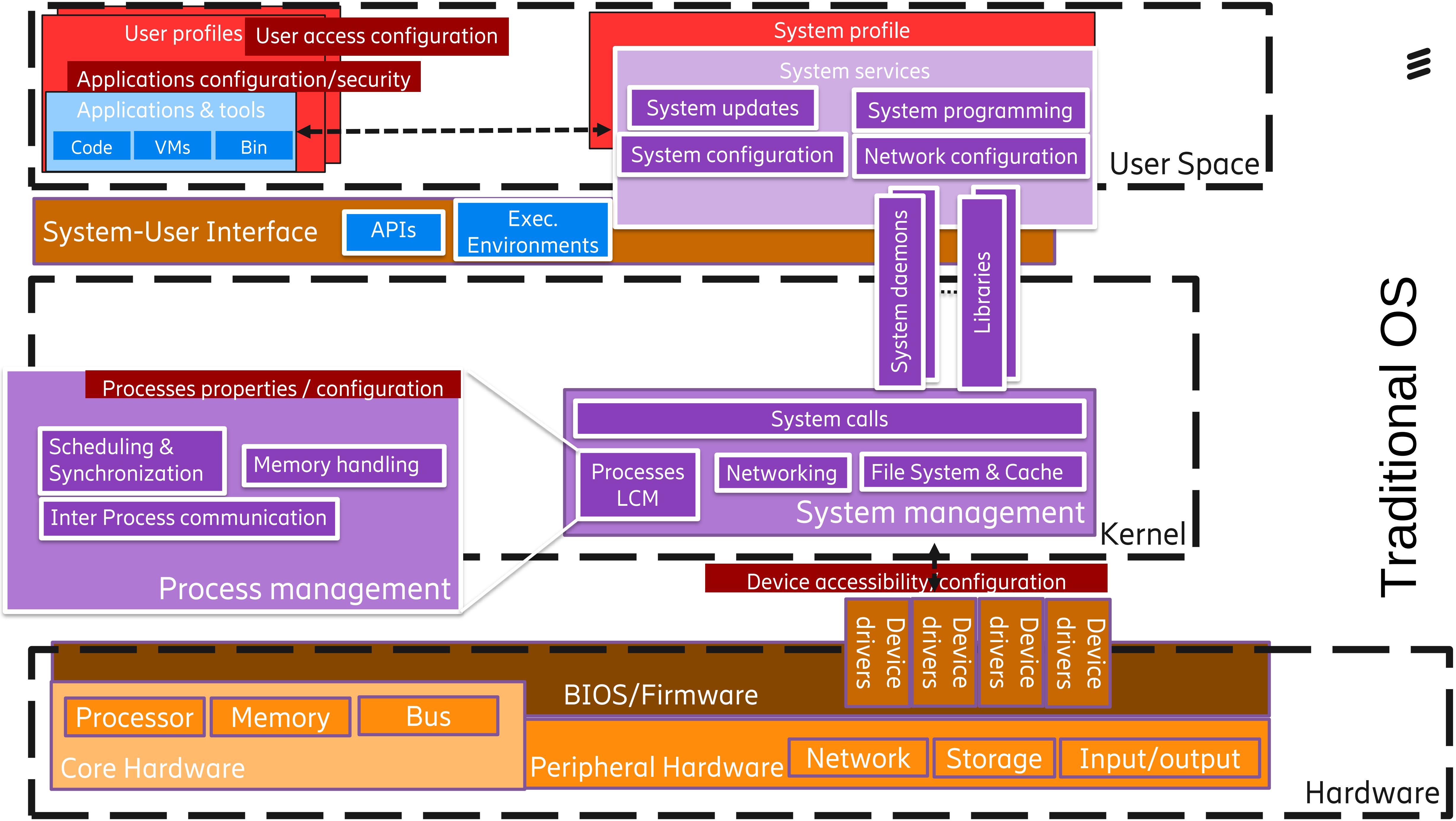
Hardware



Traditional OS

User Space

User profiles

User access configuration

Applications configuration/security

Applications & tools

Code

VMs

Bin

System profile

System services

System updates

System programming

System configuration

Network configuration

System-User Interface

APIs

Exec. Environments

System daemons

…

Libraries

Kernel

Processes properties / configuration

Scheduling & Synchronization

Memory handling

Inter Process communication

Process management

System calls

Processes LCM

Networking

File System & Cache

System management

Device accessibility/configuration

Device drivers

Device drivers

Device drivers

Device drivers

BIOS/Firmware

Hardware

Processor

Memory

Bus

Core Hardware

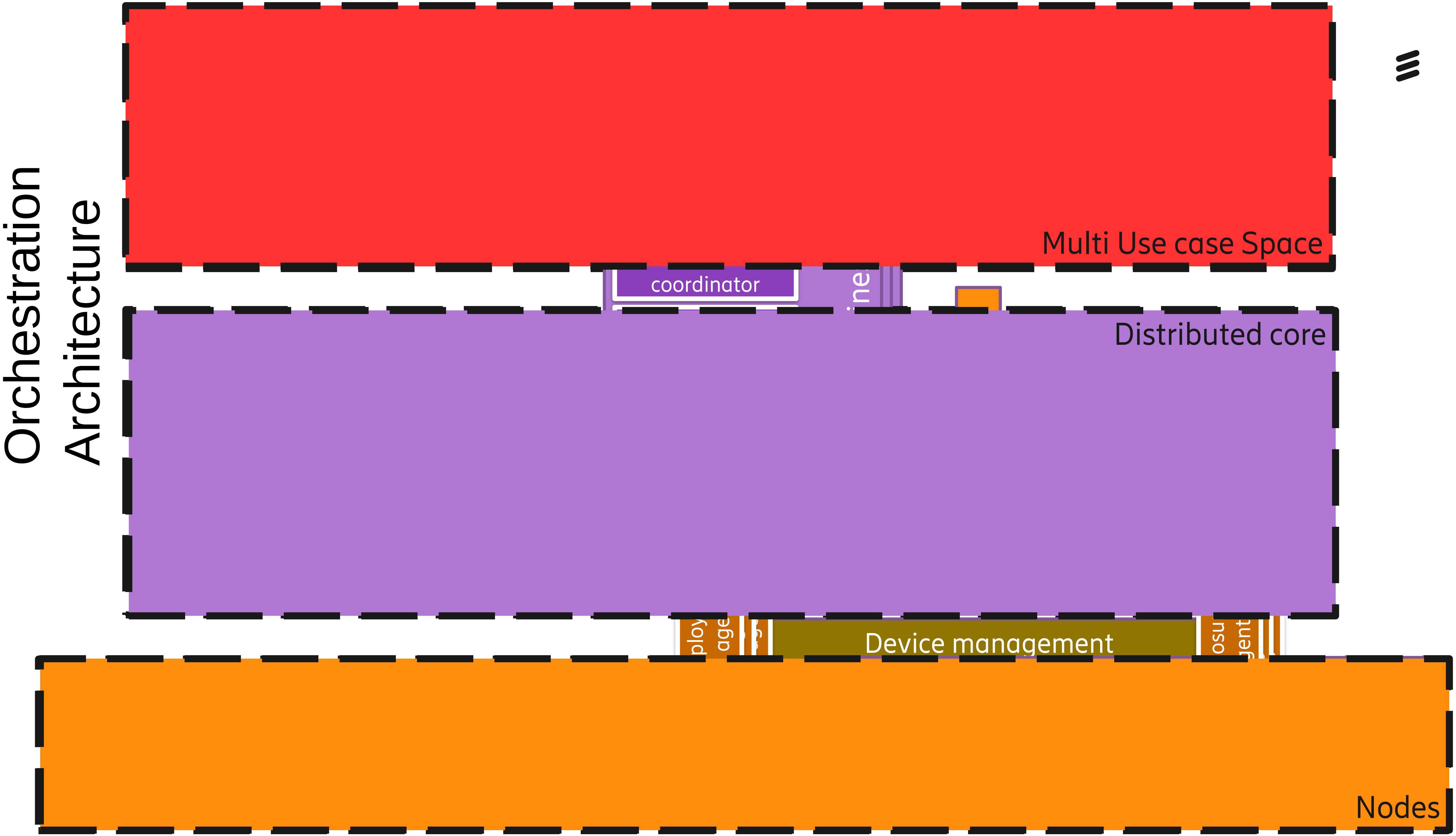
Peripheral Hardware

Network

Storage

Input/output

# Orchestration Architecture



# What is achieved with this architecture

### Platform-less & server-less

- Re-usability of framework for orchestration control
- Workflow as orchestration unit
- Instantiation of generic/general abstractions

### Multivendor & multiparty enablement

- Multi-deployment adaptation
- Mediation and facilitation over service provisioning
- Adaptability to heterogeneity

### Exposure as a key automation enabler

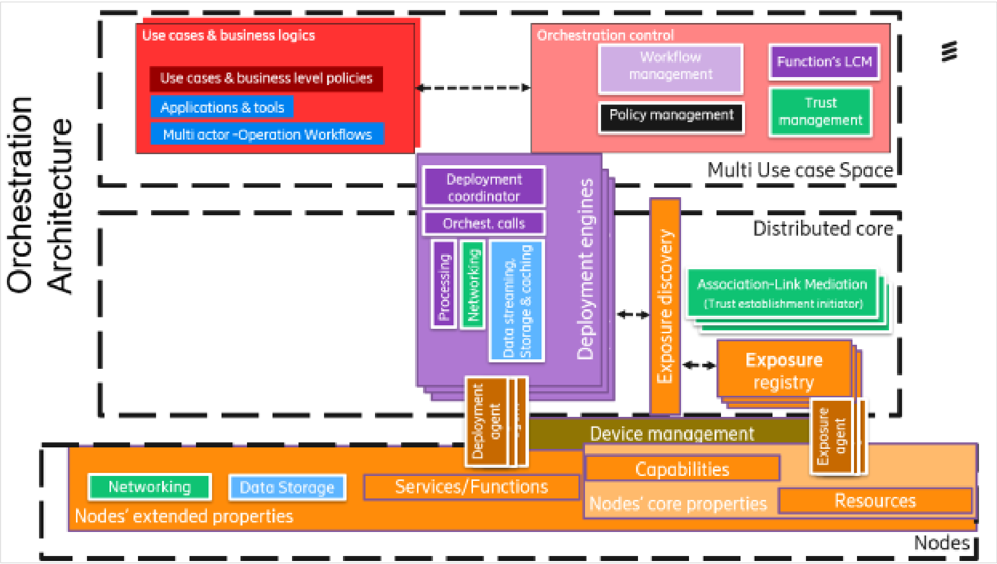
- Dynamic flows & nomadic data and function's execution

### Evolvability without deprecation (legacy support)

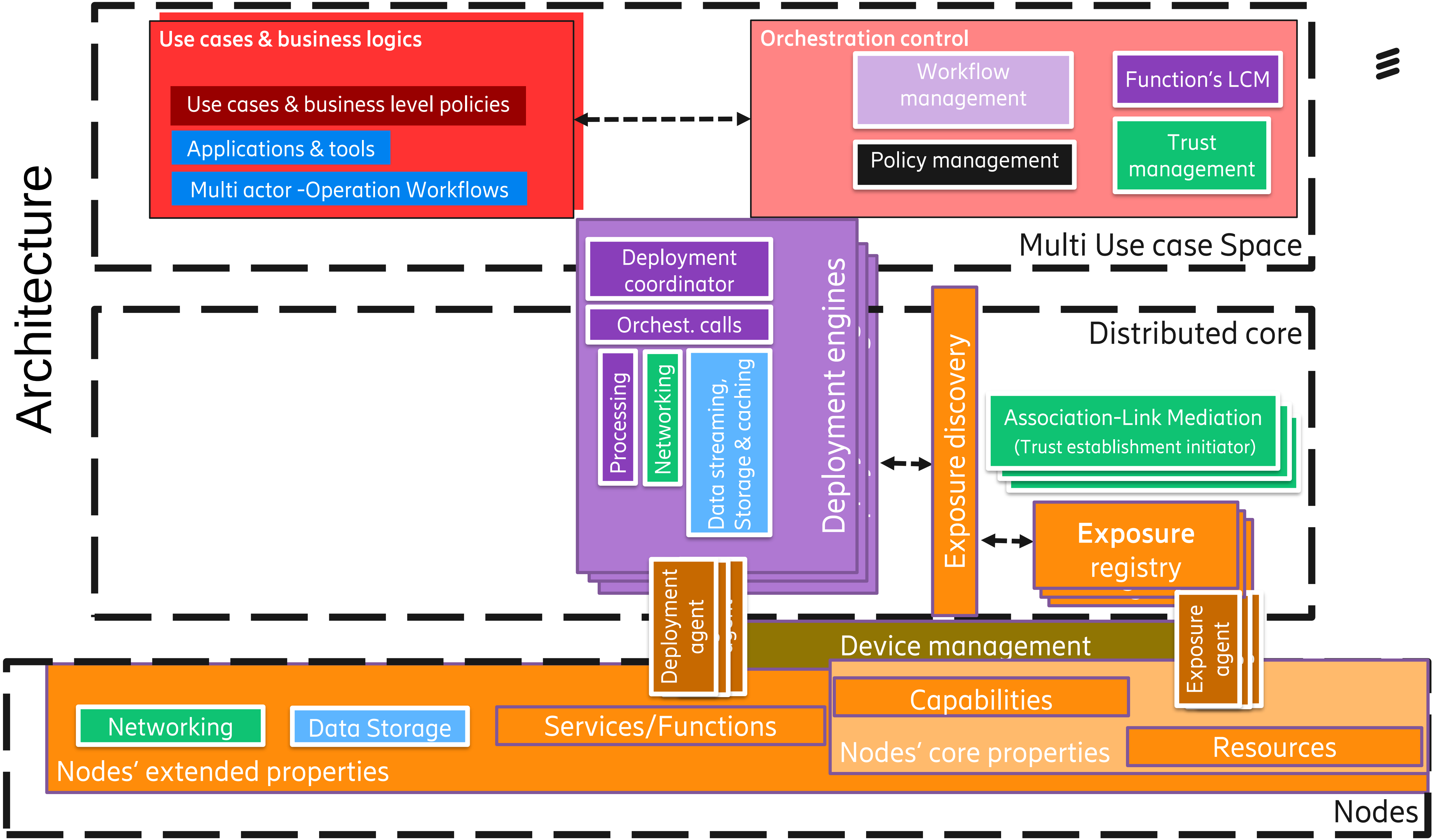
- New features as new device drivers, libraries, daemons

### Policies and life-cycle management fully embedded

- Management of non-functional requirements in each layer
- Enablement of repurposing & handling of new services



# Orchestration Architecture



Use cases & business logics

Use cases & business level policies

Applications & tools

Multi actor -Operation Workflows

Orchestration control

Workflow management

Function's LCM

Policy management

Trust management

Multi Use case Space

Deployment coordinator

Orchest. calls

Processing

Networking

Data streaming, Storage & caching

Deployment engines

Exposure discovery

Distributed core

Association-Link Mediation (Trust establishment initiator)

Exposure registry

Deployment agent

Exposure agent

Device management

Networking

Data Storage

Services/Functions

Nodes' extended properties

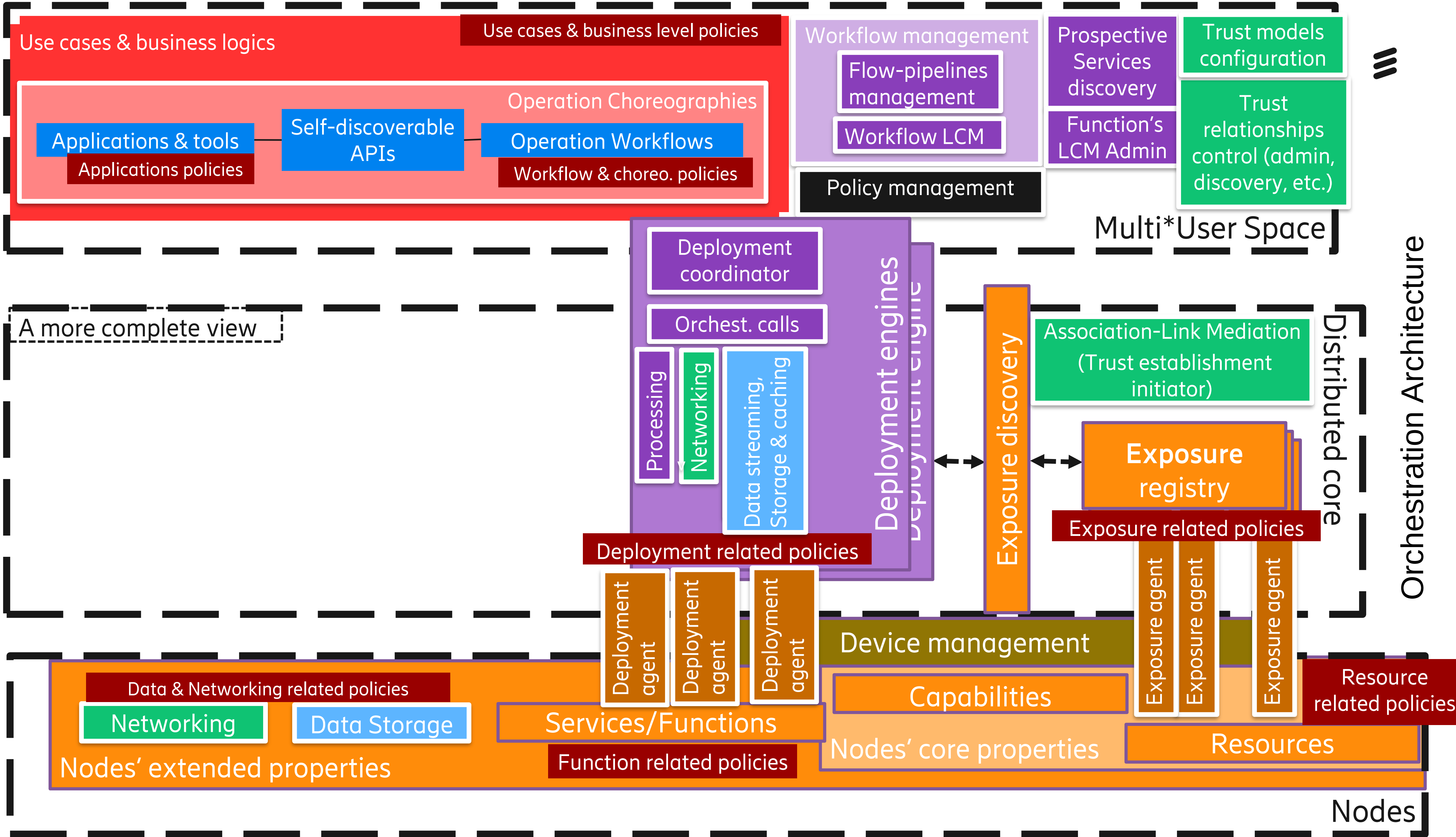
Capabilities

Nodes' core properties

Resources

Nodes

A more complete view



Use cases & business logics

Use cases & business level policies

Operation Choreographies

Applications & tools

Applications policies

Self-discoverable APIs

Operation Workflows

Workflow & choreo. policies

Workflow management

Flow-pipelines management

Workflow LCM

Policy management

Prospective Services discovery

Function’s LCM Admin

Trust models configuration

Trust relationships control (admin, discovery, etc.)

Multi*User Space

Deployment coordinator

Orchest. calls

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Deployment engines

Deployment engine

Deployment related policies

Exposure discovery

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Exposure related policies

Distributed core

Orchestration Architecture

Deployment agent

Deployment agent

Deployment agent

Exposure agent

Exposure agent

Exposure agent

Device management

Capabilities

Resources

Resource related policies

Nodes’ core properties

Data & Networking related policies

Networking

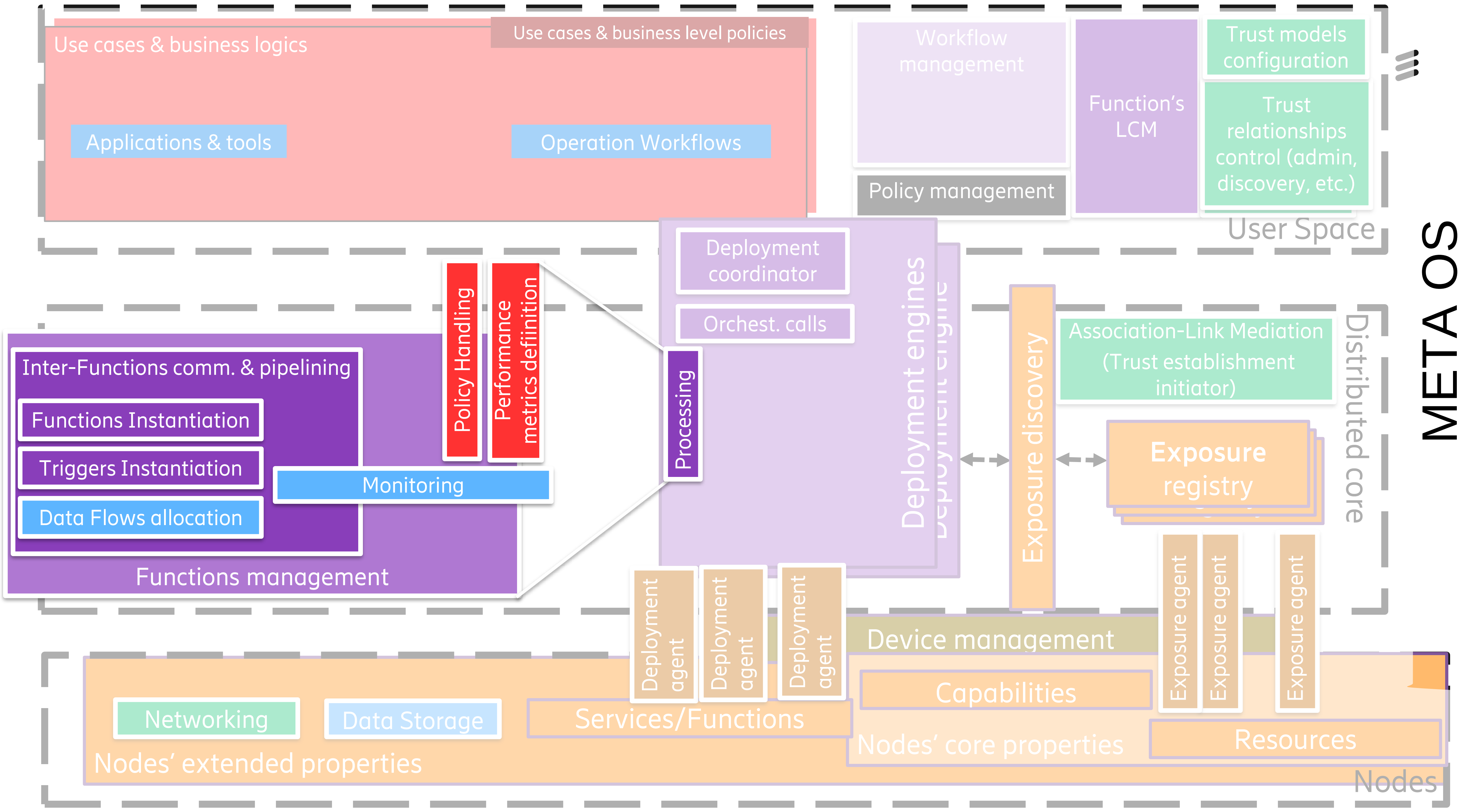
Data Storage

Services/Functions

Function related policies

Nodes’ extended properties

Nodes



META OS

User Space

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Use cases & business level policies

Applications & tools

Operation Workflows

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Distributed core

Deployment coordinator

Orchest. calls

Deployment engines

Processing

Policy Handling

Performance metrics definition

Functions management

Inter-Functions comm. & pipelining

Functions Instantiation

Triggers Instantiation

Data Flows allocation

Monitoring

Exposure discovery

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Exposure registry

Exposure agent

Exposure agent

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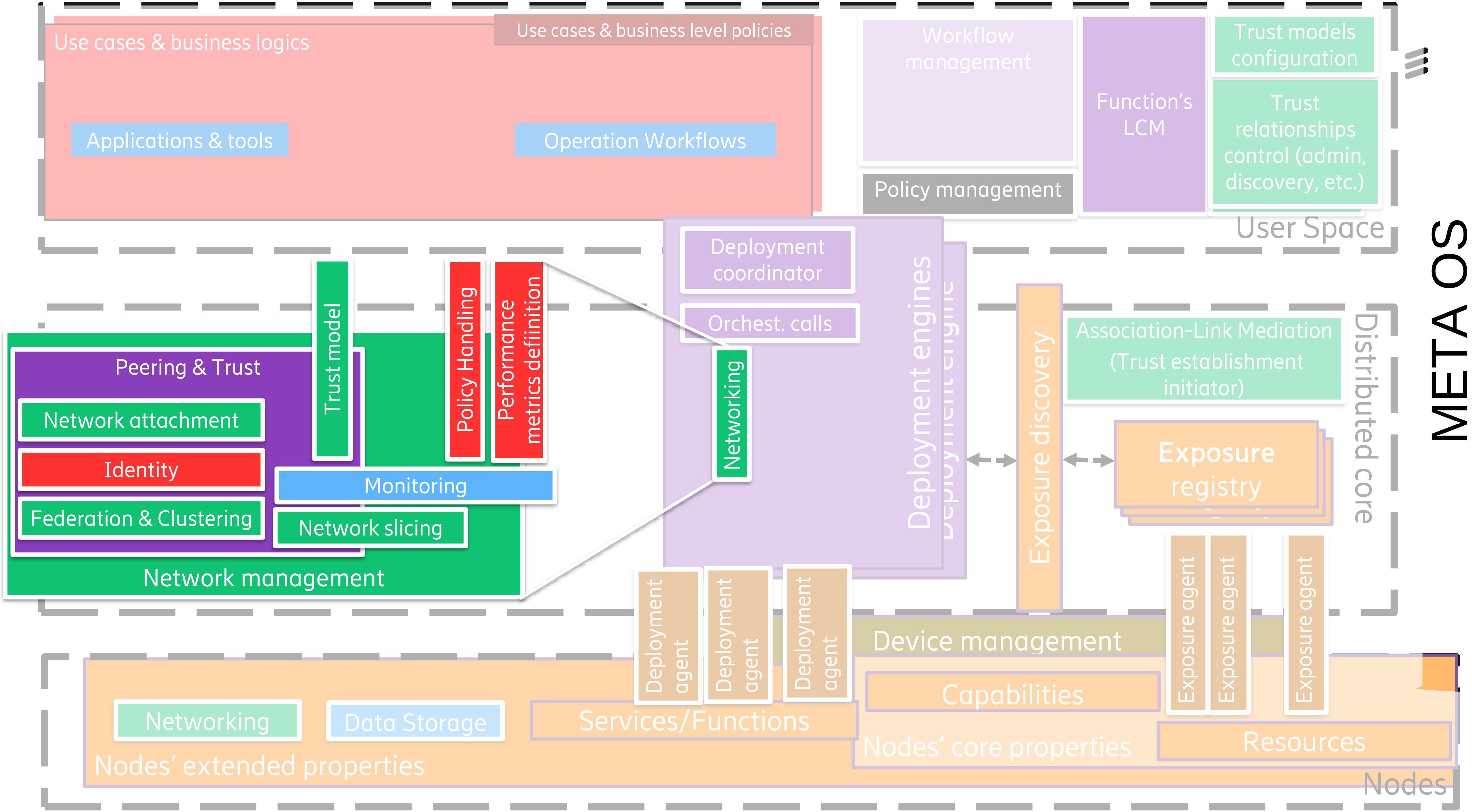

META OS

User Space

Use cases & business logics

Use cases & business level policies

Applications & tools

Operation Workflows

Workflow management

Policy management

Function's LCM

Trust models configuration

Trust relationships control (admin, discovery, etc.)

Distributed core

Deployment coordinator

Orchest. calls

Networking

Deployment engines

Deployment engine

Exposure discovery

Association-Link Mediation (Trust establishment initiator)

Exposure registry

Trust model

Policy Handling

Performance metrics definition

Peering & Trust

Network attachment

Identity

Federation & Clustering

Monitoring

Network slicing

Network management

Nodes

Deployment agent

Deployment agent

Deployment agent

Exposure agent

Exposure agent

Exposure agent

Device management

Capabilities

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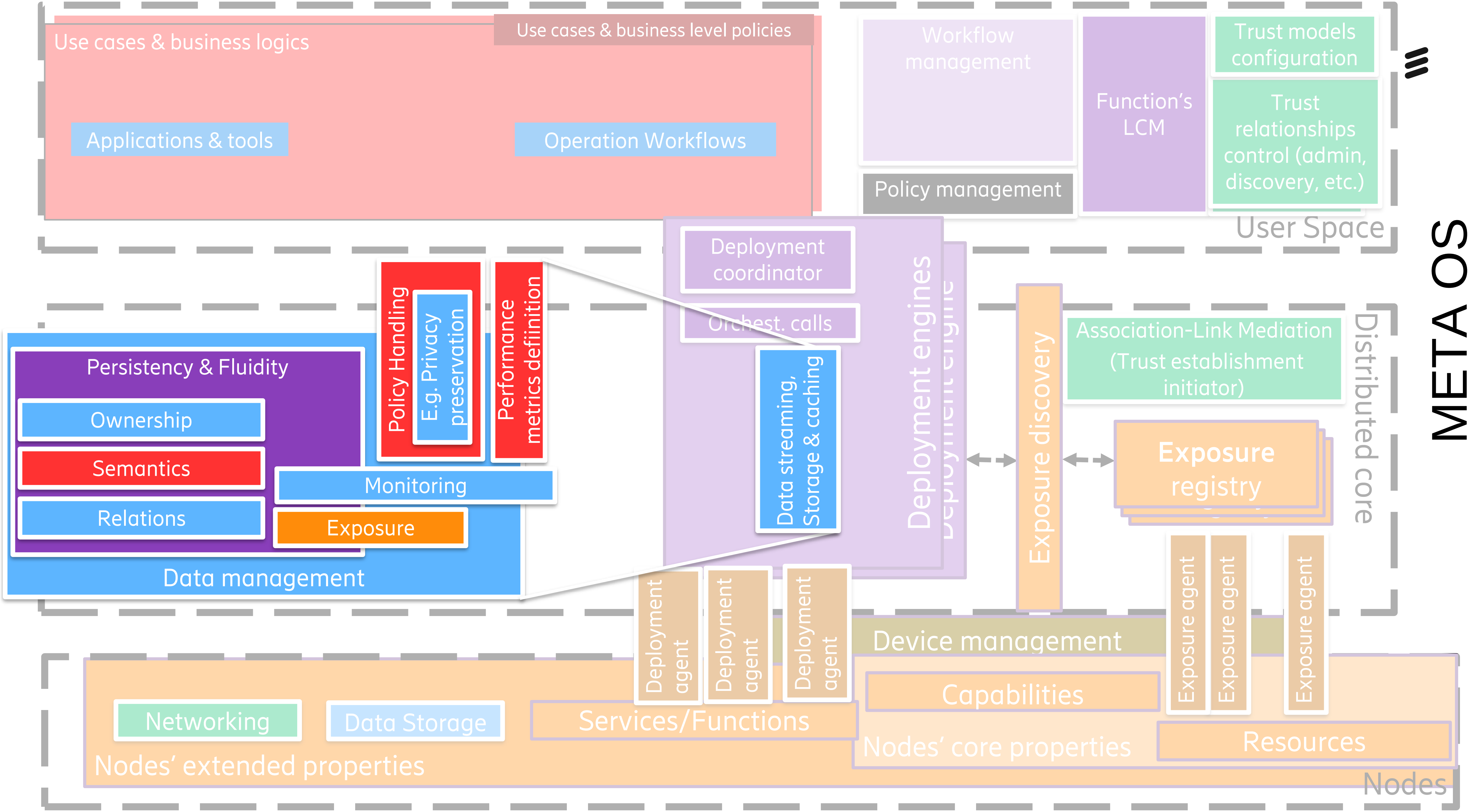
Nodes' extended properties



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Use cases & business level policies

Applications & tools

Operation Workflows

Workflow management

Policy management

Function's LCM

Trust models configuration

Trust relationships control (admin, discovery, etc.)

Distributed core

Deployment coordinator

Orchest. calls

Data streaming, Storage & caching

Deployment engines

Deployment engine

Exposure discovery

Association-Link Mediation (Trust establishment initiator)

Exposure registry

Exposure agent

Exposure agent

Exposure agent

Persistency & Fluidity

Ownership

Semantics

Relations

Policy Handling

E.g. Privacy preservation

Performance metrics definition

Monitoring

Exposure

Data management

Deployment agent

Deployment agent

Deployment agent

Device management

Nodes

Networking

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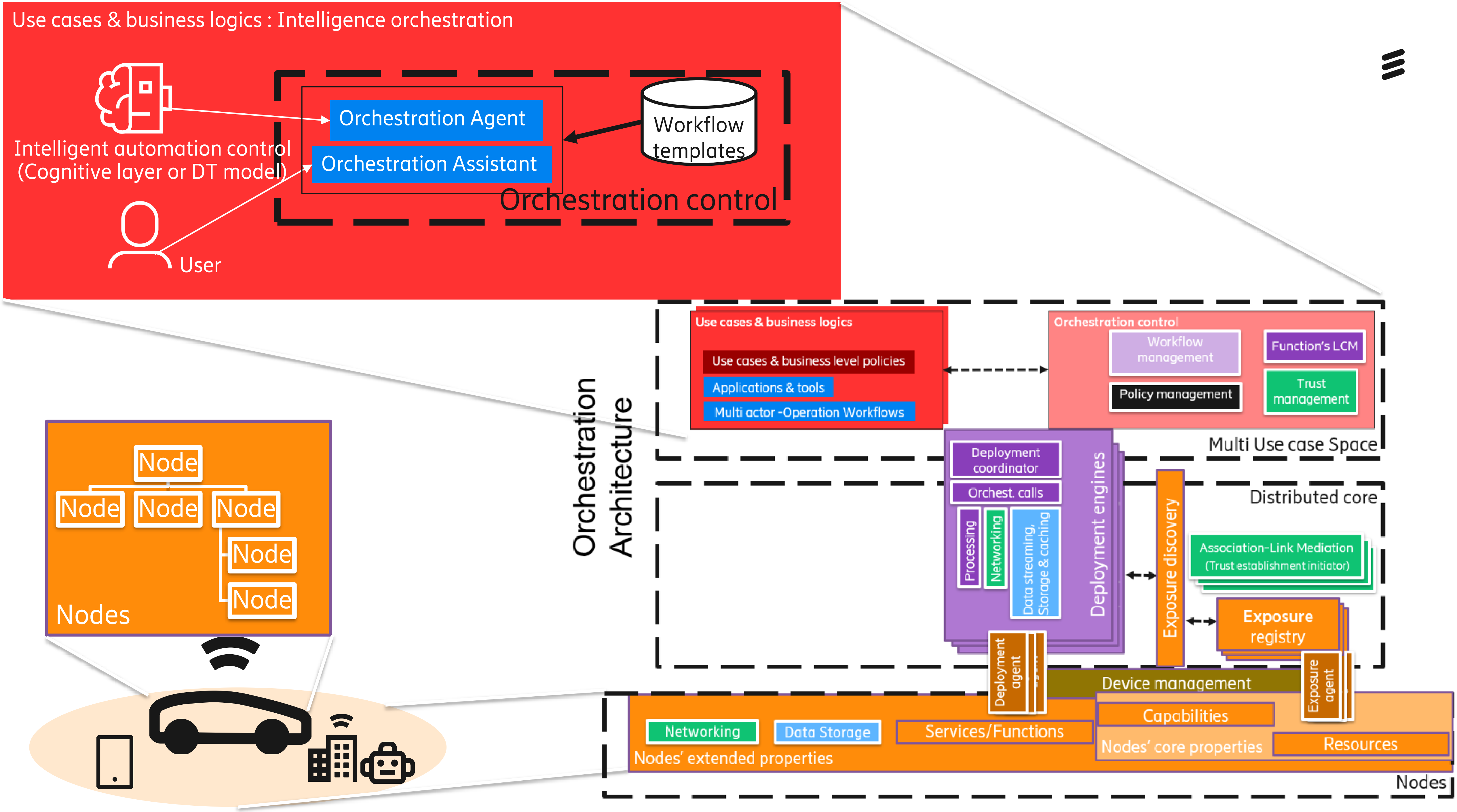
Nodes' core properties

Nodes' extended properties



Use cases & business logics : Intelligence orchestration

Intelligent automation control
(Cognitive layer or DT model)

User

Orchestration Agent

Orchestration Assistant

Workflow templates

Orchestration control

Orchestration Architecture

Use cases & business logics

Use cases & business level policies

Applications & tools

Multi actor -Operation Workflows

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Nodes

Node

Node

Node

Node

Node

Node

Nodes

# Summary
# (Why it matters & what is enabled)

- Deploy intelligence (AI) anywhere and in anything
- Translate real world constraints and dynamicity into the automation realm (**not only security but also physical word constrains**)
- Life Cycle Management of AI in any device/thing/system
- Enable dynamic use of our network special capabilities
- Enable IoT Orchestration automation (e.g., by the Cognitive reasoner)
- Embrace heterogeneity and focus on solving ecosystems friction points

**Publications**:
Intelligence orchestration for future IOT platforms
https://iot.ieee.org/newsletter/november-2021/intelligence-orchestration-for-future-iot-platforms

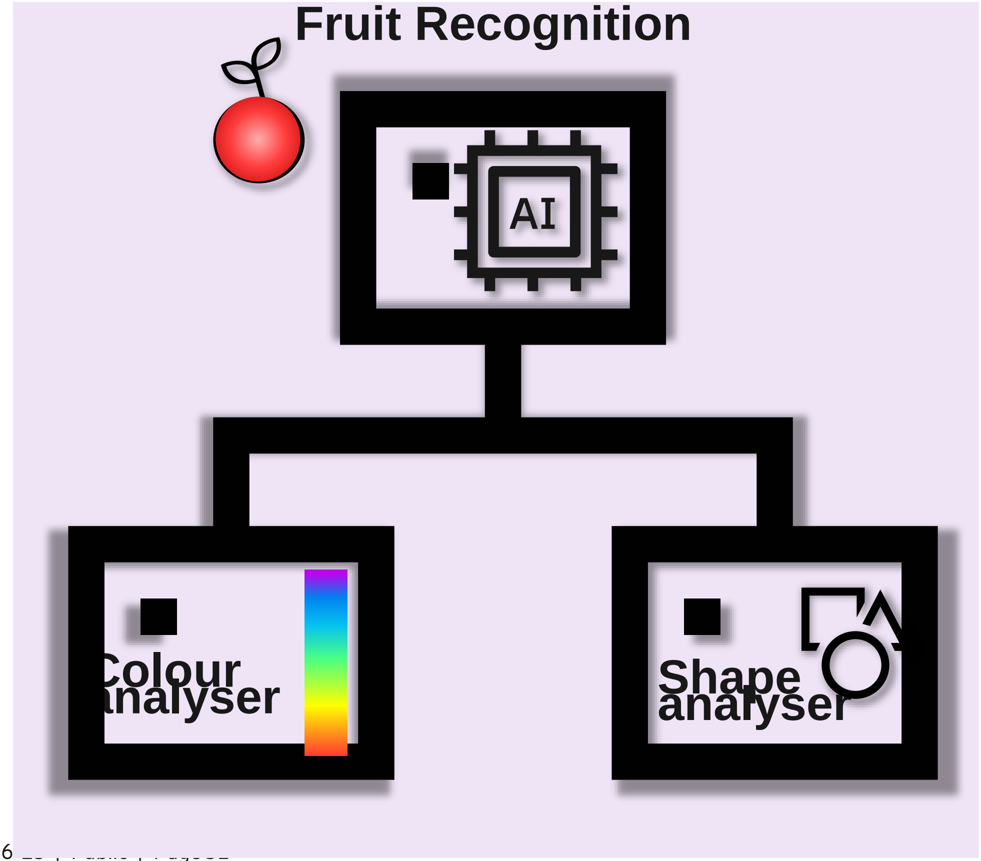
Architecture Framework for Intelligence Orchestration in AIoT and IoT
https://www.researchgate.net/publication/361183370_Architecture_Framework_for_Intelligence_Orchestration_in_AIoT_and_IoT

#TechnologyJourneys
#ResearchInsights

# Backup slides

# Intelligence Distribution Aspects (1/5)

## AI Service Functional Distribution

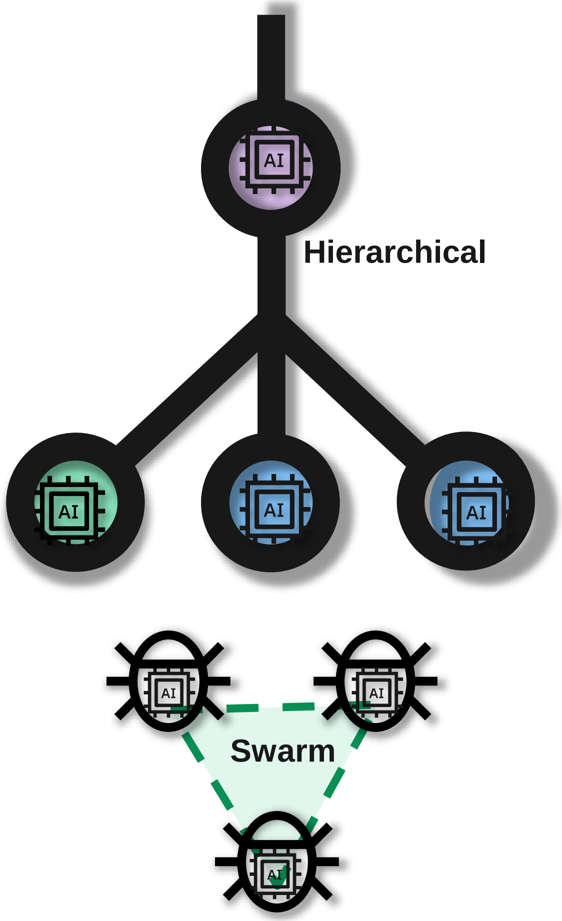


- AI Models **modularity**
- Combination (**composition**) of multiple domains and techniques to achieve a concrete task
- A concrete example:

  **Generative Adversarial Network (GAN)**

# Intelligence Distribution Aspects (2/5)

## Agent Functional Distribution

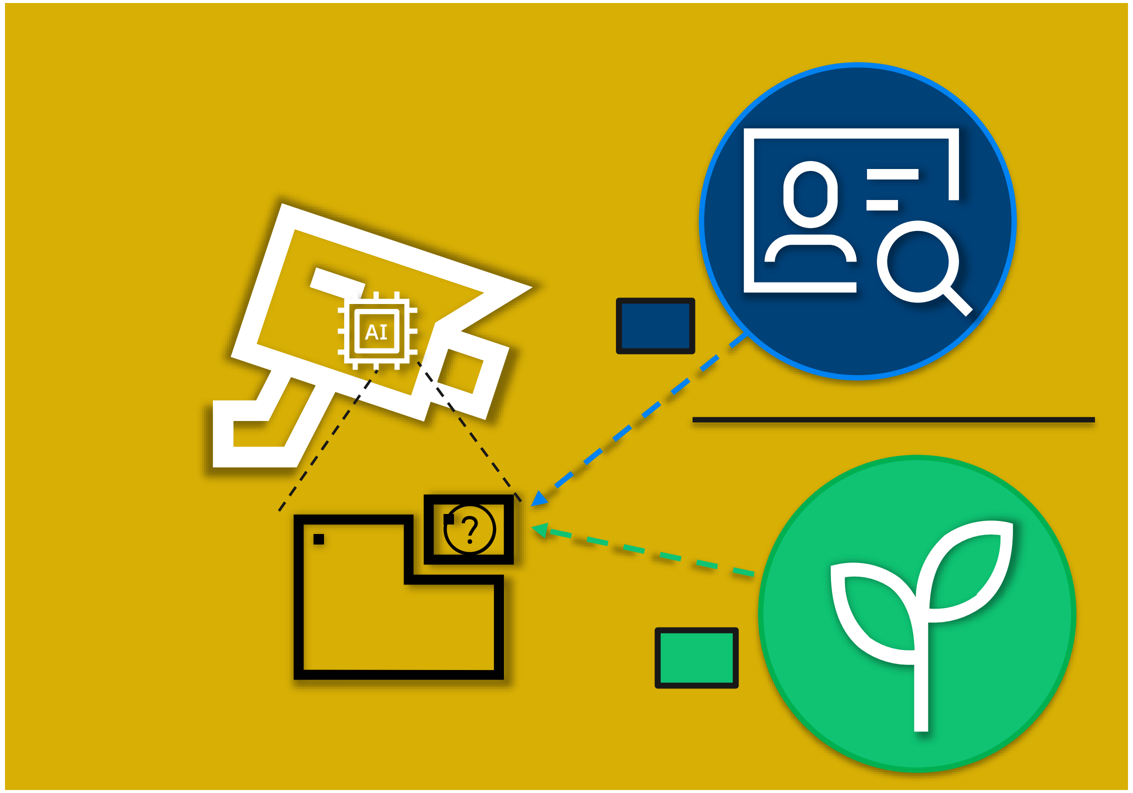


- Intelligence interaction with other intelligences
- The rational agents strategies and conducts involved
- The degree of communication between agents
- The perception of intelligence organization
- Interesting example:

  Neural networks that design other neural networks

# Intelligence Distribution Aspects (3/5)

## Intelligence provisioning (Model distribution)

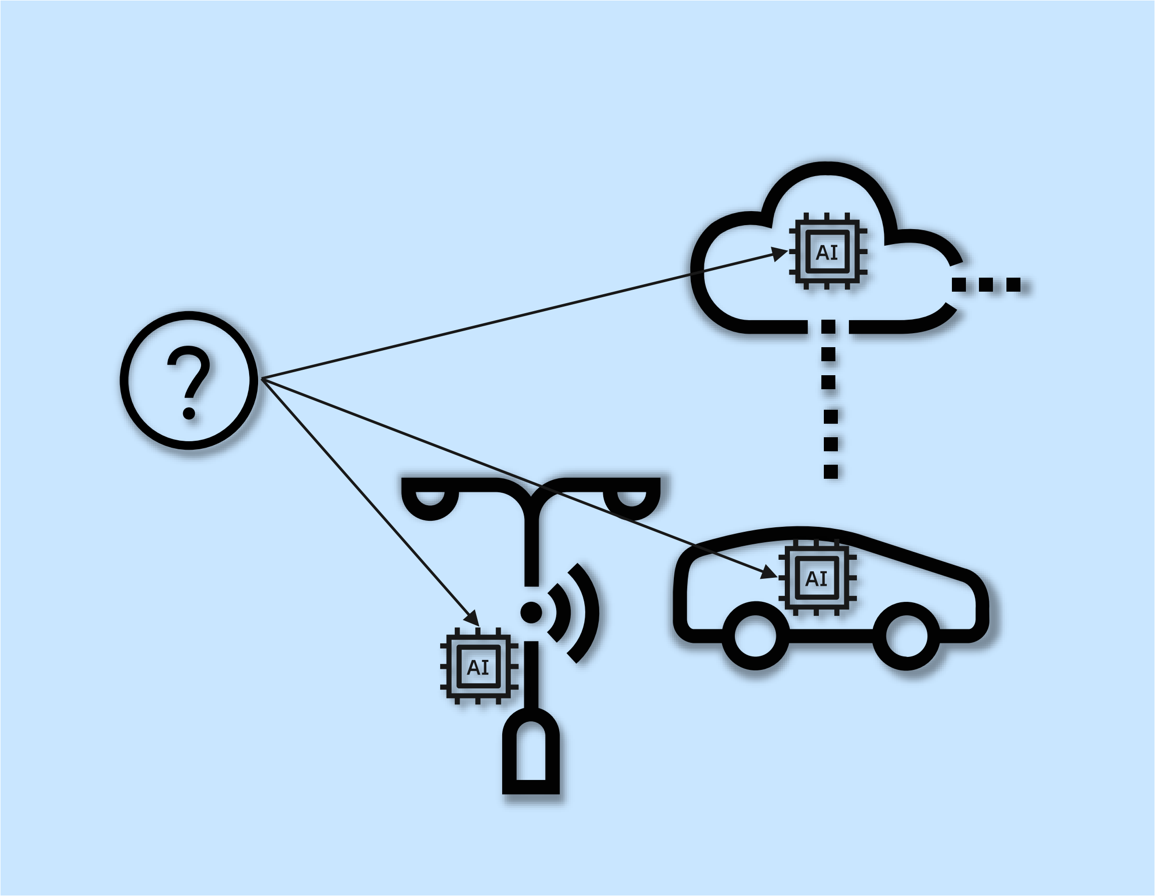


- Onboard or update an intelligence model
- Exploiting general hardware, cloud facilities and local acceleration from AI
- Mass marketing and standardizing AI models
- Example:

ONNX (Open Neural Network Exchange)

# Intelligence Distribution Aspects (4/5)

## Inference Execution Distribution



- Where and how the intelligence inferencing is executed
- Privacy, hardware capabilities, connectivity, latency and control-loop response times as main discriminator requirements
- May include different intelligence solutions for different domains
  - Execution domain may also switch according to availability, environment changes or variable requirements

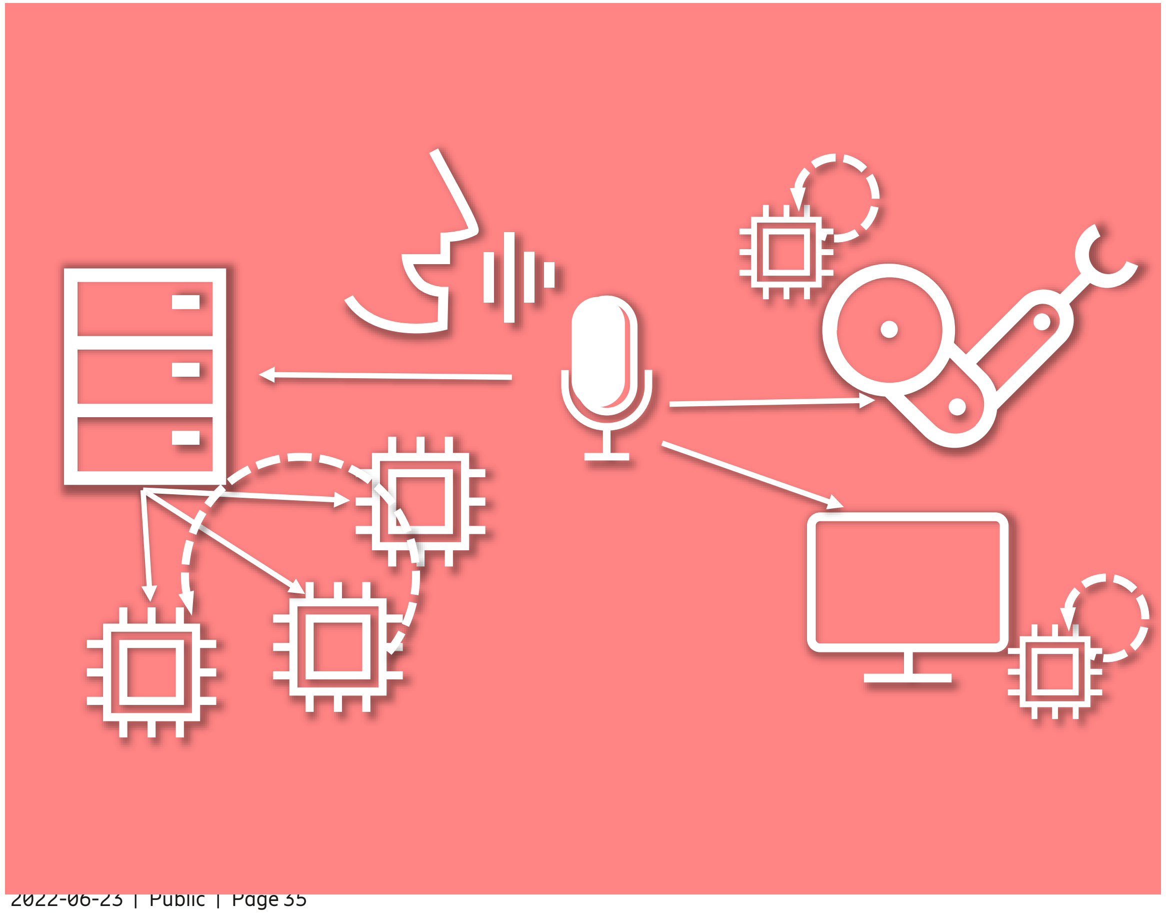
    Interesting example:

    **Actor Based microservices frameworks**

    **(e.g. Calvin)**

# Intelligence Distribution Aspects (5/5)

## Training Execution Distribution

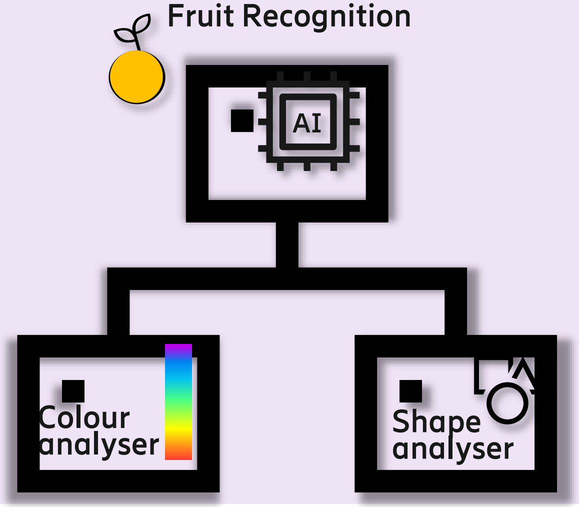


- Where and how the intelligence training is executed
- Similar than inference execution distribution
- Additionally to hardware constrains and particularities of the inference hardware, the location and volumes of training data and the sensitivity plays a big role in the decision of distribution
- Continuously generated data and consolidation is another consideration
- Interesting example:

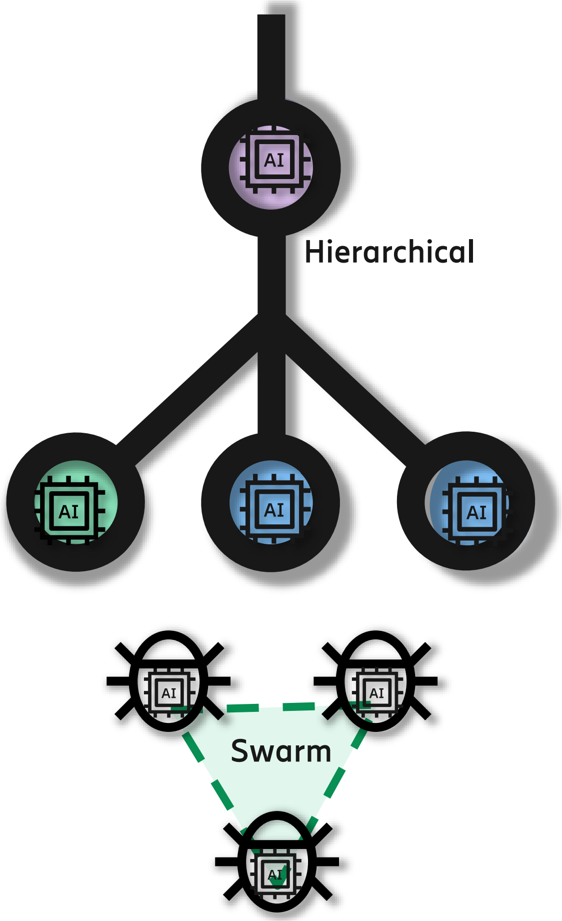
  Federated learning

# Computational Intelligence Distribution Aspects

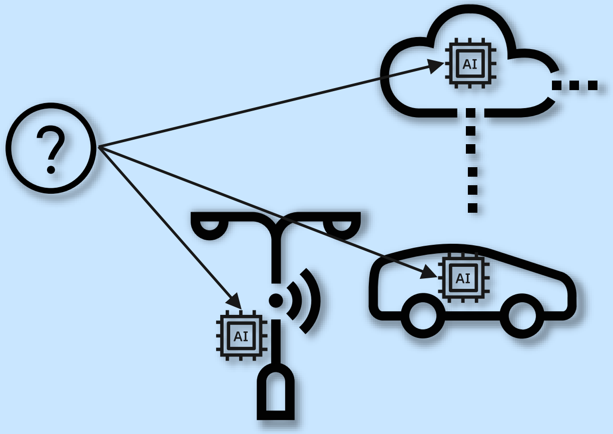
## AI Service Functional Distribution



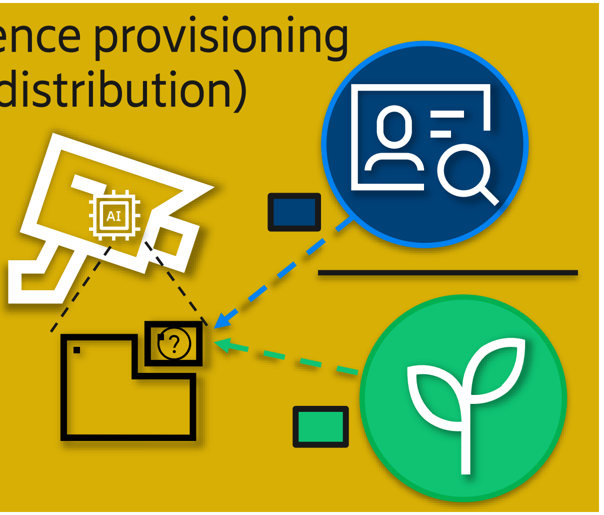
## Agent Functional Distribution



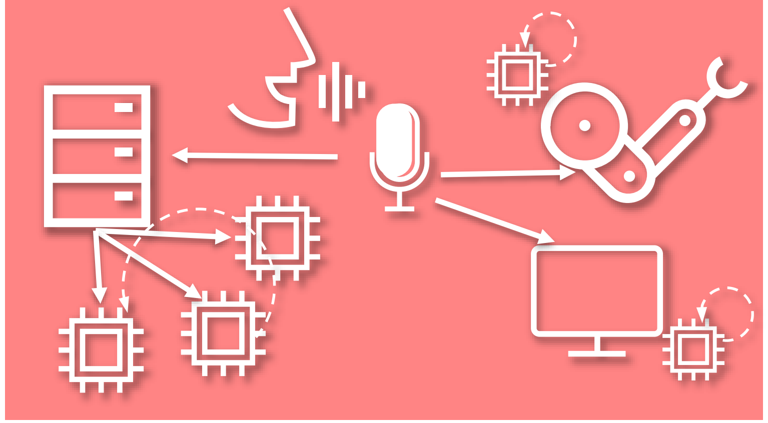
## Inference Execution Distribution



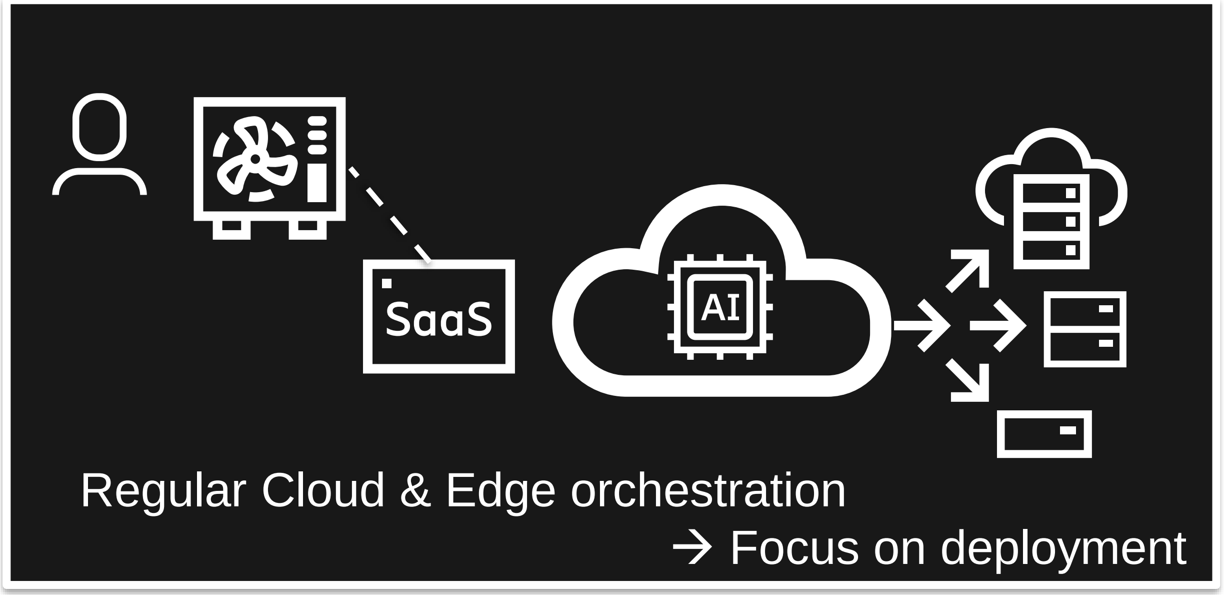
## Intelligence provisioning (Model distribution)



## Training Execution Distribution



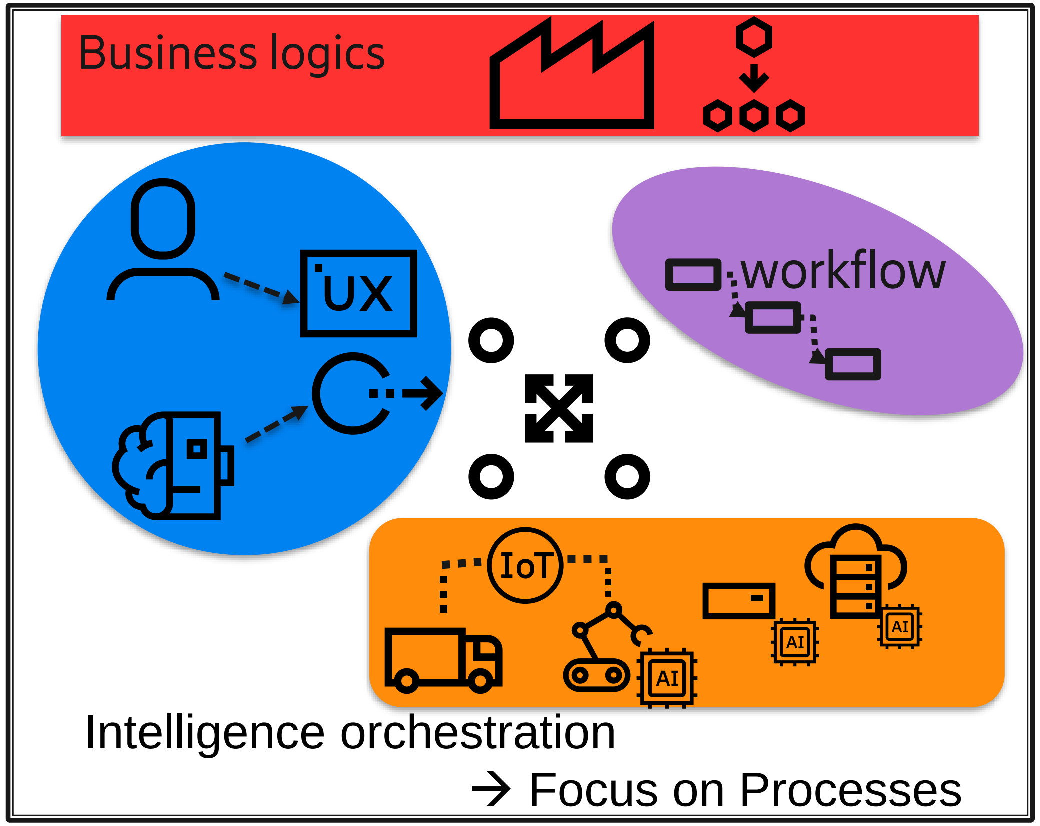
# Orchestration of AI in IoT differs



Regular Cloud & Edge orchestration

→ Focus on deployment

- Micro-services & platforms
- Relations between micro-services
- Adaptation to deployment variations & requirements



Intelligence orchestration

→ Focus on Processes

- Serverless paradigm based, deploy anywhere
- Coordination and composition of processing units (triggers, pipelines, and multiplatform)
- Workflows including **data flows**, **policies** and **application enablers** as an integral part