OPIL: Optimizing Mobile Robot Deployment using IoT

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Mobile World Capital Barcelona

Smart logistics for manufacturing

L4MS

European Commission

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 767642

EU SMEs need to sustain competitiveness

IMPROVING PRODUCTIVITY
WHILE
KEEPING UP WITH COMPLEXITY GROWTH

ENABLING FLEXIBILITY
WHILE
BEING RESILIENT TO CHANGE

Improving Competitiveness

ERP,
MES,
WMS

Impr… Operational Excellence

- Cont… provement
- Tota… e Maintenance
- Quali… gement
- …

Robots
End
effector
etc

AVGs,
Mobile
Robots

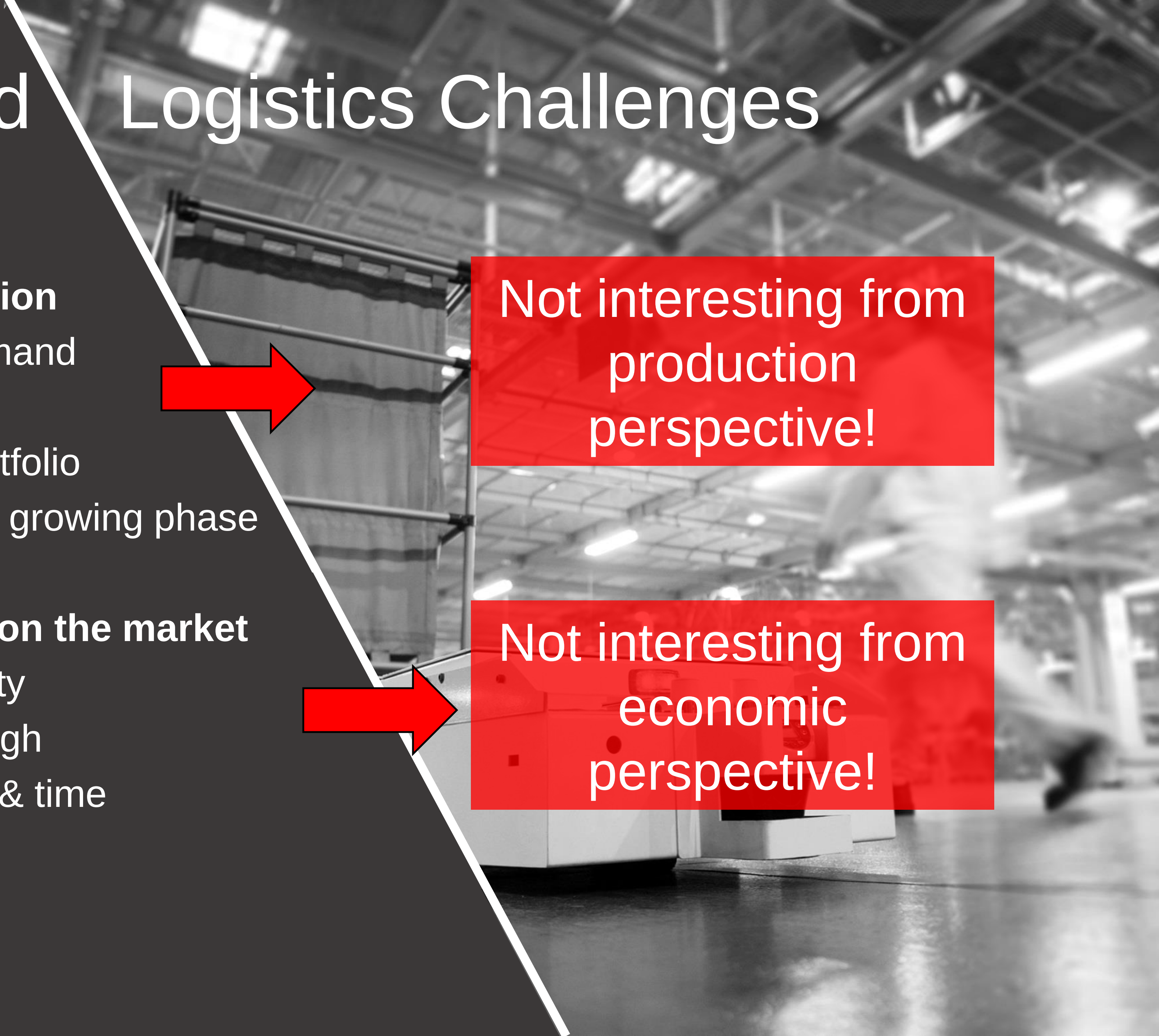
Are hitting a plateau

Implementing new technologies

Logistics account for up to **50%** of total manufacturing costs

Automating information flows
Automating production cells
Automating internal logistics

SMEs & Automated Logistics Challenges



Challenge 1: Changes in production

- Uncertainty regarding future demand requirements
- Uncertainty in future product portfolio
- Layout changes specially during growing phase

Not interesting from production perspective!

Challenge 2: Available solutions on the market

- Traditionally have low adaptability
- Software integration costs are high
- System expansion is expensive & time consuming
- Vendor lock

Not interesting from economic perspective!

What SME´s do need

- Fast integration
- Low integration costs
- Easy to integrate with hardware
- Easy to expand

OPIL: IoT Platform for Logistics Automation

Factory Equipment
& Devices

Enterprise
Applications
For inventory

OPIL

Sensing &
Perception

Human
Machine
Interaction

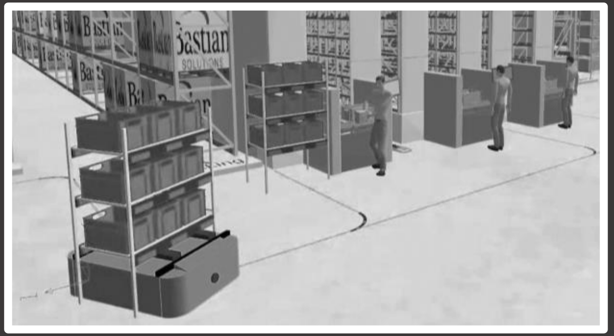
Task
planner

Suit of Software Solutions

ERP

ME
S

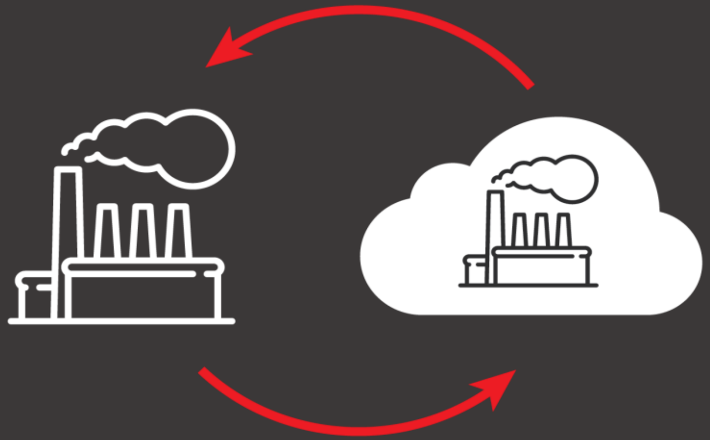
PLM



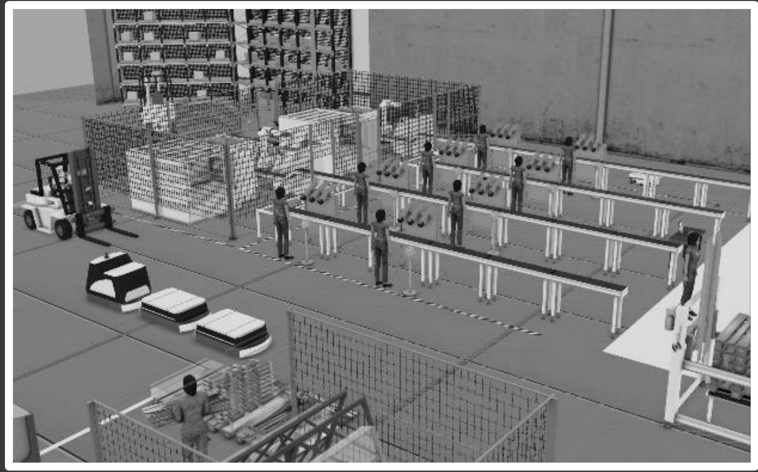
3D Simulation of the
factory floor

Using OPIL and Digital Twin

Execution phase
Connect devices and steer logistic operations



Continuous adaptation & reconfiguration of logistic system with lower effort



Planning phase
3D factory simulation to design layout, routes, schedules

SOFTWARE SYSTEM LAYER (3)
CYBERPHYSICAL MIDDLEWARE LAYER (2)
IoT NODES LAYER (1)
TASK PLANNER
BUSINESS PROCESS OPTIMIZATION
TASK SUPERVISOR
MOTION TASK PLANNING
ADVANCED HMI
TASK SPECIFICATION
TASK PARAMETERIZATION
TASK MONITORING & CONTROL
SENSING & PERCEPTION
MAPPING
LOCALIZATION
VISUAL COMPONENTS 3D SIMULATION
CONTEXT MANAGEMENT
FIWARE ORION CONTEXT BROKER
BACKEND DEVICE MANAGEMENT & PROTOCOL ADAPTER
FIWARE IDAS
ADVANCED WIDGET MASHUP HMI
FIWARE WIRECLOUD
ROBOT AGENT NODE
COMMUNICATION / MESSAGING
LOCAL ABSTRACTION LAYER
LOCAL EXECUTION LAYER
LEGACY HARDWARE ABSTRACTION LAYER
HUMAN AGENT NODE
COMMUNICATION / MESSAGING
LOCAL HMI LAYER
LEGACY HARDWARE ABSTRACTION LAYER
SENSOR AGENT NODE
COMMUNICATION / MESSAGING
LOCAL ABSTRACTION LAYER
LOCAL EXECUTION LAYER
LEGACY HARDWARE ABSTRACTION LAYER
VISUAL COMPONENTS
ROBOT AGENT NODE
HUMAN AGENT NODE
SENSOR AGENT NODE

Advantages & Benefits

Adaptation of new layouts

Design, redesign and optimize

Speed & precision with Visual Components simulations

Adaptation to changing production volumes

Easy to include new AGVs, Human Agents, etc.

Changes in Production Planning & Scheduling automatically considered

Investment estimation

Time and installation costs drastically reduced

Time for system adaption drastically lower

Standard interfaces

Adaptation to new technologies

Plug and Play functionality to sensors, ROS based Automated Guided Vehicles (AGV)

Funding up to 250,000€ to develop flexible, responsive logistics system

APPLY at l4ms.eu!

Deadline 30th November 13:00 CET

Interested but don't have a partner?
https://l4ms-registration.fundingbox.com/

Do you have questions?
helpdesk@l4ms.eu

Send your proposal using this link!
https://www.l4ms.eu/

Smart logistics for manufacturing L4MS

Thank you!

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Youtube: L4 MS

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H2020 Innovation Action - This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 767642

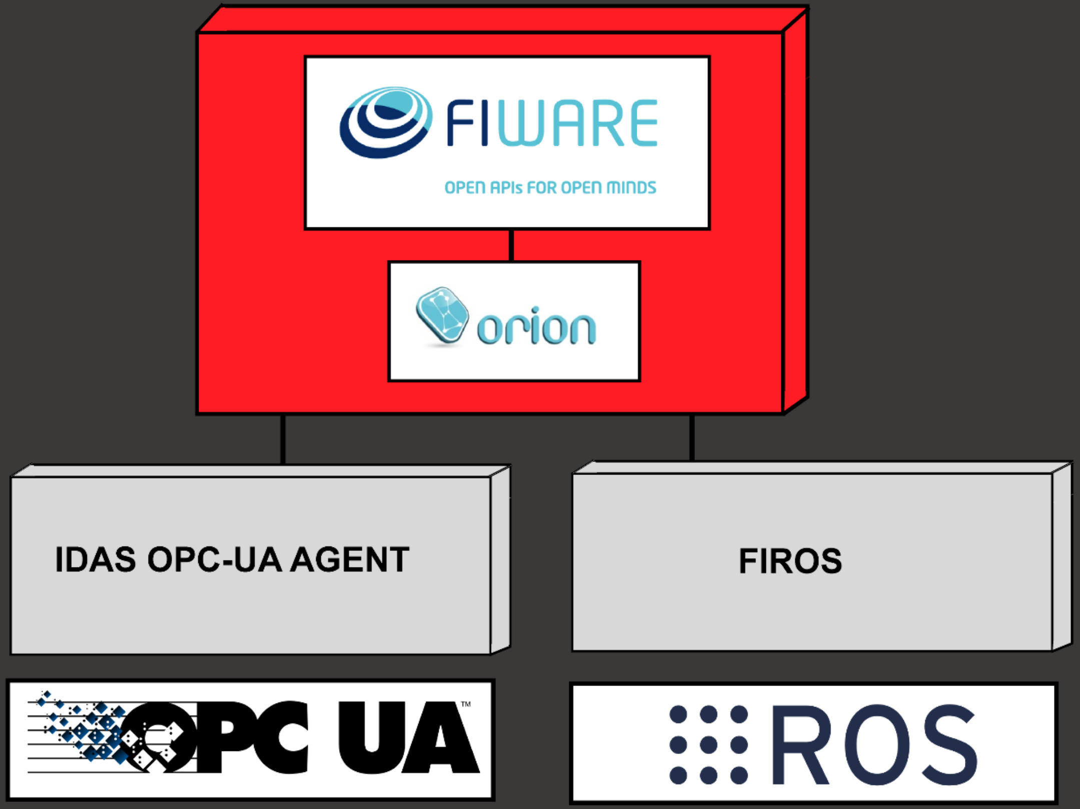
Smart logistics for manufacturing

Project Coordinator

OPIL Technical Tools

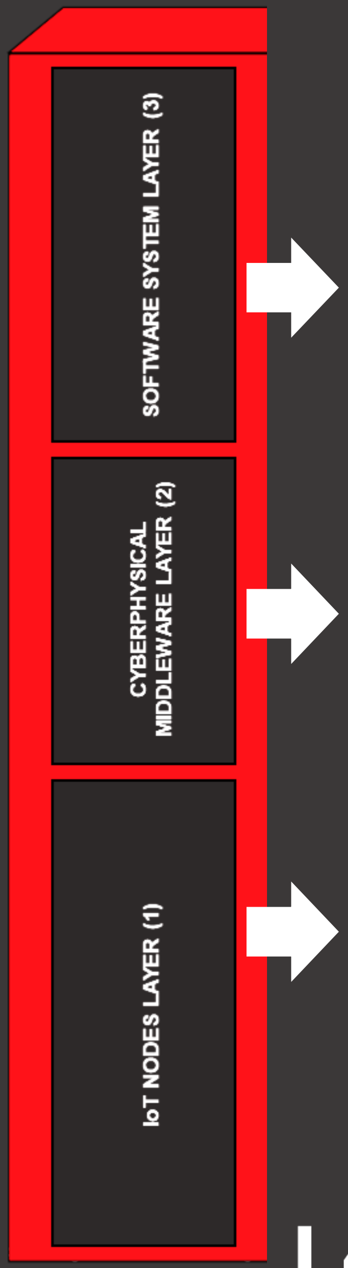
- **ROS (Robotic Operation System)**
  - Provides libraries specifically developed for robot control

- **FIWARE Orion Context Broker (OCB):**
  - Data distributed service
  - Every node of OPIL can write and read messages
  - The tool used by the nodes of the architecture to communicate



OPIL modules

Architecture



- **Software System Layer**
  - Logistics functionality
  - Simulation
- **Cyber Physical System Layer**
  - Middleware
  - Enables communication among different systems
- **IoT nodes**
  - Production floor
  - The ones that perform logistics tasks

Goal of task planner?

- **Robot Fleet Management**
  - High level fleet tasking
  - Optimization of logistic tasks based on specifications
  - Coordination of logistics workers robots/humans
  - Supervision of task execution

Task Planner sub-modules

- Consists of 3 different sub-modules:

1) **Task Supervisor**

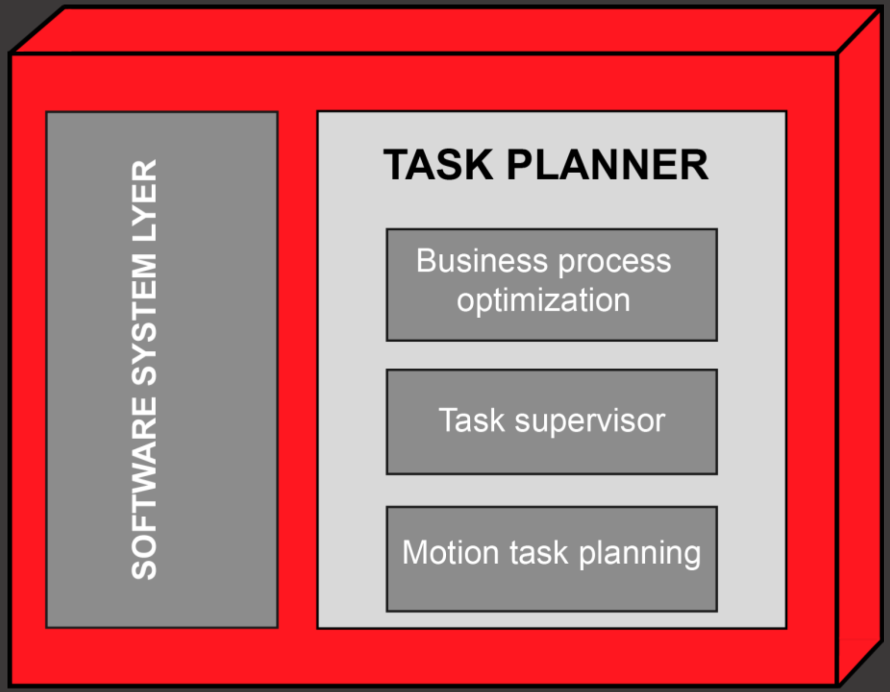
   monitors the execution of the task dispatched to the agents

2) **Business Process Optimization**

   decides and optimizes the tasks to be dispatched to the different agents

3) **Motion Task Planning**

   plans the motion tasks for the robot agents



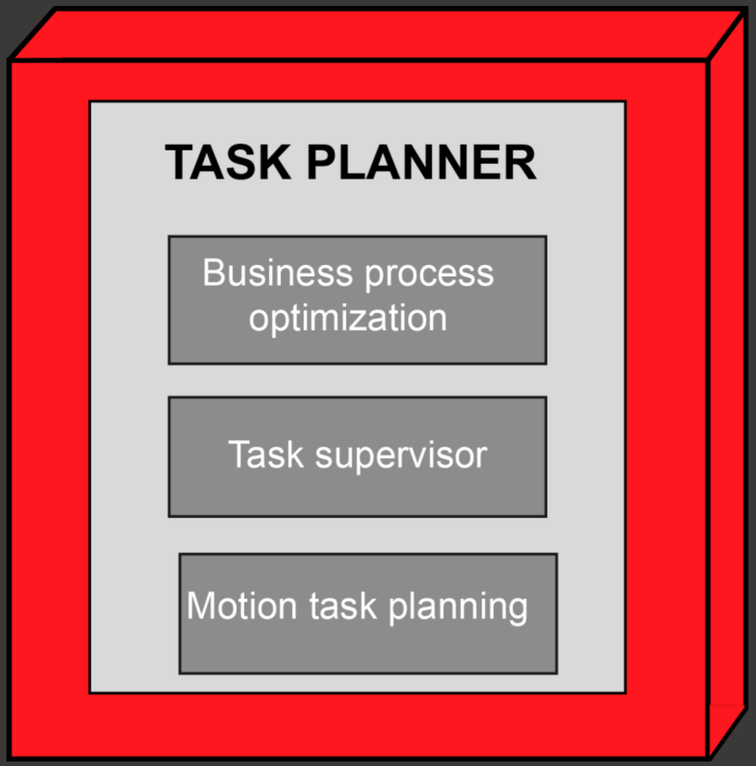
Task Supervisor

1) **Receives a "Task Specification"**
   - "Task Specification": A specification of the sought logistic task in the "Logistics Task Specification Language"

   - "Logistics Task Specification Language": A programming language introduced in OPIL that is appropriate for logistics operations

2) **Parses the "Task Specification" to generate the "Task Plan" for the BPO**

3) **Monitors the execution of the "sequence of operations" received from BPO**
   - If the execution fails it informs the BPO to provide an alternative sequence



Task Supervisor components

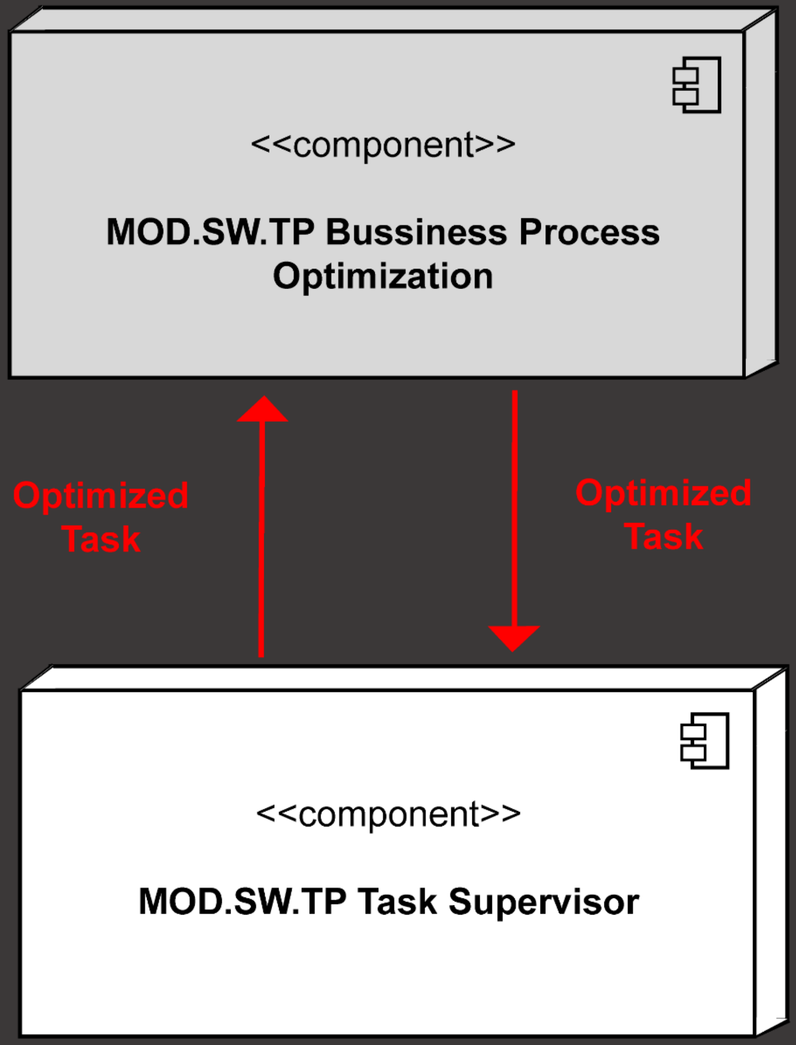
- **TaskSchedular**:
  - Responsible for creating and monitoring TaskManager.
  - Denotes a collection of one or more TaskManager.

- **TaskManager**:
  - Responsible for creating and monitoring Tasks.
  - TaskManager has collection of one or more Tasks.

- **Task**:
  - Describes a transport order that is being executed.
  - Has information on what will be transported, from where to which destination, how this task will be triggered.

Business Process Optimization

- **Determines which robots/humans where pick up items and where to drop them off**
- **Handles on-the-fly optimization of tasks received from Task Supervisor**
- **User provides specifications of logistics tasks:**
  - Resources to which machines, drop-off places and pick-up places.
- **Minimizes logistics resources required for a given task.**
  - Battery life, distance, types of AGVs.



Business Process Optimization

Set-up through the Human-Machine-Interface in two levels:

- SI have to first populate the system with predetermined tasks and resources in the system.
- Factory managers can, during manufacturing operations, select which tasks have to be fulfilled when.
- ERPs, or WMS can also steer the selection of predefined tasks.

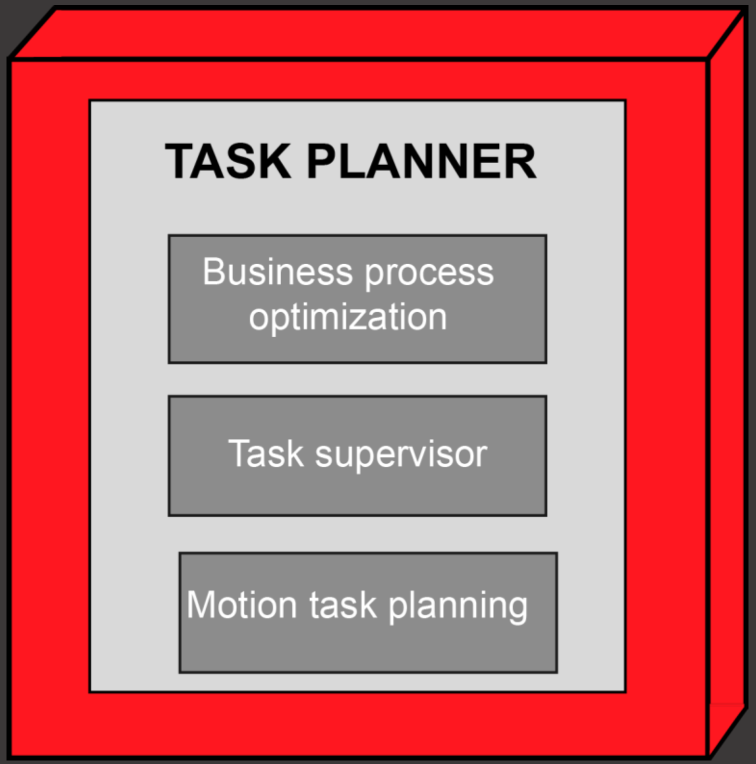
Business Process Optimization

1) **Receives a “Task Plan” from the Task Supervisor**
    - “Task Plan”: A description of the sought logistic state vs the current logistic state

2) **Calculates the required resources to fulfil the “Task Plan” by receiving input from the MTP**

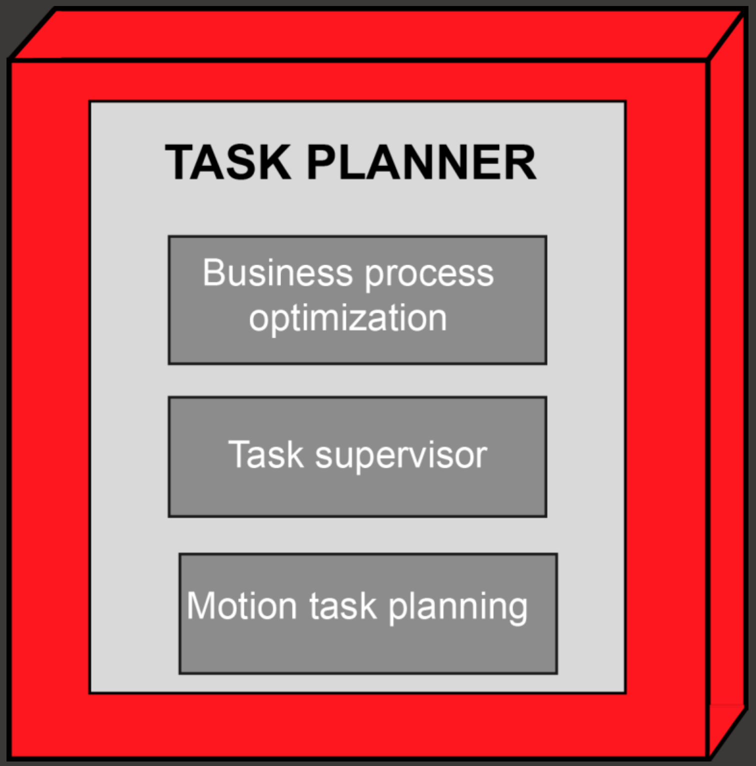
3) **Calculates the “sequence of operations” that are required to fulfil the “Task Plan”**

4) **Optimizes 2. and 3.**



Motion Task Planning

- Receives start and end destinations of **Robot/ Human Agent Nodes.**
- Computes best, shortest and/or fastest path for navigation
- Handles communication with **RAN** (MOD.SW.RAN).
- Its aware of states (current pose, position, current task)
- Cost is used by **the BMO** to find local optimum for input scenarios.
- Provides deadlock-free, (Near) optimal optimal path
- Avoid loops and collisions



OPIL: Human Machine Interface

Functionality

Run on Visual Components

VC Robot Agent Node – VC RAN

VC Sensor Agent Node – VC SAN

VC Sensor Actuator Agent Node – VC A SAN

Function modules
- Determine operations
- Have SMART behavior

Inform

Steer

Nodes
- Perform operations
- Follow tasks

Task Planner - TP

Sensing & Perception - SP

Human Machine Interaction - HMI

Robot Agent Node - RAN

Sensor Agent Node - SAN

Human Agent Node - HAN

Run on OPIL Server

Run on local device

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Run on local device

Human Agent Node (HAN)

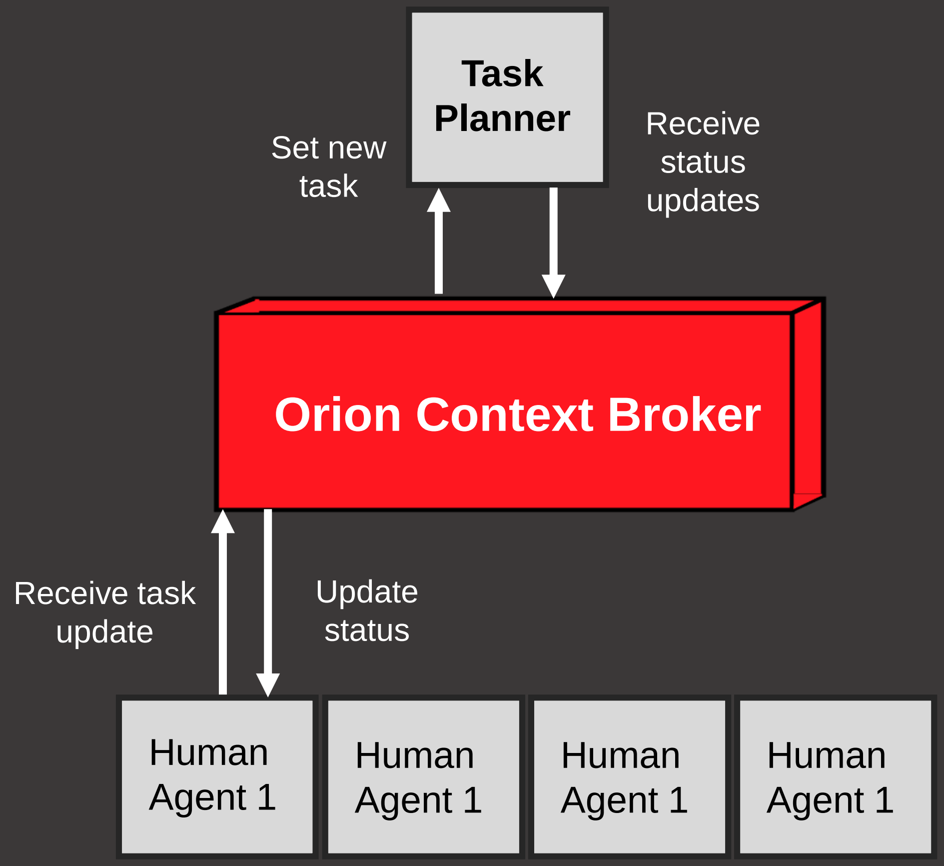
- **Local Human Machine Interface for logistic workers**
- **Receive tasks**
  - New tasks from **Task Planner**
- **Read information of the tasks**
  - What is the task, where to perform the task
- **Send status updates**
  - Task started/ finished
  - Availability
  - Location information

Tablets and similar mobile devices

Workstations (Desktop, laptops)

Human Agent Node (HAN)

- **Each human agent workstation has own HAN**
- **Unlimited number of HAN**
- **Via OCB from task planner:**
  - Received tasks
  - Send Status updates



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Run on local device

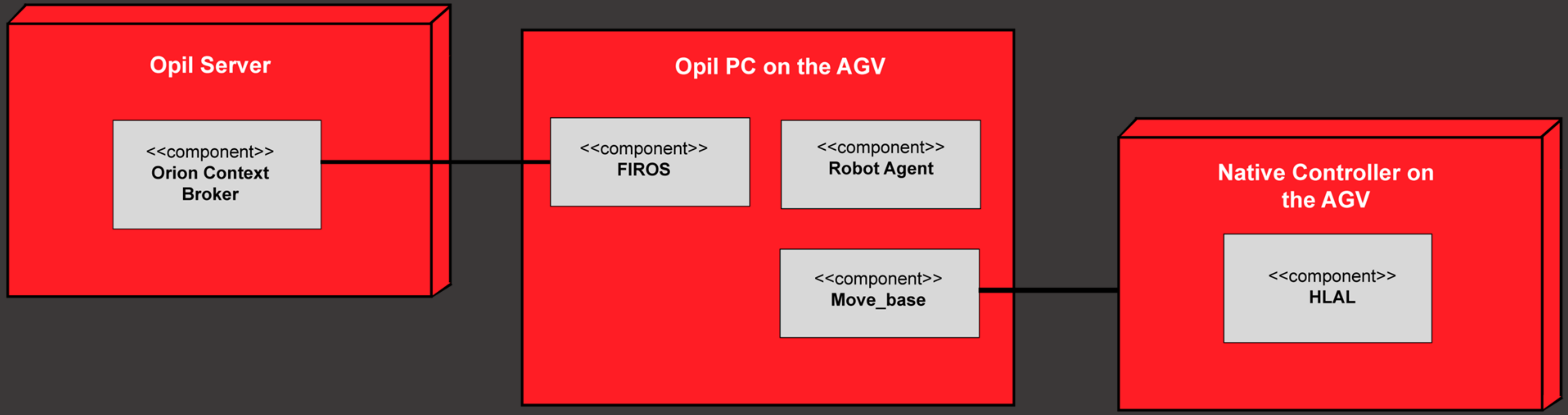
RAN

- RAN Has two main components:
  - Core:
    - Task management:
      - In charge on managing sequence of tasks to perform
      - Allows for task updates (modifying tasks already assigned)
      - it load and unload trough roller conveyors or forklifts

    - Robot navigation: In charge of managing motion according to coordinates

  - RAN-AVG Interface:
    - In charge of translating motion to AGV´s native controller.

RAN Module in OPIL



task_management_channel: on this topic CancelTask messages are sent by the TP to the RAN; these messages will be used inside the RAN.

motion_channel: on this topic MotionAssignment messages commanding the root movement are sent by the TP to the RAN; these messages will be processed and low-level motion control messages will be sent to the robot.

action_channel: on this topic ActionAssignment messages are sent by the TP to the RAN; these messages, telling the robot which action to perform, will be processed and eventually forwarded to the robot.

action_channel_AGV: on this topic action data are forwarded to the AGV using ActionDefinition messages.

status_channel: on this topic RANState messages are forwarded by the RAN from the robot to the TP.

description_channel: on this topic the RobotDescription messages are forwarded by the RAN from the robot to the TP.

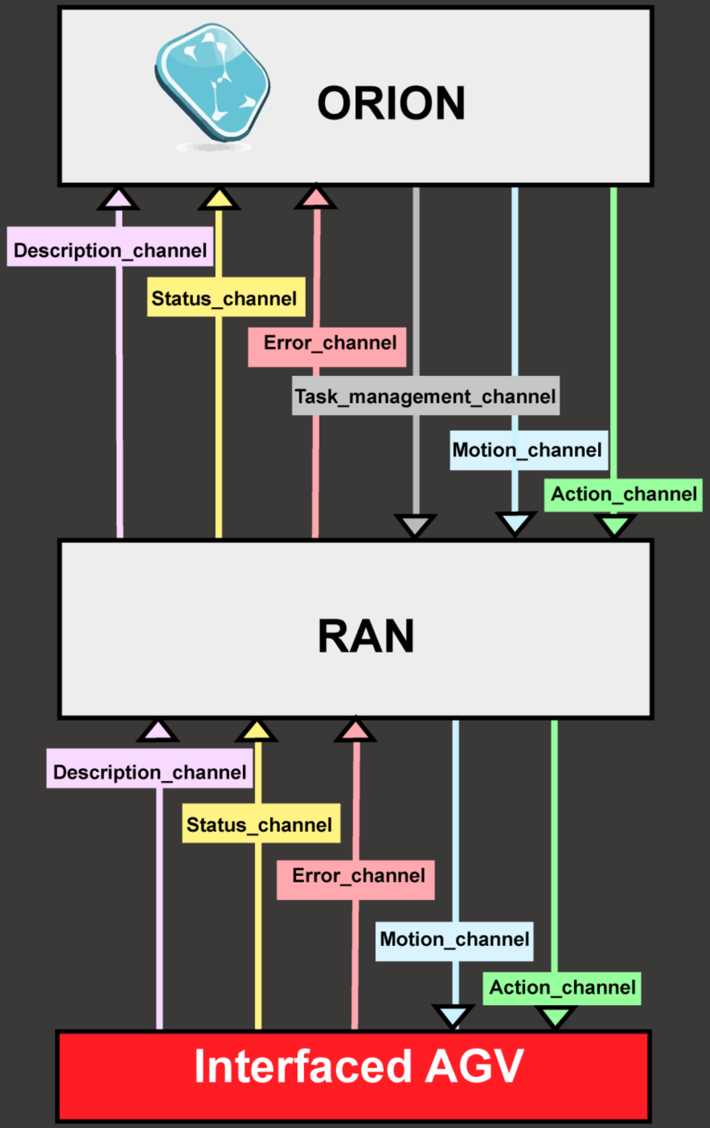
cmd_vel: on this topic are published commands that control the Robot – from RAN to HW.

status_channel_AGV: on this topic RobotState messages are sent from the Robot/AGV to the RAN.

description_channel_AGV: on this topic, RobotDescriptionAGV messages are sent from the Robot/AGV to the RAN.

error_channel: on this topic errors from AGV or RAN are sent to the TP via ErrorRAN messages.

error_channel_AGV: on this topic errors from AGV or RAN are sent to the TP via ErrorRAN messages.



Sensor Agent Node

Run on Visual Components

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- Have SMART behavior

Inform

Steer

Nodes
- Perform operations
- Follow tasks

Task Planner - TP

Sensing & Perception - SP

Human Machine Interaction - HMI

Run on OPIL Server

Robot Agent Node - RAN

Sensor Agent Node - SAN

Human Agent Node - HAN

Run on local device

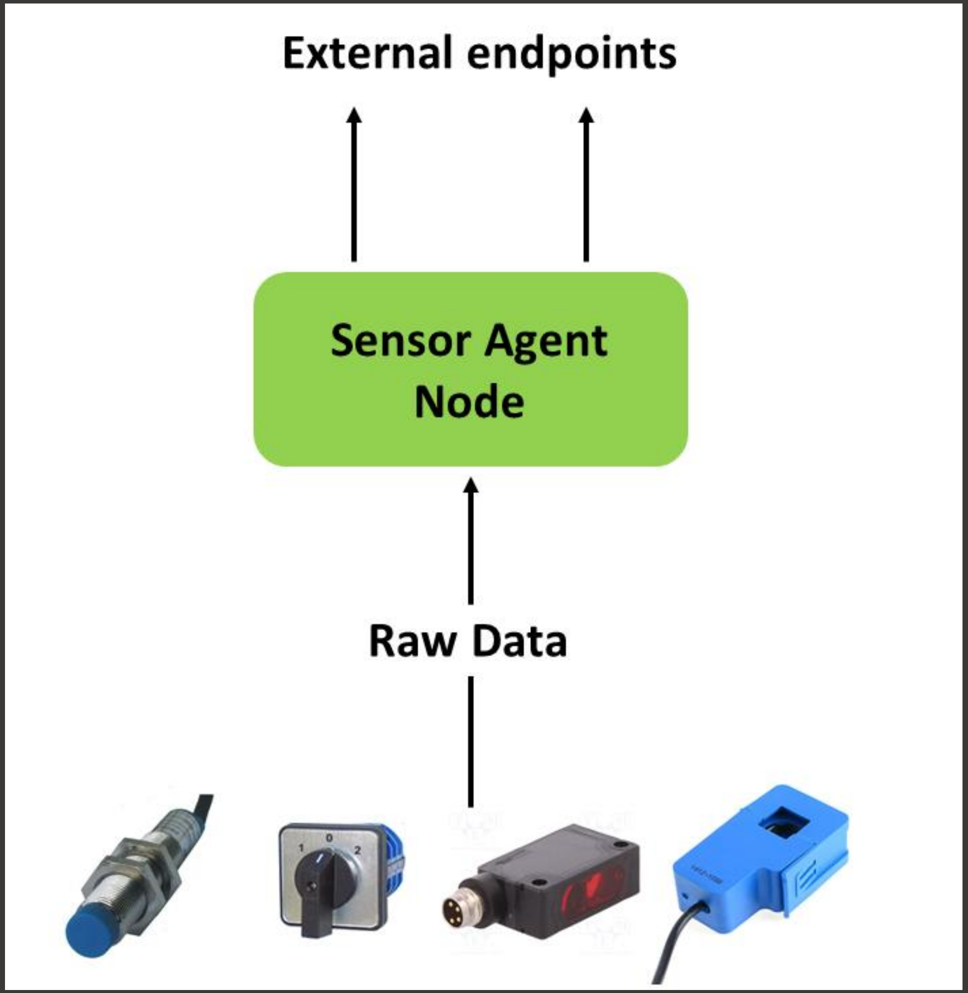
SAN

An Industrial IoT (Internet of Things) module responsible for:

- Receiving raw data from sensors
- Wrapping it into a designated entity format containing necessary data
- Providing other OPIL Nodes with data
- Raspberry Pi and Revolution Pi are supported

Working principle of Sensor Agent Node

- Sensors' raw data is received by SAN
- Connection with Cyber-Physical Middlelayer is handled automatically
- Context data is provided to other modules upon update

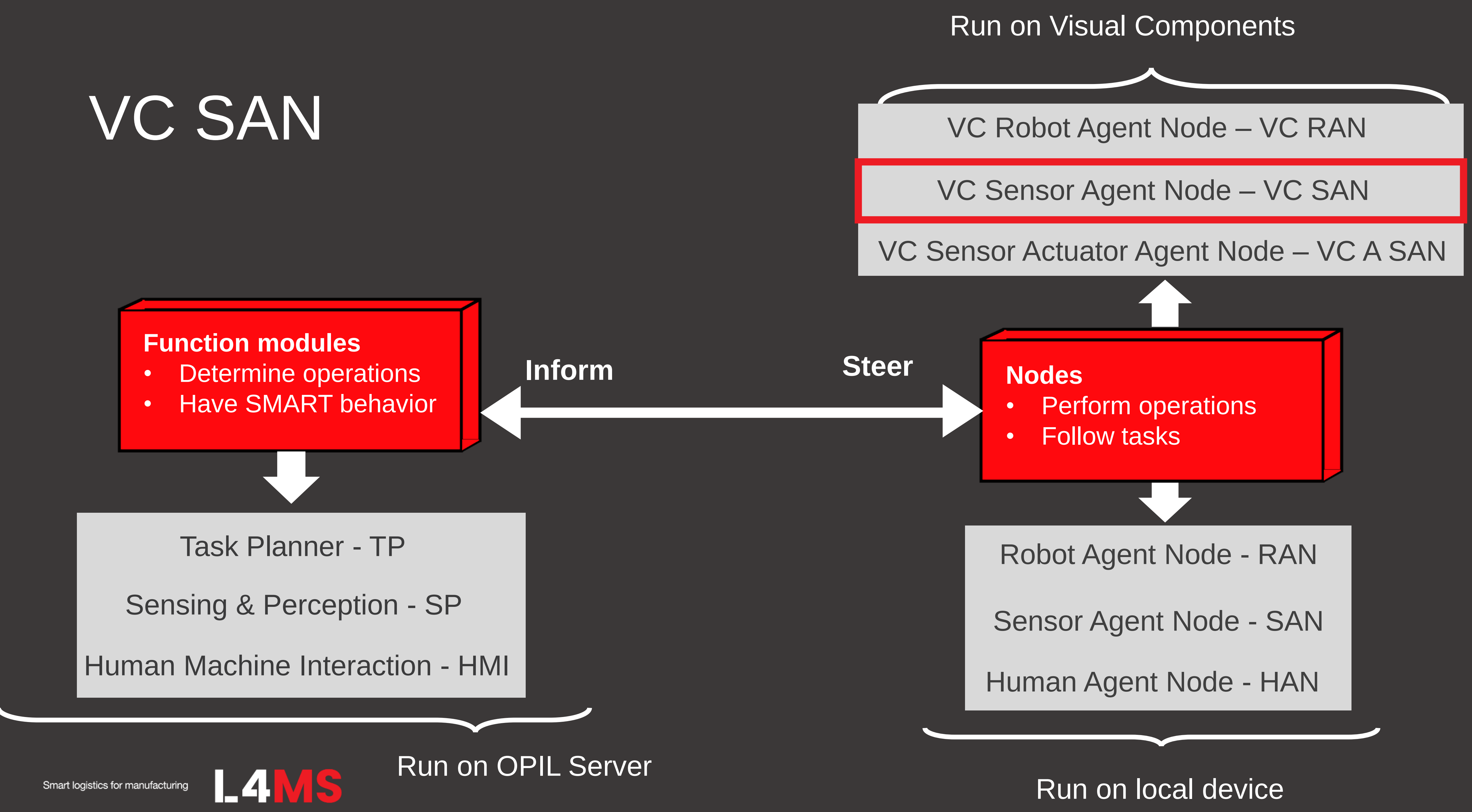


Development

In further versions:

- Creating a link over industrial protocols for most of the PLCs
- Making SAN a server
- Creating framework entities for most used sensors

VC SAN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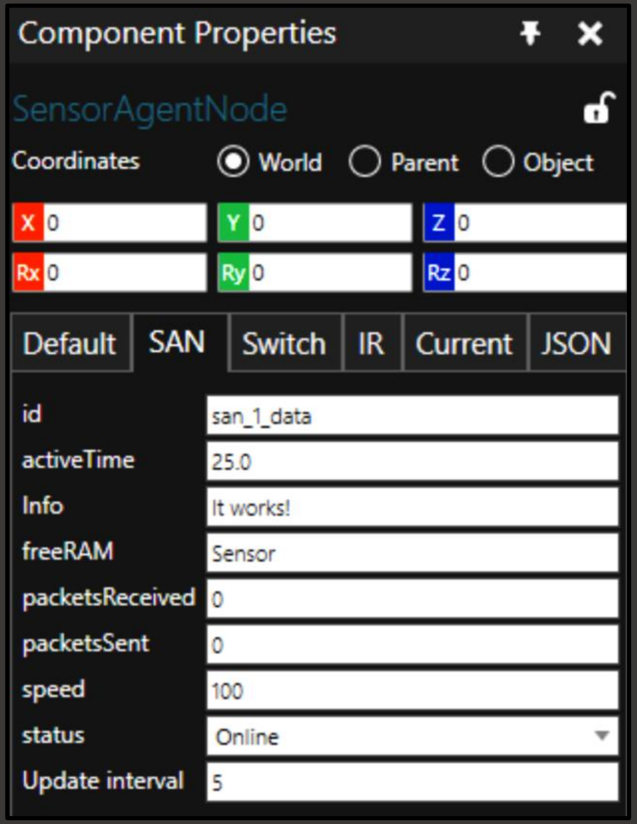
Run on OPIL Server
Run on local device

Structure of VC SAN

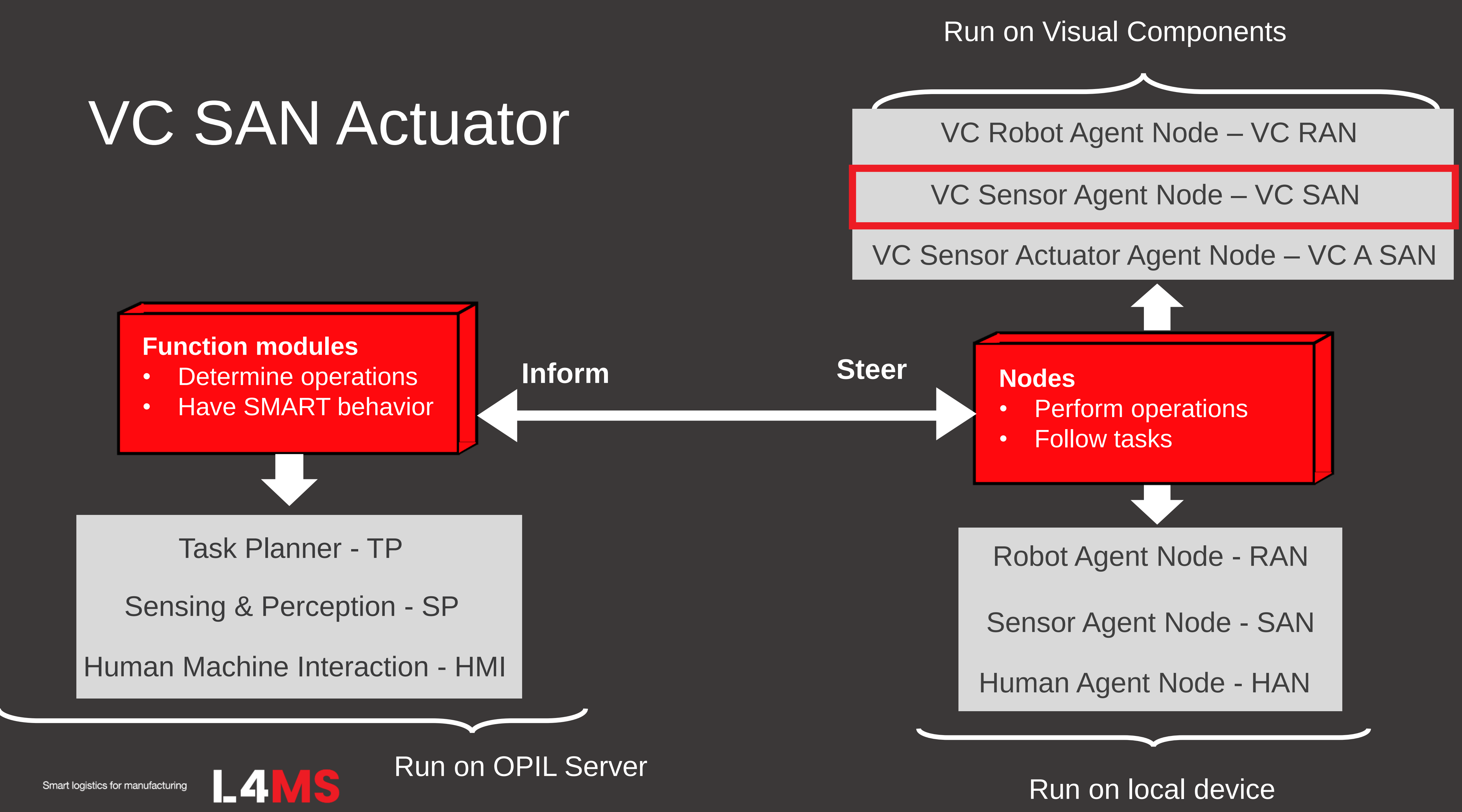
- Mimic behaviors of real sensors
- Supports:
  - Creating entities when simulation is started
  - Update entities during simulation
  - Deleting entity after simulation
- OCB has only 1 entity per simulation

How it works

- Gathers data from sensors through component interface and translates component information to JSON format and updates the entity in OCB
- Creates, updates and deletes entity automatically
- Currently updates entity immediately after sensor data is received
    - Later it can be possible to send gather more data and send it periodically.

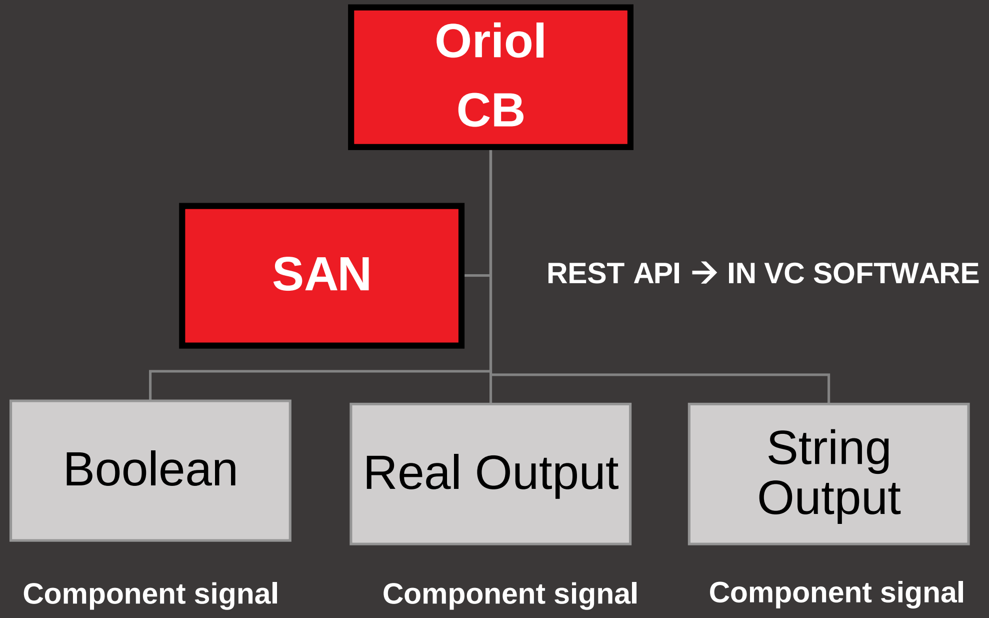


VC SAN Actuator



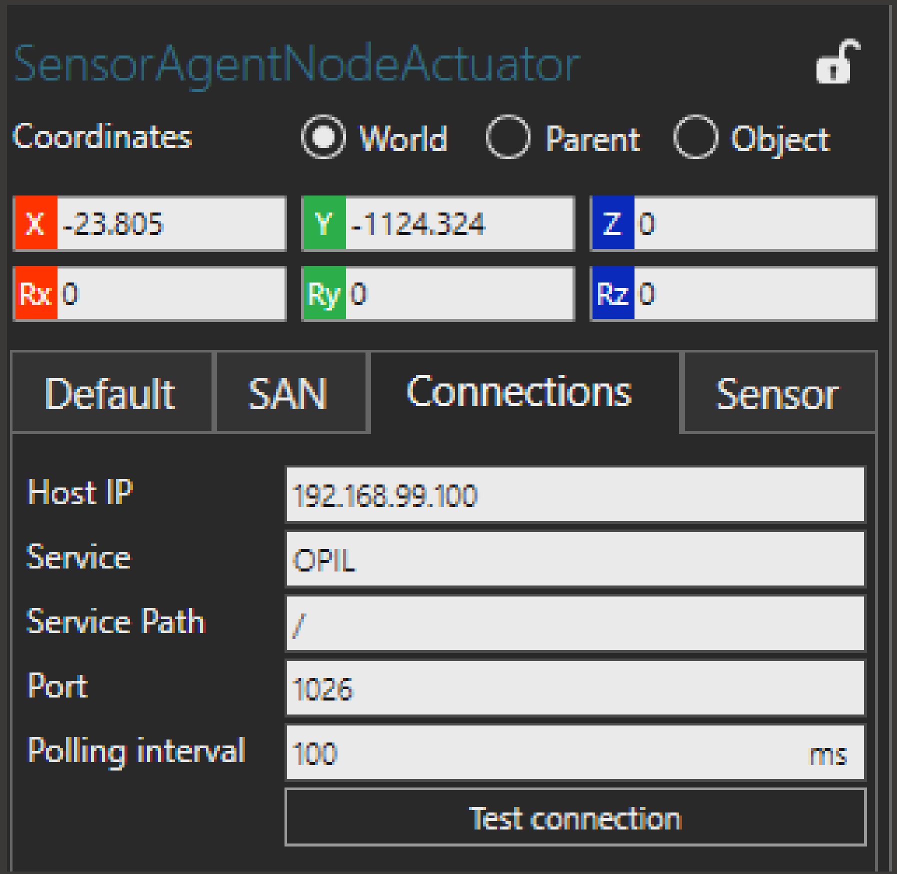
VC SAN Actuator

- SAN actuator is a component which enables sending real word sensors
- SAN communicates directly with Orion CB and translate them to Boolean, real or string signals
- OCB has only one entity per SAN



How it works

- SAN actuator communication settings are similar to SAN component
- Requires to set up IP address of the OCB and valid port
- After configuring Test connection



VC RAN

Run on Visual Components

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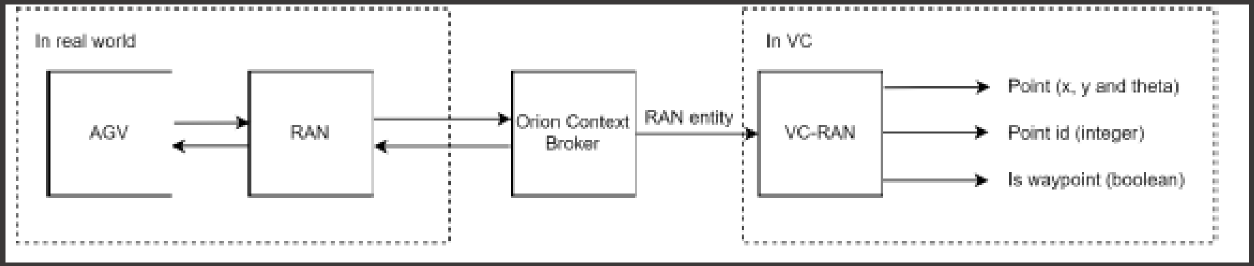
Human Agent Node - HAN

Run on OPIL Server

Run on local device

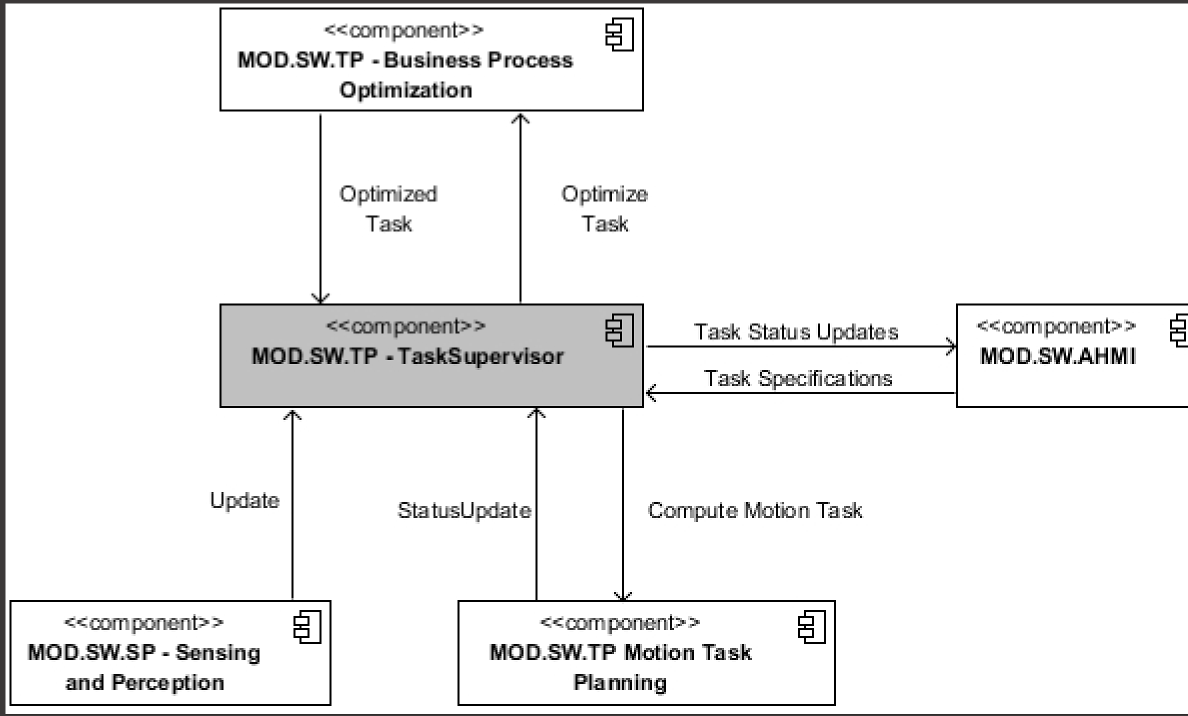
VC RAN Description

- VC-RAN is a component that mirrors behavior of the actual RAN
- The component enables retrieving RAN messages from OCB to VC
- Operation:
  - RAN sets navigation goals, actions and other tasks for AGV -> OCB (stored as RAN entity)
  - VC RAN reads three attributes
  - VC RAN outputs these values



Task Supervisor

- Monitors information on ongoing tasks and general status.
- Responsible for publishing information about the running tasks as well as those that were stopped (not implemented yet).
- Receives task specification from the Advanced HMI Module using formal language and parameterized task specification.
- Sends current state information to the Advanced HMI



Sensing and Perception

Run on Visual Components

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Run on OPIL Server

Run on local device

Sensing & Perception

- Localization: Determine where are the AGVS
- Topology: specify nodes and edges.
  - Nodes are used to specify where AVGs can be placed.
  - The nodes define goals of the route planning algorithm.
  - The list of goals for a given route are send to task planner.
  - Edges specify their movement directions.

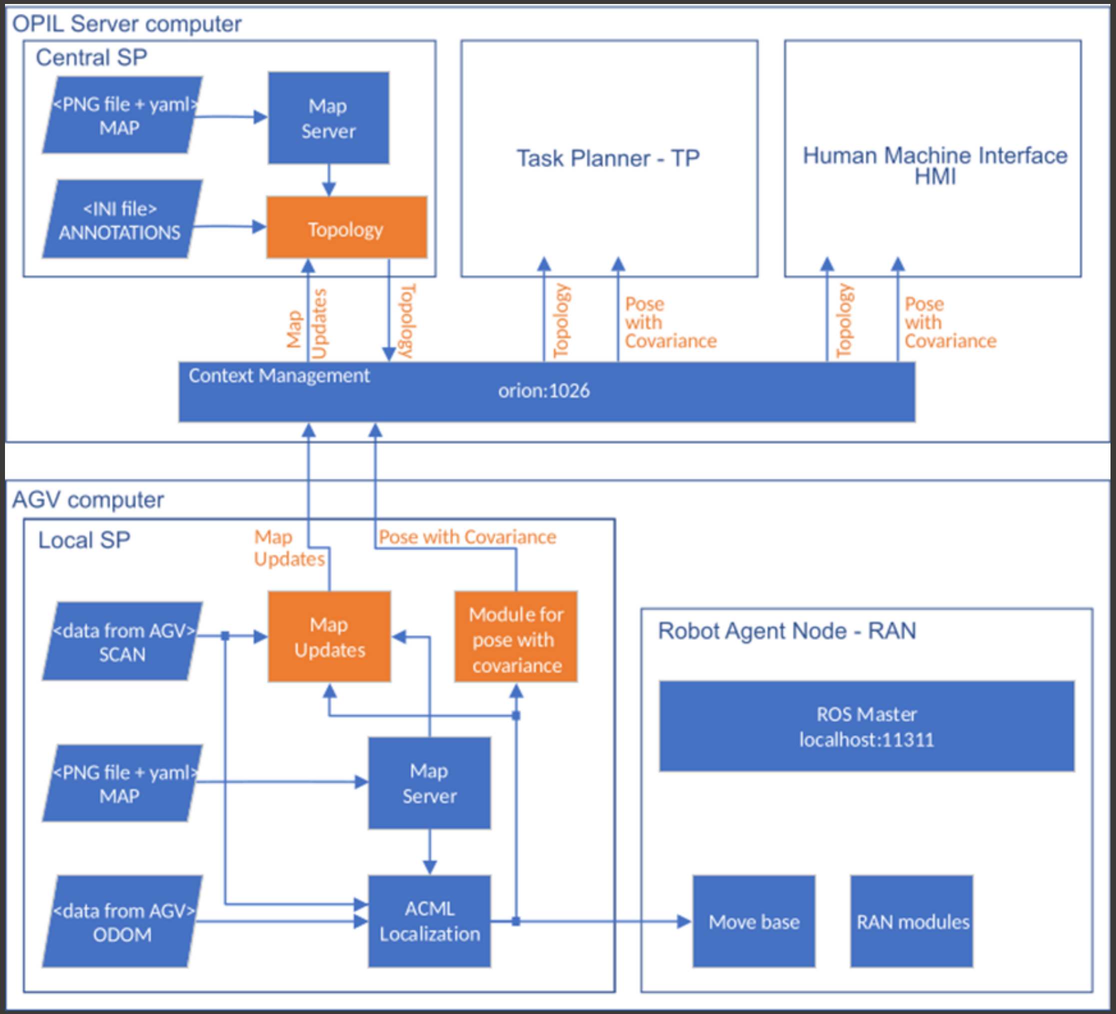
- If the geometry of the factory in case not provided.
  - Update the geometry of the factory in case differences between reality and layout model.
  - It uses SLAM to generate layout (Simultaneous Location And Mapping)

Sensing and perception modules

- **Local SP:**
  - Provides position of AGV inside the built map of the environment in which the AGV is navigating
  - Updates the map with the new sensor readings.
  - Can build the map with SLAM (Simultaneous Localization And Mapping) (using laser scan data, odometry sensors (encoders, IMU), and an initial map for map building and updating the map, and for localization within the built map.
  - Each AGV has its own Local SP that takes care of localization and mapping.

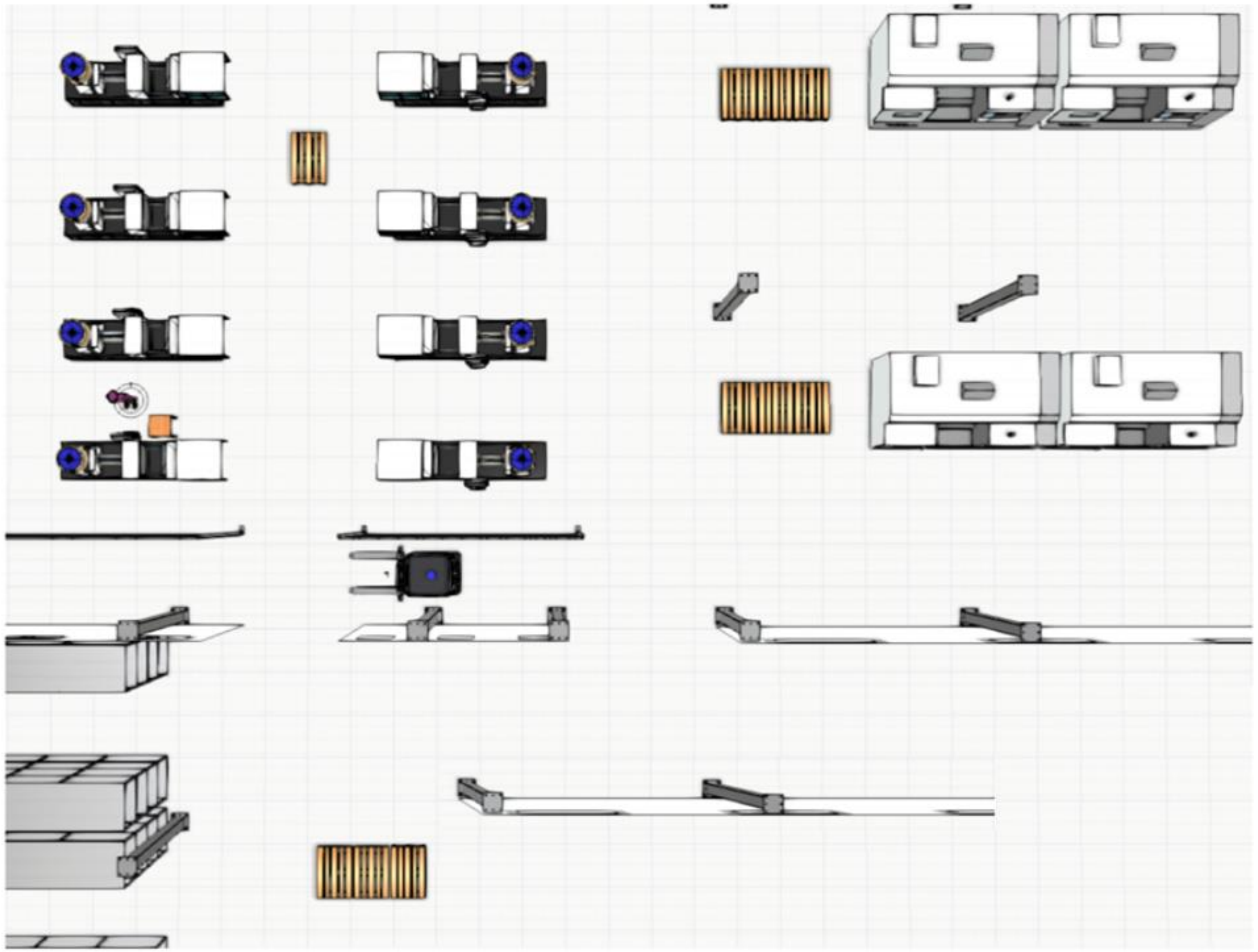
- **Central SP:**
  - Creates topology map of the factory floor plan for the Task Planner (TP) and Human Machine Interface (HMI)

Sensing and perception modules



Overview

Overview | Floor Plan Management | Task Management | Robots | Sensor Data | User Management | System Settings



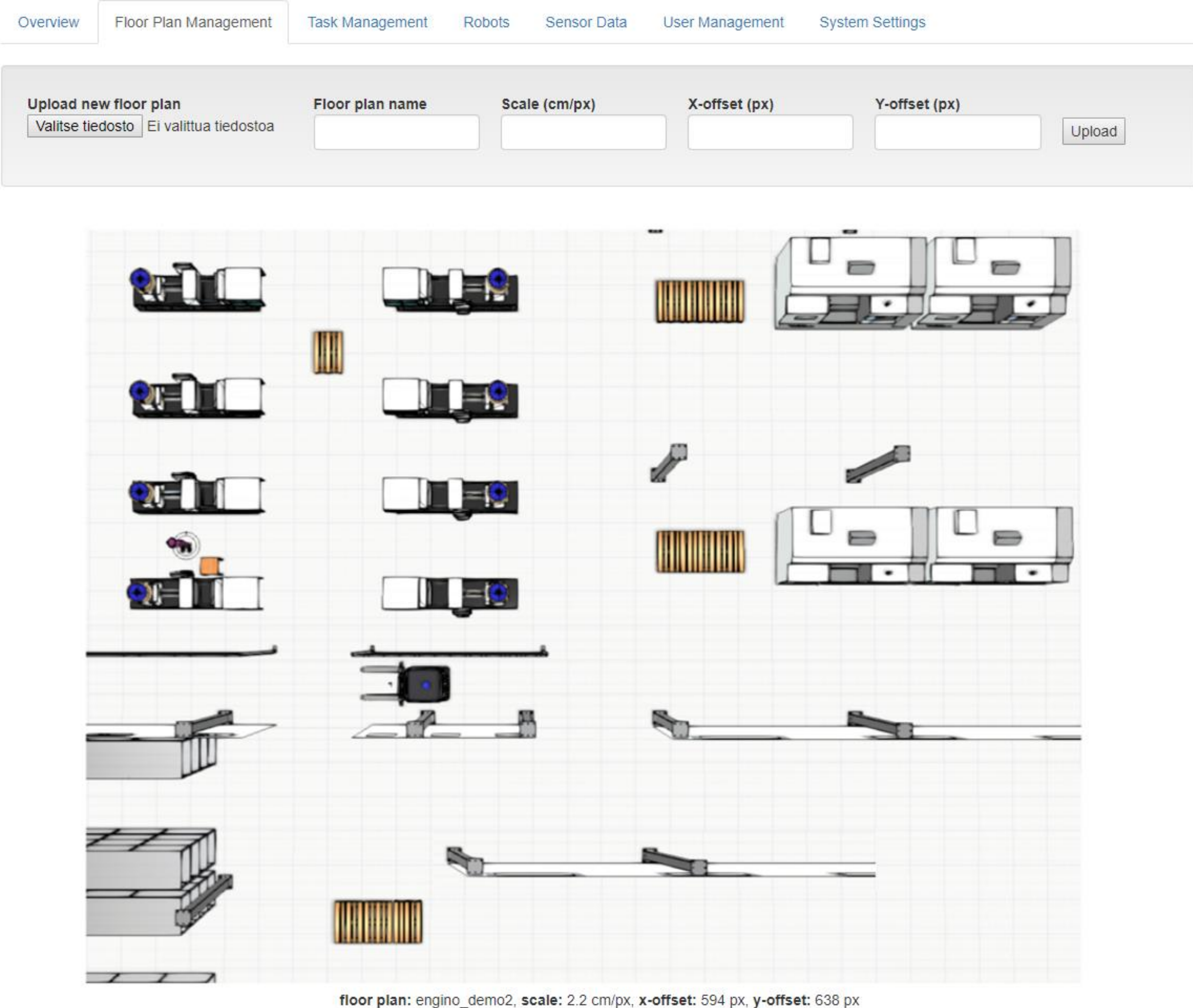
Robots:

ID	RAN status	Pos X	Pos Y	Theta

Sensors:

ID	Type	Pos X	Pos Y	Set position

Floor plant management



Task Management

Sent task specifications

TaskSpec ID	Status	Message	Task Specification
TaskSpec_zaea01ictzpjtob6a8z	Idle	Success	position = "moldingArea_palletPlace" end Position warehouse_pos1 type = "pallet" position = "warehouse_destination_pos" end #### task Transport_moldingPallet Transport from moldingPallet to warehouse_pos1 end

Current tasks in the system

Task ID	Task Description	Status	Time
184da983-f200-44d6-879c-45abfcd05659	Transport_moldingPallet	Finished	2019-03-25 12:09:38.113777
af942bde-9ae1-44b4-b05d-df1910388882	Transport_moldingPallet	Finished	2019-03-25 12:09:53.196519
9c685ac8-cae2-4046-a67e-db88e5d258a0	Transport_moldingPallet	Finished	2019-03-25 12:10:08.293168
292c48c3-b087-4d2f-a500-7fa0bd80eb6b	Transport_moldingPallet	Finished	2019-03-25 12:10:23.406914
4a38c5f6-108b-4f44-8ba4-cb5ec59f5018	Transport_moldingPallet	Finished	2019-03-25 12:10:38.502269
b9bd0c5b-6f97-4bae-8f73-585d742f4fd2	Transport_moldingPallet	Finished	2019-03-25 12:10:53.588865
0427f4f3-2ddd-4a0b-8d9d-b7c17ad18e7f	Transport_moldingPallet	Finished	2019-03-25 12:11:08.668463
34cb9b20-634c-4a77-96b0-94441bcf56d9	Transport_moldingPallet	Finished	2019-03-25 12:11:23.752368
db0dd8d2-a70c-4cec-a57b-9f55795e91cb	Transport_moldingPallet	Finished	2019-03-25 12:11:38.865088
38ee298e-aea7-4deb-954f-1bf2e0431408	Transport_moldingPallet	Finished	2019-03-25 12:11:53.944772
b087ca45-c412-4152-b401-52d7d40a3cab	Transport_moldingPallet	Finished	2019-03-25 12:12:09.032540
b5a4ef9d-d2cb-4458-ad97-b7bafbd96227	Transport_moldingPallet	Finished	2019-03-25 12:12:24.115944
d9d4de7f-281f-4679-b86a-fdb5fc097d5a	Transport_moldingPallet	Finished	2019-03-25 12:12:39.245565
8c94d69b-c9dd-4e4a-9913-07ff7b6b74f5	Transport_moldingPallet	Finished	2019-03-25 12:12:54.322138

Overview | Floor Plan Management | Task Management | Robots | Sensor Data | User Management | System Settings

Send new task specification

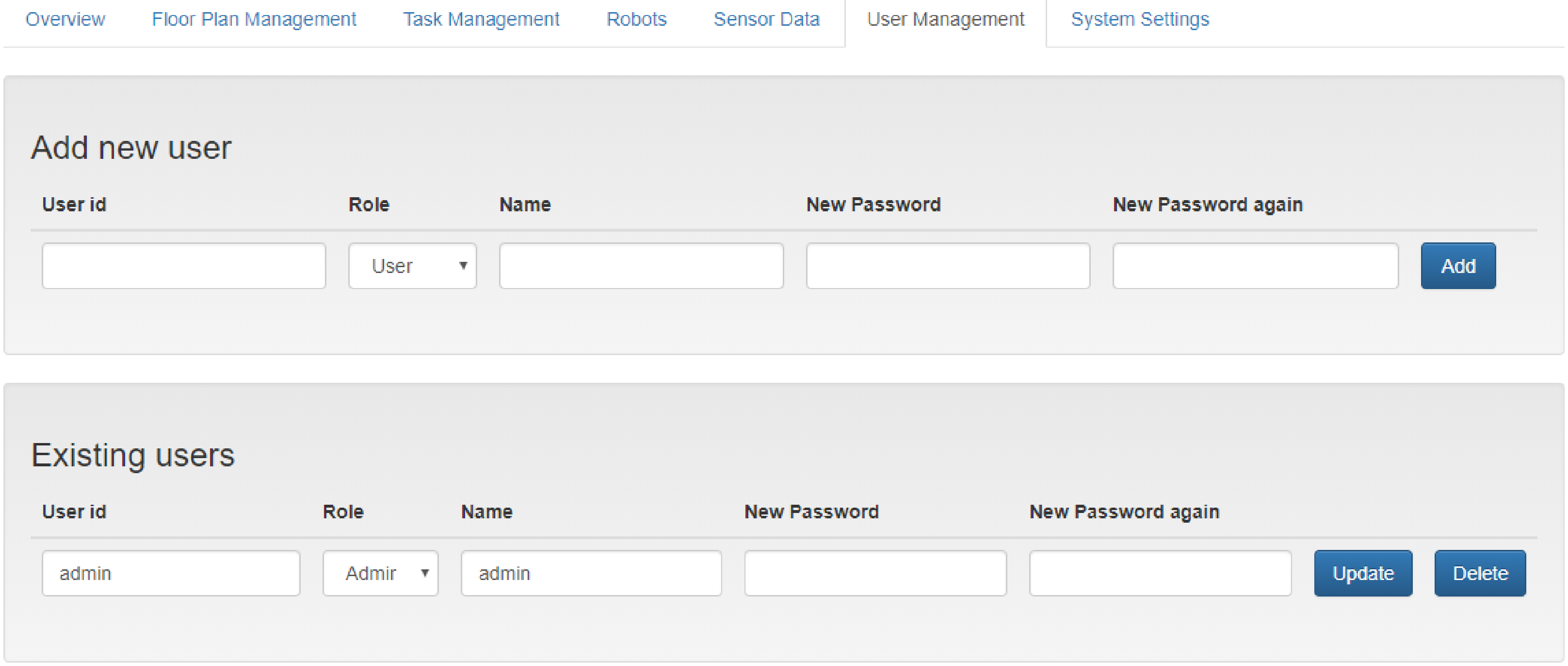
```
template Position
    position
    type
end

####

Position moldingPallet
    type = "pallet"
    position = "moldingArea_palletPlace"
end

Position warehouse_pos1
    type = "pallet"
    position = "warehouse_destination_pos"
end

####

task Transport_moldingPallet
    Transport
    from moldingPallet
    to warehouse_pos1
end
```

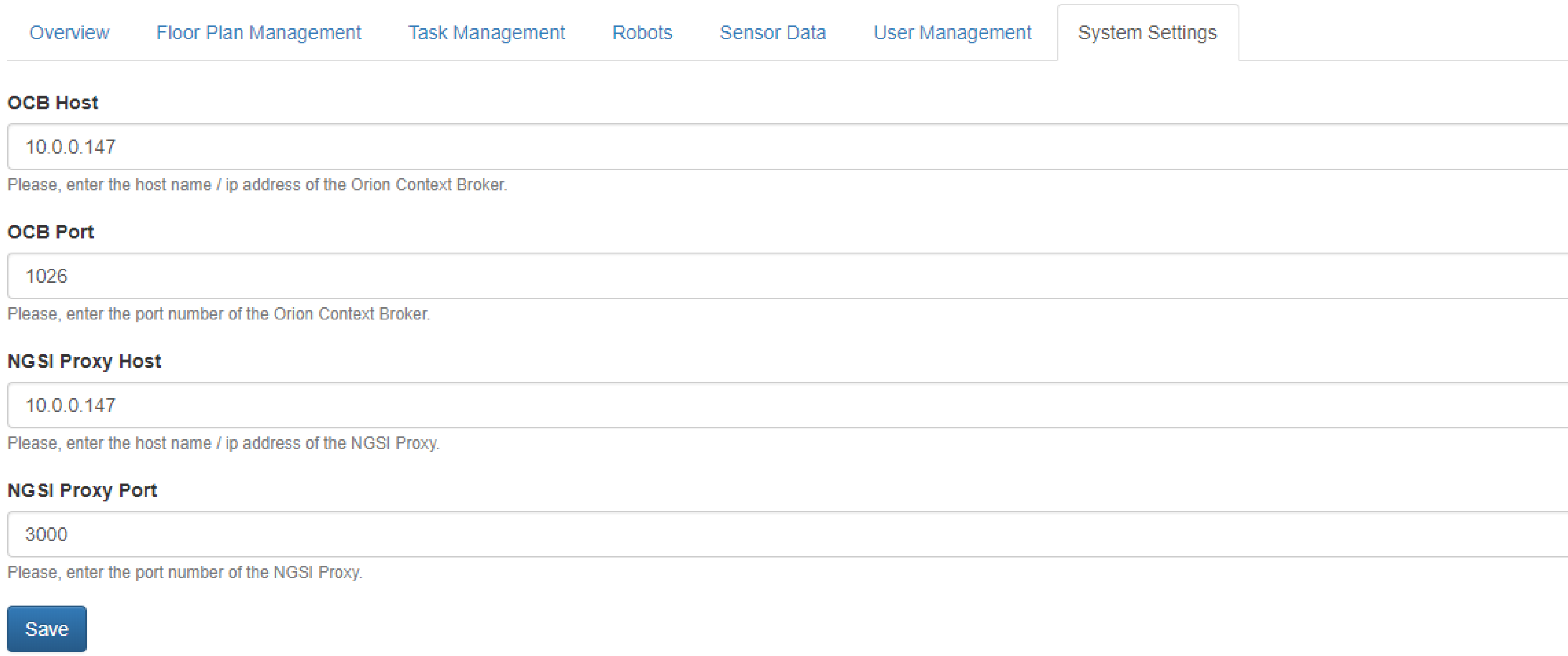
Send task specification

Sent task specifications

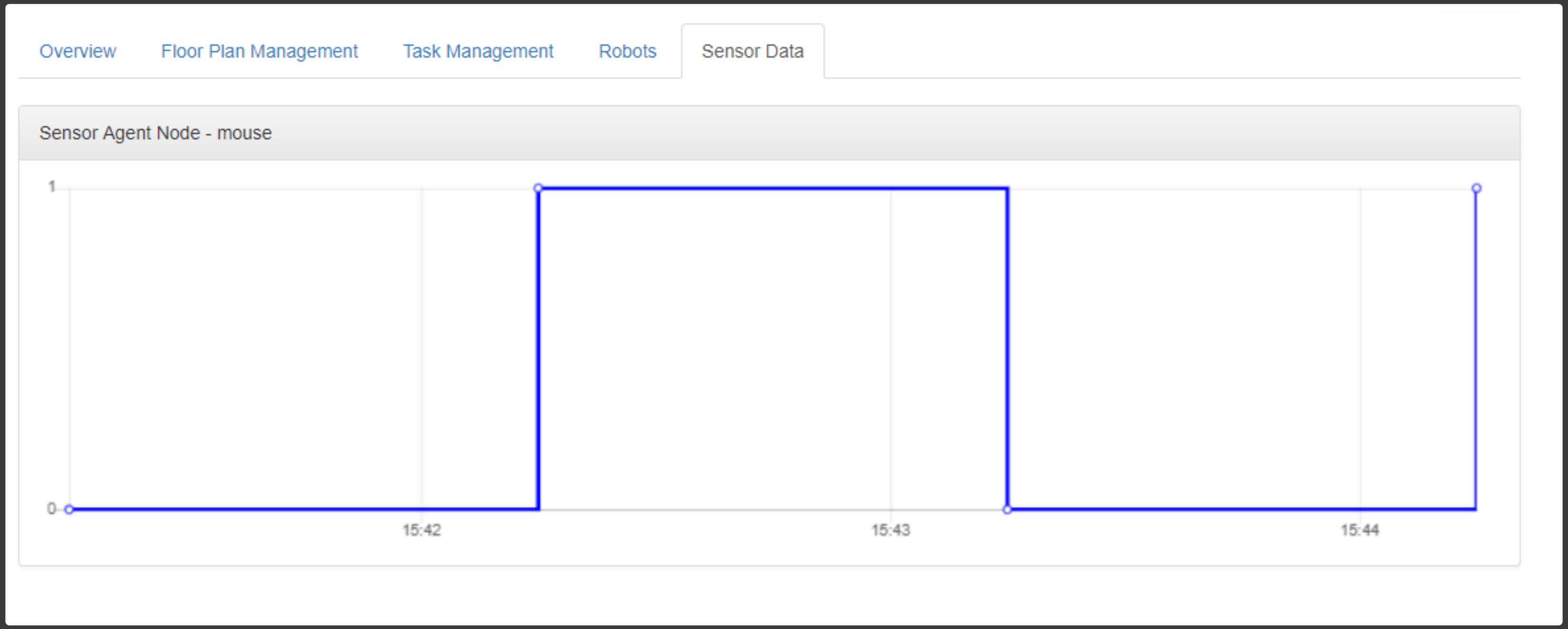
TaskSpec ID	Status	Message	Task Specification
TaskSpec_zaea01ictzpjtob6a8z	Idle	Success	position = "moldingArea_palletPlace" end Position warehouse_pos1 type = "pallet" position = "warehouse_destination_pos" end #### task Transport_moldingPallet Transport from moldingPallet to warehouse_pos1 end

User & System Settings





Sensor data


Overview
Floor Plan Management
Task Management
Robots
Sensor Data
Sensor Agent Node - mouse
1
0
15:42
15:43
15:44