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NEXUS: A ROS 2 framework for orchestrating industrial robotic lines and cells

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Automation is changing into advanced robotics

Traditional automation (last 70 years)

Program once, repeat forever

- High speed (PPM) and no operator
- Predictability & reliability
- Simple logic code with low complexity (e.g. ladder code)
- Well established hardware-based solutions
- Certification & standards
- Ecosystem of key market players

Advanced robotics (last 5 years)

Adaptive perception & manipulation with ML/AI
Coordination/cooperation, task mgmt. and autonomy

- ML/AI + complex algorithms
- Learning behaviours
- Software-based solutions
- High-level programming languages, high performance computation with GPUs
- Open-source software
- Not many standards, metrics, etc.

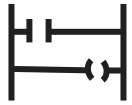
Challenges with traditional automation

Market demand for customization
Need for advanced automation for high-mix, low-volume use cases

Lack of agility, flexibility & reusability
Robotic applications cannot be easily modified or reconfigured

Long development time
Need to reduce effort and deployment costs

Hardware dependency & lack of interoperability
Technology transfer across geographies is challenging
Silo solutions, require custom integration for orchestration



Use of PLC logic
Control logic is hardcoded in PLCs
Supporting a “recipe” for a new product requires reprogramming the PLC

Availability of digital twins
No easy way to accurately simulate complex custom robotic solutions

We need an architecture for robotic platforms with...

Seamless orchestration & control

- At robotic workcell level
- At line level (multiple robotic workcells)

Modularity

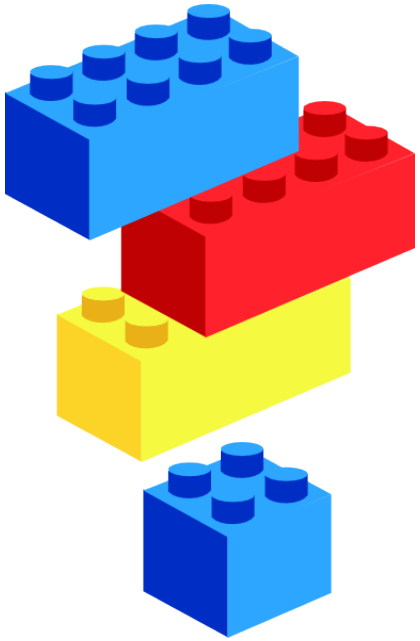
- Cells can be easily added, exchanged, modified

Flexibility & agility

- Easy reconfiguration of process flows

Scalability

- Lowers the cost for robotic cell adoption, reconfiguration, upgrade, etc.

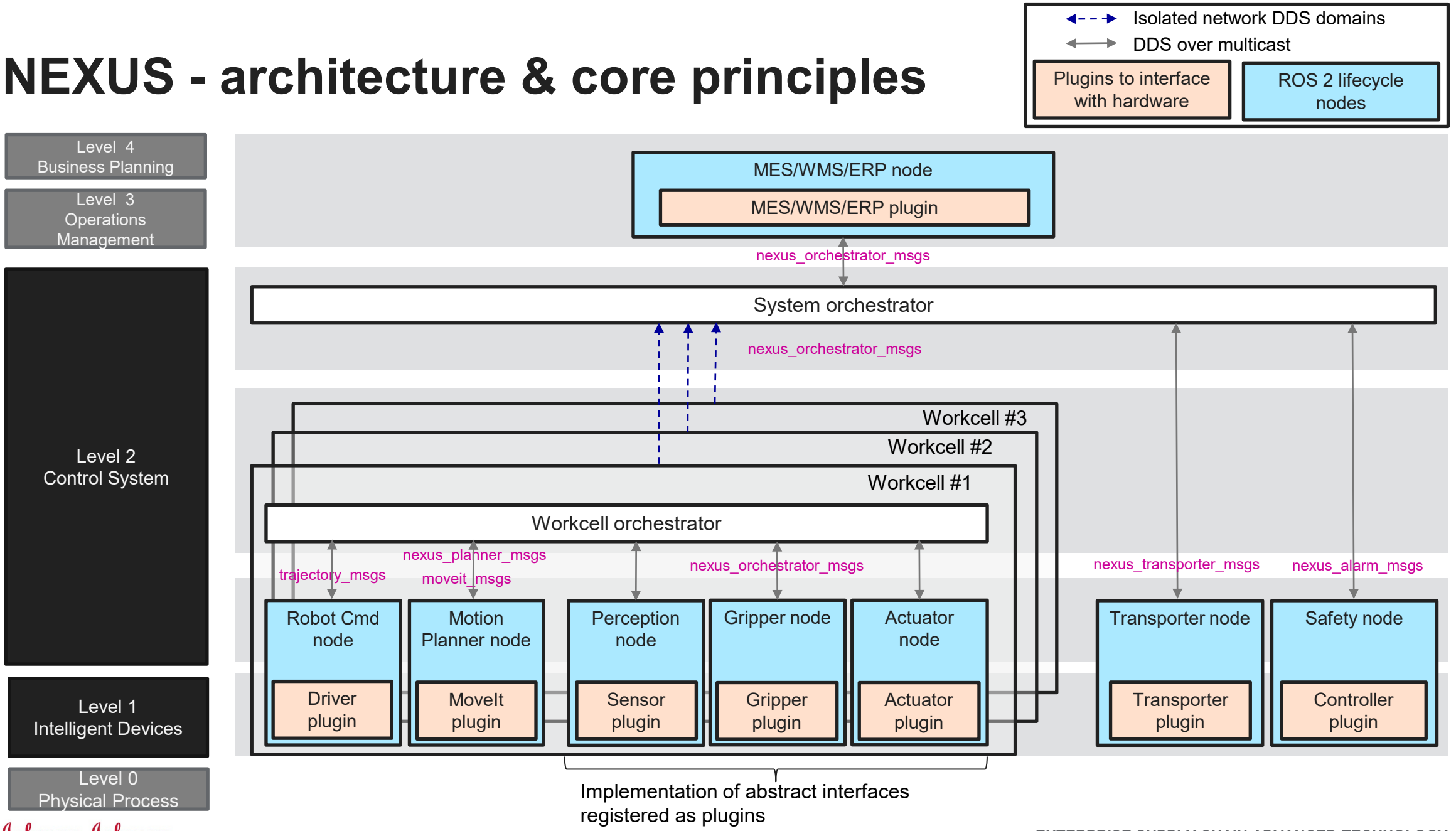


Line

Robotic workcells

Hardware components

NEXUS - architecture & core principles

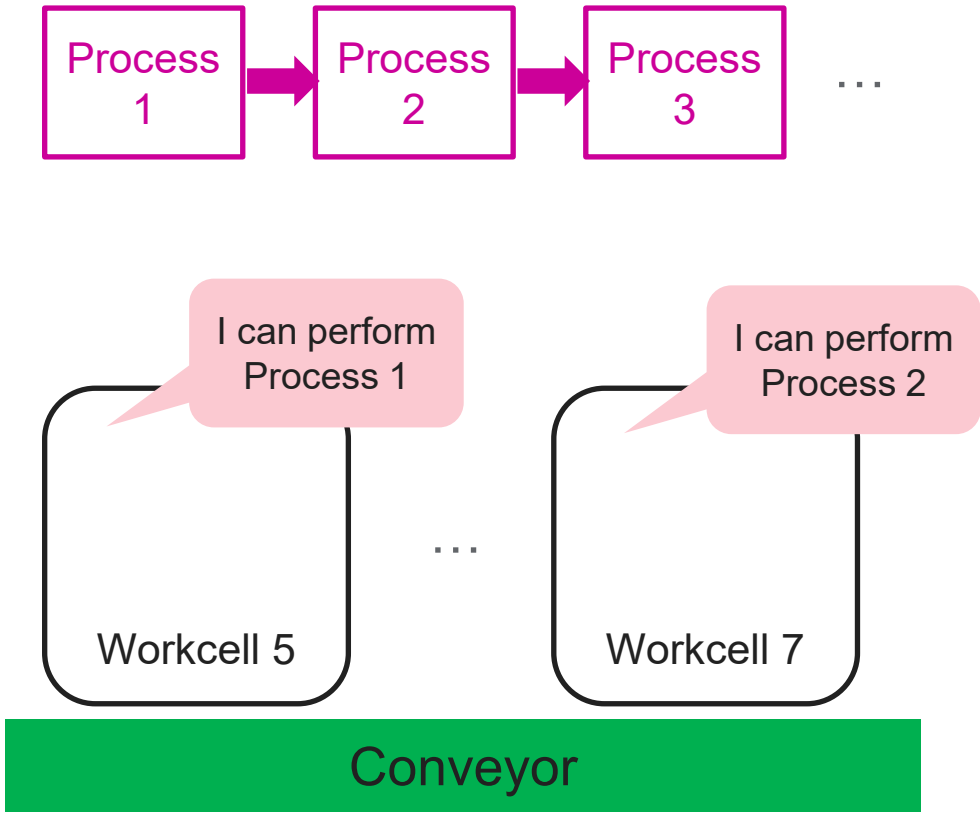


NEXUS - architecture & core principles

- Hardware - service providers
  - Orchestrator - coordinates activities among hardware.
- **Modularity** - Behavior trees to specify workflows and trigger hardware
  - BT nodes are capabilities/skills, available at the line or workcell level.
- **Flexibility** - Hardware registration, transmits capability to the orchestrator (e.g. transport, detect, move). Task capability is inferred based on registered hardware.
- **Agility** - Hardware agnostic logic
  - ROS 2 lifecycle (stateful) nodes
  - Runtime loadable plugins for hardware nodes
- **Scalability** - Hardware interfaces are standardized
  - Minimal network traffic by selecting endpoints between workcells and line orchestrator

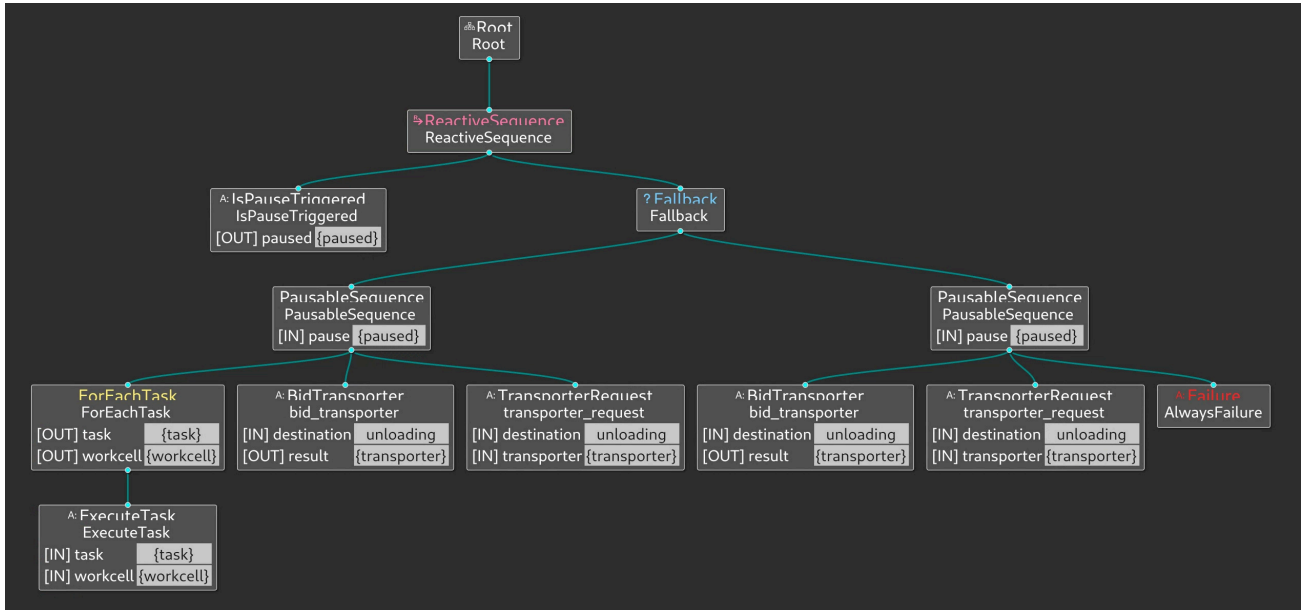
Intelligent recipe execution

- Recipe = one or more **process steps** in a line (different workcells)
- Recipes and process data stored in WMS/MES/ERP
  - Recipe execution dispatched (job request) to the line orchestrator
  - Enables **intuitive processes to onboard new recipes** (e.g. GUI) vs PLC programming
- Line orchestrator coordinates workcells and transporters to execute recipe (job)
  - Available workcells and transporters bid to execute a process – **self-organization**
  - Automatic queuing and buffering
- If a line and/or workcells reconfigure, the response to a recipe will be **adapted** by the line orchestrator

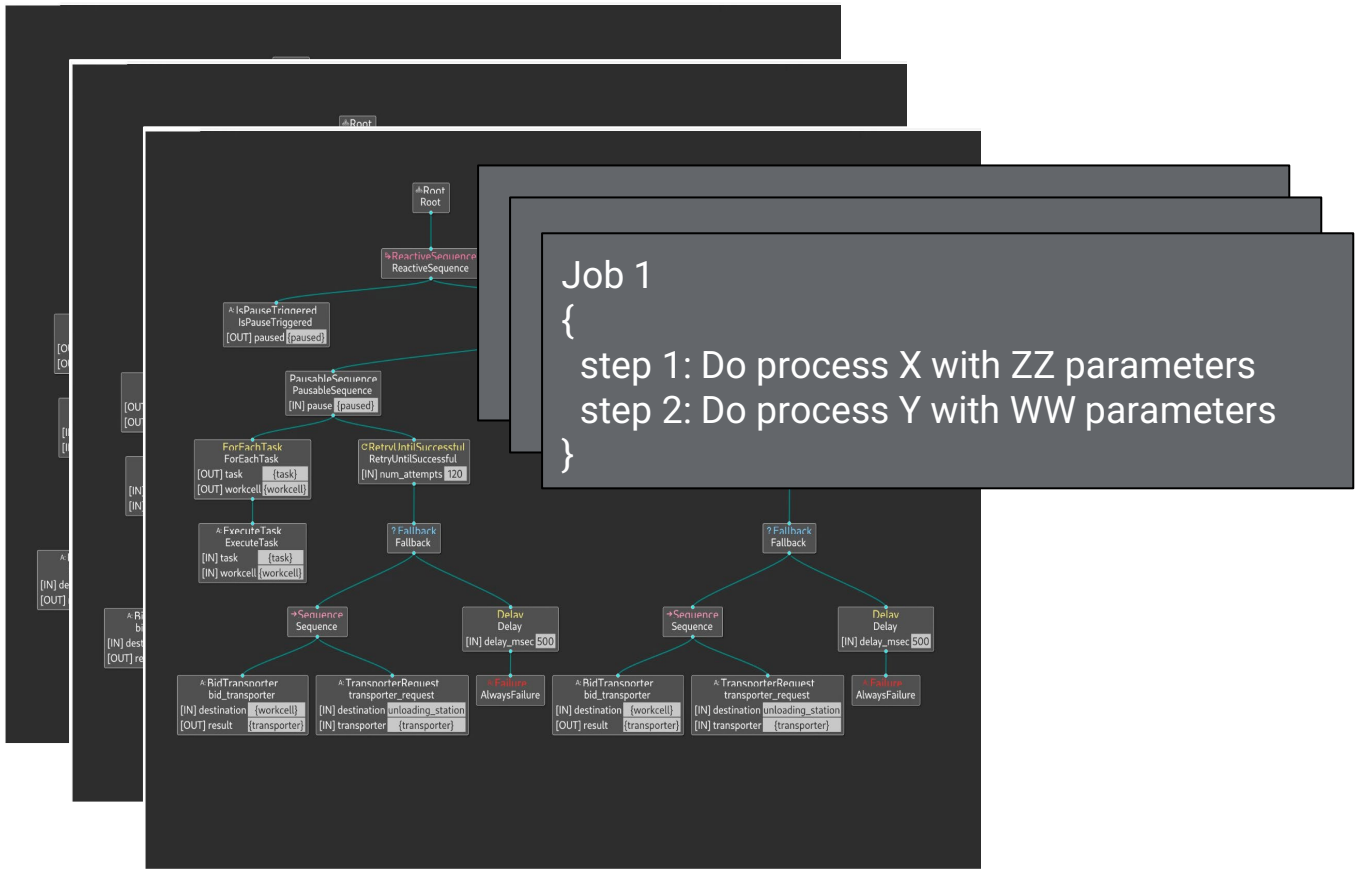


Behaviour Trees to specify process flows

- **Intuitive** representation of processes
- Enables **sequential and parallel** process execution
- Easy to **reconfigure**
- Applicable at line and workcell levels
- **Composable**
- Can be edited via GUI

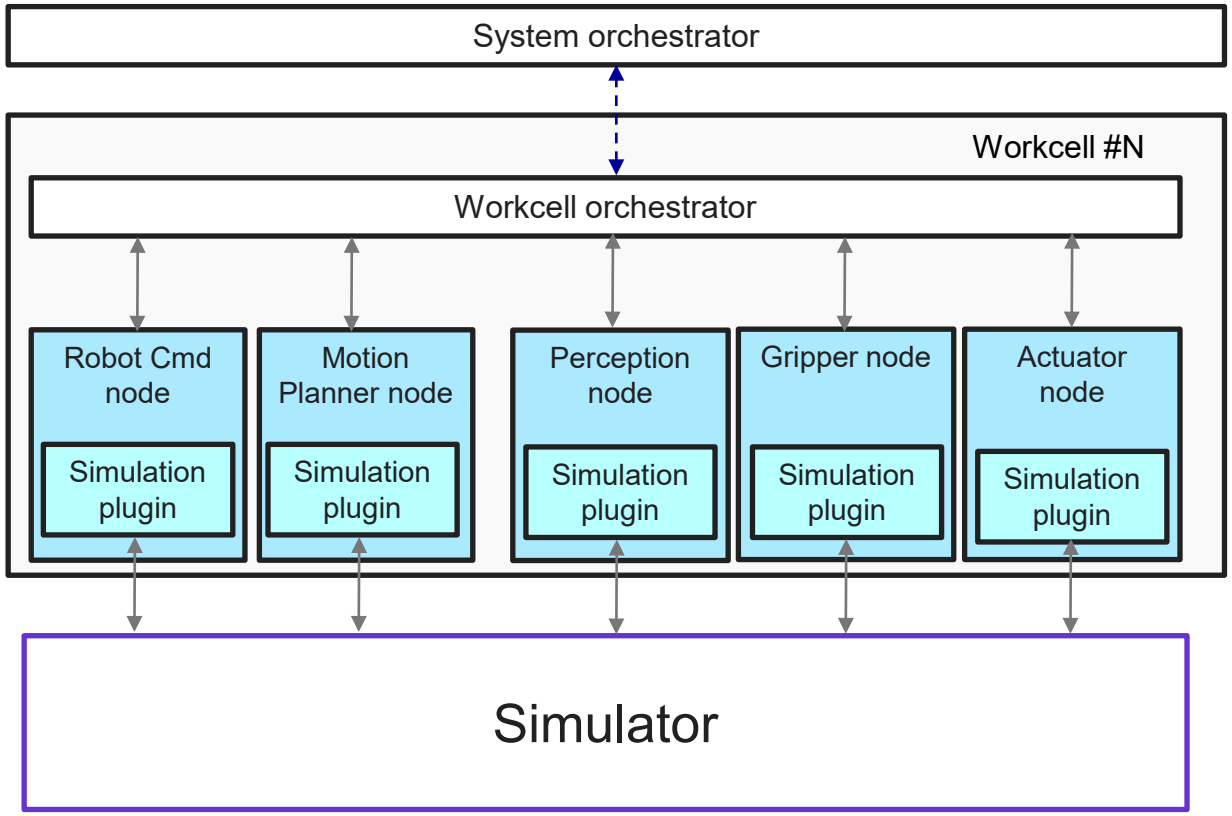


Coordination of processes and control in workcells



- Multiple jobs can be executed concurrently – **enables high-mix, low volume**
- Steps between workcells are synchronized using **ROS services**
- **Data propagates** from one workcell to other workcells automatically
- Workcell orchestrators coordinate hardware from different vendors through **ROS as a middleware**

Simulations to test exhaustively



- Running the orchestrators and nodes (code) with simulated hardware
- Simulation plugins can interface with Gazebo, RViz, etc. or customized hardware models
- Mixes of hardware and simulation are possible for individual component testing

Adopting NEXUS

Workcell setup

- Plugins for hardware components
- Algorithms with parametrization for adaptation to recipes
- Build behaviour trees for workcells - codes for each process step

Line setup

- Building behaviour trees for line orchestrators

Recipe preparation

- DB of recipes to create jobs in WMS/EMS/ERP – lists of processes, steps and parameters

Open challenges

ROS

- Lack of support for open-source **drivers** in ROS 2 (robots, sensors, industrial equipment)
- **ROS 2** capabilities and optimization are work in progress

Other

- Lack of an ecosystem of **system integrators who work with ROS.**
- **Certification** – how to?
- Adoption of new tools & algorithms – frequent **upgrades** might be required
- Cybersecurity – **authentication and data encryption**

Thank you

For more details and information please contact us

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