A Communication Architecture to Observe and Partially Preserve Efficiency in Automated Production Systems

Source:

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Concept: Observation and Compensation in aPS

- **Observation**: Early detection of threats to OEE (availability)
  - Record process data; extract features, detect trends
- **Knowledge**: Relate and contextualize data from distributed sources
- **Compensation**: Trigger reactions to avoid availability threats

OEE =

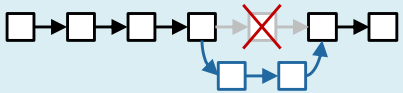
Availability

x Performance

x Quality

Process Observation
Detect risks to availability

Compensation
Behavior changes at runtime to maintain availability



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Concept: Distributed Computation from Field to Cloud

aPS / PLC

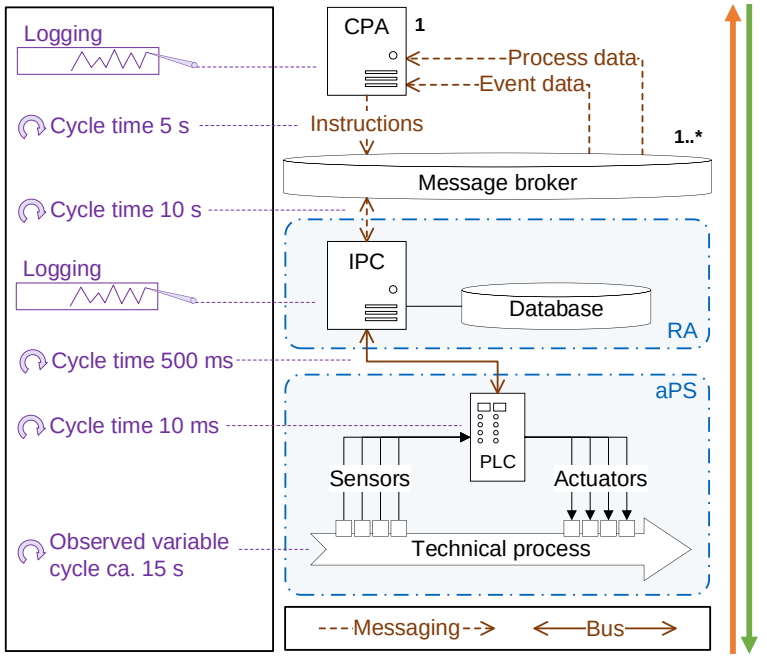
- Real-time execution of the application program
- Sampling of process values; stored in temporary variables
- Change behavior based on global variable value

Resource Agent (RA)

- Sampling PLC's process value variables
- Transmit values to buffered message queue
- Receive and execute changes to PLC's global variables

Cyber-physical Agent (CPA)

- Communicate with <u>one or many</u> RAs via message queues
- Detect value degradations and select suitable instruction



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Evaluation: Communication Architecture Prototype

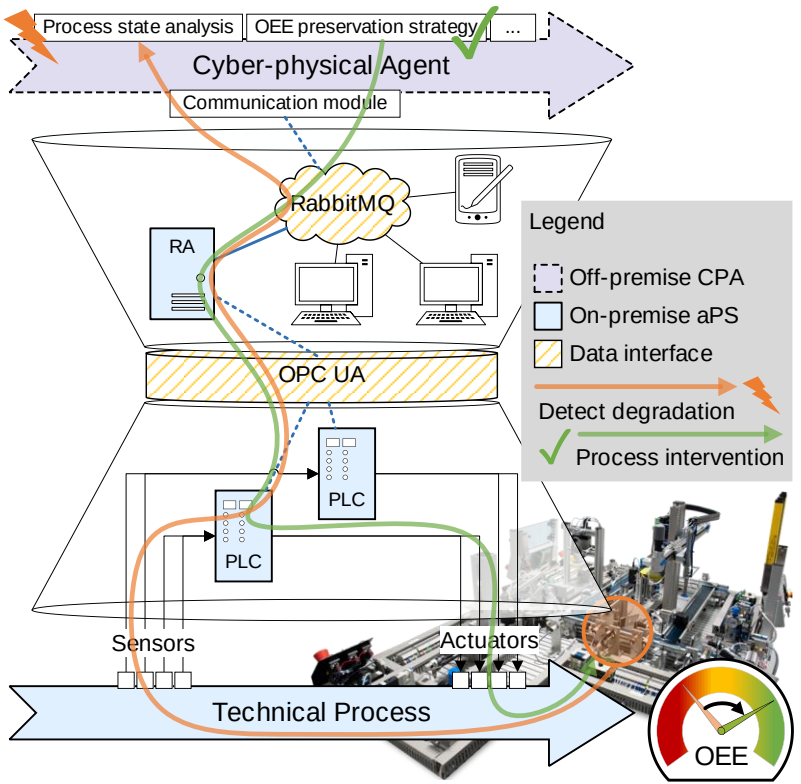
Communication Protocols

- PLC *(Beckhoff CX9020; 1 core, 1 GHz)* ⇔ RA *(1 core, 1.86 GHz)* via OPC UA; PLC as OPC UA server
- RA ⇔ CPA *(4 cores, 1.3 GHz)* via RabbitMQ over AMQP

Cycle Times

- PLC samples process every 10 ms
- RA ⇔ PLC every 500 ms
- RA ⇔ message broker every 10 s
- CPA ⇔ message broker every 5 s

➢ Worst-case reaction time = 31.02 s
(compute times at each level are negligible)



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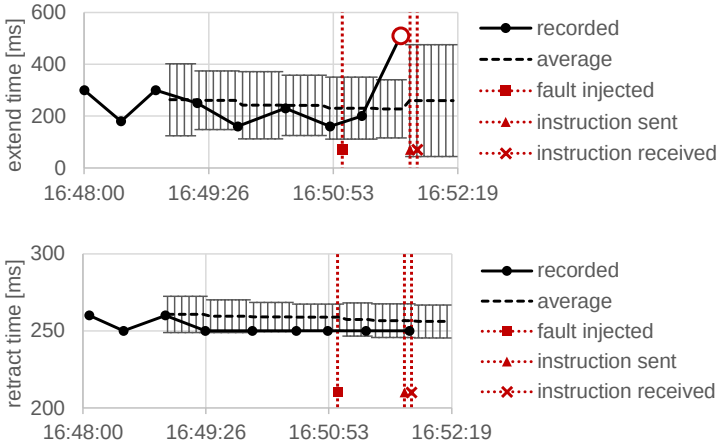
Evaluation: Investigation of Runtime Behavior

- Get timestamped extend/retract times (PLC → RA → CPA)
- Compute running average and standard deviation (CPA)
- Trigger compensation, if average ± two standard deviations is exceeded (CPA → RA → PLC)

- A **fault can be injected manually** (cylinder delay)

Timely Behavior

- Timestamps based on synchronized clocks (PLC, RA, CPA)
- Sampling delay causes shifts between process value changes and CPA reactions



Summary and Outlook

Distribution of Computations over the Hierarchy

- Currently, only vertical distribution (1 PLC, 1 RA, 1 CPA)
- Future work: larger horizontal setups (n PLCs with n RAs)

Detection of Threats to Efficiency

- Currently, simple observation of average and standard deviation
- Future work: Remaining Useful Life, closed-loop control, etc.

Injection of Compensation Strategies

- Currently, a preconfigured strategy is activated on demand
- Future work: Generate strategies based on knowledge of the PLC's behavior capabilities