Dynamic Behavior of industrial networks

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What is an industrial network?
How to operate an industrial network?
Error types and impact
Flexibility use case

supportive protocol means more than configuration
Example car body shop

1. >75000 sensors, actuators
2. >25000 of them smart (data + power, fast robust efficient process data transfer typically 1 bit at extreme low cost)
3. >5000 IO-Boxes links together several sensors/actuators (fast robust efficient process data transfer typically <8 Bytes at low cost)
4. > 1000 Smart Field Devices (fast robust efficient process data transfer varying data length at moderate cost)
5. > 1000 Robots and Programmable Controllers (PLC -- robust efficient process data transfer typically varying data length at moderate cost)

→ Performance, Precision, Robustness required
→ Good std coverage (too many?) at fieldbus level
→ Proprietary solutions at cell level

Groups with 25-50 Robots/PLC for a specific task
Groups are linked together
Keep running is not so easy …

**Grouping, errors**

1. **Grouping:**
   - IO ➔ Aggregates ➔ Machines ➔ Cells ➔ Lines ➔ Hall ➔ Plant

2. **Operation 24/6or7**
   - Repair time is typically a few minutes

3. **Statistical component errors >20 per day**
   - (assumes FIT of 10% of components per year)

4. **Higher Error rates caused by installation errors and**
   - temperature
   - mechanics
   - shock: up to 70,000kN force (equivalent to 500 cars falling down),
   - vibration: operation at resonance frequency
   - electrical
   - power supply surges/etc., magnetic interference of motors,
   - electrical discharge by conveyor belts etc.
   - chemical, dust, water etc.

5. **Practical is an error rate of around 100 per day**

6. **A couple of “TSN-visible” (bridge related) errors per day…**
   - Initial reactions within ca. 10ms avoiding domino effects

**Goal is complete error recovery within 15 min – some plants have other figures**
   - MTTR is the most important factor for availability
Effects on TSN

Each TSN error has to be handled

- No TSN experts on site
- Errors may be reported on different places not in order of occurrence some latency included
- Error should be reported clearly within 1-2 seconds after event This includes all time intervals and related actions (e.g. RSTP)
- Overall Start-up time after repair should be in the range of 10s Repair means always power down, sometimes topology change … several startups maybe needed Should indicate that the system can work properly after this time (Ethernet Autonegotiation takes sometimes >3s; this reduces the time)
- Critical would be the indication that everything is correct but it is not
Example change at the operational level

**Dynamics as of KUKA slides from 2015**

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**KUKA industrial robots are „partly completed machines“**

- EU Machinery Directive 2006/42/EG:
  - …are not allowed to have CE marking
  - …must have assembly instructions and a declaration of incorporation
- Have „Hands“, but no Fingers…
  - …this makes them very flexible
  - …can grab several tools directly
# Examples of operation

## Integration of process tools into robots

<table>
<thead>
<tr>
<th>Robot</th>
<th>Welding</th>
<th>Gluing</th>
<th>Screwing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanics</td>
<td><img src="image1" alt="Mechanics" /></td>
<td><img src="image2" alt="Gluing" /></td>
<td><img src="image3" alt="Screwing" /></td>
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<tr>
<td>Controllers</td>
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<td><img src="image5" alt="Controllers" /></td>
<td><img src="image6" alt="Controllers" /></td>
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Operational after tool change <1s
Conclusion

- Configuration is just one aspect of
  ... Administration and Management (AM) of networks
- Flexibility needed
  ... to handle erroneous situations
  ... to reflect changes in production
- OAM must be robust and fairly deterministic
  - No multicast/broadcast discovery
  - No dependability from complex loop elimination algorithm
  - Efficient monitoring of communication
  - Must not cause congestion
  - Must be scalable

 ➔ Key is reliability, a clear architecture
YANG and Restconf vs Layer 2 integrated approach

- YANG is a viable standard for an electronic data sheet for TSN
- Useful for offline Configuration
- Safety/Security impacts must be addressed

OAM of TSN as embedded (hierarchical) protocol

- Well known RSTP, .1AS etc
- Enhancement needed for quick access to individual nodes
  - No overload, just a route to any nodes
  - Can carry data from and to multiple nodes
    - Used already in some existing Ethernet Fieldbuses and implemented in a Fraunhofer(Lemgo) research project
- Binary encoding exist for almost all data needed to be exchanged (TLV)
  ... Textual encoding not very helpful
- What about a proper protocol option in LRP to address this??