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 )

Groups with 25-50 Robots/PLC for a specific task
Groups are linked together

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

1. Grouping:
   IO ➞ Aggregates ➞ Machines ➞ Cells ➞ Lines ➞ Hall ➞ Plant

2. Operation 24/6 or 7
   ➞ 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
   2 times higher FIT per 10°C increase beyond 25°C
   shock: up to 70,000 kN 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. Statistically such a car body shop **never** works (completely)

7. A couple of “TSN-visible” errors per day...

8. Goal is 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

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>
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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