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 24/6or7**
   ➔ 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 2 times higher FIT per 10ºC increase beyond 25ºC
   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

Each TSN error has to be handled

- No TSN experts on site

- Errors may be reported on different places
  not in order of occurence
  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

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

Robot	Welding	Gluing	Screwing

Mechanics

Operational after tool change <1s

Controllers

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??