Distributed real-time system architecture: layers & patterns in real-life

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metsoDNA architecture

- Background / history
- General structure
- Some cases (layers & patterns)
- Motivation
- Summary
Compatibility with Innovative Evolution

**Connectability**
- All existing systems can be connected to extensions

**Upgradeability**
- New features can be upgraded to existing systems

**Openness**
- Open to all solutions

**Integration of**
- MCS, DCS, QCS, Drive and Info applications one system
- Field & embedded solutions
- Knowledge and information
- User friendly, powerful, flexible and reliable platform for advanced pulp & paper and process & energy solutions

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Dematic
“Classic”

Dematic XD
Dematic XDi

metsoDNA

metsoDNA CR

1979 2006

1988

250 kb

100 Mb

2 Mb

10 Mb

250 kb 2 Mb 10 Mb 100 Mb

© Metso
metsoDNA CR Architecture

Operation, Maintenance, Reporting
Remote connections
Reporting, Enterprise integration

Star or ring topology
redundant Ethernet network

Centralized or
distributed

Name based communication

Controls, Optimization, Connectivity and Safety instrumented system

Ethernet and serial links

Engineering & Maintenance, Asset Management, Information services

No need of internal communication links
No need of internal servers
One Platform for All Needs

- Same platform for different types of controls
- Process, machine, quality, drive controls and optimizations
- Asset management solutions
  - Field device and vibration monitoring
- Integrated Safety related controls
- Benefits
  - One user interface and alarm handling
  - No links between systems
  - One history data collection and trending
  - Common engineering tools
  - Spare parts and trainings
Scalable metsoDNA from small to huge

Powerful Architecture

Tiny embedded application
• 10 - 250 IO’s
• typically installed to field or embedded to machines

Large mill network
• 17 system
• Different versions
• Different system generations
• ~ 100 000 IO’s

Benefits
• One system grows according the needs
• Seamless communication
• For all types of controls
• Asset management
**metsoDNA Networks**

**Topology / design**

**Recommended topology: Ring topology network (Turbo Ring)**
- Metso brand labelled switches (Moxa).
- Simple structure.
- Expected longer switch life span
- Can be expanded to cover large and very distributed mill’s (sub-rings).
- One switch model covers basically whole structure.
- Use for new mills
  - also where <300ms recovery times needed for redundancy.

**RSTP (tree-like) solution**
- Cisco, Hewlett Packard and Metso (Moxa brand labeled) switches.
- Three different level of configuration templates exists for supported devices.
- Can be expanded to cover large and very distributed mill’s
  - need for high density fiber switches (rare - no options - expensive)
  - need to use couple of different switch models mill wide.
- Existing RSTP solutions should be primarily expanded using RSTP
Redundancy patterns

- Redundant functionality
- Redundancy switch
- Centralized synchronization
Hardware changes: CPU models

- **Damatic Classic**
  - Zilog Z80 based 8-bit CPU

- **Damatic XD**
  - Motorola 68k based 16-bit CPU

- **metsoDNA**
  - Intel x86, powerPC, VIA, Motorola (all still supported)
Operating systems

- Operating systems:
  - Embedded kernel
  - HP-UX
  - Sco Xenix
  - Sco Unix
  - Windows NT, XP, Vista, Windows7
  - Linux
Operating system patterns

- Hardware abstraction layer (HAL)
- Device proxy
- Concurrent execution
- Operating system abstraction
Applications implemented by Visual Language
Application execution

• Applications from late 1980 still possible to run..

• Operating system:
  - Hardware abstraction layer (BSP: Board Specific Porting, see Linux examples)
  - Operating system abstraction (Windows / Linux, POSIX interface)

• Applications:
  - Visual language compiled to byte code (Domain Specific Visual Language)
  - Virtual machine runs byte code (like Java virtual machine) for Function Block applications
  - Subroutines encapsulated into Function Blocks
Real-time separation patterns

- Separate real-time
- Early work
- Operator profile
- Opportunistic delegation
- Third-Party confinement
- Static resource allocation
- Static scheduling
- Limp home
- Isolate control algorithm
Safety-oriented patterns

- Safe state
- Next stable state
- Distributed safety
- Heart beat
- Watchdog
Field bus Solutions, ACN node

PROFIBUS DP
- max. 125 units
- max. 12 Mbits/s (single / fiber ring)
- fiber 2 km, twisted pair max 1 km

PROFIBUS PA
- max. 30 units
- 31.25 kbits/s
- twisted pair 1900 m
- power and data via same cable

AS-i
- 156 kbit/s
- twisted pair 100 m
- power and data via same cable
(max. 62 devices in v2.1
max. 31 devices in v2.0)

Foundation Fieldbus
- HSE 100 Mbits/s
- twisted pair 100 m / fiber 2 km
- H1 31.25 kbits/s
- twisted pair 1900 m
- power and data via same cable

FOUNDATION FIELDBUS
- H1
- max. 12 units

Three PROFIBUS-DP buses can be connected to one ACN PCS. Several DP/PA couplers and AS-i gateways can be connected to PROFIBUS-DP. Also several FF Linking Devices with four H1 segments can be connected to ACN PCS.
Communication

• Several levels:
  - Devices connected to I/O-units
  - I/O-units to rack controllers
  - Rack controllers via fieldbus to CPU
  - CPUs are connected to system bus
  - One system to own "segment”

• Fieldbus protocols:
  - Profibus DP/PA
  - Foundation fieldbus HSE/H1
  - Ethernet/IP, EtherCAT
Communication principles

- Deterministic
- Robust
- Diagnostic data coming more important

- Master / slave
- Broadcast
- Heart beat
- Watch dog (fail safe function)
Messaging patterns

- Isolate functionalities (subsystems)
- Bus abstraction (change, no actual location)
- Message queue (acyclic, performance)
- One at a time (master / slave principle)
- Prioritized messages (alarms/events,...., background)

- Early warning
- Converting message filter
- Distributed transaction
- Message channel selection
- Vector clock
- Permission request
- Unique confirmation
- Locker key
metsoDNA CR – User Interaction Activity

Operation, Maintenance, Reporting

Remote connections

Star or ring topology redundant Ethernet network

Firewall

Centralized or distributed

Controls, Optimization, Connectivity and Safety instrumented system

Reporting, Enterprise integration

Office

Engineering & Maintenance, Asset Management, Information Services

XML
DNAuse – Efficient Problem Solving
Time machine feature for any picture

- For collected tags
  - History replay from any picture
  - Drag ‘n Drop to analysis tools

Switch to history mode
History mode indication
Select time in history and replay
Integration Increases Awareness of Situation
Optional Analysis Tools with DNAuse

- Analysis Tools interact with DNAuse
  - Fast analysis by one click
  - Predefined parameters are passed between tools

- USE CASE DNAtracer:
  - Open tool from Action Menu
  - Loop tag name automatically as parameter
  - Trends and related events combined automatically
  - Further analysis from event row in DNAtracer
    - Alarms and Events analysis
    - Diary entries
DNAals - Event Browser Filtering Feature

Helps focusing on situation at hand – Refiners area

Updating value

Alarm limits
DNAuse Replay – Alarm & Events Included
Something wrong with the Feed Pump?

DNAmachineAssessor knows history mode too!
DNAhelp – Functional Descriptions
How the Feed Pump should work?

Online user comments possible!

25P-100 Feed pump

Operation mode

- The feed pump pumps stock from the stock chest to the refining line.
- Loop controls the feed pump.

Start up procedure

- In automatic mode (mode is automatic), the start up and the stop sequences control the motor.
- In manual mode (mode is automatic), the operator can control the motor.
DNAdiary – Disturbance Entry

Report faulty Feed Pump and send notification to CMMS

<table>
<thead>
<tr>
<th>Field</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title</td>
<td>Feed pump</td>
</tr>
<tr>
<td>Author</td>
<td>Oliver Operator</td>
</tr>
<tr>
<td>Entry Group</td>
<td>Operators</td>
</tr>
<tr>
<td>Date/Time</td>
<td>26/10/2009 15:54:19</td>
</tr>
<tr>
<td>Description</td>
<td>Feed pump not operating with full capacity. Needs maintenance check. Automatic request sent to Maintenance Management System.</td>
</tr>
<tr>
<td>Entry Tag</td>
<td>26P-100</td>
</tr>
</tbody>
</table>
Key Strengths of User Interaction

Focus areas in User Interfaces

• Industrial design with high usability comes from the experience
  - Application of systematic usability methods and usability field tests
  - Hundreds of studies and thousands of deliveries through 20 years

• Integration of real-time and history data
  - Exactly the same user interface is able to use real-time and history information
  - No need to do the system setup, training or maintenance twice

• Tools for analyzing, reporting and log book integrated
  - All tools can be opened from Operator Interface with tag as a parameters
  - Drag n’ drop from pictures to trends

• Exactly the same tools for Control Room and Office users
  - Everyone is using the same system, one version of the truth
Key Features to Boost Daily Operations
Transparency integrated history functions

- DNAuse TEA brings time machine to the mill or plant

- DNAuse with History Mode and Replay
  - Ultimate troubleshooting tool - metsoDNA CR has a memory!
  - Replay can be set up completely and fast by using Metso standard

- My Community Tools for Analyzing and Reporting
  - Power full trending and reporting tools to Control Room
    - Replace alarm printers with DNAreport AE
    - Replace manual log book with DNAdiary
    - Replace short DCS trends with DNAtracer

- Bottom line – today a production organization cannot survive global competition without help of history functions in every day operations
User Interaction is Easy to Set up and Maintain
Efficient engineering tools and install free user tools

• Setting up data collection with familiar tools
  - No need for OPC gateways, interfaces to Metso systems are in-build
  - Configuration is done using regular metsoDNA engineering tools (DNAexplorer)

• Web based My Community tools are installation free
  - Longer life cycle since the operating system is not a critical issue
  - If client software update is needed, only Server side needs to be updated.
  - No need to select dedicated end users – only web browser is needed

• Non-web clients – DNAtracer and DNAview are Click Once - applications
  - Installed upon first usage and updated automatically
  - Firm look and feel of native windows application
User interfaces summary

- Operating system neutral
- Both Windows & Linux supported (QT)

- Common communication for all components
  - Data from real-time environment
  - Data from different databases

- Feature rich client applications
- Interaction between applications
Motivation

- C / C++ used as programming language in embedded environments
- Java in some optimization / web applications
- C# is coming more common in UI / web applications
- Security coming very important
- Concurrent / parallel execution due multi-core CPUs
  - Thread Building Blocks (TBB), http://threadingbuildingblocks.org/
- Continuous Integration, CI
  - Cruise Control, http://cruisecontrol.sourceforge.net/
- Automated Testing

Software production methods needed for efficient & high quality systems.
Summary

- Principles done in 1980 are still valid

- It is easier to use them as they are commonly "known" solutions

- Some parts of implementations can be hidden, compilers can do more
  - More libraries are supporting abstraction like OpenMP, QT