IEC 61499 in Material handling

Research in Progress with Glidepath Ltd, New Zealand

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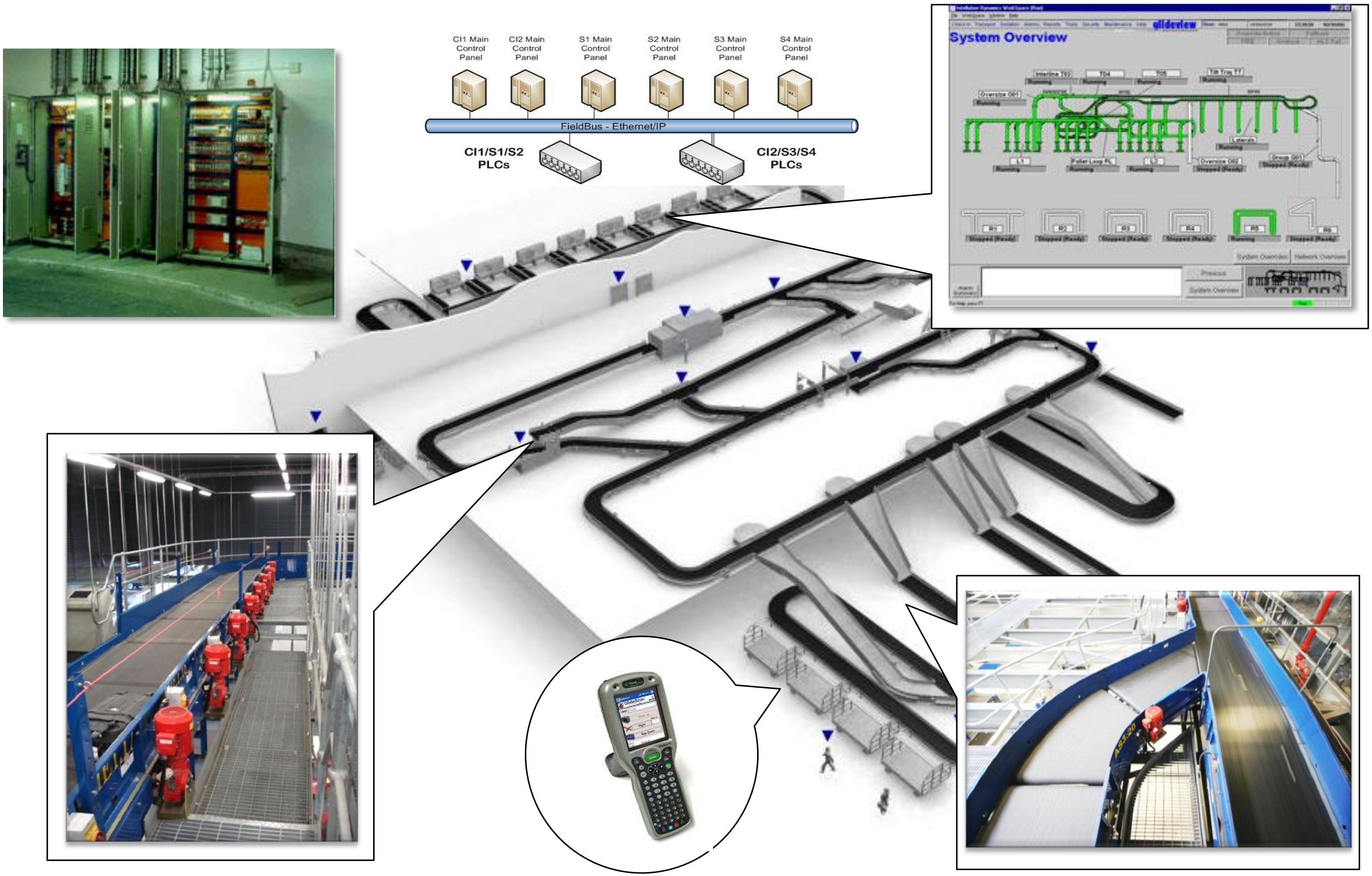
THE UNIVERSITY OF AUCKLAND
FACULTY OF ENGINEERING

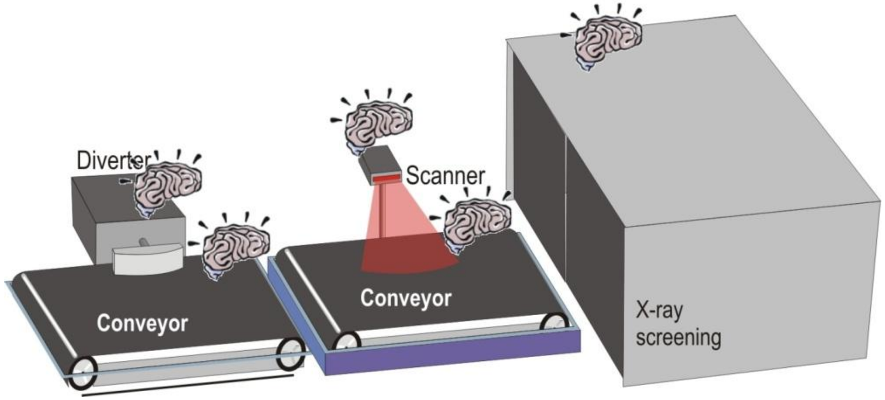
Airport Baggage Handling Systems



Outline

- Challenges
  - Performance:
    - Spatially dispersed
    - Real-time requirements
  - Engineering
    - Re-use
    - Verification and Validation
- Distributed approach
- Pathway
  - Performance and class-oriented design pattern
  - Migration
    - Re-use of PLC code inside of IEC 61499 FBs
    - Semantic model
  - Testing

Machines need more Intelligence !



Now That's Smart!

Information Infrastructure of Intelligent Machines Based on the IEC 61499 Architecture

The requirements of flexible manufacturing and material handling systems, such as rapid integration and reconfiguration, as well as the growing information intensity of the production environments imply that manufacturing equipment is becoming more autonomous and intelligent.

A large number of intelligent machine concepts have been proposed in the last decade (see overview in [10]). Their systematic discussion and evaluation is beyond the goals of this article. A few characteristic concepts, however, need to be mentioned. The holonic manufacturing systems (HMSs) [3] emphasize the idea of self-configurability, envisioning that holonic machines will form new production configurations "on the fly," reacting to the external and internal changes. For example, an external change could be a change in the product specification. An internal change can be a break-down of a certain machine in the production system. The reconfigurable manufacturing systems (RMSs) [2] and the intelligent mechatronic actors introduced by Lastra in [10] rely on the "offline" (in advance) customization of the machinery driven by the changing production

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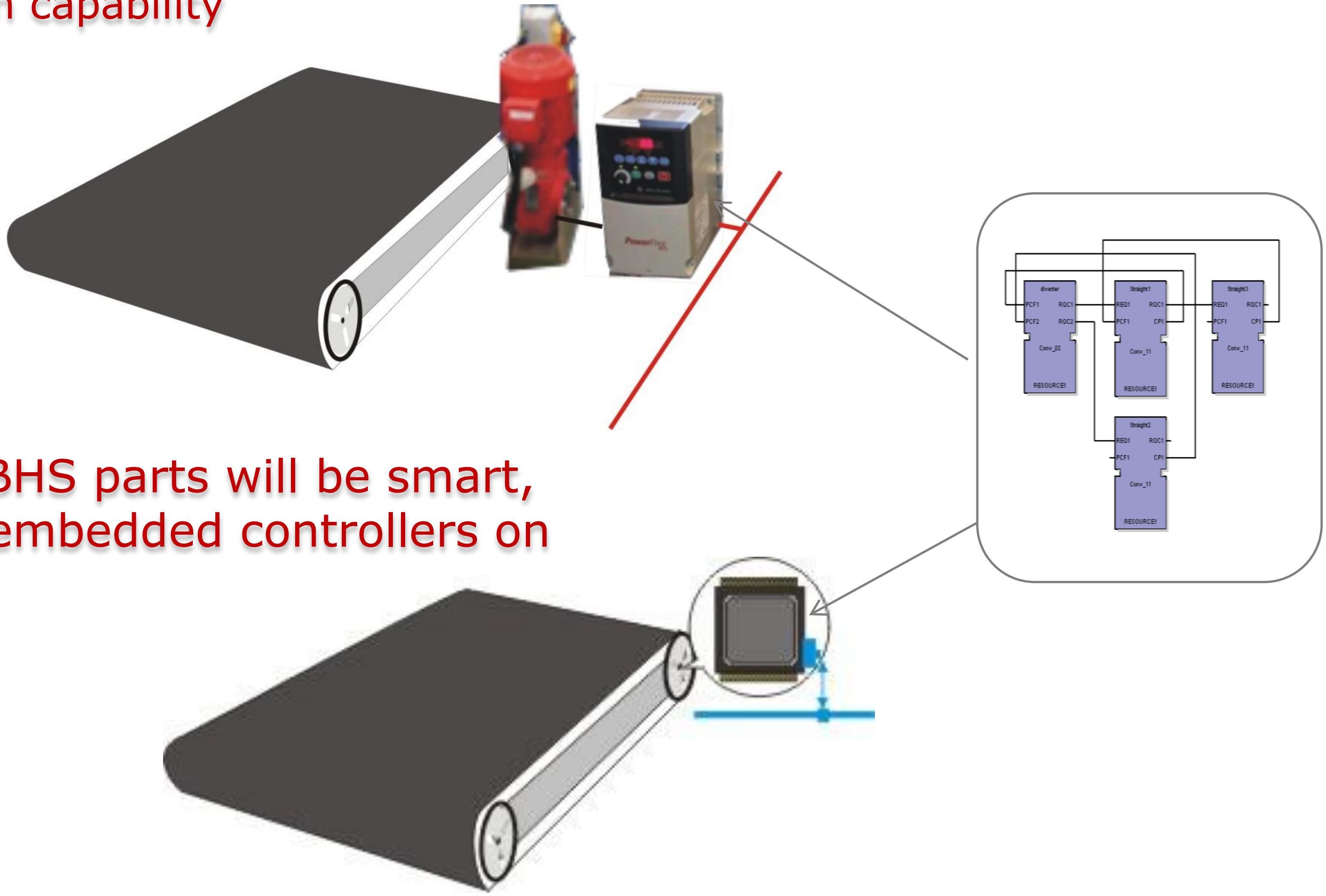
Truly Distributed Control Potential

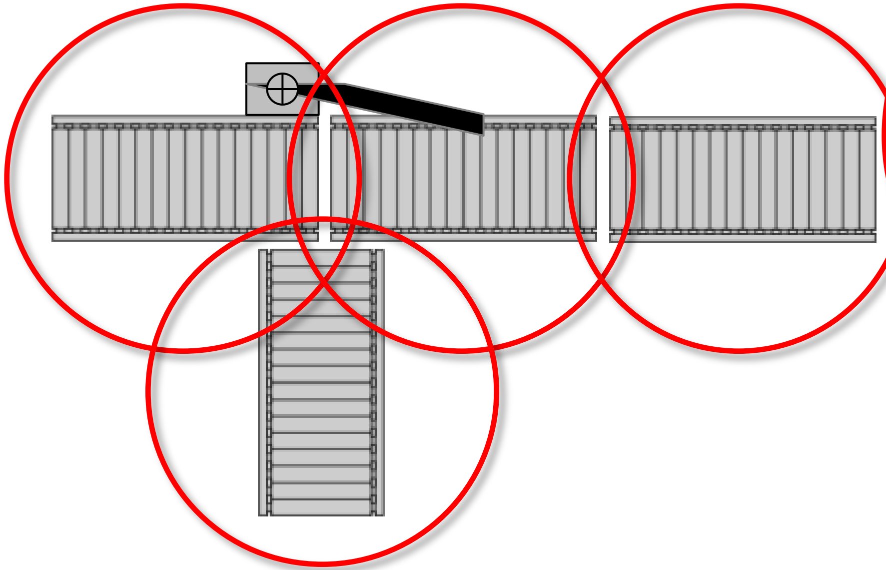
Conveyors already have a motor control unit and network connectivity, so it won’t be a big deal to equip them with the function blocks execution capability



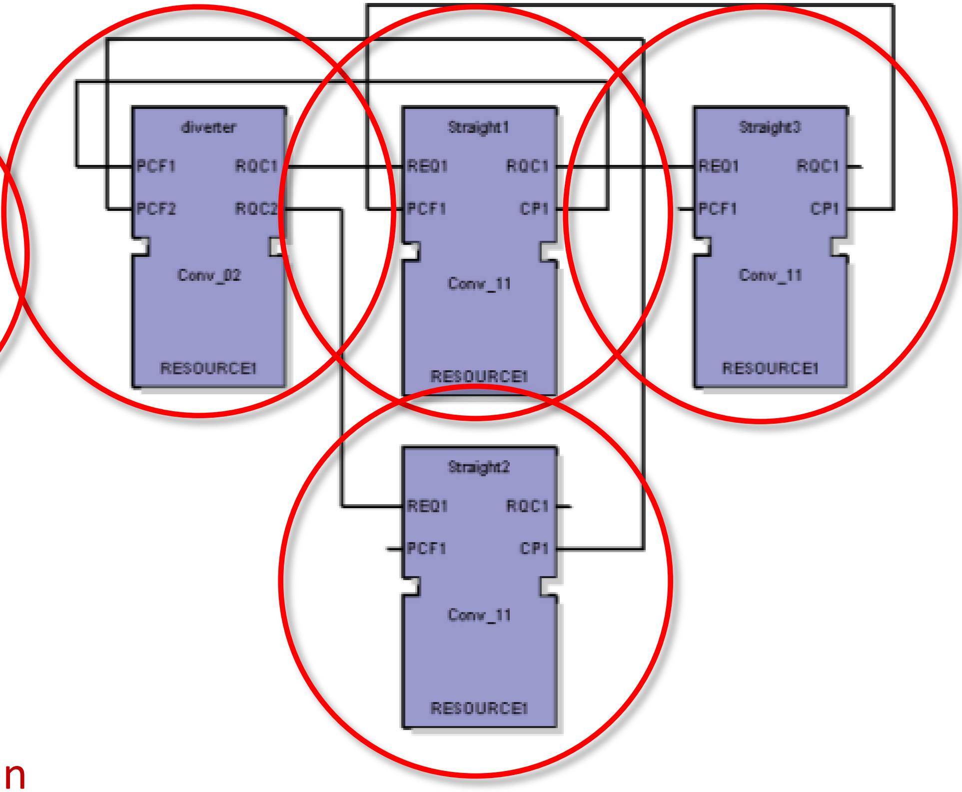
Future BHS parts will be smart, having embedded controllers on board

Modular Machines = Modular Code

If we have several conveyor sections interconnected like this:



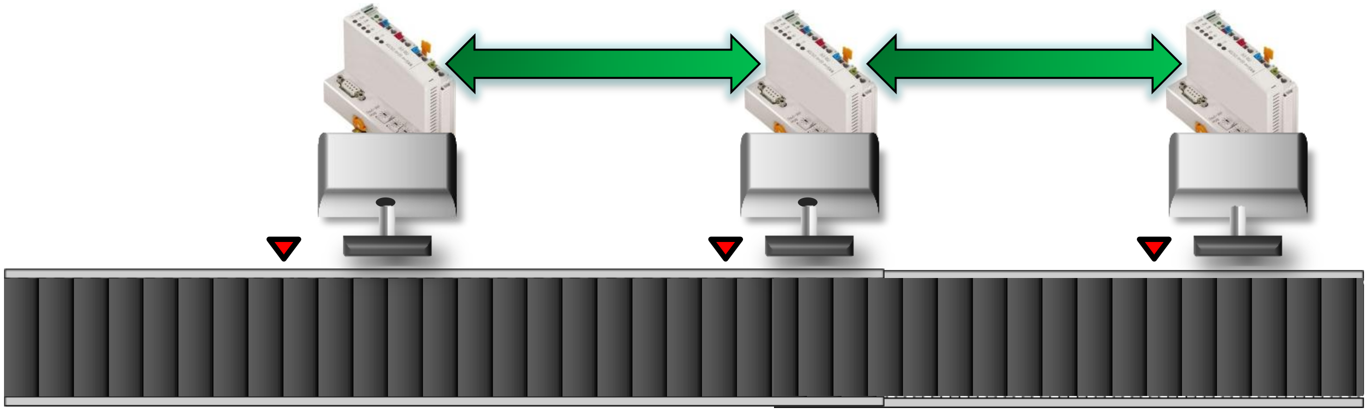
Then the control program will look like this network of function blocks



And if we add one more conveyor, then the program will be augmented with one more function block!

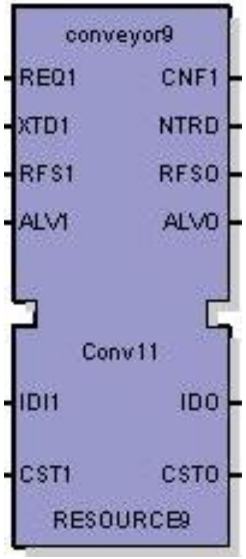
Intelligent Distributed BHS

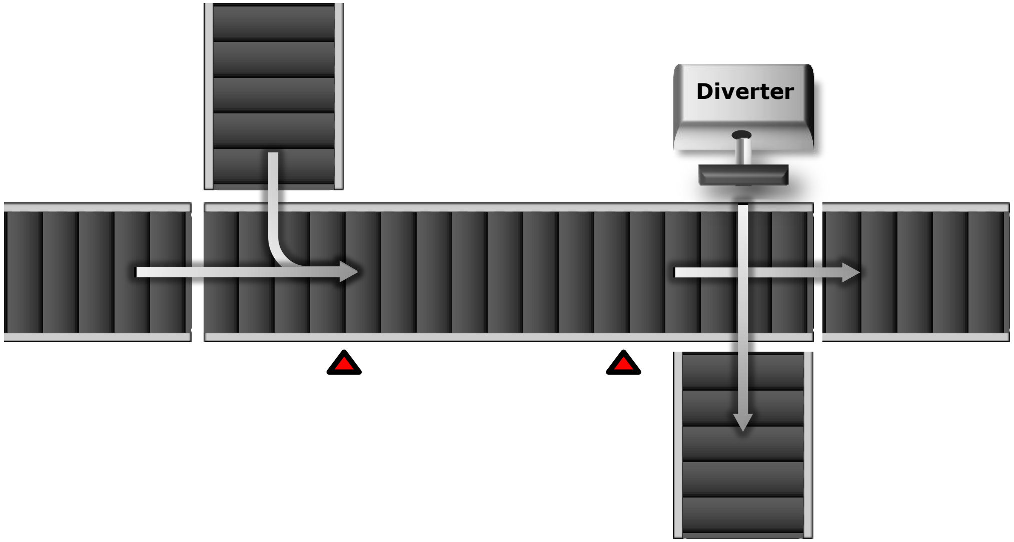
- Truly distributed logic
- Each conveyor and mechatronic object may have its own controller hardware
- Communication between components



Design Pattern:
Generic Conveyor Function Block

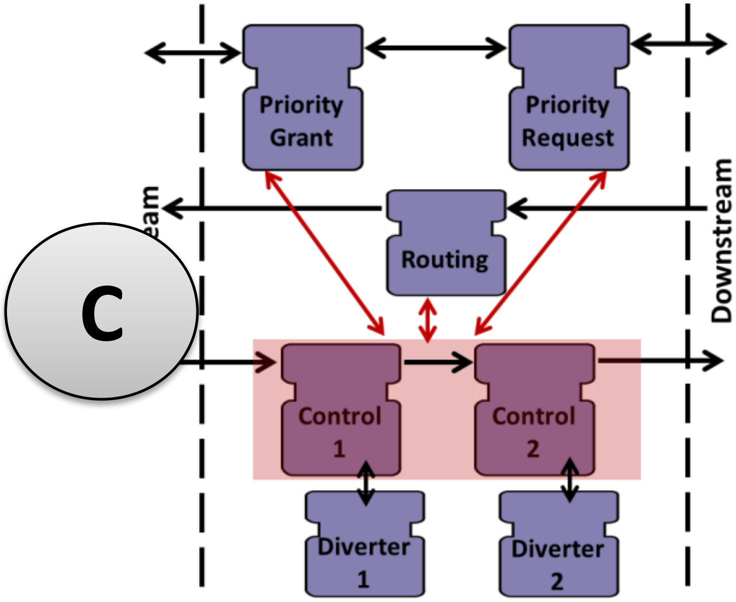
- Encapsulates functionality of a single conveyor
  - Merge
  - Divert
  - Routing and tracking
  - Emergency/Cascade stop





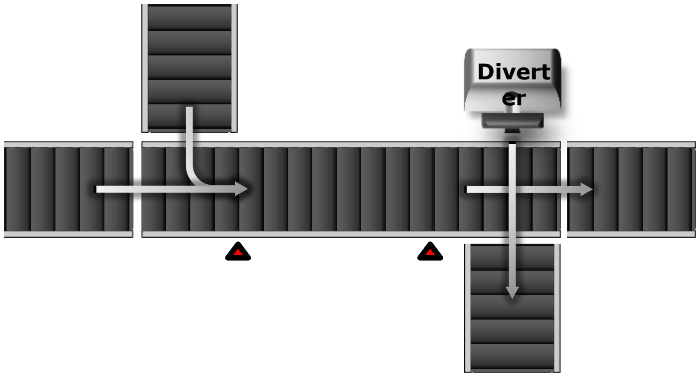
Modelling the Conveyor

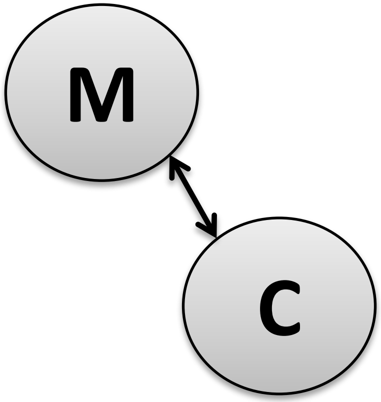
- IEC 61499 Composite Function Block
- MVC Design Pattern
  - **Distributed Control Design**



Modelling the Conveyor

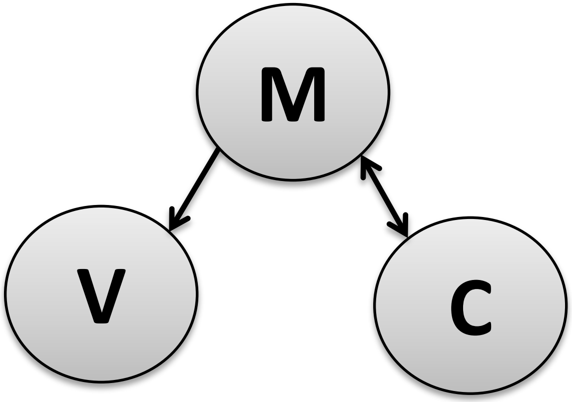
- IEC 61499 Composite Function Block
- MVC Design Pattern
  - **Distributed Control Design**
  - **Behavioural Model**



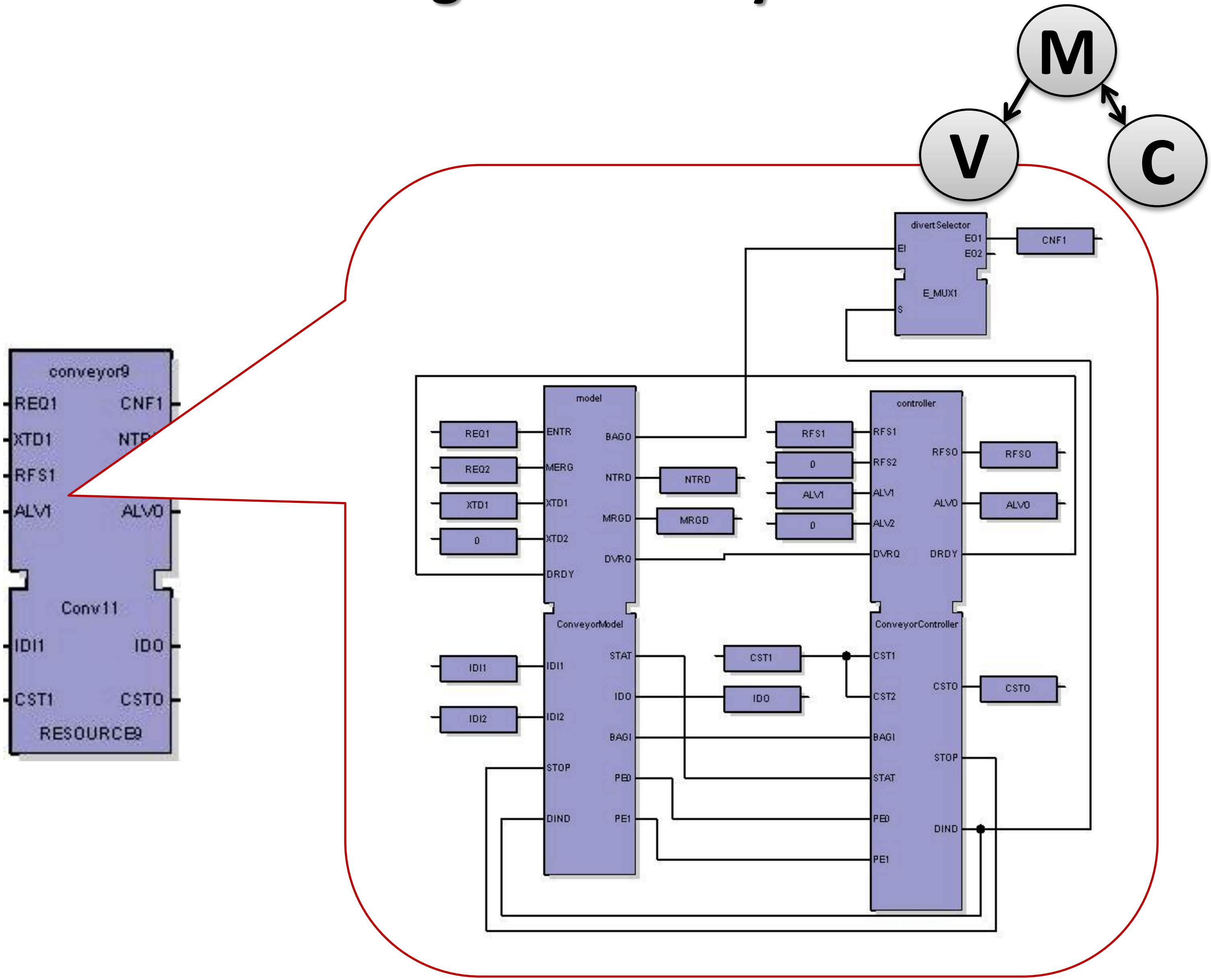


Modelling the Conveyor

- IEC 61499 Composite Function Block
- MVC Design Pattern
  - **Distributed Control Design**
  - **Behavioural Model**
  - **Visualization**

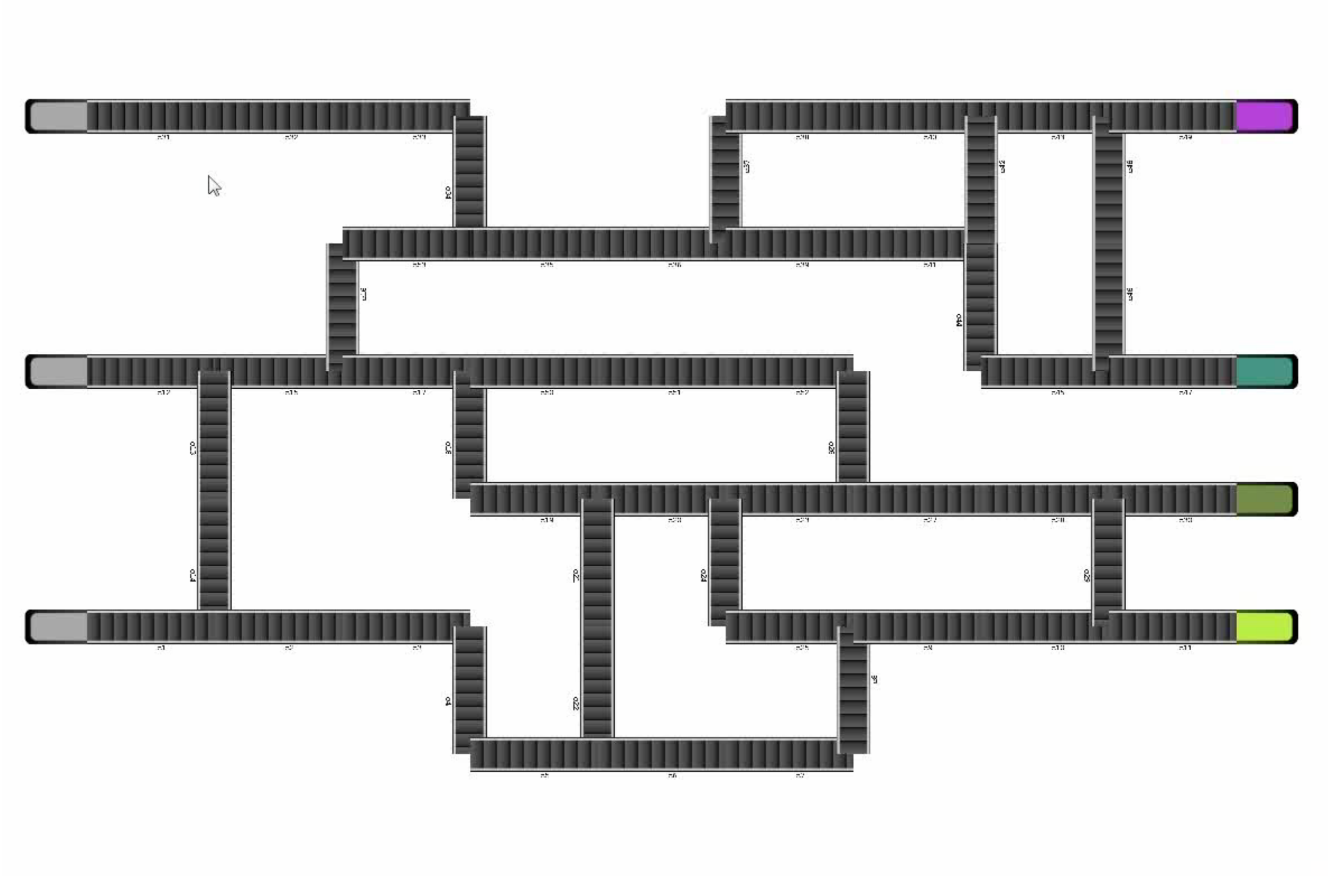


Modelling the Conveyor



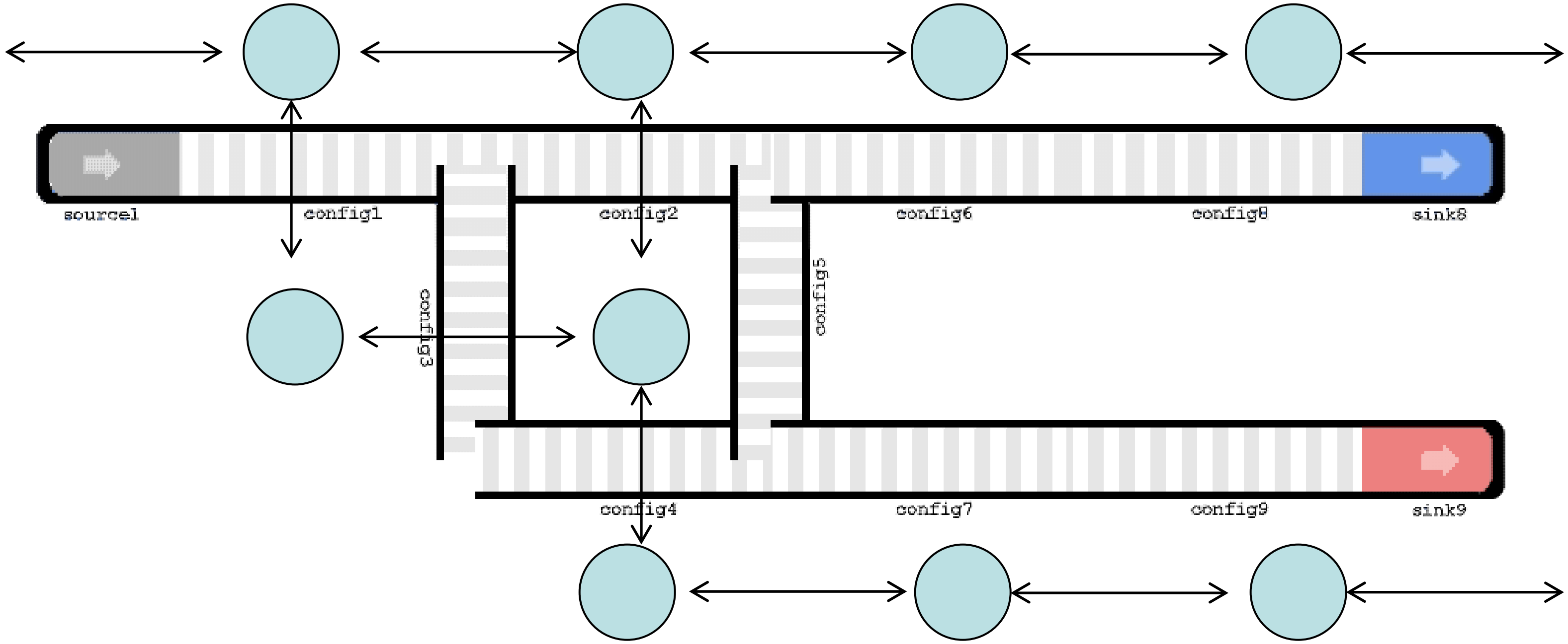
Visualization

- Gives a quick view of the system state
- Generated based on graph model of BHS



Distributed Algorithms

- Merging, Diverting, Fault tolerance handled using distributed techniques



G. Black, V. Vyatkin, "Intelligent Component – based Automation of Baggage Handling Systems with IEC 61499", *IEEE Transactions on Automation Science and Engineering*, 2010, 7(2)

Distributed Routing

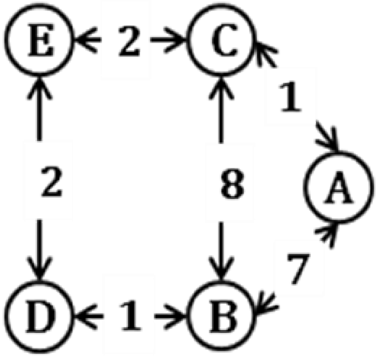
Distributed Bellman-Ford algorithm is applied

t=0

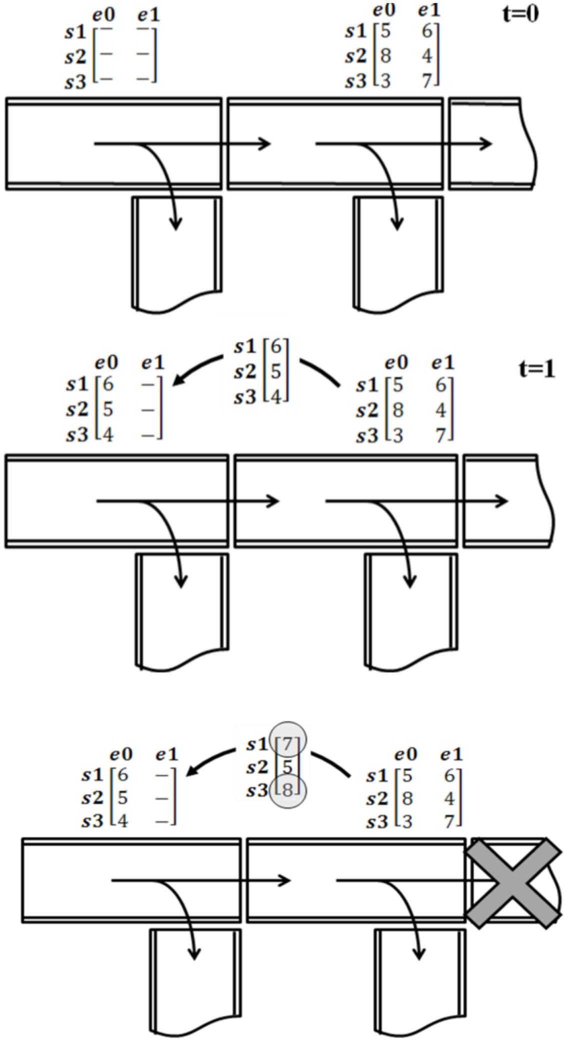
$$\begin{array}{cc|ccccc} & & \multicolumn{5}{c}{\text{via}} \\ & & A & B & C & D & E \\ & A & - & - & - & - & - \\ & B & - & 7 & - & - & - \\ \text{to} & C & - & - & 1 & - & - \\ & D & - & - & - & - & - \\ & E & - & - & - & - & - \end{array}$$

t=1

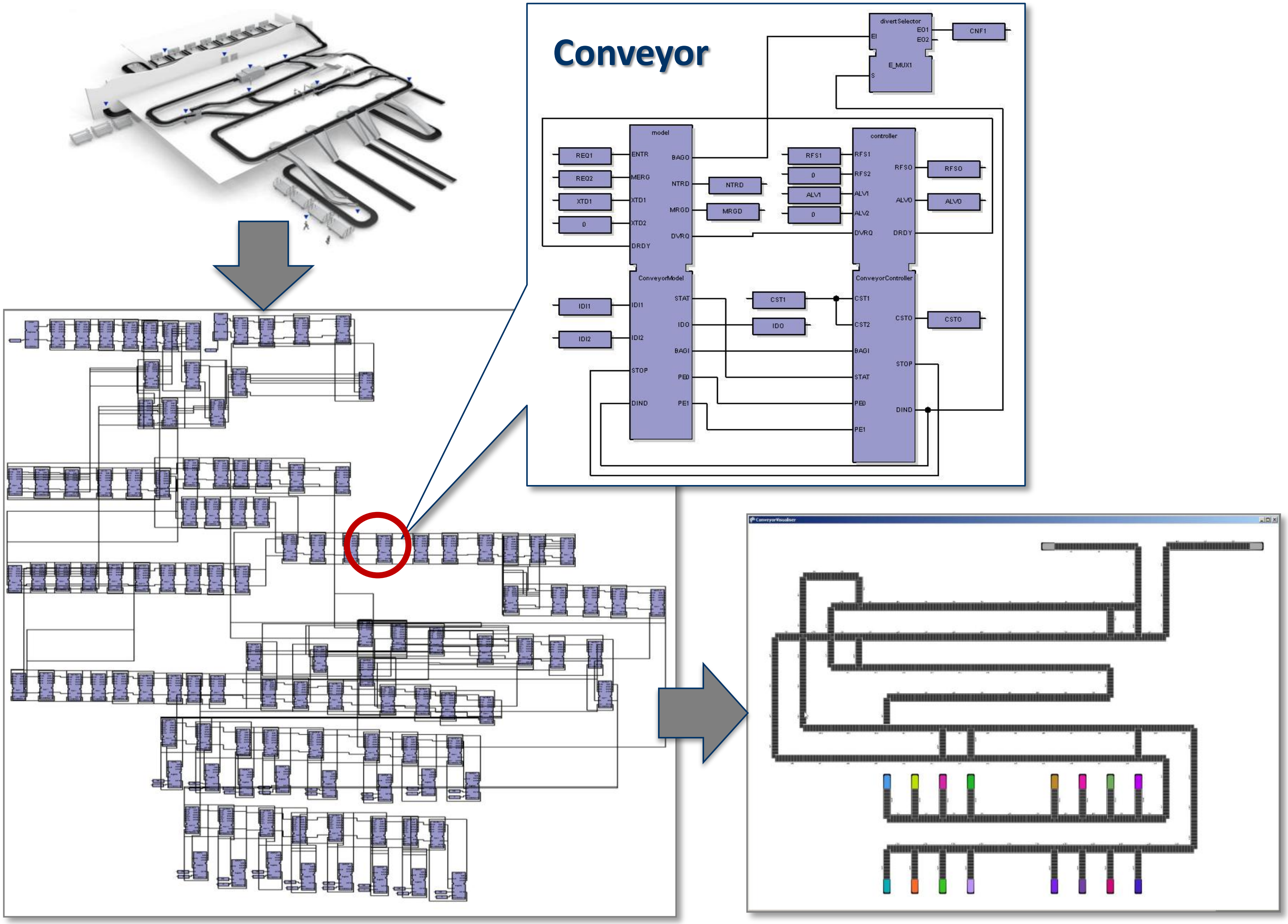
$$\begin{array}{cc|ccccc} & & \multicolumn{5}{c}{\text{via}} \\ & & A & B & C & D & E \\ & A & - & - & - & - & - \\ & B & - & 7 & 9 & - & - \\ \text{to} & C & - & 15 & 1 & - & - \\ & D & - & 8 & - & - & - \\ & E & - & - & 3 & - & - \end{array}$$



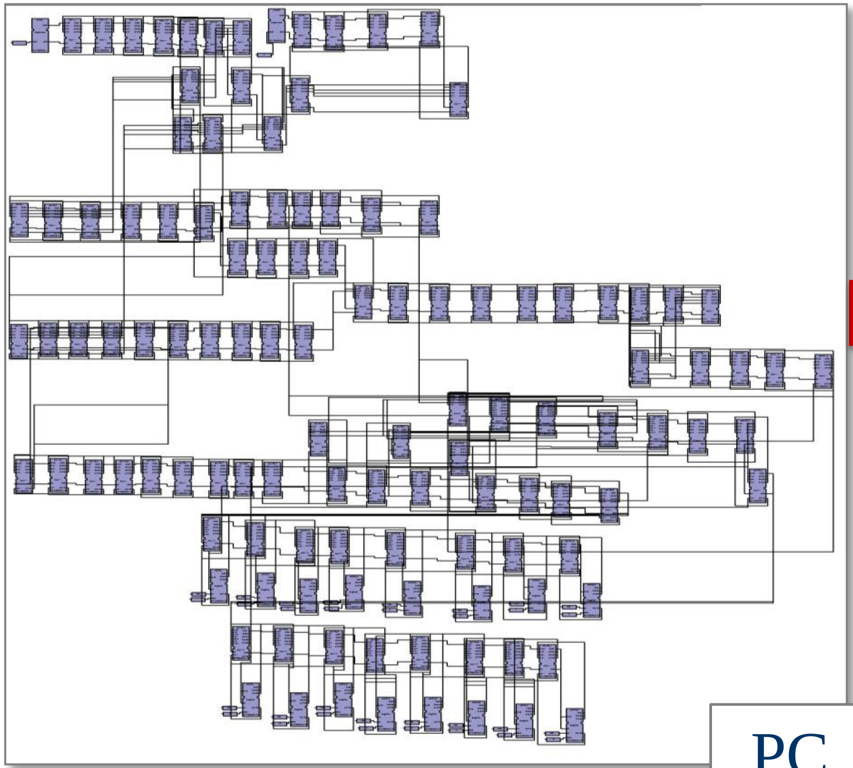
Network of 5 conveyors with distance metrics and the routing tables for Node A at time t=0 and t=1

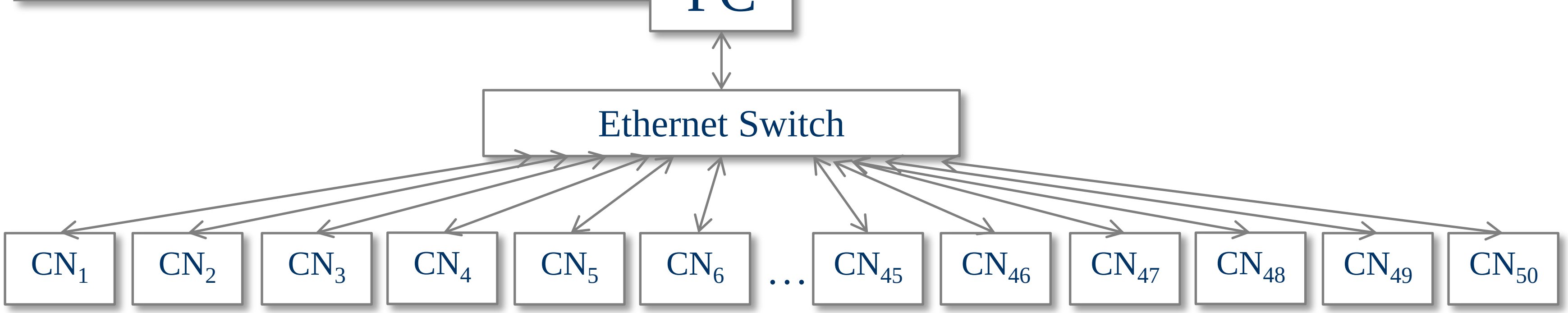


Scaling


Conveyor
divertSelector
EI
EO1
EO2
S
E_MUX1
CNF1
model
REQ1
REQ2
XTD1
0
ENTR
MERG
XTD1
XTD2
DRDY
BAGO
NTRD
MRGD
DVRQ
NTRD
MRGD
ConveyorModel
IDI1
IDI2
STOP
DIND
STAT
IDO
BAGI
PE0
PE1
CST1
IDO
controller
RFS1
0
ALV1
0
RFS1
RFS2
ALV1
ALV2
DVRQ
RFSO
ALVO
DRDY
RFSO
ALVO
ConveyorController
CST1
CST2
BAGI
STAT
PE0
PE1
CSTO
STOP
DIND
CSTO
ConveyorVisualiser

Distributed FB Testbed with 50+ Nodes





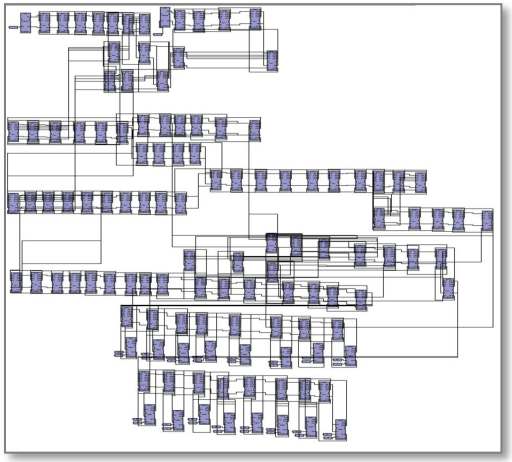
PC

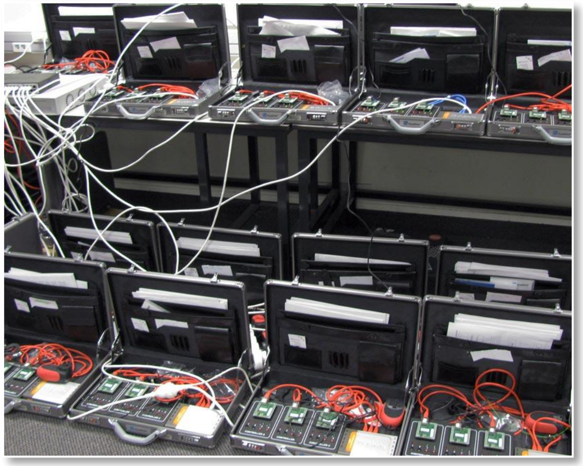
Ethernet Switch

CN$_1$ CN$_2$ CN$_3$ CN$_4$ CN$_5$ CN$_6$ … CN$_{45}$ CN$_{46}$ CN$_{47}$ CN$_{48}$ CN$_{49}$ CN$_{50}$

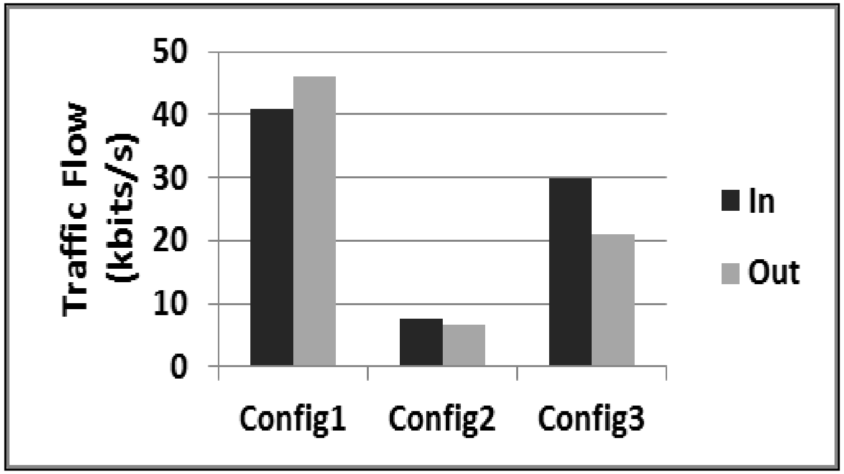
Yan J., and Vyatkin V., "Distributed Execution and Cyber-Physical Design of Baggage Handling Automation with IEC 61499", *9th International IEEE Conference on Industrial Informatics*, (INDIN'11), July, 2011, Lisbon, Portugal

Performance?

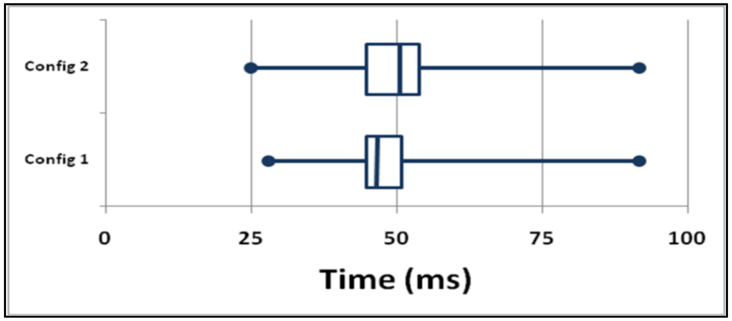




Network traffic and response time have been measured using PRTG Traffic Analyzer.



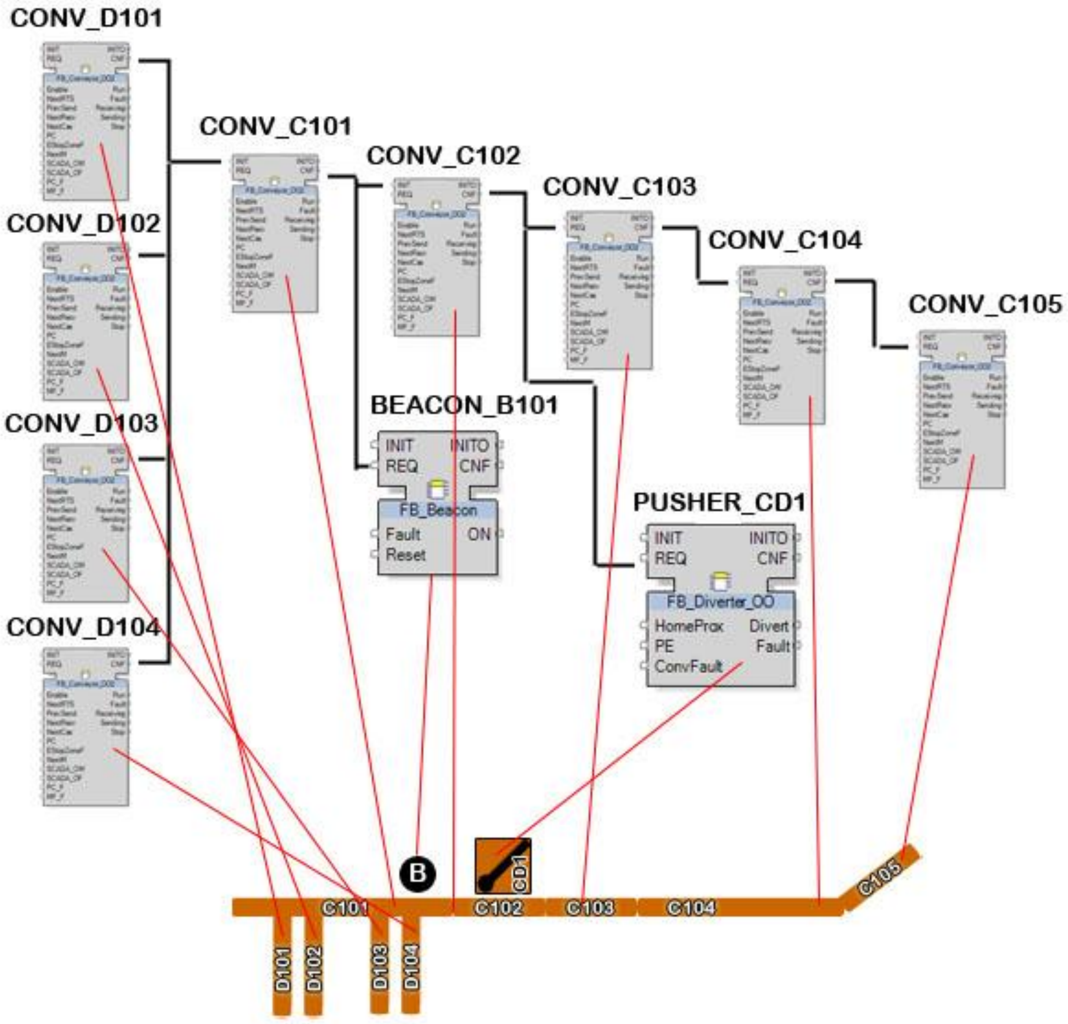
Network traffic for 3 selected control nodes



Event transmission delays between two control nodes

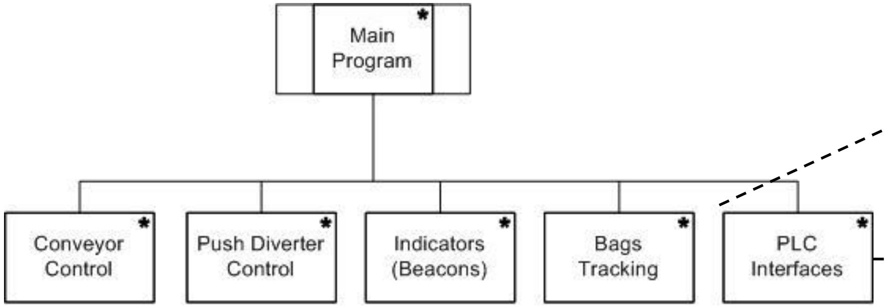
Object Oriented Design

- Connect FBs according to physical layout

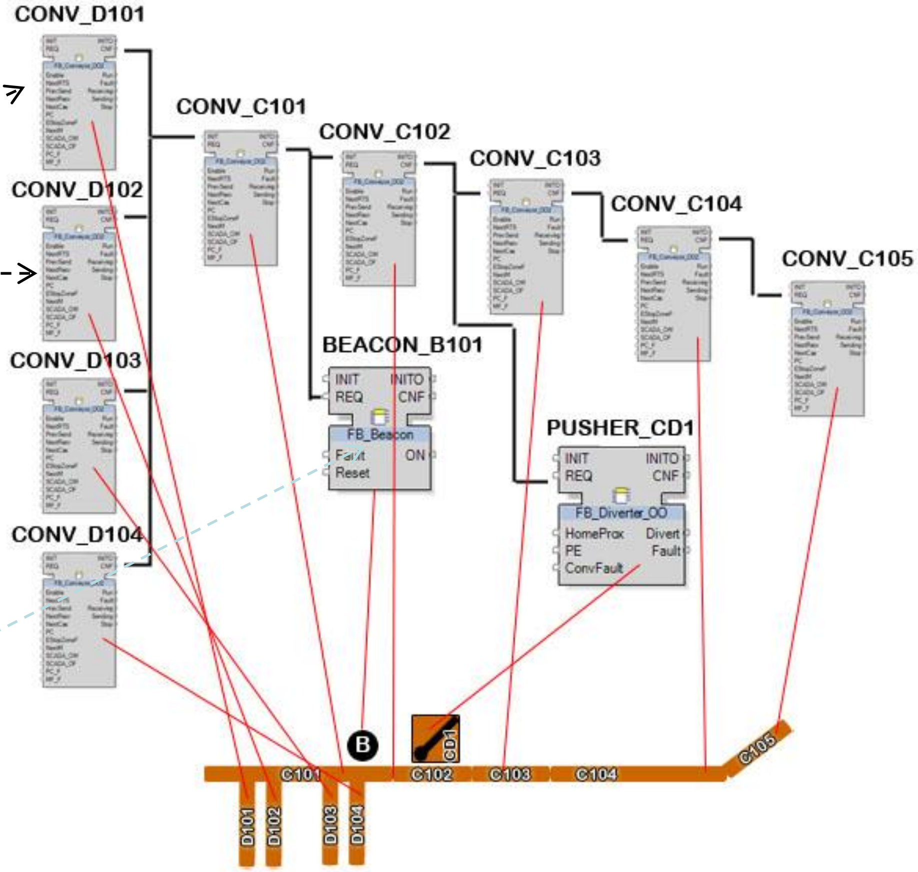


Migration to Object-oriented Architecture

PLC Program Structure

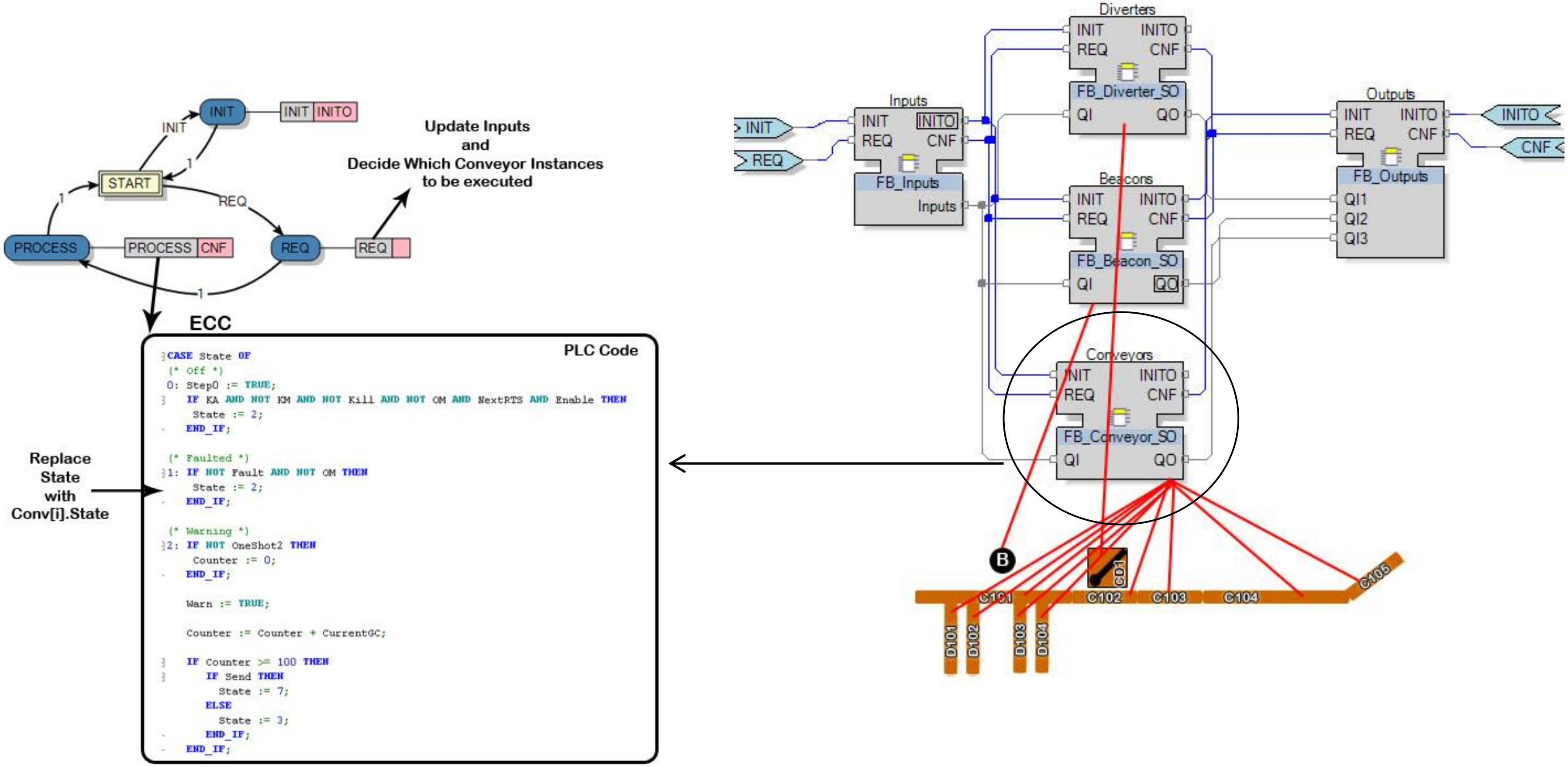


FB Program Structure for BHS



Class-Oriented Design

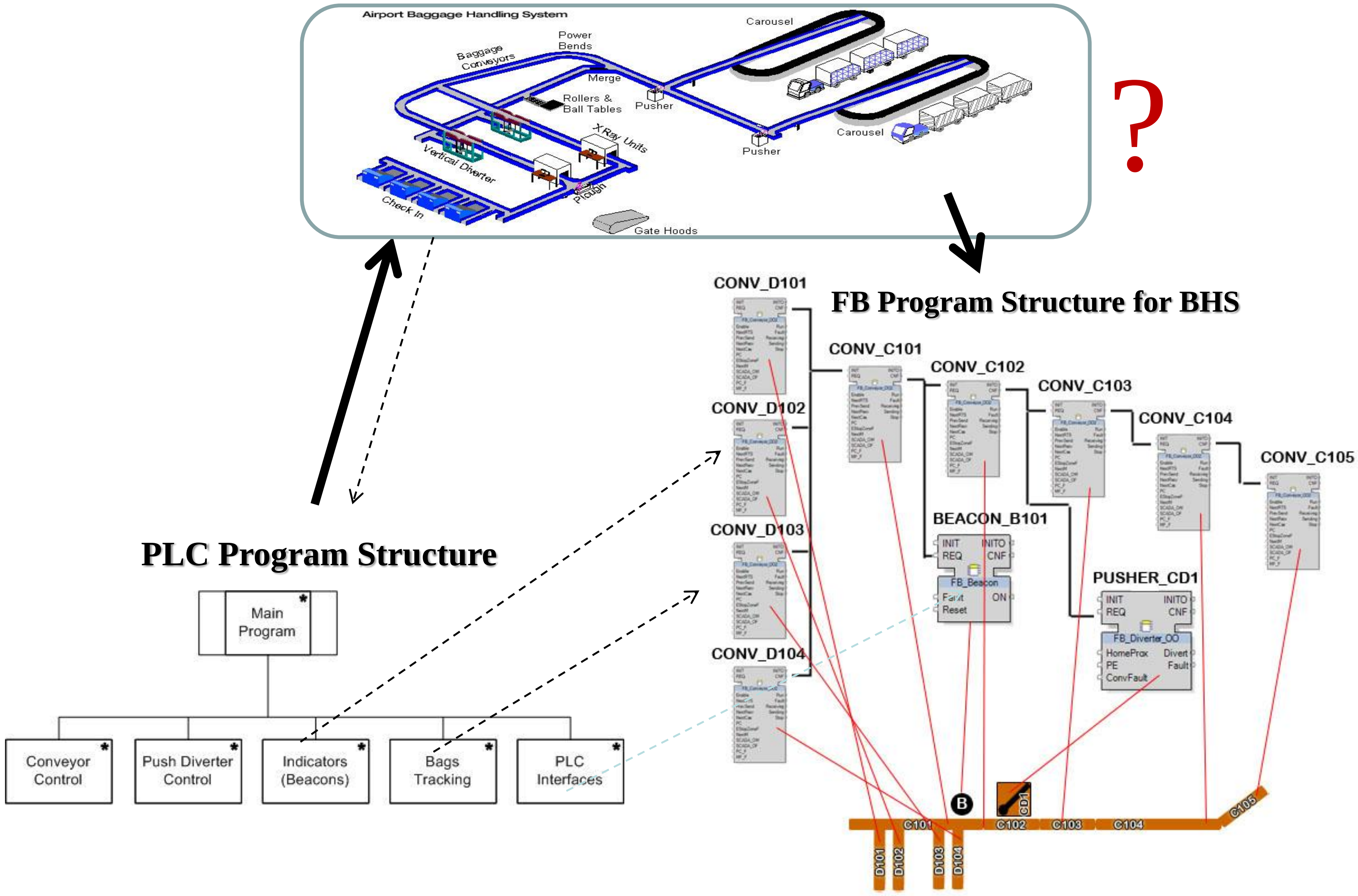
- Connect FB Class with Physical Input and output FBs



```
CASE State OF
 (* Off *)
 0: Step0 := TRUE;
    IF KA AND NOT KM AND NOT Kill AND NOT OM AND NextRTS AND Enable THEN
     State := 2;
    END_IF;

 (* Faulted *)
 1: IF NOT Fault AND NOT OM THEN
     State := 2;
    END_IF;

 (* Warning *)
 2: IF NOT OneShot2 THEN
     Counter := 0;
    END_IF;

    Warn := TRUE;

    Counter := Counter + CurrentGC;

    IF Counter >= 100 THEN
       IF Send THEN
         State := 7;
       ELSE
         State := 3;
       END_IF;
    END_IF;
```

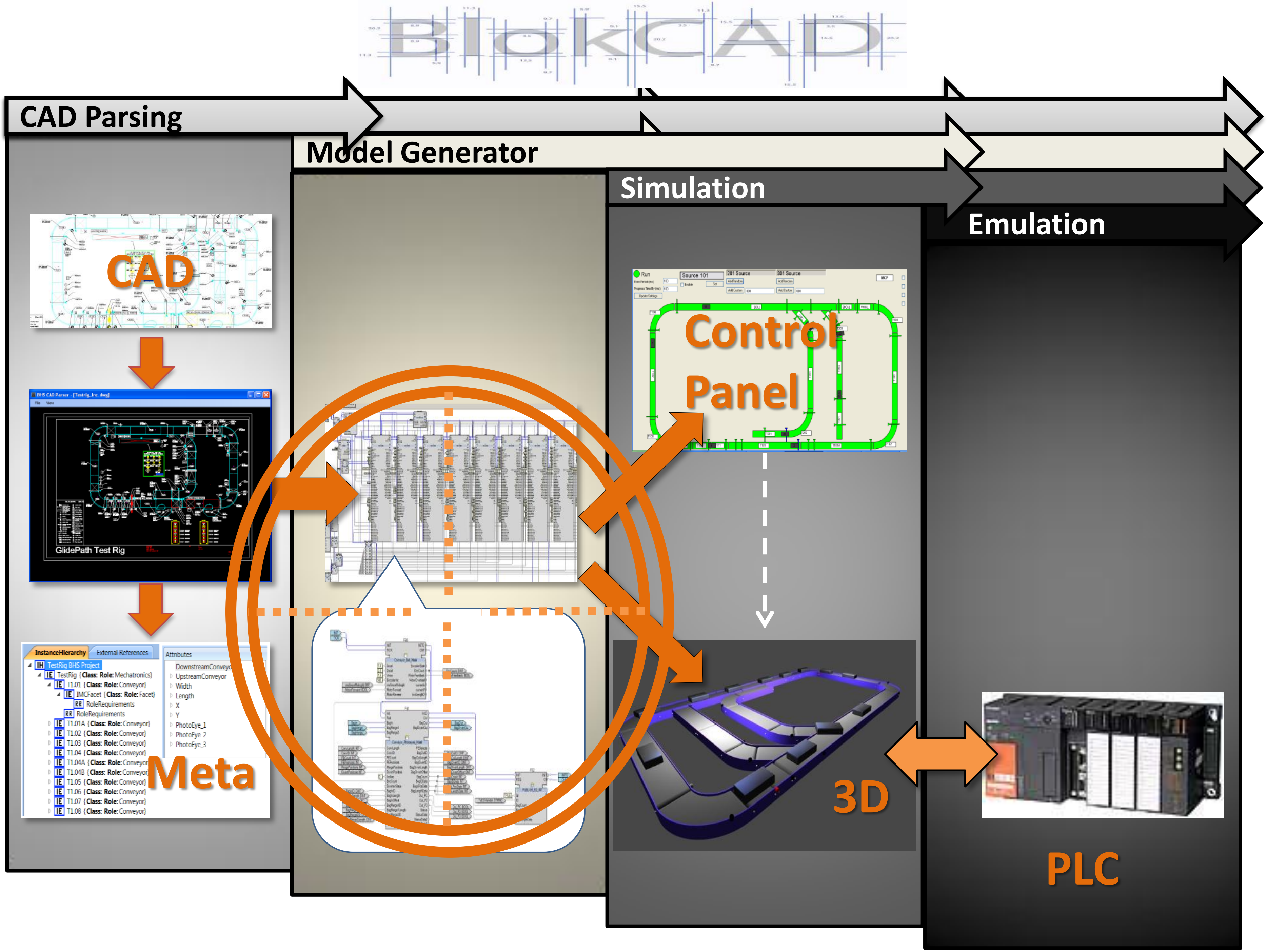
W. Dai, V. Vyatkin, “Redesign Distributed IEC 61131-3 PLC System in IEC 61499 Function Blocks”, IEEE International Conference on Emerging Technologies and Factory Automation (ETFA’10), Bilbao, Spain, September, 2010

Semantic model of automated BHS



FB Program Structure for BHS

PLC Program Structure


BlokCAD
CAD Parsing
Model Generator
Simulation
Emulation
CAD
GlidePath Test Rig
InstanceHierarchy
External References
Attributes
TestRig BHS Project
TestRig {Class: Role: Mechatronics}
T1.01 {Class: Role: Conveyor}
IMCFacet {Class: Role: Facet}
RoleRequirements
RoleRequirements
T1.01A {Class: Role: Conveyor}
T1.02 {Class: Role: Conveyor}
T1.03 {Class: Role: Conveyor}
T1.04 {Class: Role: Conveyor}
T1.04A {Class: Role: Conveyor}
T1.04B {Class: Role: Conveyor}
T1.05 {Class: Role: Conveyor}
T1.06 {Class: Role: Conveyor}
T1.07 {Class: Role: Conveyor}
T1.08 {Class: Role: Conveyor}
DownstreamConveyor
UpstreamConveyor
Width
Length
X
Y
PhotoEye_1
PhotoEye_2
PhotoEye_3
Meta
Run
Source 101
201 Source
301 Source
Control Panel
3D
PLC