Industrial Campus Network for Virtualized Programmable Logic Controller (PLC)
Industry 4.0 and Smart Manufacturing Require More to PLC

Industry 4.0 and Smart Manufacturing request competitive production systems for individualized products. PLCs, as the key components of the production systems, new requirements are aroused to PLCs for transformation.

The transformation approach is the virtualized PLC.

**Requirements**

**More data to be processed**
- More data are generated and sent to PLC.
- It includes not only logical data, analog data, but also video, image data.

**More Flexible to adjust**
- Services or market requirements changing cause procedure flow or data changing.
- PLCs are requested to adjust accordingly.

**More coordinated to control**
- There are more factors to be considered to implement the control and manufacturing.
- There are more interactions and communications with other devices and systems to optimize decisions based on data.

**Approaches of vPLC**

**More computing power to be provided**
- The vPLC based on cloud / edge computing could be expanded for more computing power dynamically.
- The IT technologies (e.g. AI, big data, etc.) could be introduced in vPLC to process huge amount of data with different types.

**More ease to verify, update and run vPLC with new functionalities**
- There are full maintenance procedures derived from cloud / edge computing.
- It’s ease and highly efficient to implement verification, update and running vPLC program with new functionalities.

**Decoupled, more ease to coordinate with the others**
- The vPLCs are decoupled from control modules of classic PLCs.
- Naturally, it’s able to communicate to other vPLCs, I/O modules or other systems conveniently.
- More data could be involved into the control progress, it will be more accurate or proper to implement the control capability.
Understanding of Virtualized PLC via Comparison

- Virtualized PLC, that is to decoupling the classic PLC, separates its logical control functionalities and I/O functionalities, standardizes logical control functionalities as modules, deploys and runs the control modules remotely and centrally in virtual environment.

<table>
<thead>
<tr>
<th>Items</th>
<th>Category</th>
<th>Hard PLC</th>
<th>Soft PLC</th>
<th>Virtualized PLC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hardware</strong></td>
<td></td>
<td>Proprietary hardware</td>
<td>Industrial PC</td>
<td>General hardware server</td>
</tr>
<tr>
<td><strong>System</strong></td>
<td></td>
<td>Embedded real-time system (hard real-time)</td>
<td>OS with extended real-time features (soft real-time)</td>
<td>Real-time OS (RTOS)</td>
</tr>
<tr>
<td><strong>Coupling of hardware &amp; software</strong></td>
<td></td>
<td>Completely coupling</td>
<td>Partially decoupling</td>
<td>Completely decoupling</td>
</tr>
<tr>
<td><strong>Place of the controller deployed</strong></td>
<td></td>
<td>Field level</td>
<td>Near field level</td>
<td>Remotely</td>
</tr>
<tr>
<td><strong>Computing power</strong></td>
<td></td>
<td>Limited by the hardware</td>
<td>Expand limitedly</td>
<td>Nearly unlimited</td>
</tr>
<tr>
<td><strong>Reliability</strong></td>
<td></td>
<td>High</td>
<td>Medium</td>
<td>Low (currently)</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td></td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
</tr>
</tbody>
</table>

Network / protocol related aspects:
- Protocol Stack Integration
- Low Latency / Determinism (End to end)
- Security Access
- High Reliability
Along the routine from vPLC to Device, the end to end network and protocol stack integration are involved.

<table>
<thead>
<tr>
<th>Item</th>
<th>Aspects involved</th>
<th>Scenarios</th>
<th>Challenges</th>
</tr>
</thead>
</table>
| Controller Side               | 1) Protocol stack integration                                                                      | • Network protocol stack integration with RTOS  
• vPLCs to access devices with security                                                                                       | • Network  
✓ Low latency / determinism  
✓ High reliability  
• Protocol & Access Interface  
✓ Ease to integrate protocol stack, avoid influence to device / system  
✓ Ease to access, different network, bus, wire or wireless network etc.  
✓ Auto discovery & networking  
• Security  
✓ Access certification,  
✓ Risk isolation, etc. |
| Industrial Backbone Network   | 2) Transferring different kind of streams                                                           | • To transfer different kind of industrial streams, including periodical streams (anticipated) or non-periodical streams (not anticipated, event triggered)  
• High reliability, fault recovery time not to affect the industrial service                                                                 |                                                                                                                                 |
| Access Network                | 3) Connecting the field devices directly                                                            | • Field devices to access different network with different interface                                                                         |                                                                                                                                 |
| Field Device Side             | 1) Protocol stack integration                                                                      | • Network protocol stack integration with field device  
• Field devices to be accessed with security                                                                                     |                                                                                                                                 |

**Diagram: E2E Network / Protocol Involved, from vPLCs to Field Devices, Challenges**

- **Controller Side**
  - Virtualized PLC instances
    - Virtualized PLC 1
    - Virtualized PLC 2
    - Virtualized PLC 3
    - Virtualized PLC n
  - Protocol stack integration

- **Industrial Backbone Network**
  - Transferring different kind of streams
  - IT / OT network

- **Access Network**
  - Connecting the field devices directly

- **Field Device Side**
  - Protocol stack integration

- **Other Edge Applications**
  - Industrial Campus Data Center

- **Campus Network / Factory Network (example)**
Possible Aspects for Further Discussion

➢ The Virtualized PLC is the identified trend, many industry automatic venders are boosting the evolution to vPLC.

➢ The vPLC will be deployed remotely and centrally. The whole industrial campus network and the protocol integrated by devices / systems might be involved to assure the QoS for the industrial services.

➢ How the industrial campus network to implement and support the vPLC? There are several points could be analyzed based on such end to end scenarios as followings:

   □ Low latency and Determinism
   □ High reliability
   □ Protocol stack integration
   □ Network interface access
   □ Security access
   □ Etc.
Call for Interest to Discuss and Initiate a Work Item

➢ Call for interest to discuss about the scenarios and possible technologies evolution.
   □ From the end to end routine of industrial campus network which connects vPLCs and filed devices, there are different kind of networks / protocols involved (e.g. TSN, existing industrial field bus based on Ethernet or non-Ethernet, etc.).
   □ Based on the current status of the different networks / protocols, how to support to vPLCs scenarios?
   □ Is there any gaps respectively for each related network, bus, protocol?
   □ There might be possible optimization directions to be studied and analyzed.

➢ In the fullness to time and discussion, to initiate a new Work Item within Nendica to develop an IEEE 802 Nendica Report.
   □ To analyze the end to end industrial campus network / protocol for vPLC.
   □ To analyze the challenges of the end to end industrial campus network / protocol to support vPLC.
   □ To frame high-level solutions to issues and challenges.
   □ Possible standardization considerations.
   □ Other aspects, etc..
Thank you.