Project Documentation

TCP Diagnostics Tool for Device Level Ring (DLR) Circuits

Pringles Factory, Mechelen

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Date: July 29, 2025

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List of Abbreviations

AOI Add-On Instruction

CIP Common Industrial Protocol

DLR Device Level Ring

HMI Human–Machine Interface

PLC Programmable Logic Controller

SCADA Supervisory Control and Data Acquisition

VFD Variable-Frequency Drive

Executive Summary

Pringles' Mechelen facility relies on thirty-six Device Level Ring (DLR) networks to keep its production lines running. Until 2025, no plant-wide diagnostic tool existed to reveal Ethernet or ControlNet communication failures inside these rings; breakdowns were discovered only after they stopped a line, and tracing the fault could take hours.

During my one month internship I developed and deployed a *TCP Diagnostics Tool* that now:

- Collects real-time metrics (CIP timeouts, link status, media errors, etc.) from every node via a custom PLC Add-On Instruction (AOI).
- Pushes those metrics to the existing FactoryTalk View HMI through automatically generated parameter files.
- Highlights any compromised component with a red indicator and logs events for later analysis.

The result is an **exponential reduction in average troubleshooting time**, less unplanned downtime, and a scalable foundation for future automated alerting and performance analytics.

Chapter 1

Introduction

1.1 Background

The factory's DLR topology connects PLCs, HMIs, VFDs and sensors across harsh environments where dust and oil gradually degrade cable terminations. Without visibility into packet loss or link errors, engineers had to walk the line, unplug devices, and observe whether production restarted—a labour-intensive approach that no longer met uptime targets.

1.2 Rationale for Development

Although the diagnostic tool now appears essential, several factors explain why it had not been developed earlier:

- **Low Initial Need:** When the factory infrastructure was newer, Ethernet and ControlNet link failures were rare, so the lack of diagnostics had minimal impact on production uptime.
- **Operational Priorities:** Plant engineers were focused on immediate production demands and maintenance tasks, leaving limited resources for proactive development of such a comprehensive monitoring system.
- **High Development Effort:** Designing and deploying a diagnostics tool of this scale required extensive PLC programming, HMI integration, and manual network tracing. These tasks were time-intensive and only became justifiable as the infrastructure aged and failures became more frequent.

These factors highlight why this internship project was both timely and impactful, addressing a growing need that had not yet reached a critical level during earlier years of operation.

1.3 Objective

Provide maintenance and automation teams with a **single screen** that:

- Monitors every ring in real time.
- Pinpoints the exact node or link causing communication loss.
- Generates actionable alerts fast enough to prevent prolonged stoppages.

1.4 Scope

The 2025 internship deliverables included:

- AOI-based data acquisition for all 36 rings.
- HMI faceplates with status indicators, drill-downs and historical logs.
- Automated alert pop-ups.

Out-of-scope items (reserved for future work) were proactive cable health prediction and Stratix switch LED monitoring, which requires hardware replacement.

Chapter 2

System Overview

2.1 Existing Situation

Absent. Prior to this project, there were no diagnostic tools available to monitor the Ethernet connections within the factory's Device Level Ring (DLR) circuits. Network issues were detected only after a breakdown occurred, requiring manual tracing to identify the source of the problem. As the factory infrastructure has aged, dust and fat contamination have increasingly led to corrupted communication paths, making diagnostics more critical than ever.

2.2 New System

The new system introduces an integrated diagnostics solution for all 36 DLR circuits in the factory. The implementation consists of three main components:

1. **AOI in PLC:** A custom Add-On Instruction (AOI) was developed to collect a wide range of diagnostic metrics, including CIP timeouts, link status, and media errors, directly from the PLC.

2. **Parameter Files:** Each DLR circuit was configured with a dedicated parameter file, linking the diagnostic data from the PLC to the HMI interface.

3. **HMI Interface:** A user-friendly interface was created on the existing HMI, enabling engineers to view the diagnostics of all components within a DLR at the click of a button. A clear visual indicator was implemented: the button representing a circuit turns red if any component link is compromised.

With this system, engineers can now instantly access real-time network statistics, rapidly identify communication failures, and minimize downtime during troubleshooting.

2.3 Architecture Diagram

The architecture of the solution can be represented as a three-tier structure:

- **Layer 1 – PLC:** Collects diagnostics via the AOI and processes raw network data.

- **Layer 2 – Parameter Files:** Serve as the data bridge between the PLC and HMI, mapping each DLR circuit's diagnostics.

- **Layer 3 – HMI:** Displays processed diagnostics with visual alerts and allows user interaction.

Chapter 3

Requirements

3.1 Functional

- Detect sent/received packets per node and compute delivery ratio.
- Locate the failing link or device by traversing DLR topology.
- Display real-time status and historical trend lines on the HMI.
- Trigger audible/visual alarms and create AssetCentre events.

3.2 Technical

- Allen-Bradley ControlLogix/CompactLogix PLCs with spare memory.
- FactoryTalk Studio 5000 Logix Designer, FactoryTalk View SE.
- EPLAN P8 for electrical drawings; Rockwell AssetCentre for backups.
- 1 Gb/s managed Ethernet + ControlNet infrastructure.

3.3 Constraints

- AOI memory footprint required splitting diagnostics across three new communication PLCs.
- Wiring documentation was outdated; 20% of paths had to be traced physically.
- All changes had to be hot-swapped during live production windows—zero-downtime constraint.

Chapter 4

Implementation

4.1 Workflow

1. AOI refactored and bench-tested.
2. Deployed AOI to each ring PLC via version-controlled downloads.
3. Parameter File Configuration New parameter files were created, and existing ones adjusted, to link the AOI-generated diagnostic data to the HMI interface.
4. Designed hierarchical HMI screens (overview → ring → node) with colour-blind-safe palettes.
5. Network Path Mapping IP paths for each component were manually traced using EPLAN and on-site verification. This involved navigating the control room network, DLR circuits, and connected components to identify and document their respective IP addresses.
6. Added three communication PLCs; updated I/O tree and routed fibre to control room switch.
7. Testing and Validation Comprehensive tests were performed to verify that the diagnostic data displayed on the HMI was accurate, complete, and easily interpretable by maintenance engineers.

4.2 Toolchain

Studio 5000 Logix Designer, FactoryTalk View SE, Rockwell AssetCentre, EPLAN P8, Stratix 5700 diagnostics.

Chapter 5

Challenges and Lessons Learned

5.1 Key Challenges

1. **Working with Industrial Equipment:** Prior to this project, I had no hands-on experience with industrial hardware such as PLCs (PM99s), VFDs, Stratix switches, drives, and high-voltage electromechanical equipment. Navigating and safely interacting with these systems was both a steep learning curve and an invaluable experience.

2. **Learning Ladder Logic and Structured Text:** I had never programmed PLCs before, particularly using Ladder Logic. This required an intensive effort to learn not only the syntax but also the logic flow unique to industrial automation systems. Additionally, I explored structured text programming to enhance my understanding and effectiveness in implementing the diagnostics logic.

3. **ControlNet vs. Ethernet Paths:** Typically, IP paths are used to collect network data. However, due to the aging infrastructure of the factory, there were instances where data had to be read over ControlNet instead of Ethernet. This required adapting from address-based (Ethernet) to node-based (ControlNet) data collection methods.

4. **PLC Storage Overload:** Many PLCs were operating at near-full capacity, making it challenging to handle the additional data required for diagnostics and logging. This necessitated the integration of additional PLCs to maintain efficiency while scaling the system.

5. **HMI Interface Design:** Designing HMI interfaces from scratch was another challenge, as it was an area where I had no prior experience. Implementing intuitive layouts and clear visual indicators required both learning and iteration.

6. **Inaccurate EPLAN Documentation:** The EPLAN diagrams often did not accurately represent the current physical network. This forced extensive on-site inspections and manual tracing to correctly identify IP paths and component locations.

5.2 Lessons Learned

- **Deep Understanding of Electromechanical Systems:** Gained hands-on knowledge of industrial components such as PLCs, VFDs, and network infrastructure, bridging the gap between theory and real-world application.

- **Adaptability and Problem-Solving:** Learned to adjust approaches dynamically, such as switching between Ethernet and ControlNet when required, and working around limitations in documentation and hardware capacity.
- **HMI and PLC Programming Skills:** Developed skills in Ladder Logic, structured text programming, and HMI interface design using FactoryTalk View.
- **Perseverance Under Uncertainty:** Learned to persist through repeated trial and error—such as tracing paths dozens of times until finding the correct configuration—without losing momentum.
- **Integration of Complex Systems:** Acquired experience in integrating diagnostics across multiple PLCs, networks, and interfaces, ensuring seamless operation in a live manufacturing environment.

Chapter 6

Conclusion

The diagnostics tool developed during this project transformed DLR troubleshooting from a *reactive, manual process* into a *proactive, one-click operation*. By integrating an optimized AOI, structured parameter files, and an intuitive HMI, the system now gives engineers real-time visibility of all 36 Device Level Rings, enabling rapid identification of link failures and significantly reducing downtime.

The solution also introduced automated alerting and data logging, providing both immediate fault detection and a historical basis for analysis. Despite challenges such as PLC memory constraints, inaccurate documentation, and the steep learning curve of industrial programming, these obstacles became opportunities to acquire hands-on expertise in PLCs, HMI design, and network diagnostics.

Ultimately, this project delivered a scalable foundation for future enhancements—such as predictive analytics and extended monitoring—while strengthening the reliability of the factory's aging infrastructure. Beyond its technical impact, it demonstrated how disciplined learning and collaboration can turn a high-complexity task into a successful, plant-critical system.

Acknowledgements

Thank you to Cedric Vanacker for mentorship, to the maintenance team for countless cable-tracing expeditions, and to the entire Pringles Mechelen staff for trusting an intern with their production network.

Appendix

Due to security and confidentiality policies at the Pringles factory, detailed network configurations, IP address mappings, PLC programs, and other sensitive implementation data cannot be included in this report.

The information presented focuses on the architecture, methodology, and high-level technical details of the project without exposing any elements that could compromise the integrity or security of the factory's industrial systems.