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CENTRALIZED INTERLOCKING (CIXL) FOR MOVING BLOCK RESEARCH PROJECT

SUMMARY

From September 9, 2019, to March 8, 2021, the Federal Railroad Administration (FRA) sponsored Transportation Technology Center, Inc. (TTCI), to develop and analyze a concept for a centralized interlocking (CIXL) system that supports moving block methods of train control, improves overall availability and maintainability, and satisfies the needs of North American railroads.

This CIXL system leverages the Quasi-Moving Block (QMB) functional architecture [2], the intrinsic interlocking performed by Positive Train Control Exclusive Authorities (PTCEA), and train-wayside peer-to-peer communications.

Figure 1 presents the QMB architecture with CIXL. Wayside Status Messages (WSM) handle time critical communications from wayside to trains, relaxing the communication demands between the office and the field as compared to the existing centralized interlocking architectures.

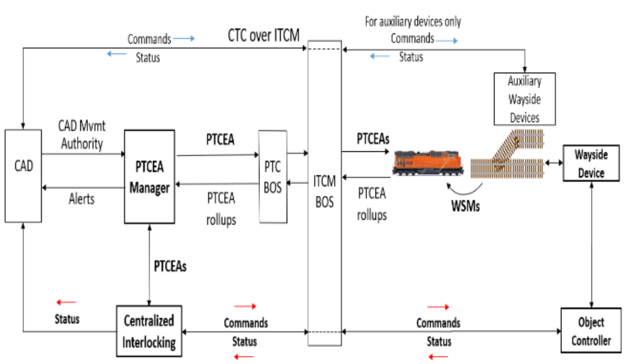

Figure 1. QMB Architecture with Centralized Interlocking (CIXL)

TTCI assessed the feasibility of the proposed CIXL system in areas such as hardware, software, communications, as well as Reliability, Availability, and Maintainability (RAM) implications [1]. The feasibility assessment indicated that the proposed system should be capable of working with the existing technology as well as improving the overall system maintainability, resulting in increased system availability; however, the benefits could be marginal because no hardware simplification is achieved in the field. Thus, the CIXL system implementation should be analyzed on a scenario-by-scenario basis to identify where the benefits outweigh the costs.

BACKGROUND

TTCI identified and researched new methods of train control that have the potential to enhance railway safety, reliability, and operational performance while leveraging Positive Train Control (PTC) technology.

The currently implemented form of PTC technology, referred to here as Overlay PTC (O-PTC), has evolved into three new modes of train control: Enhanced Overlay PTC (EO-PTC), Quasi-Moving Block (QMB), and Full Moving Block (FMB).

Both the QMB and FMB concepts use the exclusive non-overlapping movement authority PTCEA to grant movement authority to each train in the territory. Office functions manage the creation and safety validation of the PTCEAs that, because of their non-overlapping property, can perform core interlocking functions.

As a spin-off of TTCI's QMB project, the creation of the current research project was to design the concept of operations for a CIXL system, in which the execution of the interlocking functions is in the office instead of through current wayside implementations. The motivation for this change is the potential to leverage core interlocking functions that will have already been implemented in the office as part of QMB as well as to eliminate redundant field interlocking functions.

OBJECTIVES

The objectives of this project were to:

- Understand the status, direction, and possible applications of the technology of existing solutions that implement centralized interlocking
- Identify the variety of configurations of field interlocking systems in use on North American railroads today
- Develop the CIXL system for moving block concept operations and a high-level implementation/migration plan for the deployment of the system
- Assess the feasibility of the proposed CIXL system concept

METHODS

TTCI completed the following tasks:

1. **Perform a Technology Survey.**
   TTCI identified existing solutions that would implement centralized interlocking based on publicly available sources, and gathered and analyzed the available information from those sources. The initial data analysis showed that additional details about the solutions were needed for the purpose of the project.

   Then, TTCI issued a Request for Information (RFI) to five signaling system suppliers with a presence in North America, to collect additional details about the identified solutions that would complement the initial findings. The RFI requested multiple details about the solutions including the following: architecture, hardware, software, communications, interfaces, safety, maintainability, failure modes, provider experience, and applicability to moving block train control methods.

   TTCI analyzed the information received in the responses and used it to generate the results and conclusions of the task.

2. **Perform an Inventory of Control Point (CP) Topologies and Functions.**
   TTCI reviewed documentation about railroad signaling systems, especially in areas related to the operations of CPs and field interlocking. Based on this review, researchers prepared a questionnaire and sent it to the Railroads part of the Advisory Group (AG) to gather details about those systems that could influence or that must be included in the concept of a CIXL system.

   The questionnaire included questions about the size of railroad operations, control point topologies and functions, code line systems in use, network operations and failover recovery process, and the signaling system monitoring and maintenance process.

   TTCI compiled the responses and analyzed them, as well as followed up with the railroads to clarify or expand the information in the responses.

3. **Develop a CIXL System Concept of Operations**
   TTCI developed a CIXL system concept of operations that included architecture, features, functions, failure modes, and a high-level implementation plan of the CIXL system.

   To define the CIXL system functions, each CP function, identified in the inventory of the CP functions subtask, was individually analyzed to determine whether it could be moved to the office and how to provide the same functionality when implemented in the office.

The high-level CIXL system implementation/migration plan describes the key tasks that need to be performed when implementing and deploying CIXL, and the different approaches that can be selected by a railroad, based on its specific needs.

4. **Develop a CIXL Feasibility Assessment.**
TTCI assessed the feasibility of the proposed CIXL concept. The analysis included the following: whether the proposed concept would result in RAM improvements; the communication needs of the proposed architecture; the potential reduction in costs due to field hardware simplification, if any; and whether current hardware and software technologies can satisfy CIXL functional, performance, and safety needs.

CONCLUSIONS

TTCI based the proposed CIXL system on the concept that the creation of PTCEAs are in QMB with vital interlocking functionality, which grants movement authority directly to trains. It also leverages the peer-to-peer communications between the trains and Wayside Interface Units that broadcast the status of wayside devices through WSM.

This architecture allows a train to compare its PTCEA with wayside conditions and apply the most restrictive condition out of the two, relaxing the office–wayside communication demands, as compared to conventional centralized interlocking solutions. Researchers identified that the relaxation of office-wayside communication demands as loose office-wayside coupling.

The two main components of the CIXL system architecture are the Office Component (CIXL-O) and the Field Component (CIXL-F).

The feasibility assessment indicates that the proposed CIXL system is attainable both from the hardware and software needs perspectives without requiring new technologies to be developed. It also suggests that the CIXL communication needs should not exceed those of Centralized Traffic Control (CTC) over Interoperable Train Control Messaging (ITCM).

The qualitative RAM analysis concluded that, even though the proposed CIXL solution can simplify CP software and very likely improve the maintainability of system components, resulting in overall higher system availability, the improvements might be marginal. No reduction in CP hardware was found to be attributable to the CIXL system.

A quantitative RAM analysis is needed to prove or discard the benefits of the proposed system, especially regarding maintainability of the system, since the performed qualitative analysis did not provide incontestable evidence to support or reject the significance of the benefits.

The CIXL system implementation should be analyzed on a scenario-by-scenario basis to identify if the benefits outweigh the implementation costs.

The scenarios where it is more likely that this will occur are:

- Territories where future changes in track configurations are likely. If the changes include CP configuration modifications or additions, it is less costly to implement the CIXL system while taking advantage of those required modifications.
- New signaled QMB territory or territory with greenfield signaling deployments. These territories are candidates for the CIXL system since it is less costly to implement the CIXL system and QMB together rather than both separately.
- Territory where FMB is or will be implemented. These are also candidates for the CIXL system since field the CIXL system is not practical

with FMB (i.e., fixed block track circuits will be eliminated).

Currently available centralized interlocking solutions generally do not satisfy the needs of Class I railroads in areas such as compatibility and interfacing with PTC moving block train control technologies (e.g., QMB and FMB), office-wayside loose coupling design, and standard interfaces with other office systems.

The high level-implementation plan identified that the CIXL system CPs in boundaries with field interlocking territories need to include the Track Code Generation function to coordinate with field CIXL system CPs and to allow trains to have a seamless transition between territories. Additionally, it is recommended that reduced Track Code Generation functionality be retained at all CPs for the benefits they provide in regard to maintenance, set-up, and detection performance.

REFERENCES

[1] Vieira, Paulo, A. P. (2020). *Higher Reliability and Capacity Train Control*. In Press.

[2] Kindt, Joel, B. P. (2020). *Quasi-Moving Block Train Control.* In Press.

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KEYWORDS

Centralized interlocking system, CIXL, Quasi-Moving Block, QMB, Positive Train Control, PTC, Communications-Based Train Control, CBTC, control point, CP, Wayside Status Messages, WSM, railroad, train control

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