Interoperable Positive Train Control – Update on FRA Tests on Communication-Based Signaling Interoperability as defined by AREMA C&S Manual.

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Abstract:

This paper updates the status of a system that uses new technologies to evolve proven signaling principles and safety-critical architectures to achieve the safety, cost and performance benefits of positive train control systems. An overview of the proposed system and related AREMA Manual Parts was presented at the AREMA C&S Technical Conference in 2007. AREMA Committee 37 has been developing a set of Recommended Practices to specify system architecture, communications protocols, message contents and infrastructure databases as a way of achieving interoperability. Operation is based on applying existing signaling principles, as recommended in the current AREMA C&S Manual, and through modification of existing designs of safety-critical (vital) equipment currently used in revenue service.

The Federal Railroad Administration has now awarded a grant for demonstration of the system. This project covers development of a test environment and obtaining equipment from multiple suppliers demonstrating the overall system architecture as well as verifying that the Communication-Based Signaling Manual Parts from AREMA allow interoperability to be achieved.

This paper will provide a brief review of the architecture, communications, safety and operational benefits. Status of the Manual Parts being created by AREMA committee 37 will be updated. The paper will describe the FRA project goals, the testing environment and equipment, the test plans, and status of the project.

Communications-Based Signaling is a system based on using new technologies such as wireless data communication, and on-board location systems, to achieve cost-effective systems with a similar level of safety that conventional wayside-based signal systems achieve today; without the need to maintain the underlying method of operation. Most of the communications-based systems being tested today are overlay systems, and are thus dependent on the existing method of operation (either train orders or conventional cTc) to achieve their safety. CBS extends the usefulness of those systems by providing the safety needed to enhance the existing method of operation, thus allowing railroads economic benefit as well as a safety benefit.

The CBS interoperability idea started at an AREMA C&S conference in 2005 when Railroad signaling leaders asked AREMA committee 37 (Signaling and Train Control) to consider developing a set of Recommended Practices for interoperability of radio-based signaling. AREMA committee 37 consists of representatives from railroads, manufacturers, consultants, and regulators. A sub-group of people with expertise in the area was formed to move the project forward. One of the more interesting tasks was getting the major North American suppliers of safety-critical signaling equipment to agree to support these Recommended Practices, including modifying their equipment to meet them in response to market demand. Surprisingly, the suppliers quickly agreed that this was the best approach to support the railroads need for interoperability.

After substantial work, the first set of Manual Parts have been approved by the full membership of AREMA committee 37 and will be published in the 2009 AREMA C&S Manual, available in the fall of 2008. Following is an overview of the Manual Parts. (At the time of this writing, it is assumed that they will be published in a new section of the AREMA Manual (Section 23)).

23.2.1 Recommended Functional Requirements of a CBS System.

This section defines the functional requirements for a Communication-Based Signaling (CBS) system, including safety-critical train protection functions and train operation functions. Systems may vary widely in complexity and not all functions are required for all systems.

23.2.2 Recommended RAMS, Environmental and Other Requirements for Signaling Systems Using CBS Architecture.

This manual part defines the recommended reliability, availability, maintainability, safety, environmental, electromagnetic compatibility, and quality assurance requirements for the CBS system.

For the CBS system, there is no difference recognized between a safety-critical system and a vital system as others attempt to do. In both cases, you have to analyze the functions and make sure that any credible failures (and secondary failures) result in a safe state being maintained. Basic subsystems will be built on platforms already in use to accomplish vital functions (e.g. interlocking controllers, onboard controllers, etc.). Use of signaling philosophy and existing platforms provide a substantial advantage in verifying the safety of the system.

23.3.1 Recommended Design Guidelines for a CBS System

This manual part defines the system architecture and the interfaces for a system design based on conventional signaling principles as needed to meet the functional requirements specified in Section 23.2.1

23.4.1 Recommended Communications Protocols for a CBS system

This manual part defines the recommended system communication protocols without going into specific radio or network systems. Use of ATCS protocols and addressing is recommended to meet the safety and performance requirements, as well as to leverage the large amount of existing addressing schemes currently in use and the ATCS protocol expertise. These addresses and protocols can be used over any type of communication systems, not necessarily an ATCS radio system. Given the rate of change in communication technology, this approach allows use of any desired communication framework, while maintaining the interoperability and safety requirements.

23.4.2 Recommended Communications Messages for a CBS System

This manual part defines the recommended system messages (i.e. what information are you communicating between users) used between subsystems of the CBS system. Detailed message contents are included within the manual part. Samples of the messages defined include

- Train Location / Database Revision / Temporary Speed Restriction Information
- Governing Aspect / Switch Position
- Temporary Speed Restriction List
- Switch Position

CBS.5.1 Recommended Onboard Database Guidelines for a CBS system

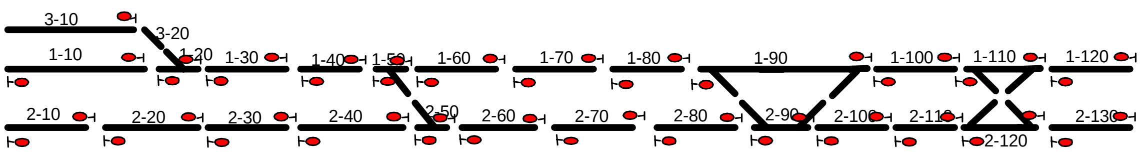
This manual part defines the structure and content of the onboard database to facilitate interoperability. It includes the naming structure for each track section, switch, signal, etc based upon ATCS addressing techniques, as well as the necessary links to define how the various components are linked together.

Late last year, the Federal Railroad Administration (FRA) (www.fra.dot.gov) provided a grant (through the Office of Railroad Development) to demonstrate the operation of an Interoperable Communication-Based Signaling (ICBS) system as defined by AREMA Recommended Practices on Communication-Based Signaling (CBS). The grant takes the form of a cooperative agreement between the Railroad Research Foundation (www.railroadresearch.org) and the FRA. This includes demonstrating the ability of multiple suppliers to achieve and demonstrate interoperability by following the Recommended Practices. The grant is being administered through the Railroad Research Foundation, who subcontracts with the suppliers, project manager, and the supplier of the integration facilities and test environment. Additional background information on the project can be found at www.billpetit.com and selecting the icbs tab.

The FRA grant covers a laboratory demonstration of the system with each of the participating suppliers providing interoperable equipment based on the AREMA Manual

Parts. This simulation effort is part of a pathway to a fully interoperable system and is complementary with other standards work being done by the industry. General Electric Transportation Systems (GETS), Safetran Systems Corporation (SSC), and Union Switch & Signal (US&S) will each have a portion of their expenses paid through the grant. Alstom Signals has joined the project after it's original start and is contributing toward completion of the project. Critical Link (www.criticallink.com) has been contracted to provide the test environment, including simulators, physical interfaces, and integration support.

The territory to be simulated consists of 4 contiguous segments, each with double track. Each section contains one siding, one single crossover, one universal crossover and one scissors crossover.   Following is an example of the territory to be controlled by a supplier. Each supplier will have a similar territory to control, and the overall territory will have 4 of these sections operating contiguously (i.e. a vehicle supplied by a single supplier can move seamlessly across all 4 sections).



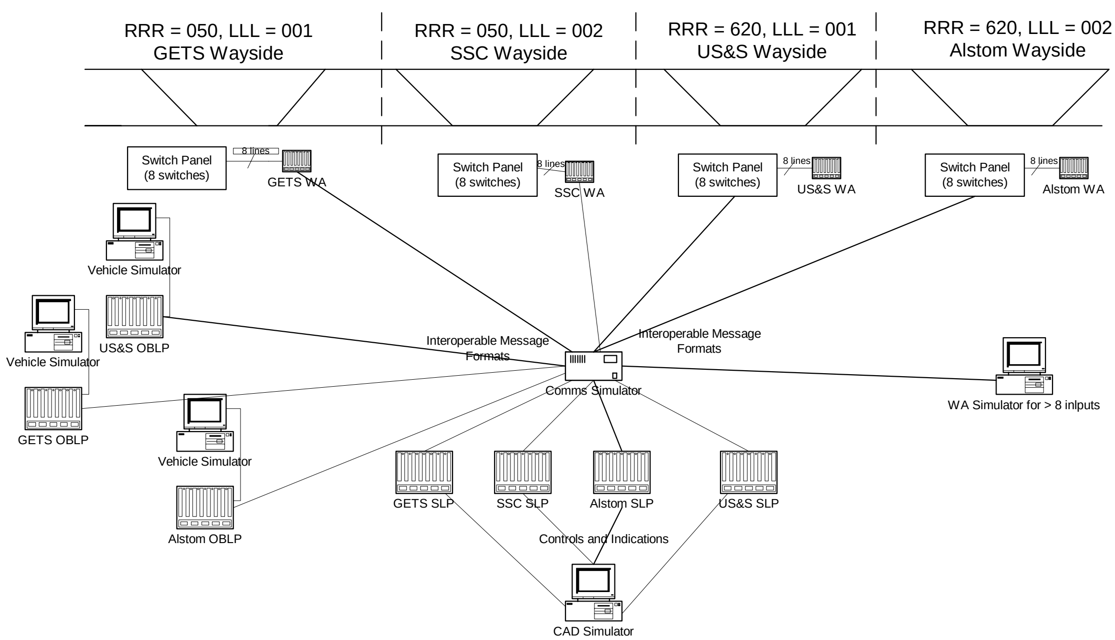
Following is a partial example of the database that is used to represent the territory. Starting from the left you can see the specific identity of the block currently being occupied by the head of the train. This is used as the entry point into the database. For example the block labeled 1-10 above (on the left side of the diagram) identifies track 1, block number 00010. This correlates to the block ID 100010 in row 13 of the table below. (The lead portion of the address for all the blocks consists of the RRR.LLL ATCS address, which specifically identifies the Railroad Number and Line Number being operated on). Since all of the territory being discussed is on the same RRR.LLL section, that portion of the address is not included in what is shown.   Methods of transitioning between RRR.LLL segments are included in the Manual Parts.

Once you know the block being occupied, you can use the database to determine Lat/Long information, curvature, grade, identification of any switch located within the block, civil speed, block length, governing signal aspects for that block, as well as information regarding which block will be entered next along with its governing signal information. The block to be entered next is further conditioned on whether you are traveling UP or DOWN (as defined in the Manual Part) and the position of a switch in the block. The blocks can be further divided into subsections, which allows multiple sections to be defined for grades, curvatures, civil speeds, etc.

Row Number	Track Section (Block ID)	Track Sub-section	Sub-section Type	Ck Address	Status	St Lat	St Lon	End Lat	End Lon	St MP	End MP	Block Length (feet)	Grade	Curve	Curve Length	Civil spd	Track Section & Subsection UP	Track Section & Subsection DN	Sig Up	Sig Up type	Sig Dn	Sig DN Type
12	199900	00	99	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	99999	0	0	0	0	10001000	00000000	0	0	0	0
13	100010	00	17	0	0	43.0500	76.0000	43.0500	76.0259	0.0000	1.1364	6000	0	0	0	060	10002001	19990000	001.01.01	A	001.01.02	A
14	100020	01	03	001.03.01	0011(N)	43.0500	76.0259	43.0500	76.0272	1.1364	1.1932	300	0	0	0	060	10002002	10001000	001.01.04	C	001.01.05	C
15	100020	01	03	001.03.01	1100(R)	43.0500	76.0259	43.0500	76.0272	1.1364	1.1932	300	0	0	0	030	10002002	10001000	001.01.04	C	001.01.05	C
16	100020	02	03	001.03.01	0011(N)	43.0500	76.0272	43.0500	76.0274	1.1932	1.2027	50	0	0	0	060	10003000	10002001	001.01.04	C	001.01.05	C
17	100020	02	03	001.03.01	1100(R)	43.0500	76.0272	43.0500	76.0274	1.1932	1.2027	50	0	0	0	030	10003000	10002003	001.01.99	C	001.01.05	C
18	100020	03	03	001.03.01	0011(N)	43.0500	76.0259	43.0500	76.0272	1.1364	1.1932	300	0	0	0	030	10002002	30001000	001.01.99	C	001.01.05	C
19	100020	03	03	001.03.01	1100(R)	43.0500	76.0259	43.0500	76.0272	1.1364	1.1932	300	0	0	0	030	10002002	30001000	001.01.99	C	001.01.05	C
20	100030	00	01	0	0	43.0500	76.0274	43.0500	76.0533	1.2027	2.3390	6000	0	0	0	060	10004000	10002002	001.01.06	A	001.01.07	A
21	100040	00	01	0	0	43.0500	76.0533	43.0500	76.0791	2.3390	3.4754	6000	0	0	0	060	10005001	10003000	001.01.08	A	001.01.09	A
22	100050	01	02	001.03.02	0011(N)	43.0500	76.0791	43.0500	76.0793	3.4754	3.4848	50	0	0	0	060	10005002	10004000	001.01.10	C	001.01.11	C
23	100050	01	02	001.03.02	1100(R)	43.0500	76.0791	43.0500	76.0793	3.4754	3.4848	50	0	0	0	030	10005003	10004000	001.01.10	C	001.01.39	C
24	100050	02	02	001.03.02	0011(N)	43.0500	76.0793	43.0500	76.0800	3.4848	3.5133	150	0	0	0	060	10006000	10005001	001.01.10	C	001.01.11	C
25	100050	02	02	001.03.02	1100(R)	43.0500	76.0793	43.0500	76.0800	3.4848	3.5133	150	0	0	0	060	00000000	10005001	00000000		001.01.11	C

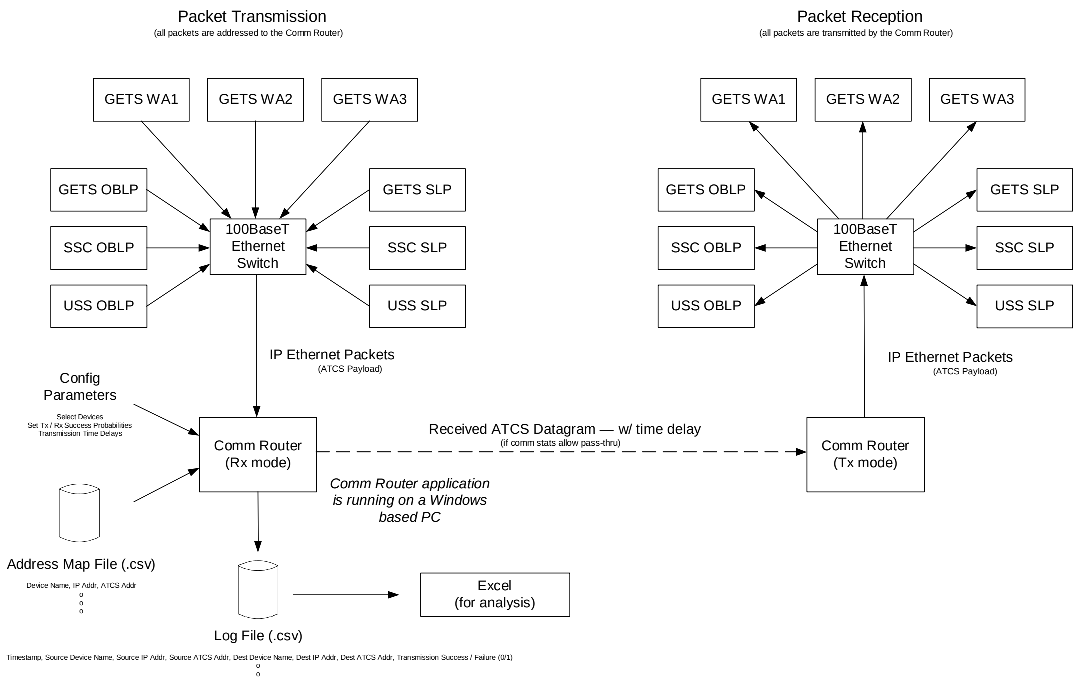
For the demonstration project, a dispatch office based on existing US&S control office technology provides simulated office control for routing trains and tracking movement. Onboard Logic Processors (OBLP) are being provided by Alstom, GETS and US&S; and will be based on their existing onboard platforms. A Vehicle Simulator will be used for each of the OBLP's for controlling the trains' movement. Each of the four suppliers are providing both Signaling Logic Processors (SLP) and Wayside Appliance controllers (WA), based on their existing interlocking controllers or object controllers. The SLP's perform the signaling logic necessary to move the trains through the territory and interface to the office over a standard US&S GENISYS interface. The WA's are used to control and monitor wayside devices, such as switches.

The following diagram shows the overall architecture of the simulation.



Communications will use the messages and protocols defined in the AREMA Manual Parts. The messages will be transported over an IP network through a communications simulator that will be used to introduce errors and limit bandwidth to that which would be provided by various over the air RF communication infrastructures.

The following diagram shows dataflows for the communication packets. (Subsystems are named for example purposes only. All 4 suppliers will interconnect in a similar manner).



When fully integrated, the demonstration will show the ability of trains controlled by different suppliers OBLP's (each simulating a different railroad) to seamlessly move through the 4 territory sections, each of which is controlled by equipment from a different supplier. Each supplier will use a common database (as defined in the Manual Parts) for describing the territory. Demonstrations of the system operation for interested parties are currently planned for the end of this year. For additional information on the project or the CBS architecture, please visit www.billpetit.com and select the ICBS link.

As expected, we are learning new information as the detailed designs of the subsystems and messages are being implemented by each of the suppliers. Continuous communication among the participants keeps everybody aware of corrections or enhancements that are necessary for the successful implementation of the project. Lessons learned from this demonstration project will be used to enhance and expand the Manual Parts, subject to committee approval. Status reports are provided to AREMA Committee 37, as well as other interested parties, such as the AAR Railway Electronics Standards Committee (RESC).

Successful completion of this demonstration will show a high level of cooperation among the principal suppliers of signaling systems for North American railroads toward implementing an interoperable system that should serve the railroads well for the long-term future. The CBS approach can be viewed either as a complementary enhancement or, in some cases, an alternative to overlay systems currently being tested by some North American railroads. Overlay systems are safety justified based on the underlying method of operation being maintained, whether that underlying method be rules-based (e.g. dispatcher issued train orders) or signals-based (cTc). Without the ability to change the underlying method of operation, it becomes more difficult to achieve operating efficiencies such as closer spacing, increased velocity, or the ability to support following moves between switching points. Since CBS is based on well-accepted signaling principles, and implementations are based on proven safety-critical architectures (many already in revenue service), it can be used as a stand-alone system allowing replacement or enhancement of the existing method of operation. Removing the physical limitations of existing wayside-based cTc systems provides for improved performance (e.g. ability to increase traffic density by shortening block length or by increasing the number of signal aspects available). Additional capabilities through the use of digital radio transmission allows for continuous on-board display of signal aspects, allowing them to be updated mid-block, as well as providing continuous speed enforcement.