(57) Abrégé/Abstract:
Systems and methods for controlling rail vehicle data communication are provided. In one embodiment, a multiple-unit rail vehicle system includes a first rail vehicle including a first wireless network device to detect a wireless network. The wireless network is provided by a wayside device. The rail vehicle further comprises a first communication management system to send, through the wireless network, a data communication to a second rail vehicle of the multiple-unit rail vehicle system.
Title: METHODS AND SYSTEMS FOR DATA COMMUNICATIONS FOR MULTIPLE-UNIT RAIL VEHICLES

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METHODS AND SYSTEMS FOR DATA COMMUNICATIONS FOR
MULTIPLE-UNIT RAIL VEHICLES

FIELD

[0001] The present disclosure is directed to methods and systems for controlling rail vehicle data communications.

BACKGROUND

[0002] A set of vehicles under multiple-unit (MU) control, such as a consist of rail vehicles, includes a plurality of vehicles for providing power to propel the consist that are controlled from a single location. Typically, the vehicles are spread throughout the consist to provide increased efficiency and greater operational flexibility. In one example configuration, control data generated at a lead control vehicle is sent through a dedicated, narrow-band radio link to the other, remote vehicles, to control operation of the consist from a single location.

[0003] However, under some conditions, radio transmissions between the lead vehicle and the remote vehicles are lost or degraded. For example, on some terrain, long consist configurations lose direct line-of-site between remote vehicles, and radio transmission signals do not properly reflect off of the surrounding terrain to reach the remote vehicles, resulting in a loss of data communication. Such periods of lost data communication result in reduced performance capability, increased fuel consumption, and an overall reduction in reliability of operation of the consist.
BRIEF DESCRIPTION OF THE INVENTION

[0004] Accordingly, to address the above issues, various embodiments of systems and methods for controlling rail vehicle data communications are described herein. For example, in one embodiment, a multiple-unit rail vehicle system comprises a first rail vehicle including a first wireless network device to detect a wireless network. The wireless network is provided by a wayside device. The rail vehicle further comprises a first communication management system to send, through the wireless network, a data communication to a second rail vehicle of the multiple-unit rail vehicle system. By relaying data communications between rail vehicles through a wireless network, the likelihood of a loss in data communication between the rail vehicles can be reduced relative to a direct radio link. For example, the wireless network provides a greater coverage range that increases the likelihood of receiving a transmitted data communication. Moreover, by employing the wireless network communication path as well as the direct radio link communication path, data communication diversity techniques can be employed to accommodate varying operating conditions. In this way, the reliability of rail vehicle data communications can be improved.

[0005] This brief description is provided to introduce a selection of concepts in a simplified form that are further described below in the detailed description. This brief description is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter. Furthermore, the claimed subject matter is not limited to implementations that solve any or all disadvantages noted in any part of this disclosure.
BRIEF DESCRIPTION OF THE DRAWINGS

[0006] The present invention will be better understood from reading the following description of non-limiting embodiments, with reference to the attached drawings, wherein below:

[0007] FIG. 1 is schematic diagram of an example embodiment of a rail vehicle system of the present disclosure.

[0008] FIG. 2 is a flow diagram of an example embodiment of a method for relaying data communications through a wayside wireless network between remote rail vehicles of a multiple-unit rail vehicle system.

[0009] FIG. 3 is a flow diagram of an example embodiment of a method for relaying data communications through a wayside wireless network between remote rail vehicles of a multiple-unit rail vehicle system in response to a loss of data communications.

[0010] FIG. 4 is a flow diagram of an example embodiment of a method for transferring control to a rail vehicle of a multiple-unit rail vehicle system through a wayside wireless network.

[0011] FIG. 5 is a flow diagram of an example embodiment of a method for distributing operating tasks to different remote resources of a multiple-unit rail vehicle system through a wayside wireless network responsive to resource degradation.

[0012] FIG. 6 is a flow diagram of an example embodiment of a method for distributing operating tasks to different remote resources of a multiple-unit rail vehicle system through a wayside wireless network responsive to a change in operating load.
DETAILED DESCRIPTION

[0013] The present disclosure is directed to systems and methods for data communications between remote rail vehicles of a multiple-unit rail vehicle configuration. More particularly, the present disclosure is directed to systems and methods for providing data communications through different data paths based on operating conditions. For example, in a multiple-unit rail vehicle configuration where a lead control rail vehicle remotely controls operation of the other rail vehicles, data communications are sent from the lead control rail vehicle directly to the other rail vehicles through a dedicated, narrow-band radio link, or the data communications are sent relayed through a wireless network provided by a wayside device to the remote rail vehicles based on operating conditions. In one example, data communications are relayed through the wireless network provided by the wayside device in response to not receiving a confirmation from a remote rail vehicle of receiving a data communication sent through the radio link. In another example, when the rail vehicle is in range to recognize the wireless network provided by the wayside device, data communications are relayed through the wireless network, and when the rail vehicle does not recognize the wireless network, the same data communications are sent through a different data communication path (e.g., data radio). By directing data communications through different data communication paths based on operating conditions, the same data can be sent through different communication paths and the remote rail vehicles in a multiple-unit rail vehicle configuration can remain in communication even as operating conditions vary. Accordingly, data communication between remote rail vehicles is made more reliable.
[0014] FIG. 1 is a schematic diagram of an example embodiment of a vehicle system, herein depicted as a rail vehicle system 100, configured to travel on a rail 102. The rail vehicle system 100 is a multiple-unit rail vehicle system including a plurality of rail vehicles, herein depicted as a lead control rail vehicle 104 and a remote rail vehicle 140. The lead control rail vehicle 104 and the remote rail vehicle 140 represent rail vehicles that provide tractive effort to propel the rail vehicle system 100. In one example, the plurality of rail vehicles are diesel-electric vehicles that each include a diesel engine (not shown) that generates a torque output that is converted to electricity by an alternator (not shown) for subsequent propagation to a variety of downstream electrical components, such as a plurality of traction motors (not shown) to provide tractive power to propel the rail vehicle system 100.

[0015] Although only two rail vehicles are depicted, it will be appreciated that the rail vehicle system may include more than two rail vehicles. Furthermore, the rail vehicle system 100 may include rolling stock that does not provide power to propel the rail vehicle system 100. For example, the lead control rail vehicle 104 and the remote rail vehicle 140 may be separated by a plurality of units (e.g., passenger or freight cars) that do not provide propulsion. On the other hand, every unit in the multiple-unit rail vehicle system may include propulsive system components that are controllable from a single location. The rail vehicles 104, 140 are physically linked to travel together along the rail 102.

[0016] In the illustrated embodiment, the lead control rail vehicle 104 includes an on-board computing system 106 to control operation of the rail vehicle system 100. In particular, the on-board computing system 106 controls operation of a propulsion system
(not shown) on-board the lead control rail vehicle 104 as well as provides control commands for other rail vehicles in the rail vehicle system, such as the remote rail vehicle 140. The on-board computing system 106 is operatively coupled with a communication management system 114 that, in turn, is operatively coupled with a plurality of communication devices 120. When the on-board computing system 106 generates data communications (e.g., control commands), the communication management system 114 determines which communication path (or device) to use for sending the data communications to the remote rail vehicle 140.

[0017] In an embodiment, the on-board computing system 106 includes a positive train control (PTC) system 108 that includes a display 110, and operational controls 112. The PTC system 108 is positioned in a cabin of the lead control rail vehicle 104 to monitor the location and movement of the rail vehicle system 100. For example, the PTC system 108 enforces travel restrictions including movement authorities that prevent unwarranted movement of the rail vehicle system 100. Based on travel information generated by the rail vehicle system 100 and/or received through the plurality of communication devices 120, the PTC system 108 determines the location of the rail vehicle system 100 and how fast it can travel based on the travel restrictions, and determines if movement enforcement is performed to adjust the speed of the rail vehicle 100. The travel information includes features of the railroad track (rail 102), such as geometry, grade, etc. Also, the travel information includes travel restriction information, such as movement authorities and speed limits, which can be travel zone or track dependent. The travel restriction information can take into account rail vehicle system state information such as length, weight, height, etc. In this way, rail vehicle collisions,
over speed derailments, incursions into work zones, and/or travel through an improperly positioned switch can be reduced or prevented. As an example, the PTC system 108 provides commands to the propulsion systems of the lead control rail vehicle 104 as well as to the other rail vehicles, such as the remote rail vehicle 140, to slow or stop the rail vehicle system 100 in order to comply with a speed restriction or a movement authority.

[0018] In one example, the PTC system 108 determines location and movement authority of the rail vehicle system 100 based on travel information that is organized into a database (not shown) that is stored in a storage device of the PTC system 108. In one example, the database houses travel information that is updated by the remote office 136 and/or the wayside device 130 and is received by the communication management system 114 through one or more of the plurality of communication devices 120. In a particular example, travel information is received over a wireless network 134 provided by a wireless access point 133 of the wayside device 130 through a wireless network device 122. In one example, the rail vehicle location information is determined from GPS information received through a satellite transceiver 124. In one example, the rail vehicle location information is determined from travel information received through a radio transceiver 126. In one example, the rail vehicle location information is determined from sensors, such as beginning of rail vehicle location and end of rail vehicle location sensors that are received through the radio transceiver 126 and/or multiple-unit lines 128 from other remote rail vehicles, such as the remote rail vehicle 140 of the rail vehicle system 100.

[0019] The display 110 presents rail vehicle state information and travel information to an operator in the cabin of the lead control rail vehicle 104. In one example, the
display 110 presents a rolling map that provides an indication of the location of the rail vehicle system 100 to the operator. For example the rolling map includes a beginning of rail vehicle location, an end of rail vehicle location, rail vehicle length, rail road track zone, mile post markers, wayside device location, GPS location, etc. Furthermore, the rolling map is annotated with movement authority regulations and speed restrictions.

[0020] The operational controls 112 enable the operator to provide control commands to control operation of the rail vehicle system 100. In one example, the operational controls 112 include buttons, switches, and the like that are physically actuated to provide input. In one example, the operational controls 112 include a touch sensitive display that senses touch input by the operator. For example, the operational controls 112 include a speed control that initiates the sending of control commands to propulsion systems of the different rail vehicles of the rail vehicle system 100. In one example, the speed control includes a throttle input, a brake input, and a reverse input. In one example, the operational controls 112 include an automated control feature that automatically determines control commands based on travel information received by the PTC system 108 to automatically control operation of the rail vehicle system 100.

[0021] The communication management system 114 determines which data communication path to use for sending and receiving data communications between remote rail vehicles of the rail vehicle system 100 based on operating conditions. For example, operating conditions may include availability of a data communications path. If a plurality of data communications paths is available, operating conditions may include prioritization criteria for selecting a data communications path. Non-limiting examples of prioritization criteria include a lowest cost data communications path that is available,
a highest reliability data communications path that is available, a highest bandwidth data communications path that is available, etc. The plurality of communications paths provide redundancy that enables the same data to be sent through different data paths to enable data communication between rail vehicle even as operating conditions vary.

Furthermore, the communication management system 114 manages operation of resources distributed throughout the rail vehicle system 100 and/or resources off-board the rail vehicle system 100 to meet an operational load of the rail vehicle system 100. In one example, the operational load includes processing tasks that are assigned to different computing systems of the rail vehicle system 100, the wayside device 130, and/or the remote office 136. In particular, the communication management system 114 determines which processors are available and assigns processing tasks to available processors to meet the operational load of the rail vehicle system 100. Non-limiting examples of processing tasks include determining location, determining braking distance, determining optimum speed, etc. In cases where processing tasks are performed off-board the rail vehicle system 100, such as at a remote computing system 132 of the wayside device 130, data communications are sent from the lead control rail vehicle 104 (or another rail vehicle) to the wireless network 134 through the wireless network device 122. The remote computing system 132 performs the processing task and the results are sent back to the lead control rail vehicle 104 on the wireless network 134.

In another example, operational load includes a propulsive load that is to be generated by the rail vehicle system 100 to meet a desired speed. In particular, the communication management system 114 determines the propulsive capability of available rail vehicles and relays propulsion system control commands to on-board
computers on selected rail vehicles through the wireless network 134 provided by the wayside device 130 to the selected rail vehicles so as to collectively generate enough tractive power to meet the desired speed. If the speed is lower than the collective capability of the plurality of rail vehicles of the rail vehicle system 100, then control commands are relayed to some selected rail vehicle while others remain dormant. As operation load varies, the control commands can be sent to the dormant rail vehicles to provide additional capability.

[0024] Furthermore, the communication management system 114 switches operational control of the rail vehicle system 100 between on-board computers of different rail vehicles of the rail vehicle system 100 based on operating conditions. In one example, in response to degradation of the on-board computing system 106 on the lead control rail vehicle 104 (the on-board computing system 106 thereby being a degraded computing system), the communication management system 114 commands initialization of an on-board computing system on a different rail vehicle, such as remote rail vehicle 140, to take control of operation of the rail vehicle system 100.

[0025] The communication management system 114 includes a processor 116 and a non-transitive storage device 118 that holds instructions that when executed perform operations to control the communication management system 114. For example, the storage device 118 includes instructions that when executed by processor 116 perform methods described in further detail below with reference to FIGS. 2-6.

[0026] As discussed above, the rail vehicle system 100 is equipped with a plurality of different communication devices 120 that form different data communication paths between rail vehicles of the rail vehicle system 100 as well as data communication paths
off-board the rail vehicle system 100 such as with the wayside device 130 and/or the remote office 136. The communication management system 114 determines which communication device to use for data communications based on operating conditions. The plurality of communications devices 120 includes a wireless network device 122, a satellite transceiver 124, a radio transceiver 126, and multiple-unit lines 128.

[0027] The wireless network device 122 dynamically establishes a wireless communication session with a wireless network, such as the wireless network 134 provided by the wireless access point 133 of the wayside device 130, to send and receive data communications between different rail vehicles of the rail vehicle system 100. As the rail vehicle system 100 travels through different travel zones, the wireless network device 122 detects different wireless network access points provided by wayside devices or other communication devices along the railroad track (rail 102). In one example, a single wireless network covers a travel territory, and different wayside devices provide access points to the wireless network. Non-limiting examples of protocols that the wireless network device 122 follows to connect to the wireless network 134 include IEEE 802.11, Wi-Max, Wi-Fi, etc. In one example, the wireless network communications operate around the 220 MHz frequency band. The wireless network device 122 generates a unique identifier that indicates the rail vehicle system 100. The unique identifier is employed in data communication messages of rail vehicles in the rail vehicle system 100 so that wireless network devices on rail vehicles of the same rail vehicle system appropriately identify and receive message intended for them. By relaying intra-train data communications through the wireless network 134, data communication is made more reliable, especially in conditions where direct radio communication can be lost.
[0028] The satellite transceiver 124 sends and receives data communications that are relayed through a satellite. In one example, the satellite transceiver 124 communicates with the remote office 136 to send and receive data communications including travel information and the like. In one example, the satellite transceiver 124 receives rail vehicle system location information from a third-party global position system to determine the location of the rail vehicle system. In one example, the communication management system 114 assigns processing tasks to a remote computing system 138 at the remote office 136 and the data communications are sent and received through the satellite transceiver 124.

[0029] The radio transceiver 126 provides a direct radio frequency (RF) data communications link between rail vehicles of the rail vehicle system 100. For example, the radio transceiver 126 of the lead control rail vehicle 104 sends a data communication that is received by a radio transceiver on the remote rail vehicle 140. In one example, the rail vehicle system 100 may include repeaters to retransmit direct RF data communications between radio transceivers. In one example, the radio transceiver 126 includes a cellular radio transceiver to enable data communications, through a third-party, to remote sources, such as the remote office 136.

[0030] In some embodiments, the radio transceiver 126 includes a cellular radio transceiver (e.g., cellular telephone module) that enables a cellular communication path. In one example, the cellular radio transceiver communicates with cellular telephony towers located proximate to the track. For example, the cellular transceiver enables data communications between the rail vehicle system 100 and the remote office 136 through a third-party cellular provider. In one embodiment, each of two or more rail vehicles in the
system (e.g., consist) has a respective cellular radio transceiver for communications with other rail vehicles in the system through the third-party cellular provider.

[0031] The multiple-unit (MU) lines 128 provide wired power connections between rail vehicles of the rail vehicle system 100. In one example, the multiple-unit lines 128 include 27 pin cables that connect between each of the rail vehicles. The multiple-unit lines 128 supply 74 Volt direct current (DC), 1 Amp power to the rail vehicles. As another example, the multiple-unit lines supply 110 Volt DC power to the rail vehicles. The power signal sent through the multiple-unit lines 128 is modulated to provide additional data communications capability. In one example, the power signal is modulated to generate a 10M/second information pipeline. Non-limiting examples of data communications passed through the multiple-unit lines 128 includes travel information, rail vehicle state information and rail vehicle control commands, such as reverse, forward, wheel slip indication, engine run, dynamic brake control, etc.

[0032] It will be appreciated that one or more of the plurality of communication devices discussed above may be omitted from the rail vehicle system 100 without departing from the scope of the present disclosure.

[0033] The wayside device 130 may embody different devices located along a railroad track (rail 102). Non-limiting examples of wayside devices include signaling devices, switching devices, communication devices, etc. The wayside device 130 includes the remote computing system 132. In one example, the remote computing system 132 provides travel information to the rail vehicle system 100. In one example, the remote computing system 132 is assigned a processing task by the communication management system 114 in the event that available on-board processing capabilities of
the rail vehicle system do not meet the operational load of the rail vehicle system 100. The wayside device 130 includes the wireless access point 133 which allows the wireless network device 122 as well as wireless network devices on other rail vehicles in range to connect to the wireless network 134. The communication management system 114 onboard rail vehicles of the rail vehicle system 100 dynamically establish network sessions with the wireless network 134 through the wireless network device 122 to relay data communication between rail vehicles of the rail vehicle system 100.

[0034] In some embodiments, under some conditions, information and/or operations are transferred between wayside devices by relaying communication over the network and through the rail vehicle system. For example, data communications are sent from the wayside device 130, through the network 134, to the wireless network device 122, and the data communications are relayed by the wireless network device 122 to a remote wayside device 148 that is in data communication range. In some cases, the rail vehicle system extends the data communication range of the wayside devices due to the length of the consist. In some cases, the wayside device 130 sends data communications through the network 134 to the remote wayside device 148 without relaying the data communications through the wireless network device 122. In one example, two wayside devices are configured to perform similar or equivalent operations, and in response to degradation of one of the wayside devices, the functionality of the degraded wayside device is transferred to the other wayside device, by sending data communications over the wireless network and relayed through the wireless network device of the rail vehicle system.
For example, two signaling light processing units are positioned within communication range of the rail vehicle system, upon degradation of one of the signaling light processing units, processing operations for the degraded signal light processing unit are transferred over the wireless network to the functioning signaling light processing unit to carry out the processing operations in order to maintain operation of the signaling light having the degraded processing unit.

Furthermore, in some cases, functionality or processing operations are transferred from a wayside device to the rail vehicle system. For example, the remote computing system 132 of the wayside device 130 is configured to calculate a braking curve for a section of track. Upon degradation of the remote computing system 132, the wayside device 130 transfers, through the wireless network 134, the brake curve calculation to the on-board computing system 106. Accordingly, the on-board computing system 106 calculates the brake curve in order to maintain functionality that would otherwise be lost due to degradation of the remote computing system 132. As another example, a switch is configured to calculate a setting or block occupancy. Upon degradation of the switch, the setting or block occupancy calculation is transferred, through the wireless network 134, to the on-board computing system 106. By relaying data communications between remote wayside devices through a rail vehicle, processing operation can be transferred between different wayside devices. Moreover, by establishing a wireless network session between a wayside device and a rail vehicle system, wayside device processing operations can be transferred from a wayside device to processing resources of a rail vehicle system. Accordingly, data communications and
processing operations is made more robust since functionality is maintained even upon degradation of a rail vehicle or wayside device component.

[0037] The remote office 136 includes the remote computing system 138. In one example, the remote computing system 138 provides travel information to the rail vehicle system 100, such as a travel database that is downloaded to the on-board computing system 106. In one example, the remote office 136 communicates directly with the rail vehicle system 100 (e.g., through satellite transceiver 124). In one example, the remote office 136 relays data communications through the wireless network 134 of the wayside device 130 to the rail vehicle system 100. In one example, the remote computing system 138 is assigned a processing task by the communication management system 114 in the event that available on-board processing capabilities of the rail vehicle system do not meet the operational load of the rail vehicle system 100.

[0038] In some embodiments, the components in the lead control rail vehicle 104 are replicated in each rail vehicle in the rail vehicle system 100. For example, the remote rail vehicle 140 includes an on-board computing system 144 that is operatively coupled with a communication management system 146 that, in turn, is operatively coupled with a plurality of communication devices 142. For example, the plurality of communication devices includes a wireless network device, a satellite transceiver, a radio transceiver and multiple-unit lines. These components provide equivalent functionality and capability as the instances on the lead control rail vehicle 104. By replicating the components on each rail vehicle, each rail vehicle is capable of communicating and/or controlling the other rail vehicles in the rail vehicle system 100. Accordingly, operation of the rail vehicle system 100 is made more flexible and reliable. Note in some embodiments, one or more
of the communication devices may be omitted from a rail vehicle without departing from the scope of the present disclosure.

[0039] FIG. 2 is a flow diagram of an example embodiment of a method 200 for relaying data communications through a wayside wireless network between remote rail vehicles of a multiple-unit rail vehicle system. In one example, the method 200 is performed by the communication management system 114 of the rail vehicle system 100 depicted in FIG. 1.

[0040] At 202, the method includes determining operating conditions. Determining operating conditions includes determining whether or not an on-board computing system is functioning properly and whether or not the on-board computing system is controlling operation of remote rail vehicles of the rail vehicle system. Determining operating conditions includes determining an availability of data communication paths for the rail vehicle system. Determining operating conditions includes receiving rail vehicle state and location information.

[0041] At 204, the method includes determining if the rail vehicle system is in a coverage range of a wireless network provided by a wayside device. In one example, the wireless network device 122 detects wireless network coverage by receiving wireless network signals from a wayside device. If it is determined that wireless network coverage is detected, the method moves to 206. Otherwise, the method moves to 210.

[0042] At 206, the method includes dynamically establishing a data communication session with the detected wayside wireless network. In one example, establishing the data communication session includes assigning a unique address to the rail vehicle system, so that rail vehicles in the rail vehicle system can identify messages intended for
the rail vehicles as opposed to message intended for another rail vehicle system. The unique address may include a symbol for the rail vehicle system or unique attribute of rail vehicle system.

[0043] At 208, the method includes relaying data communications through the wayside wireless network to a remote rail vehicle of the rail vehicle system and/or a remote wayside device. In one example, the communication management system 114 sends data communications through the wireless network device 122 to the wireless access point 133. Subsequently, the data communications are relayed over the wireless network 134 to a wireless network device of a remote rail vehicle. For example, the wireless access point 133 sends the data communications to the wireless network device of the remote rail vehicle. In one example, the data communications include control commands to remotely control operation of the remote rail vehicle. In one example, data communications are sent from the wayside device 130, over the wireless network 134 and relayed through the wireless network device 122, to the remote wayside device 148.

[0044] At 210, the method includes sending data communication through an alternative communication path to the remote rail vehicle. Since there is insufficient wireless network coverage, the communication management system 114 selects a different communication device to send the data communications to the remote rail vehicle. Insufficient network coverage includes little or no network coverage that would make data communication through the wireless network less reliable. In one example, the communication management system 114 sends data communication through the radio transceiver 126 to the remote rail vehicle. In one example, the communication management system 114 sends data communications through the multiple-unit lines 128
to the remote rail vehicle. Note the same data is sent through the different communication paths to enable data communication between rail vehicles of the rail vehicle system 100.

[0045] The above described method enables intra-train data communications to be sent from one rail vehicle in a multiple-unit rail vehicle system (e.g., consist), relayed through a wayside wireless network, and received by a remote rail vehicle of the multiple-unit rail vehicle system. By relaying intra-train data communications through the wayside wireless network when network coverage is available, the reliability of data communications can be improved by the established data communications session. Moreover, the above-described method enables flexible operation by sending data communications through another communication path when wireless network coverage is not available.

[0046] FIG. 3 is a flow diagram of an example embodiment of a method 300 for relaying data communications through a wayside wireless network between remote rail vehicles of a multiple-unit rail vehicle system in response to a loss in data communications through an alternative data path. In one example, the method 300 is performed by the communication management system 114 of the rail vehicle system 100 depicted in FIG. 1.

[0047] At 302, the method includes determining operating conditions. Determining operating conditions includes determining whether or not an on-board computing system is functioning properly and whether or not the on-board computing system is controlling operation of remote rail vehicles of the rail vehicle system. Determining operating conditions includes determining an availability of data communication paths for the rail
vehicle system. Determining operating conditions includes receiving rail vehicle state and location information.

[0048] At 304, the method includes sending data communications through a selected communication path to a remote rail vehicle in the multiple-unit rail vehicle system. In one example, the selected data communication path includes a direct RF link to the remote rail vehicle, where data communications are sent through the radio transceiver 126.

[0049] At 306, the method includes determining if data communications feedback is received. In one example, data communications feedback includes a confirmation received from the remote rail vehicle indicating that the remote rail vehicle received the data communications. In one example, where the data communications include control commands, the data communications feedback includes an adjustment in operation of the remote rail vehicle. If it is determined that data communication feedback is received, the method moves returns to 304. Otherwise, the method moves to 308.

[0050] In one example, data communications are sent through a direct RF link between remote rail vehicles. However, various conditions may cause a loss of data communications. For example, a rail vehicle system configuration, such as a very long consist where there is a large distance between rail vehicles, may cause a loss of data communications through the direct RF link. As another example, geography, such as terrain that does not reflect a radio signal to a remote vehicle, may cause a loss of data communications through the direct RF link.

[0051] At 308, the method includes relaying data communications through the wayside wireless network to a remote rail vehicle of the rail vehicle system and/or a
remote wayside device. The same data is relayed through the wayside wireless network in response to a loss of data communications by an alternative data communications path. In one example, the communication management system 114 sends data communications to the wireless network 134 through the wireless network device 122. Subsequently, the wireless network 134 relays the data communications to a wireless network device of a remote rail vehicle. In one example, the data communications include control commands to remotely control operation of the remote rail vehicle. In one example, data communications are sent from the wayside device 130, over the wireless network 134 and relayed through the wireless network device 122, to the remote wayside device 148.

[0052] By relaying data communications through a wayside wireless network in response to a loss of data communications by an alternative data communications path (e.g., a direct RF link), intra-train data communication can be achieved between remote rail vehicles even when operating conditions prevent communication by the alternate communications path. Accordingly, intra-train data communications and remote control of rail vehicles in a multi-unit rail vehicle system is made more robust and reliable as operating conditions vary.

[0053] FIG. 4 is a flow diagram of an example embodiment of a method 400 for transferring control to a rail vehicle of a multiple-unit rail vehicle system through a wayside wireless network. In one example, the method 400 is performed by the communication management system 114 of the rail vehicle system 100 depicted in FIG. 1.

[0054] At 402, the method includes determining operating conditions. Determining operating conditions includes determining whether or not an on-board computing system is functioning properly and whether or not the on-board computing system is controlling
operation of remote rail vehicles of the rail vehicle system. Determining operating conditions includes determining an availability of data communication paths for the rail vehicle system. Determining operating conditions includes receiving rail vehicle state and location information.

[0055] At 404, the method includes determining if the on-board computing system is degraded. In one example, the degradation determination is made responsive to setting of a localized flag indicating a component of the on-board computing system is not functioning properly. In one example, the degradation determination is made based on unresponsiveness to control adjustment made manually or automatically. If it is determined that the on-board computing system is degraded, the method moves to 406. Otherwise, the method returns to other operations.

[0056] At 406, the method includes sending a notification, through the wayside wireless network, indicating degradation of the on-board computing system. In some cases, the notification is relayed to other remote rail vehicles of the rail vehicle system. In some cases, the notification is relayed to a remote office. In one example, the notification includes a signal commanding an alarm to sound to notify an operator locally or remotely.

[0057] At 408, the method includes sending a command, through the wayside wireless network, to initialize a remote computing system to control the rail vehicle system. In one example, the initialization command is sent to a remote computing system located off-board the rail vehicle system, such as at a remote office to control the rail vehicle system remotely. In one example, the initialization command is sent to another on-board computing device located in a different rail vehicle of the rail vehicle system.
Since each rail vehicle is equipped with the same or a similar set of components, control of the rail vehicle system can be transferred from an on-board computing system on one rail vehicle to an on-board computing system on another rail vehicle.

[0058] By transferring operational control from an on-board computing system to a remote computing system through the wayside wireless network based on degradation of the on-board computing system, operation control of the rail vehicle system can be maintained even when a controlling on-board computing system becomes degraded. In this way, the rail vehicle is made more robust.

[0059] FIG. 5 is a flow diagram of an example embodiment of a method 500 for distributing operational tasks to different resources of a multiple-unit rail vehicle system through a wayside wireless network responsive to resource degradation. In one example, the method 500 is performed by the communication management system 114 of the rail vehicle system 100 depicted in FIG. 1. In another example, the method 400 is performed by the remote computing system 132 of the wayside device 130 depicted in FIG. 1.

[0060] At 502, the method includes determining operating conditions. Determining operating conditions includes determining whether or not an on-board computing system or a remote computing system of the rail vehicle system is functioning properly. Determining operating conditions includes determining an availability of data communication paths for the rail vehicle system. Determining operating conditions includes receiving rail vehicle state and location information. Determining operating conditions includes determining the collective capabilities of resources of the rail vehicle system. In one example, the collective capabilities include processing capabilities of available computing systems on-board or off-board the rail vehicle system. In one
example, the collective capabilities include available propulsive/braking capabilities of the rail vehicles in the rail vehicle system. For example, the propulsive capabilities include the torque output capability of each traction motor of the rail vehicle system based on operating conditions.

[0061] At 504, the method includes sending, through the wayside wireless network, operational task assignments to distributed resources of the rail vehicle system to meet an operational load. In cases where the operational load is a processing load, processing tasks are assigned to available processing resources of different remote computing systems. In some cases, the remote computing systems are on-board computing system located on remote rail vehicles of the rail vehicle system. In some cases, the remote computing systems are off-board computing systems located at the remote office or in the wayside device. In cases where the operational load is a propulsive/braking load, such as a torque output or brake demand to meet a desired travel speed, the operational tasks include a desired propulsive/brake output to be produced by each remote rail vehicle in order for the rail vehicle system to meet the desired travel speed.

[0062] At 506, the method includes determining if a rail vehicle system or wayside device resource is degraded. In one example, the rail vehicle or wayside device resource includes a processing resource of a computing system the can become degraded or unavailable. In one example, the rail vehicle resource includes a propulsive/brake resource, such as a traction motor or an air brake. If it is determined that the rail vehicle system resource is degraded, the method moves to 508. Otherwise, the method returns to 504.
[0063] At 508, the method includes determining if a spare rail vehicle system resource is available. Under some conditions, the entirety of the capabilities of the rail vehicle system resources are not used to meet the operational load, thus additional resources are available for use. If it is determined that a spare rail vehicle system resource is available for use, the method moves to 510. Otherwise, the method moves to 512.

[0064] At 510, the method includes re-assigning, through the wayside wireless network, the operational task from the degraded rail vehicle system resource to the spare rail vehicle system resource. In one example where the operational task is a processing task, re-assigning includes sending a command for a remote computing system on-board or off-board of the rail vehicle system to perform the processing task. In one example where the operational task is a propulsive/braking output, re-assigning includes sending a command for a spare propulsive/braking resource to adjust operation to meet the propulsive/braking output.

[0065] At 512, the method includes adjusting rail vehicle system operation to reduce the operational load to comply with the reduced capability of the distributed rail vehicle system resources. In one example where the operational load is a processing load, adjusting rail vehicle operation includes cancelling a processing task or delaying a processing task from being carried out until a processing resource becomes available. In one example where the operational load is a propulsive/brake load, adjusting rail vehicle operation includes reducing travel speed or operating a different brake component. Furthermore, in cases where the operational load is less than the collective capability of
the remaining distributed resources, the operational task can be re-assigned to a remaining available resource.

[0066] By re-assigning operational tasks to distributed resources of the rail vehicle system and/or a wayside device in response to resource degradation or unavailability, the operational load is still met by the remaining resources. In this way, the rail vehicle system is made more robust since operation is maintained even when a rail vehicle system resource degrades. Moreover, by sending data communications through the wayside wireless network, which has a high data rate transport capability, the data communication path has the capacity to handle the intra-train data communications.

[0067] FIG. 6 is a flow diagram of an example embodiment of a method for distributing operational tasks to different remote resources of a multiple-unit rail vehicle configuration through a wayside wireless network responsive to a change in operational load. In one example, the method 500 is performed by the communication management system 114 of the rail vehicle system 100 depicted in FIG. 1.

[0068] At 602, the method includes determining operating conditions. Determining operating conditions includes determining whether or not an on-board computing system or a remote computing system of the rail vehicle system is functioning properly. Determining operating conditions includes determining an availability of data communication paths for the rail vehicle system. Determining operating conditions includes receiving rail vehicle state and location information. Determining operating conditions includes determining the collective capabilities of resources of the rail vehicle system. In one example, the collective capabilities include processing capabilities of available computing systems on-board or off-board the rail vehicle system. In one
example, the collective capabilities include available propulsive/braking capabilities of
the rail vehicles in the rail vehicle system. For example, the propulsive capabilities
include the torque output capability of each traction motor of the rail vehicle system
based on operating conditions.

[0069] At 604, the method includes sending, through the wayside wireless network,
operational task assignments to distributed resources of the rail vehicle system to meet an
operational load. In cases where the operational load is a processing load, processing
tasks are assigned to available processing resources of different remote computing
systems. In some cases, the remote computing systems are on-board computing system
located on remote rail vehicles of the rail vehicle system. In some cases, the remote
computing systems are off-board computing systems located at the remote office or in the
wayside device. In cases where the operational load is a propulsive/braking load, such as
a torque output or brake demand to meet a desired travel speed, the operational tasks
include a desired propulsive/brake output to be produced by each remote rail vehicle in
order for the rail vehicle system to meet the desired travel speed.

[0070] At 606, the method includes determining if the operational load is increased.
In cases where the operational load is a processing load, the operational load is increased
when another processing task is generated and needs to be carried out. Non-limiting
examples of processing tasks include, calculating brake distance, determining location,
determining railroad track state, calculating speed for optimum fuel efficiency, etc. In
cases where the operational load a propulsive load, the operational load is increased when
the output (e.g., torque, speed) demand is increased. If it is determined that the
operational load is increased, the method moves to 608. Otherwise, the method returns to 604.

[0071] At 608, the method includes determining if a spare rail vehicle system resource is available. Under some conditions, the entirety of the capabilities of the rail vehicle system resources are not used to meet the operational load, thus additional resources are available for use. If it is determined that a spare rail vehicle system resource is available for use, the method moves to 610. Otherwise, the method moves to 612.

[0072] At 610, the method includes assigning, through the wayside wireless network, the operational task associated with the increase in operational load to the spare rail vehicle system resource. In one example where the operational task is a processing task, assigning includes sending a command for a remote computing system on-board or off-board of the rail vehicle system to perform the processing task. In one example where the operational task is a propulsive/braking output, assigning includes sending a command for a spare propulsive/braking resource to adjust operation to meet the propulsive/braking output. In some cases, a plurality of resources is commanded to adjust operation to collectively meet the increase in operational load.

[0073] At 612, the method includes adjusting rail vehicle system operation to reduce the operational load to comply with the capability of the distributed rail vehicle system resources. In one example where the operational load is a processing load, adjusting rail vehicle operation includes cancelling a processing task or delaying a processing task from being carried out until a processing resource becomes available. In one example where the operational load is a propulsive/brake load, adjusting rail vehicle operation includes
reducing output (e.g., torque demand, speed demand) or operating a different brake component. Furthermore, in cases where the operational load is less than the collective capability of the remaining distributed resources, the operational task can be assigned to a remaining available resource.

[0074] By assigning new operational tasks to distributed resources of the rail vehicle system in response to an increase in operational load, the operational load is met even as operating conditions vary. In this way, the rail vehicle system is made more robust. Moreover, by sending data communications through the wayside wireless network, which has a high data rate transport capability, the data communication path has the capacity to handle the intra-train data communications, as opposed to other data communication paths that have less bandwidth and do not have the capacity to handle some levels of data communications.

[0075] Another embodiment relates to a method for controlling data communication for a rail vehicle. The method comprises establishing (at the rail vehicle) a data communication session with a wireless network provided by a wayside device. The method further includes sending a data communication from the rail vehicle to a remote rail vehicle through the wireless network. (The rail vehicle and remote rail vehicle are in a train or other rail vehicle consist.)

[0076] In an embodiment, the wireless network provided by a wayside device is a general purpose, non-rail wireless network, meaning a wireless network set up for general communications by multiple parties (e.g., the public) and not specifically for purposes of rail vehicle communications. Examples include cellular networks and Wi-Fi “hotspots” at public commercial establishments.
[0077] In an embodiment, a wireless network is a telecommunications/computer network whose interconnections between nodes are implemented using RF signals, for purposes of data communications (e.g., transmission of addressed data packets) between nodes.

[0078] This written description uses examples to disclose the invention, including the best mode, and also to enable a person of ordinary skill in the relevant art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those of ordinary skill in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.
CLAIMS:

1. A multiple-unit rail vehicle system comprising:

   a first rail vehicle comprising:

   a first wireless network device to detect a wireless network provided by a
   wayside device; and

   a first communication management system to send, through the wireless
   network, a data communication to a second rail vehicle of the multiple-unit rail
   vehicle system.

2. The system of claim 1, wherein the data communication includes control
   commands to control operation of the second rail vehicle.

3. The system of claim 1, wherein the first rail vehicle comprises a first radio
   transceiver and the second rail vehicle comprises a second communication management
   system and a second radio transceiver, the first radio transceiver and the second radio
   transceiver forming a direct radio link;

   during a first condition, the first communication management system sends data
   communications through the wireless network to the second communication management
   system; and

   during a second condition, the first communication management system sends
   data communications through the direct radio link to the second communication
   management system.
4. The system of claim 3, wherein the first condition includes the wireless network providing network coverage to the multiple-unit rail vehicle system, and the second condition includes the multiple-unit rail vehicle system being outside of network coverage of the wireless network.

5. The system of claim 3, wherein the first condition includes receiving no feedback subsequent to sending data communications through the direct radio link, and the second condition includes receiving feedback indicating that data communications sent through the direct radio link were received by the second communication management system, and wherein the data communications sent during the first condition and the data communications sent during the second condition include the same data.

6. The system of claim 1, wherein the first rail vehicle comprises a first on-board computing system to control operation of the multiple-unit rail vehicle system and the second rail vehicle comprises a second on-board computing system, the first on-board computing system generating control commands to control operation of the second rail vehicle that are sent, through the wireless network, to the second on-board computing system by the first communication management system.

7. The system of claim 6, wherein the first communication management system sends an initialization command, through the wireless network, to the second on-board computing system to transfer control of operation of the multiple-unit rail vehicle
system to the second on-board computing system in response to degradation of the first on-board computing system.

8. The system of claim 6, wherein the first communication management system sends an initialization command, through the wireless network, to a remote computing system off-board the multiple-unit rail vehicle system to perform an operational task previously assigned to be carried out by the first on-board computing system in response to degradation of the first on-board computing system.

9. The system of claim 6, wherein the first on-board computing system distributes operational tasks between at least the first rail vehicle and the second rail vehicle to meet an operational load of the multiple-unit rail vehicle system; and

   the communication management system, in response to degradation of a degraded on-board computing system, re-assigns operational tasks previously assigned to be carried out by the degraded on-board computing system, through the wireless network, to an available computing system to meet the operational load.

10. The system of claim 6, wherein the first on-board computing system distributes operational tasks between at least the first rail vehicle and the second rail vehicle to meet an operational load of the multiple-unit rail vehicle system; and

    the communication management system, in response to an increase in the operational load, assigns additional operational tasks, through the wireless network, to an available computing system to meet the increase in operational load.
11. A method for controlling data communication for a rail vehicle comprising:
establishing a data communication session with a wireless network provided by a
wayside device; and

sending a data communication, through the wireless network, to a remote rail
vehicle.

12. The method of claim 11, wherein the data communication includes control
commands to control operation of the remote rail vehicle.

13. The method of claim 11, further comprising:
in response to insufficient wireless network coverage, sending a data
communication including the same data as the data communication to be sent through the
wireless network, through a direct radio link to the remote rail vehicle.

14. The method of claim 11 further comprising:
in response to degradation of an on-board computing system of the rail vehicle,
sending a initialization command, through the wireless network, to transfer control of
operation of the rail vehicle to a remote on-board computing system of the remote rail
vehicle.
15. The system of claim 11, further comprising:

in response to degradation of an on-board computing system of the rail vehicle, sending an initialization command, through the wireless network, to a remote off-board computing system that is not located on a rail vehicle to perform an operational task previously assigned to be carried out by the on-board computing system.

16. A multiple-unit rail vehicle system comprising:

a first rail vehicle comprising:

a first wireless network device to detect a wireless network provided by a wayside device; and

a first radio transceiver forming a direct radio link with a second radio transceiver of a second rail vehicle of the multiple-unit rail vehicle system; and

a first communication management system configured to, during a first condition, send a data communication through the wireless network to a second communication management system of at least the second rail vehicle, and during a second condition, send the data communication through the direct radio link to at least the second communication management system.

17. The system of claim 16, wherein the first condition includes the wireless network providing network coverage to the multiple-unit rail vehicle system, and the second condition includes the multiple-unit rail vehicle system being outside of network coverage of the wireless network.
18. The system of claim 16, wherein the first condition includes receiving no feedback subsequent to sending data communications through the direct radio link, and the second condition includes receiving feedback indicating that data communications sent through the direct radio link were received by the second communication management system.

19. The system of claim 16, wherein the data communication includes control commands to control operation of the second rail vehicle.

20. The system of claim 16, wherein the first rail vehicle comprises a first on-board computing system to control operation of the multiple-unit rail vehicle system and the second rail vehicle comprises a second on-board computing system, the first on-board computing system generating control commands to control operation of at least the second rail vehicle that are sent, through the wireless network, to at least the second on-board computing system by the first communication management system; and wherein the first communication management system sends an initialization command, through the wireless network, to the second on-board computing system to transfer control of operation of the multiple-unit rail vehicle system to the second on-board computing system in response to degradation of the first on-board computing system.
START

DETERMINE OPERATING CONDITIONS

SEND DATA COMMUNICATIONS THROUGH ALTERNATIVE COMMUNICATION PATH TO REMOTE RAIL VEHICLE

WAYSIDE WIRELESS NETWORK COVERAGE DETECTED?

NO

YES

ESTABLISH DATA COMMUNICATION SESSION WITH DETECTED WAYSIDE WIRELESS NETWORK

RELAY DATA COMMUNICATIONS THROUGH WAYSIDE WIRELESS NETWORK TO REMOTE RAIL VEHICLE/WAYSIDE DEVICE

RETURN

FIG. 2
START

DETERMINE OPERATING CONDITIONS

SEND DATA COMMUNICATION THROUGH SELECTED COMMUNICATION PATH TO REMOTE RAIL VEHICLE

YES
DATA COMMUNICATIONS FEEDBACK RECEIVED?

NO
RELAY DATA COMMUNICATIONS THROUGH WAYSIDE WIRELESS NETWORK TO REMOTE RAIL VEHICLE/WAYSIDE DEVICE

RETURN

FIG. 3
4/6

START

DETERMINE OPERATING CONDITIONS

ON-BOARD COMPUTING SYSTEM DEGRADATION?

NO

YES

SEND NOTIFICATION INDICATING ON-BOARD COMPUTING SYSTEM DEGRADATION THROUGH WAYSIDE WIRELESS NETWORK

SEND COMMAND TO INITIALIZE REMOTE COMPUTING SYSTEM TO CONTROL RAIL VEHICLE SYSTEM THOUGH WAYSIDE WIRELESS NETWORK

RETURN

FIG. 4
START

Determine operating conditions

Send operational task assignments to distributed resources of rail vehicle system through wayside wireless network to meet operational load

No

Rail vehicle system resource degradation?

Yes

Spare rail vehicle system resource?

No

Adjust rail vehicle system operation to reduce operational load to comply with reduced capability of distributed resources

Yes

Re-assign operational task from degraded resource to spare resource through wayside wireless network

Return

FIG. 5
START

DETERMINE OPERATING CONDITIONS

SEND OPERATIONAL TASK ASSIGNMENTS TO DISTRIBUTED RESOURCES OF RAIL VEHICLE SYSTEM THROUGH WAYSIDE WIRELESS NETWORK TO MEET OPERATIONAL LOAD

OPERATIONAL LOAD INCREASED?

SPARE RAIL VEHICLE SYSTEM RESOURCE?

ADJUST RAIL VEHICLE SYSTEM OPERATION TO REDUCE OPERATIONAL LOAD TO COMPLY WITH CAPABILITY OF DISTRIBUTED RESOURCES

ASSIGN OPERATING TASK TO SPARE RESOURCE THROUGH WAYSIDE WIRELESS NETWORK TO MEET INCREASED OPERATIONAL LOAD

RETURN

FIG. 6