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(54) **TRAIN CONTROL SYSTEM BASED ON VEHICLE-VEHICLE COMMUNICATION, AND LINK ESTABLISHMENT METHOD AND APPARATUS, AND LINK REMOVAL METHOD AND APPARATUS**

(57) Provided by the present disclosure are a train control system based on vehicle-vehicle communication, and a method and apparatus for establishing and tearing down a link. The train control system includes an STC and onboard equipment. The STC is configured to handle a route, perform temporary speed restriction management, implement train management, verify legality, receive information transmitted from the onboard equipment of a train, transmit state information of wayside equipment to the onboard equipment of the train, determine signal authority, establish a vehicle-vehicle communication link, and tear down the vehicle-vehicle communication link. The onboard equipment is configured to determine movement authority of a present train and control the train based on the movement authority, transmit operation data information of the present train to other trains, and receive operation data information of the other trains. The train control system provided by the present disclosure has more concise architecture, and can reduce implementation cost for the project construction. For the transmission of signals between equipment, due to the simplicity of the system architecture, transmission resources of the signals are saved, the probability of signal transmission error is reduced, and thus the driving safety is improved.

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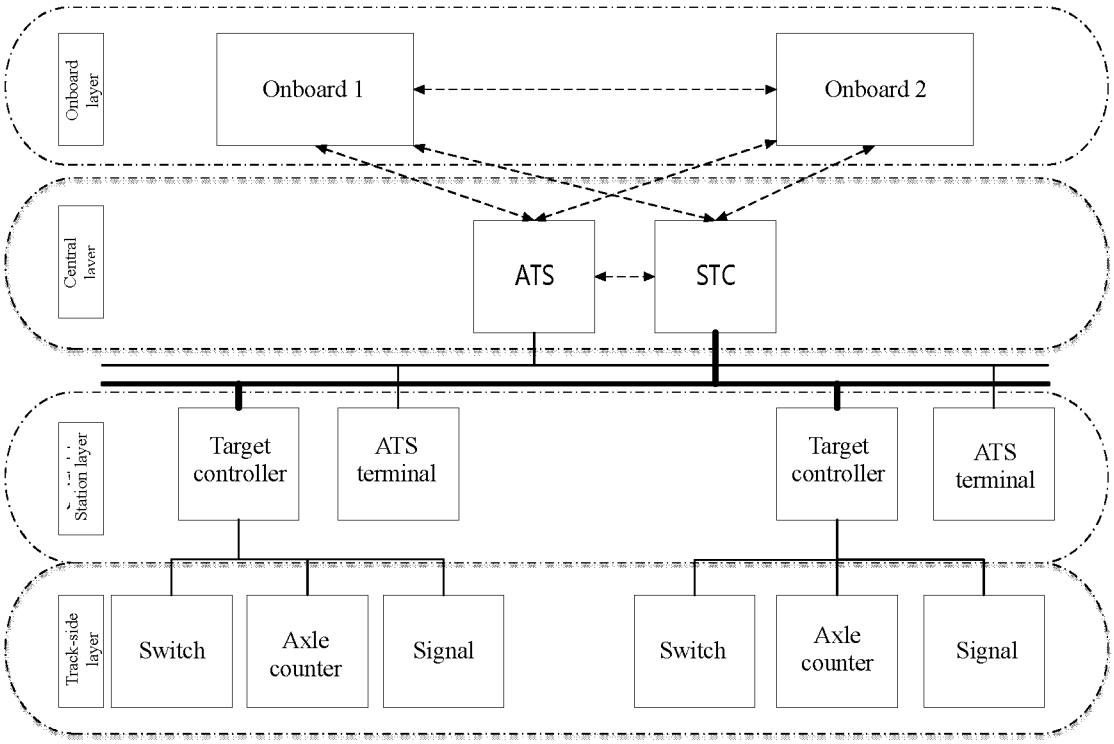
Onboard layer
Onboard 1
Onboard 2
Central layer
ATS
STC
Station layer
Target controller
ATS terminal
Target controller
ATS terminal
Track-side layer
Switch
Axle counter
Signal
Switch
Axle counter
Signal

FIG. 3

Description

TECHNCIAL FIELD

[0001] The present disclosure belongs to the technical field of train control, and in particular to a train control system for vehicle-vehicle communication, and a method and apparatus for establishing and tearing down a link.

BACKGROUND ART

[0002] A system architecture of an existing CBTC (communication based train control system) includes an automatic train supervision system (ATS) at a central layer, a ZC (zone control) system on the ground, CBI (computer based interlock), onboard equipment on an onboard layer, as well as track-side balise and switch. FIG. 1 shows a CBTC system architecture in the prior art. In the train control, the above equipment executes mutual data transmission to achieve the control of the train. The system architecture cannot meet the requirements of vehicle-vehicle communication, and thus the system architecture of vehicle-vehicle communication appears in the prior art. FIG. 2 shows a block diagram of data transmission between control equipment under the vehicle-vehicle communication architecture in the prior art. As shown in FIG. 2, a route command, temporary speed restriction and manual operation command are transmitted between ATS and CBI, and the position and state of the train, the movement authority, temporary speed restriction and other commands are transmitted between onboard equipment and the ZC. In the vehicle-vehicle communication architecture in the prior art, ground train control equipment (e.g., a resource manager OC, a train control center TMC, etc.) is responsible for train management, which is configured to record the ID numbers, communication IP addresses and positions of all trains, manage the trains registered with the equipment in the form of the list of trains, and transmit the list of trains to all trains registered with the ground train control equipment. The train searches all train positions in the list of positions according to its own position, finds the closet preceding train, and then establishes a communication link to achieve vehicle-vehicle communication. However, there are some defects in this system architecture. For example, the basis for the following train to find the preceding train is only related to the position of the preceding train. For example, when the preceding train is reachable h a line where the present train is located, the preceding train is considered as the preceding train related to the present train, a vehicle-vehicle communication link is established. The basis for the following train to find the preceding train is only related to the position of the preceding train, if the preceding train is unreachable to the line where the present train is located, it is considered that the preceding train is not the preceding train related to the present train, and the vehicle-vehicle communication link is torn down immediately.

[0003] Based on the existing train control system, the method for establishing inter-train communication based on vehicle-vehicle communication will have the potential safety hazard of establishing wrong links. For example, if there are down-degraded and engineering trains between two CTC (Communication Train Control) trains, the two CTC trains can establish the link; and the recovery of normal operation of the train after downgrade is slow.

SUMMARY

[0004] In order to solve at least one of the problems, the present disclosure provides a train control system based on vehicle-vehicle communication, and a method and apparatus for establishing and tearing down a link.

[0005] The present disclosure provides a train control system based on vehicle-vehicle communication, including an STC, and onboard equipment.

[0006] The STC is configured to handle a route, perform temporary speed restriction management, implement train management, verify legality, receive information transmitted from the onboard equipment of a train, transmit state information of wayside equipment to the onboard equipment of the train, determine signal authority, establish a vehicle-vehicle communication link, and tear down the vehicle-vehicle communication link.

[0007] The onboard equipment is configured to determine movement authority of a present train and control the train based on the movement authority, transmit operation data information of the present train to other trains, and receive operation data information of the other trains.

[0008] In some embodiments, an ATS is configured to verify legality of IP information and ID information of the train, perform consistency check on a communication protocol version and a data version after the legality verification is passed, trigger a route of the train after the consistency check is passed, and transmit route information to the STC.

[0009] In some embodiments, the STC is further configured to determine whether a following train is registered with the STC, determine whether the route of the train has been connected to a preceding train, determine whether a route occupied by the preceding train is a multi-train route, determine whether the train has completed secure localization and front-rear discrimination, and determine whether both the preceding and following trains are in a normal train-ground communication state, or whether the preceding train is in a normal train-ground communication state.

[0010] In some embodiments,

the route handling includes determining a switch area resource, a track resource, a state of a signal, and temporary speed restriction of the train; and/or the performing temporary speed restriction management includes transmitting temporary speed restric-

tion to the onboard equipment of the train; and/or
the implementing train management includes registering or de-registering the train.

[0011] In some embodiments, the onboard equipment is further configured to transmit position information the present train, speed information, a braking distance, an overlap section, an operation level and operation mode information to the STC.

[0012] In some embodiments, the operation data information includes a train position, speed information, and braking distance information.

[0013] The present disclosure provides a method for establishing a link based on the train control system. The method includes the following steps:

establishing, by an STC, a route of a following train according to route information of the following train received from an ATS, and transmitting signal authority to the following train;
identifying, by the STC, a preceding train according to a position of the following train, a list of positions of all trains, and the farthest distance of the signal authority, and generating the preceding train associated with the following train;
transmitting, by the STC, identified IP information and ID information of the preceding train to the following train; and
establishing, by the following train, communication with the preceding train according to the received IP information and ID information of the preceding train.

[0014] In some embodiments,
the establishing, by the following train, communication with the preceding train according to the received IP information and ID information of the preceding train includes the following steps:

performing, by the following train, consistency check on the IP and ID after receiving the IP information and ID information of the preceding train;
performing addressing after the consistency check of the IP and ID is passed; after the addressing is successful, performing, by the preceding train, consistency check on received communication protocol and data version transmitted by the following train when requesting to establish a link; and after the check is successful, transmitting, by the preceding train, a link establishment consent message of a transport layer to the following train;
transmitting, by an upper-layer application protocol of the preceding train, the ID, IP, communication protocol version and map version of the preceding train to the following train, and enabling the following train to maintain the link after checking the communication protocol version and the map version;
transmitting, by the following train, application data to the preceding train, and checking the legality and consistency of the ID, IP, communication protocol version and map version information of the following train in the application data for the second time; and
finally, transmitting the application data between the preceding train and the following train according to a protocol cycle. In the embodiment of the present disclosure, after the link is established, the following train transmits a link establishment request to the preceding train. The preceding train checks a communication protocol and data version in the link establishment request information transmitted from the following train, transmits a link establishment consent message to the following train after the check is passed, and sends its own communication protocol version and data version to the following train. The following train, after receiving the link establishment consent message and communication protocol version and data version of the preceding train, performs the second check, thus completing link establishment.

[0015] **In** some embodiments, after the communication between the preceding train and the following train is established, the following train determines whether to use train information of the preceding train according to an acquired operation direction of the preceding train, an activation end, a safe envelope of the train, speed of the train, a braking distance of the train, an operation control level of the train, a driving mode of the train, a vehicle state, and ID information of the STC for controlling the train.

[0016] In some embodiments, prior to establishing a route of the following train and transmitting signal authority to the following train by the STC, the method further includes the following steps:
determining, by the STC, whether the preceding and following trains are both in a normal vehicle-ground communication, whether a route of the following train has been connected to the preceding train, whether the route occupied by the preceding train is a multi-train route, whether the preceding train has completed the secure localization, whether the preceding train has completed rear discrimination, whether the following train has completed front discrimination, and whether the following train is registered with the STC.

[0017] In some embodiments, the following train transmits the route information to the STC after the ATS has completed the registration, which includes the following steps:

transmitting, by the following train, IP information and ID information of the following train to the ATS;
performing, by the ATS, legality verification on the IP and ID, and establishing a link after the legality verification is passed;
performing consistency check on a communication protocol version and a data version;
after the consistency check is passed, matching, by

the ATS, the registered following train to an operation plan to be executed, and endowing the registered following train with a train number;

executing, by the ATS, a train operation plan through the train number of the train; and

triggering, by the ATS, the route of the following train according to the ID of the preceding and following trains, operation plans of the preceding and following trains, and positions and envelopes of the preceding and following trains, and transmitting route information to the STC.

[0018] The present disclosure further provides a method for tearing down a link based on the train control system. The method includes the following steps:

determining, by a STC, whether a condition for tearing down a link between two trains with established vehicle-vehicle communication is met; and

if the condition for tearing down the link is met, controlling, by the STC, to tear down the link between the two trains.

[0019] In some embodiments, if there is a branching route between a preceding train and a following train, it is considered that the condition for tearing down the link is met.

[0020] In some embodiments, the controlling, by the STC, to tear down the link between the two trains includes the following steps:

transmitting, by the STC, empty preceding train information or a link tear-down instruction to the following train;

disconnecting, by the following train, the vehicle-vehicle communication with the preceding train after receiving the empty preceding train information or link tear-down instruction;

disconnecting, by the following train, the vehicle-vehicle communication with the preceding train after receiving a link tear-down request from the preceding train; and

enabling the following train to enter a CTC mode, and recomputing movement authority only according to signal authority transmitted by the STC.

[0021] In some embodiments, the link between the two trains is torn down again within predetermined time when determining that the condition for link tear-down is met.

[0022] Compared with the prior art, the present disclosure has the following beneficial effects:

Compared with the prior art, the train control system provided by the present disclosure has more concise architecture, and can reduce implementation cost for the project construction. For the transmission of signals between equipment, due to the simplicity of the system architecture, transmission resources of the signals are saved, the probability of signal transmission error is reduced, and thus the driving safety is improved.

[0023] Such an architecture logic of the train control system provided by the present disclosure is suitable for establishing a communication link between the preceding train and the following train in vehicle-vehicle communication, and effectively detecting a communication interrupted train, a failure train and an engineering vehicle which do not establish communication link with the ground. There will be no wrong link establishment, and the safety of the train operation is ensured.

[0024] Based on the architecture logic of the train control system provided by the present disclosure, after the communication between the preceding train and the following train is disconnected, the train can continue to run according to the wayside signal authority, the influence on the operation after the vehicle-vehicle communication is interrupted, the problem that the original vehicle-vehicle communication can only rely on the dispatching command for manual driving after the link is interrupted, and the safety of train operation is ensured.

[0025] Other features and advantages of the present disclosure will be set forth in the following description, and will be apparent in part from the description, or may be learned by implementing the present disclosure. The objectives and other advantages of the present disclosure may be implemented and acquired from the structure pointed out in the specification, claims and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] To describe the technical solutions of the present disclosure or in the prior art more clearly, the following briefly introduces the accompanying drawings required for describing the embodiments or the prior art. Apparently, the accompanying drawings in the following description show merely some embodiments of the present disclosure, and those of ordinary skill in the art may still derive other drawings from these accompanying drawings without creative efforts.

FIG. 1 shows a CBTC system architecture in the prior art.

FIG. 2 shows a block diagram of data transmission between control equipment in the prior art;

FIG. 3 shows a diagram of a vehicle-vehicle communication system architecture according to an embodiment of the present disclosure;

FIG. 4 shows a functional architecture of equipment in a vehicle-vehicle communication system according to an embodiment of the present disclosure as well as a comparison diagram of the functional architecture and each equipment architecture of the CBTC system;

FIG. 5 shows a structural diagram of data transmission between control equipment in a vehicle-vehicle communication system according to an embodiment of the present disclosure;

FIG. 6 shows a schematic structural diagram of establishment of a vehicle-vehicle communication link according to an embodiment of the present disclosure;

FIG. 7 shows a schematic structural diagram of tear-down of a vehicle-vehicle communication link according to an embodiment of the present disclosure.

DETAILED DESCRIPTION

[0027] To make the objectives, technical solutions and advantages of the present disclosure more clearly, the following clearly and completely describes the technical solutions in the embodiments of the present disclosure with reference to the accompanying drawings in the embodiments of the present disclosure. Apparently, the described embodiments are merely a part rather than all of the embodiments of the present disclosure. All other embodiments obtained by a person of ordinary skill in the art based on the embodiments of the present disclosure without creative efforts shall fall within the protection scope of the present disclosure.

[0028] FIG. 3 shows a diagram of a vehicle-vehicle communication system architecture according to an embodiment of the present disclosure in an exemplary manner. As shown in FIG. 3, an onboard layer of a vehicle-vehicle communication system includes onboard equipment. A central layer includes a general ATS and an STC. A station layer includes an object controller, and an ATS terminal. A track-side layer includes a switch, an axle counter, and a signal. The OC of the station layer is in data connection with the switch, axle counter and signal of the track-side layer and the STC of the central layer. The STC of the central layer is in data connection with the general ATS and the onboard equipment of the onboard layer. The general ATS in the central layer is in data connection with the onboard equipment of the onboard layer and the ATS terminal of the station layer. **In** an embodiment of the present disclosure, the OC is only an executive component for executing according to instructions of the STC and the onboard equipment, which does not have the function of logical calculation, and the function of executing a safety policy after failure. It should be noted that in an embodiment of the present disclosure, each piece of equipment can be set according to a railway network, not necessarily according to such a structure. For example, the STC is not necessarily located at the central layer, but at the station layer.

[0029] FIG. 4 shows a functional architecture of equipment in a vehicle-vehicle communication system according to an embodiment of the present disclosure as well as a comparison diagram of the functional architecture and each equipment architecture of the CBTC system. As shown in FIG. 4, in a train control system based on vehicle-vehicle communication, the general ATS of the central layer is mainly used for display, planning and implementation of plans, which can display line resources of each station layer. The ATS terminal of the station layer is a terminal under the management of the general ATS, which is used to display line resource information of the station, such as states of signal station equipment and wayside equipment, train position and state information, occupied and unoccupied information of track resources, and some line physical data such as the position of equipment. It should be noted that the main function of the ATS of the station layer includes making and executing a plan, tracking a train operation timetable, counting transportation data, and the displaying relevant information convenient for operators to observe and determine, etc. **In** the vehicle-vehicle communication, ATS is not necessarily used as a display device for displaying the linking and tear-down of the communication link. The STC can handle the route (for example, a switch area resource, a track (straight track) resource, a state of the signal, temporary speed restriction of a platform and a train, etc.), control the opening and closing of a platform door of the station, perform temporary speed restriction management (transmitting the temporary speed restriction to the onboard equipment of the train), implement train management (for example, registration and de-registration of the train), and execute legality verification (for example, when the train is registered, the legality of the train, the data consistency and legality consistency of the communication protocol are checked), receive the relevant information transmitted by the onboard equipment of the train (for example, after the train is registered, the onboard equipment of the train transmits position information of the present train, and state information such as speed, a braking distance, an overlay section, an operation level and an operation mode to the STC), rank the preceding and following trains according to the route information and the train position (real-time or non-real-time), transmit the state information of the wayside equipment to the onboard equipment of the train, establish and tear down the communication between the trains, and determine signal authority. The onboard equipment of the onboard layer can receive operation data information of other trains and check the received operation data information, determine the own movement authority, and control the train to run according to the determined movement authority MA. The operation data information of the train, such as the own train position, the state information of the train, the movement authority information, the driving speed and the braking distance information are transmitted to the other trains.

[0030] As can be seen from the comparison in FIG. 4, the function of the ATS is the same as that of the vehicle-vehicle communication system (or autonomous operation control system) under the CBTC system architecture. In the vehicle-vehicle communication system, the STC equipment executes some functions of CI and ZC in the CBTC system, and transfers the function for determining the movement authority implemented by ZC in the CBTC system to the onboard equipment. In an embodiment of the present disclosure, the adjusting of such a

functional architecture takes full consideration of the demands of the vehicle-vehicle communication, and adaptively reduces the complexity of the system.

[0031] FIG. 5 is a structural diagram of data transmission between equipment in a vehicle-vehicle communication system according to an embodiment of the present disclosure. As shown in FIG. 5, the ATS transmits a train operation plane (such as train timetable), a door strategy (for example, open the door on the left or right side of a vehicle body, open the door manually or with equipment, close the door manually or with equipment, etc.), contraposition isolation, and the other data. The train position state and contraposition isolation and the like information received from the onboard equipment, and a temporary speed restriction instruction and manual operation instruction received from the STC are displayed. The STC transmits a temporary speed restriction command, state information of the wayside equipment, and door linkage information to the onboard equipment (for example, the door linkage information may be an instruction or information which makes a platform screen door and the vehicle door act at the same time or delays the simultaneous action). After the train stops steady in place, the onboard equipment transmits a door linkage request to the STC, and the STC transmits a consent instruction to the onboard equipment after detecting that the door linkage request is executable. When opening the door, the vehicle door acts after the screen door acts for 1 second (data can be configured in the system). When closing the door, the screen door executes the action after the train starts to close the door for 1 second (the data can be configured in the system). That is, the execution of the simultaneous command is delayed according to the equipment performance. Such a way can protect the security of the passengers getting on and off. The onboard equipment transmits the position information of the train, the state information of the train, the information of the overlay section, the door linkage result information, and determined movement authority to the STC.

[0032] On the basis of the vehicle-vehicle communication system mainly composed of the STC and the onboard equipment, an embodiment of the present disclosure also provides a method for establishing a vehicle-vehicle communication link. FIG. 6 shows a schematic structural diagram of establishment of a vehicle-vehicle communication link according to an embodiment of the present disclosure. In the process of establishing a communication link between the vehicles, related data is transmitted among the onboard equipment of the preceding train, the onboard equipment of the following train, the STC and the ATS. As shown in FIG. 6, the preceding train is about to enter a deceleration stage, and the following train runs at the normal speed. After the routes of the preceding and following trains are connected, the following train have a deceleration process before catching up with the preceding train.

[0033] The onboard equipment of the train transmits information of a mode of the train and a route occupied by the train to the STC. For the preceding and following trains needing to establish, communication connection, the STC determines whether the two trains are in a CM(Code train operating Mode)-VV/AM(ATO Mode)-VV mode (in this mode, the train-ground communication is in a good condition) or whether the preceding train is in a CM-VV/AM-VV mode (in this mode, the train-ground communication is also in a good condition), whether the route of the following train has been connected to that of the preceding train, whether the route occupied by the preceding train is a multi-train route, whether the preceding train has completed secure localization, whether the preceding train has completed rear discrimination, whether the following train has completed front discrimination, and whether the rear train is registered with the STC. In a case that the above determination results are that the two trains are in the CM-VV/AM-VV mode, the preceding train is in the CM-VV/AM-VV mode, the route of the following train has been connected to that of the preceding train the route occupied by the preceding train is the multi-train route, the preceding train has completed secure localization, the preceding train has completed rear discrimination, the following train has completed front discrimination, and the rear train is registered with the STC, a linking process of the preceding train and the following train is started. Otherwise, the linking process of the preceding train and the following train is not started. In an embodiment of the present disclosure, the STC achieves the train management function according to the received information.

[0034] For the determination of the conditions, considering the efficiency of program operation and the reduction of memory occupation during program execution, the STC can make determinations according to the following order:

1. determining whether the following train is registered with the STC, if the following train is not registered with the STC, terminating, and if the following train is registered with the STC, performing the following steps;
2. determining whether the route of the train has been connected to that of the preceding train, if the route of the train has not been connected to that of the preceding train, terminating, and if the route of the train has been connected to the preceding train, performing the following steps;
3. determining whether the route occupied by the preceding train is a multi-train route, if the route occupied by the preceding train is not the multi-train route, terminating, and if the route occupied by the preceding train is the multi-train route, performing the following steps;
4. determining whether the train has completed secure localization and front-rear discrimination, if the train has not completed the secure localization and front-rear discrimination, terminating, and if the train

has completed the secure localization and front-rear discrimination, performing the following steps;

5. determining whether the preceding train and the following train are both in a CM (code train operating mode)-CTC/AM (ATO Mode)-CTC mode; if the preceding train and the following train are not in the CM-CTC/AM-CTC mode, terminating, if the preceding train and the following train are in the CM-CTC/AM-CTC mode, performing the following steps.

[0035] It should be noted that it is not necessary to determine according to the above sequence in the embodiment of the present disclosure.

[0036] Besides registering to the STC, the train also needs to register with the ATS: the train transmits its own IP and ID information to the ATS (addressing to the ATS is also performed through IP and ID), and the ATS verifies the legality of the IP and ID, establishes a link between the train and the ATS after the legality verification is passed, and then checks the consistency of a communication protocol version and a data version of the train. After the consistency check is passed, the ATS considers that the train can enter the operation. The ATS matches the registered train with an operation plan to be executed, and endows the registered train with a train number. The ATS is configured to execute the train operation plan according to the train number of the train, such as setting departure time and stopping time of the train. By interacting information with the train through the IP and ID, the ATS transmits information, such as an operation plan, the train number, a door control strategy, as well as tripping, car detaining and turn-back commands, and a return mode, to the train. The train transmits position and state information of the train to the ATS. After the train is registered with the ATS, the ATS triggers the route of the following train according to the IDs, operation plans and position envelopes of the preceding and following trains, and transmits the route information to STC.

[0037] The STC establishes a route of the following train according to route information of the following train received from the ATS, and transmits signal authority to the following train.

[0038] The STC identifies the preceding train according to the own position of the following train, a list of positions of all trains, the farthest distance of the signal authority, generates a preceding train associated with the present train, and transmits the identified IP information and ID information of the preceding train to the following train. The following train establishes a communication with the preceding train according to the received IP information and ID information of the preceding train. That is, the following train, after receiving the IP information and ID information of the preceding train, performs consistency check on the IP and ID, performs addressing according to the IP information after the check is passed, and checks consistency of the communication protocol and data versions after the addressing is successful. After the consistency check is successful, the preceding train will transmit a link establishment consent message of a transport layer to the following train. An upper-layer application protocol of the preceding train transmits ID, IP, communication protocol version and map version of the preceding train to the following train according to pre-established rules. After determining that these information meet the requirements, that is, after verifying that the communication protocol version and the regional version are legal, the preceding train is configured to transmit application data, which includes the position, speed, braking distance, mode level and the like of the preceding train, and then transmit the application data according to the protocol cycle. After the communication between the preceding train and the following train is established, the following train obtains train information of the preceding train, such as an operation direction of the preceding train, an activation end, a safe envelope of the train, speed of the train, a braking distance of the train, an operation control level of the train, a driving mode of the train, a vehicle state (e.g., the integrity of the train, stopping guarantee, turn-back state, etc.), and ID information of the STC for controlling the train. The onboard equipment of the following train determines whether to use the train information of the preceding train according to the received train information of the preceding train. Exemplary, whether to use the train information of the preceding train is determined through the following ways: determining whether the ID and IP of the preceding train have passed the legality verification, that is, the ID and IP have been registered, thus preventing illegal access, and determining that the communication protocol version and the map version are consistent, i.e., consistency check, and performing determination according to the operation level mode of the train, such as data available in the CM or AM mode of CTC or VV level, data unavailable due to the loss of train integrity, data unavailable of turn-back state, etc.

[0039] According to the signal authority transmitted by the STC, the position and speed of the preceding vehicle, the braking distance and the temporary speed restriction, the following train computes movement authority by considering the comprehensive physical conditions of a line (speed restriction, slope and curve of the line). Whether to run based on the movement authority is comprehensively determined according to the signal authority transmitted by the STC to the present train, whether the route occupied by the preceding train is the multi-train route, the signal display of the route, and the train information of the preceding train. The movement authority is used to ensure the safe interval of train operation.

[0040] The mode of the following train is upgraded to CM-VV (vehicle-vehicle)/AM-VV mode, the movement authority of the train can be updated in real time according to the train information and signal authority of the preceding train, and the following train can run according to the computed movement authority, thus ensuring the safe interval of train operation.

[0041] In the whole vehicle-vehicle communication

process, the operation mode of the preceding train may remain unchanged.

[0042] In an embodiment of the present disclosure, through the setting of the vehicle-vehicle communication system architecture, the STC, ATS and other basic equipment for train management can grasp all the information related to the safe operation of trains in real time, such as the position, operation mode, movement authority and route information of all trains. Therefore, such a way of setting of the STC to achieve link logic operation in the embodiment of the present disclosure can save the mutual transmission of information between equipment and save the computing power and communication resources of the onboard equipment.

[0043] In the embodiment of the present disclosure, when a route prepared for the following train is connected to the route of the preceding train, the route is available, and the route of the preceding train is a multi-train route. In this case, the wayside STC transmits key information such as the ID and IP of the preceding train with pre-established vehicle-vehicle communication to the following train. The following train, after receiving the information, actively establishes a communication link with the preceding train. Such a way of establishing the communication link can prevent operation risk of train conflicts caused by a situation that a down-degraded train, a faulty train, an engineering train, and other trains without establishing links with the STC caught between the two trains with established communication links cannot be recognized by an operation control system, thus ensuring the safety of train operation.

[0044] On the basis of the vehicle-vehicle communication system mainly composed of the STC and the onboard equipment, the embodiment of the present disclosure also provides a method for tearing down a vehicle-vehicle communication link. FIG. 7 shows a schematic structural diagram of tear-down of a vehicle-vehicle communication link according to an embodiment of the present disclosure. In the process of tearing down a communication link between the vehicles, related data is transmitted among the onboard equipment of the preceding train, the onboard equipment of the following train, the STC and the ATS.

[0045] The STC determines whether there is a branching route between two trains that have established vehicle-vehicle communication. If there is a branching route between the two trains, the vehicle-vehicle communication between the two trains can be started. When there is a branching route between the following train and the preceding train, the STC transmits empty preceding train information or a link tear-down command to the following train.

[0046] The preceding train disconnects the vehicle-vehicle communication with the following train after receiving the empty preceding train information or link tear-down command.

[0047] The following train, after receiving a link tear-down request from the preceding train, disconnects the vehicle-vehicle communication with the preceding train.

[0048] When the following train enters a CM-CTC/AM-CTC mode, the movement authority can be recomputed only according to the signal permission transmitted by the STC.

[0049] **In** the whole process of tearing down the vehicle-vehicle communication, the mode of the preceding train may remain unchanged.

[0050] In the embodiment of the present disclosure, through the setting of a vehicle-vehicle communication architecture, when the preceding and following trains are both in a vehicle-vehicle communication state, and the following train has established the communication link with the preceding train, and after the STC determines that a route between the preceding and following trains has changed and there is a route of a branching switch between the two trains, the STC transmits a communication link tear-down command to the preceding and following trains. That is, in a case that a different route appears between the preceding and following trains in the communication link, a communication link tear-down operation is carried out. Assuming that the branching route between the trains is s connecting route within a certain configuration time, there is no need to tear down the communication link.

[0051] In order to prevent such an operation of tearing down the link when there is no need to remove the link after the wrong operation is corrected immediately (for example, in the running of the train, some faulty lines are immediately restored after debugging, e.g., the correction is carried out immediately after the switch is turned, the route is canceled, or the wrong operation is carried out due to mistakenly thought). In the embodiment of the present disclosure, the tolerance restriction is added in the system, the link tear-down operation can be performed within a certain period of time when determining that the link tear-down condition is met, such as after 6 seconds. If the link tear-down condition is no longer met within the predetermined time (that is, the above wrong operation is corrected), it is unnecessary to perform the link tear-down operation.

[0052] In an embodiment of the present disclosure, the communication link between the two trains can be removed only when there is a branching route between the route prepared for the following train and the route of the preceding train (for example, not only referring to disconnection, but also including the situation that the destinations are different in a short distance), or when the route prepared for the following train is not connected to the route of the preceding train, and the disconnection needs to be maintained for a configured time. Such a setting way can prevent the situations that the communication link between the trains is not torn down when the tear-down is required, the communication link is torn down when there is no need to tear down, or the communication link is established and torn down frequently.

[0053] Although the present disclosure has been described in detail with reference to the foregoing embodi-

ments, those of ordinary skill in the art should understand that it is still possible to modify the technical solution described in the foregoing embodiments, or to replace some technical features with equivalents. However, these modifications or replacements do not make the essence of the corresponding technical solutions deviate from the spirit and scope of the technical solutions of various embodiments of the present disclosure.

Claims

1. A train control system based on vehicle-vehicle communication, comprising a safety train control device (STC), and onboard equipment, **characterized in that**:

   the STC is configured to handle a route, perform temporary speed restriction management, implement train management, verify legality, receive information transmitted from the onboard equipment of a train, transmit state information of wayside equipment to the onboard equipment of the train, determine signal authority, establish a vehicle-vehicle communication link, and tear down the vehicle-vehicle communication link; and
   the onboard equipment is configured to determine movement authority of a present train and control the train based on the movement authority, transmit operation data information of the present train to other trains, and receive operation data information of the other trains.

2. The train control system according to claim 1, further comprising an automatic train supervision system (ATS), **characterized in that**
   the ATS is configured to verify legality of IP information and ID information of the train, perform consistency check on a communication protocol version and a data version after the legality verification is passed, trigger a route of the train after the consistency check is passed, and transmit route information to the STC.

3. The train control system according to claim 1 or 2, **characterized in that**
   the STC is further configured to determine whether a following train is registered with the STC, determine whether the route of the train has been connected to a preceding train, determine whether a route occupied by the preceding train is a multi-train route, determine whether the train has completed secure localization and front-rear discrimination, and determine whether both the preceding and following trains are in a normal train-ground communication state, or whether the preceding train is in a normal train-ground communication state.

4. The train control system according to claim 1, **characterized in that**

   the route handling comprises determining a switch area resource, a track resource, a state of a signal, and temporary speed restriction of the train; and/or
   the performing temporary speed restriction management comprises transmitting temporary speed restriction to the onboard equipment of the train; and/or
   the implementing train management comprises registering or de-registering the train.

5. The train control system according to claim 1, **characterized in that**
   the onboard equipment is further configured to transmit position information, speed information, braking distance, overlap section, operation level and operation mode information of the present train to the STC.

6. The train control system according to claim 1, **characterized in that**
   the operation data information comprises a train position, speed information, and braking distance information.

7. A method for establishing a link by using the train control system according to any one of claims 1 to 6, comprising the following steps:

   establishing, by an STC, a route of a following train according to route information of the following train received from an ATS, and transmitting signal authority to the following train;
   identifying, by the STC, a preceding train according to a position of the following train, a list of positions of all trains, and the farthest distance of the signal authority, and generating the preceding train associated with the following train;
   transmitting, by the STC, identified IP information and ID information of the preceding train to the following train; and
   establishing, by the following train, communication with the preceding train according to the received IP information and ID information of the preceding train.

8. The method according to claim 7, **characterized in that**
   the establishing, by the following train, communication with the preceding train according to the received IP information and ID information of the preceding train comprises the following steps:

   performing, by the following train, consistency check on the IP information and ID information after receiving the IP information and ID infor-

mation of the preceding train;
performing addressing after the consistency check of the IP information and ID information is passed; after the addressing is successful, performing, by the preceding train, consistency check on received communication protocol and data version transmitted by the following train when requesting to establish a link; and after the check is successful, transmitting, by the preceding train, a link establishment consent message of a transport layer to the following train;
transmitting, by an upper-layer application protocol of the preceding train, the ID information, IP information, communication protocol version and map version of the preceding train to the following train, and enabling the following train to maintain the link after checking the communication protocol version and the map version;
transmitting, by the following train, application data to the preceding train, and checking the legality and consistency of the ID information, IP information, communication protocol version and map version information of the following train in the application data for the second time; and
finally, transmitting the application data between the preceding train and the following train according to a protocol cycle.

9. The method according to claim 7, **characterized in that**
after the communication between the preceding train and the following train is established, the following train determines whether to use train information of the preceding train according to an acquired operation direction of the preceding train, an activation end, a safe envelope of the train, speed of the train, a braking distance of the train, an operation control level of the train, a driving mode of the train, a vehicle state, and ID information of the STC for controlling the train.

10. The method according to any one of claims 7 to 9, **characterized in that**, prior to establishing a route of the following train and transmitting signal authority to the following train by the STC, the method further comprises the following steps:
determining, by the STC, whether the preceding and following trains are both in a normal vehicle-ground communication, whether a route of the following train has been connected to the preceding train, whether the route occupied by the preceding train is a multi-train route, whether the preceding train has completed the secure localization, whether the preceding train has completed rear discrimination, whether the following train has completed front discrimination, and whether the following train is registered with the STC.

11. The method according to any one of claims 7 to 9, wherein the following train transmits the route information to the STC after the ATS has completed the registration, which comprises the following steps:

transmitting, by the following train, IP information and ID information of the following train to the ATS;
performing, by the ATS, legality verification on the IP information and ID information, and establishing a link after the legality verification is passed;
performing, by the preceding train, consistency check on a communication protocol version and a data version;
after the consistency check is passed, matching, by the ATS, the registered following train to an operation plan to be executed, and endowing the registered following train with a train number;
executing, by the ATS, a train operation plan through the train number of the train; and
triggering, by the ATS, the route of the following train according to the ID information of the preceding and following trains, operation plans of the preceding and following trains, and positions and envelopes of the preceding and following trains, and transmitting route information to the STC.

12. A method for tearing down a link by using the train control system according to any one of claims 1 to 6, comprising the following steps:

determining, by an STC, whether a condition for tearing down a link between two trains with established vehicle-vehicle communication is met; and
if the condition for tearing down the link is met, controlling, by the STC, to tear down the link between the two trains.

13. The method according to claim 12, **characterized in that**
if a branching route exists between a preceding train and a following train, the condition for tearing down the link is met.

14. The method according to claim 12 or 13, **characterized in that** the controlling, by the STC, to tear down the link between the two trains comprises the following steps:

transmitting, by the STC, empty preceding train information or a link tear-down command to the following train;
disconnecting, by the following train, the vehicle-vehicle communication with the preceding train after receiving the empty preceding train infor-

mation or link tear-down command;
disconnecting, by the following train, the vehicle-vehicle communication with the preceding train after receiving a link tear-down request of the preceding train; and
enabling the following train to enter a communication train control (CTC) mode, and recomputing movement authority only according to signal authority transmitted by the STC.

15. The method according to claim 12, comprising the following steps:
tearing down the link between the two trains again within predetermined time when the condition for link tear-down is met.

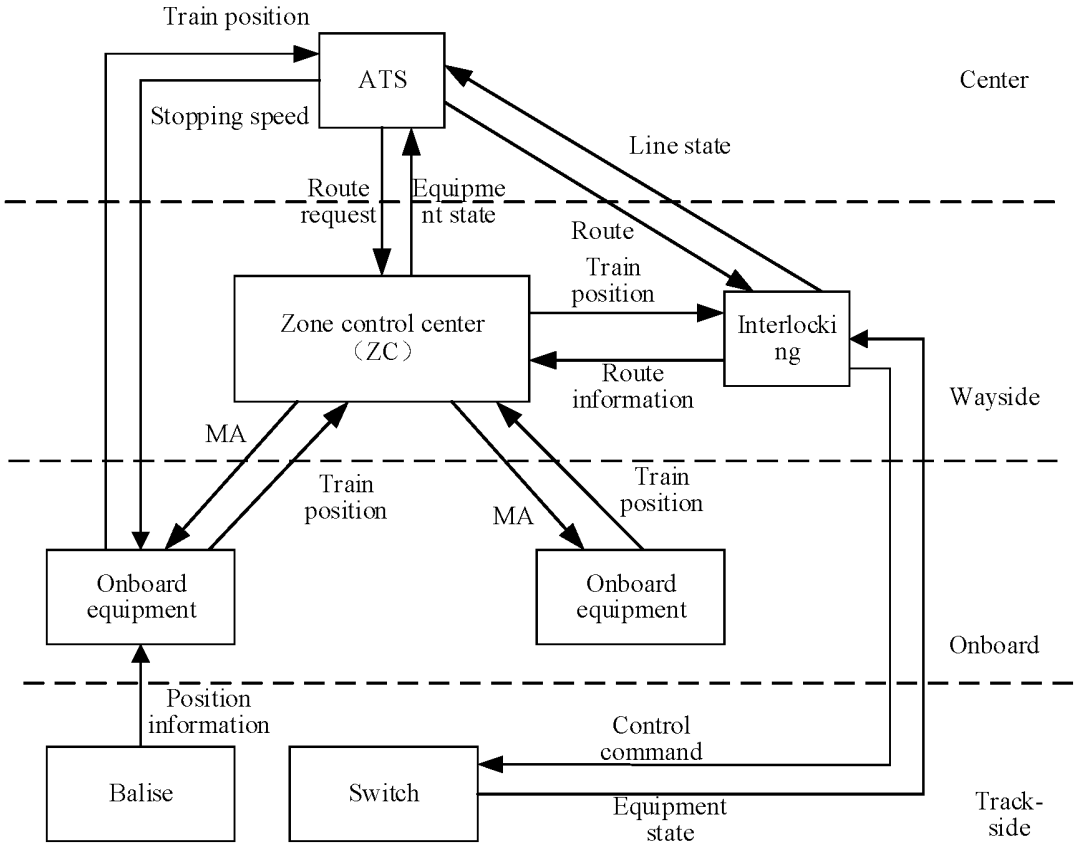
Train position
ATS
Center
Stopping speed
Line state
Route request
Equipment state
Route
Train position
Zone control center (ZC)
Interlocking
Route information
Wayside
MA
Train position
MA
Train position
Onboard equipment
Onboard equipment
Onboard
Position information
Control command
Balise
Switch
Equipment state
Track-side

FIG. 1

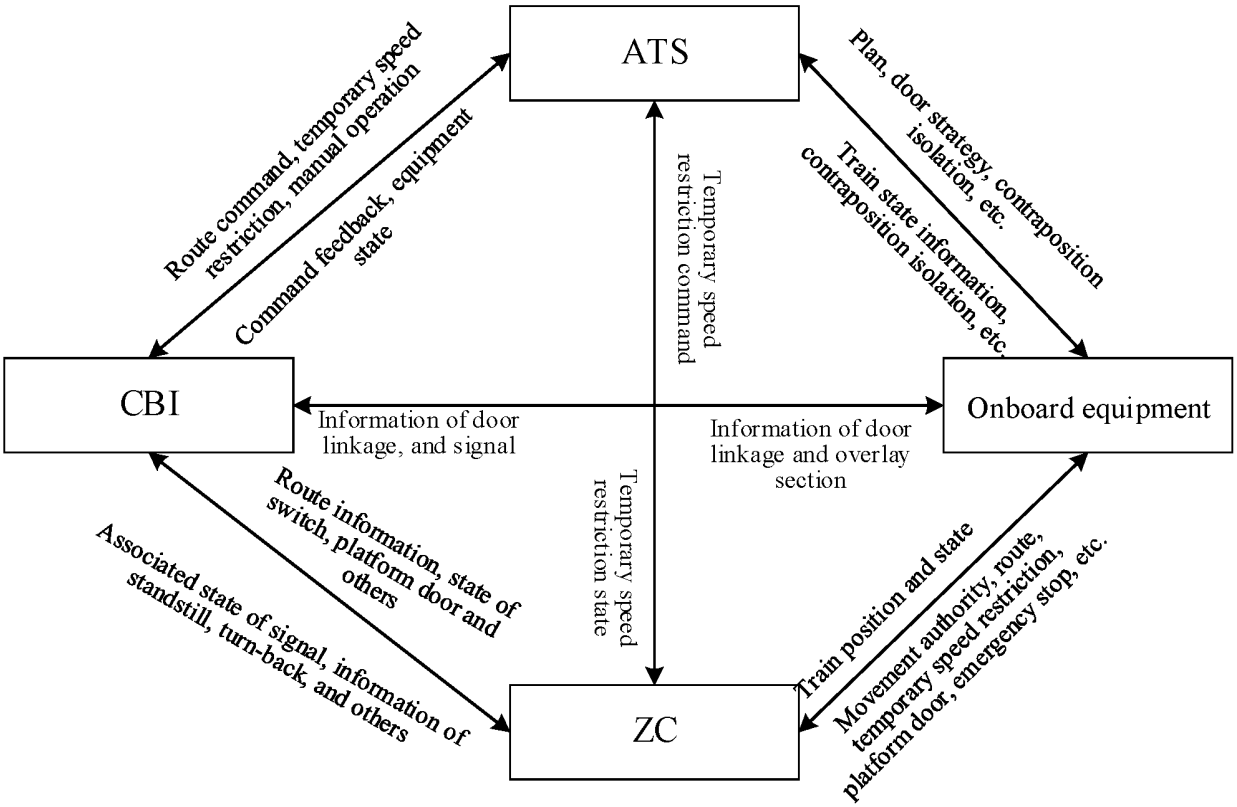
ATS
Route command, temporary speed restriction, manual operation
Command feedback, equipment state
Temporary speed restriction command
Plan, door strategy, contraposition isolation, etc.
Train state information, contraposition isolation, etc.
CBI
Onboard equipment
Information of door linkage, and signal
Information of door linkage and overlay section
Route information, state of switch, platform door and others
Associated state of signal, information of standstill, turn-back, and others
Temporary speed restriction state
Train position and state
Movement authority, route, temporary speed restriction, platform door, emergency stop, etc.
ZC

FIG. 2

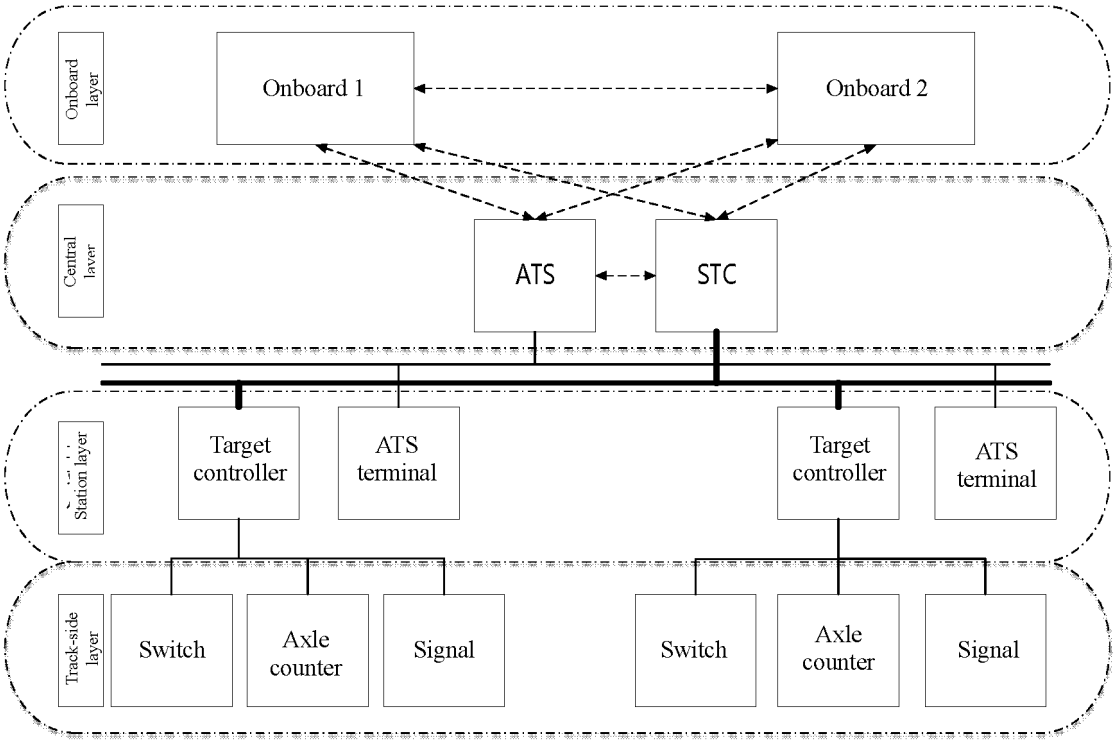
Onboard layer
Onboard 1
Onboard 2
Central layer
ATS
STC
Station layer
Target controller
ATS terminal
Target controller
ATS terminal
Track-side layer
Switch
Axle counter
Signal
Switch
Axle counter
Signal

FIG. 3

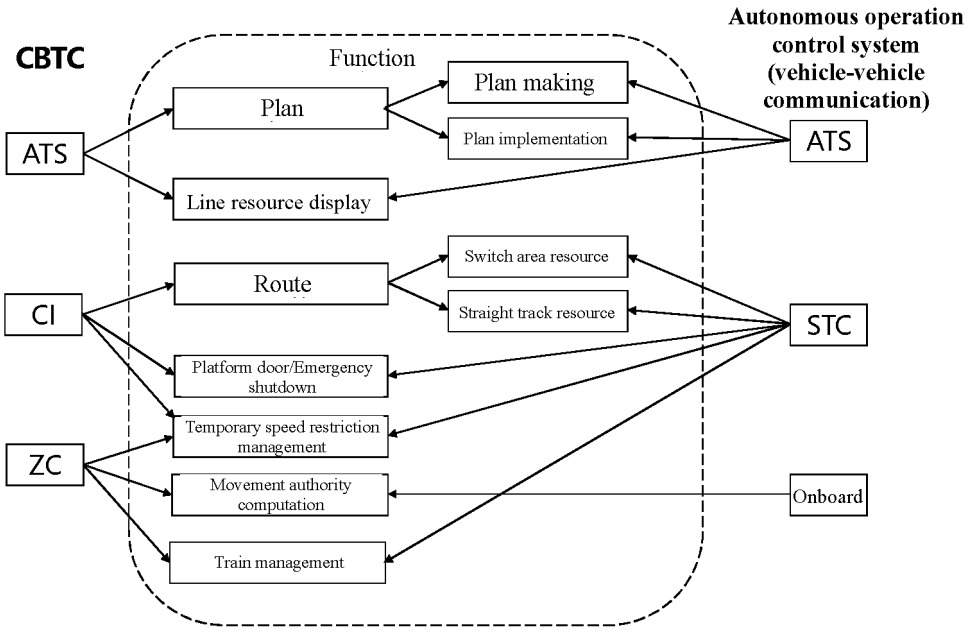
CBTC
Function
Autonomous operation control system (vehicle-vehicle communication)
ATS
Plan
Plan making
Plan implementation
ATS
Line resource display
CI
Route
Switch area resource
Straight track resource
STC
Platform door/Emergency shutdown
Temporary speed restriction management
ZC
Movement authority computation
Onboard
Train management

FIG. 4

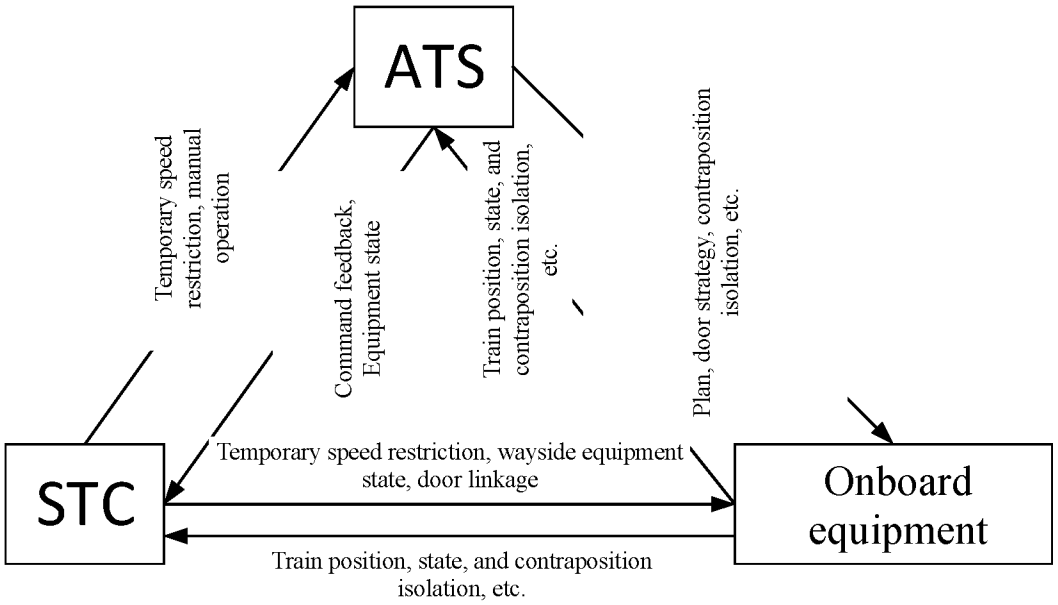
ATS
Temporary speed restriction, manual operation
Command feedback, Equipment state
Train position, state, and contraposition isolation, etc.
Plan, door strategy, contraposition isolation, etc.
STC
Temporary speed restriction, wayside equipment state, door linkage
Onboard equipment
Train position, state, and contraposition isolation, etc.

FIG. 5

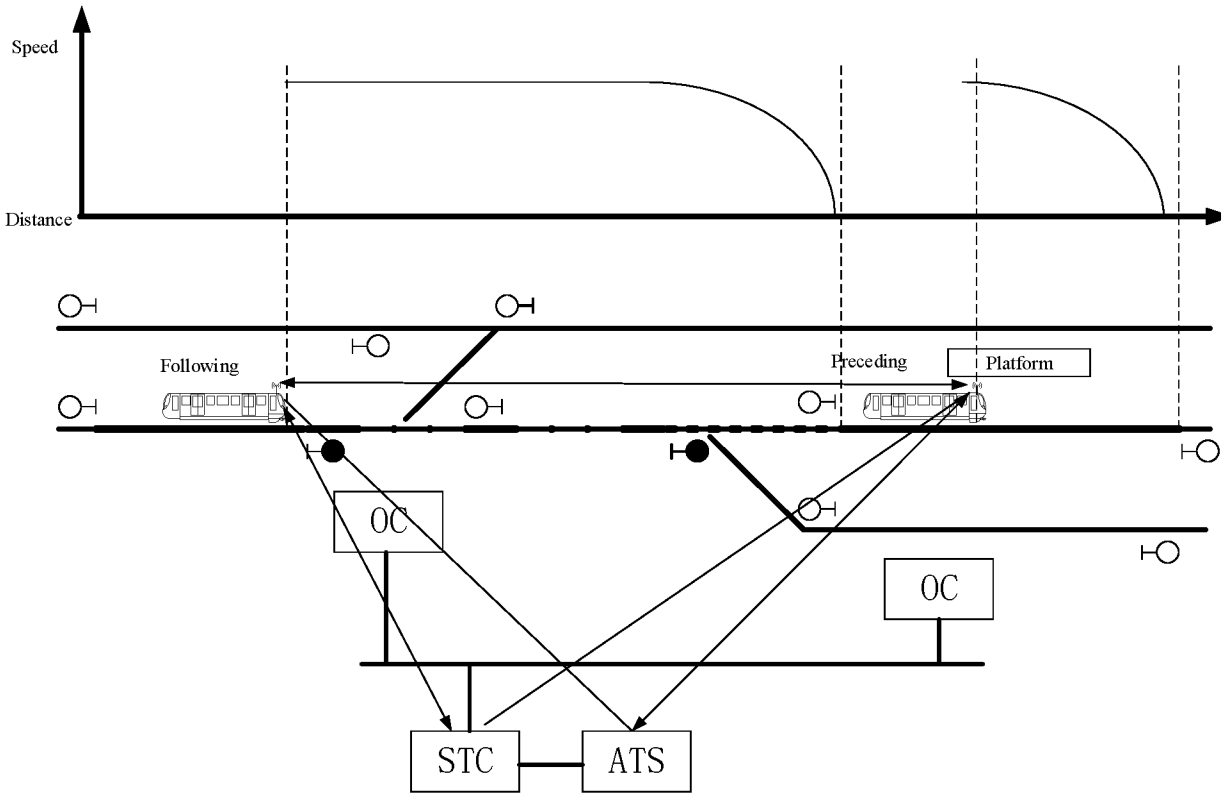
Speed
Distance
Following
Preceding
Platform
OC
OC
STC
ATS

FIG. 6

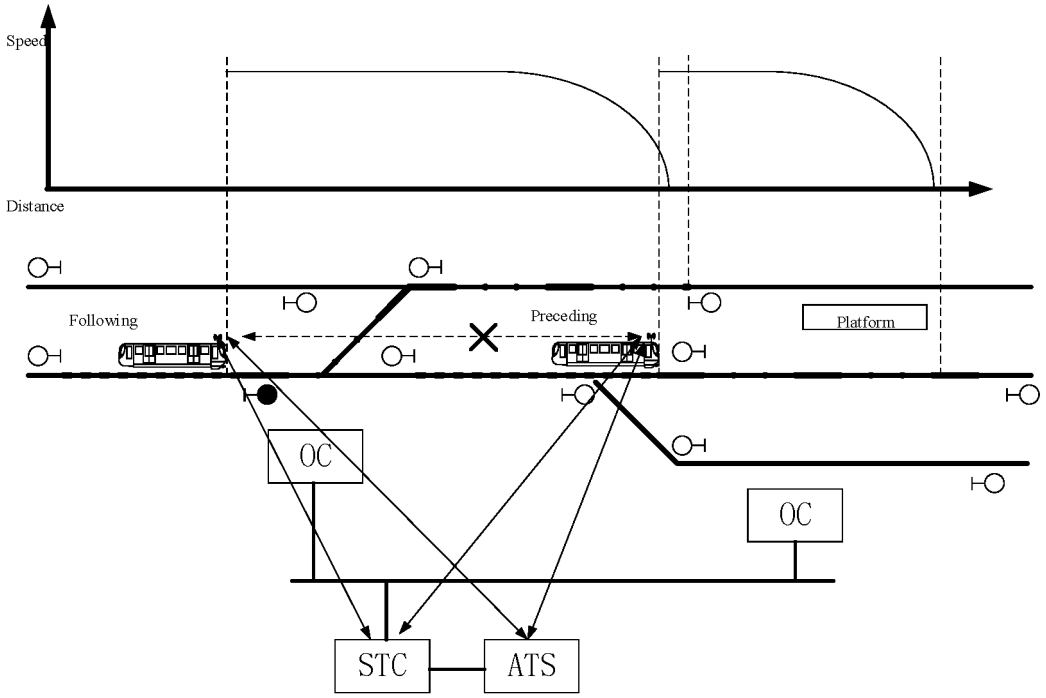

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2023/122259

A. CLASSIFICATION OF SUBJECT MATTER

B61L27/00(2022.01)i; B61L27/40(2022.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: B61L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNABS, CNTXT, CNKI: 车, 通信, 列车, 控制, 安全, 中心, 自动, 监控, 进路, 限速, 链接; VEN, USTXT, EPTXT, WOTXT, ISI: vehicle, communication, train, control, safety, centre, automatic, monitor, route, speed, limit, link

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	CN 115973233 A (BEIJING NATIONAL RAILWAY RESEARCH & DESIGN INSTITUTE OF SIGNAL & COMMUNICATION GROUP CO., LTD.) 18 April 2023 (2023-04-18) claims 1-15, and description, paragraphs 27-44, and figures 3-7	1-15
Y	CN 115257864 A (CASCO SIGNAL LTD.) 01 November 2022 (2022-11-01) description, paragraphs 52-109, and figures 1-8	1-7, 9-15
Y	CN 107031683 A (BEIJING NATIONAL RAILWAY RESEARCH & DESIGN INSTITUTE OF SIGNAL & COMMUNICATION GROUP CO., LTD.) 11 August 2017 (2017-08-11) description, paragraphs 65-98	1-7, 9-15
Y	CN 109649435 A (TIANJIN JINHANG INSTITUTE OF COMPUTING TECHNOLOGY) 19 April 2019 (2019-04-19) description, paragraphs 48-139, and figures 2-9	1-7, 9-15
Y	CN 106985880 A (BEIJING JIAOTONG UNIVERSITY) 28 July 2017 (2017-07-28) description, paragraphs 42-83, and figures 1-8	1-7, 9-15
A	CN 104506794 A (BEIJING JIAOTONG UNIVERSITY et al.) 08 April 2015 (2015-04-08) entire document	1-15

☑ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
04 January 2024	**06 January 2024**
Name and mailing address of the ISA/CN **China National Intellectual Property Administration (ISA/CN)** **China No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088**	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2023/122259

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 106926871 A (BEIJING JIAOTONG UNIVERSITY) 07 July 2017 (2017-07-07) entire document	1-15
A	KR 20180015786 A (KRRI) 14 February 2018 (2018-02-14) entire document	1-15
A	KR 20170056084 A (KRRI) 23 May 2017 (2017-05-23) entire document	1-15

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2023/122259

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
CN 115973233 A	18 April 2023	CN 115973233 B	30 May 2023
CN 115257864 A	01 November 2022	None	
CN 107031683 A	11 August 2017	CN 107031683 B	04 December 2018
CN 109649435 A	19 April 2019	CN 109649435 B	21 July 2020
CN 106985880 A	28 July 2017	None	
CN 104506794 A	08 April 2015	CN 104506794 B	27 July 2018
CN 106926871 A	07 July 2017	None	
KR 20180015786 A	14 February 2018	KR 101864340 B1	07 June 2018
KR 20170056084 A	23 May 2017	KR 101784393 B1	07 November 2017

Form PCT/ISA/210 (patent family annex) (July 2022)