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(54) **COMMUNICATION DEVICE AND COMMUNICATION METHOD**

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(57) **ABSTRACT**

A communication device includes a communication control unit. The communication control unit includes a plurality of protocol processing units and a plurality of received data storage areas. A received message that is a CAN message received by the communication device is input into the plurality of protocol processing units. In a case where the destination of the received message is a virtual machine corresponding to the protocol processing unit itself, each protocol processing unit stores the payload of the received message in the received data storage area accessible from the destination virtual machine.

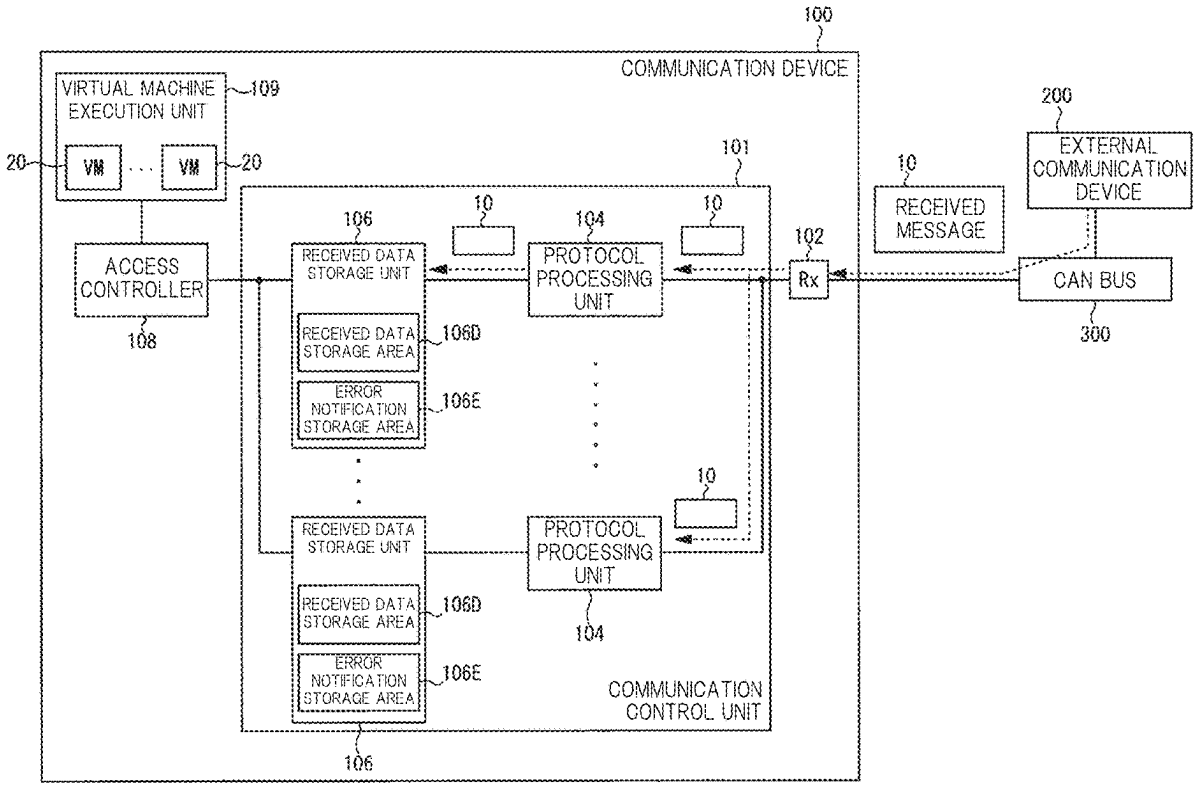


FIG. 1

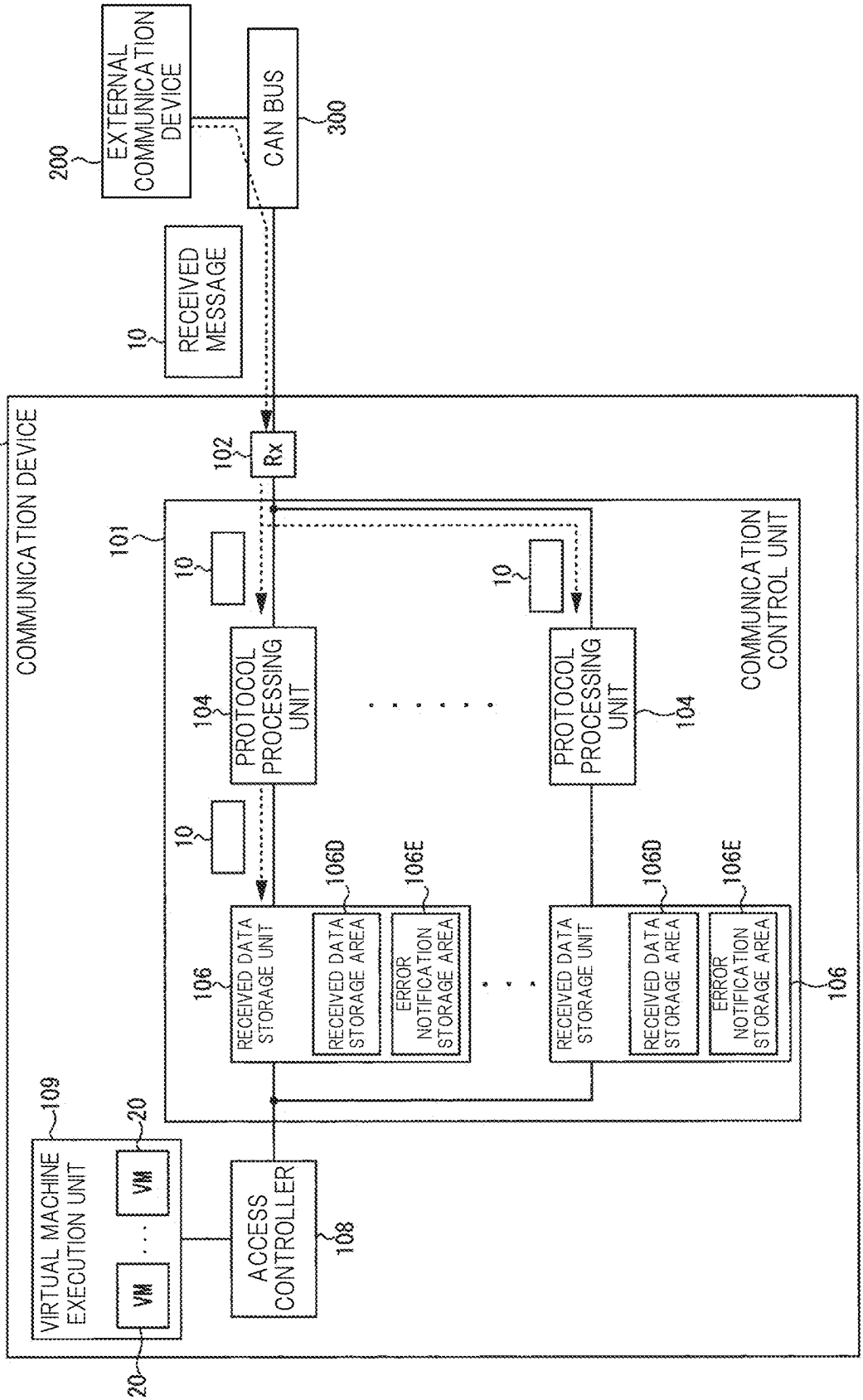

EXTERNAL COMMUNICATION DEVICE
200
CAN BUS
300
RECEIVED MESSAGE
10
100
COMMUNICATION DEVICE
102
Rx
101
COMMUNICATION CONTROL UNIT
PROTOCOL PROCESSING UNIT
104
RECEIVED DATA STORAGE UNIT
106
RECEIVED DATA STORAGE AREA
106D
ERROR NOTIFICATION STORAGE AREA
106E
VIRTUAL MACHINE EXECUTION UNIT
109
VM
20
ACCESS CONTROLLER
108

FIG. 2

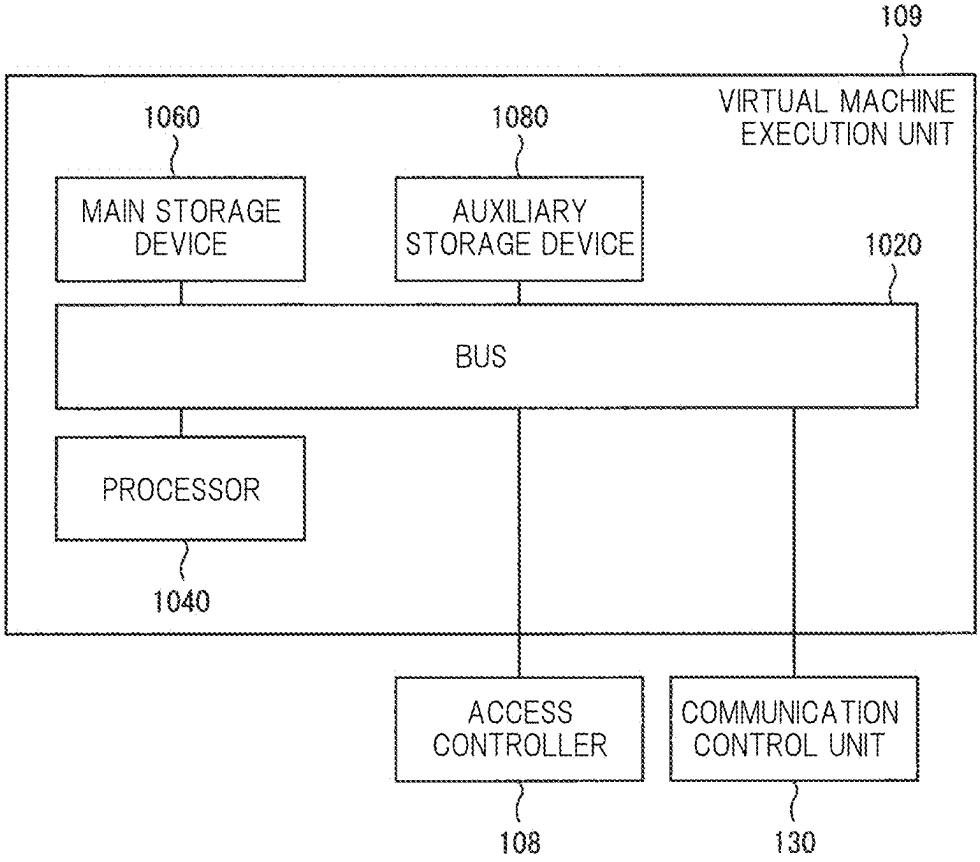

109
VIRTUAL MACHINE EXECUTION UNIT
1060
MAIN STORAGE DEVICE
1080
AUXILIARY STORAGE DEVICE
1020
BUS
PROCESSOR
1040
ACCESS CONTROLLER
108
COMMUNICATION CONTROL UNIT
130

FIG. 3

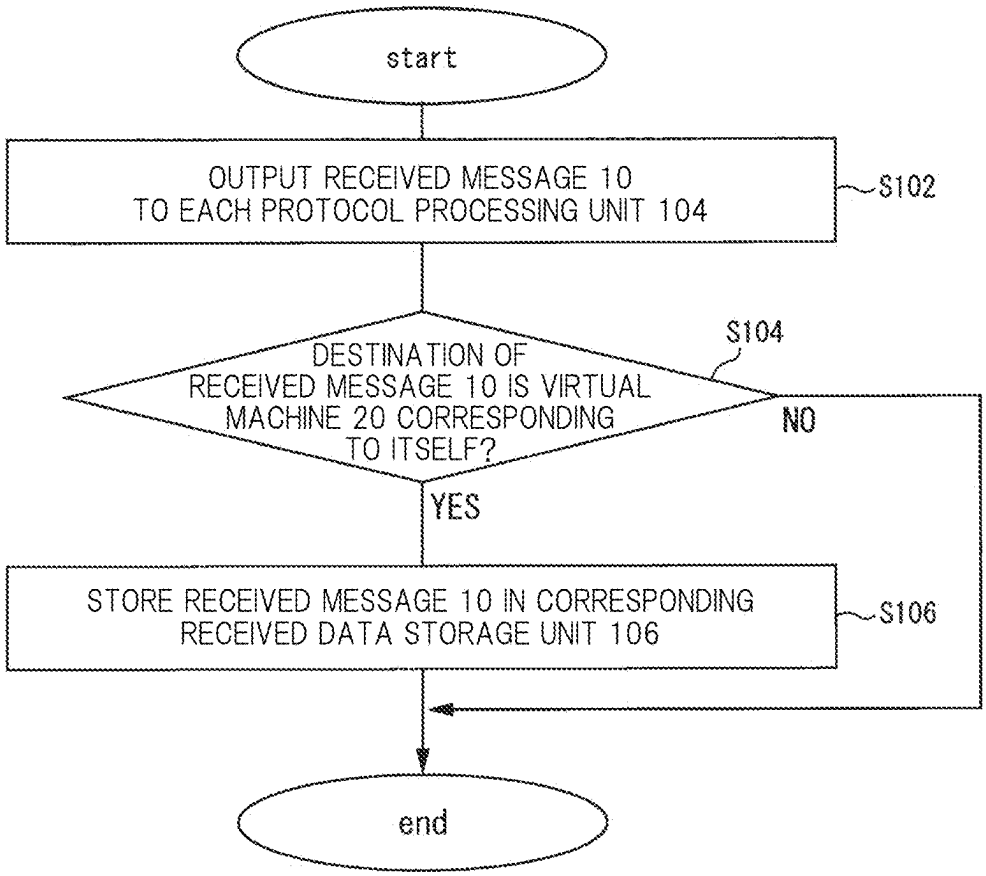

start
OUTPUT RECEIVED MESSAGE 10 TO EACH PROTOCOL PROCESSING UNIT 104
S102
DESTINATION OF RECEIVED MESSAGE 10 IS VIRTUAL MACHINE 20 CORRESPONDING TO ITSELF?
S104
NO
YES
STORE RECEIVED MESSAGE 10 IN CORRESPONDING RECEIVED DATA STORAGE UNIT 106
S106
end

FIG. 4

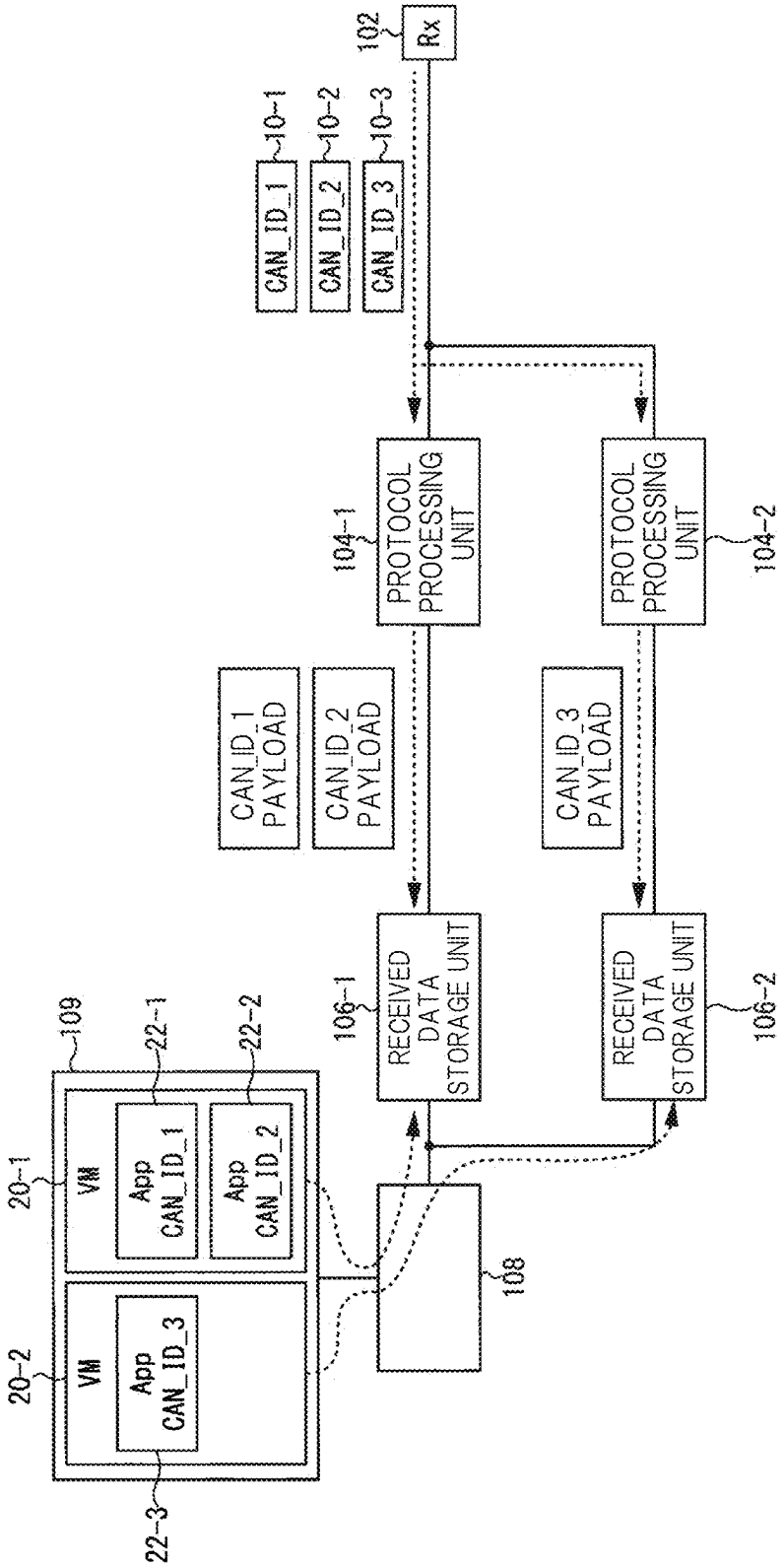

102
Rx
10-1
CAN_ID_1
10-2
CAN_ID_2
10-3
CAN_ID_3
104-1
PROTOCOL PROCESSING UNIT
104-2
PROTOCOL PROCESSING UNIT
CAN_ID_1 PAYLOAD
CAN_ID_2 PAYLOAD
CAN_ID_3 PAYLOAD
106-1
RECEIVED DATA STORAGE UNIT
106-2
RECEIVED DATA STORAGE UNIT
108
109
20-1
VM
22-1
App CAN_ID_1
22-2
App CAN_ID_2
20-2
VM
App CAN_ID_3
22-3

FIG. 5

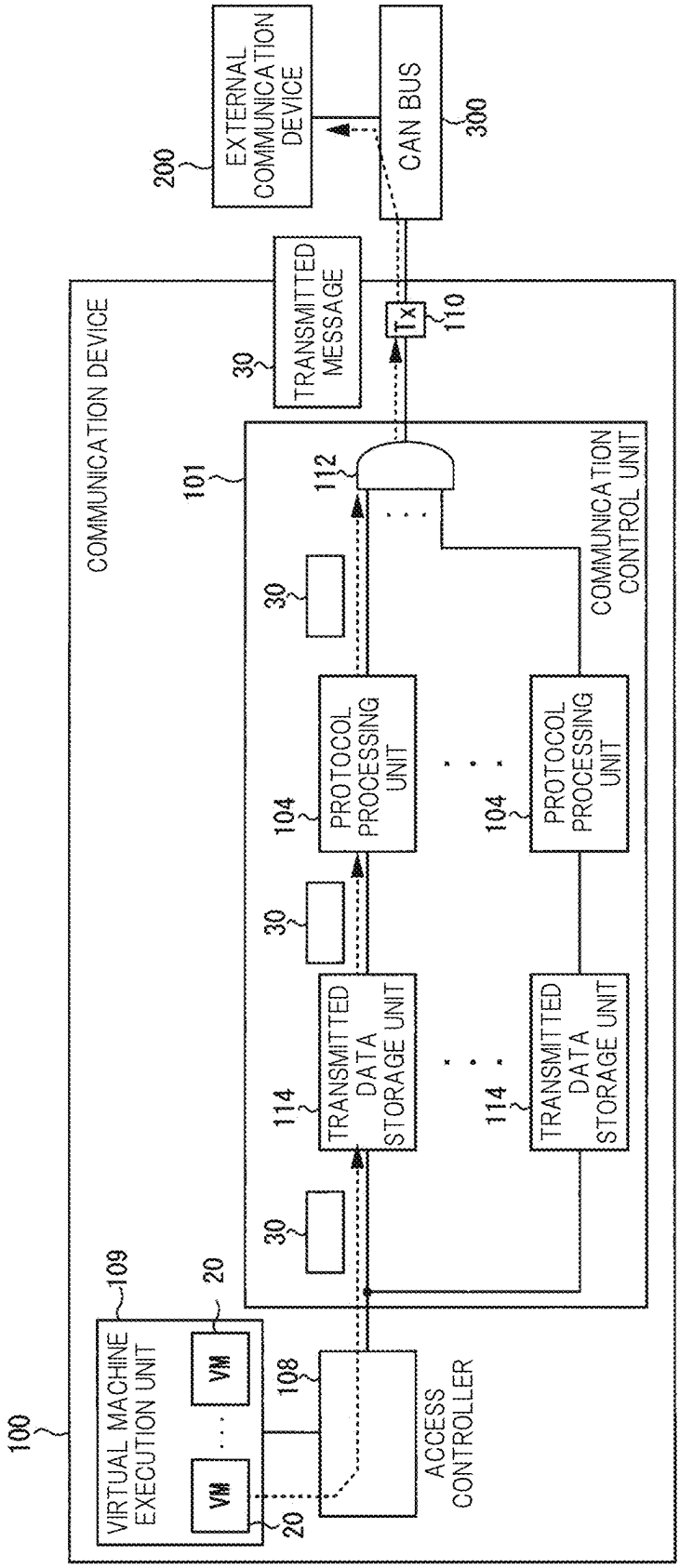

100
COMMUNICATION DEVICE
VIRTUAL MACHINE EXECUTION UNIT
109
VM
VM
20
20
ACCESS CONTROLLER
108
101
COMMUNICATION CONTROL UNIT
112
Tx
110
TRANSMITTED MESSAGE
30
30
30
30
PROTOCOL PROCESSING UNIT
PROTOCOL PROCESSING UNIT
104
104
TRANSMITTED DATA STORAGE UNIT
TRANSMITTED DATA STORAGE UNIT
114
114
CAN BUS
300
EXTERNAL COMMUNICATION DEVICE
200

FIG. 6

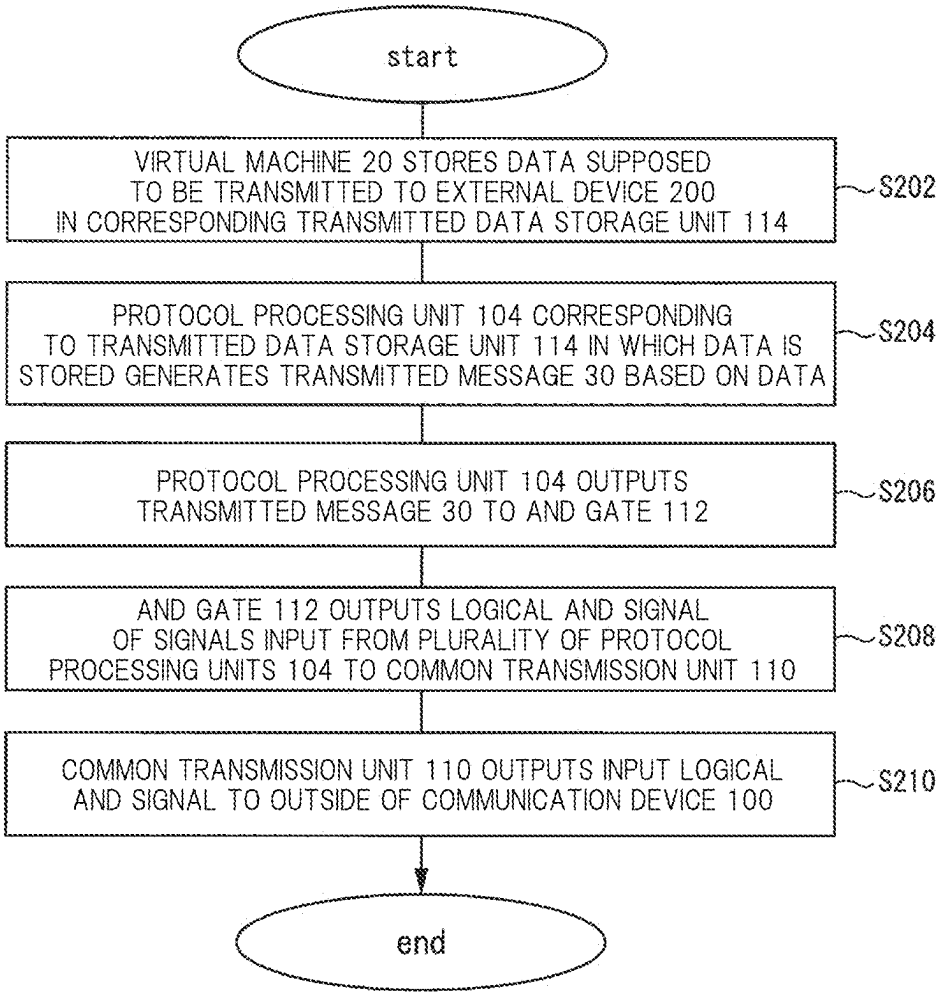

start
VIRTUAL MACHINE 20 STORES DATA SUPPOSED TO BE TRANSMITTED TO EXTERNAL DEVICE 200 IN CORRESPONDING TRANSMITTED DATA STORAGE UNIT 114
S202
PROTOCOL PROCESSING UNIT 104 CORRESPONDING TO TRANSMITTED DATA STORAGE UNIT 114 IN WHICH DATA IS STORED GENERATES TRANSMITTED MESSAGE 30 BASED ON DATA
S204
PROTOCOL PROCESSING UNIT 104 OUTPUTS TRANSMITTED MESSAGE 30 TO AND GATE 112
S206
AND GATE 112 OUTPUTS LOGICAL AND SIGNAL OF SIGNALS INPUT FROM PLURALITY OF PROTOCOL PROCESSING UNITS 104 TO COMMON TRANSMISSION UNIT 110
S208
COMMON TRANSMISSION UNIT 110 OUTPUTS INPUT LOGICAL AND SIGNAL TO OUTSIDE OF COMMUNICATION DEVICE 100
S210
end

FIG. 7

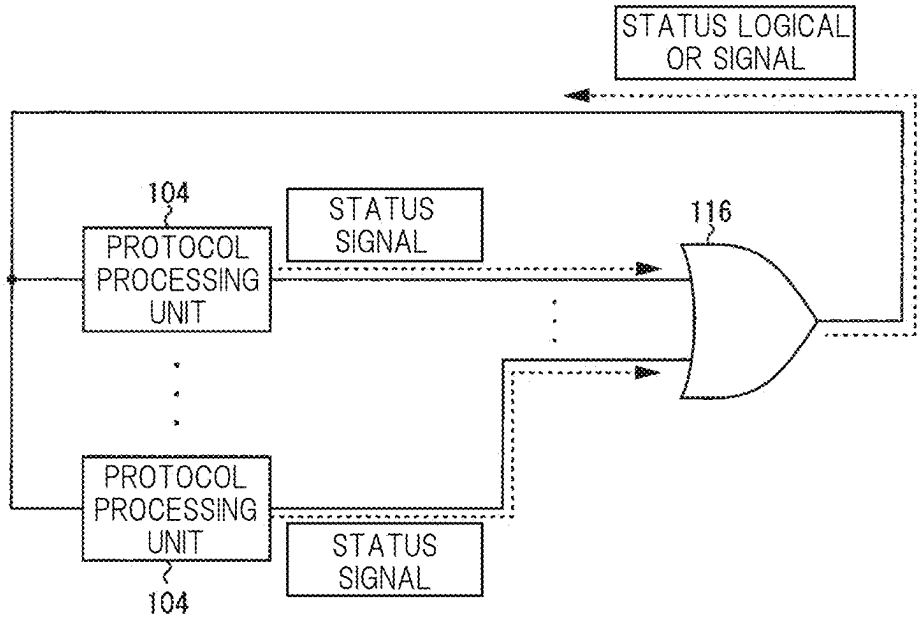

STATUS LOGICAL OR SIGNAL
104
PROTOCOL PROCESSING UNIT
STATUS SIGNAL
116
PROTOCOL PROCESSING UNIT
STATUS SIGNAL
104

FIG. 8

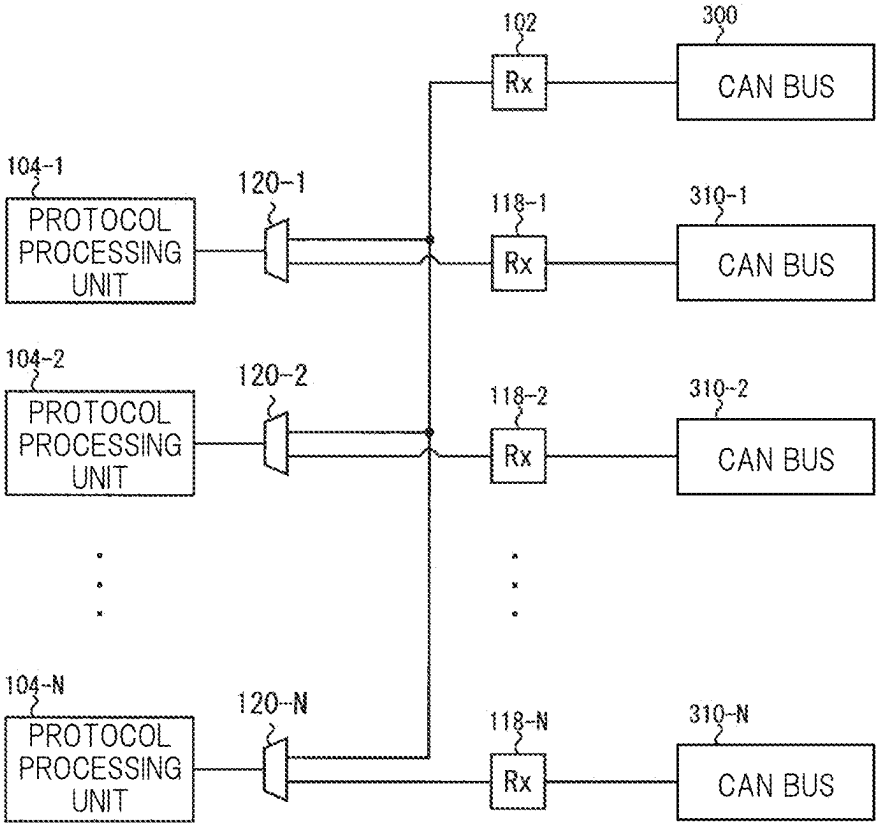

102
300
Rx
CAN BUS
104-1
120-1
PROTOCOL PROCESSING UNIT
118-1
310-1
Rx
CAN BUS
104-2
120-2
PROTOCOL PROCESSING UNIT
118-2
310-2
Rx
CAN BUS
104-N
120-N
PROTOCOL PROCESSING UNIT
118-N
310-N
Rx
CAN BUS

FIG. 9

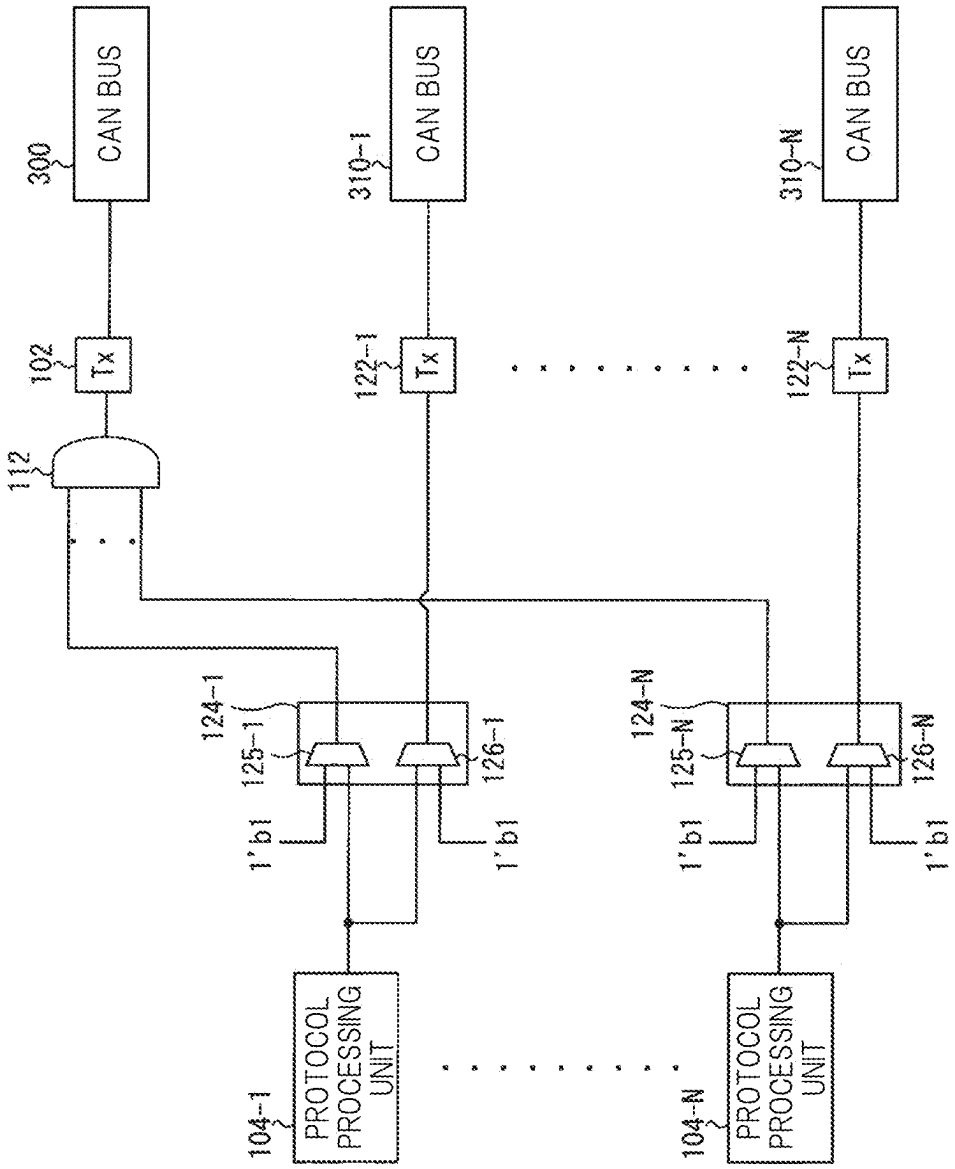

300
CAN BUS
310-1
CAN BUS
310-N
CAN BUS
102
Tx
122-1
Tx
122-N
Tx
112
124-1
125-1
126-1
124-N
125-N
126-N
1'b1
1'b1
1'b1
1'b1
104-1
PROTOCOL PROCESSING UNIT
104-N
PROTOCOL PROCESSING UNIT

FIG. 10

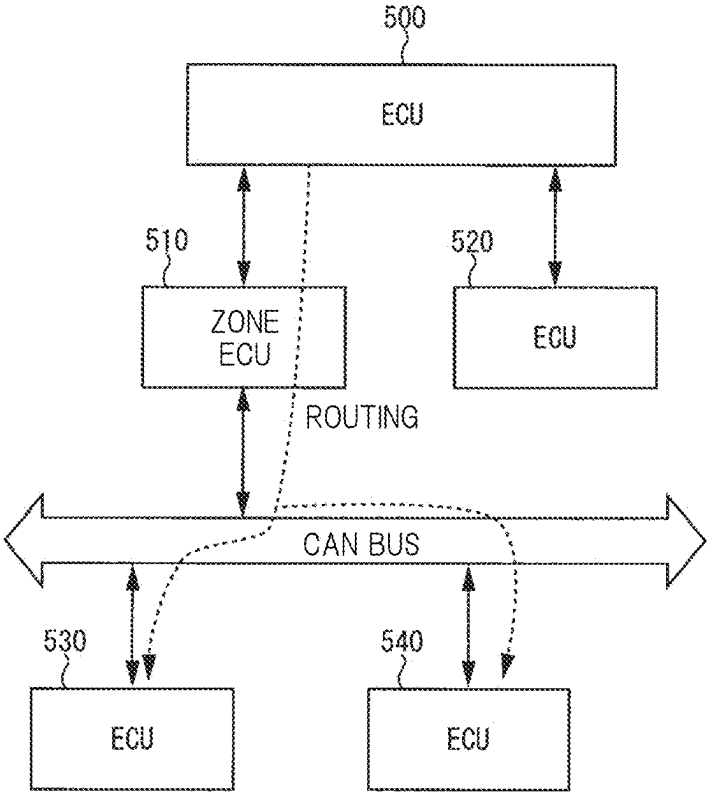


FIG. 11

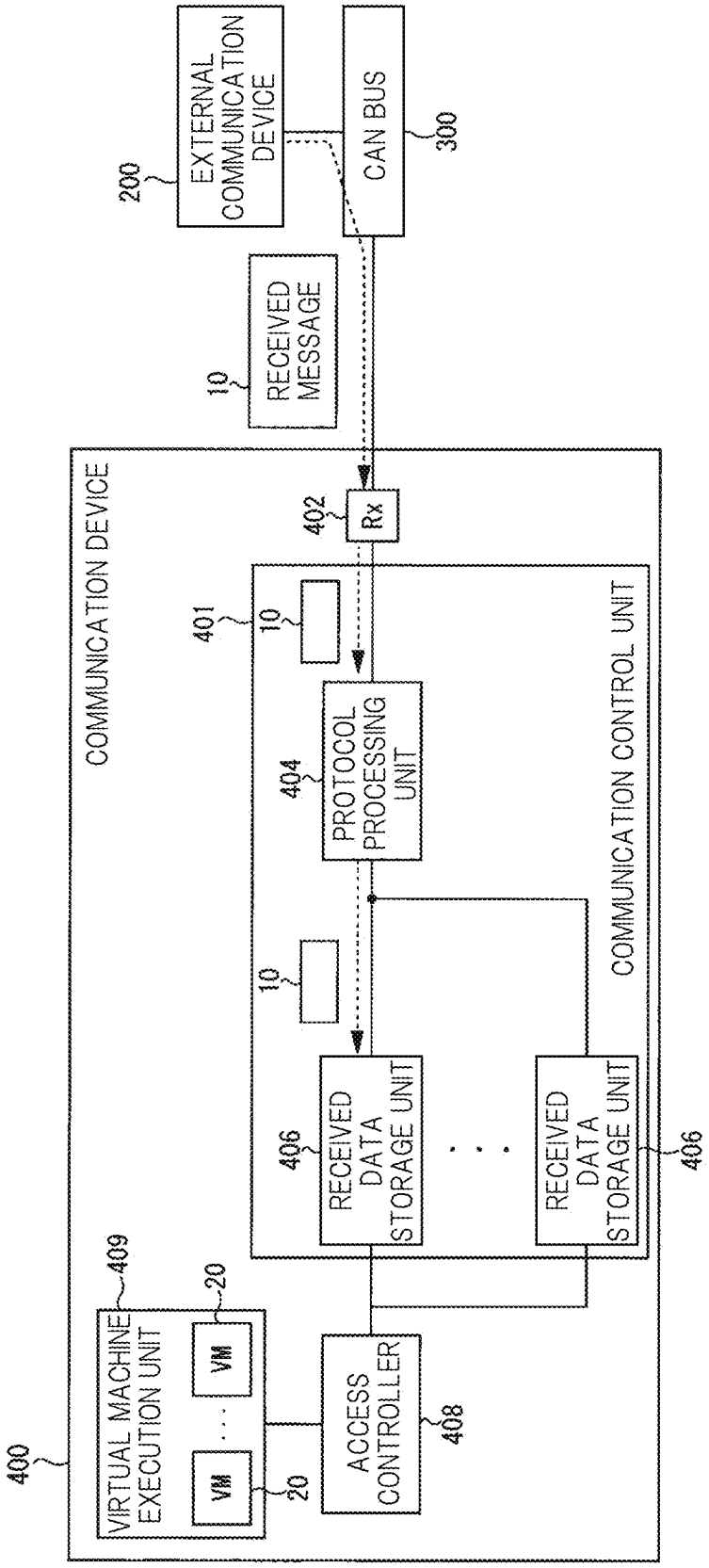

200
EXTERNAL COMMUNICATION DEVICE
CAN BUS
300
10
RECEIVED MESSAGE
COMMUNICATION DEVICE
402
Rx
401
10
404
PROTOCOL PROCESSING UNIT
COMMUNICATION CONTROL UNIT
10
406
RECEIVED DATA STORAGE UNIT
406
RECEIVED DATA STORAGE UNIT
409
VIRTUAL MACHINE EXECUTION UNIT
20
VM
VM
20
ACCESS CONTROLLER
408
400

FIG. 12

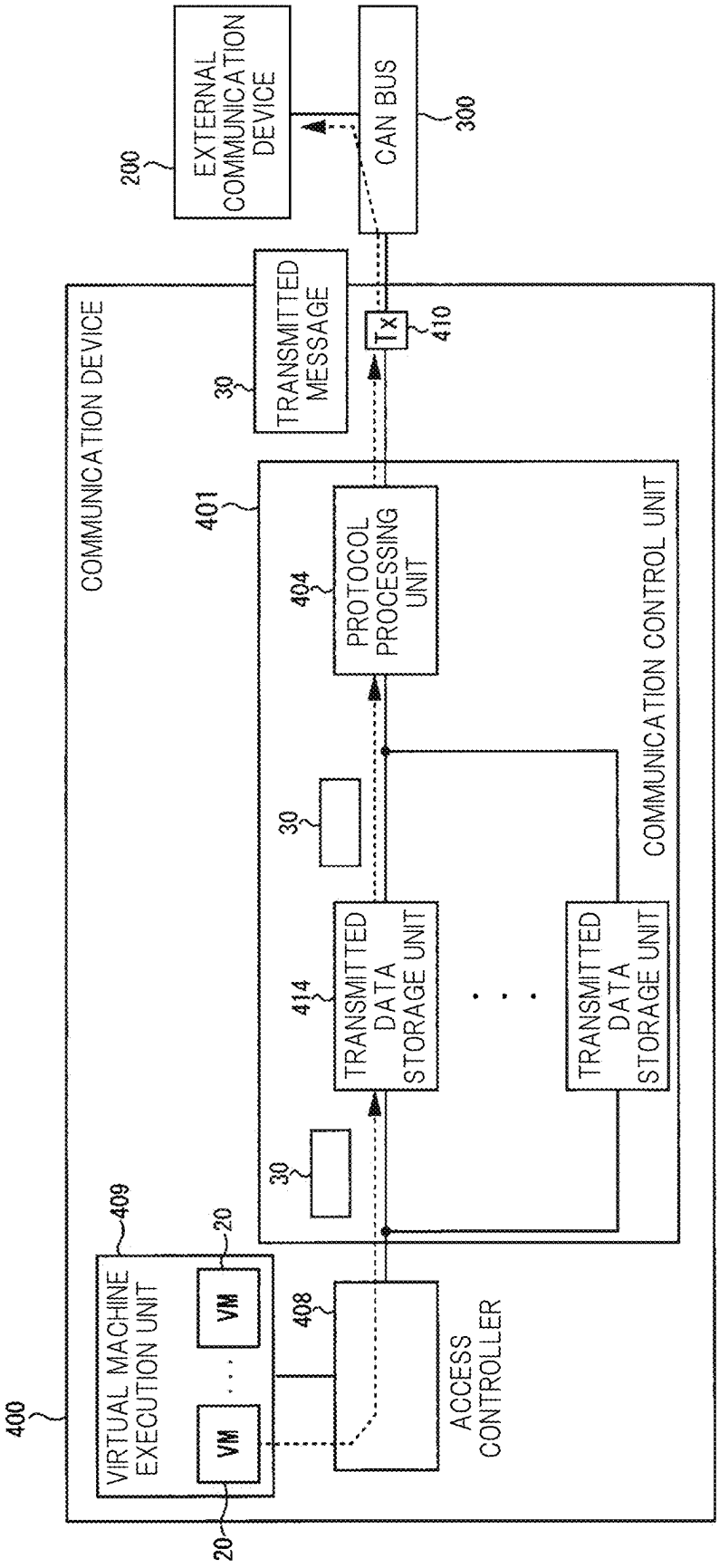

200
EXTERNAL COMMUNICATION DEVICE
CAN BUS
300
COMMUNICATION DEVICE
TRANSMITTED MESSAGE
30
Tx
410
401
PROTOCOL PROCESSING UNIT
404
COMMUNICATION CONTROL UNIT
30
TRANSMITTED DATA STORAGE UNIT
414
TRANSMITTED DATA STORAGE UNIT
30
409
20
VIRTUAL MACHINE EXECUTION UNIT
VM
VM
408
ACCESS CONTROLLER
400
20

FIG. 13

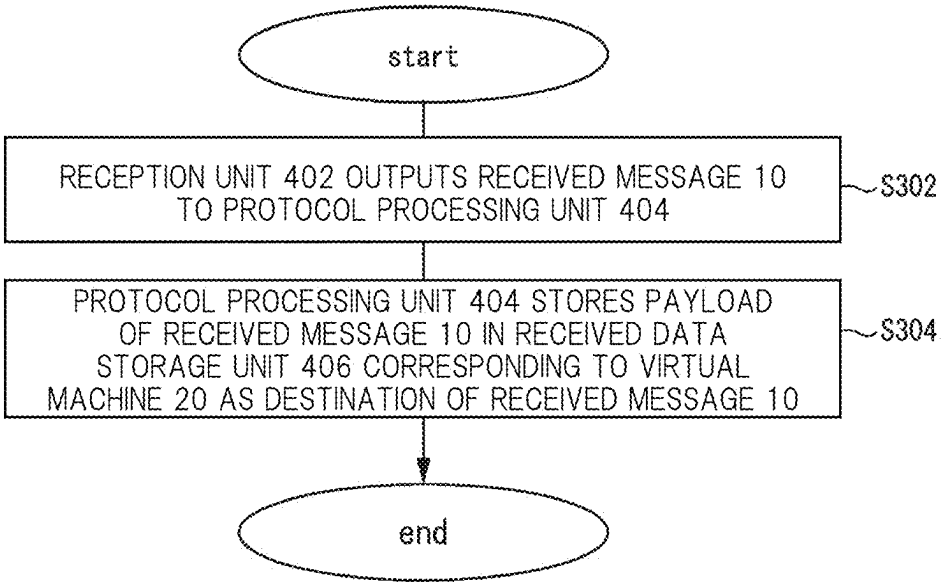
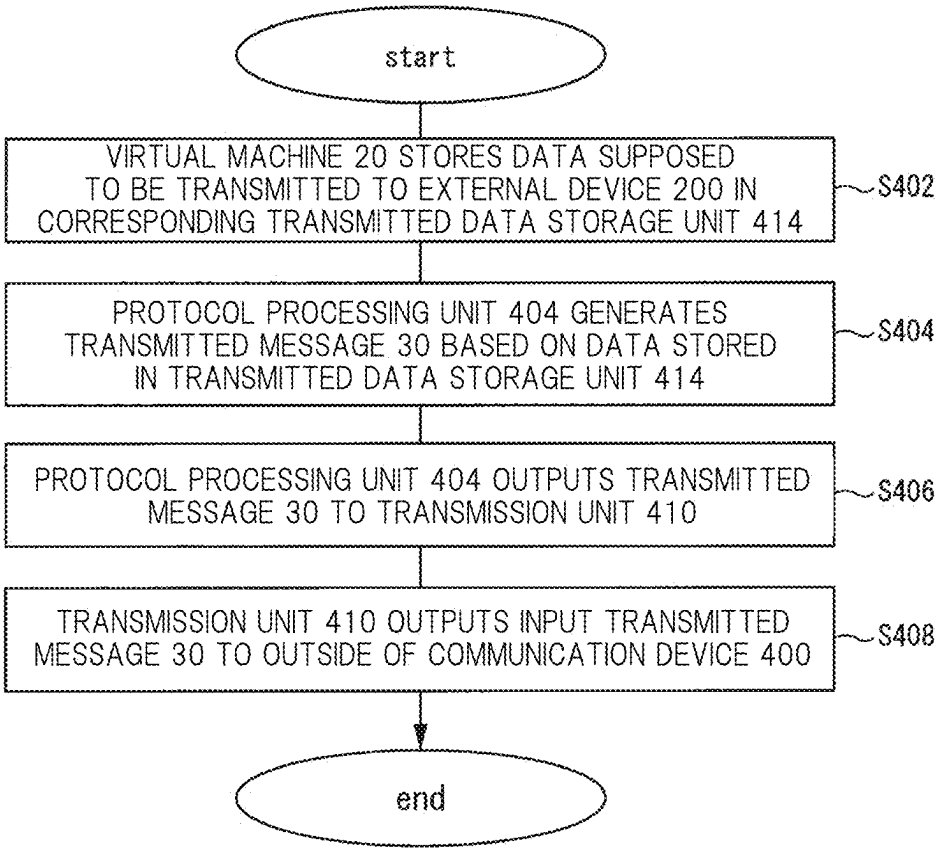

start
RECEPTION UNIT 402 OUTPUTS RECEIVED MESSAGE 10 TO PROTOCOL PROCESSING UNIT 404
S302
PROTOCOL PROCESSING UNIT 404 STORES PAYLOAD OF RECEIVED MESSAGE 10 IN RECEIVED DATA STORAGE UNIT 406 CORRESPONDING TO VIRTUAL MACHINE 20 AS DESTINATION OF RECEIVED MESSAGE 10
S304
end

FIG. 14


start
VIRTUAL MACHINE 20 STORES DATA SUPPOSED TO BE TRANSMITTED TO EXTERNAL DEVICE 200 IN CORRESPONDING TRANSMITTED DATA STORAGE UNIT 414
S402
PROTOCOL PROCESSING UNIT 404 GENERATES TRANSMITTED MESSAGE 30 BASED ON DATA STORED IN TRANSMITTED DATA STORAGE UNIT 414
S404
PROTOCOL PROCESSING UNIT 404 OUTPUTS TRANSMITTED MESSAGE 30 TO TRANSMISSION UNIT 410
S406
TRANSMISSION UNIT 410 OUTPUTS INPUT TRANSMITTED MESSAGE 30 TO OUTSIDE OF COMMUNICATION DEVICE 400
S408
end

COMMUNICATION DEVICE AND COMMUNICATION METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The disclosure of Japanese Patent Application No. 2024-024420 filed on Feb. 21, 2024 including the specification, drawings and abstract is incorporated herein by reference in its entirety.

BACKGROUND

[0002] The present disclosure relates to a technology for performing communication in accordance with a controller area network (CAN) protocol.

[0003] There are disclosed techniques listed below.

[0004] [Patent Document 1] Japanese Unexamined Patent Application Publication No. 2022-123826

[0005] A system that performs communication in accordance with a CAN protocol (hereinbelow, CAN communication) has been developed. For example, Patent Document 1 discloses a technology for a CAN controller to transfer a CAN message to a virtual machine in a microcontroller in which a plurality of virtual machines operate.

SUMMARY

[0006] The CAN controller in Patent Document 1 uses a direct memory access (DMA) controller to store the CAN message in a random access memory (RAM) of the virtual machine. Patent Document 1 does not disclose, as a method for enabling the virtual machine to use the CAN message, a method other than a method of storing the CAN message in the RAM of the virtual machine by using the DMA controller. Other objects and novel features will become apparent from the description of the present specification and the accompanying drawings.

[0007] A communication device according to an embodiment includes a plurality of protocol processing units and a plurality of received data storage areas. A CAN message received by the communication device is input into the plurality of protocol processing units. In a case where the destination of the CAN message is a virtual machine corresponding to the protocol processing unit itself, each protocol processing unit stores the payload of the CAN message in a received data storage area accessible from the destination virtual machine.

[0008] According to the present disclosure, there is provided a new technology for causing a virtual machine as a destination of a CAN message to use the CAN message received by a communication device in which a plurality of virtual machines operate.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** is a diagram illustrating a configuration of a communication device according to a first embodiment.

[0010] FIG. **2** is a block diagram illustrating a hardware configuration of a virtual machine execution unit.

[0011] FIG. **3** is a flowchart illustrating a procedure of message reception processing in the communication device.

[0012] FIG. **4** is a diagram illustrating a case where a CAN ID is allocated to each application.

[0013] FIG. **5** is a diagram illustrating a configuration related to transmission of a transmitted message in the configuration of the communication device.

[0014] FIG. **6** is a flowchart illustrating a procedure of message transmission in the communication device.

[0015] FIG. **7** is a diagram illustrating a configuration in which a status signal is output from a protocol processing unit.

[0016] FIG. **8** is a diagram illustrating a configuration in which an individual reception unit is provided for each protocol processing unit.

[0017] FIG. **9** is a diagram illustrating a configuration in which an individual transmission unit is provided for each protocol processing unit.

[0018] FIG. **10** is a diagram illustrating a hierarchical structure of a system having a zone ECU FIG. **11** is a diagram illustrating a configuration of a communication device according to a second embodiment.

[0019] FIG. **12** is a diagram illustrating a configuration of the communication device related to transmission of a transmitted message.

[0020] FIG. **13** is a flowchart illustrating a procedure of message reception in the communication device.

[0021] FIG. **14** is a flowchart illustrating a procedure of message transmission in the communication device.

DETAILED DESCRIPTION

[0022] Hereinbelow, embodiments of the present disclosure will be described in detail with reference to the drawings. In the drawings, the same or corresponding elements are denoted by the same reference numerals, and redundant description is omitted as necessary for clarity of description. In addition, unless otherwise described, preset values such as predetermined values and threshold values are stored in advance in a storage device or the like accessible from a device using the values.

[0023] Furthermore, unless otherwise described, a storage unit includes as many storage devices as the freely-selected number that is one or more.

First Embodiment

Overview

[0024] FIG. **1** is a diagram illustrating a configuration of a communication device **100** according to a first embodiment. The communication device **100** transmits and receives a CAN message to and from an external communication device **200** in accordance with a CAN protocol. The communication device **100** is connected to the external communication device **200** via a CAN bus **300**. The CAN bus **300** is a communication path used for CAN communication between the communication device **100** and the external communication device **200**, and is, for example, a bus.

[0025] For example, the communication device **100** is an integrated circuit provided inside an electronic control unit (ECU) or the like. A more specific example of the communication device **100** is a system on chip (SoC) such as a micro control unit (MCU). Similarly to the communication device **100**, for example, the external communication device **200** is an integrated circuit provided inside an ECU or the like.

[0026] The communication device **100** includes a common reception unit **102**, a communication control unit **101**, an access controller **108**, and a virtual machine execution unit **109**. In the communication device **100**, the common reception unit **102** is an interface into which the CAN

message (hereinbelow, a received message **10**) transmitted from the external communication device **200** is input. The common reception unit **102** is configured to output the input received message **10** to the communication control unit **101**. More specifically, the common reception unit **102** is configured to receive a signal flowing through the CAN bus **300** and output the received signal to the communication control unit **101**. Note that the common reception unit **102** and the CAN bus **300** are connected via a suitable interface such as a CAN transceiver as necessary.

[0027] The communication control unit **101** includes a plurality of protocol processing units **104** and a plurality of received data storage units **106**. The received data storage unit **106** is a storage area provided in a freely-selected type of storage device (for example, a RAM, a register, or the like). For example, the plurality of received data storage units **106** include different partial storage areas included in one storage device (for example, one RAM or register), respectively. Alternatively, for example, the plurality of received data storage units **106** may be storage areas included in different storage devices (for example, different RAMs and registers), respectively.

[0028] Also, each of the plurality of received data storage units **106** includes a received data storage area **106**D and an error notification storage area **106**E. The received data storage area **106**D stores received data included in the received message **10**.

[0029] The error notification storage area **106**E stores an error notification related to communication.

[0030] The received data storage area **106**D and the error notification storage area **106**E included in each received data storage unit **106** may be different partial storage areas of one storage device (for example, one RAM or register), respectively. Alternatively, for example, the received data storage area **106**D and the error notification storage area **106**E may include different storage devices, respectively. In this case, for example, the received data storage area **106**D includes a partial storage area included in one storage device (for example, one RAM or register). On the other hand, the error notification storage area **106**E includes a different storage device (for example, one RAM or register) from the storage device including the received data storage area **106**D.

[0031] The virtual machine execution unit **109** operates a plurality of virtual machines (VMs) **20**. For example, the virtual machine execution unit **109** operates a hypervisor for managing the virtual machines. The plurality of virtual machines **20** operates under the management by the hypervisor. Note that the plurality of virtual machines **20** may include a virtual machine for management.

[0032] The plurality of virtual machines **20** are configured to be able to access different received data storage units **106**, respectively. Hereinbelow, the received data storage unit **106** accessible by the virtual machine **20** is also referred to as a "received data storage unit **106** corresponding to the virtual machine **20**".

[0033] The access controller **108** controls access from the virtual machine **20** to the received data storage unit **106**. Specifically, in a case where the received data storage unit **106** to be accessed by the virtual machine **20** is the received data storage unit **106** corresponding to the virtual machine **20**, the access controller **108** permits the virtual machine **20** to access the received data storage unit **106**. On the other hand, in a case where the received data storage unit **106** to be accessed by the virtual machine **20** is not the received data storage unit **106** corresponding to the virtual machine **20**, the access controller **108** does not permit the virtual machine **20** to access the received data storage unit **106**. Note that the correspondence relationship between the virtual machines **20** and the received data storage units **106** is stored in advance in a freely-selected storage area accessible from the access controller **108**, for example.

[0034] The protocol processing unit **104** performs processing on the received message **10** so that the virtual machine **20** that is the destination of the received message **10** can use a payload of the received message **10**. The protocol processing unit **104** is also referred to as a CAN protocol engine or the like. The plurality of protocol processing units **104** are associated with different virtual machines **20**, respectively.

[0035] Specifically, the protocol processing unit **104** extracts the payload and a CAN identifier (CAN ID) from the received message **10** in accordance with the CAN protocol. Whether to store the extracted payload in the received data storage area **106**D is determined by a reception filter, which is not illustrated in FIG. **1**. In other words, it is determined whether the received message **10** is a message to be used in the corresponding virtual machine **20**. The extracted payload is stored in the received data storage area **106**D corresponding to the virtual machine **20** based on the determination result.

[0036] On the other hand, in a case where the received message **10** is not one for use in the corresponding virtual machine **20**, the payload of the received message **10** is not stored in the received data storage area **106**D.

[0037] As a result of processing by the reception filter, which is not illustrated in FIG. **1**, the payload of the received message **10** is stored in one received data storage area **106**D. The received data storage area **106**D in which the payload of the received message **10** is stored is included in the received data storage unit **106** accessible from the virtual machine **20** that is to use the received message **10**. Therefore, the payload of the received message **10** is stored in the received data storage unit **106** so as to be accessible only from the virtual machine **20** that is to use the received message **10**.

[0038] Here, the virtual machine **20** recognizes that data is stored in the received data storage area **106**D corresponding to the virtual machine itself by an appropriate method. For example, the virtual machine **20** recognizes that new data is stored in the received data storage area **106**D by periodically checking the content of the received data storage area **106**D corresponding to the virtual machine itself. Alternatively, for example, in response to data being stored in the received data storage area **106**D, a specific notification may be transmitted to the virtual machine **20** corresponding to the received data storage area **106**D. In this case, the virtual machine **20** recognizes that new data is stored in the received data storage area **106**D corresponding to the virtual machine itself by receiving the specific notification.

[0039] Note that, in the received data storage area **106**D, not only the payload extracted from the received message **10** but also the CAN ID may be stored by the protocol processing unit **104**, for example.

Example of Operation and Effect

[0040] According to the present disclosure, there is provided a new technology for enabling a virtual machine as a destination of a CAN message to use a payload of the CAN message in the communication device **100** that receives the

CAN message. Specifically, in the communication device **100**, the received message **10** is input into the plurality of protocol processing units **104**. Further, only the protocol processing unit **104** corresponding to the virtual machine **20** as a destination of the received message **10** stores the payload of the received message **10** in the received data storage unit **106** corresponding to the virtual machine **20**. Access to the received data storage unit **106** by each virtual machine **20** is controlled by the access controller **108**.

[0041] In this manner, according to the communication device **100**, one protocol processing unit **104** and one received data storage unit **106** are associated with one virtual machine **20**. Such a correspondence relationship between one protocol processing unit **104** and one virtual machine **20** is the same as the correspondence relationship between one protocol processing unit **104** and one physical machine (one OS) in a case where the virtualization environment is not used. Therefore, software usability is higher than in a case where a plurality of virtual machines **20** are handled by one protocol processing unit **104** and one received data storage unit **106**.

[0042] For example, in a case where the plurality of virtual machines **20** share one protocol processing unit **104** and one received data storage unit **106**, data used by the plurality of virtual machines **20** is stored in one received data storage unit **106**. The fact that data is newly stored in the received data storage unit **106** is recognized only by the virtual machine **20** operating at that time.

[0043] For example, it is assumed that the first virtual machine **20** recognizes that new data is stored in the received data storage unit **106**. At this time, the data stored in the received data storage unit **106** is not necessarily data to be used in the first virtual machine. The first virtual machine **20** needs to confirm whether or not the data stored in the received data storage unit **106** is data to be used by the first virtual machine **20**. In a case where the data stored in the received data storage unit **106** is not for use in the first virtual machine **20** operating at that time, the first virtual machine **20** may need to notify the second virtual machine **20** that the data to be used in the second virtual machine **20** has been stored in the received data storage unit **106**. In a case where the plurality of virtual machines **20** share one protocol processing unit **104** and one received data storage unit **106**, it is necessary to prepare software assuming such a situation for each virtual machine **20**.

[0044] On the other hand, according to the communication device **100**, as described above, one protocol processing unit **104** and one received data storage unit **106** are allocated to each virtual machine **20**. Therefore, the fact that the data is stored in the received data storage unit **106** allocated to the first virtual machine **20** is easily recognized by the first virtual machine **20** that is to use the data. That is, the first virtual machine **20** only needs to grasp the data storage state in the received data storage unit **106** allocated thereto, and does not need to notify the other virtual machines **20** of the data storage state. Therefore, it is possible to heighten software usability related to communication processing of the virtual machine **20**.

[0045] Hereinbelow, the communication device **100** of the present embodiment will be described in more detail.

Example of Hardware Configuration of Communication Device **100**

[0046] The communication device **100** is achieved by, for example, an integrated circuit such as an MCU as described above. The communication device **100** may be achieved by an integrated circuit provided on one substrate, or may be achieved by connecting integrated circuits correspondingly provided on a plurality of substrates to each other. The communication device **100** may be achieved by a dedicated integrated circuit designed to achieve the communication device **100**, or may be achieved by a general-purpose integrated circuit.

Example of Hardware Configuration of Virtual Machine Execution Unit **109**

[0047] FIG. **2** is a block diagram illustrating a hardware configuration of the virtual machine execution unit **109**. In the configuration in FIG. **2**, the virtual machine execution unit **109** includes a bus **1020**, a processor **1040**, a main storage device **1060**, and an auxiliary storage device **1080**.

[0048] The bus **1020** is a communication path for the processor **1040**, the main storage device **1060**, and the auxiliary storage device **1080** to transmit and receive data to and from each other. The processor **1040** is a freely-selected type of processor such as a central processing unit (CPU) and a field-programmable gate array (FPGA). The main storage device **1060** is a main storage device achieved by using a RAM or the like. The auxiliary storage device **1080** is an auxiliary storage device achieved by using a flash memory or the like.

[0049] The auxiliary storage device **1080** stores programs for achieving the virtual machine execution unit **109**. The programs for achieving the virtual machine execution unit **109** include, for example, a program for achieving a hypervisor, programs executed on each virtual machine **20**, and the like. The programs executed on the virtual machine **20** includes, for example, an operating system (OS) that operates on the virtual machine **20**, an application program that operates on the OS, and the like. The processor **1040** reads these various programs into the main storage device **1060** and executes the programs to operate the hypervisor and each virtual machine **20**.

[0050] The virtual machine execution unit **109** is connected to the access controller **108** via the bus **1020**.

[0051] Communication performed by the virtual machine execution unit **109** is not limited to CAN communication. In a case where the virtual machine execution unit **109** performs communication other than CAN communication, the virtual machine execution unit **109** is connected to a control unit that controls the communication via the bus **1020**. In FIG. **2**, the virtual machine execution unit **109** is connected to a communication control unit **130**. The communication control unit **130** is, for example, a control unit for Ethernet (registered trademark) communication.

[0052] Note that, in the virtualization environment, the plurality of virtual machines may share one physical hardware element (processor or storage device). Therefore, in the virtual machine execution unit **109**, one physical hardware element may be shared by the plurality of virtual machines **20**. For example, the plurality of virtual machines **20** may share one processor provided in the virtual machine execution unit **109**.

[0053] However, the virtual machine execution unit **109** may include the same type of physical hardware element for each virtual machine **20**. In this case, for example, the plurality of virtual machines **20** may use different processors, respectively.

<Procedure of Processing>

[0054] FIG. **3** is a flowchart illustrating a procedure of message reception processing in the communication device **100**. The common reception unit **102** outputs the received message **10** to each of the plurality of protocol processing units **104** (S**102**).

[0055] S**104** and S**106** are executed by the plurality of protocol processing units **104**. The protocol processing unit **104** determines whether or not the destination of the received message **10** input from the common reception unit **102** is the virtual machine **20** corresponding to the protocol processing unit itself (S**104**). In a case where the destination of the received message **10** is the virtual machine **20** corresponding to the protocol processing unit itself (S**104**: YES), the protocol processing unit **104** stores the payload of the received message **10** in the received data storage unit **106** corresponding to the protocol processing unit itself (S**106**). On the other hand, in a case where the destination of the received message **10** is not the virtual machine **20** corresponding to the protocol processing unit itself (S**104**: NO), the processing of storing the payload of the received message **10** in the received data storage unit **106** is not performed.

<Specification of Destination of Received Message **10**>

[0056] The protocol processing unit **104** determines whether or not the destination of the received message **10** is the virtual machine **20** corresponding to the protocol processing unit itself (S**104**). For this purpose, the protocol processing unit **104** specifies the destination of the received message **10**.

[0057] The destination of the received message **10** is represented using, for example, the CAN ID indicated in the header of the received message **10**. In this case, the correspondence relationship between the protocol processing units **104** and the virtual machines **20** is represented by the correspondence relationship between the protocol processing units **104** and the CAN IDs. In addition, the correspondence relationship between the received data storage units **106** and the virtual machines **20** is also represented by the correspondence relationship between the received data storage units **106** and the CAN IDs.

[0058] Therefore, for example, information indicating the CAN IDs corresponding to each protocol processing unit **104** and the received data storage units **106** corresponding to the CAN IDs is stored in storage area accessible from each protocol processing unit **104**. Each protocol processing unit **104** can specify the CAN ID corresponding to the protocol processing unit itself by referring to this information. Further, each protocol processing unit **104** can specify the received data storage unit **106** in which the payload of the received message **10** is to be stored by referring to this information.

[0059] The protocol processing unit **104** determines whether or not the CAN ID indicated in the header of the received message **10** is the CAN ID corresponding to the protocol processing unit itself. In a case where the CAN ID indicated in the header of the received message **10** is the CAN ID corresponding to the protocol processing unit itself, the protocol processing unit **104** stores the received message **10** in the received data storage unit **106** corresponding to the CAN ID. On the other hand, in a case where the CAN ID indicated in the header of the received message **10** is not the CAN ID corresponding to the protocol processing unit itself, the protocol processing unit **104** does not store the received message **10** in any received data storage unit **106**.

[0060] The CAN ID is allocated to the virtual machine **20**, for example. In this case, in order to represent the correspondence relationship between the protocol processing unit **104** and the virtual machine **20**, the protocol processing unit **104** and the CAN ID allocated to the virtual machine **20** corresponding to the protocol processing unit **104** are associated with each other.

[0061] Alternatively, for example, the CAN ID is allocated to an application that operates on the virtual machine **20**. In this case, in order to represent the correspondence relationship between the protocol processing unit **104** and the virtual machine **20**, the protocol processing unit **104** and the CAN ID allocated to the application that operates on the virtual machine **20** corresponding to the protocol processing unit **104** are associated with each other. In a case where a plurality of applications operate on the virtual machine **20**, a plurality of CAN IDs can be associated with one protocol processing unit **104**.

[0062] FIG. **4** is a diagram illustrating a case where a CAN ID is allocated to each application. In the example in FIG. **4**, the communication device **100** includes two protocol processing units **104** (a protocol processing unit **104-1** and a protocol processing unit **104-2**). Furthermore, the communication device **100** includes two received data storage units **106** (a received data storage unit **106-1** and a received data storage unit **106-2**). In the virtual machine execution unit **109**, two virtual machines **20** (a virtual machine **20-1** and a virtual machine **20-2**) are operating.

[0063] On the virtual machine **20-1**, two applications **22** (an application **22-1** and an application **22-2**) are operating. The CAN ID allocated to the application **22-1** is CAN_ID_1, and the CAN ID allocated to the application **22-2** is CAN_ID_2.

[0064] The virtual machine **20-1** is associated with the protocol processing unit **104-1** and the received data storage unit **106-1**. Therefore, both the protocol processing unit **104-1** and the received data storage **106-1** are associated with two CAN IDs, CAN_ID_1 and CAN_ID_2. In addition, the access controller **108** is set to permit the virtual machine **20-1** to access the received data storage unit **106-1**.

[0065] On the virtual machine **20-2**, one application **22-3** is operating. The CAN ID allocated to the application **22-3** is CAN_ID_3. Therefore, the CAN ID associated with the protocol processing unit **104-2** is CAN ID **3**.

[0066] The virtual machine **20-2** is associated with the protocol processing unit **104-2** and the received data storage unit **106-2**. Therefore, both the protocol processing unit **104-2** and the received data storage **106-2** are associated with one CAN ID, which is CAN ID **3**. In addition, the access controller **108** is set to permit the virtual machine **20-2** to access the received data storage unit **106-2**.

[0067] In a case where the CAN ID indicated in the header of the received message **10** is CAN_ID_1 or CAN_ID_2, the protocol processing unit **104-1** stores the payload of the received message **10** in the received data storage unit **106-1**.

On the other hand, the protocol processing unit **104-2** does not store the payload of the received message **10** in the received data storage unit **106-2**.

[0068] The virtual machine **20-1** can access the received data storage unit **106-1** corresponding to the virtual machine itself. Therefore, both the application **22-1** and the application **22-2** operating on the virtual machine **20-1** can acquire the payload of the received message **10-1** whose destinations are the applications themselves from the received data storage unit **106-1**.

[0069] In a case where the CAN ID indicated in the header of the received message **10** is CAN_ID_3, the protocol processing unit **104-1** does not store the payload of the received message **10** in the received data storage unit **106-1**. On the other hand, the protocol processing unit **104-2** stores the payload of the received message **10** in the received data storage unit **106-2**.

[0070] The virtual machine **20-2** can access the received data storage unit **106-2** corresponding to the virtual machine itself. Therefore, the application **22-3** operating on the virtual machine **20-2** can acquire the payload of the received message **10-3** whose destination is the application itself from the received data storage unit **106-2**.

[0071] Note that, in two or more virtual machines **20**, applications allocated to the same CAN ID may operate. In this case, one received message **10** is stored in two or more received data storage units **106**. Therefore, one received message **10** is used by the plurality of virtual machines **20**.

[0072] For example, in the example in FIG. **4**, it is assumed that the application **22** to which the CAN ID, which is CAN_ID_1, is allocated is operating in the virtual machine **20-2** as well. In this case, the received message **10** whose CAN ID is CAN_ID_1 is stored not only in the received data storage unit **106-1** by the protocol processing unit **104-1**, but also in the received data storage unit **106-2** by the protocol processing unit **104-2**.

<Notification of Error>

[0073] The protocol processing unit **104** may provide various error notifications as well as the received message **10** to the virtual machine **20**. The error notification is, for example, a notification of an acknowledgement error (Ack error) indicating that there is no node that correctly receives a transmitted message on the CAN bus **300**. In addition, for example, the error notification is a notification of a bit error indicating that the data transmitted by the protocol processing unit itself is different from the data monitored in the CAN bus **300**.

[0074] The protocol processing unit **104** stores the error notification to be provided to the virtual machine **20** in the error notification storage area **106**E of the received data storage unit **106** corresponding to the protocol processing unit **104**. The virtual machine **20** can acquire the error notification transmitted from the protocol processing unit **104** by reading the error notification stored in the error notification storage area **106**E of the received data storage unit **106** corresponding to the virtual machine itself. Note that the method of recognizing that the error notification is stored in the error notification storage area **106**E of the received data storage unit **106** is similar to the method of recognizing that the payload of the received message **10** is stored in the received data storage unit **106**.

[0075] In this manner, according to the present embodiment, when confirming the error notification, the virtual machine **20** is only required to confirm the error notification storage area **106**E of the received data storage unit **106** allocated to the virtual machine itself. As a result, the virtual machine **20** can easily grasp the error notification related to processing of the virtual machine itself. That is, the error can be notified directly to the virtual machine **20** that is supposed to require the error notification. In addition, the virtual machine **20** does not need to perform processing for an error notification related to processing of another virtual machine **20**, that is, an error notification not related to processing of the virtual machine itself. In other words, inter-virtual machine communication for error notification is unnecessary. Therefore, it is possible to heighten software control usability related to communication processing of the virtual machine **20**.

<Transmission of Message by Communication Device **100**>

[0076] The communication device **100** may transmit a message to the external communication device **200**. A message transmitted from the communication device **100** is called a transmitted message.

[0077] FIG. **5** is a diagram illustrating a configuration related to transmission of a transmitted message in the configuration of the communication device **100**. In FIG. **5**, the common reception unit **102** and the received data storage unit **106** are omitted.

[0078] The communication control unit **101** includes a plurality of transmitted data storage units **114**. The plurality of virtual machines **20** are configured to be able to access different transmitted data storage units **114**, respectively. Hereinbelow, the transmitted data storage unit **114** accessible by the virtual machine **20** is also referred to as a "transmitted data storage unit **114** corresponding to the virtual machine **20**".

[0079] The transmitted data storage unit **114** is a storage area provided in a freely-selected type of storage device (for example, a RAM, a register, or the like). For example, the plurality of transmitted data storage units **114** include different partial storage areas included in one storage device (for example, one RAM or register), respectively. Alternatively, for example, the plurality of transmitted data storage units **114** may be storage areas included in different storage devices (for example, different RAMs and registers), respectively.

[0080] The access controller **108** controls access from the virtual machine **20** to the transmitted data storage units **114**. Specifically, in a case where the transmitted data storage unit **114** to be accessed by the virtual machine **20** is the transmitted data storage unit **114** corresponding to the virtual machine **20**, the access controller **108** permits the virtual machine **20** to access the transmitted data storage unit **114**. On the other hand, in a case where the transmitted data storage unit **114** to be accessed by the virtual machine **20** is not the transmitted data storage unit **114** corresponding to the virtual machine **20**, the access controller **108** does not permit the virtual machine **20** to access the transmitted data storage unit **114**. Note that the correspondence relationship between the virtual machines **20** and the transmitted data storage units **114** is stored in advance in a storage area accessible from the access controller **108**, for example.

[0081] A transmitted message **30** includes a payload generated by the virtual machine **20**. For example, an application operating on the virtual machine **20** stores a pair including a CAN ID and a payload allocated to the appli-

cation in the transmitted data storage unit **114**. Note that, in a case where the CAN ID is allocated to the virtual machine **20**, the application stores the CAN ID corresponding to the virtual machine **20** in the transmitted data storage unit **114**.

[0082] The transmitted data storage unit **114** corresponding to the virtual machine **20** is associated with the protocol processing unit **104** corresponding to the virtual machine **20**. For this reason, the plurality of protocol processing units **104** are associated with different transmitted data storage units **114**, respectively.

[0083] The protocol processing unit **104** generates the transmitted message **30** by using the pair including the CAN ID and the payload stored in the transmitted data storage unit **114** corresponding to the protocol processing unit itself. Further, the protocol processing unit **104** outputs the generated transmitted message **30** to a common transmission unit **110** provided in the communication device **100**. The common transmission unit **110** is an interface for outputting a signal from the communication device **100** to the outside of the communication device **100**. A signal representing the transmitted message **30** is output from the common transmission unit **110** to the CAN bus **300**. Note that the common transmission unit **110** and the CAN bus **300** are connected via a suitable interface such as a CAN transceiver as necessary.

[0084] Here, the communication device **100** is configured such that an output from each of the plurality of protocol processing units **104** toward the common transmission unit **110** is input into the common transmission unit **110** via an AND gate **112**. An output from the AND gate **112** represents a logical AND of a plurality of input bits. Therefore, the output from the AND gate **112** is a logical AND signal of the signals output from the respective protocol processing units **104**. The logical AND signal is input into the common transmission unit **110**. The common transmission unit **110** outputs the logical AND signal output from the AND gate **112** to the CAN bus **300**.

[0085] Here, in the CAN protocol, 0 is a dominant bit, and 0 is prioritized over 1. By using the AND gate **112**, 0 can be prioritized over 1 in the signals input from the plurality of protocol processing units **104** to the common transmission unit **110**.

[0086] Therefore, by employing the configuration in which the logical AND signal of the outputs from the plurality of protocol processing units **104** is input into the common transmission unit **110**, it is possible to cause the plurality of protocol processing units **104** to share one transmission interface in accordance with the CAN protocol. That is, the transmission of the CAN message to the CAN bus by the plurality of protocol processing units **104** can be handled by one transmission interface.

[0087] Note that the protocol processing unit **104** recognizes that data is stored in the transmitted data storage unit **114** corresponding to the protocol processing unit itself by an appropriate method. As a method of recognizing that data is stored in the transmitted data storage unit **114**, a similar method to the method of recognizing that data is stored in the received data storage unit **106** can be employed.

<Procedure of Processing>

[0088] FIG. **6** is a flowchart illustrating a procedure of message transmission in the communication device **100**. The virtual machine **20** stores data supposed to be transmitted to the external communication device **200** in the transmitted data storage unit **114** corresponding to the virtual machine **20** itself (S**202**). The protocol processing unit **104** corresponding to the transmitted data storage unit **114** in which data is stored by the virtual machine **20** generates the transmitted message **30** based on the data (S**204**). The protocol processing unit **104** outputs the generated transmitted message **30** to the AND gate **112** (S**206**). The AND gate **112** outputs a logical AND signal of the signals input from the plurality of protocol processing units **104** to the common transmission unit **110** (S**208**). The common transmission unit **110** outputs the logical AND signal input from the AND gate **112** to the outside of the communication device **100** (S**210**).

<Handling of Collision>

[0089] Here, the outputs from the plurality of protocol processing units **104** are collected at the AND gate **112**. Therefore, in a case where the transmitted messages **30** are simultaneously output by the plurality of protocol processing units **104**, a collision occurs inside the communication device **100**. Each protocol processing unit **104** handles the collision by performing collision detection and arbitration in accordance with the CAN protocol.

[0090] Specifically, the protocol processing unit **104** performs collision detection in accordance with the CAN protocol on the signal input from the common reception unit **102** to the protocol processing unit **104**. Here, the signal output from the common transmission unit **110** to the CAN bus **300** is input into each protocol processing unit **104** since the signal flowing through the CAN bus **300** is input into the common reception unit **102**. Therefore, by performing collision detection in accordance with the CAN protocol in each protocol processing unit **104**, it is possible to detect collision of the transmitted messages **30** transmitted from the plurality of protocol processing units **104**. Also, by performing arbitration in accordance with the CAN protocol in each protocol processing unit **104**, it is possible to perform arbitration among the plurality of protocol processing units **104**.

<Sharing of Transmission State between Protocol Processing Units **104**>

[0091] In CAN communication, when correctly receiving a message, a node connected to the CAN bus **300** returns an acknowledgement (Ack). This allows the transmission source node to confirm that the message has been received by another node. Furthermore, the transmission source node can perform operations such as retransmission of a message in a case where the Ack is not returned from the other node, that is, in a case of an Ack error. However, since the Ack does not include the transmission source information, the transmission source node cannot recognize which node has returned the Ack.

[0092] Here, in the communication device **100** having the configuration illustrated in FIG. **5**, one of the plurality of virtual machines **20** is referred to as a virtual machine **20-1**, and another one is referred to as a virtual machine **20-2**. In addition, one of the plurality of protocol processing units **104** is referred to as a protocol processing unit **104-1** corresponding to the virtual machine **20-1**, and another one is referred to as a protocol processing unit **104-2** corresponding to the virtual machine **20-2**. It is assumed that a transmitted message created by the corresponding protocol processing unit **104-1** based on an instruction from the virtual machine **20-1** is output to the external communica-

tion device **200** connected to the CAN bus **300**. When correctly receiving the transmitted message on the CAN bus **300**, the external communication device **200** returns an Ack. On the other hand, in the communication device **100**, the protocol processing unit **104-2** corresponding to the virtual machine **20-2** can also receive the message on the CAN bus **300** via the common reception unit **102**. The protocol processing unit **104-2** transmits an Ack when correctly receiving the message. Therefore, the protocol processing unit **104-2** provided in the communication device **100** can return the Ack in response to the message transmitted by the protocol processing unit **104-1** in the same communication device **100**.

[0093] If the Ack in response to the transmitted message **30** output from a certain protocol processing unit **104** is returned from another protocol processing unit **104** in the same communication device **100**, even in a case where the destination external communication device **200** fails to receive the transmitted message **30** for some reason and does not return the Ack, the protocol processing unit **104** as transmission source recognizes that the transmitted message is correctly received. Therefore, it is difficult for the transmission source protocol processing unit **104** to confirm whether the transmitted message **30** has been received by the destination external communication device **200**.

[0094] Therefore, the communication device **100** is preferably configured such that another protocol processing unit **104** does not return an Ack in response to the transmitted message **30** output from a certain protocol processing unit **104**. To achieve this, for example, each protocol processing unit **104** is configured to be able to detect a state in which the transmitted message **30** is being output by another protocol processing unit **104**.

[0095] For example, each protocol processing unit **104** is configured to output a status signal indicating whether or not the transmitted message **30** is being transmitted. When receiving the CAN message, each protocol processing unit **104** checks the status signal to determine whether or not another protocol processing unit **104** is in a state of being transmitting a message. Then, in a case where the status signal indicates that any of the protocol processing units **104** is in a state of being transmitting a message, the protocol processing unit **104** does not return an Ack. On the other hand, in a case where the status signal indicates that none of the protocol processing units **104** is in a state of being transmitting a message, the protocol processing unit **104** returns an Ack.

[0096] FIG. **7** is a diagram illustrating a configuration in which a status signal is output from each protocol processing unit **104**. In FIG. **7**, the status signal output from each protocol processing unit **104** is input into an OR gate **116**. A signal representing a logical OR of the status signals input from the respective protocol processing units **104** (hereinbelow, the signal is referred to as a status logical OR signal) is output from the OR gate **116**. The status logical OR signal is input into each protocol processing unit **104**.

[0097] Here, if any one of the status signals output from the plurality of protocol processing units **104** indicates 1, the status logical OR signal is 1. Therefore, the status logical OR signal being 1 indicates that at least one protocol processing unit **104** is in a state of being transmitting a message.

[0098] Each protocol processing unit **104** is configured to return an Ack in a case where the status logical OR signal that indicates 0 is input. In addition, each protocol processing unit **104** is configured not to return an Ack in a case where the status logical OR signal that indicates 1 is input.

[0099] More specifically, for example, each protocol processing unit **104** is configured to overwrite an Ack slot of a CAN message output from the protocol processing unit **104** with a recessive state while the status logical OR signal indicates 1. The Ack slot is a slot that is set to be in a dominant state only when the Ack is returned. Therefore, overwriting the Ack slot with the recessive state means that the Ack is not returned.

<Protocol Processing Unit **104** Not Sharing Reception Unit>

[0100] The common reception unit **102** is not necessarily shared by all the protocol processing units **104** provided in the communication device **100**. In other words, in the communication device **100**, there may be a protocol processing unit **104** that does not use the common reception unit **102**.

[0101] For example, the communication device **100** includes not only the common reception unit **102** but also a reception unit (hereinbelow, an individual reception unit) individually for each protocol processing unit **104**. Then, the communication device **100** is configured to be able to set, for each protocol processing unit **104**, from which of the common reception unit **102** and the individual reception unit an output is input.

[0102] FIG. **8** is a diagram illustrating a configuration in which an individual reception unit is provided for each protocol processing unit **104**. In this example, an individual reception unit **118** and a selector **120** are provided for each protocol processing unit **104**. Specifically, individual reception units **118-1** to **118**-N are provided corresponding to protocol processing units **104-1** **104**-N, respectively. Furthermore, selectors **120-1** to **120**-N are provided corresponding to the protocol processing units **104-1** to **104**-N, respectively. Note that, in the following description, the individual reception unit **118** is used as any one of the individual reception units **118-1** to **118**-N for convenience. The selector **120** is used to as any one of the selectors **120-1** to **120**-N for convenience.

[0103] The individual reception unit **118** is an interface into which a CAN message is input from a CAN bus **310**, which is different from the CAN bus **300**. The individual reception units **118** are connected to different CAN buses **310**, respectively. Specifically, the individual reception units **118-1** to **118**-N are connected to the corresponding CAN buses **310-1** to **310**-N, respectively. Each individual reception unit **118** and each CAN bus **310** are connected via a suitable interface such as a CAN transceiver as necessary.

[0104] Both the common reception unit **102** and the individual reception unit **118** are connected to the input interface of the selector **120**. The protocol processing unit **104** corresponding to the selector **120** is connected to the output interface of the selector **120**. The selector **120** can be set to output only either the signal input from the common reception unit **102** or the signal input from the individual reception unit **118**.

[0105] It is assumed that the selector **120** corresponding to the protocol processing unit **104** is set to output the signal input from the common reception unit **102**. In this case, the protocol processing unit **104** shares a reception unit with another protocol processing unit **104** and is connected to the CAN bus **300**. On the other hand, it is assumed that the selector **120** corresponding to the protocol processing unit

104 is set to output the signal input from the individual reception unit **118**. In this case, the protocol processing unit **104** does not share a reception unit with another protocol processing unit **104** and is connected to the corresponding CAN bus **310**.

[0106] Note that, in FIG. **8**, in order to facilitate the description of the individual reception unit **118**, all the individual reception units **118** are connected to the CAN buses **310**. However, in actual operation, the individual reception unit **118** may be connected to the CAN bus **310** only in a case where the individual reception unit **118** is used. That is, in a case where a certain selector **120** is set to output a signal input from the common reception unit **102**, the individual reception unit **118** corresponding to the selector **120** does not need to be connected to the CAN bus **310**.

[0107] By employing the configuration illustrated in FIG. **8**, it is possible to easily set whether or not each protocol processing unit **104** shares a reception unit with another protocol processing unit **104**. In other words, it is possible to easily set whether each protocol processing unit **104** is to participate in the same CAN network as that for another protocol processing unit **104** or to participate in a different CAN network from that for another protocol processing unit **104**.

<Protocol Processing Unit **104** Not Sharing Transmission Unit>

[0108] The common transmission unit **110** is not necessarily shared by all the protocol processing units **104** provided in the communication device **100**. In other words, in the communication device **100**, there may be a protocol processing unit **104** that does not use the common transmission unit **110**.

[0109] For example, the communication device **100** includes not only the common transmission unit **110** but also a transmission unit (hereinbelow, an individual transmission unit) individually for each protocol processing unit **104**. Then, the communication device **100** is configured to be able to set to which of the common transmission unit **110** and the individual reception unit the output from each protocol processing unit **104** is input.

[0110] FIG. **9** is a diagram illustrating a configuration in which an individual transmission unit is provided for each protocol processing unit **104**. In the example in FIG. **9**, an individual transmission unit **122** and a selector **124** are provided for each protocol processing unit **104**. Specifically, individual transmission units **122-1** to **122**-N are provided corresponding to the protocol processing units **104-1** to **104**-N, respectively. Furthermore, selectors **124-1** to **124**-N are provided corresponding to the protocol processing units **104-1** to **104**-N, respectively. Note that, in the following description, the individual transmission unit **122** is referred to as any one of the individual transmission units **122-1** to **122**-N for convenience. The selector **124** is referred to as any one of the selectors **124-1** to **124**-N for convenience.

[0111] Each individual transmission unit **122** is an interface for outputting a signal to not the CAN bus **300** but the CAN bus **310**. Note that the individual transmission units **122** are connected to different CAN buses **310**, respectively. Specifically, the individual transmission units **122-1** to **122**-N are connected to the CAN buses **310-1** to **310**-N, respectively. Each individual transmission unit **122** and each CAN bus **310** are connected via a suitable interface such as a CAN transceiver as necessary.

[0112] The selector **124** is configured to output the transmitted message **30** input from the protocol processing unit **104** to either the common transmission unit **110** or the individual transmission unit **122**. For this purpose, the selector **124** includes a first selector **125** and a second selector **126**.

[0113] The first selector **125** is a selector used to transmit the output from the protocol processing unit **104** to the common transmission unit **110**. On the other hand, the second selector **126** is a selector used to transmit the output from the protocol processing unit **104** to the individual transmission unit **122**.

[0114] A signal output from the protocol processing unit **104** and a signal always representing 1 (in other words, the signal is a signal always representing a recessive state) are input into the input interface of the first selector **125**. The AND gate **112** is connected to the output interface of the first selector **125**.

[0115] A signal output from the protocol processing unit **104** and a signal always representing 1 (in other words, the signal is a signal always representing a recessive state) are input into the input interface of the second selector **126**. The individual transmission unit **122** is connected to the output interface of the second selector **126**.

[0116] In a case where the protocol processing unit **104** is caused to use the common transmission unit **110**, the first selector **125** is set to output a signal input from the protocol processing unit **104**, while the second selector **126** is set to output a signal always representing 1. In a case where the protocol processing unit **104** is caused to use the individual transmission unit **122**, the first selector **125** is set to output a signal always representing 1, while the second selector **126** is set to output a signal input from the protocol processing unit **104**.

[0117] Note that, in FIG. **9**, in order to facilitate the description of the individual transmission unit **122**, all the individual transmission units **122** are connected to the CAN buses **310**. However, in an actual operation, in a case where a certain protocol processing unit **104** is caused to use the common transmission unit **110**, the individual transmission unit **122** corresponding to the protocol processing unit **104** does not need to be connected to the CAN bus **310**.

[0118] By employing the configuration illustrated in FIG. **9**, it is possible to easily set whether or not each protocol processing unit **104** shares a transmission unit with another protocol processing unit **104**. In other words, it is possible to easily set whether each protocol processing unit **104** is to participate in the same CAN network as that for another protocol processing unit **104** or to participate in a different CAN network from that for another protocol processing unit **104**.

Usage Example of Communication Device **100**

[0119] For example, the communication device **100** is suitable for an ECU that achieves a plurality of virtual ECUs (ECUs achieved by virtual machines) such as a zone ECU. FIG. **10** is a diagram illustrating a hierarchical structure of a system having a zone ECU. The zone ECU has a routing function of transferring data received from a superordinate system to a subordinate ECU. For example, in FIG. **10**, a zone ECU **510** executes routing for transferring data received from a superordinate ECU **500** to a subordinate ECU **530** or ECU **540** via the CAN bus.

[0120] In a case where a plurality of virtual machines are operated in one physical ECU, each of the virtual machines can be treated as a virtual ECU. Therefore, for example, in the communication device **100**, one of the plurality of virtual machines **20** is used as a virtual ECU for routing.

[0121] Here, the protocol processing unit **104** corresponding to the virtual ECU for routing is preferably set to use the individual reception unit **118** and the individual transmission unit **122**. With this setting, it is possible to reduce the influence of the routing of the CAN message by the virtual ECU for routing on the transmission and reception of the CAN message performed by another virtual ECU.

[0122] Note that, in a case where the virtual machine execution unit **109** includes a plurality of processors, it is preferable to allocate a dedicated processor to the virtual ECU for routing.

[0123] By allocating a dedicated processor to the virtual ECU for routing, the influence of the routing processing on the processing of another virtual ECU can further be reduced.

Second Embodiment

[0124] FIG. **11** is a diagram illustrating a configuration of a communication device according to a second embodiment. Similarly to the communication device **100**, a communication device **400** transmits and receives a CAN message to and from the external communication device **200** connected to the CAN bus **300** in accordance with the CAN protocol. Similarly to the communication device **100**, the communication device **400** is, for example, an integrated circuit provided inside an ECU or the like, and more specifically, is an SoC such as an MCU.

[0125] On the other hand, unlike in the communication device **100**, in the communication device **400**, reception of the CAN message for a plurality of virtual machines is controlled by means of a communication control unit **401** including one protocol processing unit. For this purpose, the communication device **400** includes a reception unit **402**, the communication control unit **401**, and an access controller **408**. The communication control unit **401** includes a protocol processing unit **404** and a plurality of received data storage units **406**.

[0126] The reception unit **402** is an interface that receives a message on the CAN bus **300**. The reception unit **402** is configured to output a message received by the reception unit **402**, that is, the received message **10**, to the protocol processing unit **404**. Note that the reception unit **402** is connected to the CAN bus **300** via a suitable interface such as a CAN transceiver as necessary.

[0127] Similarly to the received data storage area **106**D of the received data storage unit **106**, the received data storage unit **406** is a storage area provided in a freely-selected type of storage device.

[0128] Similarly to the virtual machine execution unit **109**, the virtual machine execution unit **409** operates the plurality of virtual machines **20**. The plurality of virtual machines **20** are associated with different received data storage units **406**, respectively.

[0129] Similarly to the access controller **108**, the access controller **408** controls access to the received data storage units **406** from the virtual machines **20**. That is, in a case where the received data storage unit **406** to be accessed by the virtual machine **20** is the received data storage unit **406** corresponding to the virtual machine **20**, the access controller **408** permits the virtual machine **20** to access the received data storage unit **406**. On the other hand, in a case where the received data storage unit **406** to be accessed by the virtual machine **20** is not the received data storage unit **406** corresponding to the virtual machine **20**, the access controller **408** does not permit the virtual machine **20** to access the received data storage unit **406**. Note that the correspondence relationship between the virtual machine **20** and the received data storage unit **406** is stored in advance in a freely-selected storage area accessible from the access controller **408**, for example.

[0130] The protocol processing unit **404** extracts a payload and a CAN ID from the received message **10** in accordance with the CAN protocol. In which received data storage unit **406** the extracted payload is to be stored is determined by a reception filter, which is not illustrated in FIG. **11**. In other words, it is determined in which virtual machine **20** the received message **10** is to be used (which virtual machine **20** is the destination of the received message). The extracted payload is stored in the received data storage unit **406** corresponding to the virtual machine **20** that is to use the payload based on the determination result.

[0131] As a result of the above processing, the payload of the received message **10** is stored in one received data storage unit **406**. The received data storage unit **406** in which the payload of the received message **10** is stored is the received data storage unit **406** accessible from the virtual machine **20** that is the destination of the received message **10**. Therefore, the payload of the received message **10** is stored in the received data storage unit **406** so as to be accessed only from the virtual machine **20** that is the destination of the received message **10**. Note that, similarly to the case of the first embodiment, the received data storage unit **406** can store the CAN ID and the like as well as the payload of the received message **10**.

[0132] Further, the communication device **400** controls transmission of the CAN message by a plurality of virtual machines by means of one protocol processing unit **404**. FIG. **12** is a diagram illustrating a configuration of the communication device **400** related to transmission of the transmitted message **30**. In FIG. **12**, the reception unit **402** and the received data storage unit **406** are omitted.

[0133] The communication control unit **401** includes a transmission unit **410** and a plurality of transmitted data storage units **414**. Similarly to the transmitted data storage unit **114**, the transmitted data storage unit **414** is a storage area provided in a freely-selected type of storage device. The plurality of virtual machines **20** is configured to be able to access different transmitted data storage units **414**, respectively. Hereinbelow, the transmitted data storage unit **414** accessible by the virtual machine **20** is also referred to as a "transmitted data storage unit **414** corresponding to the virtual machine **20**".

[0134] The access controller **408** controls access from the virtual machine **20** to the transmitted data storage unit **414** by a similar method to a method in which the access controller **108** controls access from the virtual machine **20** to the transmitted data storage unit **114**. Specifically, in a case where the transmitted data storage unit **414** to be accessed by the virtual machine **20** is the transmitted data storage unit **414** corresponding to the virtual machine **20**, the access controller **408** permits the virtual machine **20** to access the transmitted data storage unit **414**. On the other hand, in a case where the transmitted data storage unit **414** to be

accessed by the virtual machine **20** is not the transmitted data storage unit **414** corresponding to the virtual machine **20**, the access controller **408** does not permit the virtual machine **20** to access the transmitted data storage unit **414**. Note that the correspondence relationship between the virtual machine **20** and the transmitted data storage unit **414** is stored in advance in a freely-selected storage area accessible from the access controller **408**, for example.

[0135] The virtual machine **20** of the second embodiment stores data (such as a payload and a CAN ID) to be transmitted to the external communication device **200** in the transmitted data storage unit **414**. In a case where data is stored in any one of the transmitted data storage units **414**, the protocol processing unit **404** generates the transmitted message **30** using the data. Further, the protocol processing unit **404** outputs the generated transmitted message **30** to the transmission unit **410**. The transmission unit **410** outputs the transmitted message **30** input from the protocol processing unit **404** to the CAN bus **300**.

Example of Operation and Effect

[0136] With the above-described configuration, according to the communication device **400**, unlike the technology disclosed in Patent Document 1, only the virtual machine **20** as the destination of the received message **10** can use the payload of the received message **10**. Therefore, each virtual machine **20** only needs to grasp whether data is stored in the received data storage unit **406** allocated to the virtual machine itself. Also, each virtual machine **20** does not need to notify another virtual machine that a new message has been stored. That is, it is possible to heighten software usability related to processing in a plurality of virtual machines.

[0137] In addition, according to the communication device **400**, since one protocol processing unit **404** can handle the plurality of virtual machines **20**, the number of protocol processing units **404** provided in the communication device **400** can be reduced. This brings about an advantage that the manufacturing cost of the communication device **400** can be reduced and an advantage that the size of the communication device **400** can be reduced.

Example of Hardware Configuration

[0138] The hardware configuration of the communication device **400** is similar to the hardware configuration of the communication device **100**. That is, the hardware configuration of the virtual machine execution unit **409** is represented by, for example, FIG. **2**.

<Procedure of Reception>

[0139] FIG. **13** is a flowchart illustrating a procedure of message reception in the communication device **400**. The reception unit **402** outputs the received message **10** input from the CAN bus **300** to the protocol processing unit **404** (S**302**). The protocol processing unit **404** stores the payload of the received message **10** in the received data storage unit **406** corresponding to the virtual machine **20** as the destination of the received message **10** (S**304**).

<Procedure of Transmission>

[0140] FIG. **14** is a flowchart illustrating a procedure of message transmission in the communication device **400**. The virtual machine **20** stores data supposed to be transmitted to the external communication device **200** in the transmitted data storage unit **414** corresponding to the virtual machine **20** (S**402**). The protocol processing unit **404** generates the transmitted message **30** based on the data stored in the transmitted data storage unit **414** (S**404**). The protocol processing unit **404** outputs the generated transmitted message **30** to the transmission unit **410** (S**406**). The transmission unit **410** outputs the transmitted message **30** to the outside of the communication device **400** (S**408**).

[0141] Although the invention made by the present inventor has been specifically described based on the embodiments, the present invention is not limited to the above embodiments, and it goes without saying that various modifications can be made without departing from the gist of the present invention.

[0142] Note that the CAN also includes a standard called CAN with Flexible Data Rate (CAN FD) and a standard called CAN eXtra Large payload (CAN XL). In the above example, the message may be a message in accordance with the CAN standard, the CAN FD standard, or the CAN XL standard.

[0143] Note that, in the above-described example, the program includes a command group (or software code) for causing the computer to perform one or more functions described in the embodiment when being read by the computer. The program may be stored in a non-transitory computer-readable medium or a tangible storage medium. By way of example and without limitation, the computer-readable medium or the tangible storage medium includes a RAM, a ROM, a flash memory, an SSD, or another memory technology, a CD-ROM, a digital versatile disc (DVD), a Blu-ray (registered trademark) disc, or another optical disc storage, a magnetic cassette, a magnetic tape, a magnetic disc storage, or another magnetic storage device. The program may be transmitted on a transitory computer-readable medium or a communication medium. By way of example and without limitation, the transitory computer-readable medium or the communication medium includes an electric, optical, acoustic, or another form of propagated signal.

What is claimed is:

1. A communication device comprising:

a virtual machine execution unit that includes at least one processor and a storage device and is configured to operate a plurality of virtual machines;

a first reception unit that receives a message transmitted from an outside of the communication device;

a communication control unit that includes a plurality of received data storage units allocated to the plurality of virtual machines, respectively, and stores a received message that is a message received by the first reception unit in the received data storage unit allocated to the virtual machine that is to use the received message; and

an access controller that is configured to allow each of the plurality of virtual machines to access the received data storage unit associated to the virtual machine.

2. The communication device according to claim **1**,

wherein the received message is a Controller Area Network (CAN), CAN with Flexible Data Rate (CAN FD), or CAN eXtra Large payload (CAN XL) message.

3. The communication device according to claim **2**,

wherein the communication control unit includes a plurality of protocol processing units corresponding to the different virtual machines, respectively,

wherein the first reception unit outputs the received message to each of the plurality of protocol processing units, and

wherein, in a case where a destination of the received message is the virtual machine corresponding to the protocol processing unit, the protocol processing unit stores data included in the received message in the received data storage unit corresponding to the protocol processing unit.

4. The communication device according to claim **3**,

wherein a different CAN identifier is allocated to each of the virtual machines,

wherein the protocol processing unit is associated with a CAN identifier allocated to the virtual machine corresponding to the protocol processing unit,

wherein the received data storage unit is associated with a CAN identifier allocated to the virtual machine corresponding to the received data storage unit, and

wherein, in a case where a CAN identifier indicated in the received message is the CAN identifier corresponding to the protocol processing unit, the protocol processing unit stores data included in the received message in the received data storage unit corresponding to the CAN identifier.

5. The communication device according to claim **3**,

wherein one or more applications are operating on each of the virtual machines,

wherein a different CAN identifier is allocated to each of the applications,

wherein the protocol processing unit is associated with a CAN identifier allocated to each of the one or more applications operating on the virtual machine corresponding to the protocol processing unit,

wherein the received data storage unit is associated with a CAN identifier allocated to each of the one or more applications operating on the virtual machine corresponding to the received data storage unit, and

wherein, in a case where a CAN identifier indicated in the received message is the CAN identifier corresponding to the protocol processing unit, the protocol processing unit stores data included in the received message in the received data storage unit corresponding to the CAN identifier.

6. The communication device according to claim **3**,

wherein each of the protocol processing units includes a second reception unit that receives the received message from the outside of the communication device and outputs the received message to the protocol processing unit, and

wherein each of the protocol processing units includes a selector that outputs either a signal input from the first reception unit or a signal input from the second reception unit to the protocol processing unit.

7. The communication device according to claim **3**, comprising:

a plurality of transmitted data storage units that correspond to the different virtual machines;

an AND gate that outputs a logical AND signal representing a logical AND of a plurality of signals input from the plurality of protocol processing units; and

a first transmission unit that outputs the logical AND signal input from the AND gate to the outside of the communication device,

wherein the access controller permits the virtual machine to access the transmitted data storage unit corresponding to the virtual machine,

wherein the virtual machine stores data to be transmitted to the outside of the communication device in the transmitted data storage unit, and

wherein the protocol processing unit generates a transmitted message that is a message to be transmitted to the outside of the communication device based on the data stored in the transmitted data storage unit by the virtual machine corresponding to the protocol processing unit, and outputs the transmitted message to the AND gate.

8. The communication device according to claim **7**,

wherein each of the protocol processing units outputs a status signal indicating whether or not the transmitted message is in a state of being output,

wherein an OR gate is provided that outputs a logical OR signal representing a logical OR of the status signals input from the protocol processing units, to each of the protocol processing units, and

wherein each of the protocol processing units does not return an acknowledgment in a case where the logical OR signal indicates that the transmitted message is in a state of being transmitted by at least one of the protocol processing units.

9. The communication device according to claim **7**,

wherein each of the protocol processing units includes a second transmission unit that outputs the transmitted message output from the protocol processing unit to the outside of the communication device, and

wherein each of the protocol processing units includes a selector that outputs the transmitted message input from the protocol processing unit to either the first transmission unit or the second transmission unit.

10. The communication device according to claim **3**, further comprising a plurality of error notification storage units allocated to the plurality of virtual machines, respectively.

11. A communication method executed by a communication device, the communication device including

a virtual machine execution unit that includes at least one processor and a storage device and is configured to operate a plurality of virtual machines,

a first reception unit that receives a message transmitted from an outside of the communication device,

a communication control unit that includes a plurality of received data storage units allocated to the plurality of virtual machines, respectively, and

an access controller that is configured to allow each of the plurality of virtual machines to access the received data storage unit associated to the virtual machine,

the communication method comprising:

outputting, by the first reception unit, a received message, which is the message received, to the communication control unit; and

storing, by the communication control unit, the received message in the received data storage unit allocated to the virtual machine that is to use the received message.

12. The communication method according to claim **11**,

wherein the received message is a Controller Area Network (CAN), CAN with Flexible Data Rate (CAN FD), or CAN eXtra Large payload (CAN XL) message.

13. The communication method according to claim 12,
wherein the communication control unit includes a plurality of protocol processing units corresponding to the different virtual machines, respectively,
the communication method comprising:
outputting, by the first reception unit, the received message to each of the plurality of protocol processing units; and
in a case where a destination of the received message is the virtual machine corresponding to the protocol processing unit, storing, by the protocol processing unit, data included in the received message in the received data storage unit corresponding to the protocol processing unit.

14. The communication method according to claim 13,
wherein a different CAN identifier is allocated to each of the virtual machines,
wherein the protocol processing unit is associated with a CAN identifier allocated to the virtual machine corresponding to the protocol processing unit, and
wherein the received data storage unit is associated with a CAN identifier allocated to the virtual machine corresponding to the received data storage unit,
the communication method comprising, in a case where a CAN identifier indicated in the received message is the CAN identifier corresponding to the protocol processing unit, storing, by the protocol processing unit, data included in the received message in the received data storage unit corresponding to the CAN identifier.

15. The communication method according to claim 13,
wherein one or more applications are operating on each of the virtual machines,
wherein a different CAN identifier is allocated to each of the applications,
wherein the protocol processing unit is associated with a CAN identifier allocated to each of the one or more applications operating on the virtual machine corresponding to the protocol processing unit, and
wherein the received data storage unit is associated with a CAN identifier allocated to each of the one or more applications operating on the virtual machine corresponding to the received data storage unit,
the communication method comprising, in a case where a CAN identifier indicated in the received message is the CAN identifier corresponding to the protocol processing unit, storing, by the protocol processing unit, data included in the received message in the received data storage unit corresponding to the CAN identifier.

16. The communication method according to claim 13,
wherein, in the communication device, each of the protocol processing units includes a second reception unit that receives the received message from the outside of the communication device, and a selector,
the communication method comprising:
outputting, by the second reception unit, the received message to the selector corresponding to the second reception unit; and
outputting, by the selector, either a signal input from the first reception unit or a signal input from the second reception unit to the protocol processing unit corresponding to the selector.

17. The communication method according to claim 13,
wherein the communication device includes a plurality of transmitted data storage units that correspond to the different virtual machines, an AND gate, and a first transmission unit, and
wherein the access controller permits the virtual machine to access the transmitted data storage unit corresponding to the virtual machine,
the communication method comprising:
storing, by the virtual machine, data to be transmitted to the outside of the communication device in the transmitted data storage unit;
generating, by the protocol processing unit, a transmitted message that is a message to be transmitted to the outside of the communication device based on the data stored in the transmitted data storage unit by the virtual machine corresponding to the protocol processing unit, and outputting the transmitted message to the AND gate;
outputting, by the AND gate, a logical AND signal representing a logical AND of a plurality of signals output from the plurality of protocol processing units; and
outputting, by the first transmission unit, the logical AND signal input from the AND gate to the outside of the communication device.

18. The communication method according to claim 17,
wherein the communication device includes an OR gate,
the communication method comprising:
outputting, by each of the protocol processing units, a status signal indicating whether or not the transmitted message is in a state of being output;
outputting, by the OR gate, a logical OR signal representing a logical OR of the status signals input from the protocol processing units, to each of the protocol processing units; and
not returning, by each of the protocol processing units, an acknowledgment in a case where the logical OR signal indicates that the transmitted message is in a state of being transmitted by at least one of the protocol processing units.

19. The communication method according to claim 17,
wherein, in the communication device, each of the protocol processing units includes a second transmission unit that outputs the transmitted message output from the protocol processing unit to the outside of the communication device, and a selector,
the communication method comprising outputting, by the selector, the transmitted message input from the protocol processing unit corresponding to the selector to either the first transmission unit or the second transmission unit.

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