COMMUNICATION METHOD AND RELATED APPARATUS

TECHNICAL FIELD

[0001] The present disclosure relates to the field of communication technologies, and in particular, to a communication method and related apparatus.

BACKGROUND

[0002] Radio Frequency Identification (RFID) is a well-known technology that is widely used in many industries for automated identification. While it may never totally replace the ubiquitous barcode tags, it is replacing or complimenting barcode tags in some industries such as apparel retail, logistics etc. RFID tags can be classified as active or passive tags based on whether the tags carry their own power source or they require power from an external source (such as RF power or backscattering). The tags can also be classified based on the frequency of the wireless signal used to operate the tags, e.g., classified as low frequency tags, high frequency tags, ultra high frequency tags, microwave tags, etc.

[0003] This background information is provided to reveal information believed by the applicant to be of possible relevance to the present disclosure. No admission is necessarily intended, nor should be construed, that any of the preceding information constitutes prior art against the present disclosure.

SUMMARY

[0004] In a first aspect, a communication method implemented by a tag is provided by the present disclosure, and the method comprises:

receiving a request frame from a reader via a wireless signal, where the wireless signal follows an Institute of Electrical and Electronics Engineers (IEEE) 802.11 protocol, where the request frame carries a radio frequency identification (RFID) command and a request instruction for indicating that the request frame carries the RFID command.

[0005] The tag can be accessed through a request frame, where the request frame carries an RFID command and

a request instruction for indicating that the request frame carries the RFID command. The tag is activated by a wireless signal following IEEE 802.11 protocol, that is, the RFID protocol is integrated with the 802.11 protocol, and thus the tag can be accessed by an RFID reader supporting the 802.11 protocol without major hardware upgrade.

[0006] In a possible implementation of the first aspect, the request instruction comprises a first frame type identification and a first payload type identification, where the first frame type identification indicates that the request frame is a data frame and the first payload type identification indicates that a payload of the data frame comprises the RFID command.

[0007] The request frame used for accessing the tag can be a sub-type of data frame, where the data frame is indicated by the first frame type identification, and the request frame carrying the RFID command is indicated by the first payload type identification.

[0008] In a possible implementation of the first aspect, the request instruction comprises a second frame type identification, and the second frame type identification indicates that the request frame carries the RFID command.

[0009] The request frame used for accessing the tag can also be a frame other than a data frame, and the request frame carrying the RFID command can be directly indicated by second frame type identification.

[0010] In a possible implementation of the first aspect, a timing for starting a next interaction between the tag and the reader is determined based on a predefined first timing parameter associated with the request frame.

[0011] After the tag receives the request frame from the reader, the next interaction between the tag and the reader may depends on the RFID command carried in the request frame. The next interaction may be that the tag generates and transmits a response to the reader, or it may also be that it is not necessary for the tag to respond. The first timing parameter associated with the request frame can be fixed and hence not signaled explicitly in the request frame, thereby saving signaling overhead.

[0012] In a possible implementation of the first aspect, the request frame further comprises a first timing field for indicating a first timing parameter associated with the request frame.

[0013] The first timing parameter associated with the request frame can also be signaled explicitly in the request frame, thereby improving the designing flexibility for this parameter to meet different requirements.

[0014] In a possible implementation of the first aspect, the first timing parameter and the RFID command are delivered from a first part of a media access control (MAC) layer of the tag to a second part of the MAC layer of the tag for handling the RFID command by the second part of the MAC layer; where the first part of the MAC layer of the tag corresponds to a first part of a physical layer at which the request frame is received.

[0015] In the case that the tag handles the request frame received from the reader, when the request frame is received by a first part of a physical layer (e.g., AMP (Ambient Power) RFID PHY), it is forwarded to a first part of the MAC layer (e.g., AMP RFID MAC), the AMP RFID MAC extracts the encapsulated RFID command and the first timing parameter and forwards them to a second part of the MAC layer (e.g., UHF RFID MAC). With such data flows, that is, with such tag structure, the tag can be accessed by an RFID reader supporting the 802.11 protocol without major hardware upgrade.

[0016] In a possible implementation of the first aspect, a flag is maintained in the second part of the MAC layer of the tag for indicating that the RFID command is from the first part of the MAC layer of the tag.

[0017] The flag can be used for distinguishing that the RFID command is from the first part of the MAC layer (e.g., AMP RFID MAC), not the second part of the MAC layer (e.g., UHF RFID MAC).

[0018] In a possible implementation of the first aspect, a timing for transmitting a response frame corresponding to the request frame to the reader is determined based on a predefined second timing parameter associated with the request frame.

[0019] The first timing parameter (e.g., RTcal parameter) is used for indicating a timing for starting a next interaction between the tag and the reader, while the second timing parameter (e.g., TRcal or TRcal_factor parameter) is used for indicating a timing for transmitting a response frame corresponding to the request frame to the reader. The second timing parameter associated with the request frame can be fixed and hence not signaled explicitly in the request frame, thereby saving signaling overhead.

[0020] In a possible implementation of the first aspect, the request frame further comprises a second timing field for indicating a second timing parameter for transmitting a response frame corresponding to the request frame to the reader.

[0021] The second timing parameter associated with the request frame can also be signaled explicitly in the request frame, thereby improving the designing flexibility for this parameter to meet different requirements.

[0022] In a possible implementation of the first aspect, the request frame comprises a presence field for indicating whether the second timing field is present.

[0023] After the tag receives the request frame from the reader, it may not be necessary for the tag to respond, that is, the second timing parameter is necessary when the tag is required to generate a response. Therefore, if the presence field indicates the second timing field is not present, it is obvious there is no second timing parameter and it may not necessary to execute a reading operation, thereby improving data processing efficiency.

[0024] In a possible implementation of the first aspect, the second timing parameter is delivered from a first part of a media access control (MAC) layer of the tag to a second part of the MAC layer of the tag for obtaining an RFID response corresponding to the RFID command by the second part of the MAC layer; where the first part of the MAC layer of the tag corresponds to a first part of a physical layer at which the request frame is received.

[0025] The data flows for processing the second timing parameter is similar to that for the first timing parameter. In the case that the tag handles the request frame received from the reader, when the request frame is received by a first part of a physical layer (e.g., AMP RFID PHY), it is forwarded to a first part of the MAC layer (e.g., AMP RFID MAC), the AMP RFID MAC extracts the second timing parameter and forwards it to a second part of the MAC layer (e.g., UHF RFID MAC). With such data flows, that is, with such tag structure, the tag can be accessed by an RFID reader supporting the 802.11 protocol without major hardware upgrade.

[0026] In a possible implementation of the first aspect, at least one response parameter is predefined or indicated in the request frame, and the at least one response parameter is used by the tag for transmitting a response frame corresponding to the request frame.

[0027] In a possible implementation of the first aspect, the request frame further comprises a cyclic redundancy check (CRC) field, where a value of the CRC field is calculated based on all fields other than the CRC field of the request frame.

[0028] In a possible implementation of the first aspect, the method further comprises: transmitting an RFID response to the reader in response to the request frame.

[0029] The RFID response can be encapsulated in a response frame, or can also be directly transmitted, thereby expanding the transmission manner of the RFID response.

[0030] In a possible implementation of the first aspect, the transmitting the RFID response to the reader in response to the request frame comprises:

transmitting a response frame carrying the RFID response to the reader in response to the request frame, where the response frame carries a response instruction for indicating that the response frame carries the RFID response.

[0031] The RFID response can be encapsulated in a response frame, this format may be easier for data management, and the data transmission accuracy is thus ensured.

[0032] In a possible implementation of the first aspect, the response instruction comprises a third frame type identification and a second payload type identification, where the third frame type identification indicates that the

response frame is a data frame and the second payload type identification indicates that a payload of the data frame comprises the RFID response.

[0033] Similar to the request frame from the reader to the tag, the response frame transmitted by the tag to the reader can be a sub-type of data frame, where the data frame is indicated by the third frame type identification, and the RFID response is indicated by the second payload type identification.

[0034] In a possible implementation of the first aspect, the response instruction comprises a fourth frame type identification, and the fourth frame type identification indicates that the response frame carries the RFID response.

[0035] The response frame transmitted by the tag to the reader can also be a frame other than a data frame, and the RFID response can be directly indicated by the fourth frame type identification.

[0036] In a possible implementation of the first aspect, the response frame further comprises a cyclic redundancy check (CRC) field, where a value of the CRC field is calculated based on all fields other than the CRC field of the response frame.

[0037] In a possible implementation of the first aspect, at least one response parameter and the RFID response are delivered from a second part of a MAC layer of the tag to a first part of the MAC layer of the tag, where the at least one response parameter is used by a first part of a physical layer of the tag for transmitting the RFID response to the reader under an instruction of the first part of the MAC layer.

[0038] The data flows for a response is in the reverse direction of the data flows for the request frame. Once the response is ready, a second part of the MAC layer (e.g., UHF RFID MAC) passes the response to a first part of the MAC layer (e.g., AMP RFID MAC), which in turn forwards the response to a first part of a physical layer (e.g., AMP RFID PHY). With such data flows, that is, with such tag structure, the tag can be accessed by an RFID reader supporting the 802.11 protocol without major hardware upgrade.

[0039] In a possible implementation of the first aspect, the first part of the MAC layer is an Ambient Power (AMP) MAC layer.

[0040] The request frame for accessing a tag carries the RFID command, while the request frame is processed through the AMP MAC layer (or referred to as AMP RFID MAC), it means that the RFID technologies are combined with the AMP technologies, thus the tag can be accessed by an RFID reader supporting the 802.11 protocol without major hardware upgrade.

[0041] In a possible implementation of the first aspect, the second part of the MAC layer is any one of a low frequency (LF), a high frequency (HF) or an ultra high frequency (UHF) MAC layer.

[0042] When the RFID technologies are combined with the AMP technologies, RFID tags in different frequencies (e.g., LF tags, HF tags, UHF tags, etc.) can be enabled with the AMP technologies. Correspondingly, the first part of the MAC layer may be AMP RFID MAC, while the second part of the MAC layer may be an LF MAC layer (or referred to as LF RFID MAC), an HF MAC layer (or referred to as HF RFID MAC), or a UHF MAC layer (or referred to as UHF RFID MAC), etc.

[0043] In a possible implementation of the first aspect, the request frame is an AMP RFID frame.

[0044] In a second aspect, a communication method implemented by a reader is provided by the present disclosure, and the method comprises:

transmitting a request frame to a tag via a wireless signal, where the wireless signal follows an Institute of Electrical and Electronics Engineers (IEEE) 802.11 protocol, where request frame carries a radio frequency identification (RFID) command and a request instruction for indicating that the request frame carries the RFID command.

[0045] The reader can access the tag through a request frame, where the request frame carries an RFID command and a request instruction for indicating that the request frame carries the RFID command. The tag is activated by a wireless signal following IEEE 802.11 protocol, that is, the RFID protocol is integrated with the 802.11 protocol, thus the tag can be accessed by an RFID reader supporting the 802.11 protocol without major hardware upgrade.

[0046] In a possible implementation of the second aspect, the request instruction comprises a first frame type identification and a first payload type identification, where the first frame type identification indicates that the request frame is a data frame and the first payload type identification indicates that a payload of the data frame comprises the RFID command.

[0047] The request frame used for accessing the tag can be a sub-type of data frame, where the data frame is indicated by the first frame type identification, and the request frame carrying the RFID command is indicated by the first payload type identification.

[0048] In a possible implementation of the second aspect, the request instruction comprises a second frame type identification, and the second frame type identification indicates that the request frame carries the RFID command.

[0049] The request frame used for accessing the tag can also be a frame other than a data frame, and the request frame carrying the RFID command can be directly indicated by second frame type identification.

[0050] In a possible implementation of the second aspect, a timing for starting a next interaction between the tag and the reader is determined based on a predefined first timing parameter associated with the request frame.

[0051] After the reader transmits the request frame to the reader, the next interaction between the tag and the reader may depends on the RFID command carried in the request frame. The next interaction may be that the tag generates and transmits a response to the reader, or it may also be that it is not necessary for the tag to respond. The first timing parameter associated with the request frame (e.g., RTcal parameter) can be not signaled explicitly (be fixed) in the request frame, thereby saving signaling overhead.

[0052] In a possible implementation of the second aspect, the request frame further comprises a first timing field for indicating a first timing parameter associated with the request frame.

[0053] The first timing parameter associated with the request frame can also be signaled explicitly in the request frame, thereby improving the designing flexibility for this parameter to meet different requirements.

[0054] In a possible implementation of the second aspect, the first timing parameter and the RFID command are delivered from a station management entity (SME) of the reader to a media access control (MAC) sublayer management entity (MLME) of the reader for transmitting the request frame by the MLME.

[0055] In a possible implementation of the second aspect, a confirmation is delivered from the MLME to the SME for confirming a successful reception of the first timing parameter and the RFID command.

[0056] In a possible implementation of the second aspect, a timing for transmitting a response frame corresponding to the request frame is determined based on a predefined second timing parameter associated with the request frame.

[0057] The first timing parameter (e.g., RTcal parameter) is used for indicating a timing for starting a next interaction between the tag and the reader, while the second timing parameter (e.g., TRcal or TRcal_factor parameter) is used for indicating a timing for transmitting a response frame corresponding to the request frame. The second timing parameter associated with the request frame can be fixed and hence not signaled explicitly in the request frame, thereby saving signaling overhead.

[0058] In a possible implementation of the second aspect, the request frame further comprises a second timing field for indicating a second timing parameter for transmitting a response frame corresponding to the request frame.

[0059] The second timing parameter associated with the request frame can also be signaled explicitly in the request frame, thereby improving the designing flexibility for this parameter to meet different requirements.

[0060] In a possible implementation of the second aspect, the request frame comprises a presence field for indicating whether the second timing field is present.

[0061] After the reader transmits the request frame to the tag, it may not necessary for the tag to respond, that

is, the second timing parameter is necessary when the tag is required to generate a response. Therefore, if the presence field indicates the second timing field is not present, it is obvious there is no second timing parameter and it may not be necessary to execute a reading operation, thereby improving data processing efficiency.

[0062] In a possible implementation of the second aspect, the second timing parameter is delivered from a station management entity (SME) of the reader to a media access control (MAC) sublayer management entity (MLME) of the reader for transmitting the request frame by the MLME.

[0063] In a possible implementation of the second aspect, a duration of a carrier signal is delivered from an SME of the reader to an MLME of the reader, and the carrier signal is transmitted by the MLME after transmission of the request frame.

[0064] In a possible implementation of the second aspect, the request frame further comprises a cyclic redundancy check (CRC) field, where a value of the CRC field is calculated based on all fields other than the CRC field of the request frame.

[0065] In a possible implementation of the second aspect, the method further comprises: receiving an RFID response corresponding to the request frame from the tag.

[0066] The RFID response can be encapsulated in a response frame, or can also be directly transmitted, thereby expanding the transmission manner of the RFID response.

[0067] In a possible implementation of the second aspect, the receiving the RFID response corresponding to the request frame from the tag comprises:

receiving a response frame carrying the RFID response from the tag in response to the RFID command in the request frame, where the response frame carries a response instruction for indicating that the response frame carries the RFID response.

[0068] The RFID response can be encapsulated in a response frame, this format may be easier for data management, and the data transmission accuracy is thus ensured.

[0069] In a possible implementation of the second aspect, the response instruction comprises a third frame type identification and a second payload type identification, where the third frame type identification indicates that the response frame is a data frame and the second payload type identification indicates that a payload of the data frame comprises the RFID response.

[0070] Similar to the request frame from the reader to the tag, the response frame transmitted by the tag to the reader can be a sub-type of data frame, where the data frame is indicated by the third frame type identification, and

the RFID response is indicated by the second payload type identification.

[0071] In a possible implementation of the second aspect, the response instruction comprises a fourth frame type identification, and the fourth frame type identification indicates that the response frame carries the RFID response.

[0072] The response frame transmitted by the tag to the reader can also be a frame other than a data frame, and the RFID response can be directly indicated by the fourth frame type identification.

[0073] In a possible implementation of the second aspect, the response frame further comprises a cyclic redundancy check (CRC) field, where a value of the CRC field is calculated based on all fields other than the CRC field of the response frame.

[0074] In a possible implementation of the second aspect, the RFID response is delivered from an MLME of the reader to an SME of the reader for forwarding the RFID response to an application layer of the reader by the SME.

[0075] In a third aspect, a communication apparatus is provided by the present disclosure, and the apparatus comprises various modules configured to execute the communication method according to the first aspect or any possible implementation of the first aspect.

[0076] In a fourth aspect, a communication apparatus is provided by the present disclosure, and the apparatus comprises various modules configured to execute the communication method according to the second aspect or any possible implementation of the second aspect.

[0077] In a fifth aspect, a communication apparatus is provided by the present disclosure, and the apparatus comprises at least one processor, where the at least one processor is configured to execute the communication method according to the first aspect or any possible implementation of the first aspect or according to the second aspect or any possible implementation of the second aspect.

[0078] In a possible implementation of the fifth aspect, the above apparatus further comprises a memory, and the memory stores instructions that cause the at least one processor to execute the communication method according to the first aspect or any possible implementation of the first aspect or according to the second aspect or any possible implementation of the second aspect.

[0079] In a sixth aspect, a communication apparatus is provided by the present disclosure, and the apparatus is configured to execute the communication method according to the first aspect or any possible implementation of the first aspect or according to the second aspect or any possible implementation of the second aspect.

[0080] In a seventh aspect, a tag is provided by the present disclosure, and the tag comprises processing circuitry for executing the communication method according to the first aspect or any possible implementation of the first

aspect.

[0081] In an eighth aspect, a tag is provided by the present disclosure, and the tag comprises a transceiver and a processor connected to the transceiver;

the transceiver is configured to receive a request frame, where the request frame carries a radio frequency identification (RFID) command;

the processor is configured to:

when the request frame is received at a first part of a physical layer, extract the RFID command at a first part of a MAC layer corresponding to the first part of the physical layer and process the RFID command at a second part of the MAC layer;

when the request frame is received at a second part of the physical layer, process the request frame at the second part of the MAC layer.

[0082] In a possible implementation of the eighth aspect, the above tag further comprises a memory connected to the processor; the processor is further configured to determine an RFID response based on information stored in the memory and a part of the physical layer at which the request frame is received, and control the transceiver to transmit the RFID response.

[0083] In a possible implementation of the eighth aspect, the request frame is an Ambient Power (AMP) RFID frame.

[0084] In a ninth aspect, a reader is provided by the present disclosure, and the reader comprises processing circuitry for executing the communication method according to the second aspect or any possible implementation of the second aspect.

[0085] In a tenth aspect, a communication system is provided by the present disclosure, and the communication system comprises the tag according to the seventh or eighth aspect and the reader according to the eighth aspect.

[0086] In an eleventh aspect, a chip is provided by the present disclosure, and the chip comprises an input/output (I/O) interface and a processor, where the processor is configured to call and run computer execution instructions stored in a memory, to enable a device installing with the chip to execute the communication method according to the first aspect or any possible implementation of the first aspect or according to the second aspect or any possible implementation of the second aspect.

[0087] In a twelfth aspect, a computer-readable medium is provided by the present disclosure, and the computer-readable medium comprises computer execution instructions which, when executed by a processor, causes the

processor to execute the communication method according to the first aspect or any possible implementation of the first aspect or according to the second aspect or any possible implementation of the second aspect.

[0088] In a thirteenth aspect, a computer program product is provided by the present disclosure, and the computer program product comprises computer execution instructions which, when executed by a processor, causes the processor to execute the communication method according to the first aspect or any possible implementation of the first aspect or according to the second aspect or any possible implementation of the second aspect.

[0089] A communication method and related apparatus are provided by the present disclosure. The reader transmits a request frame to the tag via a wireless signal, where the wireless signal follows IEEE 802.11 protocol, where the request frame carries an RFID command and a request instruction for indicating that the request frame carries the RFID command. The tag is activated by a wireless signal following IEEE 802.11 protocol and the request frame for accessing the tag carries the RFID command, that is, the RFID protocol is integrated with the 802.11 protocol, thus the tag can be accessed by an RFID reader supporting the 802.11 protocol without major hardware upgrade.

BRIEF DESCRIPTION OF DRAWINGS

[0090] The accompanying drawings are used to provide a further understanding of the present disclosure, constitute a part of the specification, and are used to explain the present disclosure together with the following specific embodiments, but should not be construed as limiting the present disclosure.

[0091] FIG. 1 is a schematic illustration of possible configurations for reading a tag with a reader according to one or more embodiments of the present disclosure.

[0092] FIG. 2 is a schematic illustration of a stack architecture of a tag according to one or more embodiments of the present disclosure.

[0093] FIG. 3 is a block diagram of a tag architecture according to one or more embodiments of the present disclosure.

[0094] FIG. 4 is a schematic illustration of frame exchanges between a reader and a tag according to one or more embodiments of the present disclosure.

[0095] FIG. 5 is a flowchart of a communication method according to one or more embodiments of the present disclosure.

[0096] FIG. 6 is a flowchart of another communication method according to one or more embodiments of the

present disclosure.

[0097] FIG. 7A is a schematic illustration of a frame format of an AMP frame according to one or more embodiments of the present disclosure.

[0098] FIG. 7B is a schematic illustration of the Frame Type field of the AMP frame according to one or more embodiments of the present disclosure.

[0099] FIG. 7C is a schematic illustration of the Type Dependent Content field of the AMP frame according to one or more embodiments of the present disclosure.

[0100] FIG. 7D is a schematic illustration of the Payload Type field carried in the Type Dependent Content field according to one or more embodiments of the present disclosure.

[0101] FIG. 8A is a schematic illustration of an AMP Data frame used as the AMP UHF (Ultra High Frequency) frame according to one or more embodiments of the present disclosure.

[0102] FIG. 8B is a schematic illustration of the Payload field of the AMP UHF frame according to one or more embodiments of the present disclosure.

[0103] FIG. 8C is a schematic illustration of the Link Timing Parameters field of the AMP UHF frame according to one or more embodiments of the present disclosure.

[0104] FIG. 9 is a schematic illustration of an example of the UHF Command Or Response field carrying the UHF query command according to one or more embodiments of the present disclosure.

[0105] FIG. 10 is a schematic illustration of an example of the UHF Command Or Response field carrying the UHF RN16 response according to one or more embodiments of the present disclosure.

[0106] FIG. 11 is another schematic illustration of a stack architecture of a tag according to one or more embodiments of the present disclosure.

[0107] FIG. 12 is a schematic illustration of the interaction between the AMP RFID (radio frequency identification) MAC (media access control) and the UHF RFID MAC according to one or more embodiments of the present disclosure.

[0108] FIG. 13 is another schematic illustration of the interaction between the AMP RFID MAC and the UHF RFID MAC according to one or more embodiments of the present disclosure.

[0109] FIG. 14 is a schematic illustration of parameters of a primitive at the tag side according to one or more embodiments of the present disclosure.

[0110] FIG. 15 is a schematic illustration of parameters of another primitive at the tag side according to one or

more embodiments of the present disclosure.

[0111] FIG. 16 is a schematic illustration of a reference model for a reader according to one or more embodiments of the present disclosure.

[0112] FIG. 17 is a schematic illustration of the interaction between the SME (station management entity) and the MLME (MAC sublayer management entity) according to one or more embodiments of the present disclosure.

[0113] FIG. 18 is another schematic illustration of the interaction between the SME and the MLME according to one or more embodiments of the present disclosure.

[0114] FIG. 19 is a schematic illustration of parameters of a primitive at the reader side according to one or more embodiments of the present disclosure.

[0115] FIG. 20A is a schematic illustration of parameters of another primitive at the reader side according to one or more embodiments of the present disclosure.

[0116] FIG. 20B is a schematic illustration of the overall interaction between a tag and a reader according to one or more embodiments of the present disclosure.

[0117] FIG. 21 is another schematic illustration of frame exchanges between a reader and a tag according to one or more embodiments of the present disclosure.

[0118] FIG. 22A is another schematic illustration of a frame format of an AMP frame according to one or more embodiments of the present disclosure.

[0119] FIG. 22B is another schematic illustration of the Frame Type field of the AMP frame according to one or more embodiments of the present disclosure.

[0120] FIG. 23A is a schematic illustration of the AMP UHF frame according to one or more embodiments of the present disclosure.

[0121] FIG. 23B is a schematic illustration of the Type Dependent Content field of the AMP UHF frame according to one or more embodiments of the present disclosure.

[0122] FIG. 24 is still another schematic illustration of frame exchanges between a reader and a tag according to one or more embodiments of the present disclosure.

[0123] FIG. 25 is yet another schematic illustration of frame exchanges between a reader and a tag according to one or more embodiments of the present disclosure.

[0124] FIG. 26 is a block diagram of a communication apparatus according to one or more embodiments of the present disclosure.

[0125] FIG. 27 is a block diagram of another communication apparatus according to one or more embodiments of the present disclosure.

[0126] FIG. 28 is a schematic structural diagram of a communication apparatus according to one or more embodiments of the present disclosure.

DESCRIPTION OF EMBODIMENTS

[0127] In the following description, reference is made to the accompanying figures, which form part of the present disclosure, and which show, by way of illustration, specific aspects of embodiments of the present disclosure or specific aspects in which embodiments of the present disclosure may be used. It is understood that embodiments of the present disclosure may be used in other aspects and include structural or logical changes not depicted in the figures. The following detailed description, therefore, is not to be taken in a limiting sense, and the scope of the present disclosure is defined by the appended claims.

[0128] The technical solution provided by the present disclosure may be applied to wireless local area network (WLAN) systems, such as Wi-Fi systems, etc. The technical solution provided by the present disclosure may be applied to a series of Institute of Electrical and Electronics Engineers (IEEE) 802.11 protocols, e.g., the 802.11a/b/g protocol, the 802.11n protocol, the 802.11ac protocol, the 802.11ax protocol, the 802.11be protocol, or a next-generation protocol, which is not limited here. The technical solution provided by the present disclosure may also be applied to the wireless personal area network (WPAN) based on the millimeter wave (MMW) and ultra wideband (UWB) technologies. The technical solution provided by the present disclosure may also be applied to communication systems such as Internet of Things (IoT) systems, vehicle to everything (V2X, X may represent anything) systems, device to device (D2D) systems, narrowband Internet of Things (NB-IoT) systems, long term evolution (LTE) systems, the fifth generation (5G) communication system, or other communication systems in future. For example, the V2X system may include: vehicle to vehicle (V2V) communication, vehicle to infrastructure (V2I) communication, vehicle to pedestrian (V2P) communication, or vehicle to network (V2N) communication, etc.

[0129] The above describes possible scenarios or generalized description of the examples of the present disclosure, the motivation and technical concepts of the present disclosure are illustrated in the following.

[0130] Radio Frequency Identification (RFID) is a well-known technology that is widely used in many industries for automated identification. While it may never totally replace the ubiquitous barcode tags, it is replacing or complimenting barcode tags in some industries such as apparel retail, logistics etc. RFID tags can be classified as

active or passive tags based on whether the tags carry their own power source or they require power from an external source (such as RF power or backscattering). The tags can also be classified based on the frequency of the wireless signal used to operate the tags, e.g., classified as low frequency tags, high frequency tags, ultra high frequency tags, microwave tags, etc.

[0131] Low Frequency (LF) tags operates at 125 KHz and 134 KHz (typically at 134.2 KHz) using near-field inductive coupling and are used for animal tracking, automotive industry etc. The LF tags are passive tags and have a short-read range of a few inches.

[0132] High Frequency (HF) tags operates between 3 MHz to 30 MHz (typically at 13.56 MHz) using near-field inductive coupling. HF tags are passive tags and have a short-read range, typically less than 3 feet.

[0133] Ultra High Frequency (UHF) tags typically operates at 433 MHz and 860–960 MHz. The 433 MHz frequency is used for active tags, while the 860–960 MHz range is used mostly for passive tags and some semi-passive tags. The passive and the semi-passive tags in this frequency range use far-field radiative coupling, or backscatter coupling and have a read range of about 15 feet. Passive UHF tags are the mostly commonly used RFID tags in the apparel industry.

[0134] Microwave tags typically operates at 2.45 GHz and are available as passive, semi-passive, and active types. Passive microwave tags are usually smaller than passive UHF tags and have the same read range of about 15 feet. The semi-passive microwave tags have a read range of about 100 feet, while the active microwave tags have a read range of about 350 feet.

[0135] AMbient Power (AMP) is a new TIG (Top Interest Group) /SG (Study Group) within the IEEE 802.11 working group that is studying the support of Ambient Power communication in IEEE 802.11 network. The goal is to address the need of ambient power-enabled Wi-Fi IoT (Internet of Things) devices. The group is exploring technologies that can significantly increase the battery lifespan of IoT devices, such as RF power harvesting (or backscattering) etc.

[0136] In view of the above, we may combine the RFID and the AMP technologies to enable reading of RFID (LF/HF/UHF) tags using a Wi-Fi device at a very short range, that is, we may design IEEE 802.11 compliant protocol to read AMP+ RFID tags (i.e., AMP enabled LF/HF/UHF tags, or referred to as AMP RFID tags) with compatible Wi-Fi readers (e.g., smartphones). In other words, an AMP RFID reader (i.e., a Wi-Fi device that can read AMP enabled tags) can be an add-on feature to existing Wi-Fi devices without major hardware upgrade. Integrating the RFID protocol with existing Wi-Fi (IEEE 802.11) protocol is not trivial, and there is no technical solution about

designing a feasible RFID+AMP system (i.e., AMP enabled system for accessing LF/HF/UHF tags). It should be noted that, RFID tags in other frequencies (LF/HF tags) can also be enabled with AMP technologies, UHF tags are illustrative but not restrictive in the present disclosure.

[0137] The present disclosure proposes an AMP RFID tag that can be accessed (read and write) with an AMP RFID reader. Based on the design, the proposed AMP RFID tag can also be a dual use AMP RFID tag that can be accessed (read and write) both with an UHF reader (e.g., an existing GS1 EPC (electronic product code) UHF reader) as well as with an AMP RFID reader. We propose the overall system architecture for the AMP RFID protocol and also propose to encapsulate GS1 UHF commands and responses in AMP frames. An AMP frame that encapsulates a GS1 UHF command or response is referred to as an AMP UHF frame.

[0138] The present disclosure can be applicable in any device and tags that use the AMP RFID protocol, and may be implemented in tags, smartphones, access points, laptops, etc.

[0139] Before describing possible configurations for reading an AMP RFID tag with an AMP RFID reader, the following terminologies used in the present disclosure will be introduced:

- AMP AP STA: an AP (Access Point) that can transmit and receive AMP PPDU (PHY Protocol Data Unit) and communicate with AMP non-AP STAs.
- AMP non-AP STA: a non-AP STA that can transmit and receive AMP PPDU and communicate with an AMP AP STA or another AMP non-AP STA.
- AMP assisting STA: an AMP STA (either AP or non-AP) that provides assistance to an AMP assisted non-AP STA to communicate using an AMP protocol. The assistance may be providing energy (Wireless power), or relay service or transmitting carrier signals for RF backscattering etc. In the context of AMP RFID protocol, the assistance is by transmitting carrier signals to the AMP RFID tags for RF backscattering, where the AMP RFID protocol is an AMP protocol designed for use with RFID devices.
- AMP assisted non-AP STA: an AMP non-AP STA that can communicate using the AMP protocol with the assistance provided by an AMP assisting STA.
- AMP RFID reader: an AMP assisting STA that can read an AMP RFID tag (e.g., a smartphone).
- AMP RFID tag: an AMP assisted non-AP STA that at least supports the AMP RFID protocol and also supports the non-AMP RFID protocol (e.g., UHF RFID protocol).

[0140] Based on its capabilities an AMP STA may be classified as Type A AMP STA, Type B AMP STA and Type C AMP STA. Type A AMP STA has capability to support legacy 802.11 protocols (e.g., 802.11b/g/n) and

support their own energy sources, e.g., batteries. Type B AMP STA may not support legacy 802.11 protocols and only support low power transceiver operations and also possess some sort of small energy source, e.g., large capacitor, or ambient power source etc. Type C AMP STA may not support legacy 802.11 protocols and only support low power transceiver operations and do not possess any energy source. Type C AMP STA uses backscattering technique for their transmissions. An AMP RFID tag is a special sub-category of Type C AMP STA.

[0141] Three possible configurations for reading an AMP RFID tag with an AMP RFID reader are illustrated in FIG. 1. Either the AMP AP STA or the AMP assisting non-AP STA can act as the AMP RFID reader, while the AMP assisted non-AP STA refers to the AMP RFID tag.

[0142] Configuration 1: the AMP RFID reader is associated with an AP (e.g., an AMP AP STA), e.g., the AMP RFID reader is part of an infrastructure Basic Service Set (BSS). The AMP RFID reader has access to external network (e.g., internet) via the AP that is connected to the Distribution System (DS). In this case:

- the AMP RFID reader (AMP assisting non-AP STA 1) operates in the existing mode (e.g., infrastructure BSS, BSS1 in FIG. 1). However, it may be in a Power Save (PS) mode with the AP before performing any communication with the tag and may not have any active Service Period with the AP on the relevant channel during this time. This is to avoid any ongoing AMP RFID read operation being interrupted by downlink communication from the AP to the AMP RFID reader.
- the AMP RFID tag (AMP assisted non-AP STA 2) operates outside the context of a BSS (OCB). IEEE 802.11synchronization, authentication, association are not used for the tag, i.e., AMP assisted non-AP STA 2 is not part of BSS1.

[0143] Configuration 2: when the AMP RFID reader is an AP,

- the AMP RFID reader (AMP AP STA) operates in the existing mode (e.g., infrastructure BSS). The AMP RFID reader has access to external network (e.g., internet) via the Distribution System (DS).
- the AMP RFID tag (AMP assisted non-AP STA 1) operates outside the context of a BSS (OCB). IEEE 802.11synchronization, authentication, association are not used for the tag, i.e., AMP assisted non-AP STA 1 is not part of BSS1.

[0144] Configuration 3: when the AMP RFID reader (AMP assisting non-AP STA 2) is not associated with an AP, both the AMP RFID reader and the tag (AMP assisted non-AP STA 3) operate outside the context of a BSS (OCB). The AMP RFID reader may have access to external network (e.g., internet) via non-IEEE 802.11 technology such as cellular connections etc.

[0145] In order to enable IEEE 802.11 devices to access (read or write) RFID tags, we propose a dual use AMP RFID tag that can be accessed (read and write) both with an UHF reader as well as with an AMP RFID reader (a dual AMP and UHF RFID tag usage). A possible PHY and MAC stack architecture of such an AMP RFID tag is illustrated in FIG. 2. For any RFID tag, the most important component is the non-volatile memory (common memory) which stores the tag's unique identification information as well as other user information. For example, in case of the GS1 EPC (Electronic product code) UHF tag (e.g., as defined by GS1 EPC Tag Data Standard (TDS)), the memory may include the Access password, Kill Password, the EPC, the Tag Identification (TID) bits, and also user defined information. To enable a dual use tag, we design a common user memory that can be accessible directly (path 1) via the UHF RFID PHY and the UHF RFID MAC, or indirectly (path 2) via the AMP RFID PHY and the AMP RFID MAC. Each of the two line depicts the path that an incoming over-the-air RFID read command (from the reader) takes via the PHY and MAC to reach the memory and continues as an outgoing response (to the reader) via the MAC and PHY and over the air to the reader.

[0146] It can be seen that the over-the-air UHF RFID commands (e.g., as defined by the EPC™ Radio-Frequency Identity Protocols Generation-2 UHF RFID Standard) are received by the UHF RFID PHY and passed on to the UHF RFID MAC which can access the common memory directly. The outgoing UHF response is passed by the UHF RFID MAC to the UHF RFID PHY which backscatters it to the UHF reader. Here it is assumed that the UHF RFID PHY and UHF RFID MAC follows the UHF RFID protocol as defined by the EPC™ Radio-Frequency Identity Protocols Generation-2 UHF RFID Standard including the tag states, all applicable commands, link timing parameters etc.

[0147] As for the over-the-air AMP RFID frames (may be referred to as AMP UHF frames in the case that UHF tags are taken as an example to combine with AMP), to simplify the protocol, instead of the AMP RFID MAC directly accessing the common memory, the AMP RFID frames encapsulate the GS1 UHF commands and responses. When the over-the-air AMP RFID frames are received by the AMP RFID PHY, they are forwarded to the AMP RFID MAC, which extracts the encapsulated GS1 UHF command and forwards them to the UHF RFID MAC which can access the common memory directly. In this case the UHF RFID MAC maintains a flag to remember that the RFID command came from AMP RFID MAC (and not the UHF RFID PHY). In the reverse direction, once the response is ready, the UHF RFID MAC passes the response to the AMP RFID MAC which in turn forwards the response to the AMP RFID PHY to backscatter it to the AMP RFID reader.

[0148] A potential implementation block diagram of the dual use AMP RFID tag is illustrated in FIG. 3. The tag

includes three main functional blocks: 1) Analog Front End, 2) Digital Control and 3) Memory.

[0149] The analog front end is connected to the RF antenna and its functions are: 1) to convert the incoming RF signal to stable DC power for use by the other components of the tag; 2) to demodulate the received RF signal and forward the data received from the reader to the digital control; 3) to transmit (backscatter) the tag's response to the reader.

[0150] The digital control is the tag's processing module and its functions are: 1) to decode the incoming digital data from the analog front end; 2) to maintain the tag's state machines; 3) to access the tag's memory and 4) to prepare and encode the tag's outgoing response (if needed).

[0151] As explained earlier, the memory stores the tag's unique identification information, the EPC as well as other user information.

[0152] In order to enable a dual AMP and UHF RFID tag usage, the additional components that are required (in addition to UHF only tags) are marked with bold lines, and will be introduced in the following.

[0153] Protocol Arbitration unit: decides whether the incoming signal is an AMP signal or an UHF signal and passes the AMP signal to the AMP Processing unit and the UHF signal to the UHF Processing unit. The AMP signal means that the frame carried in the received signal is an AMP UHF frame and UHF signal means that the frame carried in the received signal is traditional UHF frame (following UHF RFID protocol), the arbitration may be done by some fields in the frame carried on the received signal, which is not limited in the embodiments of the present disclosure.

[0154] AMP Processing unit: processes the incoming AMP signal and if an UHF command is encapsulated, passes the encapsulated UHF command to the UHF Processing unit. Here it is assumed that the UHF Processing unit follows the UHF RFID protocol as defined by the EPC™ Radio-Frequency Identity Protocols Generation-2 UHF RFID Standard.

[0155] Transmit Arbitration unit: decides whether the outgoing UHF response should be encoded in AMP format or UHF format. For example, the flag maintained by the UHF RFID MAC to remember whether the RFID command came from AMP RFID MAC or the UHF RFID MAC may be used for the arbitration.

[0156] AMP Data encoding unit: encodes the UHF response per the AMP protocol.

[0157] FIG. 4 is a conceptual frame exchanges illustrating the encapsulation of GS1 UHF command and response in AMP frames. An AMP frame that encapsulates a GS1 UHF command or response is termed an AMP UHF frame (generally termed an AMP RFID frame). The frame exchange is initiated by the AMP RFID reader that

transmits an AMP UHF frame encapsulating the UHF command to the AMP RFID tag. The AMP RFID reader continues to transmit the continuous wave (CW) immediately following the AMP UHF frame. The CW acts as the carrier signal for the AMP RFID tag's backscattered response (if any), and for no response case, the CW provides DC power as shown in FIG. 3. If the encapsulated UHF command requires a UHF response from the AMP RFID tag, the AMP RFID tag backscatters the AMP UHF frame that encapsulates the UHF response. The time gap (Tn, n = 1 to 7) between the two frames follows the link timing specified by the EPC™ Radio-Frequency Identity Protocols Generation-2 UHF RFID Standard. Although not shown in the figure, an AMP preamble (and other AMP PHY header) is transmitted in front of each AMP UHF frame.

[0158] The above briefly describes technical concepts of the present disclosure with reference to the proposed tag architecture and an exemplary scenario showing interaction between the AMP RFID reader and the AMP RFID tag, and then specific embodiments of the present disclosure will be elaborated in the following description.

[0159] An embodiment of the present disclosure provides a communication method, as shown in FIG. 5, the method includes:

step 502, receiving a request frame from a reader via a wireless signal, where the wireless signal follows an Institute of Electrical and Electronics Engineers (IEEE) 802.11 protocol, where the request frame carries a radio frequency identification (RFID) command and a request instruction for indicating that the request frame carries the RFID command.

[0160] The method can be implemented by a tag, and the tag may be an AMP RFID tag with reference to FIGs. 2 to 4 in the case that the RFID technologies are combined with the AMP technologies, or may also be a part of a device (e.g., implemented as a module which can be integrated into the device), which is not limited here. It should be noted that in a case where the tag is implemented as a module, the receiving operation may also be an inputting operation, it is not necessary to receive but just to input the request frame from a certain device with a receiving function, the specific details with regard to the receiving operation performed by the tag throughout the document also apply for the inputting operation.

[0161] The request frame can be received by a tag from a reader. The reader may be an AMP RFID reader, e.g., a Wi-Fi device (e.g., a smartphone), or may also be a part of the Wi-Fi device (e.g., implemented as a module which can be integrated into the Wi-Fi device), which is not limited here. It should be noted that in a case where the reader is implemented as a module, the transmitting operation may also be an outputting operation, it is not necessary to transmit but just to output the request frame to a certain device with a transmitting function, the specific details with

regard to the transmitting operation performed by the reader throughout the document also apply for the outputting operation.

[0162] A request frame may be initiated by the reader, and may carry an RFID command, e.g., a query command, a select command, etc. The request frame may be referred to as the aforementioned AMP RFID frame (e.g., AMP UHF frame in FIG. 4). It should be noted that, the UHF tags are taken as an example of RFID tags enabled with AMP technologies throughout the context, therefore, the AMP UHF frame is only illustrative but not restrictive in the present disclosure, the request frame may also be AMP LF frame, AMP HF frame, or the like, which is not limited here. The AMP UHF frame may be a sub-type of AMP data frame, or the AMP UHF frame may also be one type of AMP frame, parameters associated with the AMP UHF frame may be signaled explicitly or fixed for the AMP RFID use case and are not signaled explicitly. Regarding different frame types of the AMP UHF frame, the RFID command can be indicated with corresponding request instructions, and the two frame structures for the AMP UHF frame will be described later.

[0163] The tag can be accessed through a request frame, where the request frame carries an RFID command and a request instruction for indicating that the request frame carries the RFID command. The tag is activated by a wireless signal following IEEE 802.11 protocol (e.g., a Wi-Fi signal) and the request frame for accessing the tag carries the RFID command, that is, the RFID protocol is integrated with the 802.11 protocol, thus the tag can be accessed by an RFID reader supporting the 802.11 protocol (e.g., a Wi-Fi device) without major hardware upgrade. It should be noted that Wi-Fi signal is simply an example of the above wireless signal, the proposed solution applies as long as the wireless signal is formed according to the IEEE 802.11 protocol. The wireless signal following IEEE 802.11 protocol may also be referred to as a wireless signal based on IEEE 802.11 protocol, or other similar expressions, which is not limited here.

[0164] In a possible implementation, the request instruction may include a first frame type identification and a first payload type identification, where the first frame type identification indicates that the request frame is a data frame and the first payload type identification indicates that a payload of the data frame includes the RFID command. The request frame used for accessing the tag can be a sub-type of data frame, where the data frame is indicated by the first frame type identification, and the request frame carrying the RFID command is indicated by the first payload type identification, so the RFID command is taken as the payload in this case. The request frame being the AMP UHF frame is taken as an example, in a case that the AMP UHF frame is a sub-type of AMP data frame, the AMP data frame is indicated by the first frame type identification (e.g., the frame type field is set as the AMP data frame),

and the AMP UHF frame is indicated by the first payload type identification (e.g., the payload type field is set as the AMP UHF frame).

[0165] In another possible implementation, the request instruction includes a second frame type identification, and the second frame type identification indicates that the request frame carries the RFID command. The request frame used for accessing the tag can also be a frame other than a data frame, and the request frame carrying the RFID command can be directly indicated by second frame type identification. The request frame being the AMP UHF frame is taken as an example, in a case that the AMP UHF frame is one type of AMP frame, the AMP UHF frame is indicated by the second frame type identification (e.g., the frame type field is set as the AMP UHF frame).

[0166] The above describes possible manners for indicating the request frame carrying the RFID command, and next timing parameters associated with the request frame will be introduced, e.g., a first timing parameter for indicating a timing for starting a next interaction between the tag and the reader (e.g., RTcal parameter), a second timing parameter for indicating a timing for transmitting a response frame corresponding to the request frame to the reader (e.g., TRcal or TRcal_factor parameter), etc.

[0167] In a possible implementation, a timing for starting a next interaction between the tag and the reader is determined based on a predefined first timing parameter associated with the request frame. It means that the first timing parameter associated with the request frame can be fixed and hence not signaled explicitly in the request frame, thereby saving signaling overhead. In another possible implementation, the request frame further includes a first timing field for indicating a first timing parameter associated with the request frame. It means that the first timing parameter associated with the request frame can also be signaled explicitly in the request frame, thereby improving the designing flexibility for this parameter to meet different requirements. The first timing parameter may be RTcal parameter, and the first timing field may be RTcal field carried in link timing parameters field. RTcal parameter can be encoded based on a correspondence between a value of the first timing field and the first timing parameter, where an encoded value of RTcal field corresponds to a certain value of RTcal parameter. The specific configuration of the first timing field and the exemplary correspondence (e.g., Table 1) will be described later.

[0168] In a case that the reader initiates a request frame, the tag may or may not respond to the request frame after receiving the request frame, it depends on the RFID command carried in the request frame. For example, the request frame carries a query command, then, the tag may transmit a response frame to the reader in response to the query command, and in this case, the next interaction may be a response frame, that is, the first timing parameter is used for determining the time gap between the request frame and the response frame. For another example, the

request frame carries a select command, then, the tag may not respond to the select command, and in this case, the next interaction may be the next request frame transmitted by the reader to the tag, that is, the first timing parameter is used for determining the duration between the two adjacent request frames.

[0169] In a possible implementation, the first timing parameter and the RFID command are delivered from a first part of a media access control (MAC) layer of the tag to a second part of the MAC layer of the tag for handling the RFID command by the second part of the MAC layer; where the first part of the MAC layer of the tag corresponds to a first part of a physical layer at which the request frame is received. The first part of the MAC layer of the tag may be an AMP MAC layer (referred to as AMP RFID MAC in FIGs. 2 and 11), and the second part of the MAC layer of the tag may be an LF MAC layer, an HF MAC layer or an UHF MAC layer (referred to as UHF RFID MAC in FIGs. 2 and 11), etc. The first part of the physical layer may refer to AMP RFID PHY in FIGs. 2 and 11. Still taking the request frame being the AMP UHF frame as an example, when an AMP UHF frame is received by the AMP RFID PHY, it is forwarded to the AMP RFID MAC, which extracts the encapsulated RFID command and the first timing parameter and forwards them to the UHF RFID MAC which can access the memory directly. The transfer of information between the AMP RFID MAC and the UHF RFID MAC can be implemented through UHF MAC SAP (Service Access Point) primitives (e.g., AMP-UHF.Indication primitive, AMP-UHF.Request primitive). The AMP-UHF.Indication primitive may include RFID command and link parameters required to calculate the link timings (e.g., RTcal, TRcal, etc.), the AMP-UHF.Request primitive may include RFID response and link parameters required to transmit the RFID response (e.g., DR (Data rate), M (Modulation), TRext (Presence/Absence of Pilot tones), BLF (Backscatter link frequency), etc.), and details about the primitives will be described later.

[0170] In the case that the tag handles the request frame received from the reader, when the request frame is received by a first part of a physical layer (e.g., AMP RFID PHY), it is forwarded to a first part of the MAC layer (e.g., AMP RFID MAC), the AMP RFID MAC extracts the encapsulated RFID command and the first timing parameter and forwards them to a second part of the MAC layer (e.g., UHF RFID MAC). With such data flows, that is, with such tag structure, the tag can be accessed by an RFID reader supporting the 802.11 protocol without major hardware upgrade.

[0171] In a possible implementation, a flag is maintained in the second part of the MAC layer of the tag for indicating that the RFID command is from the first part of the MAC layer of the tag. Since the tag may be a dual use tag, e.g., an AMP RFID tag that can be accessed both with an UHF reader as well as with an AMP RFID reader, that is, there may be two paths (path 1 and path 2 in FIG. 2) to access the tag. The flag can be used for distinguishing that

the RFID command is from the first part of the MAC layer (e.g., AMP RFID MAC), not the second part of the MAC layer (e.g., UHF RFID MAC). In this case, the UHF RFID MAC maintains a flag to remember that the RFID command is from the AMP RFID MAC, not the UHF RFID PHY.

[0172] The above describes configurations associated with a first timing parameter for determining a timing for starting a next interaction between the tag and the reader. The first timing parameter (e.g., RTcal parameter) is always necessary for the tag, while the second timing parameter (e.g., TRcal or TRcal_factor parameter) is necessary when the tag is required to generate a response. Configurations associated with the second timing parameter for determining a timing for transmitting a response frame corresponding to the request frame to the reader will be described in the following.

[0173] In a possible implementation, a timing for transmitting a response frame corresponding to the request frame to the reader is determined based on a predefined second timing parameter associated with the request frame. It means that the second timing parameter associated with the request frame can be fixed and hence not signaled explicitly in the request frame, thereby saving signaling overhead. In another possible implementation, the request frame further includes a second timing field for indicating a second timing parameter for transmitting a response frame corresponding to the request frame to the reader. It means that the second timing parameter associated with the request frame can also be signaled explicitly in the request frame, thereby improving the designing flexibility for this parameter to meet different requirements. The second timing parameter may be TRcal or TRcal_factor parameter, and the second timing field may be TRcal or TR_factor field carried in, e.g., link timing parameters field. Here TRcal_factor can be used for calculating TRcal, for example, TRcal = RTcal x TRcal_factor. TRcal or TRcal_factor parameter can be encoded based on a correspondence between a value of the second timing field and the second timing parameter, where an encoded value of TRcal or TRcal_factor field corresponds to a certain value of TRcal or TRcal_factor parameter. TR_factor field may be taken an example, in this way, bits occupied by the field can be saved. A specific configuration of TR_factor field and the exemplary correspondence (e.g., Table 2) will be described later.

[0174] In a possible implementation, the request frame includes a presence field for indicating whether the second timing field is present. The presence field may be TRcal or TR_factor presence field carried in, e.g., link timing parameters field. After the tag receives the request frame from the reader, it may not be necessary for the tag to respond, that is, the second timing parameter is necessary when the tag is required to generate a response. Therefore, if the presence field indicates the second timing field is not present, it is obvious there is no second timing

parameter and it may not necessary to execute a reading operation, thereby improving data processing efficiency.

[0175] In a possible implementation, the second timing parameter is delivered from a first part of a media access control (MAC) layer of the tag to a second part of the MAC layer of the tag for obtaining an RFID response corresponding to the RFID command by the second part of the MAC layer; where the first part of the MAC layer of the tag corresponds to a first part of a physical layer at which the request frame is received. The first part of the MAC layer of the tag may be an AMP MAC layer (referred to as AMP RFID MAC in FIGs. 2 and 11), and the second part of the MAC layer of the tag may be an LF MAC layer, an HF MAC layer or an UHF MAC layer (referred to as UHF RFID MAC in FIGs. 2 and 11), etc. The first part of the physical layer may refer to AMP RFID PHY in FIGs. 2 and 11. In a possible implementation, additional parameters (including DR (Data rate), M (Modulation), TRext (Presence/Absence of Pilot tones), Sel, Session, Target, Q as will be illustrated later) may be predefined or indicated in the request frame, and these parameters are used by the tag for transmitting a response frame corresponding to the request frame, for example, these parameters can be indicated in UHF Command field. The transfer of information between the AMP RFID MAC and the UHF RFID MAC can be implemented through UHF MAC SAP (Service Access Point) primitives (e.g., AMP-UHF.Indication primitive, AMP-UHF.Request primitive). The AMP-UHF.Indication primitive may include RFID command and link parameters required to calculate the link timings (e.g., RTcal, TRcal, etc.), the AMP-UHF.Request primitive may include RFID response and link parameters required to transmit the RFID response (e.g., DR (Data rate), M (Modulation), TRext, BLF (Backscatter link frequency), etc.), and details about the primitives will be described later.

[0176] The data flows for processing the second timing parameter is similar to that for the first timing parameter. In the case that the tag handles the request frame received from the reader, when the request frame is received by a first part of a physical layer (e.g., AMP RFID PHY), it is forwarded to a first part of the MAC layer (e.g., AMP RFID MAC), the AMP RFID MAC extracts the second timing parameter and forwards it to a second part of the MAC layer (e.g., UHF RFID MAC). With such data flows, that is, with such tag structure, the tag can be accessed by an RFID reader supporting the 802.11 protocol without major hardware upgrade.

[0177] In a possible implementation, the request frame further includes a cyclic redundancy check (CRC) field, where a value of the CRC field is calculated based on all fields other than the CRC field of the request frame. The CRC field is added to implement an error detection function.

[0178] In a possible implementation, still referring to FIG. 5, the method may include:

step 502, receiving a request frame from a reader via a wireless signal, where the wireless signal follows

an Institute of Electrical and Electronics Engineers (IEEE) 802.11 protocol, where the request frame carries a radio frequency identification (RFID) command and a request instruction for indicating that the request frame carries the RFID command; and

step 504, transmitting an RFID response to the reader in response to the request frame.

[0179] The reader initiates a request frame, for example, the RFID command carried in the request frame is a query command, in this case, the tag may respond to the request frame after receiving the request frame. The RFID response can be encapsulated in a response frame, and can also be directly transmitted, thereby making the transmission manner of the RFID response more flexible.

[0180] In a possible implementation, the tag may transmit a response frame carrying the RFID response to the reader in response to the request frame, where the response frame carries a response instruction for indicating that the response frame carries the RFID response. The RFID response can be encapsulated in a response frame, this format may be easier for data management, and the data transmission accuracy is thus ensured.

[0181] In a possible implementation, the response instruction includes a third frame type identification and a second payload type identification, where the third frame type identification indicates that the response frame is a data frame and the second payload type identification indicates that a payload of the data frame includes the RFID response. Similar to the request frame from the reader to the tag, the response frame transmitted by the tag to the reader can be a sub-type of data frame, where the data frame is indicated by the third frame type identification, and the RFID response is indicated by the second payload type identification. The above description relevant to the first frame type identification and the payload type identification in the request frame may also be applicable for the third frame type identification and the second payload type identification respectively.

[0182] In a possible implementation, the response instruction includes a fourth frame type identification, and the fourth frame type identification indicates that the response frame carries the RFID response. The response frame transmitted by the tag to the reader can also be a frame other than a data frame, and the RFID response can be directly indicated by the fourth frame type identification. The above description relevant to the second frame type identification in the request frame may also be applicable for the fourth frame type identification.

[0183] In a possible implementation, the response frame further includes a cyclic redundancy check (CRC) field, where a value of the CRC field is calculated based on all fields other than the CRC field of the response frame. The CRC field is added to implement an error detection function.

[0184] In a possible implementation, at least one response parameter and the RFID response are delivered from

a second part of a MAC layer of the tag to a first part of the MAC layer of the tag, where the at least one response parameter is used by a first part of a physical layer of the tag for transmitting the RFID response to the reader under an instruction of the first part of the MAC layer. The data flows for a response is in the reverse direction of the data flows for the request frame. Once the response is ready, a second part of the MAC layer (e.g., UHF RFID MAC) passes the response to a first part of the MAC layer (e.g., AMP RFID MAC), which in turn forwards the response to a first part of a physical layer (e.g., AMP RFID PHY). With such data flows, that is, with such tag structure, the tag can be accessed by an RFID reader supporting the 802.11 protocol without major hardware upgrade. In a possible implementation, the at least one response parameter may include (but not limited to) Data rate (DR), Modulation (M), TRext, Backscatter link frequency (BLF); here the BLF is used to determine the timing of the tag's response symbol and is calculated as DR/TRcal. As described before, the TRcal can be indicated as link parameters via an AMP-UHF.Indication primitive from the AMP RFID MAC to the UHF RFID MAC. The UHF RFID MAC further gets other parameters such as Data rate (DR), Modulation (M), TRext from the UHF Command field. In this way, the UHF RFID MAC determines all response parameters and delivers them to the AMP RFID MAC.

[0185] In the above, the communication method of the present disclosure is described from the perspective of a tag. In the following, a communication method of the present disclosure will be described from the perspective of a reader in combination with FIG. 6. FIG. 6 shows a schematic flowchart of another communication method according to one or more embodiments of the present disclosure. The method can be implemented by a reader. As shown in FIG. 6, the method may include:

step 602, transmitting a request frame to a tag via a wireless signal, where the wireless signal follows an Institute of Electrical and Electronics Engineers (IEEE) 802.11 protocol, where request frame carries a radio frequency identification (RFID) command and a request instruction for indicating that the request frame carries the RFID command.

[0186] The method can be implemented by a reader. In the case that the RFID technologies are combined with the AMP technologies, the reader may be an AMP RFID reader, e.g., a Wi-Fi device (e.g., a smartphone), or may also be a part of the Wi-Fi device (e.g., implemented as a module which can be integrated into the Wi-Fi device), which is not limited here. It should be noted that in a case where the reader is implemented as a module, the transmitting operation may also be an outputting operation, it is not necessary to transmit but just to output the request frame to a certain device with a transmitting function, the specific details with regard to the transmitting operation performed by the reader throughout the document also apply for the outputting operation.

[0187] For step 602, reference may be made to the forgoing relevant description of step 502 at the tag side, which will not be repeated here.

[0188] The reader can access the tag through a request frame, where the request frame carries an RFID command and a request instruction for indicating that the request frame carries the RFID command. The tag is activated by a wireless signal following IEEE 802.11 protocol (e.g., a Wi-Fi signal), that is, the RFID protocol is integrated with the 802.11 protocol, thus the tag can be accessed by an RFID reader supporting the 802.11 protocol without major hardware upgrade.

[0189] In a possible implementation, the request instruction includes a first frame type identification and a first payload type identification, where the first frame type identification indicates that the request frame is a data frame and the first payload type identification indicates that a payload of the data frame includes the RFID command. For detailed description of the first frame type identification and the first payload type identification, reference may be made to relevant part at the tag side, which will be not repeated here for brevity.

[0190] In a possible implementation, the request instruction includes a second frame type identification, and the second frame type identification indicates that the request frame carries the RFID command. For detailed description of the second frame type identification, reference may be made to relevant part at the tag side, which will be not repeated here for brevity.

[0191] In a possible implementation, a timing for starting a next interaction between the tag and the reader is determined based on a predefined first timing parameter associated with the request frame.

[0192] In a possible implementation, the request frame further includes a first timing field for indicating a first timing parameter associated with the request frame.

[0193] In a possible implementation, the first timing parameter and the RFID command are delivered from a station management entity (SME) of the reader to a media access control (MAC) sublayer management entity (MLME) of the reader for transmitting the request frame by the MLME. The transfer of information between the MLME and the SME can be implemented through AMP RFID MLME SAP primitives (e.g., MLME-AMP-RFID.Request primitive, MLME-AMP-RFID.Confirm primitive, MLME-AMP-RFID.Indication primitive). The MLME-AMP-RFID.Request primitive may include RFID command, CW duration and link parameters required to calculate the link timings (e.g., RTcal, TRcal, etc.). The MLME-AMP-RFID.Confirm primitive may include a parameter reporting success or failure of the request, the MLME-AMP-RFID.Indication primitive may include RFID response, and details about the primitives will be described later.

[0194] In a possible implementation, a confirmation is delivered from the MLME to the SME for confirming a successful reception of the first timing parameter and the RFID command. The MLME-AMP-RFID.Confirm primitive may be a specific example of this confirmation.

[0195] In a possible implementation, a timing for transmitting a response frame corresponding to the request frame is determined based on a predefined second timing parameter associated with the request frame.

[0196] In a possible implementation, the request frame further includes a second timing field for indicating a second timing parameter for transmitting a response frame corresponding to the request frame.

[0197] In a possible implementation, the request frame includes a presence field for indicating whether the second timing field is present.

[0198] In a possible implementation, the second timing parameter is delivered from a station management entity (SME) of the reader to a media access control (MAC) sublayer management entity (MLME) of the reader for transmitting the request frame by the MLME. The transfer of information between the MLME and the SME can be implemented through AMP RFID MLME SAP primitives (e.g., MLME-AMP-RFID.Request primitive, MLME-AMP-RFID.Confirm primitive, MLME-AMP-RFID.Indication primitive). The MLME-AMP-RFID.Request primitive may include RFID command, CW duration and link parameters required to calculate the link timings (e.g., RTcal, TRcal, etc.). The MLME-AMP-RFID.Confirm primitive may include a parameter reporting success or failure of the request, the MLME-AMP-RFID.Indication primitive may include RFID response, and details about the primitives will be described later.

[0199] In a possible implementation, a duration of a carrier signal is delivered from an SME of the reader to an MLME of the reader, and the carrier signal is transmitted by the MLME after transmission of the request frame. The duration of a carrier signal may refer to the aforementioned CW duration included in the MLME-AMP-RFID.Request primitive.

[0200] In a possible implementation, the request frame further includes a cyclic redundancy check (CRC) field, where a value of the CRC field is calculated based on all fields other than the CRC field of the request frame.

[0201] In a possible implementation, the method may include:

step 602, transmitting a request frame to a tag via a wireless signal, where the wireless signal follows an Institute of Electrical and Electronics Engineers (IEEE) 802.11 protocol, where request frame carries a radio frequency identification (RFID) command and a request instruction for indicating that the request frame carries the RFID command; and

step 604, receiving an RFID response corresponding to the request frame from the tag.

[0202] In a possible implementation, the reader may receive a response frame carrying the RFID response from the tag in response to the RFID command in the request frame, where the response frame carries a response instruction for indicating that the response frame carries the RFID response.

[0203] In a possible implementation, the response instruction includes a third frame type identification and a second payload type identification, where the third frame type identification indicates that the response frame is a data frame and the second payload type identification indicates that a payload of the data frame includes the RFID response. For detailed description of the third frame type identification and the second payload type identification, reference may be made to relevant part at the tag side, which will be not repeated here for brevity.

[0204] In a possible implementation, the response instruction includes a fourth frame type identification, and the fourth frame type identification indicates that the response frame carries the RFID response. For detailed description of the fourth frame type identification, reference may be made to relevant part at the tag side, which will be not repeated here for brevity.

[0205] In a possible implementation, the response frame further includes a cyclic redundancy check (CRC) field, where a value of the CRC field is calculated based on all fields other than the CRC field of the response frame.

[0206] In a possible implementation, the RFID response is delivered from an MLME of the reader to an SME of the reader for forwarding the RFID response to an application layer of the reader by the SME. For example, the RFID response can be delivered using the above mentioned MLMLE-AMP-RFID.Indication primitive.

[0207] It should be understood by a person skilled in the art that, the relevant description of the communication method from the perspective of the reader in the embodiments of the present disclosure may be understood with reference to the relevant description of the communication method from the perspective of the tag in the embodiments of the present disclosure.

[0208] In order to elaborate the communication methods of the present disclosure more clearly, in the following, specific examples will be given for elaborating the solution of the present disclosure more clearly. It should be noted that the architecture based on the AMP and the UHF technologies is illustrative but not restrictive, and the UHF command carried by the AMP RFID frame may be a specific example of the above RFID command or the UHF RFID command; correspondingly, the UHF response may be a specific example of the above RFID response or the UHF RFID response.

[0209] An exemplary frame format of an AMP frame is illustrated in FIG. 7A. The second row are the fields of

the frame while the first row shows the number of bits occupied by each field. The AMP frame includes two mandatory fields: 1) Frame Type field, 2) Type Dependent Content field and the optional CRC (Cyclic Redundancy Check) field. It should be noted that the specific names and possible values of the fields are illustrative rather than restrictive, they may have other names or may take other values in actual applications.

[0210] The Frame Type field is illustrated in FIG. 7B and differentiates the various types of AMP frames. A specific type of AMP frame, for example AMP Data frame (e.g., Frame Type 0) is defined to carry various AMP related data (e.g., UHF command, UHF response, or sensor data etc.).

[0211] The format of the Type Dependent Content field depends on the value of the Frame Type field and may be different for different frame types. The Type Dependent Content field when the Frame Type indicates AMP Data frame is illustrated in FIG. 7C. The first field of the Type Dependent Content field (Payload Type field) field further classifies the type of data carried in the second field of the Type Dependent Content field (Payload field).

[0212] The Payload Type field is illustrated in FIG. 7D. When the Payload Type field is set as 0, the AMP Data frame is used as the AMP UHF frame and the Payload field carries the content of the AMP UHF frame. Other values of the Payload Type field may be used to indicate other types of payload, for example sensor data, or frames used to encapsulate messages of other protocols etc.

[0213] FIG. 8A illustrates an AMP Data frame used as the AMP UHF frame. The Frame Type field is set as the AMP Data frame and the Payload Type field is set as AMP UHF frame. The Payload field of an AMP UHF frame is illustrated in FIG. 8B. The Link Timing Parameters field carries parameters that are required for the AMP RFID tag to compute the parameter related to link timings as defined by the EPC™ Radio-Frequency Identity Protocols Generation-2 UHF RFID Standard. The UHF Command Or Response field encapsulates the GS1 EPC UHF command or response as defined in the GS1 structure except the CRC field of the Command or Response.

[0214] An exemplary Link Timing Parameters field is illustrated in FIG. 8C and carries information regarding the GS1 UHF RTcal and TRcal parameters. RTcal is the Interrogator-to-Tag calibration symbol while TRcal is the Tag-to-Interrogator calibration symbol. In GS1 UHF, some of the parameters required by the RFID tag to transmit the response (e.g., Data Rate (DR), Modulation (M), Presence/Absence of Pilot tones (TRext) etc.) are communicated with an UHF command (e.g., Query command). However, some other information, namely the RTcal and TRcal are communicated in the UHF preamble that precedes the UHF Query command. In the case of AMP RFID frame, since the UHF command is encapsulated within an AMP UHF frame (in this case, the UHF command may be a specific example of the aforementioned RFID command), the UHF preamble does not exist and hence

these parameters need to be explicitly carried in the Link Timing Parameters field of the AMP UHF frame. The Backscatter link frequency (BLF) that is used to determine the timing of the tag's response symbol is calculated as DR/TRcal. RTcal is used to compute the link timing parameters such as the time gap between the UHF command and UHF response. The GS1 EPC UHF Standard defines TRcal as 1.1 RTcal <= TRcal <= 3 RTcal. Hence, instead of carrying the TRcal, the Link Timing Parameters field carries the TRcal_factor field which together with the RTcal field is used to compute TRcal as TRcal = RTcal * TRcal_factor. While the RTcal is always necessary for the tag, the TRcal is only necessary when the tag is required to generate a response. Hence the Link Timing Parameters field always carries the RTcal while the TRcal_factor field is optionally present. In an example, the following table 1 shows the encoding used for the RTcal field to signal RTcal from 15 μS to 78 μS, while Table 2 shows the encoding used for the TRcal_factor field to signal values from 1.0 to 4.1.

Table 1: RTcal Encoding

RTcal field value	Value of RTcal parameter (μS)
0	15
1	16
2	17
…	…
63	78

Table 2: TRcal_factor Encoding

TRcal_factor field value	Value of TRcal_factor
0	1.0
1	1.1
2	1.2
…	…
31	4.1

[0215] Alternatively, instead of the above tables, there may be other manners for indicating values of RTcal and TRcal_factor. For example, value of RTcal may also be expressed as:

RTcal = 15 + value of the RTCal field.

[0216] And value of TRcal_factor may also be expressed as:

TRcal_factor = 1.0 + (value of the RTCal field)/10.

[0217] The CRC field of the AMP UHF frame in FIG. 8A is optionally present depending on the encapsulated UHF command or response and when present carries the 5-bits or 16-bits CRC as defined in the GS1 UHF structure but the CRC computation is done over the entire AMP UHF frame (i.e., the CRC also covers the Frame Type field and the Type Dependent Content field in addition to the encapsulated UHF command or response). When the CRC field is not defined by the GS1 UHF structure for the encapsulated UHF command or response, the size and the CRC algorithm may be defined by the AMP protocol, for example using the 16 bits CRC defined for IEEE 802.11 WUR (wake-up radio) frames.

[0218] FIG. 9 shows the UHF Command Or Response field encapsulating the GS1 EPC UHF Query command except the CRC field. The length of the field is 17 bits. In this case (when the UHF Command Or Response field encapsulates the GS1 EPC UHF Query command), the CRC field of the AMP UHF frame is 5 bits long as per the GS1 EPC UHF standard but the CRC computation also includes the Frame Type field, the Payload Type field and the Link Timing Parameters field.

[0219] FIG. 10 shows the UHF Command Or Response field encapsulating the RN16 response to the GS1 EPC UHF Query command when the tag's slot counter is zero. In this case (when the UHF Command Or Response field encapsulates the GS1 EPC UHF Response command, and in this case, the UHF Response command is a specific example of the above RFID response), since the GS1 UHF structure does not require a CRC for RN16, the CRC field of the AMP UHF frame is as defined by the AMP protocol.

[0220] On the AMP RFID tag, the UHF MAC SAP (Service Access Point) interface (shown with bold lines in FIG. 11) and two UHF MAC SAP primitives are defined to facilitate the transfer of information between the AMP RFID MAC (layer) and the UHF RFID MAC (layer). The UHF MAC SAP primitives can be of two types: 1) Type 1 UHF MAC SAP primitive that does not trigger a response from the UHF RFID MAC, 2) Type 2 UHF MAC SAP primitive that triggers a response from the UHF RFID MAC.

[0221] The Type 1 UHF MAC SAP primitive is illustrated in FIG. 12. When the AMP RFID MAC receives an AMP UHF frame from the AMP RFID reader, it generates the AMP-UHF.Indication primitive to pass the encapsulated UHF command to the UHF RFID MAC. For Type 1 UHF MAC SAP primitive the encapsulated UHF command (e.g., UHF Select command) does not trigger any response from the UHF RFID MAC.

[0222] The Type 2 UHF MAC SAP primitive is illustrated in FIG. 13. The first part is same as the Type 1 UHF

MAC SAP primitive. When a response is required for the received UHF command, the AMP-UHF.Request primitive is issued by the UHF RFID MAC to request the AMP RFID MAC to transmit a response.

[0223] The AMP-UHF.Indication primitive is issued by the AMP RFID MAC when an AMP UHF frame is received by the AMP RFID MAC. The parameters of the AMP-UHF.Indication primitive are listed in FIG. 14, and the format of the AMP-UHF.Indication primitive may be as follows:

```
AMP-UHF.Indication (
    UHF Command,
    Link Parameters
    )
```

[0224] Upon receiving the AMP-UHF.Indication primitive, the UHF RFID MAC executes the UHF Command carried in the primitive and also uses the link parameters to calculate the link timing parameters for the UHF operation.

[0225] The AMP-UHF.Request primitive is issued by the UHF RFID MAC to request the AMP RFID MAC to transmit the UHF Response (in an AMP UHF frame). The parameters of the AMP-UHF.Request primitive are listed in FIG. 15, and the format of the AMP-UHF.Request primitive may be as follows:

```
AMP-UHF.Request (
    UHF Response,
    Link Parameters
    )
```

[0226] Upon receiving the AMP-UHF.Request primitive, the AMP RFID MAC instructs the AMP RFID PHY to construct (including adding the CRC field) and backscatter the AMP UHF frame carrying the UHF Response passed in the primitive using the link parameters indicated in the primitive.

[0227] The above describes configurations from the tag side, then configurations from the reader side will be described.

[0228] FIG. 16 illustrates a possible reference model for the AMP RFID Reader. An AMP RFID Reader is an AMP assisting STA (e.g., a smartphone) that can read an AMP RFID tag. The AMP RFID Reader's PHY layer includes the AMP RFID PHY while the AMP RFID Reader's MAC layer includes the AMP RFID MAC. A dedicated RFID Reader Application operates on top of the IEEE 802.11 PHY/MAC layer and provides the RFID reader functions such as selecting, inventorying and accessing the AMP RFID tags. The RFID Reader Application may also

have access to a backend database that provides additional information based on the tag's identity (e.g., EPC, TID etc.). For example, based on the EPC retrieved from the AMP RFID tag, a shopper may use the AMP RFID Reader (e.g., a compatible AMP RFID enabled smartphone) to retrieve information such as price, stock availability, manufacturer information etc. from the product data based housed in the shop's server.

[0229] Two AMP RFID MLME SAP primitives are defined to facilitate the transfer of information between the MLME and the SME (and onwards to the RFID Reader Application). The AMP RFID MLME SAP primitives can be of two types: 1) Type 1 AMP RFID MLME SAP primitive that does not trigger a response from the target AMP RFID Tag; 2) Type 2 AMP RFID MLME SAP primitive that triggers a response from the target AMP RFID Tag.

[0230] The Type 1 AMP RFID MLME SAP primitive is illustrated in FIG. 17. When the SME receives a UHF command from the RFID Reader Application, it generates the MLME-AMP-RFID.Request primitive to pass the UHF command to the MLME. The MLME generates the MLME-AMP-RFID.Confirm primitive to inform the SME of the result of the request.

[0231] The Type 2 AMP RFID MLME SAP primitive is illustrated in FIG. 18. The first part is same as Type 1 AMP RFID MLME SAP primitive. When an AMP UHF frame carrying the AMP RFID tag's UHF response is received, the MLME generates the MLME-AMP-RFID.Indication primitive to pass the UHF response to the SME.

[0232] The MLME-AMP-RFID.Request primitive is issued to request the MLME to transmit the UHF Command (in an AMP UHF frame). The parameters of the MLME-AMP-RFID.Request primitive are listed in FIG. 19, and the format of the MLME-AMP-RFID.Request primitive may be as follows:

```
MLME-AMP-RFID.Request (
        UHF Command,
        Link Parameters,
        CW Duration
                )
```

[0233] Upon receiving the MLME-AMP-RFID.Request primitive, the AMP RFID MAC instructs the AMP RFID PHY to transmit the AMP UHF frame (carrying the UHF Command and Link Parameters carried in the primitive). The AMP RFID MAC also instructs the AMP RFID PHY to transmit the CW immediately following the AMP UHF frame for the requested CW duration.

[0234] The MLME-AMP-RFID.confirm primitive includes a Result Code parameter reporting success or failure of the request, and is generated by the MLME when the requested AMP UHF frame transmission is completed, or

fails.

[0235] The MLMLE-AMP-RFID.Indication primitive is issued by the MLME when an AMP UHF frame is received by the AMP RFID MAC. The parameters of the MLME-AMP-RFID.Indication primitive are listed in FIG. 20A, and the format of the MLME-AMP-RFID.Indication primitive may be as follows:

```
MLMLE-AMP-RFID.Indication (
    UHF Response,
)
```

[0236] Upon receiving the MLMLE-AMP-RFID.Indication primitive, the SME forwards the UHF Response carried in the primitive to the RFID Reader Application.

[0237] The overall interaction between the AMP RFID Reader and the AMP RFID Tag is illustrated in FIG. 20B, for the interaction, reference may be made to the forgoing relevant description, which will not be repeated here. The steps within the dashed line box are optionally present when a response is generated by the AMP RFID Tag.

[0238] An exemplary frame exchange involved in reading an AMP RFID tag is illustrated in FIG. 21. The AMP RFID reader selects a particular tag for the subsequent read operation by transmitting an UHF Select command encapsulated in an AMP UHF frame. The UHF Select command may assert the SL (select) flag of the AMP RFID tag. After a duration of T4 (as defined in the GS1 UHF specification), the AMP RFID reader transmits the encapsulated UHF Query command. Since the communication range of AMP RFID is expected to be very short (less than 10cm), the chances of multiple tags responding is low. Hence the Query command sets the value of the Q parameter to zero so that the tag's slot counter is initialized to zero. Since its slot counter is zero, the AMP RFID tag responds to the Query command with an encapsulated response: RN16 (i.e., a 16-bits long random number). After a gap of T2, the AMP RFID reader transmits an encapsulated UHF ACK command that carry the same RN16. Upon receiving the ACK command, the tag responds with its EPC encapsulated in an AMP UHF frame and thereby completing the read operation. The intervals T4 and T1 shown in FIG. 21, as specific examples describing the timing for the next interaction between the AMP RFID reader and the AMP RFID tag may be dependent to the parameter RTcal.

[0239] The above example describes that the AMP UHF frame is a sub-type of AMP Data frame, another example where the AMP UHF frame is one type of AMP frame will be described in the following.

[0240] Another exemplary frame format of the AMP frame is illustrated in FIG. 22A. The second row are the fields of the frame while the first row shows the number of bits occupied by each field. The AMP frame includes

two mandatory fields: 1) Frame Type field, 2) Type Dependent Content field and the optional CRC field. The only difference from the AMP Frame format in FIG. 7A is that the Frame Type field is 3 bits instead of 2 bits and only UHF commands are encapsulated in the AMP UHF frame (but not the UHF response).

[0241] The Frame Type field is illustrated in FIG. 22B and differentiates the various types of AMP frames. A specific type of AMP frame (e.g., Frame Type 1) is defined as the AMP UHF frame to carry the UHF command.

[0242] FIG. 23A illustrates an AMP UHF frame, where the Frame Type field is set as AMP UHF frame. The Type Dependent Content field of an AMP UHF frame is illustrated in FIG. 23B and encapsulates the GS1 EPC UHF command as defined in the GS1 structure except the CRC field of the command.

[0243] The CRC field of the AMP UHF frame in FIG. 23A is optionally present depending on the encapsulated UHF command and when present carries the 5-bits or 16-bits CRC as defined in the GS1 UHF structure but the CRC computation is done over the entire AMP UHF frame (i.e., the CRC also covers the Frame Type field in addition to the encapsulated UHF command). When the CRC field is not defined by the GS1UHF structure for the encapsulated UHF command, the size and the CRC algorithm may be defined by the AMP protocol, for example using the 16 bits CRC defined for IEEE 802.11 WUR frames.

[0244] In this example, to simplify operations, the UHF PHY parameters (e.g., RTcal, TRcal, TRext etc.) are fixed for the AMP RFID use case and are not signalled explicitly. The parameters may be pre-configured in the UHF RFID MAC and used whenever an UHF command is received via an AMP UHF frame, or the UHF response is transmitted in response to an AMP UHF frame. It should be noted that although in the specific examples, the UHF PHY parameters (e.g., RTcal, TRcal, TRext etc.) for the case where the AMP UHF frame is a sub-type of AMP Data frame is explicitly indicated, but it is also possible to omit the indication fields and simply predefine the UHF PHY parameters. Similarly, it is also possible to explicitly indicate the UHF PHY parameters (e.g., RTcal, TRcal, TRext etc.) in the case where the AMP UHF frame is one type of AMP frame, for example, in addition to the UHF Command/Response, there is an additional Link Timing Parameters field as shown in FIG. 8C.

[0245] FIG. 24 is another conceptual frame exchange illustrating the encapsulation of GS1 UHF command and response in AMP frames. The difference from FIG. 4 is that the UHF Response is not encapsulated in an AMP UHF frame but is transmitted in the same format as defined by the GS1 UHF specification (including the CRC field if any) but using the AMP waveform. This results in some air-time savings since the AMP frame overhead is omitted. The AMP RFID reader can predict that the AMP backscattered signal received within a certain duration from the end of the UHF Command is the expected UHF Response. Although not shown in the figure, AMP preamble (and

other AMP PHY header) is transmitted in front of the AMP UHF frame as well as before the UHF Response.

[0246] Another exemplary frame exchange involved in reading an AMP RFID tag is illustrated in FIG. 25, for the frame exchange, reference may be made to the forgoing relevant description, which will not be repeated here. The only difference from FIG. 21 is that the UHF Responses (RN16 and EPC) are not encapsulated in an AMP UHF frame but is transmitted in the same format as defined by the GS1 UHF specification but using the AMP waveform.

[0247] The present disclosure proposes an AMP RFID system architecture which enables AMP + UHF dual tags, and introduces the AMP RFID frame format for the AMP RFID tag operation. In the proposed system, AMP RFID frames are incorporated in the AMP framework, UHF commands and responses can be directly encapsulated in AMP RFID frames. The AMP + UHF dual tag usage is enabled, which allows the tag to be read with an AMP RFID reader with minimal changes to the GS1 UHF protocol.

[0248] Next, embodiments of products related to the communication methods will be described.

[0249] FIG. 26 shows a schematic structural diagram of a communication apparatus according to one or more embodiments of the present disclosure. As shown in FIG. 26, the communication apparatus 2600 may include:

a receiving module 2602, configured to receive a request frame from a reader via a wireless signal, where the wireless signal follows an Institute of Electrical and Electronics Engineers (IEEE) 802.11 protocol, where the request frame carries a radio frequency identification (RFID) command and a request instruction for indicating that the request frame carries the RFID command.

[0250] In a possible implementation, the request instruction includes a first frame type identification and a first payload type identification, where the first frame type identification indicates that the request frame is a data frame and the first payload type identification indicates that a payload of the data frame includes the RFID command.

[0251] In a possible implementation, the request instruction includes a second frame type identification, and the second frame type identification indicates that the request frame carries the RFID command.

[0252] In a possible implementation, a timing for starting a next interaction between the tag and the reader is determined based on a predefined first timing parameter associated with the request frame.

[0253] In a possible implementation, the request frame further includes a first timing field for indicating a first timing parameter associated with the request frame.

[0254] In a possible implementation, the first timing parameter and the RFID command are delivered from a first part of a media access control (MAC) layer of the tag to a second part of the MAC layer of the tag for handling the RFID command by the second part of the MAC layer; where the first part of the MAC layer of the tag corresponds

to a first part of a physical layer at which the request frame is received.

[0255] In a possible implementation, a flag is maintained in the second part of the MAC layer of the tag for indicating that the RFID command is from the first part of the MAC layer of the tag.

[0256] In a possible implementation, a timing for transmitting a response frame corresponding to the request frame to the reader is determined based on a predefined second timing parameter associated with the request frame.

[0257] In a possible implementation, the request frame further includes a second timing field for indicating a second timing parameter for transmitting a response frame corresponding to the request frame to the reader.

[0258] In a possible implementation, the request frame includes a presence field for indicating whether the second timing field is present.

[0259] In a possible implementation, the second timing parameter is delivered from a first part of a media access control (MAC) layer of the tag to a second part of the MAC layer of the tag for obtaining an RFID response corresponding to the RFID command by the second part of the MAC layer; where the first part of the MAC layer of the tag corresponds to a first part of a physical layer at which the request frame is received.

[0260] In a possible implementation, at least one response parameter is predefined or indicated in the request frame, and the at least one response parameter is used by the tag for transmitting a response frame corresponding to the request frame.

[0261] In a possible implementation, the request frame further includes a cyclic redundancy check (CRC) field, where a value of the CRC field is calculated based on all fields other than the CRC field of the request frame.

[0262] In a possible implementation, the method further includes a transmitting module 2604, configured to transmit an RFID response to the reader in response to the request frame.

[0263] In a possible implementation, the transmitting module is specifically configured to: transmit a response frame carrying the RFID response to the reader in response to the request frame, where the response frame carries a response instruction for indicating that the response frame carries the RFID response.

[0264] In a possible implementation, the response instruction includes a third frame type identification and a second payload type identification, where the third frame type identification indicates that the response frame is a data frame and the second payload type identification indicates that a payload of the data frame includes the RFID response.

[0265] In a possible implementation, the response instruction includes a fourth frame type identification, and the fourth frame type identification indicates that the response frame carries the RFID response.

[0266] In a possible implementation, the response frame further includes a cyclic redundancy check (CRC) field, where a value of the CRC field is calculated based on all fields other than the CRC field of the response frame.

[0267] In a possible implementation, at least one response parameter and the RFID response are delivered from a second part of a MAC layer of the tag to a first part of the MAC layer of the tag, where the at least one response parameter is used by a first part of a physical layer of the tag for transmitting the RFID response to the reader under an instruction of the first part of the MAC layer.

[0268] In a possible implementation, the first part of the MAC layer is an Ambient Power (AMP) MAC layer.

[0269] In a possible implementation, the second part of the MAC layer is any one of a low frequency (LF), a high frequency (HF) or an ultra high frequency (UHF) MAC layer.

[0270] In a possible implementation, the request frame is an AMP RFID frame.

[0271] It should also be noted that, the functions of the receiving module and the transmitting module may also be implemented by a transceiving module.

[0272] The communication apparatus may be the tag as described in the above method embodiments. It should be understood by a person skilled in the art that, the relevant description of the above modules in the embodiments of the present disclosure may be understood with reference to the relevant description of the communication method in the embodiments of the present disclosure.

[0273] FIG. 27 shows a schematic structural diagram of another communication apparatus according to one or more embodiments of the present disclosure. As shown in FIG. 27, the communication apparatus 2700 may include:

a transmitting module 2702, configured to transmit a request frame to a tag via a wireless signal, where the wireless signal follows an Institute of Electrical and Electronics Engineers (IEEE) 802.11 protocol, where request frame carries a radio frequency identification (RFID) command and a request instruction for indicating that the request frame carries the RFID command.

[0274] In a possible implementation, the request instruction includes a first frame type identification and a first payload type identification, where the first frame type identification indicates that the request frame is a data frame and the first payload type identification indicates that a payload of the data frame includes the RFID command.

[0275] In a possible implementation, the request instruction includes a second frame type identification, and the second frame type identification indicates that the request frame carries the RFID command.

[0276] In a possible implementation, a timing for starting a next interaction between the tag and the reader is determined based on a predefined first timing parameter associated with the request frame.

[0277] In a possible implementation, the request frame further includes a first timing field for indicating a first timing parameter associated with the request frame.

[0278] In a possible implementation, the first timing parameter and the RFID command are delivered from a station management entity (SME) of the reader to a media access control (MAC) sublayer management entity (MLME) of the reader for transmitting the request frame by the MLME.

[0279] In a possible implementation, a confirmation is delivered from the MLME to the SME for confirming a successful reception of the first timing parameter and the RFID command.

[0280] In a possible implementation, a timing for transmitting a response frame corresponding to the request frame is determined based on a predefined second timing parameter associated with the request frame.

[0281] In a possible implementation, the request frame further includes a second timing field for indicating a second timing parameter for transmitting a response frame corresponding to the request frame.

[0282] In a possible implementation, the request frame includes a presence field for indicating whether the second timing field is present.

[0283] In a possible implementation, the second timing parameter is delivered from a station management entity (SME) of the reader to a media access control (MAC) sublayer management entity (MLME) of the reader for transmitting the request frame by the MLME.

[0284] In a possible implementation, a duration of a carrier signal is delivered from an SME of the reader to an MLME of the reader, and the carrier signal is transmitted by the MLME after transmission of the request frame.

[0285] In a possible implementation, the request frame further includes a cyclic redundancy check (CRC) field, where a value of the CRC field is calculated based on all fields other than the CRC field of the request frame.

[0286] In a possible implementation, the method further includes a receiving module 2704, configured to receive an RFID response corresponding to the request frame from the tag.

[0287] In a possible implementation, the receiving module is specifically configured to: receive a response frame carrying the RFID response from the tag in response to the RFID command in the request frame, where the response frame carries a response instruction for indicating that the response frame carries the RFID response.

[0288] In a possible implementation, the response instruction includes a third frame type identification and a second payload type identification, where the third frame type identification indicates that the response frame is a data frame and the second payload type identification indicates that a payload of the data frame includes the RFID response.

[0289] In a possible implementation, the response instruction includes a fourth frame type identification, and the fourth frame type identification indicates that the response frame carries the RFID response.

[0290] In a possible implementation, the response frame further includes a cyclic redundancy check (CRC) field, where a value of the CRC field is calculated based on all fields other than the CRC field of the response frame.

[0291] In a possible implementation, the RFID response is delivered from an MLME of the reader to an SME of the reader for forwarding the RFID response to an application layer of the reader by the SME.

[0292] It should also be noted that, the functions of the transmitting module and the receiving module may also be implemented by a transceiving module.

[0293] The communication apparatus may be the reader as described in the above method embodiments. It should be understood by a person skilled in the art that, the relevant description of the above modules in the embodiments of the present disclosure may be understood with reference to the relevant description of the communication method in the embodiments of the present disclosure.

[0294] FIG. 28 is a schematic structural diagram of a communication apparatus according to one or more embodiments of the present disclosure, the apparatus may be a tag or a reader. As shown in FIG. 28, the communication apparatus 2800 includes a processor 2802, an interface 2804 for communicating with other devices, and a memory 2806. The memory 2806 may be stored with computer execution instructions, and the processor 2802 executes computer execution instructions stored in the memory 2806 to enable the apparatus to execute any of the above communication methods.

[0295] In some aspects of the present disclosure, there is provided a tag including processing circuitry for executing any of the above communication methods. It should be understood that the tag can execute the steps performed by the tag in the above method embodiments, which will not be repeated here.

[0296] In some aspects of the present disclosure, there is provided a reader including processing circuitry for executing any of the above communication methods. It should be understood that the reader can execute the steps performed by the reader in the above method embodiments, which will not be repeated here.

[0297] In some aspects of the present disclosure, there is provided a communication apparatus which includes a processor and a memory. The memory is storing instructions that cause the processor to perform any of the above communication methods.

[0298] In some aspects of the present disclosure, there is provided a communication system, including a tag and a reader. The tag is configured to execute the steps executed by the tag in any of the above communication methods,

and the reader is configured to execute the steps executed by the reader in any of the above communication methods.

[0299] In some aspects of the present disclosure, there is provided a chip, including an input/output (I/O) interface and a processor, where the processor is configured to call and run computer execution instructions stored in a memory, to enable a device installing with the chip to execute any of the above communication methods.

[0300] In some aspects of the present disclosure, there is provided a computer-readable medium storing computer execution instructions which, when executed by a processor, causes the processor to execute any of the above communication methods.

[0301] In some aspects of the present disclosure, there is provided a computer program product including computer execution instructions which, when executed by a processor, causes the processor to execute any of the above communication methods.

[0302] Although the present disclosure describes methods and processes with steps in a certain order, one or more steps of the methods and processes may be omitted or altered as appropriate. One or more steps may take place in an order other than that in which they are described, as appropriate.

[0303] Note that the expression "at least one of A or B", as used herein, is interchangeable with the expression "A and/or B". It refers to a list in which you may select A or B or both A and B. Similarly, "at least one of A, B, or C", as used herein, is interchangeable with "A and/or B and/or C" or "A, B, and/or C". It refers to a list in which you may select: A or B or C, or both A and B, or both A and C, or both B and C, or all of A, B and C. The same principle applies for longer lists having a same format.

[0304] Although the present disclosure is described, at least in part, in terms of methods, a person of ordinary skill in the art will understand that the present disclosure is also directed to the various components for performing at least some of the aspects and features of the described methods, be it by way of hardware components, software or any combination of the two. Accordingly, the technical solution of the present disclosure may be embodied in the form of a software product. A suitable software product may be stored in a pre-recorded storage device or other similar non-volatile or non-transitory computer readable medium, including DVDs, CD-ROMs, USB flash disk, a removable hard disk, or other storage media, for example. The software product includes instructions tangibly stored thereon that enable a processing device (e.g., a personal computer, a server, or a network device) to execute examples of the methods disclosed herein. The machine-executable instructions may be in the form of code sequences, configuration information, or other data, which, when executed, cause a machine (e.g., a processor or other processing device) to perform steps in a method according to examples of the present disclosure.

[0305] The present disclosure may be embodied in other specific forms without departing from the subject matter of the claims. The described example embodiments are to be considered in all respects as being only illustrative and not restrictive. Selected features from one or more of the above-described embodiments may be combined to create alternative embodiments not explicitly described, features suitable for such combinations being understood within the scope of this disclosure.

[0306] All values and sub-ranges within disclosed ranges are also disclosed. Also, although the systems, devices and processes disclosed and shown herein may include a specific number of elements/components, the systems, devices and assemblies could be modified to include additional or fewer of such elements/components. For example, although any of the elements/components disclosed may be referenced as being singular, the embodiments disclosed herein could be modified to include a plurality of such elements/components. The subject matter described herein intends to cover and embrace all suitable changes in technology.

[0307] Although embodiments have been described above with reference to the accompanying drawings, those of skill in the art will appreciate that variations and modifications may be made without departing from the scope thereof as defined by the appended claims.

CLAIMS

1. A communication method implemented by a tag, comprising:

receiving a request frame from a reader via a wireless signal, wherein the wireless signal follows an Institute of Electrical and Electronics Engineers (IEEE) 802.11 protocol, wherein the request frame carries a radio frequency identification (RFID) command and a request instruction for indicating that the request frame carries the RFID command.

2. The method according to claim 1, wherein the request instruction comprises a first frame type identification and a first payload type identification, wherein the first frame type identification indicates that the request frame is a data frame and the first payload type identification indicates that a payload of the data frame comprises the RFID command.

3. The method according to claim 1, wherein the request instruction comprises a second frame type identification, and the second frame type identification indicates that the request frame carries the RFID command.

4. The method according to any one of claims 1 to 3, wherein a timing for starting a next interaction between the tag and the reader is determined based on a predefined first timing parameter associated with the request frame.

5. The method according to any one of claims 1 to 3, wherein the request frame further comprises a first timing field for indicating a first timing parameter associated with the request frame.

6. The method according to claim 4 or 5, wherein the first timing parameter and the RFID command are delivered from a first part of a media access control (MAC) layer of the tag to a second part of the MAC layer of the tag for handling the RFID command by the second part of the MAC layer;

wherein the first part of the MAC layer of the tag corresponds to a first part of a physical layer at which the request frame is received.

7. The method according to claim 6, wherein a flag is maintained in the second part of the MAC layer of the tag for indicating that the RFID command is from the first part of the MAC layer of the tag.

8. The method according to any one of claims 1 to 7, wherein a timing for transmitting a response frame corresponding to the request frame to the reader is determined based on a predefined second timing parameter associated with the request frame.

9. The method according to any one of claims 1 to 7, wherein the request frame further comprises a second timing field for indicating a second timing parameter for transmitting a response frame corresponding to the request

frame to the reader.

10. The method according to claim 9, wherein the request frame comprises a presence field for indicating whether the second timing field is present.

11. The method according to any one of claims 8 to 10, wherein the second timing parameter is delivered from a first part of a media access control (MAC) layer of the tag to a second part of the MAC layer of the tag for obtaining an RFID response corresponding to the RFID command by the second part of the MAC layer;

wherein the first part of the MAC layer of the tag corresponds to a first part of a physical layer at which the request frame is received.

12. The method according to any one of claims 1 to 11, wherein the request frame further comprises a cyclic redundancy check (CRC) field, wherein a value of the CRC field is calculated based on all fields other than the CRC field of the request frame.

13. The method according to any one of claims 1 to 12, further comprising:

transmitting an RFID response to the reader in response to the request frame.

14. The method according to claim 13, wherein the transmitting the RFID response to the reader in response to the request frame comprises:

transmitting a response frame carrying the RFID response to the reader in response to the request frame, wherein the response frame carries a response instruction for indicating that the response frame carries the RFID response.

15. The method according to claim 14, wherein the response instruction comprises a third frame type identification and a second payload type identification, wherein the third frame type identification indicates that the response frame is a data frame and the second payload type identification indicates that a payload of the data frame comprises the RFID response.

16. The method according to claim 14, wherein the response instruction comprises a fourth frame type identification, and the fourth frame type identification indicates that the response frame carries the RFID response.

17. The method according to any one of claims 14 to 16, wherein the response frame further comprises a cyclic redundancy check (CRC) field, wherein a value of the CRC field is calculated based on all fields other than the CRC field of the response frame.

18. The method according to any one of claims 13 to 17, wherein at least one response parameter and the RFID response are delivered from a second part of a MAC layer of the tag to a first part of the MAC layer of the tag, wherein the at least one response parameter is used by a first part of a physical layer of the tag for transmitting the

RFID response to the reader under an instruction of the first part of the MAC layer.

19. The method according to claim 6, 7, 11 or 18, wherein the first part of the MAC layer is an Ambient Power (AMP) MAC layer.

20. The method according to claim 19, wherein the second part of the MAC layer is any one of a low frequency (LF), a high frequency (HF) or an ultra high frequency (UHF) MAC layer.

21. The method according to any one of claims 1 to 20, wherein the request frame is an AMP RFID frame.

22. A communication method implemented by a reader, comprising:

transmitting a request frame to a tag via a wireless signal, wherein the wireless signal follows an Institute of Electrical and Electronics Engineers (IEEE) 802.11 protocol, wherein the request frame carries a radio frequency identification (RFID) command and a request instruction for indicating that the request frame carries the RFID command.

23. The method according to claim 22, wherein the request instruction comprises a first frame type identification and a first payload type identification, wherein the first frame type identification indicates that the request frame is a data frame and the first payload type identification indicates that a payload of the data frame comprises the RFID command.

24. The method according to claim 22, wherein the request instruction comprises a second frame type identification, and the second frame type identification indicates that the request frame carries the RFID command.

25. The method according to any one of claims 22 to 24, wherein a timing for starting a next interaction between the tag and the reader is determined based on a predefined first timing parameter associated with the request frame.

26. The method according to any one of claims 22 to 24, wherein the request frame further comprises a first timing field for indicating a first timing parameter associated with the request frame.

27. The method according to claim 25 or 26, wherein the first timing parameter and the RFID command are delivered from a station management entity (SME) of the reader to a media access control (MAC) sublayer management entity (MLME) of the reader for transmitting the request frame by the MLME.

28. The method according to claim 27, wherein a confirmation is delivered from the MLME to the SME for confirming a successful reception of the timing parameter and the RFID command.

29. The method according to any one of claims 22 to 28, wherein a timing for transmitting a response frame corresponding to the request frame to the reader is determined based on a predefined second timing parameter associated with the request frame.

30. The method according to any one of claims 22 to 28, wherein the request frame further comprises a second timing field for indicating a second timing parameter for transmitting a response frame corresponding to the request frame to the reader.

31. The method according to claim 30, wherein the request frame comprises a presence field for indicating whether the second timing field is present.

32. The method according to any one of claims 29 to 31, wherein the second timing parameter is delivered from a station management entity (SME) of the reader to a media access control (MAC) sublayer management entity (MLME) of the reader for transmitting the request frame by the MLME.

33. The method according to any one of claims 22 to 32, wherein a duration of a carrier signal is delivered from an SME of the reader to an MLME of the reader, and the carrier signal is transmitted by the MLME after transmission of the request frame.

34. The method according to any one of claims 22 to 33, wherein the request frame further comprises a cyclic redundancy check (CRC) field, wherein a value of the CRC field is calculated based on all fields other than the CRC field of the request frame.

35. The method according to any one of claims 22 to 34, further comprising:

receiving an RFID response corresponding to the request frame from the tag.

36. The method according to claim 35, wherein the receiving the RFID response corresponding to the request frame from the tag comprises:

receiving a response frame carrying the RFID response to the reader in response to the RFID command in the request frame, wherein the response frame carries a response instruction for indicating that the response frame carries the RFID response.

37. The method according to claim 36, wherein the response instruction comprises a third frame type identification and a second payload type identification, wherein the third frame type identification indicates that the response frame is a data frame and the second payload type identification indicates that a payload of the data frame comprises the RFID response.

38. The method according to claim 36, wherein the response instruction comprises a fourth frame type identification, and the fourth frame type identification indicates that the response frame carries the RFID response.

39. The method according to any one of claims 36 to 38, wherein the response frame further comprises a cyclic redundancy check (CRC) field, wherein a value of the CRC field is calculated based on all fields other than the CRC

field of the response frame.

40. The method according to any one of claims 35 to 39, wherein the RFID response is delivered from an MLME of the reader to an SME of the reader for forwarding the RFID response to an application layer of the reader by the SME.

41. A communication apparatus, comprising modules for executing the method according to any one of claims 1 to 21.

42. A communication apparatus, comprising modules for executing the method according to any one of claims 22 to 40.

43. A communication apparatus, comprising at least one processor and a memory, wherein the memory stores instructions that cause the at least one processor to execute the method according to any one of claims 1 to 21 or the method according to any one of claims 22 to 40.

44. A computer-readable medium storing computer execution instructions which, when executed by a processor, causes the processor to execute the method according to any one of claims 1 to 21 or the method according to any one of claims 22 to 40.

45. A computer program product comprising computer execution instructions which, when executed by a processor, causes the processor to execute the method according to any one of claims 1 to 21 or the method according to any one of claims 22 to 40.