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(54) **CHANNEL PREDICTION METHOD AND RELATED DEVICE**

KANALVORHERSAGEVERFAHREN UND ZUGEHÖRIGE VORRICHTUNG

PROCÉDÉ DE PRÉDICTION DE CANAL ET DISPOSITIF ASSOCIÉ

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Description

TECHNICAL FIELD

[0001] This application relates to the field of wireless network technologies, and in particular, to a channel prediction method and a related device.

BACKGROUND

[0002] In a wireless communications system, a transmitter sends a signal, and a receiver receives the signal sent by the transmitter. A wireless link between the transmitter and the receiver is referred to as a wireless channel. Propagation paths between the transmitter and the receiver are complex. For example, buildings, streets, and movement of other objects cause signal reflection, refraction, and diffraction. The signal received by the receiver is a superimposed signal of all signals that arrive at the receiver through different transmission paths. Therefore, the wireless channel is an important factor that affects the wireless communications system. Channel estimation is to estimate a wireless channel response between a transmit antenna and a receive antenna, to be specific, estimate time domain or frequency domain characteristics of the channel based on a receiving sequence whose amplitude and phase are changed due to impact of the multipath channel of the receiver and to which a white noise is superimposed. However, accuracy of a channel coefficient estimated by using an existing channel estimation algorithm is low.

[0003] In "Multi-antenna fading channel prediction empowered by artificial intelligence" by Jiang Wei et al., 88th IEEE Vehicular Technology Conference, Aug. 2018, pages 1 to 6, a multi-antenna channel predictor is described, which makes use of artificial intelligence. It can be used to forecast future channel state information up to tens of symbols ahead in a fast fading channel. The predictor relies on a neural network with real-valued weights.

SUMMARY

[0004] Embodiments of this application provide a channel prediction method and a related device, to improve channel prediction accuracy.

[0005] According to a first aspect, an embodiment of this application provides a channel prediction method, including: First, a first channel coefficient sequence in a first time period is obtained, where the first channel coefficient sequence includes a plurality of complex values of a channel coefficient. Then, a prediction value of the channel coefficient in a second time period is determined based on the first channel coefficient sequence and a preset vocabulary of channel changes, where the vocabulary of channel changes includes a mapping relationship between a channel change value index and each change value of the channel coefficient, and the second time period is later than the first time period. The complex-valued channel coefficient is predicted by using the vocabulary of channel changes, so that original information of the channel coefficient is retained, and both an amplitude and a phase of a channel can be predicted. This improves accuracy of the predicted channel coefficient.

[0006] In a possible design, first, a first channel coefficient change sequence is determined based on the first channel coefficient sequence, where the first channel coefficient change sequence includes a plurality of change values of the channel coefficient. Then, the vocabulary of channel changes is searched for a channel change value index corresponding to each change value in the first channel coefficient change sequence, and a first channel change value index sequence is generated. The first channel change value index sequence is input into a channel prediction model for prediction, to obtain a channel change value index prediction sequence. Finally, the prediction value of the channel coefficient is determined based on the channel change value index prediction sequence. Each change value in the first channel coefficient change sequence is converted into the channel change value index by using the vocabulary of channel changes, and the channel change value index is input into the channel prediction model for prediction, so that the complex-valued channel coefficient is predicted, and the accuracy of the predicted channel coefficient is improved.

[0007] In another possible design, a complex value of the channel coefficient at a former moment is subtracted from a complex value of the channel coefficient at a latter moment in the first channel coefficient sequence, to obtain each change value in the first channel coefficient change sequence; or a complex value of the channel coefficient at a latter moment is subtracted from a complex value of the channel coefficient at a former moment in the first channel coefficient sequence, to obtain each change value in the first channel coefficient change sequence. A quantity of words in the vocabulary of channel changes can be reduced by calculating the change value, for example, changing numerical precision of the change value. This improves search efficiency.

[0008] In another possible design, a complex value of the channel coefficient at a last moment is subtracted from a complex value of the channel coefficient at a moment before the last moment in the first channel coefficient sequence, to obtain each change value in the first channel coefficient change sequence; or a complex value of the channel coefficient at a start moment is subtracted from a complex value of the channel coefficient at a moment after the start moment in the first channel coefficient sequence, to obtain each change value in the first channel coefficient change sequence. A quantity of words in the vocabulary of channel changes can be reduced by calculating the change value, for example, changing numerical precision of the change value. This improves search efficiency.

[0009] In another possible design, a channel coefficient change value prediction sequence corresponding to the channel change value index prediction sequence is determined based on the vocabulary of channel changes. The prediction value of the channel coefficient is determined based on the channel coefficient change value prediction sequence. The channel change value index prediction sequence is converted into the channel coefficient change value prediction sequence by using the vocabulary of channel changes, so that a complex value of the prediction value of the channel coefficient is obtained.

[0010] In another possible design, statistics on occurrence frequency of each of the plurality of change values of the channel coefficient in the first channel coefficient change sequence may be collected. Then, an integer is assigned to each change value of the channel coefficient based on the occurrence frequency, to obtain the channel change value index. Finally, the mapping relationship between the channel change value index and each change value is established, to generate the vocabulary of channel changes.

[0011] In another possible design, when occurrence frequency of a target change value in the plurality of change values is greater than a preset threshold, an integer is assigned to the target change value of the channel coefficient. The threshold is set to reduce the quantity of words in the vocabulary of channel changes.

[0012] In another possible design, the vocabulary includes a plurality of key-value pairs. A value corresponding to a key may be obtained by searching for the key in the vocabulary. The vocabulary of channel changes may include a vocabulary A of channel changes and a vocabulary B of channel changes. A key in the vocabulary A of channel changes is the change value of the channel coefficient, and a value in the vocabulary A of channel changes is the channel change value index. A key in the vocabulary B of channel changes is the channel change value index, and a value in the vocabulary B of channel changes is the change value of the channel coefficient. The vocabulary A of channel changes is used when the channel coefficient change sequence is converted into the channel change value index sequence. The vocabulary B of channel changes is used when the channel change value index sequence is converted into the channel coefficient change sequence. Channel coefficient conversion before channel prediction is implemented by using the vocabulary A of channel changes, and channel coefficient conversion after the channel prediction is implemented by using the vocabulary B of channel changes, so as to predict the complex-valued channel coefficient.

[0013] In another possible design, first, a second channel coefficient sequence may be obtained, where the second channel coefficient sequence includes a plurality of complex values of the channel coefficient. Second, a second channel coefficient change sequence is determined based on the second channel coefficient sequence, where the second channel coefficient change sequence includes a plurality of change values of the channel coefficient. Then, the vocabulary of channel changes is searched for a channel change value index corresponding to each change value in the second channel coefficient change sequence, and a second channel change value index sequence is generated. Finally, the second channel change value index sequence is input into a neural network for training, to obtain the channel prediction model. A large quantity of channel coefficient sequences are input into the neural network for training, to improve prediction accuracy of the channel prediction model, so as to improve channel prediction accuracy.

[0014] In another possible design, an input dimension of the neural network and an output dimension of the neural network are the same as a quantity of mapping relationships in the vocabulary of channel changes.

[0015] In another possible design, a probability of each prediction value output by the neural network may be obtained. Then, a difference between complex values of every two change values in the vocabulary of channel changes is determined, and a channel change difference matrix is generated. A weighted mean of probabilities of all prediction values is determined based on the channel change difference matrix and the probability of each prediction value. Finally, whether the neural network has completed training is determined based on the weighted mean. Redundant information related to the complex value in the vocabulary of channel changes is used as an input of a loss function for calculation, and the original loss function is replaced after the training is performed to a certain extent. Alternatively, as the training is performed, a weight that gradually increases is added to the original loss function. In this way, interference in a real environment is reduced.

[0016] In another possible design, after the channel prediction model is obtained through training, the channel prediction model may be trained to obtain an updated channel prediction model. For example, parameters of some layers in the channel prediction model may be kept unchanged, and parameters of some other layers are changed, to obtain the updated channel prediction model. The channel prediction model is updated, to improve accuracy of predicting the channel coefficient by using the channel prediction model.

[0017] In another possible design, a structure of the channel prediction model is a model of the neural network, and parameters (for example, a weight) in the model may be changed through training of the neural network, or may be changed in a value assignment manner. A communications device may send or receive locations and values of these parameters in a wired or wireless manner. The location may include a number of the channel prediction model to which the parameter belongs, a number of a layer in the channel prediction model to which the parameter belongs, and a number of a location in a parameter matrix of the layer in the channel prediction model to which the parameter belongs. The channel prediction model is updated, to improve accuracy of predicting the channel coefficient by using the channel prediction model.

[0018] In another possible design, after the prediction value of the channel coefficient in the second time period is determined based on the first channel coefficient sequence and the preset vocabulary of channel changes, demodulation or decoding may be performed on data based on the prediction value, or adaptive transmission may be performed based on the prediction value, to improve a system throughput.

[0019] In another possible design, when a system throughput generated by performing the demodulation, decoding, or adaptive transmission by using the prediction value is higher than a prediction throughput threshold, channel prediction may be performed by using the channel prediction model. The channel coefficient may be obtained through channel estimation when a system throughput generated by performing the demodulation, decoding, or adaptive transmission by using the prediction value is not higher than a prediction throughput threshold.

[0020] In another possible design, demodulation, decoding, or adaptive transmission may be performed on data in a channel estimation window T1 by using a channel estimation value obtained through channel estimation, or demodulation, decoding, or adaptive transmission may be performed on data in a channel prediction window T2 by using the prediction value of the channel coefficient. Alternatively, a channel estimation value obtained through channel estimation may be obtained, and a channel prediction weighted value is determined based on the channel estimation value obtained through the channel estimation and the prediction value. Demodulation, decoding, or adaptive transmission is performed on data in a channel prediction window T2 based on the channel prediction weighted value. The channel coefficient is predicted with reference to the channel estimation and the channel prediction model, to improve the channel prediction accuracy.

[0021] In another possible design, extrapolation processing may be performed on a channel coefficient sequence in a channel prediction window, to obtain a channel extrapolation value in the channel prediction window. Then, a weighted mean of a channel estimation value, the channel extrapolation value, and the prediction value is determined, and demodulation, decoding, or adaptive transmission is performed by using the weighted mean. In this way, robustness of the channel prediction value can be improved.

[0022] In another possible design, a signal value in a channel prediction window may be obtained, and the channel coefficient is predicted with reference to the signal value and the channel prediction model, to improve the channel prediction accuracy.

[0023] According to a second aspect, an embodiment of this application provides a channel prediction apparatus. The channel prediction apparatus is configured to implement the method and the function performed by the communications device in the first aspect, and is implemented by hardware/software. The hardware/software of the channel prediction apparatus includes a unit corresponding to the foregoing function.

[0024] According to a third aspect, an embodiment of this application provides a channel prediction device, including a processor, a memory, and a communications bus. The communications bus is configured to implement connection and communication between the processor and the memory, and the processor executes a program stored in the memory, to implement steps in the channel prediction method provided in the first aspect.

[0025] In a possible design, the channel prediction device provided in this embodiment of this application may include a corresponding module configured to perform behavior of the channel prediction apparatus in the foregoing method design. The module may be software and/or hardware.

[0026] In another possible design, the processor and the memory may alternatively be integrated. The channel prediction device may be a chip.

[0027] According to a fourth aspect, an embodiment of this application provides a computer-readable storage medium. The computer-readable storage medium stores an instruction. When the instruction is run on a computer, the computer is enabled to perform the method in the first aspect.

[0028] According to a fifth aspect, an embodiment of this application provides a computer program product including an instruction. When the computer program product runs on a computer, the computer is enabled to perform the method in the first aspect.

BRIEF DESCRIPTION OF DRAWINGS

[0029] To describe technical solutions in embodiments of this application or in the background clearer, the following briefly describes the accompanying drawings for describing the embodiments of this application or the background.

FIG. 1 is a schematic architectural diagram of a wireless communications system according to an embodiment of this application;

FIG. 2 shows a linear time-varying channel model according to an embodiment of this application;

FIG. 3 is a schematic structural diagram of a convolutional neural network according to an embodiment of this application;

FIG. 4 is a schematic flowchart of a channel prediction method according to an embodiment of this application;

FIG. 5 is a table of a vocabulary of channel changes according to an embodiment of this application;

FIG. 6 is a table of another vocabulary of channel changes according to an embodiment of this application;

FIG. 7 is a schematic structural diagram of a channel prediction apparatus according to an embodiment of this application; and

FIG. 8 is a schematic structural diagram of a channel prediction device according to an embodiment of this application.

DESCRIPTION OF EMBODIMENTS

[0030] The following describes the embodiments of this application with reference to the accompanying drawings in the embodiments of this application.

[0031] FIG. 1 is a schematic architectural diagram of a wireless communications system according to an embodiment of this application. The wireless communications system includes a plurality of communications devices, for example, a communications device 1, a communications device 2, and a communications device 3. The communications device may be a terminal device or a base station. The base station provides a communication service for the terminal device. The base station sends downlink data to the terminal device. The data is encoded through channel coding, and data obtained after channel coding is transmitted to the terminal device after constellation modulation. The terminal device sends uplink data to the base station. The uplink data may also be encoded through channel coding, and encoded data is transmitted to the base station after constellation modulation. The terminal device may be user equipment, may be a device that provides a voice and/or data connection to a user, may be a device connected to a computing device such as a laptop computer or a desktop computer, or may be an independent device such as a personal digital assistant (personal digital assistant, PDA). The terminal device may also be referred to as a system, a subscriber unit, a subscriber station, a mobile station, a mobile console, a remote station, an access point, a remote terminal, an access terminal, a user terminal, a user agent, or a user apparatus. The base station may be a device configured to communicate with the terminal device, may be an access point, a relay node, a base transceiver station (base transceiver station, BTS), a NodeB (NodeB, NB), an evolved NodeB (evolved NodeB, eNB), or a 5G base station (next generation NodeB, gNB), and is a device that is in an access network and that communicates with a wireless terminal over an air interface by using one or more sectors. By converting a received air interface frame into an IP packet, the base station may serve as a router between the wireless terminal and another part of the access network, and the access network may include an internet protocol network. The base station may further coordinate attribute management for the air interface. In the embodiments of this application, the wireless communications system may be used for channel prediction. A channel coefficient is obtained by using a channel prediction method, and the channel coefficient is used for data demodulation, decoding, or adaptive transmission of the base station or the terminal device, to obtain originally transmitted data.

[0032] FIG. 2 shows a linear time-varying channel model according to an embodiment of this application. The linear time-varying channel model satisfies: $r(t)=s(t)*h(t;\tau)+n(t)$, where $s(t)$ is an input signal at a moment t, $r(t)$ is an output signal at the moment t, $h(t;\tau)$ is a channel impulse response, τ represents a delay, $h(t;\tau)$ represents a distortion and a delay caused by a channel to the input signal at the moment t when the delay is τ, and * is a convolution operator. $n(t)$ is an additive noise on the modulation channel, is also referred to as additive interference, and is irrelevant to the input signal $s(t)$. It can be learned from the linear time-varying channel model that channel estimation may be represented as estimating a wireless channel response between a transmit antenna and a receive antenna, to be specific, estimating time domain or frequency domain characteristics of the channel based on a receiving sequence whose amplitude and phase are changed due to impact of a multipath channel of a receiver and to which a white noise is superimposed. Because of randomness of a real channel environment, in a common channel estimation algorithm, calculation is performed only based on a measurement signal at a current moment, and a channel coefficient estimated at a historical moment is not considered. However, as a neural network develops, the neural network is used to learn of a channel feature from seemingly random channel data at the historical moment and to perform inference, to predict a channel coefficient at the current moment or even a future moment.

[0033] It should be understood that the randomness of the channel environment is due to a complex multipath effect, a shadow effect, small-scale fading, and the like. A value of a channel coefficient complies with some statistical characteristics. Channel models proposed by a standard organization for link simulation and system simulation are obtained through fitting based on these statistical characteristics. These channel models cannot be used for channel prediction in a real channel environment. However, the neural network is suitable for handling this complex problem that cannot be modeled. An existing neural network-based channel prediction method such as an adaptive linear (adaline) or a non-linear method, includes a multilayer perceptron (multilayer perceptron, MLP), a recurrent neural network (recurrent neural network, RNN), a convolutional neural network (convolutional neural network, CNN), a deep neural network (deep neural network, DNN), and the like.

[0034] FIG. 3 is a schematic structural diagram of a convolutional neural network according to an embodiment of this application. The convolutional neural network includes parts such as an input layer, a convolutional layer, a fully connected layer, and an output layer. The input layer may be used to input data, and the input data is usually an integer. The convolutional layer is mainly used to extract features of the input data. Different convolution kernels extract different features of the input data. A larger quantity of convolution kernels in the convolutional layer indicates a larger quantity of extracted features of the input data. The fully connected layer may include a plurality of fully connected layers. A neuron node in a latter layer is connected to each neuron node in a former layer. Each neuron node in each layer performs forward propagation by using a weight on a connection line, and weighted summation is performed to obtain an input into a neuron node in a next layer. A quantity of neuron nodes in the output layer may be set based on a specific application task.

[0035] In a process of performing channel prediction based on the foregoing neural network, a channel coefficient is a complex value, and an amplitude and a phase of the channel coefficient represent power and delay changes of a transmission signal. A typical neural network cannot process the complex value, and can learn of only an amplitude (namely, power) of a channel, or separately input an amplitude and a phase of a channel into the neural network for prediction. Consequently, original information of the channel coefficient is destroyed, and accuracy of a predicted channel coefficient is low. To resolve the foregoing technical problem, the embodiments of this application provide the following solutions.

[0036] FIG. 4 is a schematic flowchart of a channel prediction method according to an embodiment of this application. As shown in the figure, steps in this embodiment of this application include at least the following steps.

[0037] S401: Obtain a first channel coefficient sequence in a first time period, where the first channel coefficient sequence includes a plurality of complex values of a channel coefficient.

[0038] During specific implementation, a communications device may estimate channel coefficients in a time period through channel estimation, to form the first channel coefficient sequence. The communications device may alternatively receive, in a wired or wireless manner, the first channel coefficient sequence sent by another communications device. The first channel coefficient sequence includes the plurality of complex values of the channel coefficient. The complex value of the channel coefficient may be represented by using Cartesian coordinates, for example, in a form of x+yi, or may be represented by using polar coordinates in a form of ae^{ib}. The channel coefficient may be a time-domain channel coefficient, or may be a frequency-domain channel coefficient. The time-domain channel coefficient and the frequency-domain channel coefficient may be mutually converted. For example, the frequency-domain channel coefficient may be converted into the time-domain channel coefficient through inverse Fourier transform, and the time-domain channel coefficient may be converted into the frequency-domain channel coefficient through Fourier transform. When the channel coefficient is obtained in a real scenario, signal processing operations such as sampling, noise reduction, filtering, amplitude normalization, and fixed-point processing may be performed on the estimated channel coefficient in time domain or frequency domain. To obtain a channel coefficient at a time-frequency resource in which no pilot sequence is placed, a channel estimation value at a time-frequency resource that is near the time-frequency resource and in which a pilot sequence is placed may also be calculated. The calculation includes signal processing operations such as interpolation and extrapolation. The calculation further includes inputting into a neural network. The first time period may be a time point, or may be a time period.

[0039] S402: Determine a prediction value of the channel coefficient in a second time period based on the first channel coefficient sequence and a preset vocabulary of channel changes, where the vocabulary of channel changes includes a mapping relationship between a channel change value index and each change value of the channel coefficient, and the second time period is later than the first time period. The second time period may be a time point, or may be a time period. This step specifically includes the following steps.

[0040] First, a first channel coefficient change sequence is determined based on the first channel coefficient sequence, where the first channel coefficient change sequence includes a plurality of change values of the channel coefficient.

[0041] In an implementation, a complex value of the channel coefficient at a former moment may be subtracted from a complex value of the channel coefficient at a latter moment in the first channel coefficient sequence, to obtain each change value in the first channel coefficient change sequence. Alternatively, a complex value of the channel coefficient at a latter moment is subtracted from a complex value of the channel coefficient at a former moment in the first channel coefficient sequence, to obtain each change value in the first channel coefficient change sequence. For example, the first channel coefficient sequence is $\{x_1, x_2, x_3, x_4, ..., x_i, ..., x_n\}$, where x_i (i=1, 2, ..., n) is a complex value. If the complex value of the channel coefficient at the former moment is subtracted from the complex value of the channel coefficient at the latter moment, the first channel coefficient change sequence is $\{x_2-x_1, x_3-x_2, x_4-x_3, ..., x_n-x_{n-1}\}$.

[0042] In another implementation, a complex value of the channel coefficient at a last moment may be subtracted from a complex value of the channel coefficient at a moment before the last moment in the first channel coefficient sequence, to obtain each change value in the first channel coefficient change sequence. Alternatively, a complex value of the channel coefficient at a start moment is subtracted from a complex value of the channel coefficient at a moment after the start moment in the first channel coefficient sequence, to obtain each change value in the first channel coefficient change sequence. The first channel coefficient change sequence includes change values of the first channel coefficient sequence, and may be obtained by performing an operation such as addition, subtraction, multiplication, division, a first-order derivative, or a second-order derivative that can represent characteristics of the complex value of the channel coefficient at the former moment and the complex value of the channel coefficient at the latter moment.

[0043] Optionally, because different moving speeds of a terminal device cause fast or slow channel changes, in an actual system, different frequency offsets also cause fast or slow phase changes of the channel coefficient. Therefore, a sampling operation or an interpolation operation may be first performed on the first channel coefficient sequence, and then the first channel coefficient change sequence is obtained based on the first channel coefficient sequence on which the sampling operation or the interpolation operation is performed. Alternatively, a phase of the first channel coefficient sequence may be multiplied by a frequency offset, so that phase rotation of a channel becomes faster or slower. For example, a first channel coefficient sequence with a length of 300,000 symbols may be sampled. A value is selected from every 30 symbols to re-form a sampling sequence, and a length of the sampling sequence is 10,000. Then, the first channel coefficient change sequence is determined based on the sampling sequence. For another example, the interpolation operation may be performed on a first channel coefficient sequence with a length of 1,000 symbols. Nine values are inserted between every two symbols, to obtain an interpolation sequence with a length of 10,000. Then, the first channel coefficient change sequence is determined based on the interpolation sequence.

[0044] Second, the vocabulary of channel changes is searched for a channel change value index corresponding to each change value in the first channel coefficient change sequence, and a first channel change value index sequence is generated.

[0045] The vocabulary of channel changes includes a set including a key (key) and a value (value), and the key is the change value of the channel coefficient in the first channel coefficient change sequence. For example, the change value of the channel coefficient may be obtained by subtracting the complex value of the channel coefficient at the former moment from the complex value of the channel coefficient at the latter moment in the first channel coefficient sequence, or subtracting the complex value of the channel coefficient at the latter moment from the complex value of the channel coefficient at the former moment in the first channel coefficient sequence. The key is unique in the vocabulary of channel changes, and one key corresponds to one value. The value is usually an integer. In other words, the change value of the channel coefficient corresponds to the channel change value index.

[0046] In this embodiment of this application, the vocabulary of channel changes may include a vocabulary A of channel changes and a vocabulary B of channel changes. A key in the vocabulary A of channel changes is the change value of the channel coefficient, and a value in the vocabulary A of channel changes is the channel change value index. A key in the vocabulary B of channel changes is the channel change value index, and a value in the vocabulary B of channel changes is the change value of the channel coefficient. The vocabulary A of channel changes is used when the channel coefficient change sequence is converted into the channel change value index sequence. The vocabulary B of channel changes is used when the channel change value index sequence is converted into the channel coefficient change sequence. The vocabulary B of channel changes is searched for the change value of the channel coefficient by using the channel change value index. If channel change value indexes are integers that start from 1 or 0 in ascending order, the vocabulary of channel changes may be degraded to a vector of the change value of the channel coefficient. Therefore, values of the integers do not need to be stored. For example, an index of the first location in the vector is an integer 0, an index of the second location in the vector is an integer 1, an index of the third location in the vector is an integer 2, and so on. The locations correspond to corresponding change values of the channel coefficient. FIG. 5 is a table of the vocabulary B of channel changes according to an embodiment of this application. Channel change value indexes in the vocabulary of channel changes are integers that start from 1 or 0 in ascending order, and are degraded to first 11 elements in a vocabulary that is in a vector representation form.

[0047] The vocabulary of channel changes may be temporarily generated based on a current change value of the channel coefficient, or may be pre-stored (generated based on another channel coefficient change sequence). A process of generating the vocabulary of channel changes includes: Statistics on occurrence frequency of each of the plurality of change values of the channel coefficient in the channel coefficient change sequence may be collected. Then, an integer is assigned to each change value of the channel coefficient based on the occurrence frequency, to obtain the channel change value index. Finally, the mapping relationship between the channel change value index and each change value is established, to generate the vocabulary of channel changes.

[0048] Specifically, the statistics on the occurrence frequency of each change value of the channel coefficient in the channel coefficient change sequence may be collected, and the change values are sorted in descending order or ascending order based on the occurrence frequency. Integers starting from 1 in ascending order may be sequentially assigned to the sorted change values, and the assigned integers are used as the channel change value indexes in the vocabulary of channel changes. For example, the vocabulary of channel changes may be represented as {keyl:valuel, key2:value2, key3:value3, ..., keyN:valueN}, where the "key" is the key in the vocabulary of channel changes, and the "value" is the value in the vocabulary of channel changes. For example, in the vocabulary of channel changes {"+0.02-0.02i":1, "+0.02+0.02i":2, "-0.02-0.02i":3, ..., "+0.001-0.2i":1234}, the change value +0.02-0.02i of the channel coefficient is used as a key and a corresponding channel change value index is 1, the change value -0.02-0.02i of the channel coefficient is used as a key and a corresponding channel change value index is 3, and the change value +0.001-0.2i of the channel coefficient is used as a key and a corresponding channel change value index is 1234.

[0049] Optionally, when occurrence frequency of a target change value in the plurality of change values is greater than a preset threshold, an integer is assigned to the target change value of the channel coefficient. Specifically, when the statistics on the occurrence frequency of each change value of the channel coefficient in the channel coefficient change sequence are collected, a threshold may be set. When occurrence frequency of a change value is greater than the preset threshold, an integer is assigned to the change value, and the change value is stored in the vocabulary of channel changes. When occurrence frequency of a change value is less than or equal to the preset threshold, no integer is assigned to the change value, and the change value is not stored in the vocabulary of channel changes. For example, the preset threshold is 10. In a channel coefficient change sequence with a length of 100,000, low-frequency change values that occur only ten times or less may not be stored in the vocabulary of channel changes. In this case, a new word may be added to the vocabulary of channel changes and a value is assigned to the word. For example, a new word "unk" is used as a key and 0 is assigned to "unk". When the channel coefficient change sequence is converted into the channel change value index sequence, for a change value that is not stored in the vocabulary of channel changes, because the change value and a corresponding integer cannot be found, the new word "unk" may be used to replace the change value and corresponds to the integer 0.

[0050] FIG. 6 is a table of another vocabulary of channel changes according to an embodiment of this application. N is a total quantity of change values in the vocabulary of channel changes, and the table lists only top 10 most and least frequently occurring change values and corresponding channel change value indexes. In addition, the vocabulary of channel changes may retain only change values whose occurrence frequency is greater than 10. For a change value whose occurrence frequency is less than or equal to 10, "unk" may be used to replace the change value and corresponds to the integer 0.

[0051] Third, the first channel change value index sequence is input into a channel prediction model for prediction, to obtain a channel change value index prediction sequence. The channel prediction model may be obtained by training the neural network. A specific method is as follows:

[0052] First, a second channel coefficient sequence may be obtained, where the second channel coefficient sequence includes a plurality of complex values of the channel coefficient. The second channel coefficient sequence may be a channel coefficient obtained based on a simulated scenario through channel model simulation, or may be a channel coefficient obtained based on a real scenario through channel estimation and statistics collection performed by a communications device in a real communication environment. Second, a second channel coefficient change sequence is determined based on the second channel coefficient sequence, where the second channel coefficient change sequence includes a plurality of change values of the channel coefficient. This step is the same as the foregoing method for determining the first channel coefficient change sequence based on the first channel coefficient sequence. Details of this step are not described again. Then, the vocabulary of channel changes is searched for a channel change value index corresponding to each change value in the second channel coefficient change sequence, and a second channel change value index sequence is generated. This step is the same as the foregoing method for searching the vocabulary of channel changes for the channel change value index corresponding to each change value in the first channel coefficient change sequence. Details of this step are not described again. Finally, the second channel change value index sequence is input into the neural network for training, to obtain the channel prediction model.

[0053] The neural network may be a recurrent neural network RNN, a convolutional neural network CNN, a deep neural network DNN, or any combination thereof. In addition to the channel change value index, an input into the neural network may further include a signal value, namely, a value obtained by performing various calculations on r(t) in FIG. 2. The RNN may be combined with a back propagation through time (back propagation through time, BPTT) method or a long short-term memory (long short-term memory, LSTM) network and variants thereof, or an RNN-based sequence-to-sequence (Seq2Seq) network and a variant thereof may be used. The Seq2Seq network can complete conversion between two sequences, and is usually used for translation between two languages. In this embodiment of this application, a sequence at a former moment may be used as a language, and a sequence at a latter moment may be used as another language. After the Seq2Seq network implements translation between the two languages, it is equivalent to that the sequence at the former moment is used to generate the sequence at the latter moment. Therefore, channel prediction is implemented. The Seq2Seq network has two RNN networks, and therefore, is more expressive. The two RNN networks may use a same vocabulary of channel changes during training.

[0054] It should be noted that in addition to corresponding to an integer, each change value in the channel coefficient change sequence further corresponds to a word vector (word vector) before the change value is input into the neural network. The word vector represents the change value and is input into a first layer of the neural network for training in the neural network, to continuously update a parameter in the layer, where the layer may also be referred to as an embedding layer (embedding layer). An input dimension of the neural network and an output dimension of the neural network may be the same as a quantity of mapping relationships in the vocabulary of channel changes. For example, each change value may be represented by a word vector with a length of 100. Before being input into the neural network, each word vector may be obtained through initialization, or may be a pre-stored and pre-trained (pre-trained) word vector. In addition, to accelerate convergence of the neural network and avoid starting training from zero, in addition to introducing a prestored word vector, a pre-stored and pre-trained channel prediction model may also be used to replace the parameter.

[0055] When the neural network is trained, prior information of the change value of the channel coefficient may be used to assist the neural network to converge more quickly. For example, it can be learned from the vocabulary of channel changes that "+0.03+0.001i" corresponds to an integer 105, and "+0.03+0.002i" corresponds to an integer 2370. A relationship between the two cannot be learned of by using the integers. However, actually, the two complex values are very close to each other, and a system can even tolerate exchange of the two complex values, but the information has been lost in an integerization process. In a training process, each change value corresponds to one word vector. If a difference between a plurality of change values is less than a specific value, word vectors corresponding to the plurality of change values are bound. For example, a word vector corresponding to a change value with a minimum loss in the plurality of change values may be assigned to the other change values in the plurality of change values. Alternatively, a change value in the plurality of change values may be selected, the other change values are all trained by using a word vector corresponding to the change value, and a loss of the change value may also be used as losses of all the other change values. Alternatively, after an average value of word vectors corresponding to all change values that are close to each other is obtained, the average value is assigned to a word vector corresponding to a change value or the word vectors corresponding to all the change values that are close to each other. In addition, a difference between complex values of every two change values in the vocabulary of channel changes may be determined, and a channel change difference matrix is generated. If there are N mapping relationships in the vocabulary of channel changes, a dimension of the channel change difference matrix is N*N. Elements in an i^{th} row in the channel change difference matrix represent differences between an i^{th} channel change value index and the first to an N^{th} channel change value index in the vocabulary of channel changes.

[0056] When the neural network is trained, a loss function may be set, and gradient descent is performed on the neural network by comparing a prediction value output by the neural network with a target value in a training set, to minimize the loss function. Cross-entropy, negative maximum likelihood, mean square error and other statistical methods may be used to calculate the loss. In addition, redundant information related to the complex value in the vocabulary of channel changes is added to the loss function for calculation. The redundant information is used to calculate the loss, and the original loss function is replaced after training is performed to a certain extent. Alternatively, as the training is performed, a weight that gradually increases is added to the original loss function. In this way, interference in a real environment is reduced.

[0057] The channel prediction model is determined with reference to the foregoing channel change difference matrix and the loss function. The following steps are specifically included: First, a probability of each prediction value output by the neural network is obtained. The difference between the complex values of every two change values in the vocabulary of channel changes is determined, and the channel change difference matrix is generated. Then, a weighted mean of probabilities of all prediction values is determined based on the channel change difference matrix and the probability of each prediction value. Finally, whether the neural network has completed training is determined based on the weighted mean.

[0058] For example, first, the difference between the complex values of every two change values in the vocabulary of channel changes is determined, and the channel change difference matrix is generated. Second, top k small differences in each row in the channel change difference matrix are normalized, and other N-k differences in the row are set to 0. Alternatively, k differences less than a preset value in each row in the channel change difference matrix may be set to 1, and other N-k differences in the row are set to 0. Alternatively, a difference in k differences less than a preset value in each row in the channel change difference matrix may be set to 1, and the other differences in the row may be set to 0, where k is a positive integer greater than 1 and less than N, and N is a positive integer. Then, in the loss function, the channel change difference matrix and the probability of each prediction value output by the neural network are called, a j^{th} row in the channel change difference matrix is read based on a target value j, and weighted summation is performed on data in the j^{th} row in the channel change difference matrix and the probability of the prediction value. Finally, an average value of all loss values obtained through calculation by using the loss function is obtained. As the training is performed, when a loss value of the training set is less than that of a validation set, overfitting occurs in the neural network. In this case, a hyperparameter may be adjusted to improve a network generalization ability and perform training again, or a current state of the neural network is stopped in advance. As the loss value decreases, the neural network is trained successfully, that is, the channel prediction model is obtained.

[0059] Optionally, after the channel prediction model is obtained through training, the channel prediction model may be trained to obtain an updated channel prediction model. For example, parameters of some layers in the channel prediction model may be kept unchanged, and parameters of some other layers are changed, to obtain the updated channel prediction model. After the channel prediction model is updated, the communications device may send the updated channel prediction model to another communications device in a wired or wireless manner. Optionally, a structure of the channel prediction model is a model of the neural network, and parameters (for example, a weight) in the model may be changed through training of the neural network, or may be changed in a value assignment manner. The communications device may send or receive locations and values of these parameters in a wired or wireless manner. The location may include a number of the channel prediction model to which the parameter belongs, a number of a layer in the channel prediction model to which the parameter belongs, and a number of a location in a parameter matrix of the layer in the channel prediction model to which the parameter belongs. For example, in transfer learning of a channel prediction model W, a base station may keep parameters of some layers in the channel prediction model unchanged, and change only a few parameters in the channel prediction model W, to predict a current channel environment. When a network is idle, the base station may alternatively broadcast, to a specific user, a parameter that needs to be modified, so that a communications device of the specific user updates the channel prediction model based on a modified parameter.

[0060] Further, optionally, in a process of updating the channel prediction model, an average bit error rate obtained after each update may be used as a reward or penalty measure, to reinforce learning of an update action of the channel prediction model, so as to obtain an optimal update action. Alternatively, an update action may be revoked. For example, decoding may be performed by using the updated channel prediction model, to obtain a bit error rate generated by the decoding, and a reward or penalty action is selected based on the bit error rate, or a scoring system is used based on the bit error rate. A lower bit error rate indicates being closer to a reward, or indicates a higher score. A higher bit error rate indicates being closer to a penalty, or indicates a lower score. Then, the reward, the penalty, or the score is fed back to a training module of the channel prediction model, to drive the training module to perform training in a reinforcement mechanism, to obtain the updated channel prediction model.

[0061] Further, optionally, in a process of updating the channel prediction model, a throughput obtained after each update may be used as a reward or penalty measure, to reinforce learning of an update action of the channel prediction model, so as to obtain an optimal update action. Alternatively, an update action may be revoked. For example, adaptive transmission may be performed by using the updated channel prediction model, to obtain a throughput generated by a transmission system, and a reward or penalty action is selected based on the throughput, or a scoring system is used based on the throughput. A higher throughput indicates being closer to a reward, or indicates a higher score. A lower throughput indicates being closer to a penalty, or indicates a lower score. Then, the reward, the penalty, or the score is fed back to a training module of the channel prediction model, to drive the training module to perform training in a reinforcement mechanism, to obtain the updated channel prediction model.

[0062] Fourth, the prediction value of the channel coefficient is determined based on the channel change value index prediction sequence.

[0063] During specific implementation, a channel coefficient change value prediction sequence corresponding to the channel change value index prediction sequence may be determined based on the vocabulary of channel changes. Then, the prediction value of the channel coefficient is determined based on the channel coefficient change value prediction sequence. For example, if the first channel coefficient change sequence is obtained by subtracting the channel coefficient at the former moment from the channel coefficient at the latter moment, the first channel coefficient change sequence is $\{x_2-x_1, x_3-x_2, x_4-x_3, ..., x_n-x_{n-1}\}$, and a channel coefficient change prediction sequence is $\{y_1, y_2, y_3, y_4, ..., y_n\}$. If the last value of the channel coefficient sequence is $y_0=x_n$, the prediction value of the channel coefficient is $\{y_0+y_1, y_0+y_1+y_2, y_0+y_1+y_2+y_3, ..., y_0+y_1+...+y_n\}$. If the first channel coefficient change sequence is obtained by subtracting the channel coefficient at the latter moment from the channel coefficient at the former moment, the channel coefficient change prediction sequence is $\{y_1, y_2, y_3, y_4, ..., y_n\}$. If the last value of the channel coefficient sequence is $y_0=x_n$, the prediction value of the channel coefficient is $\{y_0-y_1, y_0-y_1-y_2, y_0-y_1-y_2-y_3, ..., y_0-y_1-...-y_n\}$.

[0064] Optionally, after the prediction value of the channel coefficient in the second time period is determined based on the first channel coefficient sequence and the preset vocabulary of channel changes, demodulation or decoding may be performed on data based on the prediction value, or adaptive transmission may be performed based on the prediction value, to improve a system throughput. The adaptive transmission includes link adaptation, adaptive modulation, scheduling, power control, precoding selection, and the like.

[0065] Optionally, when a system throughput generated by performing the demodulation, decoding, or adaptive transmission by using the prediction value is higher than a prediction throughput threshold, channel prediction may be performed by using the channel prediction model. Conventional channel estimation may be used when a system throughput generated by performing the demodulation, decoding, or adaptive transmission by using the prediction value is not higher than a prediction throughput threshold.

[0066] For example, when a communications device A performs decoding by using the prediction value, channel estimation is not performed. When a bit error rate in a prediction termination time Tp exceeds a prediction bit error threshold Ft, the communications device A may directly disable the channel prediction model, and restart the channel estimation. Alternatively, the communications device A may request a communications device B to disable the channel prediction model. After receiving an instruction delivered by the communications device B, the communications device A disables the channel prediction model, and restarts the channel estimation. When the bit error rate in the prediction termination determining time Tp does not exceed the prediction bit error threshold Ft, the communications device A may continue to use the channel prediction model for prediction. The prediction termination determining time Tp is less than or equal to prediction duration T2. Optionally, when decoding is performed by using the prediction value, the channel prediction model is disabled after the bit error rate in the prediction termination determining time exceeds the prediction bit error threshold N times. Optionally, after the communications device A requests the communications device B to disable the channel prediction model, if no instruction sent by the communications device B is received after a waiting time length T, the communications device A may resend the request, or directly disable the channel prediction model and restart the channel estimation.

[0067] Optionally, demodulation, decoding, or adaptive transmission may be performed on data in a channel estimation window T1 by using a channel estimation value, or demodulation, decoding, or adaptive transmission may be performed on data in a channel prediction window T2 by using the prediction value of the channel coefficient. Alternatively, a channel estimation value obtained through channel estimation may be obtained, and a channel prediction weighted value is determined based on the channel estimation value obtained through the channel estimation and the prediction value. Demodulation, decoding, or adaptive transmission is performed on data in a channel prediction window T2 based on the channel prediction weighted value. Alternatively, channel estimation is performed in a former time period, and then prediction is performed in a latter time period by using the channel prediction model. Alternatively, extrapolation processing may be performed on a channel coefficient sequence in a channel prediction window, to obtain a channel extrapolation value in the channel prediction window. Then, a weighted mean of a channel estimation value, the channel extrapolation value, and the prediction value is determined, and demodulation, decoding, or adaptive transmission is performed by using the weighted mean. In this way, robustness of the channel prediction value can be improved.

[0068] In this embodiment of this application, the channel coefficient sequence including the plurality of complex values of the channel coefficient is obtained, the change values of the channel coefficient are determined, then the vocabulary of channel changes is searched for the channel change value index corresponding to each change value, to generate the channel change value index sequence, and the channel change value index sequence is input into the channel prediction model for prediction, to obtain the channel change value index prediction sequence. The complex-valued channel coefficient is predicted, so that original information of the channel coefficient is retained, and both an amplitude and a phase of a channel are predicted. This improves accuracy of the predicted channel coefficient. Prediction performed by using the channel prediction model may also improve efficiency of obtaining the channel coefficient.

[0069] FIG. 7 is a schematic structural diagram of a channel prediction apparatus according to an embodiment of this application. As shown in the figure, the apparatus in this embodiment of this application includes:

- an obtaining module 701, configured to obtain a first channel coefficient sequence in a first time period, where the first channel coefficient sequence includes a plurality of complex values of a channel coefficient; and
- a processing module 702, configured to determine a prediction value of the channel coefficient in a second time period based on the first channel coefficient sequence and a preset vocabulary of channel changes, where the vocabulary of channel changes includes a mapping relationship between a channel change value index and each change value of the channel coefficient, and the second time period is later than the first time period.

[0070] Optionally, the processing module 702 is further configured to: determine a first channel coefficient change sequence based on the first channel coefficient sequence, where the first channel coefficient change sequence includes a plurality of change values of the channel coefficient; search the vocabulary of channel changes for a channel change value index corresponding to each change value in the first channel coefficient change sequence, and generate a first channel change value index sequence; input the first channel change value index sequence into a channel prediction model for prediction, to obtain a channel change value index prediction sequence; and determine the prediction value of the channel coefficient based on the channel change value index prediction sequence.

[0071] Optionally, the processing module 702 is further configured to: subtract a complex value of the channel coefficient at a former moment from a complex value of the channel coefficient at a latter moment in the first channel coefficient sequence, to obtain each change value in the first channel coefficient change sequence; or subtract a complex value of the channel coefficient at a latter moment from a complex value of the channel coefficient at a former moment in the first channel coefficient sequence, to obtain each change value in the first channel coefficient change sequence.

[0072] Optionally, the processing module 702 is further configured to: determine, based on the vocabulary of channel changes, a channel coefficient change value prediction sequence corresponding to the channel change value index prediction sequence; and determine the prediction value of the channel coefficient based on the channel coefficient change value prediction sequence.

[0073] Optionally, the obtaining module 701 is further configured to obtain a second channel coefficient sequence, where the second channel coefficient sequence includes a plurality of complex values of the channel coefficient; and

the processing module 702 is further configured to: determine a second channel coefficient change sequence based on the second channel coefficient sequence, where the second channel coefficient change sequence includes a plurality of change values of the channel coefficient; search the vocabulary of channel changes for a channel change value index corresponding to each change value in the second channel coefficient change sequence, and generate a second channel change value index sequence; and input the second channel change value index sequence into a neural network for training, to obtain the channel prediction model.

[0074] Optionally, the obtaining module 701 is further configured to obtain a probability of each prediction value output by the neural network; and

the processing module 702 is further configured to: determine a difference between complex values of every two change values in the vocabulary of channel changes, and generate a channel change difference matrix; determine a weighted mean of probabilities of all prediction values based on the channel change difference matrix and the probability of each prediction value; and determine, based on the weighted mean, whether the neural network has completed training.

[0075] An input dimension of the neural network and an output dimension of the neural network are the same as a quantity of mapping relationships in the vocabulary of channel changes.

[0076] Optionally, the processing module 702 is further configured to: collect statistics on occurrence frequency of each of the plurality of change values of the channel coefficient; assign an integer to each change value of the channel coefficient based on the occurrence frequency, to obtain the channel change value index; and establish the mapping relationship between the channel change value index and each change value, to generate the vocabulary of channel changes.

[0077] Optionally, the processing module 702 is further configured to: when occurrence frequency of a target change value in the plurality of change values is greater than a preset threshold, assign an integer to the target change value of the channel coefficient.

[0078] Optionally, the processing module 702 is further configured to perform demodulation, decoding, or adaptive transmission on data based on the prediction value.

[0079] Optionally, the processing module 702 is further configured to: when a system throughput generated by performing the demodulation, decoding, or adaptive transmission by using the prediction value is higher than a prediction throughput threshold, perform channel prediction by using the channel prediction model.

[0080] Optionally, the obtaining module 701 is further configured to obtain a channel estimation value obtained through channel estimation; and

the processing module 702 is further configured to: determine a channel prediction weighted value based on the channel estimation value and the prediction value; and perform the demodulation, decoding, or adaptive transmission on the data based on the channel prediction weighted value.

[0081] It should be noted that, for implementation of the modules, further refer to corresponding descriptions in the method embodiment shown in FIG. 4, and the modules perform the method and function that are performed by the communications device in the foregoing embodiment.

[0082] FIG. 8 is a schematic structural diagram of a channel prediction device according to an embodiment of this application. As shown in FIG. 8, the channel prediction device 801 may include at least one processor 801, at least one communications interface 802, at least one memory 803, and at least one communications bus 804. Certainly, in some implementations, the processor and the memory may alternatively be integrated. The channel prediction device may be a chip.

[0083] In this embodiment of this application, the memory 803 may be configured to store a channel prediction model and a vocabulary of channel changes. The processor 801 may include a central processing unit, a baseband processor, and a neural network processor. For example, after receiving a channel prediction instruction of the baseband processor, the central processing unit may read the channel prediction model from the memory 803 and input the channel prediction model into the neural network processor, and the baseband processor writes a channel coefficient sequence into the neural network processor through a central processing unit. The neural network processor processes the channel coefficient sequence based on the vocabulary of channel changes, inputs a channel change value index sequence obtained through processing into the channel prediction model for prediction, and finally obtains a prediction value of the channel coefficient. Finally, the central processing unit writes the prediction value of the channel coefficient into the baseband processor, and the baseband processor performs demodulation, decoding, or adaptive transmission on data based on the prediction value.

[0084] The processor 801 may implement or execute various example logical blocks, modules, and circuits described with reference to content disclosed in this application. Alternatively, the processor may be a combination of processors implementing a computing function, for example, a combination of one or more microprocessors or a combination of a digital signal processor and a microprocessor. The communications bus 804 may be a peripheral component interconnect PCI bus, an extended industry standard architecture EISA bus, or the like. The bus may be classified as an address bus, a data bus, a control bus, or the like. For ease of representation, only one thick line is used to represent the bus in FIG. 8, but this does not mean that there is only one bus or only one type of bus. The communications bus 804 is configured to implement communication connection between these components. The communication interface 802 of the device in this embodiment of this application is configured to perform signaling or data communication with another node device. The memory 803 may include a volatile memory, for example, a nonvolatile dynamic random access memory (nonvolatile random access memory, NVRAM), a phase-change random access memory (phase change RAM, PRAM), or a magnetoresistive random access memory (magnetoresistive RAM, MRAM). The memory 803 may further include a nonvolatile memory, for example, at least one magnetic disk storage device, an electrically erasable programmable read-only memory (electrically erasable programmable read-only memory, EEPROM), a flash memory device such as a NOR flash memory (NOR flash memory) or a NAND flash memory (NAND flash memory), or a semiconductor device such as a solid-state drive (solid state drive, SSD). Optionally, the memory 803 may alternatively be at least one storage apparatus that is far away from the processor 80 The memory 803 stores a group of program code, and the processor executes a program stored in the memory 803 to perform the following operations:

obtaining a first channel coefficient sequence in a first time period, where the first channel coefficient sequence includes a plurality of complex values of a channel coefficient; and
determining a prediction value of the channel coefficient in a second time period based on the first channel coefficient sequence and a preset vocabulary of channel changes, where the vocabulary of channel changes includes a mapping relationship between a channel change value index and each change value of the channel coefficient, and the second time period is later than the first time period.

[0085] All or some of the foregoing embodiments may be implemented by using software, hardware, firmware, or any combination thereof. When software is used to implement the embodiments, the embodiments may be implemented completely or partially in a form of a computer program product. The computer program product includes one or more computer instructions. When the computer program instructions are loaded and executed on a computer, all or some of the procedures or functions according to the embodiments of this application are generated. The computer may be a general-purpose computer, a dedicated computer, a computer network, or another programmable apparatus. The computer instructions may be stored in a computer-readable storage medium or may be transmitted from a computer-readable storage medium to another computer-readable storage medium. For example, the computer instructions may be transmitted from a website, computer, server, or data center to another website, computer, server, or data center in a wired (for example, a coaxial cable, an optical fiber, or a digital subscriber line (DSL)) or wireless (for example, infrared, radio, and microwave, or the like) manner. The computer-readable storage medium may be any usable medium accessible by a computer, or a data storage device, such as a server or a data center, integrating one or more usable media. The usable medium may be a magnetic medium (for example, a floppy disk, a hard disk, or a magnetic tape), an optical medium (for example, a DVD), a semiconductor medium (for example, a solid-state drive (solid state drive, SSD)), or the like.

Claims

1. A channel prediction method, wherein the method comprises:

obtaining (S401) a first channel coefficient sequence in a first time period, wherein the first channel coefficient sequence comprises a plurality of complex values of a channel coefficient; and
wherein the method further comprises determining (S402) a prediction value of the channel coefficient in a second time period based on the first channel coefficient sequence and a preset vocabulary of channel changes, wherein the vocabulary of channel changes comprises a mapping relationship between channel change value indices and change values of the channel coefficient, and the second time period is later than the first time period.

2. The method according to claim 1, wherein the determining (S402) a prediction value of the channel coefficient in a second time period based on the first channel coefficient sequence and a preset vocabulary of channel changes comprises:

determining a first channel coefficient change sequence based on the first channel coefficient sequence, wherein the first channel coefficient change sequence comprises a plurality of change values of the channel coefficient;
searching the vocabulary of channel changes for a channel change value index corresponding to each change value in the first channel coefficient change sequence, and generating a first channel change value index sequence;
inputting the first channel change value index

sequence into a channel prediction model for prediction, to obtain a channel change value index prediction sequence; and
determining the prediction value of the channel coefficient based on the channel change value index prediction sequence.

3. The method according to claim 2, wherein the determining a first channel coefficient change sequence based on the first channel coefficient sequence comprises:

subtracting a complex value of the channel coefficient at a first moment from a complex value of the channel coefficient at a moment after the first moment in the first channel coefficient sequence, to obtain each change value in the first channel coefficient change sequence;or
subtracting a complex value of the channel coefficient at a second moment from a complex value of the channel coefficient at a moment before the second moment in the first channel coefficient sequence, to obtain each change value in the first channel coefficient change sequence.

4. The method according to claim 2 or 3, wherein the determining the prediction value of the channel coefficient based on the channel change value index prediction sequence comprises:

determining, based on the vocabulary of channel changes, a channel coefficient change value prediction sequence corresponding to the channel change value index prediction sequence; and
determining the prediction value of the channel coefficient based on the channel coefficient change value prediction sequence.

5. The method according to any one of claims 1 to 4, wherein the method further comprises:

obtaining a second channel coefficient sequence, wherein the second channel coefficient sequence comprises a plurality of complex values of the channel coefficient;
determining a second channel coefficient change sequence based on the second channel coefficient sequence, wherein the second channel coefficient change sequence comprises a plurality of change values of the channel coefficient;
searching the vocabulary of channel changes for a channel change value index corresponding to each change value in the second channel coefficient change sequence, and generating a second channel change value index sequence; and
inputting the second channel change value index sequence into a neural network for training, to obtain the channel prediction model.

6. The method according to claim 5, wherein the method further comprises:

obtaining a probability of each prediction value output by the neural network;
determining a difference between complex values of every two change values in the vocabulary of channel changes, and generating a channel change difference matrix;
determining a weighted mean of probabilities of all prediction values based on the channel change difference matrix and the probability of each prediction value; and
determining, based on the weighted mean, whether the neural network has completed training.

7. The method according to claim 5 or 6, wherein an input dimension of the neural network and an output dimension of the neural network are the same as a quantity of mapping relationships in the vocabulary of channel changes.

8. The method according to any one of claims 1 to 7, wherein the method further comprises:

collecting statistics on occurrence frequency of each of the plurality of change values of the channel coefficient;
assigning an integer to each change value of the channel coefficient based on the occurrence frequency, to obtain the channel change value index; and
establishing the mapping relationship between the channel change value index and each change value, to generate the vocabulary of channel changes.

9. The method according to claim 8, wherein the assigning an integer to each change value of the channel coefficient based on the occurrence frequency, to obtain the channel change value index comprises: when occurrence frequency of a target change value in the plurality of change values is greater than a preset threshold, assigning an integer to the target change value of the channel coefficient.

10. The method according to any one of claims 1 to 9, wherein after the determining (S402) a prediction value of the channel coefficient in a second time period based on the first channel coefficient sequence and a preset vocabulary of channel changes, the method further comprises:
performing demodulation, decoding, or adaptive

transmission on data based on the prediction value.

11. The method according to claim 10, wherein after the performing demodulation, decoding, or adaptive transmission on data based on the prediction value, the method further comprises:
when a system throughput generated by performing the demodulation, decoding, or adaptive transmission by using the prediction value is higher than a prediction throughput threshold, performing channel prediction by using the channel prediction model.

12. A channel prediction device, comprising a memory (803), a communications bus (804), and a processor (801), wherein the memory is configured to store program code, and the processor is configured to invoke the program code to perform the method according to any one of claims 1 to 11.

13. The channel prediction device according to claim 12, wherein the channel prediction device is a chip.

14. A computer-readable storage medium, wherein the computer-readable storage medium stores an instruction; and when the instruction is run on a computer, the computer is enabled to perform the method according to any one of claims 1 to 11.

15. A computer program product comprising an instruction, wherein when the computer program product runs on a computer, the computer is enabled to perform the method according to any one of claims 1 to 11.

Patentansprüche

1. Kanalprädiktionsverfahren, wobei das Verfahren umfasst:

Erhalten (S401) einer ersten Kanalkoeffizientensequenz in einem ersten Zeitraum, wobei die erste Kanalkoeffizientensequenz eine Vielzahl von komplexen Werten eines Kanalkoeffizienten umfasst; und
wobei das Verfahren ferner ein Bestimmen (S402) eines Prädiktionswerts des Kanalkoeffizienten in einem zweiten Zeitraum basierend auf der ersten Kanalkoeffizientensequenz und einem voreingestellten Vokabular von Kanaländerungen umfasst, wobei das Vokabular von Kanaländerungen eine Zuordnungsbeziehung zwischen Kanaländerungswertindizes und Änderungswerten des Kanalkoeffizienten umfasst, und der zweite Zeitraum später als der erste Zeitraum ist.

2. Verfahren nach Anspruch 1, wobei das Bestimmen (S402) eines Prädiktionswerts des Kanalkoeffizienten in einem zweiten Zeitraum basierend auf der ersten Kanalkoeffizientensequenz und einem voreingestellten Vokabular von Kanaländerungen umfasst:

Bestimmen einer ersten Kanalkoeffizientenänderungssequenz basierend auf der ersten Kanalkoeffizientensequenz, wobei die erste Kanalkoeffizientenänderungssequenz eine Vielzahl von Änderungswerten des Kanalkoeffizienten umfasst;
Durchsuchen des Vokabulars von Kanaländerungen für einen Kanaländerungswertindex, der jedem Änderungswert in der ersten Kanalkoeffizientenänderungssequenz entspricht, und Erzeugen einer ersten Kanaländerungswertindexsequenz;
Eingeben der ersten Kanaländerungswertindexsequenz in ein Kanalprädiktionsmodell für eine Prädiktion, um eine Kanaländerungswertindexprädiktionssequenz zu erhalten; und
Bestimmen des Prädiktionswerts des Kanalkoeffizienten basierend auf der Kanaländerungswertindexprädiktionssequenz.

3. Verfahren nach Anspruch 2, wobei das Bestimmen einer ersten Kanalkoeffizientenänderungssequenz basierend auf der ersten Kanalkoeffizientensequenz umfasst:

Subtrahieren eines komplexen Werts des Kanalkoeffizienten zu einem ersten Zeitpunkt von einem komplexen Wert des Kanalkoeffizienten zu einem Zeitpunkt nach dem ersten Zeitpunkt in der ersten Kanalkoeffizientensequenz, um jeden Änderungswert in der ersten Kanalkoeffizientenänderungssequenz zu erhalten; oder
Subtrahieren eines komplexen Werts des Kanalkoeffizienten zu einem zweiten Zeitpunkt von einem komplexen Wert des Kanalkoeffizienten zu einem Zeitpunkt vor dem zweiten Zeitpunkt in der ersten Kanalkoeffizientensequenz, um jeden Änderungswert in der ersten Kanalkoeffizientenänderungssequenz zu erhalten.

4. Verfahren nach Anspruch 2 oder 3, wobei das Bestimmen des Prädiktionswerts des Kanalkoeffizienten basierend auf der Kanaländerungswertindexprädiktionssequenz umfasst:

Bestimmen, basierend auf dem Vokabular von Kanaländerungen, einer Kanalkoeffizientenänderungswertprädiktionssequenz, die der Kanaländerungswertindexprädiktionssequenz entspricht; und
Bestimmen des Prädiktionswerts des Kanalkoeffizienten basierend auf der Kanalkoeffizientenänderungswertprädiktions-

sequenz.

5. Verfahren nach einem der Ansprüche 1 bis 4, wobei das Verfahren ferner umfasst:

Erhalten einer zweiten Kanalkoeffizientensequenz, wobei die zweite Kanalkoeffizientensequenz eine Vielzahl von komplexen Werte des Kanalkoeffizienten umfasst;
Bestimmen einer zweiten Kanalkoeffizientenänderungssequenz basierend auf der zweiten Kanalkoeffizientensequenz, wobei die zweite Kanalkoeffizientenänderungssequenz eine Vielzahl von Änderungswerten des Kanalkoeffizienten umfasst;
Durchsuchen des Vokabulars von Kanaländerungen für einen Kanaländerungswertindex, der jedem Änderungswert in der zweiten Kanalkoeffizientenänderungssequenz entspricht, und Erzeugen einer zweiten Kanaländerungswertindexsequenz; und
Eingeben der zweiten Kanaländerungswertindexsequenz in ein neuronales Netz für ein Training, um das Kanalprädiktionsmodell zu erhalten.

6. Verfahren nach Anspruch 5, wobei das Verfahren ferner umfasst:

Erhalten einer Wahrscheinlichkeit für jeden Prädiktionswert, der durch das neuronales Netz ausgegeben wird;
Bestimmen einer Differenz zwischen komplexen Werten von je zwei Änderungswerten in dem Vokabular von Kanaländerungen und Erzeugen einer Kanaländerungsdifferenzmatrix;
Bestimmen eines gewichteten Mittels von Wahrscheinlichkeiten von allen Prädiktionswerten basierend auf der Kanaländerungsdifferenzmatrix und der Wahrscheinlichkeit von jedem Prädiktionswert; und
Bestimmen, basierend auf dem gewichteten Mittel, ob das neuronale Netz das Training abgeschlossen hat.

7. Verfahren nach Anspruch 5 oder 6, wobei eine Eingabedimension des neuronalen Netzes und eine Ausgabedimension des neuronalen Netzes gleich einer Menge von Zuordnungsbeziehungen in dem Vokabular von Kanaländerungen sind.

8. Verfahren nach einem der Ansprüche 1 bis 7, wobei das Verfahren ferner umfasst:

Sammeln von Statistiken über die Auftrittshäufigkeit von jedem der Vielzahl von Änderungswerten des Kanalkoeffizienten;
Zuweisen einer ganzen Zahl zu jedem Änderungswert des Kanalkoeffizienten basierend auf der Auftrittshäufigkeit, um den Kanaländerungswertindex zu erhalten; und
Herstellen der Zuordnungsbeziehung zwischen dem Kanaländerungswertindex und jedem Änderungswert, um das Vokabular der Kanaländerungen zu erzeugen.

9. Verfahren nach Anspruch 8, wobei das Zuweisen einer ganzen Zahl zu jedem Änderungswert des Kanalkoeffizienten basierend auf der Auftrittshäufigkeit, um den Kanaländerungswertindex zu erhalten, umfasst:
wenn die Auftrittshäufigkeit eines Zieländerungswerts in der Vielzahl von Änderungswerten größer als ein voreingestellter Schwellenwert ist, Zuweisen einer ganzen Zahl zu dem Zieländerungswert des Kanalkoeffizienten.

10. Verfahren nach einem der Ansprüche 1 bis 9, wobei nach dem Bestimmen (S402) eines Prädiktionswerts des Kanalkoeffizienten in einem zweiten Zeitraum basierend auf der ersten Kanalkoeffizientensequenz und einem voreingestellten Vokabular von Kanaländerungen, das Verfahren ferner umfasst:
Durchführen einer Demodulation, Decodierung oder adaptiven Übertragung von Daten basierend auf dem Prädiktionswert.

11. Verfahren nach Anspruch 10, wobei nach dem Durchführen der Demodulation, Decodierung oder adaptiven Übertragung von Daten basierend auf dem Prädiktionswert, das Verfahren ferner umfasst:
wenn ein Systemdurchsatz, der durch Durchführen der Demodulation, Decodierung oder adaptiven Übertragung durch Verwenden des Prädiktionswerts erzeugt wird, größer als ein Prädiktionsdurchsatzschwellenwert ist, Durchführen einer Kanalprädiktion durch Verwenden des Kanalprädiktionsmodells.

12. Kanalprädiktionsvorrichtung, umfassend einen Speicher (803), einen Kommunikationsbus (804) und einen Prozessor (801), wobei der Speicher konfiguriert ist, um Programmcode zu speichern, und der Prozessor konfiguriert ist, um den Programmcode aufzurufen, um das Verfahren nach einem der Ansprüche 1 bis 11 durchzuführen.

13. Kanalprädiktionsvorrichtung nach Anspruch 12, wobei die Kanalprädiktionsvorrichtung ein Chip ist.

14. Computerlesbares Speichermedium, wobei das computerlesbare Speichermedium eine Anweisung speichert, und wenn die Anweisung auf einem Computer ausgeführt wird, der Computer aktiviert wird, um das Verfahren nach einem der Ansprüche 1 bis 11 durchzuführen.

15. Computerprogrammprodukt, umfassend eine Anweisung, wobei, wenn das Computerprogrammprodukt auf einem Computer ausgeführt wird, der Computer aktiviert wird, um das Verfahren nach einem der Ansprüche 1 bis 11 durchzuführen.

Revendications

1. Procédé de prédiction de canal, dans lequel le procédé comprend :

l'obtention (S401) d'une première séquence de coefficients de canal dans une première période de temps, dans lequel la première séquence de coefficients de canal comprend une pluralité de valeurs complexes d'un coefficient de canal ; et dans lequel le procédé comprend en outre la détermination (S402) d'une valeur de prédiction du coefficient de canal dans une seconde période de temps sur la base de la première séquence de coefficients de canal et d'un vocabulaire prédéfini de changements de canal, dans lequel le vocabulaire de changements de canal comprend une relation de mise en correspondance entre des indices de valeur de changement de canal et des valeurs de changement de coefficient de canal, et la seconde période de temps est postérieure à la première période de temps.

2. Procédé selon la revendication 1, dans lequel la détermination (S402) d'une valeur de prédiction du coefficient de canal dans une seconde période de temps sur la base de la première séquence de coefficients de canal et d'un vocabulaire prédéfini de changements de canal comprend :

la détermination d'une première séquence de changement de coefficient de canal sur la base de la première séquence de coefficients de canal, dans lequel la première séquence de changement de coefficient de canal comprend une pluralité de valeurs de changement du coefficient de canal ;
la recherche dans le vocabulaire des changements de canal d'un indice de valeur de changement de canal correspondant à chaque valeur de changement dans la première séquence de changement de coefficient de canal, et la génération d'une première séquence d'indice de valeur de changement de canal ;
l'entrée de la première séquence d'indice de valeur de changement de canal dans un modèle de prédiction de canal pour la prédiction, pour obtenir une séquence de prédiction d'indice de valeur de changement de canal ; et
la détermination de la valeur de prédiction du coefficient de canal sur la base de la séquence de prédiction d'indice de valeur de changement de canal.

3. Procédé selon la revendication 2, dans lequel la détermination d'une première séquence de changement de coefficient de canal sur la base de la première séquence de coefficients de canal comprend :

la soustraction d'une valeur complexe du coefficient de canal à un premier moment à partir d'une valeur complexe du coefficient de canal à un moment après le premier moment dans la première séquence de coefficients de canal, pour obtenir chaque valeur de changement dans la première séquence de changement de coefficient de canal ; ou
la soustraction d'une valeur complexe du coefficient de canal à un second moment à partir d'une valeur complexe du coefficient de canal à un moment avant le second moment dans la première séquence de coefficients de canal, pour obtenir chaque valeur de changement dans la première séquence de changement de coefficient de canal.

4. Procédé selon la revendication 2 ou 3, dans lequel la détermination de la valeur de prédiction du coefficient de canal sur la base de la séquence de prédiction d'indice de valeur de changement de canal comprend :

la détermination, sur la base du vocabulaire des changements de canal, d'une séquence de prédiction de valeur de changement de coefficient de canal correspondant à la séquence de prédiction d'indice de valeur de changement de canal ; et
la détermination de la valeur de prédiction du coefficient de canal sur la base de la séquence de prédiction de la valeur de changement de coefficient de canal.

5. Procédé selon l'une quelconque des revendications 1 à 4, dans lequel le procédé comprend en outre :

l'obtention d'une seconde séquence de coefficients de canal, dans lequel la seconde séquence de coefficients de canal comprend une pluralité de valeurs complexes du coefficient de canal ;
la détermination d'une seconde séquence de changement de coefficient de canal sur la base de la seconde séquence de coefficients de canal, dans lequel la seconde séquence de changement de coefficient de canal comprend une pluralité de valeurs de changement du coefficient de canal ;

la recherche dans le vocabulaire des changements de canal d'un indice de valeur de changement de canal correspondant à chaque valeur de changement dans la seconde séquence de changement de coefficient de canal, et la génération d'une seconde séquence d'indice de valeur de changement de canal ; et
l'entrée de la seconde séquence d'indice de valeur de changement de canal dans un réseau de neurones pour l'apprentissage, pour obtenir le modèle de prédiction de canal.

6. Procédé selon la revendication 5, dans lequel le procédé comprend en outre :

l'obtention d'une probabilité de chaque valeur de prédiction émise par le réseau de neurones ;
la détermination d'une différence entre des valeurs complexes de chaque deux valeurs de changement dans le vocabulaire des changements de canal, et la génération d'une matrice de différence de changement de canal ;
la détermination d'une moyenne pondérée des probabilités de toutes les valeurs de prédiction sur la base de la matrice de différence de changement de canal et de la probabilité de chaque valeur de prédiction ; et
la détermination, sur la base de la moyenne pondérée, du fait de savoir si le réseau de neurones a terminé l'apprentissage.

7. Procédé selon la revendication 5 ou 6, dans lequel une dimension d'entrée du réseau de neurones et une dimension de sortie du réseau de neurones sont identiques à une quantité de relations de mise en correspondance dans le vocabulaire des changements de canal.

8. Procédé selon l'une quelconque des revendications 1 à 7, dans lequel le procédé comprend en outre :

la collecte de statistiques sur la fréquence d'occurrence de chacune de la pluralité de valeurs de changement du coefficient de canal ;
l'attribution d'un entier à chaque valeur de changement du coefficient de canal sur la base de la fréquence d'occurrence, pour obtenir l'indice de valeur de changement de canal ; et
l'établissement de la relation de mise en correspondance entre l'indice de valeur de changement de canal et chaque valeur de changement, pour générer le vocabulaire des changements de canal.

9. Procédé selon la revendication 8, dans lequel l'attribution d'un entier à chaque valeur de changement du coefficient de canal sur la base de la fréquence d'occurrence, pour obtenir l'indice de valeur de changement de canal comprend :
lorsqu'une fréquence d'occurrence d'une valeur de changement cible dans la pluralité de valeurs de changement est supérieure à un seuil prédéfini, l'attribution d'un entier à la valeur de changement cible du coefficient de canal.

10. Procédé selon l'une quelconque des revendications 1 à 9, dans lequel après la détermination (S402) d'une valeur de prédiction du coefficient de canal dans une seconde période de temps sur la base de la première séquence de coefficients de canal et d'un vocabulaire prédéfini de changements de canal, le procédé comprend en outre :
la réalisation d'une démodulation, d'un décodage ou d'une transmission adaptative sur des données sur la base de la valeur de prédiction.

11. Procédé selon la revendication 10, dans lequel après avoir réalisé la démodulation, le décodage ou la transmission adaptative sur des données sur la base de la valeur de prédiction, le procédé comprend en outre :
lorsqu'un débit de système généré en réalisant la démodulation, le décodage ou la transmission adaptative à l'aide de la valeur de prédiction est supérieur à un seuil de débit de prédiction, la réalisation d'une prédiction de canal à l'aide du modèle de prédiction de canal.

12. Dispositif de prédiction de canal, comprenant une mémoire (803), un bus communications (804) et un processeur (801), dans lequel la mémoire est configurée pour stocker un code de programme et le processeur est configuré pour appeler le code de programme pour réaliser le procédé selon l'un quelconque des revendications 1 à 11.

13. Dispositif de prédiction de canal selon la revendication 12, dans lequel le dispositif de prédiction de canal est une puce.

14. Support de stockage lisible par ordinateur, dans lequel le support de stockage lisible par ordinateur stocke une instruction ; et lorsque l'instruction est exécutée sur un ordinateur, l'ordinateur est activé pour réaliser le procédé selon l'une quelconque des revendications 1 à 11.

15. Produit-programme informatique comprenant une instruction, dans lequel lorsque le produit-programme informatique est exécuté sur un ordinateur, l'ordinateur est activé pour réaliser le procédé selon l'une quelconque des revendications 1 à 11.

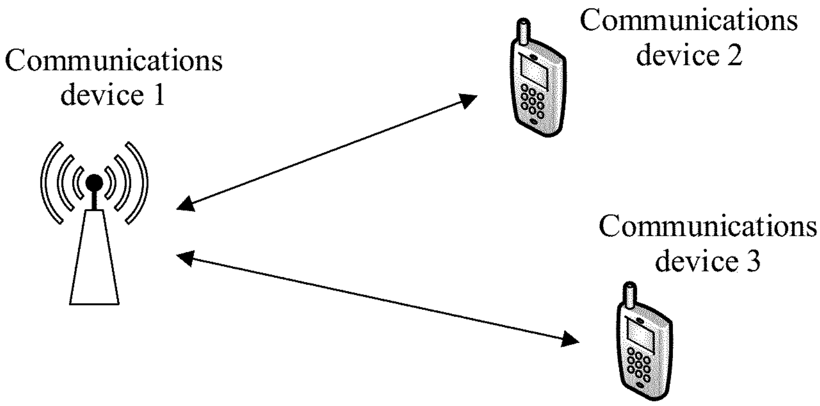
Communications
device 1
Communications
device 2
Communications
device 3

FIG. 1

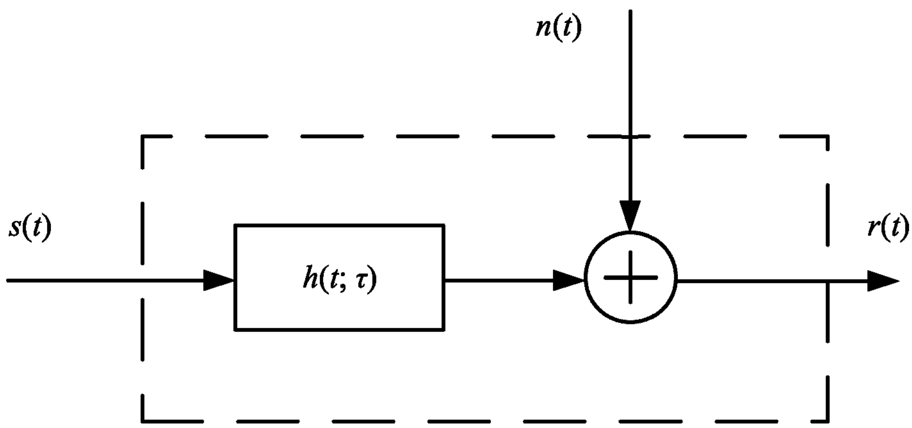
n(t)
s(t)
h(t; τ)
r(t)

FIG. 2

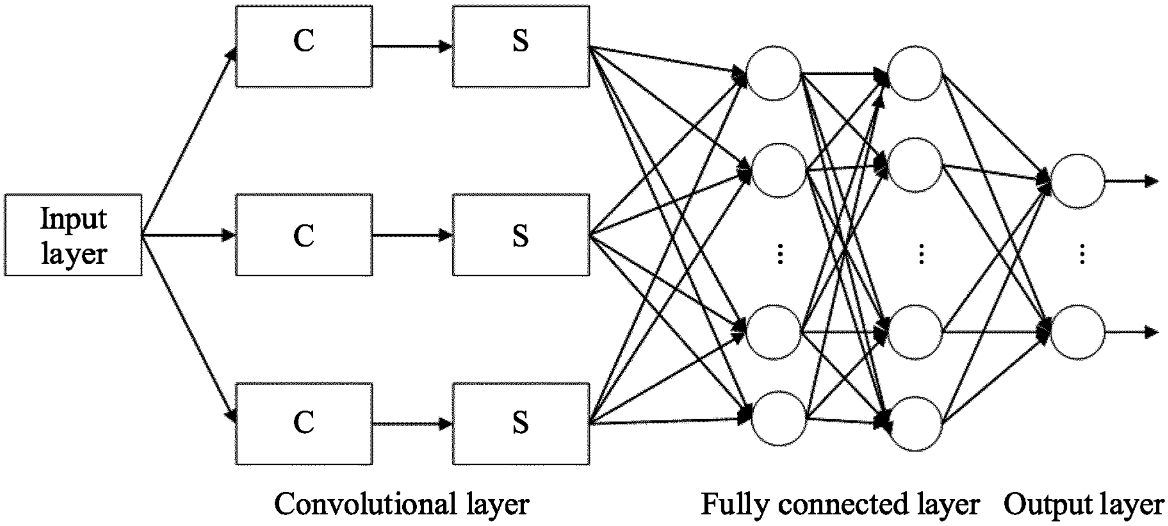
Input layer
C
S
C
S
C
S
Convolutional layer
Fully connected layer
Output layer

FIG. 3

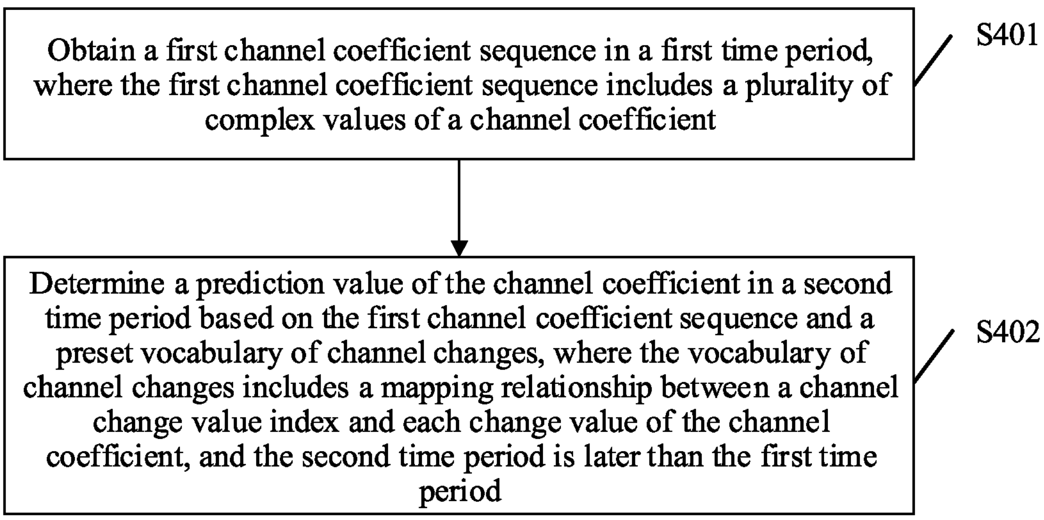
Obtain a first channel coefficient sequence in a first time period, where the first channel coefficient sequence includes a plurality of complex values of a channel coefficient
S401
Determine a prediction value of the channel coefficient in a second time period based on the first channel coefficient sequence and a preset vocabulary of channel changes, where the vocabulary of channel changes includes a mapping relationship between a channel change value index and each change value of the channel coefficient, and the second time period is later than the first time period
S402

FIG. 4

A vocabulary B of channel changes is degraded to first 11 elements in a vocabulary in a vector representation form
New word
'+0.02–0.02i'
'–0.02+0.02i'
'–0.02–0.02i'
'+0.02+0.02i'
'–0.02+0.01i'
'–0.01+0.02i'
'+0.01+0.02i'
'–0.02–0.01i'
'–0.01–0.02i'
'+0.01–0.02i'

FIG. 5

Top 10 pairs of most frequently occurring mapping relationships in a vocabulary of channel changes			Top 10 pairs of least frequently occurring mapping relationships in a vocabulary of channel changes		
Channel change value index	Change value of a channel coefficient	Occurrence frequency	Channel change value index	Change value of a channel coefficient	Occurrence frequency
1	'+0.02–0.02i'	538211	N–9	'+0.2–0.05i'	12
2	'–0.02+0.02i'	536925	N–8	'–0.04+0.2i'	12
3	'–0.02–0.02i'	535761	N–7	'–0.03+0.2i'	12
4	'+0.02+0.02i'	534726	N–6	'–0.1–0.2i'	12
5	'–0.02+0.01i'	373125	N–5	'–0.06–0.2i'	11
6	'–0.01+0.02i'	371946	N–4	'–0.05–0.2i'	11
7	'+0.01+0.02i'	371856	N–3	'+0.01+0.2i'	11
8	'–0.02–0.01i'	371778	N–2	'+0.2+0.01i'	11
9	'–0.01–0.02i'	371682	N–1	'+0.05+0.2i'	11
10	'+0.01–0.02i'	371673	N	'+0.2+0.05i'	11

FIG. 6

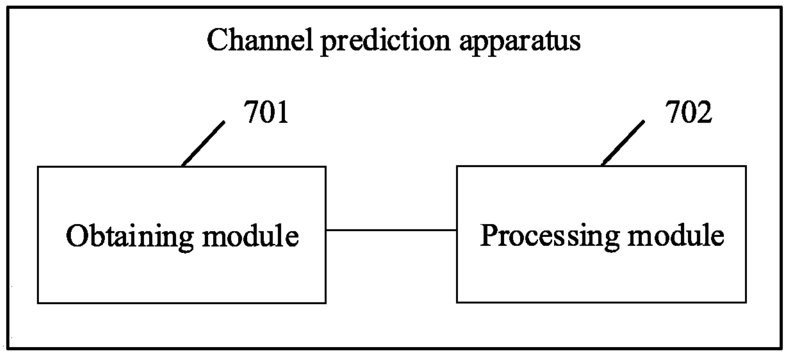
Channel prediction apparatus
701
702
Obtaining module
Processing module

FIG. 7

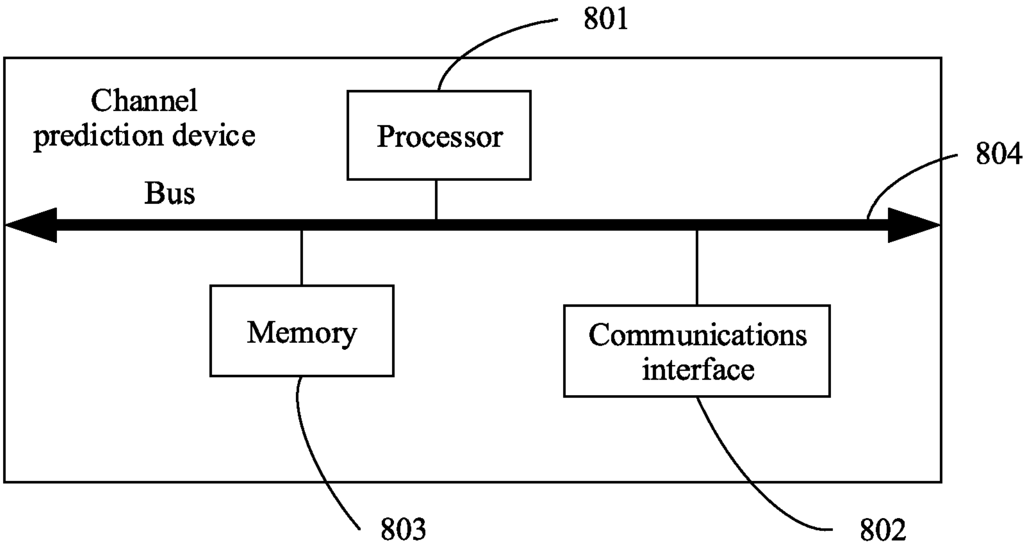
801
Channel
prediction device
Processor
804
Bus
Memory
Communications
interface
803
802

FIG. 8

REFERENCES CITED IN THE DESCRIPTION

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Non-patent literature cited in the description

- Multi-antenna fading channel prediction empowered by artificial intelligence. **JIANG WEI et al.** 88th IEEE Vehicular Technology Conference. August 2018, 1-6 **[0003]**