Virtual MIMO Communication Applied in WSNs

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Abstract

Virtual Multi-Input Multi-Output(MIMO) communication was presented based on the basis of the MIMO communication, compared with the traditional Single Input Single Output(SISO) communication, which has higher reliability, better communication channel capacity, more communication coverage, etc, and become the research hot topic in wireless sensor networks (WSNs). This article first introduces the principle and process of virtual MIMO, then expounds WSNs based on virtual MIMO, and lastly conclude this paper.

Keywords

Virtual Multi-Input Multi-Output(MIMO), Single Input Single Output(SISO), communication, wireless sensor networks(WSNs).

1. Introduction

MIMO communication is actually the communication mode of acquiring markedly space diversity gain through the technology of multiple antennas sending and receiving data. Using multiple antennas to send and receive data is equivalent to make signals transmit in several independent channels, which can effectively resist the channel fading, and improve the reliability of communication. At the same time, the spatial multiplexing gain in MIMO communication significantly increased the channel capacity of communication under the condition of keeping the original energy consumption and bandwidth of communication unchanged.

2. Virtual MIMO communication

2.1 The principle of virtual MIMO communication

The principle of virtual MIMO communication is as shown in Fig. 1, the sender and the receiver separately has N_t and N_r independent antennas. At the beginning of MIMO communication, the sender will do

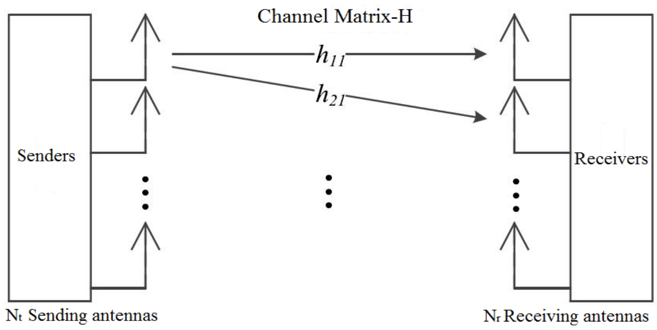

Fig. 1 The principle of MIMO communication

the data being sent with the corresponding dispose firstly, and then process the completed data to map Nt antennas to send; After the receiving end receives the data, using the corresponding decoding algorithm to deal with data, recovering the source data. The relationship between input and output in MIMO communication system as shown in the following formula:

$$y = Hx + w \tag{1}$$

There into, $y=[y_{1,}y_{2,}y_{3,}\cdots,y_{N_r}]^T$ means the received data sequences of N_r antennas at the receiving end, y_i corresponds to the *ith* antenna of the received device; $x=[x_{1,}x_{2,}x_{3,}\cdots,x_{N_t}]^T$ represents the sent data sequences of N_t antennas at the sending end, x_i corresponds to the *ith* antenna of the sender; $w=[w_{1,}w_{2,}w_{3,}\cdots,w_{N_r}]^T$ is the noise sequences, for the convenience of study, usually set w to be mean value with zero of the Gaussian white noise; H is the channel matrix of $N_r \times N_t$, as shown in the following formula:

$$H=\begin{bmatrix} h_{11},h_{12},\cdots,h_{1N_t} \\ h_{21},h_{22},\cdots,h_{2N_t} \\ \vdots,\vdots,\ddots,\vdots \\ h_{N_r1},h_{N_r2},\cdots,h_{N_rN_t} \end{bmatrix} \tag{2}$$

The elements- h_{ji} in the channel matrix expresses the channel gain coefficient about the antenna i of the sender and the antenna j of the receiver. Under the condition of known channel state information (CSI), determine the channel matrix H by the data transmission of the sender and the receiver. According to the channel matrix H regulating transmission power of each antenna, the sender achieves the best communication performance. When CSI is unknown, it is difficult to find an approximate power allocation scheme.

2.2 The classification of diversity technology

Compared with the traditional SISO communication systems, MIMO communication system can obtain better diversity gain and spatial multiplexing gain.

MIMO communication system in the process of data communication, can utilize diversity technology to increase the effect of the diversity gain. Diversity gain can effectively resist fading channel, and enhance the reliability of communication. The greater the diversity gain, the higher the reliability of communication system, the more wide the communication range. The idea of diversity is that several copies of a data sequence transmit in multiple independent channels at the same time; Receiving devices, according to the corresponding decoding algorithm, combine and decode these data, in order to get the raw data.

In wireless communication system, there are three main types of common diversity technologies: time diversity, frequency diversity and space diversity. Time diversity will cause certain communication latency, and frequency diversity needs larger communication bandwidth, and their implementation is relatively difficult. While it is relatively easy to implement spatial diversity, it will not result in a clear communication delays, and does not need additional communication bandwidth. Therefore, the technology of space diversity is one of the most commonly used in MIMO system.

Spatial diversity can be divided into two kinds: the sending end of space diversity, called transmission diversity, known as the receive diversity on that of the receiving end. Using maximal ratio combining (MRC) can achieve diversity gain at the receiving end. The realization of the transmission diversity needs to know full CSI at the sender. When CSI is unknown, space-time coding is used to implement the sender's diversity gain. At present, researchers have proposed a lot of space-time coding schemes, and one of the most classic scheme is Alamouti encoding.

2.3 Alamouti encoding

One of the important characteristic about Alamouti encoding is its encoded data sequence to be orthogonal, and its principle as shown in Fig. 2. Alamouti encoder uses two modulated symbol x_1 and x_2 as a group, according to the matrix of Fig. 2 to encode, and then the sequence of encoded separately is mapped to the transmitting antennas. The receiver restores the original source data by maximum likelihood decoding.

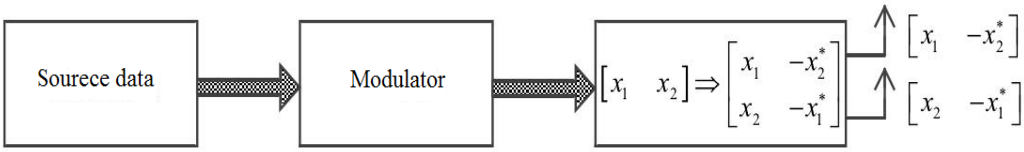

Fig. 2 The principle of Alamouti encoding

2.4 The process of virtual MIMO communicaton

In order to achieve the effect of MIMO communication, multi-antenna communication equipment of antennas must be independent of each other at work. Under ideal conditions, to make the antennas be independent of each other, the interval between any two antennas needs greater than one half of the carrier wavelength. In WSNs, the volume of nodes is small, which is usually difficult to realize MIMO communication. To realize MIMO communication in WSNs, researchers combine MIMO communication with cooperative communication, carry out the virtual MIMO communication. Several single antenna's nodes, through collaborative communication, form a virtual antenna array and then proceed virtual MIMO communication, which can obtain communication effect similar to MIMO communication. Based on virtual MIMO in WSNs as shown in Fig. 3, the source nodes (SN), adopting SISO communication, transmit the source data to the cluster head (CH), CH relays the received data to its own cooperative nodes (CN), after completing spatial encoding, CH and its cooperative nodes (CHN) form virtual double antenna sending end, through MIMO channel, and send data to multiple antenna of data gathering nodes (DGN). Although the sender is virtual double antenna array in virtual MIMO communication, it also can realize full spatial diversity gain, and achieve communication effect similar to MIMO.

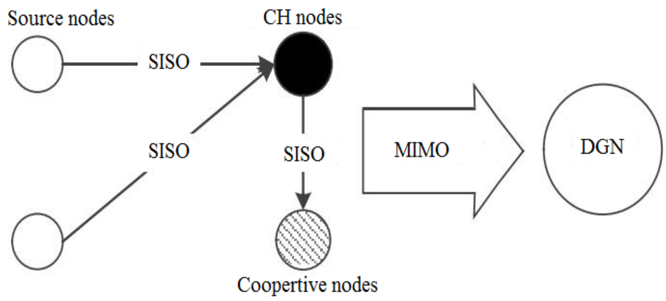

Fig. 3 WSNs based on virtual MIMO

3. WSNs based on virtual MIMO

Based on virtual MIMO of WSNs in the building of a network, adopt the corresponding clustering protocol (such as LEACH protocol) to cluster network, and then use the corresponding routing protocol to the appropriate communication path for each cluster planning. When the network set up is completed, sensor nodes begin collecting data, according to the corresponding communication strategies to transmit data to a specific network devices. In WSN, take a two sending and receiving virtual MIMO communication as an example, the communication process is as shown in Fig. 4, which is divided into communications within the cluster (intra-communication) and cluster communication (inter-communication).

Data gathering node (DGN) is a special network node, whose main function is to collect and process data from the ordinary node. DGN's volume is larger, has multiple antennas of transceiver system and strong ability of operation, and its energy is not limited. In Fig. 4, DGN is a network node with dual antennas system. Within the cluster communication stage, the two source nodes(SN) first package source data, and then using the SISO communication send the data to cluster heads(CHs);

After CHs complete the data collection, from their members choose a cooperative node (CN), and form a virtual double antenna array; CHs will relay their own collected data to their CN to proceed the space-time encoding. After the completion of space-time encoding, CHs and their cooperative nodes (CHNs) start on intra-communication. During the phase of intra-communication, CHs and CHNs forming virtual and dual antennas array, through the MIMO channel, send data to DGN.

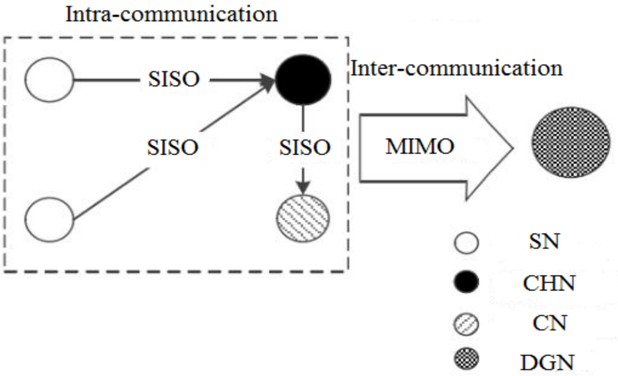

Fig. 4 The 2×2 virtual MIMO communication

4. Conclusion

In a word, the virtual MIMO of WSNs can enhance the reliability of the node communication, increase the efficiency of communication, and improve the energy-saving effect of WSNs. In the future work, we will combine distributed source encoding (DSC) with virtual MIMO to more efficiently reduce the energy consumption of communication and improve the communication efficiency.

Acknowledgements

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