MIMO techniques and MAC protocol in wireless sensor network

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1. Introduction

Wireless sensor network (WSN) is a network of many smart devices or nodes which communicates wirelessly with each other. Sensor network was operate with small batteries which hard to replace and very expensive. Thus, cooperative MIMO techniques have been used in WSN to reduce the energy consumption in the sensor nodes to allow the battery save the energy constraint. There are three major techniques in cooperative MIMO such as beam forming, spatial multiplexing and space time code. In addition, MAC protocol which suitable with the cooperative MIMO transmission is required. Combination of MAC protocol and cooperative MIMO can achieve more energy efficient and lower latency for the sensor network.

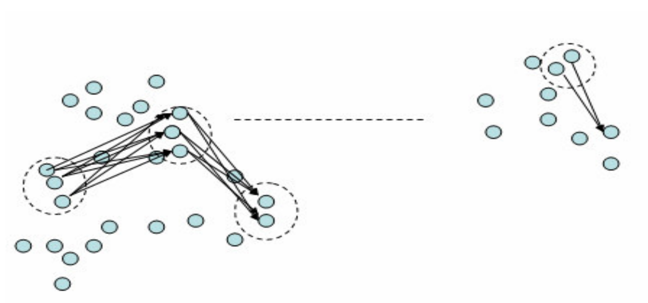

Figure 1: Nodes cooperate in transmission and/or reception of packets by forming virtual antenna arrays

2. Cooperative MIMO techniques

Cooperative MIMO techniques are useful for future cellular networks which consider wireless mesh network or wireless ad-hoc network. In wireless ad-hoc network, multiple transmit nodes communicate with multiple receive nodes. Cooperative MIMO is potential for enhancing energy efficiency [1]. This concept is based on traditional MIMO strategy. There are three types of MIMO techniques: beam forming, spatial multiplexing and space time code.

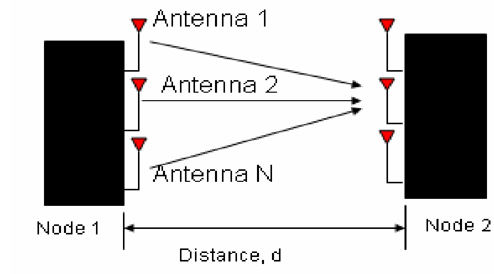

Figure 2: Traditional MIMO concept

2.1 Beam forming (BF)

Beam forming technique needs the channel information at the transmitter where each signal is weighted with this channel information before being transmit. But, it is difficult to provide the output from the receiver to transmitter about channel information before data transmission were used [2-5].

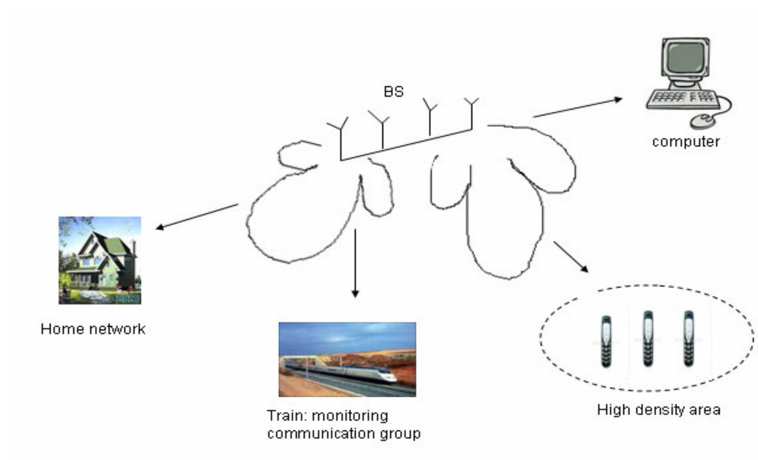

Figure 3: Beam forming technique

2.2 Spatial-multiplexing (SM)

Spatial multiplexing technique doesn't need the channel information at the transmitter. This technique can provide the higher data rate. Beside that, spatial multiplexing combat the deep fading phenomenon with the same diversity gain as beam forming technique [2].

2.3 Space time code (STC)

Space time code is a process to improve the reliability of data transmission in wireless communication system using multiple transmit antenna. Space time code doesn't need the channel information at the transmitter. Space time code depends on transmitting multiple, duplicate copies of a data stream to the receiver. Thus, at least some of them will survive between transmitter and receiver in good condition to allow the decoding process [6]. In space time code there are divided into two parts which are space time block code (STBC) and space time trellis code (STTC). Space time block code (STBC) provide only diversity gain but Space time trellis code

(STTC) can provide both coding gain and diversity gain and have a better bit error rate performance. However, this technique is more complex than space time block code to encode and decode [2].

3.0 MAC protocol

The combination of MAC protocol and cooperative transmission can make the energy efficient and lower latency [2]. MAC protocol was categorized into six: number of channels used, topology, synchronization, number of hops and random, scheduled and depending on design requirement. There are many types of MAC protocol which can use in this combination between MAC and cooperative MIMO transmission. Below are a few examples of MAC protocol.

3.1 S-MAC (Sensor MAC)

S-MAC used periodic sleep with virtual clusters features. The active period for this S-MAC is fixed at 115ms and the wake up period can take up to hundreds of milliseconds. The sleep period is adjustable. The active period for this method is divided in to three phases: SYNC, RTS and CTS. For the each phase, it was divided into time slots and each node uses the CSMA mechanism. [7].Each nodes learn the sleep schedule from its neighbours. After the SYNC phase, any node which want to transmit data need to face the channel. Any node will listen to the channel and received RTS or CTS packet. However, if the packet is not the target of the receiver, its extracts and learn the data transmission information from network allocation vector (NAV), thus enter to sleep mode. This method performance leads to higher latency because any transmitter needs to wait for the next cycle to send its data [2].

3.2 Adaptive S-MAC

This protocol is the improvement of S-MAC where nodes with network allocation vector (NAV) info wake-up around the time when data transmission expected to be finished. The nodes wait for a few times to listen for any incoming packets. By using this protocol, the latency was decreased to half [2]. But there are still energy wasted when there are no activities in the network and the active portion is remains idle.

3.3 T-MAC

This protocol is introducing to reduce the impact by using the S-MAC protocol. T-MAC can make the active period shorter. However this method increases the latency while the energy is reduced. But, T-MAC is not suitable for high load network [2].

3.4 B-MAC (Berkeley MAC)

B-MAC is different with CSMA with a preamble sampling mechanism. The preamble sampling is made better with a selective sampling method. In this method, only energy above the noise is considered. This selective measure makes sure that the receiver not wasting the energy to the unimportant activities [2].The adjustable for channel sampling was made at the receiver side when any unimportant activities are detected. If the channel is busy and the energy is above the noise floor, the receiver will turn on until the data packet is received. However, B-MAC leads to high transmission and reception power. Thus, the latency is high and overhearing.

3.5 Z-MAC

This protocol is the combination of strength between TDMA and CSMA while offset setting their weaknesses [2, 8]. Z-MAC achieves high channel utilization and low- latency under low contention like CSMA. Beside that, Z-MAC achieves high channel utilization under high contention and reduces collision among two-hop neighbours at a low cost like TDMA. A distinctive feature of Z-MAC is that its performance is robust to synchronization errors, slot assignment failures and time- varying channel conditions; in the worst case, its performance always falls back to that of CSMA. This method has advantage over B-MAC under medium to high contention while it shows competitive. However, Z-MAC performance is low than B-MAC under low contention especially for energy efficiency.

3.6 X-MAC

This method proposed the used of a series of short preamble packets with destination address is embedded in the packet [2]. the idea to embed address information of the target in the preamble. Thus, non-target receivers can quickly go back to sleep [9]. This method can reduce the total energy efficiency and the reception energy.

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