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Wireless Sensor Network with MIHOP technique & Mobile Sink

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Abstract— various radio applications in wireless sensor network where sensor nodes operate on batteries so that energy consumption must be minimized while satisfying given throughput and delay requirements. A major portion of the energy expenditure is when the nodes close to the sensor network gateways used for data collection typically suffer a large overhead as these nodes must relay on data from the remaining network. In this paper we discuss various existing energy efficient schemes for WSN and one new method to achieve efficiency, is proposed. The MIHOP (MIMO and Multi-hop) method combines cluster-based virtual MIMO and multi-hop technologies. The multi hop mode is employed in transmitting data when the related sensors are located within a specific number of hops from the sink, and the virtual MIMO mode is used in transmitting data from the remaining sensor nodes. A controllable mobile sink that reduces the energy consumed in sensor transmission is also adopted for data collection.

Index Terms*- Mobile sink; wireless sensor networks; MIHOP, energy efficiency.*

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I. INTRODUCTION

Although main power consumption term in a traditional wireless systems is due to the energy required for actual transmissions, this may not be the case in an energy-limited wireless sensor network. In fact, in some cases it is the circuit energy needed for receiver and transmitter processing that is dominant. Thus, in designing energy efficient techniques for such sensor networks one should consider both circuit and transmission power consumption terms.

The problem of data collection in sparse sensor networks is encountered in many scenarios. The objective is to collect data from sensors and deliver it to an access point in the infrastructure. These systems are expected to run unattended for long periods of time (order of months). The principal constraint is the energy budget of the sensors which is limited due to their size and cost. One of the major energy expenditures is in communicating the sensor readings, in raw or processed form, from the sensors to a central user location. Usually, these readings are relayed to a base station using ad hoc multi hop routes in the sensor network. A problem with this approach, however, is that the nodes closer to the base station relay data from nodes that are farther away. Thus, the nodes closest to the base station consume batteries faster than the remaining network, leading to a non uniform depletion of energy in the network. Once the nodes with connectivity with the base station exhaust their energy, the network is disconnected and, hence, considered dead for all practical purposes. A significant advantage in network lifetime can be gained if the energy spent in relaying data can be saved. An alternative for data transfer that does not involve relaying it over multiple hops is to use mobility. A mobile node moving through the network deployment region can collect data from the static sensor nodes over a single hop radio link as and when the mobile node is within radio range of the static nodes. This naturally avoids multi hop relaying and reduces the energy overhead at nodes near the base station, enabling the network to last longer. This may increase the latency of data transfer, but is acceptable in several delay-tolerant applications, such as in environmental studies, city traffic monitoring application, habitat monitoring scenario [2]. In certain applications, mobile elements already exist in the deployment environment and a network node can be attached to these mobile elements for data collection Otherwise, mobile nodes can be added to the system for data collection. In this case, the mobile node is a part of the network infrastructure itself and can be controlled by the network as required.

Enhancing the energy efficiency of transmission is advantageous because transceivers consume substantial energy. Hence the scheme, called MIHOP (MIMO and Multi-hop) is used which combines the advantages of multi-hop and STBC based virtual MIMO technologies [1]. In MIHOP, a mobile sink is managed so that it moves along a prepared path and pauses at certain locations to broadcast routing information. The sensor nodes near the sink are located within a specific predefined number of hops, and constitute a multi-hop network. Each node transmits data to the sink hop by hop.

The sensor nodes further from the sink uses STBC-based virtual MIMO technology to transmit data.

II.RELATED WORK

Energy conservation in Wireless Sensor Networks (WSNs) has always been a crucial issue and has received increased attention in the recent years. Numerous techniques, such as multi-hop [3] and virtual MIMO [4-6], as well as mobile data gathering schemes [7-9], have been developed for this purpose.

2.1MIMO & Cooperative MIMO

Multiple-input-multiple-output (MIMO), or multiple antenna, communication is one of the techniques that has gained considerable importance in wireless systems during recent years. However, a drawback of MIMO techniques is that they could require complex transceiver circuitry and large amount of signal processing power that may lead to large power consumptions at the circuit level. Thus, in evaluating the applicability of MIMO techniques to energy-limited wireless sensor networks, one should take into account the circuit power consumption as well as the transmit power consumption. In virtual MIMO-based cooperative communications architecture for energy-limited wireless sensor networks. Virtual multiple transmit antenna arrays are created out of single antenna sensor nodes via local transmissions. The sensor nodes in a wireless sensor network can be of small dimensions. Thus, it may not be realistic for these sensor nodes to have multiple antennas. However, it is possible to implement a *virtual MIMO communication architecture* in such energy-limited, distributed wireless sensor networks via sensor cooperation, as reported in [10].

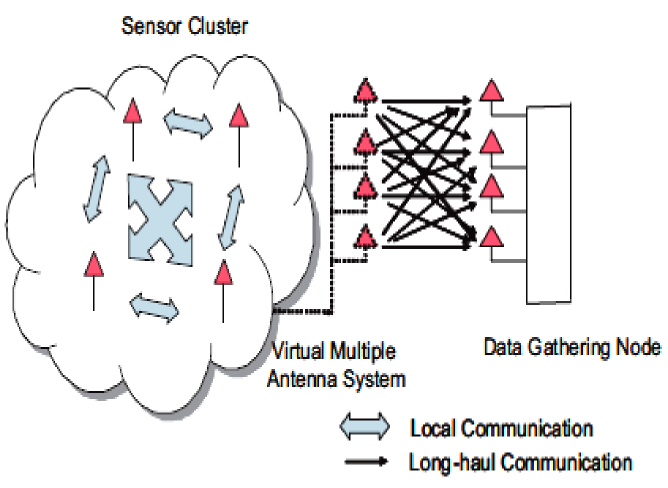

Fig.1 A virtual MIMO communication-based wireless sensor network

A common scenario in distributed wireless sensor networks is that of a lead-sensor and a set of data collection nodes (Fig. 1). In such a wireless sensor network model, the proposed virtual MIMO-based communications can be achieved as follows: Suppose a set of data collection nodes have data to be sent to the *data gathering* node (DGN). Each of these sensors which are assumed to be close to each other broadcasts their data to the others in the set using a time-division multiple-access scheme. This step is known as the local communications at the transmitter side. At the end of this step each of the data collection nodes have data from all the sensor nodes. This enables space-time block coding assuming each data collection node corresponds to a distinct transmit antenna element in a centralized multiple transmit antenna system. Once the space-time coding is performed each sensor node transmits the space-time code symbols corresponding to a specific transmit antenna element to the DGN. This step is known as the longhaul communications. The DGN is assumed to be different from the low-end data collection nodes. First, it does not have any energy constraints attached to it (or compared to the data collection nodes, the DGN has much longer battery life). Second, this sensor can be of larger physical dimensions thus enabling it to have multiple receiver antenna capability. This allows realization of true MIMO capability with only the transmitter side local communications.

2.1 Multihop Routing

Multi-hop routing and direct transmission are conventional transmission schemes for WSNs. In multi-hop networks, encoded data are generated and transmitted by one sensor to an intermediate node, and then relayed to a sink hop by hop. Ref. [3] shows that multi-hop transmission is more energy-efficient than single-hop transmission in general WSNs. However, when a sink is far from the sensor area or the area is so large that most sensor nodes need numerous hops to reach the sink, considerable retransmitting energy is consumed during transmission, thereby significantly accelerating node depletion.

III. PROPOSED METHOD

The MIHOP (MIMO and Multi-hop) scheme combines cluster-based virtual MIMO and multi-hop technologies. The multihop mode is employed in transmitting data when the related sensors are located within a specific number of hops from the sink, and the virtual MIMO mode is used in transmitting data from the remaining sensor nodes.

3.1 MIHOP System model

Figure 2 illustrates the system model of MIHOP. The sink works similar to a base station that broadcasts and gathers information. In the multi-hop network formation stage, a sink broadcasts routing information packets, and the sensors that receive the packets function as first-hop nodes. These nodes rebroadcast the routing information packets in wireless channels, and the entire multi-hop network is created through the hop-by-hop routing of an algorithm. The range of a multi-hop network is limited by maximum number of hops M_H, which can be optimized according to the model proposed further. This optimization minimizes energy consumption. Every two nodes with hops greater than M_H form a cluster on the basis of minimum cooperation range [1].

The STBC-based virtual MIMO scheme proposed which is adopted for data transmission to a sink. The nodes in one cluster are assumed located on the same tier of the virtual MIMO network, and the distance between two adjacent tiers is denoted as r (Figure 2).

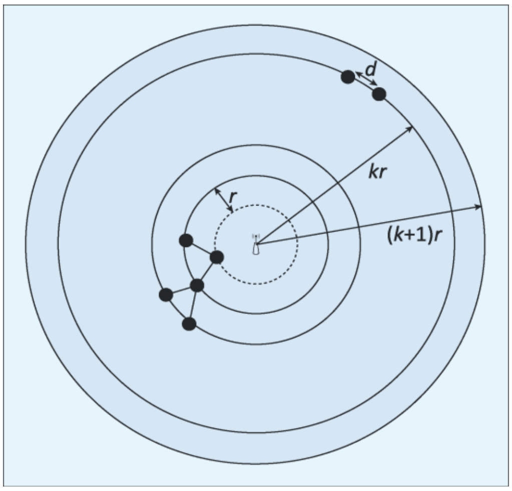

Fig.2 System model of MIHOP

Two nodes in one cluster should be located on the k^{th} tier and the collaboration distance between these nodes is expressed as d. The transmission distance from node to sink is denoted as k_r. Remaining single nodes can transmit data to a sink by SISO technology alone. After each sensor selects a transmission mode, the TDMA schedule is used by the sink to determine the sequence at which the sensors transmit data.

3.2 Mobile Sink

Existing methods indicate that multi-hop networks are advantageous for data transmission in small areas, whereas virtual MIMO schemes are more energy efficient for large-area transmission. A mobile sink is managed so that it moves along a prepared path and pauses at certain locations to broadcast routing information. The sensor nodes near the sink are located within a specific predefined number of hops, and constitute a multi-hop network. Each node transmits data to the sink hop by hop. The sensor nodes further from the sink may use STBC-based virtual MIMO technology to transmit data.

Suppose N sensor nodes are distributed in the sensing area as shown in Figure 3, to which a mobile sink is introduced. Adaptive Motion Control algorithm is used to control the motion of the mobile node [7]. We can adapt the node speed according to the network conditions to improve the data collection performance. For instance, the mobile node can spend more time in regions where the network is dense or the channel is obstructed and less time in regions where there are no or few nodes in connectivity. This sink is employed to enable movement along a fixed path, which is a cross path. It pauses at certain data gathering points to broadcast BEACON packets and periodically collect data from sensor nodes. The sink is equipped with two antennas, and each sensor has a single antenna for uploading data. Every packet has a fixed length of L bits. The network layer algorithms are used to select a route from the sink to each sensor in the multi-hop network.

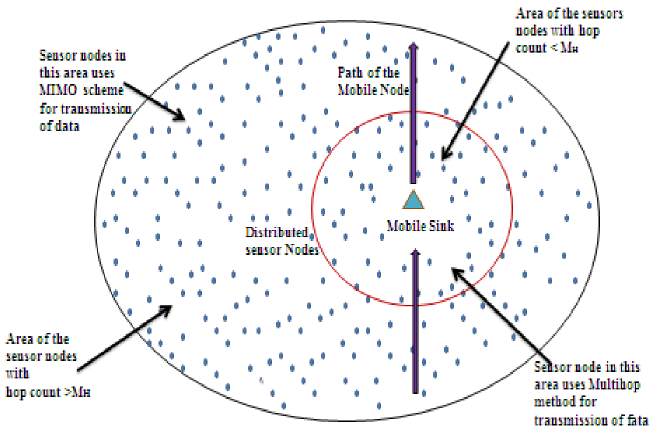

Fig.3 MIHOP System

Each sensor node maintains a parameter N_{hop}, which represents the shortest hop count to the mobile sink. The value of N_{hop} is initialized as infinite, but the N_{hop} on the mobile sink is set as 0. In the training phase, the mobile sink stops at a data gathering point and broadcasts BEACON packets with M_H and K. K is initialized as 0. Each sensor node receiving the BEACON packet adds 1 to K, then updates its N_{hop} into N_{hop} = min {N_{hop}, K} and rebroadcasts the BEACON with the new K. This process continues until all the nodes in the network receive a BEACON hop by hop. The mobile sink then moves onto the next point and again broadcast routing information. After the training phase, sensor nodes with N_{hop} higher than M_H form into clusters and the virtual MIMO mechanism is used to transmit data to the mobile sink. Other nodes with N_{hop} lower or equal to M_H adopt multi-hop transmission technology. Design flow for MIHOP technique is shown below:

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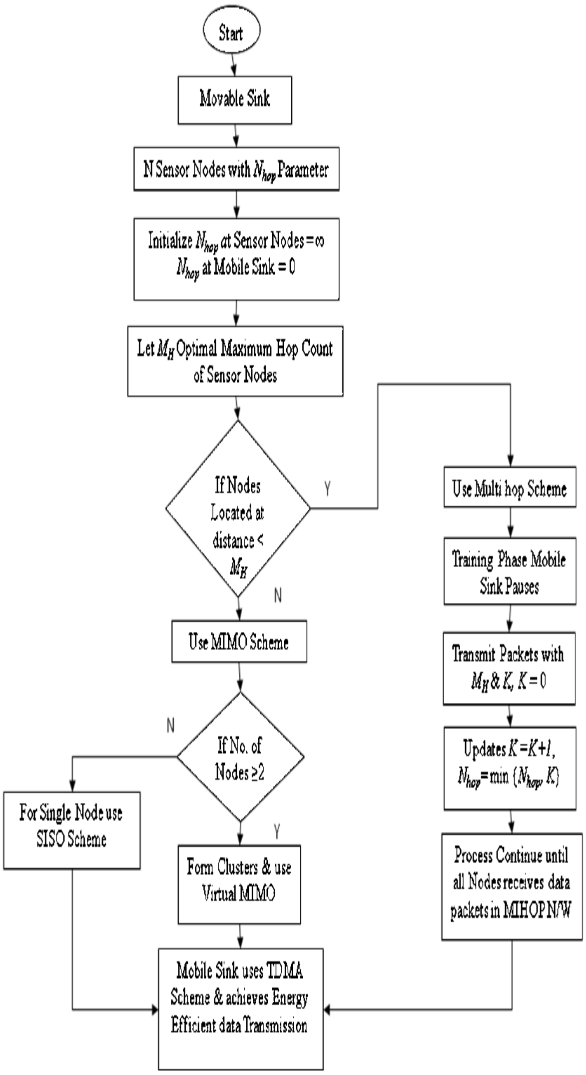

Fig.4. Design Flow for MIHOP Technique

The algorithm for determining M_H is described as follows,

1. Initialize $M_H = 1$; r is a fixed value
2. While TRUE
3. If $E^{i}_{Multihop}(M_H,r) < E^{i}_{MIMO}(M_H \times r)$
4. M_H^{++}
5. else
6. break;
7. end while.

In this algorithm E^{i}_{MIMO} is the energy consumption of the i^{th}

node that belongs to the j^{th} cluster in the virtual MIMO scheme.

3.3 Path of Mobile Sink Node:

By selecting cross path (X-path) of mobile sink node we can save more energy of sensor nodes since mobile sink in Cross path covered more area in less time. The different paths of mobile sink node are shown below [7].

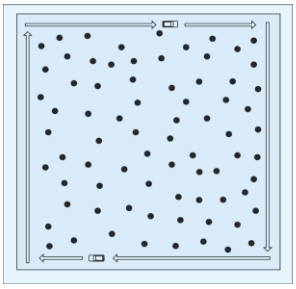

Fig. 5 Rectangular path

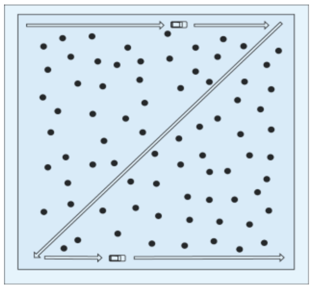

Fig. 6 Zigzag path

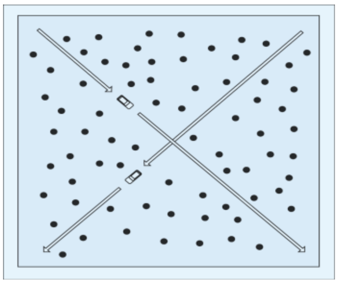

Fig.7 X path cover maximum area in less time

IV. ENERGY CONSUMPTION MODEL OF MIHOP

The total energy consumption $E_{MIHOP\text{-}total}$ of the MIHOP scheme comprises three components: the energy consumption levels of the multi-hop network, virtual MIMO scheme, and SISO scheme. N_{M1}, N_{M2} and N_{M3} are assumed to be the number of sensor nodes in the multi-hop network, virtual MIMO scheme, and SISO scheme, respectively. N_{total} denotes the total number of nodes in the MIHOP scheme, where $N_{total} = N_{M1} + N_{M\,2} + N_{M}$. If n_i indicates the i^{th} node in different transmission modes, its energy consumption E_i can be expressed as,

$$E^{i} = \begin{cases} E^{i}_{Muitihop} & When\ n_i\ is\ in\ the\ multi-hop\ network \\ E^{i}_{MIMO} & When\ n_i\ is\ in\ the\ virtual\ MIMO\ scheme \\ E^{i}_{SISO} & When\ n_i\ is\ in\ the\ SISO\ scheme \end{cases}$$

Thus, $E_{MIHOP\text{-}total}$ can be expressed as follows,

$$E_{MIHOP\_total} = \sum_{i=1}^{N_{total}} E^{i} = \sum_{i=1}^{N_{M_1}} E^{i}_{Mulitihop} + \sum_{i=1}^{N_{M_2}} E^{i}_{MIMO} + \sum_{i=1}^{N_{M_3}} E^{i}_{SISO}$$

Thus using Mobile Sink node along with MIHOP technique more amount of sensor's energy can be saved.

V. CONCLUSIONS

A new energy-efficient transmission scheme for mobile data gathering in WSNs is proposed. The motivation for doing this was to save energy in the embedded sensor nodes and increase the useful service time of a deployed system. The MIHOP technique combines cluster-based virtual MIMO and multi-hop technologies along with mobile sink node. The key intuition was that using a mobile node to establish shorter data routes reduces the data relaying overhead, especially at the nodes close to the data egress point in the network. The sensor nodes within two hops operate in multi-hop mode as they transmit data, and the remaining nodes operate in virtual MIMO or SISO mode. An algorithm for determining the optimal number of hops required to form a multi-hop network is derived, and the energy consumption model of MIHOP is developed. The MIHOP scheme significantly outperforms individual virtual MIMO, multi-hop technologies and in terms of energy efficiency.

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