Journal of Theoretical and Applied Information Technology
10th August 2014. Vol. 66 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

A POWER AWARE TRANSMISSION SCHEME SELECTION WITH DATA AGGREGATION FOR WIRELESS SENSOR NETWORKS

[1]I.S.AKILA , [2]Dr.R.VENKATESAN
[1]Assistant Professor, Department of ECE, Coimbatore Institute of Technology, India – 641 014
[2]Professor, Department of CSE, PSG College of Technology, India – 641 004
E-mail: [1]akila_subramaniam@yahoo.co.in, [2]ramanvenkatesan@yahoo.com

ABSTRACT

Many sensor applications today demand the need of extended lifetime. Among the most popular approaches which address this issue, Multiple Input Multiple Output (MIMO) and Single Input Single Output (SISO) techniques explore environment-specific performance constraints of achieving this target. Under a constant bit error rate, MIMO saves a considerable transmit power and then increases the lifetime. However, the increased overhead imposed on MIMO favors the choice of non-cooperative SISO in some sensor applications. To combine the merits of both of these approaches, this paper employs selection mechanism which suggests a suitable approach. A transmission scheme is modeled through a non-transferable coalition formation game which is destined towards prolonging network lifetime. Along with the existing scenario, we also ensure fairness of the power distribution using the centralized data-aggregation scheme in our proposed methodology. The simulation results demonstrate the improved performance of our approach in a Wireless Sensor Network application.

Keywords: *Coalition Formation, MIMO, SISO, Centralized Data Aggregation, Wireless Sensor Networks*

1. INTRODUCTION

Today various applications of Wireless Sensor Networks (WSN) have attracted significant attention. Even though the applications vary from military environment to home-automation, the limited size of sensors makes power consumption, an inevitable issue to be addressed, irrespective of the topologies and areas of application. In many cases where batteries are not rechargeable, it makes the situation worsen and highly constrains the lifetime of the sensor network over this factor.

The classical approaches in improving the lifetime of a WSN may also result in adverse impacts at certain circumstances due to the contractive nature of requirements. Dietrich and Dressler [21] have indicated that the definition of the lifetime itself becomes a complex process in a WSN.

Considering the employment of new techniques alone cannot guarantee optimized solutions and it has been widely observed in the literature that the overhead that is highly doped with these solutions may create adverse effects. The most interesting part of this problem is the inherent tradeoff among numerous performance factors which defines the margins of performance. Sliding over few of these parameters may result in the failure of WSN under specific circumstances.

The introduction of clustering arrives at improved lifetime in this atmosphere. Again, the overloading of cluster heads and sinks obviously complicates the process. Distributed load balancing mechanism is required in such scenarios.

Linear models seldom succeed in optimizing such complicated environment, which leaves very limited clues to find a solution. The selection of tools also has to been done with the closer observation on its adverse effects.

In [15], Raghunathan et al. have reported several existing solutions and various challenges that may adhere to these techniques. Availability of these multiple solutions not only allows flexible choice of requirements but also builds a complexity in the selection overhead. With an optimizing perception, our work analyzes and synthesizes the efficiency mechanisms contributed from these works.

The rest of the paper is organized as follows. Section 2 analyzes the traditional and recent works of this problem. Section 3 describes

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

the proposed system of our work. Section 4 presents the performance valuation of this approach against existing methodologies. Section 5 concludes the findings of this work.

2. RELATED WORK

As prolonging the lifetime of a WSN becomes the essential need of today's applications, many emerging solutions focusing this issue have been proposed in the recent years. It is indicated that the lifetime of a sensor network is heavily influenced by the power consumption process of that network. In [13] Pantazis and Vergados addressed limitations from various research works focusing this issue.

One novel idea proposed towards this issue is the MIMO transmission scheme to employ multiple sensors co-operatively working together to attain this target. Information theory yields encouraging system performance and improved channel capacity as a result of this approach [25, 26]. These MIMO schemes are broadly classified into spatial multiplexing and space-time coding techniques. As the results of works proposed in [12] and [14], optimal solutions are recommended for cluster-based cooperative MIMO systems, but the power dissipation at circuit blocks is ignored in these approaches. In [19], Cui et al. employed Alamouti diversity scheme to form a power efficient cooperative MIMO system. Again, this becomes a biased solution since the remaining energy of active cluster nodes are not considered here.

In [11], Pillutha and Krishnamurthy analyze the two conventional transmission schemes, namely SISO and cooperative MIMO methods, and they further investigated the tradeoff between energy and mutual information. As a proceeding of this work, Elhawaey and Hass presented a typical model of cooperative transmission and analyzed its characteristics [3].

Another form of solving power constraints is to reduce redundancy of data in transmission. The data that is collected from multiple sensors generally exhibits significant amount of correlation and redundancy, which motivates researchers to employ data aggregation techniques to supply a fused data after the removal of these features to the sink. Rajagopalan et al. adopted this mechanism for both flat and hierarchical networks [16]. In the work proposed by Gao et al. [4], an energy model which gains from both cooperative MIMO method and data aggregation process has been constructed. A tradeoff is also experienced among the goals of the data aggregation process such as energy, latency and accuracy of data in our survey [21, 23]. However, this solution demands proper formation of clusters and limited size of clusters which may not suit many real time sensor applications. In [24], it has been identified that constructing an optimal data aggregation tree is a NP-hard problem. To improve the lifetime of WSNs, cooperative MIMO scheme is adopted in recent approaches. While overhead occupies a major role, SISO scheme is promoted by these applications. Hence, it is required to select the appropriate transmission scheme for the network to prolong its lifetime.

As an emerging optimization tool, game theory is applied on various sensor networking problems to administer the complex scenarios and inputs. In [8], Ren and Ming have proposed a power aware game model for non-cooperative heterogeneous sensor networks. This model ignores the ground reality of sensor networks to cooperate on a common task. In [5], Islam and Kim have recommended an power-efficient cooperative technique for a WSN where selected numbers of sensors at the transmitting end are used to form a MIMO structure. An efficient game modeling was contributed for coalition formation in wireless and cognitive networks in [9]. In [2], another improvement has been introduced through an efficient mechanism which aims at selecting the proper transmission scheme. Renzo et al. tested [1] the effectiveness of MIMO scheme in fading channels in their experimental model.

Through the insight obtained through this survey on power aware approaches, the scope of improving the lifetime of WSN by integrating the data aggregation along with the power aware transmission scheme selection has to be focused further. As motivated from the experimental results of the above mentioned works, we attempt to develop a system that improves the lifetime of WSN under these emerging needs.

3. PROPOSED SYSTEM

3.1 Data Aggregation

In data aggregation technique, the correlation between the data depends on the distance at which nodes are placed. Our work inherits a centralized data-aggregation scheme (CAS) proposed by Gao et al. [4] which perceives and reduces the communication overhead of the network. If the

Journal of Theoretical and Applied Information Technology
10th August 2014. Vol. 66 No.1

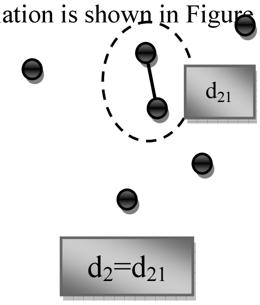
ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

nodes are placed very closely to each other, then the data sensed by the nodes will be almost similar and redundant. So, the redundancy can be reduced using some centralized scheme.

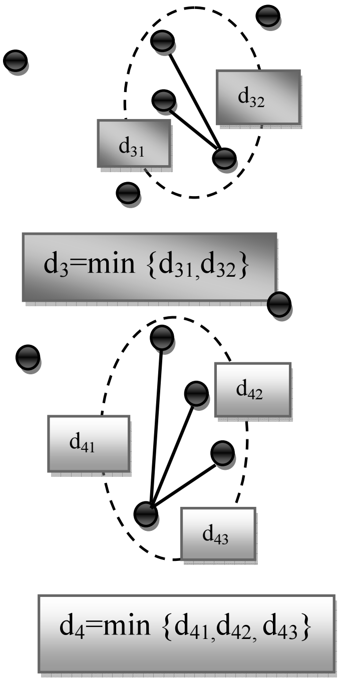
In our methodology, the clusters are formed based on LEACH (Low Energy Adaptive Clustering Hierarchy) protocol. In this technique, the Cluster Head (CH) collects all the data from the cluster nodes (CN). This phase is called gathering phase. Since the cluster head is having data processing capabilities, the degree of correlation of data can be defined as a function of the distance between a CN to CH. This information can be effectively used in compression phase for the purpose of redundancy removal. In broadcasting phase, the integrated, compressed data is sent from the cluster head to all cluster nodes.

Power consumption has to be considered in all three phases determining the total power conservation of this scheme. In gathering phase, power dissipation is calculated from that of the power amplifier and all other circuit blocks. Based on the amount of data to be compressed, the power conservation is determined in compression phase. In broadcasting phase, power amplifier and other circuitry are again considered to compute the power dissipated.

While utilizing the role of spatial correlation of data in determining the effectiveness of the mentioned compression phase, sensor applications could progress towards significant part of power saving. By assuming an empirical data set that pertains to rainfall as devised in Pattern et al. [22] and lossless compression, the minimum distance between the i^{th} node and the existing set of nodes becomes a dominant determining factor of the quantity of the data that is compressed. The procedure of calculating this minimum distance in spatial correlation is shown in Figure 1.



(a)



(c)

Figure 1: CAS Technique

3.2. Coalition Formation Game

Game theory is recently used as the tool for analyzing and studying the behavior of the nodes in a communication network in various research works [6, 9]. Cooperative game theory can be applied to significant applications in wireless networks.

In coalitional games, there is a set of players denoted by N = {1,........., N } in which each individual is ready to cooperate with each other and to form a stable coalition. The value that is obtained after forming the coalition is called coalition value 'v'. The characteristic value of a coalition depends on the players within the coalition and not on the other coalitions.

Definition 1: Depending on the action taken by a player within the coalitional structure 'S', it can receive a value x_i of a vector $x \in v(S)$ which is the result of a non transferable utility game.

Definition 2: Two coalitions $A = \{A_1,\dots,A_l\}$ and $B=\{B_1,\dots,B_m\}$ are compared using some preference order $\triangleright$ so that the coalition A is preferred over coalition B if $A \triangleright B$.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Apt and Witzel [7, 17] have analyzed partial preference relations between partitions of a grand coalition to model coalition formation in their works. Among them, this work inherits Pareto Order which has been defined as the preference order which votes for A over B, if at least one player in A is able to improve without decreasing the pay off of other players when coalition changes from B to A. The main rule for merging two coalitions is as follows.

Merge rule:

If $\bigcup_{j=1}^{m} A_j \rhd \{A_1, \dots, A_m\}$, then the set of coalition can be merged as $\{A_1, \dots, A_m\} \rightarrow \bigcup_{j=1}^{m} A_j$

3.3. Power Consumption Model

The total average power consumption for SISO and MISO schemes in our work can be contributed from the following two components:

1) The power consumption of the power amplifiers P_{pow_amp} and

2) The power consumption of all the other circuit blocks P_{ckt}.

A typical environmental setup has been exercised in aforementioned works [10, 20]. It has been observed that P_{pow_amp} is dependent on the transmit power P_{txn} and the component P_{ckt} *is* composed of $P_{ckt,txn}$ at the transmitter side and $P_{ckt,rxn}$ at the receiver side.

The circuit power consumption during transmission $P_{ckt,txn}$ is given by

$$P_{ckt,txn} = P_{DAC} + P_{MIX} + P_{FILT} + P_{SYN} \quad (1)$$

Similarly the circuit power consumption during reception $P_{ckt,rxn}$ is given by

$$P_{ckt,rxn} = P_{LNA} + P_{MIX} + P_{FILR} + P_{SYN} + P_{IFA} + P_{ADC} \quad (2)$$

where P_{DAC}, P_{MIX}, P_{LNA}, P_{IFA}, P_{FILT}, P_{FILR}, P_{ADC} and P_{SYN} are the power consumption values for the digital-to-analog converter (DAC), the mixer, the Low-Noise Amplifier (LNA), the Intermediate Frequency Amplifier (IFA), the active filters at the transmitter side, the active filters at the receiver side, the Analog to Digital Converter (ADC), and the frequency synthesizer, respectively.

The power consumption of power amplifier P_{pow_amp} is dependent on the transmit power P_{txn} and is given by $P_{pow\_amp} = (1+\alpha)P_{txn}$ where $\alpha = \left(\frac{\xi}{\eta}\right) - 1$, in which η is the drain efficiency of the RF power amplifier, and ξ is the peak-to-average ratio (PAR), which is dependent on the modulation scheme and the associated constellation size is adopted from the experimental environment of Cui et al. [20].

$$\xi = 3\left(\frac{\sqrt{M} - 1}{\sqrt{M} + 1}\right)$$

The modulation scheme selected is MQAM where M is selected as 4. The total amount of compressed data generated by a set of *n* nodes after lossless compression can approximately be calculated by the iterative formula contributed by Gao et al. [4].

$$I_i = I_{i-1} + \left[1 - \frac{1}{\left(\frac{d_i}{c}\right) + 1}\right] L \quad (3)$$

where c is a constant that refers to the degree of spatial correlation in the data, and d_i is the minimum distance between the i^{th} node and the existing set of nodes.

In case of the non-cooperative SISO, there is only one CH to transmit the data to the sink node. The power that is consumed by the sink node is omitted, because its power can be supplied from external source. The total average power consumed in SISO scheme is given by

$$P_{SISO}^{TA} = \frac{I}{nL}\left[P_{SISO} + P_{ga}^{CH} + P_{comp}^{DA}\right] \quad (4)$$

where I is the number of bits after data aggregation, n is the number of cluster nodes present with in a cluster and L is the number of bits before data aggregation. It is composed of three components, P_{SISO}, P_{ga}^{CH} and P_{comp}^{DA}. These components represent power consumption during broadcasting, data gathering and compression phases, respectively.

Journal of Theoretical and Applied Information Technology
10th August 2014. Vol. 66 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Power consumption in SISO broadcasting phase is given by:

$$P_{SISO} = P_{ckt,txn,SISO} + (1 + \alpha)P_{txn,SISO} \quad (5)$$

where $P_{ckt,txn,SISO}$ is calculated according to (1).

For data gathering phase, P_{ga}^{CH} is the power required by the CH for gathering data from all other cluster nodes within the cluster is formulated as:

$$P_{ga}^{CH} = P_{ckt,rxn,SISO} \quad (6)$$

Final component of equation (4), P_{comp}^{DA} is the power required by CH for aggregating the data that is sent by the cluster nodes. It is calculated as:

$$P_{comp}^{DA} = nLP^{comp} \quad (7)$$

In terms of the selected cooperative MIMO case, the CH selects M_t active CNs and broadcasts the data to these CNs during the local-broadcasting transmission phase. Then, the selected M_t CNs form the virtual MISO channels with the CH based on Distributed Space-Time Codes (DSTCs). Finally, the CNs communicates with the sink node together during the long-haul MISO transmission phase.

In equation (8), $P_{MISO,TA}^{CH}$ denotes the total average power consumed by a cluster head under MISO broadcasting, gathering and compression phases.

$$P_{MISO,TA}^{CH} = \frac{I}{nL}\left[P_{MISO}^{CH} + P_{ga}^{CH} + P_{comp}^{DA}\right] \quad (8)$$

MISO broadcasting phase due to CH:

$$P_{MISO}^{CH} = P_{txn,LB}^{CH} + P_{ckt,txn,LB}^{CH} + P_{pow\_amp}^{CH} + P_{ckt,txn,MISO}^{CH} \quad (9)$$

An extended version of Equation (9) is presented as follows:

$$P_{MISO}^{CH} = \left\{(1+\alpha)P_{LB} + (1+\alpha)P_{txn,MISO}^{CH} + P_{ckt,txn,LB}^{CH} + P_{ckt,txn,MISO}^{CH}\right\} \quad (10)$$

where $P_{ckt,txn,LB}^{CH}$ denotes the circuit power consumption in a CH due to the local broadcasting. $P_{ckt,txn,MISO}^{CH}$ represents the circuit power consumption in a CH due to the long haul transmission.

Gathering phase:

$$P_{ga}^{CH} = P_{ckt,rxn,MISO} \quad (11)$$

Compression phase:

Power consumption at this phase is similar to that of SISO mechanism and Equation (7) can be reproduced to calculate the final component of Equation (8).

The power component $P_{MISO,TA}^{CN}$ in Equation (12) denotes the total average power consumed by cluster nodes when they are transmitting in MISO. Here broadcasting and gathering phases only influence power consumption process. Similarly, the average power consumption for the CN_i and its inherent components are given by following Equations (12), (13) and (15). Broader forms of Equations (13) and (15) are represented in Equations (14) and (16), respectively.

$$P_{MISO,TA}^{CN} = P_{MISO}^{CN} + P_{ga}^{CN} \quad (12)$$

MISO broadcasting phase due to CN_i:

$$P_{MISO}^{CN} = P_{ckt,rxn,LB}^{CN} + P_{pow\_amp}^{CN} + P_{ckt,txn,MISO}^{CN} \quad (13)$$

$$P_{MISO}^{CN} = P_{ckt,rxn,LB}^{CN} + (1+\alpha)P_{txn,MISO}^{CN} + P_{ckt,txn,MISO}^{CN} \quad (14)$$

Gathering phase:

$$P_{ga}^{CN} = P_{ckt,txn,LB}^{CN} + P_{txn,LB}^{CN} \quad (15)$$

$$P_{ga}^{CN} = P_{ckt,txn,LB}^{CN} + [1+\alpha]P_{LB} \quad (16)$$

Journal of Theoretical and Applied Information Technology
10th August 2014. Vol. 66 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

$P^{CN}_{ckt,rxn,LB}$ is the receiver circuit power consumption in CN_i due to the local broadcasting done by CH.

3.4. Transmission Power

A path loss exponent δ and Raleigh fading frequency are incorporated in the modelling of the local-broadcasting and the long-haul MISO channels. During the formation of clusters, the CH is informed about its channels with the active CNs of the cluster. On the other hand, the long-haul MISO transmission does not yield this channel knowledge of the sink to the transmitting members, except for the CH. More precisely, for the non-cooperative SISO case, the CH directly transmits data, with power $P_{txn,SISO}$ to the sink node. To guarantee the quality-of-service (QoS) requirement of the WSN, the outage probability P_{out} has been restricted not to be larger than the threshold value P^{thr}_{out} for a fixed outage capacity C as assumed by Wu et al. [2].

$$P_{txn,SISO} = \frac{(2^c-1)\sigma^2 k^{-1} D^\delta}{\Gamma^{-1}(P_{out},1)} \quad (17)$$

where D is the distance between the cluster and the sink node, k is a constant which is an environmental dependent, σ^2 is the Gaussian noise variance.

$$\Gamma(x,a) = \frac{1}{\Gamma(a)}\int_0^a e^{-t} t^{(a-1)} dt \quad (18)$$

where, $x = \Gamma^{-1}(y,a)$

For the selected cooperative MISO case, the following two issues have to be considered:
1) The set of assisting CNs and
2) The transmit power of the transmitting members.

Assume M_t CNs have been chosen here. Due to the broadcast nature of the wireless channel, once the assisting node CN_j , has received data from the CH, the remaining assisting CNs can simultaneously receive these data. The power that is needed for broadcasting between the CH and its assisting node CN_j, i.e., P_{LB} can be presented as follows:

$$P_{LB} = \frac{(2^c-1)\sigma^2 k^{-1} d_i^\delta}{\left|h_{CH,CN_j}\right|^2} \quad (19)$$

where d_i *is* the distance between the CH and the cluster node CN_j, and h_{CH,CN_j} represents a unitary-power Rayleigh fading co-efficient between the CH and the CN_j.

After the broadcasting data is received by the assisting CNs, they form the virtual MISO channels with the CH and jointly transmit to the sink node, with the transmit power, $P^{CH}_{txn,MISO} = P^{CN}_{txn,MISO}$, during the long-haul MISO transmission. The transmission based on DSTCs with the transmit power per each node is depicted in Equations (20) and (21).

$$\frac{P^{CH}_{txn,MISO}}{M_t} = \frac{P^{CN}_{txn,MISO}}{M_t} \quad (20)$$

$$P^{CH}_{txn,MISO} = P^{CN}_{txn,MISO} = \frac{(2^{2c}-1)\sigma^2 k^{-1} D^\delta M_t}{\Gamma^{-1}(P_{out},M_t)} \quad (21)$$

3.5. Network Lifetime

Network lifetime becomes a principal need of any sensor application which makes the design of WSN critical across practical scenarios. We have inherited the definition of network lifetime as the period till the first node depletes its complete energy or none of the sensor nodes has enough energy to successfully transmit data as depicted from the works of Wu.et al.[2], Zhai et al. [10] and Himsoon et al. [18].

The lifetime of node i, can be calculated as follows: Consumed energy of the CH per unit time is calculated as [2]:

$$E_c = 1 * P^{TA}_{SISO} = P^{TA}_{SISO} \quad (22)$$

3.5.1. Lifetime calculation in SISO

In SISO, lifetime of the cluster head is formulated as the ratio of the remaining energy after cluster formation to the energy consumed by the CH. As per any active cluster node, CN_i is concerned, theoretically has infinite lifetime since it does not participate in communication.

$$T^{TA}_{SISO} = \frac{E_r}{E_c} \quad (23)$$

Journal of Theoretical and Applied Information Technology
10th August 2014. Vol. 66 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Here, E_r is the energy that is remaining in the node and E_c is the energy consumed by a CH in unit time.

As mentioned above the network lifetime is determined using Equation (24).

$$T_{net} = min\{T_{CH}^{SISO}, T_{CN1}^{SISO}, T_{CN2}^{SISO}, \dots . T_{CN_{n-1}}^{SISO}\} \quad (24)$$

3.5.2. Lifetime calculation in MISO:

For MISO, the energy depleted by a CH per unit time and its lifetime are calculated, respectively:

$$E_{CH} = 1 * P_{MISO,TA}^{CH} = P_{MISO,TA}^{CH} \quad (25)$$

$$T_{MISO,TA}^{CH} = \frac{E_r}{E_{CH}} \quad (26)$$

For MISO, the energy consumption and lifetime of a CN is determined through the given set of equations:

$$E_{CN_i} = 1 * P_{MISO,TA}^{CN} = P_{MISO,TA}^{CN} \quad (27)$$

$$T_{MISO,TA}^{CN} = \frac{E_r}{E_{CN_i}} \quad (28)$$

$$T_{net} = min\{T_{CH}^{MISO}, T_{CN1}^{MISO}, T_{CN2}^{MISO}, \dots T_{CN_{n-1}}^{MISO}\} \quad (29)$$

where, $T_{CH}, T_{CN_1}, T_{CN_2}, \dots \dots . T_{CN_{n-1}}$ are the lifetime values calculated for the cluster members CH, CN_i and CN_{n-1}, respectively.

3.6. Algorithm

1. A network scenario in which a random number of nodes are generated.
2. The nodes within the network are clusterized.
3. The power required for gathering, compression, and broadcasting phase is calculated.
4. Centralized data aggregation (CAS) technique is used for reducing the data redundancy.
   The tasks involved in the step are:
   (i) In first iteration, the distance between CH and the closest neighbor node of CH is calculated. Then the number of bits that has to transmit is found out.
   (ii) In second iteration, using the minimum distance among the distance from the next closest CN to CH and previous CN and previously obtained number of bits, a new value of number of bits that has to be transmitted is found out.
   (iii) The iterations are repeated until the distance from the farthest node within the cluster is found out.
5. For the proper transmission scheme selection, coalition formation game is used.
   The tasks involved in the step are:
   (i) Initializing the coalitions in which each coalition consists of individual cluster nodes and cluster head. i.e. S_1 = {CH} and S_i = {CN_i} where i={2,3,….,n+1}.
   (ii) An iteration that consists of merge operation with Pareto Order is repeated in terms of network lifetime. The iteration is as follows.
   Every coalition S_i is compared with S_1 to check whether $\{S_1 \cup S_i\} \triangleright \{S_1, S_i\}$. If the condition is satisfied, then the coalition having highest utility is selected and merged. $S_1 = \{S_1 \cup S_i\}$, where S_1 is the new coalition.
   (iii) S_1 searches for next merging among other coalitions which does not contain S_i. The search ends by a final merged coalition S that is composed of CH or CH and several CNs.
6. If each active CN of the cluster forms a single coalition
   Non-cooperative SISO is selected
   Else
   Cooperative MIMO is selected
7. Average lifetime of sensor network is calculated.

Journal of Theoretical and Applied Information Technology
10th August 2014. Vol. 66 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

4. RESULTS

4.1. Simulation Environment

A cluster of radius 100 m has been formed for this experimentation and CH is located at the centre of this cluster. Rayleigh fading coefficients are modeled as unitary power complex Gaussian random variables for both the local-broadcasting channels and the long-haul MISO channels. To ensure QoS (Quality of Service) requirements of the given WSN, a maximum threshold P_{out}^{thr} has been set for the outage probability. Other parameters that have been assumed for our experimentation are listed in Table 1.

Table 1: Simulation Environment

Parameters	Numerical Value
K	1
Gaussian noise variance σ^2	10^{-12} W
Path loss exponent δ	3.5
outage capacity C	1.4 b/s/Hz
L (Number of bits before data aggregation)	2000 bits
Parameter	Numerical Value
c (degree of special correlation)	100
P_{MIX}	30.3 mW
P_{LNA}	20 mW
P_{SYN}	50 mW
P_{IFA}	3 mW
P_{FILT}	5 Mw
M	4
E^{comp}	5nJ/bits/sec
η	0.35
L	2000
P_{out}^{thr}	10^{-4}

4.2. Operating Environment of the Algorithm

Sensor nodes are randomly deployed in this scenario. CH is situated at the centric position of this topology. Two varying sized sensor networks have been analyzed in this work.

4.2.1. Network scenario 1

In the first trial of our experiment, 10 sensor nodes have been randomly deployed in the mentioned experimental environment. The distance between the cluster and the sink (D) has been set as 50 m. Figure 2, shows the locations of sensor nodes deployed. The resulting coalition S contains only CH and hence SISO is selected here. For d = 200 m, the resultant coalition becomes {CH, CN_9} and it recommends the choice of MIMO. When d = 600 m, the selected cooperative MIMO scheme is chosen and the set of active CNs {CN_9, CN_8, CN_3, CN_7} participate in the long-haul MISO transmission with the CH.

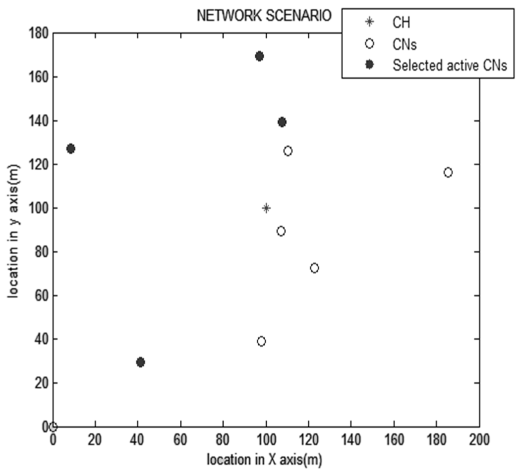


Figure 2: Sensor nodes positions: n=10

4.2.2. Network scenario 2

For the second trial (Figure 3), the number of nodes has been increased to 60 with the similar system environment. Random deployment of sensor nodes is employed in this trial also. The sink has been situated 50 m, 200 m and 600 m from the cluster in this trial. The resultant partition of this experimentation is observed as S = {CH}, S = {CH, CN_{29}, CN_{51}, CN_{44}, CN_{26}} and S = {CH, CN_6, CN_3, CN_{39}, CN_{27}, CN_{50}, CN_{31}, CN_{48}} respectively. The relationship between the choice of transmission schemes and the distance of the sink is assured through this trial also.

Journal of Theoretical and Applied Information Technology
10th August 2014. Vol. 66 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

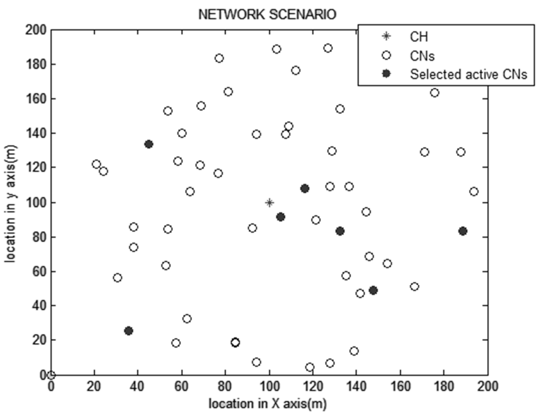


Figure 3: Sensor nodes positions: n=60

4.2.3. Transmission scheme selection

The cost incurred for establishing cooperation and the benefit acquiring will autonomously determine the proper transmission scheme. Net utility is the difference between benefit due to the cooperation and cost that has to be paid after cooperation. In our scenario, network lifetime is the net utility and CH will make decision of whether to seek cooperation from other nodes or not and if cooperation is needed, from whom the cooperation is to be accepted. It is evident from the above trials that smaller distances favor SISO and MIMO is selected for the larger values of D.

4.2.4. Cluster head election

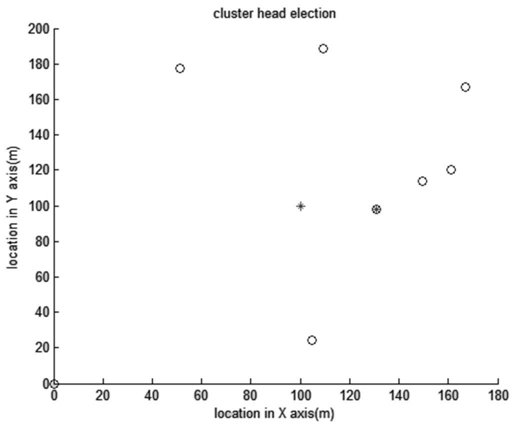


Figure 4: Cluster head election

In Figure 4, 'cluster' shows the cluster head elected in the second round. Initially, CH was positioned in 100m x 100m. After considering all the power consumption for each node in a cluster, CH is elected according to the remaining energy in each node. The node having highest energy is elected as CH.

4.3. Performance Evaluation

The proposed algorithm is evaluated against the strength of existing approaches. In algorithm 1, CH communicates with BS (Base Station) in a non-cooperative SISO way. In algorithm 2, CH selects required nodes within a cluster to help with the long-haul MISO transmission. In algorithm 3, spatial correlation is done before transmitting the data using cooperative MISO. In algorithm 4, coalition formation game is used to select the transmission scheme and to choose the cooperating nodes. In our proposed algorithm, aggregation technique with centralized scheme and coalition formation game are jointly considered.

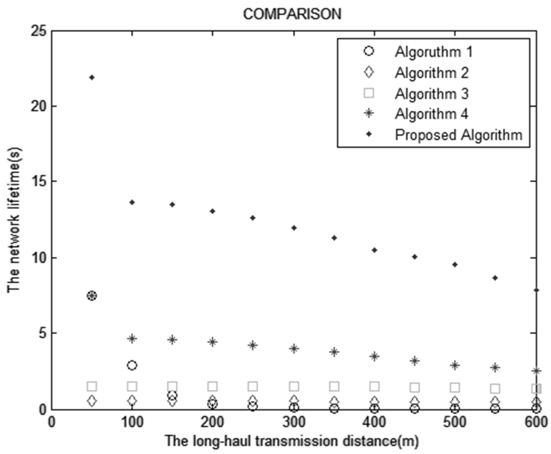


Figure 5: Network lifetime versus long-haul transmission distance in different algorithms: n=10

Figure 5, shows comparison of five transmission schemes when the number of nodes n=10. In algorithm 1, only CH will transmit data to BS and drains all of its energy immediately if the distance D is more. It shows increased network lifetime compared to algorithm 2 when the distance D is less. For algorithm 3, the performance is less compared to algorithm 4 but there is no much difference in network lifetime as the distance D increases. This is because of the reason that more nodes move to cooperate for the long-haul transmission as D gets increased. The proposed algorithm shows better performance compared to the four mentioned approaches. It happens because of the joint contribution made from intelligent selection and data aggregation techniques driven in this approach.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

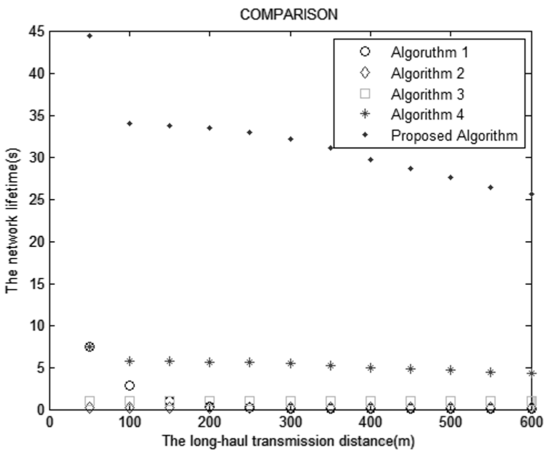


Figure 6: Network lifetime versus long-haul transmission distance in different algorithms: n=60

In Figure 6, the scalability of the proposed solution is tested with a network of 60 sensor nodes. Results demonstrate the improved lifetime yielded by the proposed algorithm against the existing algorithms.

The solution is also scalable across the size of the network from the above trials. It can be observed that more number of active sensor nodes exhibit more possibilities to find good assisting CNs across the network. Obviously, SISO method neglects the impact of number of active CNs over the network lifetime. In another approach, choice of appropriate assisting CNs could maintain solution stability regardless of the number of active CNs.

5. CONCLUSION AND FUTURE WORKS

This work observes the improvement in lifetime for a WSN. The solution arrived is proven to be scalable across the size of the network. The contribution of the data aggregation technique has been verified against the traditional algorithms. The performance of this work can further be tuned to address the implication of effective storage strategies and queuing techniques that are adopted in a wireless sensor application.

REFERENCES

[1] Macro Di Renzo and H. Haas, "Bit Error Probability of SM-MIMO Over Generalized Fading Channels", *IEEE Transactions on Vehicular Technology*, Vol. 61, No. 3, March 2012, pp.1124 -1144.

[2] D. Wu, Y. Cei, and J. Wang, "A coalition formation framework for transmission scheme selection in wireless sensor networks", *IEEE Transactions on Vehicular Technology*, Vol. 60, No. 6, July 2011, pp.2620-2630.

[3] M. Elhawaey and Z.J. Hass, "Energy-efficient protocol for cooperative networks", *IEEE Transactions on Networking*, Vol. 19, No. 2, 2011, pp.561-574.

[4] Q. Gao, Y. Zuo, J. Zhang and X.H. Peng, "Improving energy efficiency in a wireless sensor network by combining cooperative MIMO with data aggregation", *IEEE Transactions on Vehicular Technology*, Vol. 59, No. 8, 2010, pp.3956-3965.

[5] M.R. Islam and J. Kim, "On the Cooperative MIMO communication for energy-efficient cluster-to-cluster transmission at Wireless Sensor Networks", *Annals of Telecommunications*, Vol. 65, No. 5-6, 2010, pp. 325–340.

[6] W. Saad, Z. Han, M. Debbah, A. Hjørungnes and J.B. Song, "Hedonic coalition formation games for secondary base station cooperation in cognitive radio networks", in *Proceedings of IEEE Wireless Communications and Networking Conference,* April 2010, pp.1–6.

[7] K. Apt and A. Witzel, "A generic approach to coalition formation (extended version)", *International Game Theory Review*, Vol. 11, No. 3, 2009, pp. 347–367.

[8] H.L. Ren and M.Q. Meng, "Game-theoretic modeling of joint topology control and power scheduling for wireless heterogeneous sensor networks", *IEEE Transactions on Automation Science and Engineering*, Vol. 6, No. 4, October 2009, pp.610–625.

[9] W. Saad, Z. Han, M. Debbah and A. Hjørungnes, "A distributed coalition formation framework for fair user cooperation in wireless networks", *IEEE Transactions on Wireless Communications*, Vol. 8, No. 9, September 2009, pp.4580–4593.

[10] C. Zhai, J. Liu, L. Zheng and H. Xu, "Lifetime maximization via a new cooperative MAC protocol in wireless sensor networks", in *Proceedings of* **G***lobal Communications Conference*, 2009, pp. 1–6.

[11] L.S. Pillutla and V. Krishnamurthy, "Mutual information and energy tradeoff in correlated wireless sensor networks", in Proceedings of IEEE *International Conference on Communications*, 2008, pp.4402–4406.

[12] T.D. Nguyen, O. Berder and O. Sentieys "Cooperative MIMO schemes optimal selection for wireless sensor networks", in

Journal of Theoretical and Applied Information Technology
10th August 2014. Vol. 66 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Proceedings of IEEE Vehicular Technology Conference, 2007, pp.85–89.

[13] N.A. Pantazis and D.D. Vergados, "A survey on power control issues in wireless sensor networks", *IEEE Communiations Surveys & Tutorials.,* Vol. 9, No. 4, Fourth Quarter, 2007 pp.86–107.

[14] A.D. Coso, U. Spagnolini and C. Ibars, "Cooperative distributed MIMO channels in wireless sensor networks", *IEEE Journal on Selected Areas in Communications*, Vol. 25, No. 2, 2007, pp.402–414.

[15] V. Raghunathan, S. Ganeriwal and M. Srivastava, "Emerging techniques for long-lived wireless sensor networks", *IEEE Communication Magazine*, Vol. 44, No. 4, April 2006, pp.108–114.

[16] R. Rajagopalan and K.P. Varshney, "Data aggregation techniques in sensor networks: A survey", *IEEE Communications Surveys & Tutorials*, Vol. 8, No. 4, October 2006, pp.48-63.

[17] K. Apt and A. Witzel, "A generic approach to coalition formation", *Proceedings of the 1st International Workshop on Computational Social Choice*, 2006, pp.21–34.

[18] T. Himsoon, W.P. Siriwongpairat, Z. Han, and K.J.R. Liu, "Lifetime maximization by cooperative sensor and relay deployment in wireless sensor networks" in *Proceedings of IEEE Wireless Communications and Networking Conference,* pp. 439–444, 2006.

[19] S. Cui, A.J. Goldsmith and A. Bahai, "Energy-constrained modulation optimization," *IEEE Transactions on Wireless Communications*, Vol. 4, No. 5, pp. 2349 – 2360, 2005.

[20] S. Cui, A.J. Goldsmith and A. Bahai, "Energy efficiency of MIMO and cooperative MIMO techniques in sensor networks", *IEEE Journal on Selected Areas in Communications*, Vol. 22, No. 6, pp.1089–1098, 2004.

[21] Dietrich and Dressler, F., "On the lifetime of wireless sensor networks," *ACM Transactions on Sensor Networks*, Vol. 5, No. 1, pp.1-38, 2004.

[22] S. Pattern, B. Krishnamachari and R. Govindan, "The impact of spatial correlation on routing with compression in Wireless Sensor Networks," in *Proceedings of the 3rd international symposium on Information processing in Sensor Networks*, pp.28 – 35, April 2004.

[23] Boulis, S. Ganeriwal and M.B. Srivastava, "Aggregation in sensor networks: An energy accuracy tradeoff," *Elsevier Ad Hoc Networks*, Vol. 1, pp.317–331, 2003.

[24] B. Krishnamachari, D. Estrin and S. Wicker, "The impact of data aggregation in wireless sensor networks", in *Proceedings of 22nd International Conference on Distributed Computing Systems Workshop,* 2002, pp.575 – 578,.

[25] E. Telatar, "Capacity of multi-antenna Gaussian channels', *European Transactions on Telecommunications*", Vol. 10, No. 6, 1999, pp.585–595.

[26] G. Foschini and M. Gans, "On limits of wireless communications in a fading environment when using multiple antennas", *Wireless Personal Communications*, Vol. 6, No. 3, 1998, pp.311–335.