A Novel Energy Efficient Harvesting Technique for SDWSN using RF Transmitters with MISO Beamforming

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Abstract: *Software Defined Wireless Sensor Networks (SDWSN) is emerged to overcome the additional energy consumption in WSN. Even then the sensor nodes in the SDWSN suffer from scarce battery resources. Generally, the Radio Frequency (RF) transmitters are deployed around the base station in the SDWSN to overcome the high energy consumption problem. To enhance harvesting energy and coverage of nodes in the network, a new energy harvesting technique using RF transmitters with Multiple Input and Single Output (MISO) beamforming is proposed. In this method, multiple antenna RF transmitters and single antenna sensor nodes are deployed. The optimization problem subject to Signal to Noise Ratio (SNR) and energy harvesting constraints is formulated for hybrid beamforming design to reduce the transmit power in the network. The optimization problem based on convex Second Order Cone Programming (SOCP) is derived to get the optimal solution for hybrid beamforming design. The beamforming technique is used to steer the beam in the desired direction and null to the other direction improves the energy harvesting. The simulation results show that the proposed technique provides better average harvesting energy, average transmit power, average residual energy and throughput than the existing RF transmitter based energy harvesting methods.*

Keywords: *SDWSN, RF transmitters, energy harvesting, MISO, beamforming, SOCP, convex optimization.*

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1. Introduction

In Wireless Sensor Networks (WSN), the sensor node captures the data where the event occurred and forward to Base Station (BS) either in the single-hop or the multi-hop routing. The applications of WSN are medical, military, etc. The main challenge in WSN is increasing the lifetime of sensor nodes. The standard routing protocols for the formation of cluster and selection of Cluster Head (CH) are proposed to overcome the challenge [15, 16, 17, 25, 30]. A hybrid fault tolerant clustering routing protocol based on Gaussian network for WSN is proposed to reduce energy consumption, improve fault tolerance and data reliability in the network [24]. But the small change in the network needs to reanalyze the whole network which made the sensor node spend excess energy lead to the evolution of Software Defined Wireless Sensor Networks (SDWSN) [20]. The SDWSN is proposed to overcome the problems inherent in WSN [13].

The SDWSN is emerged by the fusion of SDN into WSN [23]. The SDWSN architecture is divided into three layers that simplify the network management and configuration is an infrastructure layer, control layer and application layer [5]. The infrastructure layer consists of forwarding nodes, the control layer has controllers and the application layer contain a set of applications. In SDWSN, the control plane and data plane are separated to forward the data with less energy consumption compared to WSN. The controller has an overview of the network which updates the routing metrics to send the data in the shortest path [29] and broadcast updated information instead of a sensor node. The sensor node in the network only forwards the data rather than computing the information.

Several algorithms are proposed for energy efficiency in SDWSN. The fuzzy logic in SDWSN is proposed to improve the lifetime and packet delivery ratio of the network [1]. These energy efficient algorithms are difficult to rehabilitate the energy of sensor nodes in the network. Hence the external energy source RF transmitters are deployed for providing energy to sensor nodes when required.

In this paper, we propose a clustered network with Radio Frequency (RF) transmitters for harvest energy to the sensor nodes with the beamforming technique in the SDWSN. The RF transmitters are optimally placed in order to communicate all nodes in the network, which can harvest energy to the energy required sensor nodes in the clustered network. The beamforming algorithm which transmits energy in a particular direction and cancels the signals in the other direction to enhance harvesting energy and increases the lifetime of the sensor nodes in the SDWSN. The contribution of the proposed algorithm is summarized as follows

1. The RF transmitters with beamforming for energy harvesting in the clustered SDWSN is proposed to increase the life time of the node.
2. The RF transmitters deployed in the SDWSN is introduced to harvest all the sensor nodes in the network.
3. The multi antenna RF transmitters and single antenna sensor nodes are deployed to reduce the multipath fading.
4. The optimization problem with hybrid beamforming design is proposed to reduce the transmit power in the network with respect to SNR and RF energy harvesting constraints.
5. The problem is converted from non-convex to convex Second Order Cone Programming (SOCP) formulation is developed to get an optimal solution.
6. The performance of the proposed algorithm with beamforming technique and proposed algorithm without beamforming technique is analyzed and compared with the existing algorithm.

The paper is organized as follows. Section 2 gives details about the existing methods. Section 3 presents the network model and placement of the RF transmitters. Section 4 discusses the proposed system model in the SDWSN. Section 5 introduces the system model for MISO beamforming. Section 6 presents the problem formulation for the proposed model and MISO hybrid beamforming design. Section 7 introduces the SOCP formulation. Section 8 compares the performance of the proposed algorithm with the existing algorithm. Finally, the work is concluded in section 9.

- Notations: the superscripts are $(.)^T$ is transpose, $(.)^H$ is conjugate transpose, $(.)^+$ is Moore-Penrose pseudo inverse respectively. $\|.\|$ and $|.|$ are denoting the Euclidean norm of a complex vector and the magnitude of a complex variable.

2. Literature Review

Several algorithms are proposed for energy efficiency in SDWSN. The fuzzy logic in SDWSN is proposed to improve the lifetime and packet delivery ratio of the network [1]. To optimize location and rate of control nodes at a time of execution to decrease energy consumption, efficient routing using an optimization algorithm is proposed [9]. To control failover in the SDN, the per link bidirectional forwarding hybrid approach is proposed to reduce delay and overheads and increase the response time with available shortest path [28]. The congestion and delay based multicast routing problem is formulated to find the path with lowest delay and less congestion cost in SDN to reach the destination from source node [8]. These energy efficient algorithms are difficult to rehabilitate the energy of sensor nodes in the network. Hence the external energy source RF transmitters are deployed for providing energy to sensor nodes when required.

In order to increase the lifetime of sensor nodes, the RF energy harvesting transmitters are deployed in the network for harvesting energy. The Wireless Power Transfer (WPT) technique is RF energy harvesting which converts the RF signals to electricity [3, 14]. This charging technique is very useful for energy-limited networks like Wireless Sensor Networks, Software Defined Wireless Sensor Networks, etc., For WPT, the optimization problem is formulated for the deployment of RF transmitters with branch and bound scheduling algorithm to harvest energy in SDWSN is proposed [6]. For Internet of Things (IoT) in [21], proposes the routing algorithm for energy harvesting to enhance the lifetime of sensor nodes and network metrics based on traffic and energy in the network. The latest research activities in practical RF-Energy harvesting wireless communication design is investigated in [12]. To overcome issues in hardware enabled green IOT, the green WSN and green RF identification is used [13]. The hybrid energy harvesting model for a communication system evaluates the harvesting energy by the Altinel and Kurt mixture model [4]. Therefore, previous energy harvesting algorithms are proposed without considering the beamforming technique.

The multiple antenna system sends multiple copies of data from the transmission end to reduce the effect of multipath fading at the receiving end. The Beamforming technique at the transmission end sends the signal in the desired direction instead of spreading out in all directions that increase the Signal to Interference Noise Ratio (SINR). The beamforming design in a multi user MISO with a Full-Duplex Simultaneous Wireless Information and Power Transfer (SWIPT) system employs the Semi Definite Relaxation (SDR) and S-procedure to increase the harvested energy in the network [10]. The Multiple antenna Access Point accomplish multiplexing in uplink and energy beamforming in the downlink to enhance the energy efficiency and transmit power in MISO Wireless Powered Communication Network [18]. To maximize the harvesting power, the transmitter precoding and power splitting are jointly designed in the MISO SWIPT system subject to the Quality of Service (QoS) constraint [19]. The above beamforming designs in the MISO system are implemented between the BS and sensor nodes (users), not in the clustered network and the methods are not considering the eventful data transfer between the sensor node and BS.

In the clustered network, the SWIPT system between the source to relay or destination for energy efficient transmission is implemented [7]. But it has a major disadvantage of harvesting energy only for the relay node, not for the sensor node, and the network is implemented without incorporating MISO system.

3. Network Model

In the MxM grid area, N number of sensor nodes are randomly deployed in the SDWSN. The clusters are formed and the controller node for each cluster act as a cluster head is elected based on maximum energy among the node in the cluster for sending data to BS. The BS is located in the center of the network is (X_{BS}, Y_{BS}). In the SDWSN, the clustering process happens even though the number of nodes in a particular area is less lead to an increase in the energy consumption of the network. Hence the RF transmitters are placed efficiently to harvest energy when the sensor node sends an energy request that increases the lifetime of the network. The RF transmitters as a source for simultaneously transferring energy to nodes are equipped with two antennas and the receiver is the sensor nodes that have a single antenna. The RF transmitter is considered instead of harvesting other sources of energy due to its ubiquity [2].

The harvesting energy by the RF transmitters is varied with time and distance. If the node is far away from the RF transmitter then the energy harvested by the node is less compared to a nearby node and the power required to transmit the energy for the required node is also higher. If the distance increases, the power required for transmitting the energy increases to reach the required sensor node which made the network to suffer interference from other RF transmitters. If the distance between the RF transmitter and sensor node decreases, the Single to Noise Ratio (SNR) increases which decrease the transmit power and increases the harvesting energy in the network. Therefore the RF transmitters are circularly placed in the middle of the distance between sides of the grid area and the (X_{BS}, Y_{BS}) to harvest energy and the distance between the RF transmitters in the SDWSN are equal is shown in Figure 1. The placement of RF transmitters around the base station can cover all nodes in the network for harvesting energy to sensor nodes which increases the lifetime of the network.

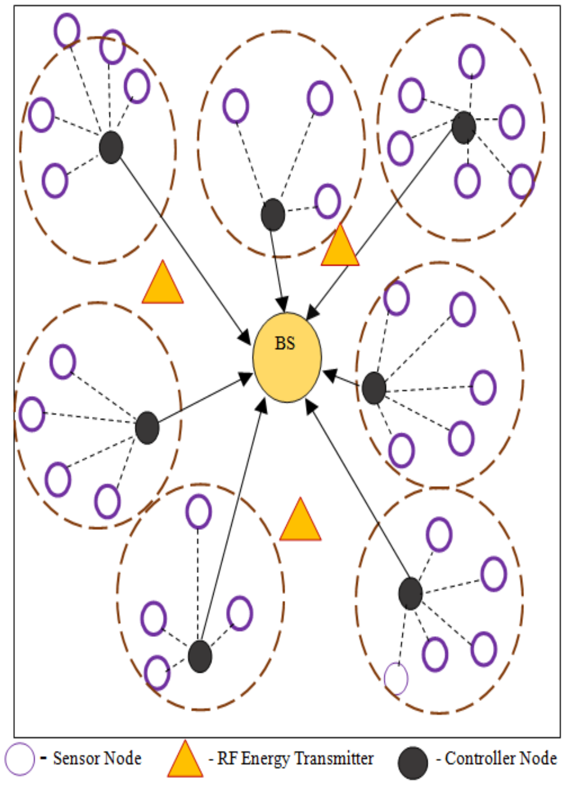

Figure 1. Network model.

4. Proposed System Model in the SDWSN

The proposed system model with beamforming design in the clustered SDWSN is shown in Figure 2. In the proposed system model, the sensor node sends an energy request to the RF transmitter if the energy is less than the threshold energy otherwise the node sends the data to BS through the controller node. The MISO hybrid beamforming design is implemented between the two antenna RF transmitter and single antenna sensor nodes in order to decrease the energy consumption in the clustered SDWSN. The optimization problem is transformed into second order cone programming to get the optimal solution. The routing provides the efficient path of transferring the energy from RF transmitters to sensor nodes. In the existing routing process [6], the energy request of the sensor node is sent to the controller node and the controller node sends the request to RF transmitters. Hence, the time taken for receiving the energy from the RF transmitter to sensor node is higher, the controller node also eventful for gathering and sending data from sensor nodes to BS can be interrupted and the controller node has to spend extra energy as an intermediate node for RF transmitter and sensor node. In the proposed algorithm routing process, the node sends the request to the nearby RF transmitter instead of the controller node. Therefore, interruption of eventful process and extra energy consumption as an intermediate node of the controller node are excluded from the SDWSN.

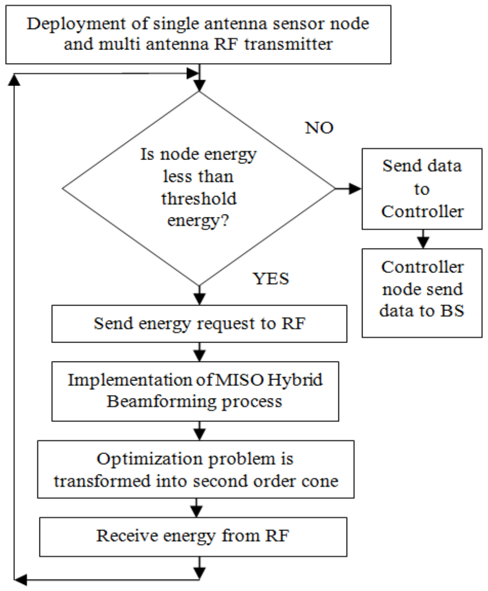

Figure 2. Proposed system model.

5. System Model for MISO Beamforming

The system model for MISO beamforming is shown in Figure 3. The RF transmitter transmits RF energy to the desired receiver k when the node energy is less than the threshold energy. In the MISO system, each transmitter having N>1 antennas for harvest energy to single antenna sensor nodes (1, 2… M) using transmit beamforming. The transmitters send the signals X_k using the transmission power P_k through beamforming vector $W_k \in \mathbb{C}^{N \times 1}$. The baseband signal at the receiver k with the beamforming scheme can be expressed as

$$y_k = \sqrt{P_k}\, \mathbb{h}_k^T W_k X_k + n_k \quad (1)$$

Where $\mathbb{h}_k=[h_{k,1}, h_{k,2}]$ is the channel vector between RF transmitter and sensor node , $X_k=[x_{k,1}, x_{k,2}]$, $W_k=[w_{k,1}, w_{k,2}]$, and n_k is the AWGN with zero mean and variance σ^2 at the receiver. A frequency non-selective MISO Rayleigh fading channel is assumed from RF transmitter to receiver where the channel is constant during a one-time slot and varies independently one from another. The harvested power received at the sensor node is equal to

$$P= P_k| \mathbb{h}_k^T W_k|^2 + \sigma^2 \quad (2)$$

The SNR at the receiver is given by

$$SNR\ (\Gamma_k) = P_k| \mathbb{h}_k^T W_k|^2 / \sigma^2 \quad (3)$$

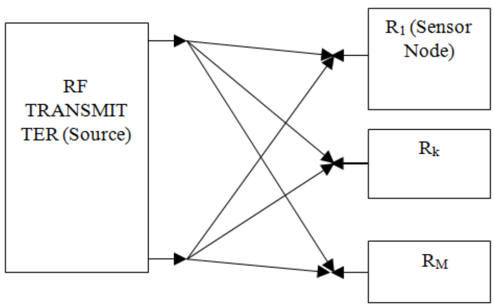

Figure 3. System model for MISO beamforming.

6. Problem Formulation for Proposed Model

In the proposed algorithm, the hybrid beamforming design in clustered SDWSN is implemented between the RF transmitter and sensor nodes. The hybrid beamforming technique which directionally transmits energy to the energy starving node instead of broadcasting signal in all directions to increase the harvesting energy of the sensor nodes in the network. The existing beamforming algorithms are implemented between BS and users without a clustered network. Further, the algorithms based on the SWIPT system between the users and relay can only harvest energy for the relay node not for the sensor nodes in the network. Thus, the Sensor nodes as an energy receiver are characterized by SNR and Radio frequency Energy Harvesting (REH) constraints to maximize each user's energy harvesting efficiency in the SDWSN. For the SNR constraint, the SNR at the receiver k should not be less than the SNR threshold Υ_k and for the REH constraint, the harvested energy at the receiver k should be higher than the energy threshold λ_k. The REH constraint represents the adequate amount of energy harvested to satisfy each sensor nodes energy requirement. In order to reduce the transmission power subject to SNR and REH constraints, the optimization problem with constraints emphasis a beamforming design and power allocation can be formulated as follows

$$\min_{P,W} \sum_{k=1}^{K} P_k \quad (4)$$

Subject to

$$\Gamma_k \geq \Upsilon_k$$
$$P \geq \lambda_k$$
$$P \geq 0$$

In the above problem to combine the beamforming and power allocation, the problem is rewritten into an equivalent form by beamforming weight $V_k=\sqrt{P_k}\, W_k$ can be expressed as follows

$$\min_{P,W} \sum_{k=1}^{K} ||V_k||^2 \quad (5)$$

Subject to

$$\Gamma_k = | \mathbb{h}_k^T W_k|^2 / \sigma^2 \geq \Upsilon_k$$
$$P = P_k| \mathbb{h}_k^T W_k|^2 + \sigma^2 \geq \lambda_k$$

6.1. MISO Hybrid Beamforming Scheme

The various beamforming schemes are previously proposed for efficient transmission such as Zero Forcing (ZF) beamforming [26], Regularized Zero Forcing (RZF) beamforming [22] and Maximum Ratio Transmission (MRT) beamforming [11] scheme. The ZF and RZF beamforming schemes improve the performance of the REH constraint without maximizing SNR constraint. The MRT beamforming scheme maximize the SNR without considering the REH constraint. But, the hybrid MRT-ZF scheme is the linear combination of ZF and MRT beamforming schemes achieve the trade-off between SNR and REH constraints. The hybrid beamforming scheme MRT-ZF provides better performance compared to the standard beamforming approach with less increase in complexity [22]. The hybrid beamforming design [27] can be expressed as

$$W_k^{(MRT-ZF)} = (\sqrt{x_k}\, r_k^{(MRT)} + \sqrt{y_k}\, r_k^{(ZF)}) / (\|\sqrt{x_k}\, r_k^{(MRT)} + \sqrt{y_k}\, r_k^{(ZF)}\|) \quad (6)$$

Where $r_k^{(MRT)}=\mathbb{h}^*_k$, $r_k^{(ZF)}=(I_N-F_k)\mathbb{h}^*_k$, I_N is the N dimensional identity matrix, $F_k = H_k^+H_k$, $H_k = [h_{1,k}, \ldots, h_{k-1,i}, h_{k+1,k}, \ldots, h_{K,k}]^T$, $H_k^+ = H_k^H(H_kH_k^H)^{-1}$ and x_k, $y_k \geq 0$ are the decision variables for tradeoff between SNR and REH constraints. In the proposed MISO beamforming technique the RF transmitter sends the signals through the hybrid beamforming vector W_k in Equation (6) to steer the beam in the desired direction and cancel the co-channel interference which maximizes the SNR and harvesting energy in the network.

7. SOCP Formulation

The problem is transformed into the Second Order Cone Programming (SOCP) formulation. Because in the SOCP, the linear programs, convex quadratic programs, and quadratically constrained convex quadratic programs can be formulated. The SOCP provides the solution with fast and less complexity compared to the SDP algorithms [27]. The SOCP formulation is derived to get the optimal solution for problem formulation with MISO hybrid beamforming design between the RF transmitters and sensor nodes in the clustered SDWSN. The link gain G_k between the RF transmitters and sensor node is

$$\begin{aligned} G_k &= |\mathbb{h}_k^T V_k^{(MRT-ZF)}|^2 \\ &= |\sqrt{x_k}\, \mathbb{h}_k^T \mathbb{h}_k^* + \sqrt{y_k}\, \mathbb{h}_k^T (I_N - F_k)\mathbb{h}_k^*|^2 \end{aligned} \quad (7)$$

Substitute $Q_k = |\mathbb{h}_k^T \mathbb{h}_k^*|$, $q_k = \mathbb{h}_k^T (I_N - F_k)\mathbb{h}_k^*$ and $s_k = \sqrt{x_k}\sqrt{y_k}$ in Equation (7). Then the link gain G_k in linear combination of the variables x_k, y_k and s_k results in

$$G_k = x_kQ_k^2 + y_kq_k^2 + 2s_kQ_kq_k \quad (8)$$

The transmit power constraint determined from the beamforming vector is $\sum_{k=1}^{K} \|W_k\|^2 \leq P_k$. Therefore,

the power P_k with the beamforming vector can be expressed as

$$\begin{aligned} P_k &= \|W_k^{(MRT-ZF)}\|_2^2 \\ &= (\sqrt{x_k}\, r_k^{(MRT)} + \sqrt{y_k}\, r_k^{(ZF)})^H (\sqrt{x_k}\, r_k^{(MRT)} + \sqrt{y_k}\, r_k^{(ZF)}) \\ &= x_kP_x + y_kP_y^2 + s_kP_s \end{aligned} \quad (9)$$

Where $P_x = \|r_k^{MRT}\|^2 = Q_k$, $P_y = \|r_k^{ZF}\|^2 = q_k$ and $P_s = r_k^{MRT}(r_k^{ZF})^H + r_k^{ZF}(r_k^{MRT})^H = 2q_k$. Substitute Equations (8) and (9) in Equation (4) then the problem becomes non-convex because of the constraint $s_k = \sqrt{x_k}\sqrt{y_k}$. By relaxing the constraint $s_k = \sqrt{x_k}\sqrt{y_k}$ into convex second order cone is $s_k \leq \sqrt{x_k}\sqrt{y_k}$ or $s_k^2 \leq x_ky_k$ as $x_k \geq 0$, $y_k \geq 0$ and $s_k \geq 0$. The convex SOCP formulation can be expressed as

$$\min_{x,y,s} \sum_{k=1}^{K} (x_kQ_k + y_kq_k + 2s_kq_k) \quad (10)$$

$$\begin{aligned} \text{subject to} \quad r_k\,\sigma^2 &= x_kQ_k^2 + y_kq_k^2 + 2s_kQ_kq_k \\ P &\geq \lambda_k \\ P &= x_kQ_k^2 + y_kq_k^2 + 2s_kQ_kq_k + \sigma^2 \\ x_ky_k &\geq s_k^2 \end{aligned}$$

In the above Equation (10), the convex SOCP formulation is formed by reducing the constraint to solve the problem in polynomial time if it is non-convex, it cannot be solved in polynomial time. The convex SOCP optimization problem to reduce the total transmit power in the network is derived with the hybrid beamforming vector W_k to get the optimal solution for the MISO beamforming scheme. The hybrid beamforming vector W_k cancels the interference of other users for the desired user to increase the harvesting energy and residual energy in the clustered SDWSN. The optimization problem of the proposed MISO beamforming technique in (10) with the SNR and REH constraints is formulated to reduce the transmit power in the clustered SDWSN.

8. Results and Discussion

The performance of the proposed algorithm is evaluated using NS2 Simulator. The homogeneous single antenna sensor nodes are randomly deployed in the network area with multi-antenna RF transmitters. The sensor nodes and RF transmitters are immobile. The RF transmitters are circularly placed around BS for harvesting energy and enhanced coverage of nodes in the network where BS is placed in the center of the network. The performance of the proposed algorithm is compared with the existing algorithm [6]. Subsequently, the MISO system (proposed algorithm without beamforming technique) in clustered SDWSN is compared with the method proposed in [6]. The simulation parameters considered for static RF transmitter in the SDWSN is shown in Table 1.

Table 1. Simulation parameters.

S.NO	PARAMETER	VALUE
1	Network size	200 m x 200 m
2	Variance (σ^2)	-40 dBm [22]
3	SNR threshold (Υ_k)	20 dB [22]
4	EH threshold (λ_k)	-30 dBm [22]
5	Number of nodes	100,125,150,175,200
6	Simulation time	50,100,125,150,175,200 s
7	Initial Energy	1 J
8	Number of RF transmitters	2,4,6,8,10
9	BS location	(100,100)

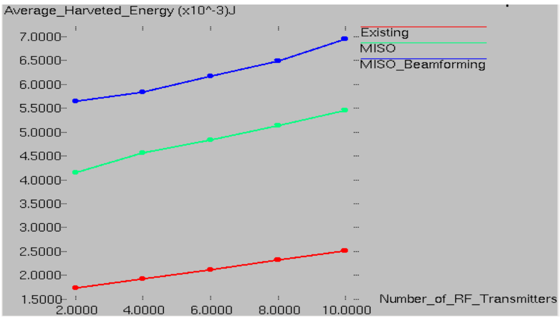

Figure 4. Average harvested energy for 100 nodes.

The average harvested energy for 100 nodes in simulation time of 200 seconds is shown in Figure 4. The harvested energy is increases when the number of RF transmitters is increases in the MISO beamforming algorithm compared to the MISO system and existing algorithm. For six RF transmitters in Figure 4, the average harvested energy of MISO beamforming is 6.18 mJ which is higher compared to 4.84 mJ of the MISO system and 2.11 mJ of the existing algorithm. Because the reliability of the wireless link gets reduced by the deployment of the single antenna RF transmitters in the existing algorithm and the two antenna RF transmitter without beamforming technique which transmit energy in all directions in the MISO system made them harvest energy less compared to the MISO beamforming algorithm. Hence, the directional transmission of two antenna RF transmitters has deployed in the MISO beamforming algorithm to increase the harvested energy in the network.

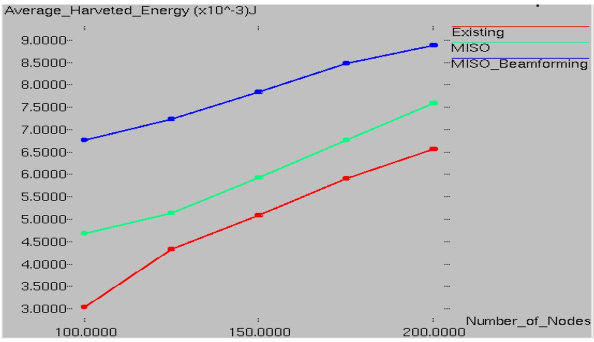

Figure 5. Average harvested energy for 6 RFTX.

Figure 5 illustrates the impact of average harvested energy in the simulation time of 50 seconds when increasing the number of nodes with the six RF transmitters. The average harvested energy for 100 nodes in Figure 5 is 7.58 mJ and 6.56 mJ for the MISO and the existing algorithm is lesser compared to 8.88 mJ in the MISO beamforming algorithm. In the MISO system, multipath fading effects will be reduced between the RF transmitter and sensor nodes in the network which leads to significant improvement in the harvested energy compared to the existing algorithm. But, the omnidirectional transmission of energy in the MISO system decreases the harvesting energy compared to the MISO beamforming algorithm. However in order to improve the energy harvesting performance, MISO beamforming is done in this proposed algorithm. The signals are steered in the desired direction by the hybrid beamforming technique in the MISO beamforming algorithm increases the harvested energy of the sensor node in the network.

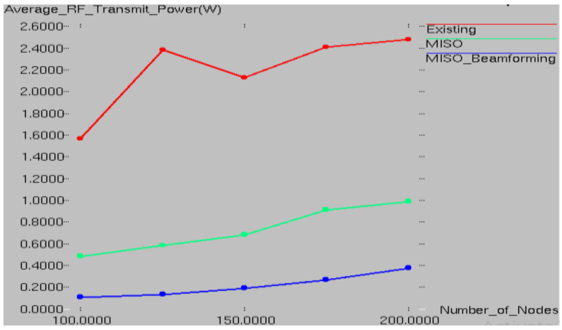

Figure 6. Average transmit power for 6 RFTX.

The average transmission power increases by increasing the number of nodes with six RF transmitters in the simulation time of 50 seconds is shown in Figure 6. This is because the number of nodes increases the RF transmitter has to support all sensor nodes. In the MISO beamforming algorithm, the optimization problem with SNR and REH constraints are formulated to reduce the transmit power in the network. Hence the transmit power of 100 nodes is 0.11 W in the MISO beamforming is better compared to 1.57 W of the existing algorithm and 0.48 W of the MISO system. The optimal deployment of a single antenna RF transmitter with equal distribution of energy that spread out energy in all directions in the existing algorithm decreases the SNR lead to increase the transmit power compared to the MISO system.

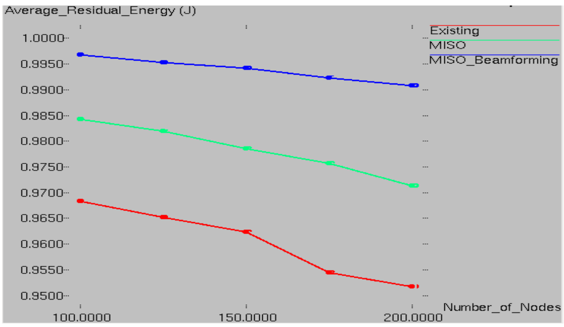

Figure 7. Average residual energy for 6 RFTX.

Figure 7 depicts the average residual energy with a number of nodes for six RF transmitters in the simulation time of 50 seconds in which the residual energy of the MISO beamforming for 100 nodes is 0.996 J outperform the 0.968 J of the existing algorithm and 0.984 J of the MISO system. In the existing algorithm, the branch and bound scheduling algorithm is implemented to get the optimal solution for the optimization problem with harvesting duration and energy charging constraints to reduce the energy consumption in the network is time-consuming and the cost for generating the solution is high are degrading the performance compared to MISO system and MISO beamforming. In the MISO system, the transmission of energy greater than threshold energy from the multiple antenna RF transmitter increases the residual energy in the network compared to the existing algorithm. In the MISO beamforming, the hybrid beamforming technique with SNR and REH constraint increases the residual energy compared to the MISO system.

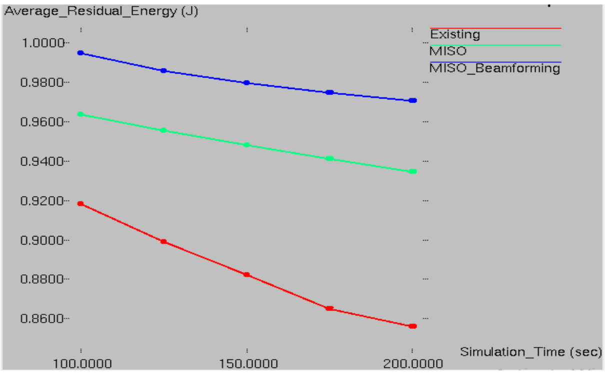

Figure 8. Average residual energy for 100 nodes.

The average residual energy for increasing simulation time with 200 nodes and six RF transmitters is illustrate in Figure 8. The performance of the MISO beamforming for the simulation time of 100 seconds is 0.99 J is improved when compare with the 0.96 J of the MISO system and the 0.92 J of the existing algorithm. Because in the existing algorithm the RF transmitter sends energy to the sensor node through the controller node. Therefore it is the time consuming and unnecessary energy consumption of the controller node in the network. But in the proposed algorithm the request for energy is sent straight to nearby RF transmitter instead of the controller node. The multiple antenna at the RF transmitter reduces the path loss in the MISO system increases the residual energy in the network compared to the existing algorithm. The narrow beam transmission by the beamforming scheme increases the residual energy of the network in the MISO beamforming algorithm compared to the MISO system.

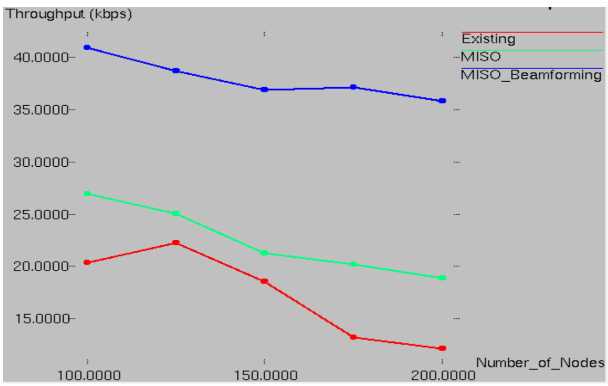

Figure 9. Throughput for 6 RFTX.

Figure 9 shows the impact of throughput with six RF transmitters in the simulation time of 50 seconds when the number of nodes increase in the SDWSN. In the existing algorithm, the transmission of data from the controller to BS is not possible for all the time because the controller node is accompanied by RF transmitters for transferring energy to the sensor nodes. Therefore request for sending data and energy together to the controller node increases the overheads which reduce the throughput. From Figure 9, the throughput for 100 nodes in MISO beamforming is 40.94 kbps is high compared to the 26.96 kbps in the MISO system and 20.34 kbps in the existing algorithm. Because in the MISO and the MISO beamforming algorithms the performance is increased by the efficient routing between RF transmitter and sensor node and further increases the throughput of the MISO beamforming algorithm in the network by the optimization problem with SNR and REH constraints

9. Conclusions

In this paper, the six RF transmitters and one base station are located in the SDWSN with randomly positioned sensor nodes. In the SDWSN, the MISO hybrid beamforming scheme between the single antenna sensor node and two antenna RF transmitters is proposed in a clustered network and investigated for harvesting energy. The optimization problem with SNR and REH constraints is formulated to decrease the total transmit power in the network. The convex SOCP problem is converted from a non-convex optimization problem to get the optimal solution for beamforming design. The average residual energy is 7.8 mJ and throughput is 36.87 kbps for 150 nodes in proposed method is higher compared to the MISO system and existing algorithm. Therefore, the directional energy transfer in the network by the hybrid beamforming technique shows enhanced network performance compared to the MISO system and existing algorithm without the MISO system and beamforming technique in terms of average harvesting energy, average transmit power, average residual energy and throughput in clustered SDWSN.

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