Convergence between Virtual MIMO and Node Deployment Strategy for High Performance Multi-hop Wireless Sensor Networks

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***Abstract*—In Wireless Sensor Networks (WSN) sensor nodes are deployed in their sensing areas for the purpose of sensing, monitoring or detecting physical phenomena, and providing measurements which help decision makers in various related applications that WSNs are used for. However, the appropriate network design plays the main role which increases the advantages of using very limited resources network such as WSN. WSNs are operated on batteries where their lifetime needs to be extended in order to meet the sensor nodes functions. The sensor node in WSNs cannot be installed with more than one single antenna for reducing the power consumption. However, Virtual Multiple-Input Multiple-Output (V-MIMO) technology has the benefits of increasing the transmission range, the throughput, and reducing the power consumption of WSNs. In addition, the height of sensor node deployment in the sensing field is usually neglected in the network design, which we believe, in this paper, that the height of the sensor node has a great impact on reducing the power consumption of WSNs, especially in multi-hop transmission scenarios, which are based on intercluster and intracluster data communication. Thus, in this paper, we propose WSN deign which is based on the convergence between the V-MIMO technology and the height strategy of nodes deployment in order to increase the WSNs performance. The simulation results show that the proposed convergence technique has high performance in terms of the network lifetime, the received signal strength, the packets reception ratio and the energy efficiency.**

***Index Terms*—WSN design, Virtual MIMO, Node deployment, power consumption of sensor nodes**

I. Introduction

WIRELESS SENSOR NETWORK (WSN) is a technology which is involved in many applications nowadays. Much attentions is focused on how to design WSN taking into account its limited power resources. Many researches proposed different Medium Access Control (MAC) methods, routing protocols, and nodes deployment techniques in order to maximize the lifetime of the batteries for sensor nodes, hence reducing the power consumption. In WSN, thousands of tiny sensor nodes are communicating with each other, carrying numerous data to their final destinations even if various difficulties can affect the network design such as the transmission ranges, the physical and environmental obstacles and the distortion of the radio communication signals [1].

In fading environment, Multiple-Input Multiple-Output (MIMO) has a great impact on increasing the channel capacity. However, MIMO technology cannot be useful for WSN since a small sensor node has a single antenna and follows Single Input Single Output (SISO) transmission method. In addition, the small space of a sensor device contradicts with installing MIMO which needs antennas to be far away from each other in order to send and receive un-correlated signals [2]. Thus, researchers introduced the Virtual MIMO (V-MIMO) to be applicable for WSNs. In V-MIMO, multiple sensor nodes cooperate with each other and form multiple antennas system for sending multiple wireless signals. So, in the network model of clustered WSNs, clusters have to include Cluster Heads (CH), relay nodes and cooperative nodes to generate V-MIMO signals [3].

In designing WSN, it is necessary to focus on how to minimize the power consumption for the whole network rather than reducing the power consumption for an individual sensor node [20]. The sensor node consumes power due to its transmission circuit, processing, and receiving circuit where the transmission power consumption is the dominant cause of energy depletion. With V-MIMO in WSN, the power consumption for transmitting signals can be minimized because a node can enter a silent mode for a long time which saves power, hence maximizing the battery lifetime [2].

Another important factor that becomes neglected in many research papers when designing WSN is the height of nodes in the deployment phase. In fact, in WSNs when a node height increases from the ground, the signal coverage can be expanded without the need for increasing the transmission power which increases the energy usage and causes many packets losses due to hidden nodes. As a result, the network performance may become low, and the height impact of nodes deployment need to be considered in designing WSNs [4].

The main contribution of this paper is twofold:

- First, we design WSN, based on the concept of V-MIMO in order to increase the network performance in terms of the minimal power consumption and the number of packets that arrived successfully to the destination node.
- Second, in our design we also investigate the impact of increasing the height of sensor nodes on the overall network coverage, based on the distance between a

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transmitter and a receiver, hence improving the network performance.

The remainder of this paper is organized as follows: In section II, we detail some related works that focus on using V-MIMO in WSNs and the impact of nodes deployment on increasing WSNs performance. In section III, we specify the network model which is based on a multi-hop WSN transmission scenario. The analysis for node deployment (the height) is discussed in section IV. The proposed V-MIMO protocol for multi-hop WSN is presented in section V. The simulation results of our works that show the improvement in WSN performance is presented in section VI. Finally, in section VII, we conclude the paper.

II. Related Works

In this section, we review some related works which focus on utilizing V-MIMO in WSNs, and the benefits that can be gained when including the height of nodes deployment in the network design phase.

Authors in [5] proposed energy efficient management techniques for multi-hop WSN, based on using multiple transmitters and receivers. The authors have included the effect of SNR on the transmission links. The simulation results showed an improvement in terms of the network lifetime in comparison with non-cooperative transmission schemes. In addition, authors studied the distances between the Cluster Heads (CHs) which have a great impact on reducing transmission power consumption. In this paper, authors have compared their proposed C-MIMO algorithm with various and similar algorithms which are dependent on V-MIMO in order to illustrate the performance improvements, gained by their algorithm. Authors in [6] proposed an enhancement in the routing procedures of LEACH protocol. This enhancement is based on using MIMO technique and finding the shortest path from a source to a destination for data transmission. Authors divide the sensing area into clusters, and in each cluster the nominated CH and cooperative CH share packets transmission. Cognitive radio WSN, based on multi-cluster MIMO technique, is proposed [7]. In this paper, authors propose a beamforming technique for uplink traffic in conjunction with OFDM. The uplink capacity is studied in presence of network interference. The proposed technique showed less computational complexity in comparison with similar techniques that are used to increase the channel capacity. The throughput maximization for V-MIMO underground WSNs that studied the resources allocation is proposed in [8]. In the network model, the underground sensor nodes are distributed in the field, and each node is equipped with a single antenna. The base station broadcasts the energy level for sensor nodes, based on the beamforming technique. Then, the sensor nodes harvest the energy level before sending their data packets. The V-MIMO technique is used to distribute the harvested energy levels equally between the underground sensor nodes, hence increasing the network performance. A significant power consumption technique and maximizing the batteries lifetimes for multi-hop hybrid V-MIMO in WSNs are discussed in [9]. The proposed techniques show higher connection probability, high throughput, low BER in compassion with SISO technique and other cooperative MIMO schemes.

For the sensor nodes deployment in WSNs, authors in [10] proposed low cost deployment strategy that avoids blinded links and distributes effectively the network loads of diffident regions on the sensing area. The idea is based on distributing the nodes in the regions where it is necessary to install more sensor nodes, since those regions have many sensing activities in comparison with other regions. Increasing the network lifetime and decreasing the energy depletion in multi-hop WSNs. based on a mobile sink node deployment strategy, is investigated in [11]. The proposed technique studied the energy hole problem, where nodes that are closed to the sink node consume a lot more power than any other node in the sensing field. The simulation results showed an improvement in the network lifetime in comparison with random deployment of sensor nodes. Nodes deployments not only focus on the correct deployment of sink nodes, but they also consider the strategies for relay nodes deployment [12]. Authors in [12] proposed two optimization steps for relay nodes deployment. The authors optimized the number of relay nodes, the size of the modulation scheme and the position of the relay nodes. The simulation results illustrate how the energy efficiency can be improved with their optimization steps. Mobile nodes deployment in WSNs is also studied in [13]. Authors proposed a grid area coverage technique for mobile nodes. Each grid weighting factor is estimated in order to determine the grid that has lower weighting factor for packets transmission. This technique expands the coverage area of the mobile sensor nodes. In the all previous node deployment techniques, there is no mention of the height of sensor nodes from the ground which has a great impact on network performance, and this factor has been neglected.

The height of node deployment from the ground is a well-known phenomenon, which is included in many wireless networks, and has a great impact on the network performance without the need for increasing the transmission power, where it is not useful for networks that have lower resources such as WSNs. Increasing the transmission power causes fast energy depletion and packets loss due to hidden terminals [14]. Authors in [15] investigated the physical layer design for different height of cells in order to achieve low power consumption. The authors showed how various heights have a huge impact on power reduction up to 30%. In [16], researchers studied the height of nodes deployment in both indoor and natural environments. Sensor nodes are places in predetermined positions, where the distances between these nodes are pre-known in the design phase. The authors showed how the packets delivery ratio is increased when the height of nodes is determined where the transmission power and the BER remained stable without any changes. The authors state that their research findings are promising and the network performance will be enhanced when topology control mechanisms are combined with their proposed technique that considers the nodes position and heights. In fact, this is what we are trying to investigate in this paper where we combine the V-MIMO scheme with the nodes deployment technique, “the height,” in order to increase WSNs performance in different metrics.

III. The Network Model

In our work, the wireless sensor nodes are distributed in a geographical area, or the Sensing Field (SF), where the nodes communicate with each other and send packets that are generated from sensing physical phenomena. Each node is equipped with single antenna for the transmission purposes. As explained earlier, in order to generate packets using MIMO technology in WSNs, it is necessary that multiple nodes that are located close to each other must cooperate in their transmission in order to form V-MIMO. Therefore, we divide the geographical area into clusters which include multiple sensor nodes with different antenna height. We present the height of antenna as the important factor that gives the opportunity for some nodes (i.e. nodes where their antenna heights are higher than other nodes in the similar cluster) to discover wider coverage area where the packets can be transmitted to nodes located far away from the source node. As a result, the transceiver for some nodes goes off, most of the time, and more energy saving can be gained. In addition, generated packets from source nodes will follow fast transmission path to their destination node i.e. the Base Station (BS) that transfers these packets to another part of the network. In general, we assume the following in the network model:

- The SF is divided into clusters.
- Each sensor node is equipped with a single antenna.
- Pre-defined heights for nodes deployment are considered. The heights of nodes from the ground vary from 0 to 3 meters (more details are explained in section IV).
- Sensor nodes are distributed randomly in the SF.
- The BS is located far away from the SF. All packets are transmitted to the BS.
- Sensor nodes form V-MIMO array system where corporative packets transmission is generated (more details are explained in section V).
- In each cluster, the main Cluster Head (CH) is nominated, and three cooperative CHs are pre-defined with specific requirements. The locations for cooperative CHs are announced in each cluster. So, the cooperative CHs in one cluster can determine the locations for other cooperative CHs in closed clusters that are discovered by their antenna ranges (more details are explained in section V).
- Sensor nodes follow multi-hop transmission scenario (i.e. packets can be transmitted from one node to another until they arrive to their destination nodes) where the path loss propagation model is considered, based on the distance between a source node and a destination [17]. Here, the total energy for bit transmission is equal to the energy consumed by the electronic circuit, plus the energy consumed by the radio amplifier. In the reception side, the total energy to recover the transmitted bit is equal to the energy consumed by the electronic circuit.
- In order to design a correct communication model, the Rayleigh fading channel is considered because WSNs are affected by many challenges, such as reflection, distraction and scattering etc.

IV. The Proposed Nodes Deployment with Different Antenna Heights

In this section, we discuss the multi-hop packets transmission and the benefits that can be gained from increasing the heights of antennas in the nodes deployment phase.

In WSNs, one of the most important deign challenges is to minimize the power consumption in order to maximize the sensor nodes lifetime. In previous packets transmission scenario, the single-hop packets transmission is used in many wireless networks where the packets are transmitted directly from the source node to the destination, which causes fast packets transmission, but this transmission mechanism consumes more transmission power that contradicts with limited power sensor nodes in WSNs, especially when the destination node is located far away from the source node [18]. However, in the single-hop transmission, relay nodes will not be involved in packets transmission and their power consumption can be saved (i.e. the power needed to listen to the communication channel, and power needed for transmission and reception of packets). Therefore, many researches focus on deploying sensor nodes in the SF, following multi-hop packets transmission scenario where packets can be transferred from source to destination nodes through some relay nodes which are located in the routing path between them [21]. This multi-hop transmission scenario causes a significant reduction in the transmission power consumption which is the dominant factor that affects the battery lifetime [1]. In addition, in Multi-hop transmission, the number of packets that can be relayed through relay nodes is decreased, which is a perfect design mechanism for limited power resources networks such as WSNs. So, packets can follow different routing paths all the way to destination nodes, making sure that the traffic load is distributed fairly between different sensor nodes which are located in various parts of the SF. However, in the SF, when the number of sensor nodes is increased, the network traffic will be increased too due to the need for sending packets, generated by a sensor node itself or the packets that should be relayed and generated from other sensor nodes [2].

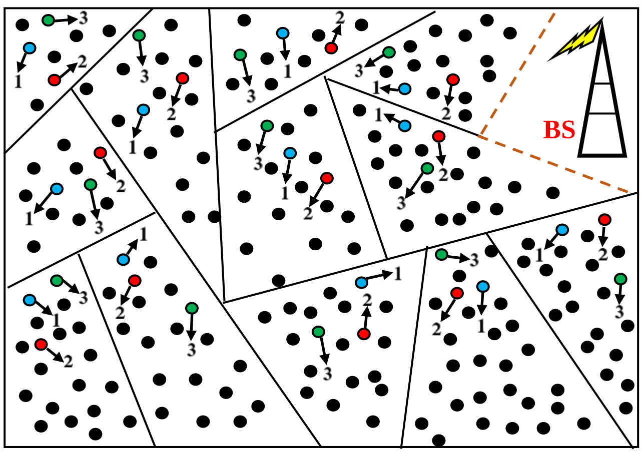
Based on the above challenges that single-hop and multi-hop transmission scenarios faced in packets transmission for WSNs, we propose multi-hop packets transmission where antenna heights can be increased from the ground in the nodes deployment phase. The purpose for this idea is to expand the signals coverage when sending packets. So, we utilize the advantage of the single-hop transmission where the packets can be arrived quickly to the destination node, and the advantage of multi-hop transmission where the transmission power consumption will not be increased as well as reducing the number of relay nodes that will be involved in packets transmission (i.e. decreasing the number of nodes involved in the multi-hop transmission). According to [4], increasing the antenna heights by 1 meter will cause an increase in the signal coverage by around three folds with the same transmission power. The signal coverage can be expanded to cover around 100 meter from the SF with minimal number of sensor nodes instead of increasing the overhead for relay nodes in order to relay packets.

In our proposed nodes deployment technique, we consider the height of antennas in the nodes deployment phase. With increasing the antenna heights, wireless radio signals can be reflected to far distances, hence increasing the coverage area. In contrast, with short antenna heights, the radio signals may suffer from a remarkable power loss. As mentioned in the previous section, in the SF, we distribute sensor nodes that have different antenna heights (i.e. from 0 meters to 3 meters). A pre-determined signal range for each antenna height is considered in our design. That is when the antenna heights are 0,1,1.5,2,2.5 and 3 meters, the radio signals can reach distances around 20,30,35,40,45 and 50 meters with 6,5,4,3,2 and 1 hops, respectively. It is obvious that in our design, when increasing the antenna heights, the coverage ranges will increase too, without increasing the signal strengths and the number of relay nodes which are responsible for relaying packets decrease. It means that packets will follow fast transmission paths to the BS. In each cluster, nodes will send their packets to the Main CH0 that collaborates with the transmission through the CH1 and CH2 (i.e. the first and the second cluster heads). Therefore, in each cluster, nodes must nominate three cluster heads (i.e. CH0, CH1 and CH2), based on the nodes with the maximum remaining power and the largest antenna heights:

$$\sum_{n=1}^{3} CH = min(\rho) + max(\tau) \qquad (1)$$

Where n is the number of cluster head in each cluster and ρ is the remaining power for each node in a cluster and τ is the factor that represents the antenna height of each node in a cluster.

Figure 1 shows how the SF is divided into clusters, and each cluster has various number of sensor nodes that are distributed randomly. In each cluster, we colored some sensor nodes as blue, red and green to represent the CH0, CH1 and CH2, respectively. The figure also shows the BS that is located far away from sensor nodes, and all packets will be redirected to that BS.



(1) The Main CH (CH0)
(2) The First CH (CH1)
(3) The Second CH (CH2)
Sensor Nodes

Fig. 1. Wireless Sensor Network (WSN) with various antenna heights, and three cluster heads per cluster (i.e. CH0, CH1 and CH2).

V. The Proposed V-MIMO Technique

In the proposed V-MIMO technique and as mentioned earlier, each cluster forms the main, the first and the second cluster head (i.e. CH0, CH1 and CH2). In such a case, packets can be transmitted from each cluster in a way that is similar to a normal MIMO technique, where there are three antennas that cooperate for sending packets. In the following subsection, we will detail the proposed V-MIMO technique and explain how to discover sensor nodes in each cluster. In addition, we will describe how to generate packets inside each cluster (i.e. intra-cluster communication) and between one cluster and another (i.e. inter-cluster communication).

A. Forming Clusters and their Members

First, sensor nodes are distributed randomly in the SF. Second, neighboring nodes will communicate with each other in order to form each cluster as follows:

- Nodes that are located close to each other will send "join" messages to each other, based on the proposed Multi-Dimensional Slotted Aloha or (MDSA) MAC protocol [19], which is based on three pre-assigned dimensional aspects (i.e. time, frequency and code) for each sensor node. Nodes will listen to the communication channel and send their "join" messages.
- Once a node has the right to access the communication channel, it will send its node identification number, the remaining energy level and the antenna height to all neighbors.
- After all nodes send their information and receive information from other nodes, they will send "connect" messages, which indicates that the connected nodes form a cluster.

B. Nominating the Main, the First and the Second Cluster Heads

Nodes that form clusters must nominate their main, the first and the second cluster heads in order to generate V-MIMO packets transmission as follows:

- When neighboring nodes form a cluster, it is essential to nominate the main cluster head CH0, based on equation 1. When the node that has the higher remaining energy along with the higher antenna height becomes CH0, it will send Request First Nomination (RFN) messages to all members to nominate the associate cluster head (i.e. CH1).
- All members respond by sending again their remaining energies as well as the antenna heights to the CH0.
- The CH0 will select the first associate cluster head (CH1), based on equation 1, and send Confirm Association One (CAO) message to only the nodes, which are selected to be CH1.
- Similar procedures will be repeated by the CH0 to select the second associate cluster head (CH2). However, the CH0 will send Request Second Nomination (RSN) messages to all members, and Confirm Association Two (CAT) message to the node that is selected to be the second associate cluster head (CH2).

Message flows for forming a cluster, nominating the main, the first and the second cluster heads is illustrated in figure 2. In the figure, ID refers to the node identification number, E refers to the remaining energy of a node, and H refers to the antenna height of a node.

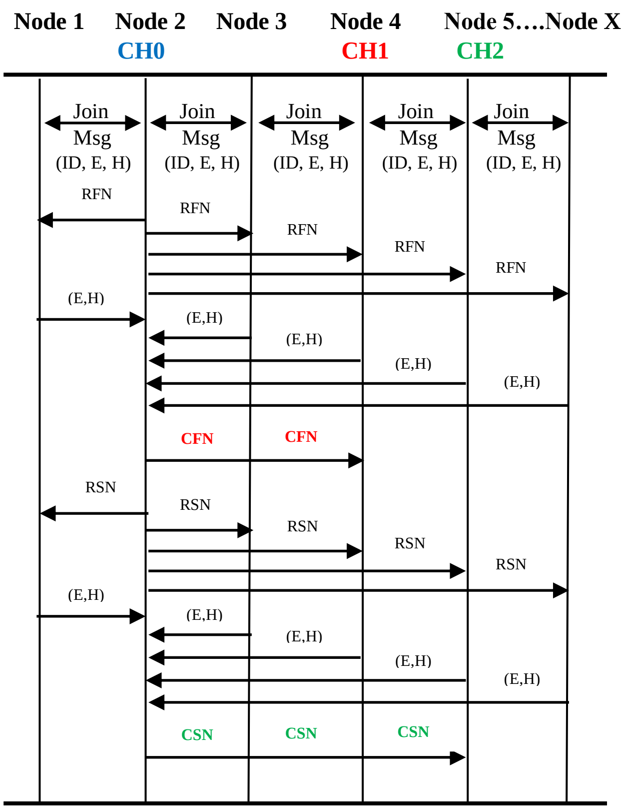


Fig. 2. Forming a cluster with CH0, CH1 and CH2.

C. *Intra-Cluster Packets Transmission*

Inside each cluster, once a node detects a phenomenon and decides to access the communication channel via MDSA MAC protocol, it will send its packet to either the CHs (i.e. CH0, CH1 and CH2) or to the closest relay node which relays that packet to the CHs in order to form V-MIMO packet transmission. The relay nodes will be involved in packets transmission only if three conditions are satisfied. First, if the distance between a source node and the relay node ($d_{s,r}$) is less than the distance between the source node and any nominated CHs ($d_{s,c}$). This condition is to avoid increase in the transmission power consumption. Second, if the antenna height of the source node (hs) is lower than the antenna height of the relay node (hr). This condition is to ensure that the packet will be transmitted in a fast way since the node with higher antenna height has a large coverage area. Third, if the remaining energy of the relay node (Er) is greater than the remaining energy of the source node (Es). This condition is to extend the lifetime of the batteries of members of each cluster. However, if the first condition is not satisfied, it means that the source node can directly sent their packets to the CHs since they are close to the source node. If the first condition is satisfied but the second condition is not satisfied, it means that the source node has a high antenna coverage range which enables the packets to be transmitted directly to the CHs. If the first and the second condition are satisfied but the third condition is not satisfied, it means that the relay node has lower remaining energy, making it involved in the packet transmission will accelerate its death. In this case, the packet will be dropped and will not be transmitted either to the relay node or to the CHs. A notification message will be sent to a neighbor node of the same cluster to give it the opportunity to send a similar packet which may follow another transmission path.

Therefore, these three conditions need to be satisfied in order to activate the relay nodes and involve them in packets transmission. In other words, in our proposed intra-cluster packets transmission, we try to minimize the number of activated relay nodes (i.e. making the relay nodes in a silent state most of the time in order to extend the network lifetime), and expand the signals coverage ranges in order to accelerate packets transmission and reduce the transmission power consumption. These conditions have great impacts on improving the network performance as we are going to prove in the performance analysis in the following section. The pseudocode for intra-cluster packets transmission is illustrated below.

The pseudocode for intra-cluster packets transmission

1) Nodes start forming their clusters and nominating three CHs per cluster (i.e. CH0, CH1 and CH2)
2) Nodes detect physical phenomena (N)
3) For i=1 to N ; *N is the number of nodes that have packets for transmission in each cluster*
4) If $d_{s,r} < d_{s,c} \,\|\, hs < hr$
5) If $Er > Es$
6) Direct the transmission to the relay node
7) Else
8) Drop the packet and notify neighbors
9) End if
10) End if
11) Direct the transmission to one of the CHs
12) End for

D. *Inter-Cluster Packets Transmission*

When the nodes in each cluster send their packets to the CHs, they aggregate the packets and then forward them to the BS. The BS is located far away from clusters. So, the CHs will send the packets to the farthest CHs that can be discovered by their antennas. The CHs will receive these packets and work as relay nodes to direct the packets to the BS following the routing path which is calculated based on the shortest path to the destination (i.e The BS is the final destination). The antennas height is the main factor that we consider to rout the packets to the BS in the way that packets should be routed to the closet CHs to the BS. For example, in figure 3, where we number the clusters from 1 to 13, nodes in cluster 2 send their packets to their CHs. Because of the antenna heights of the CHs in cluster 2, they can discover the CHs in clusters 4, 6, 7 and 10. The CHs in cluster 7 is the closest to the BS, and they will receive the packets and forward them to the next nodes in the routing path (i.e. the BS). This will cause a huge reduction in the number of relay nodes which remain in silent mode most of the time. In addition, the transmission power consumption remains the same without increasing. This has a great impact on improving the network performance as will be explained in the following section.

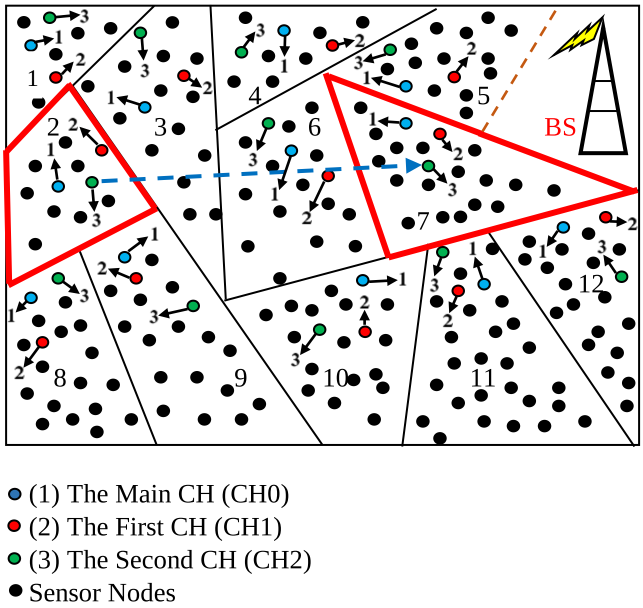


Fig. 3. Inter-cluster packets transmission where CHs in cluster 2 discover the CHs in cluster 7 which direct the packets to the BS.

VI. The Simulation Analysis

This section focuses on the validation of our proposed convergence between the V-MIMO and the antenna heights of sensor nodes in WSNs. We first deploy 2000 sensor nodes in the sensing field (SF) which has an area equal to 2000 × 2000 m. The final destination (i.e. The BS) is located in the position (*x*,*y*)= (2030,2030). In other words, the BS is located outside the area of the SF. The following table shows the simulation parameters:

TABLE I
SIMULATION PARAMETERS

The parameter	The value
Packet length	100 byte
Channel capacity	0.5 Mbps
Initial Energy for a sensor node	0.5J
The energy consumed by the electronic circuit of a sensor node	30nJ/bit
The energy consumed by the radio amplifier of a sensor node	3nJ/bit
Transmission power consumption	2dBm
Simulation time	4000 rounds
Access to the communication channel	MDSA MAC protocol, three dimensions (code, frequency, time)
Antenna heights (AH) for sensor nodes	0,1,1.5,2,2.5 and 3m
Area coverage for antennas with heights 0,1,1.5,2,2.5 and 3m.	20,30,35,40,45 and 50 m with 6,5,4,3,2 and 1 hops, respectively.

A. *Network Lifetime*

The first performance metric is the network lifetime which is defined as the duration from the first packet that is transmitted in the network until the last node becomes dead. In figure 4, we compare between two cases which are the cases when sensor nodes in a cluster send their packets via a single antenna for the transmitter/receiver to a single CH which follow the shortest path packets transmission to the BS. In this case, the antenna height is zero meter (neglected) from the ground which is the normal scenario in most cases and similar WSNs clustering packets transmission in literature. The second case is our proposed convergence between V-MIMO and antenna heights technique. In figure 4, it can be shown that the proposed technique outperforms the normal clustering technique, and the number of nodes becoming dead after running the simulation (i.e. at round 3500) is 1809 for the normal clustering technique and 786 for the proposed convergence technique i.e. when the antenna height is 2m and represents 60% of the total number of sensor nodes in the SF. Also, it is obvious that when the percentage of the number of nodes with higher antenna heights is increased, a significant improvement in the network lifetime is expected. For example, the number of dead nodes are round 3000 when the antenna heights represent 20%,30%, 40%, 50% and 60% of the total number of sensor nodes in the SF are 1034, 897, 798,702 and 658, respectively. Note, in this figure, we assume the antenna height is 2m when the signal coverage can reach up to 40m with only three hops as explained in table I.

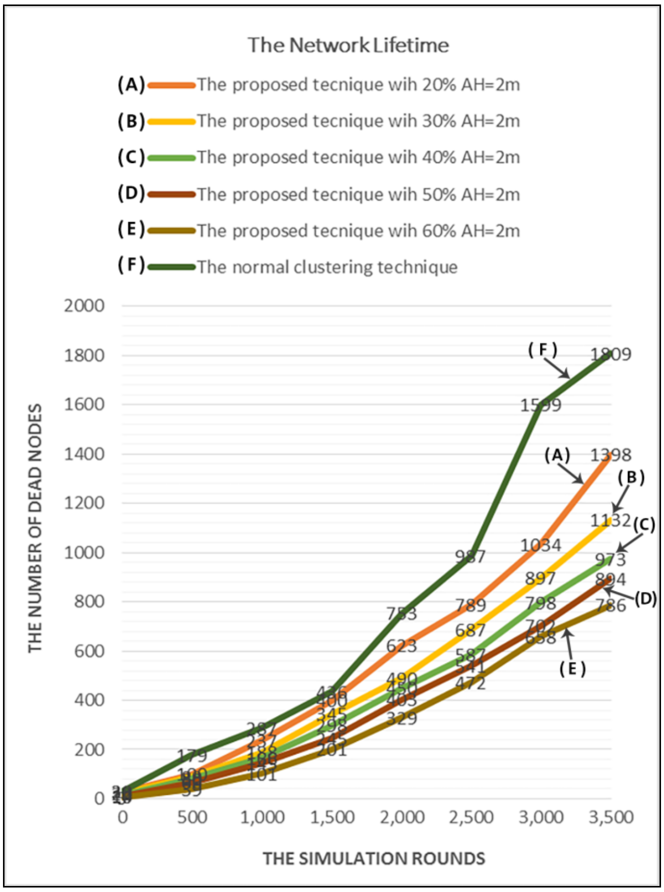


Fig. 4. Comparison between the proposed convergence technique and the normal clustering technique in the network lifetime (AH=2m).

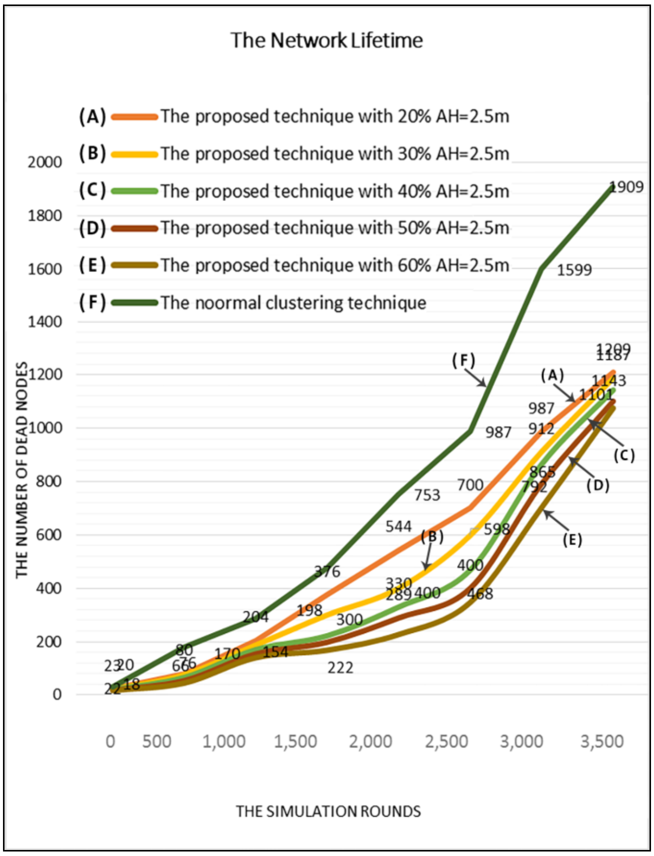


Fig. 5. Comparison between the proposed convergence technique and the normal clustering technique in the network lifetime (AH=2.5m).

When the antenna height is 2.5m and the signal coverage reach up to 45m with only two hops as explained in table I, it is obvious that in figure 5 the number of dead nodes at simulation round 3000 will be 987, 912, 865,792 and 703 when the antenna heights represent 20%,30%, 40%, 50% and 60%, respectively. Thus, increasing the antenna heights will delay the sensor nodes death and hence extending the network lifetime.

B. Received Signal Strength

In this part, we validate the impact of increasing the antenna heights for a transmitter and a receiver on the range that packets can be reached, reducing the number of hops that should be activated all the way to the destination. We pick various nodes (transmitters) that are located in different locations (distances) from the destination node (the BS). We pick 8 nodes as transmitters that are 10, 15, 20, 25, 30, 35, 40, 45 and 50m away from the BS, and send 5000 periodic packets per each transmitter to the destination to measure the received signal strengths for nodes that are located in various distances from the BS. In figure 6, we assume each transmitter antenna height is 2m and the receiver antenna heights are 1, 1.5, 2, 2.5 and 3m.

From this figure, it is obvious that the received signal strength will be improved as long as the antenna height for the reviver is increased. Further improvement in the received signal strength can be gained when increasing the antenna height for transmitters as it can be seen in figure 7 when the transmitters' antenna height is assumed to be 3m.

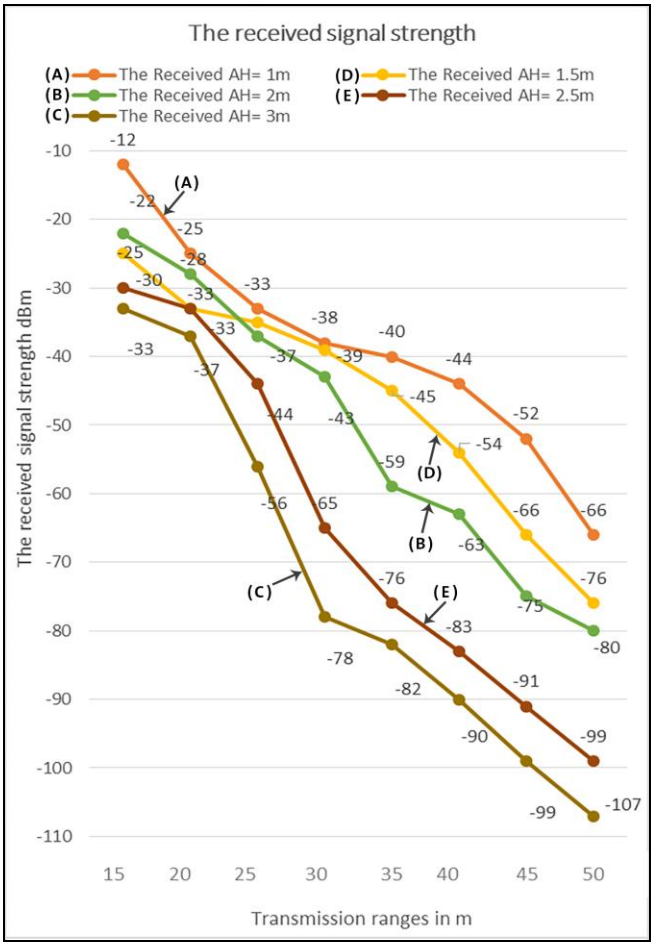


Fig. 6. Received signal strength for various nodes with different distances from the BS. The transmitters AH is 2m and the receiver AH are 1, 1.5, 2, 2.5 and 3m.

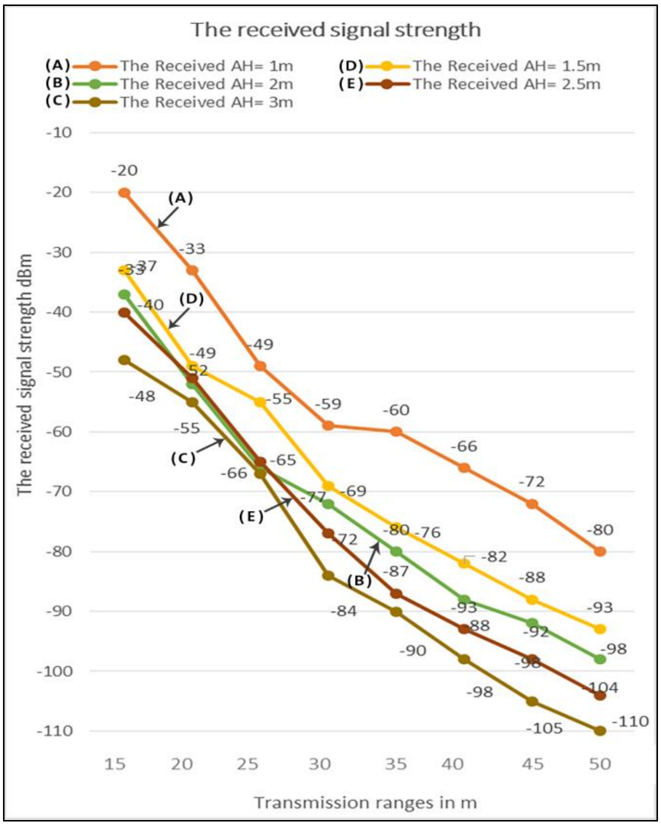


Fig. 7. Received signal strength for various nodes with different distances from the BS. The transmitters AH is 3m and the receiver AH are 1, 1.5, 2, 2.5 and 3m.

C. Packets Reception Ratio

In this part, we illustrate the packets reception ratio for various nodes which are located at different positions away from the BS. As we can see in figure 8, the antenna heights for transmitters (assumed 1m) and the receiver play a very important role in increasing the successful received packets at the BS. We send 5000 periodic packets per sensor nodes (8 sensor nodes) and we calculate the percentages for successful packets reception. In addition, V-MIMO has a great impact on increasing these percentages.

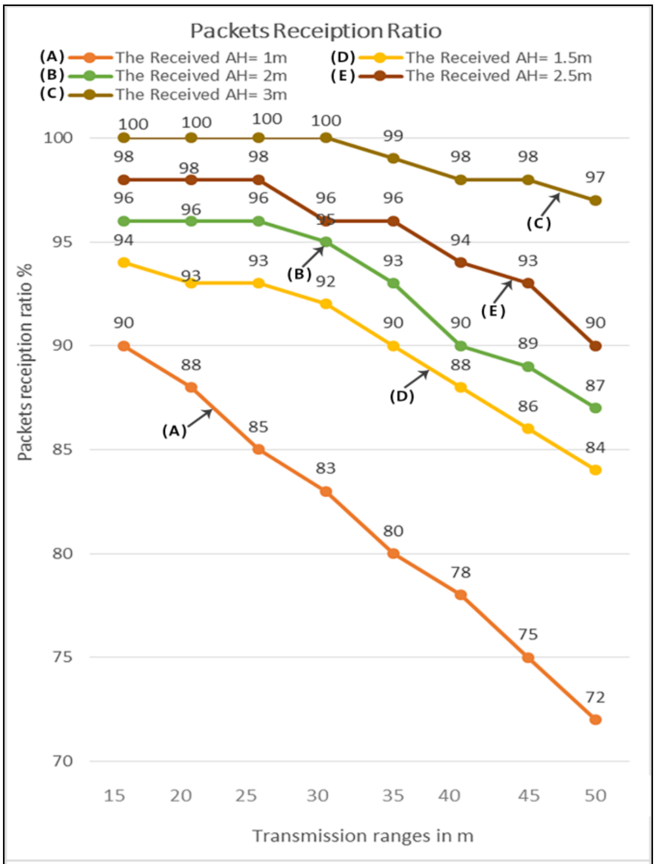


Fig. 8. Packets reception ratio for various nodes with different distances from the BS. The transmitters AH is 1m and the receiver AH are 1, 1.5, 2, 2.5 and 3m.

Further improvement in the packets reception ratio can be gained when increasing the antenna heights of the eights transmitters to 1.5m instead of 1m. Again, we send 5000 periodic packets per sensor nodes and we calculate the percentages for successful packets reception. It is obvious that in figure 9, the packets reception ratios increase when increasing the antenna heights.

D. Energy Consumption

In this part, we simulate the energy efficiency for the proposed convergence between the V-MIMO and antenna heights in the nodes deployment phase. In figure 10, we compare the proposed technique with the normal clustering technique utilized in WSNs, where there is only one CH per cluster and packets follow the shortest path transmission to the BS. V-MIMO technique has a great impact on increasing the energy efficiency where packets can be transmitted via three CHs per cluster. In addition, increasing the antenna heights causes a significant reduction in the number of hops in the routing path to the BS. This makes the relay nodes remain silent most of the time, hence reducing the power consumption and extending the network lifetime.

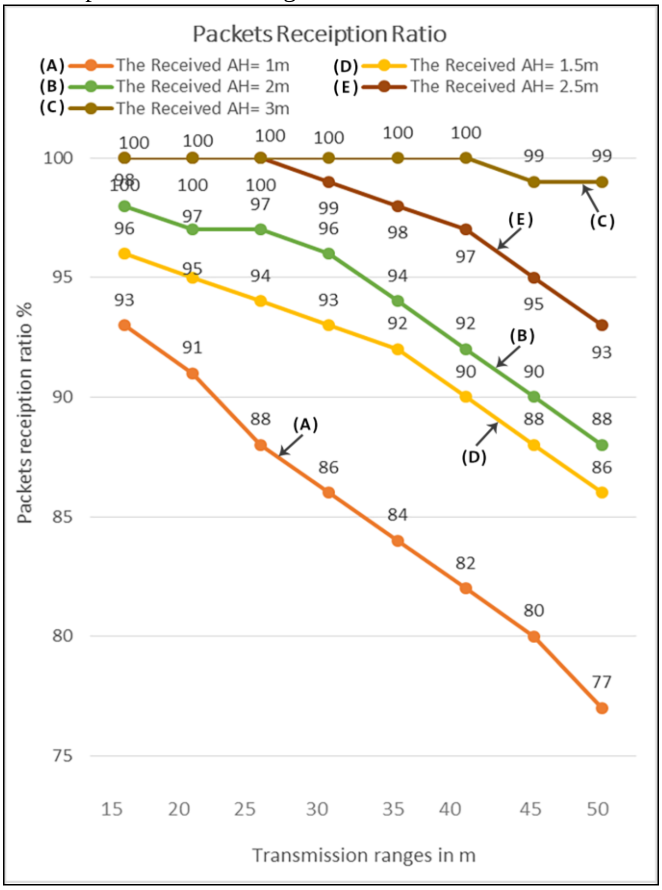


Fig. 9. Packets reception ratio for various nodes with different distances from the BS. The transmitters AH is 1.5m and the receiver AH are 1, 1.5, 2, 2.5 and 3m.

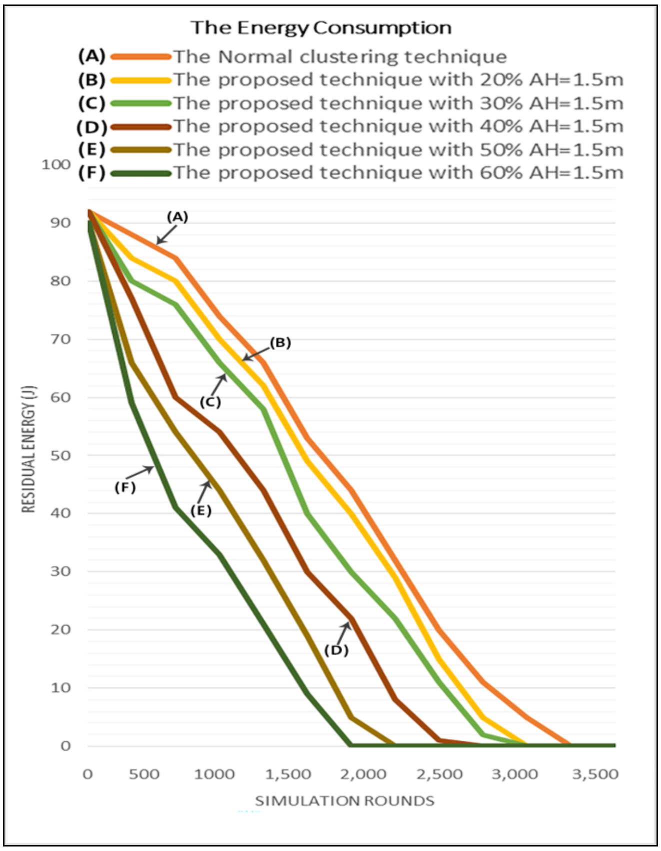


Fig. 10. Comparison between the proposed convergence technique and the normal clustering technique in the power consumption.

VII. CONCLUSION

In this paper, we proposed a convergence between V-MIMO to collaborate packets transmission in clusters and the antenna heights technique in the node deployment phase. We proposed three CHs per cluster in inter-cluster communication. For intra-cluster communication, the antenna heights for transmitter/receiver play a very important role in increasing the range of the radio signals and reducing the number of replay nodes. We apply our proposed technique in multi-hop packets transmission for WSNs. The simulation analysis that considers Rayleigh fading channels shows significant improvements in the network lifetime, the received signal strength, the packets reception ratio and the energy efficiency. The future direction of our works will focus on how to implement the proposed nodes deployment strategy based on the antenna heights on real networks, and compare the network performance metrics for two scenarios where the antenna heights is considered in the nodes deployment phase and the normal scenario where all sensor nodes have the same antenna heights.

REFERENCES

[1] A. Mateen, M. Sehar, K. Abbas and M. A. Akbar, "Comparative analysis of wireless sensor networks with wireless multimedia sensor networks," 2017 IEEE International Conference on Power, Control, Signals and Instrumentation Engineering (ICPCSI), Chennai, 2017, pp. 80-83.

[2] K. G. Panda, D. Agrawal and A. Hossain, "Virtual MIMO in wireless sensor network - a survey," 2016 Online International Conference on Green Engineering and Technologies (IC-GET), Coimbatore, 2016, pp. 1-4.

[3] L. Grira and R. Bouallegue, "Energy Efficiency of Cooperative MIMO in Wireless Sensor Networks over Rayleigh Fading Channel," 2017 IEEE 31st International Conference on Advanced Information Networking and Applications (AINA), Taipei, 2017, pp. 107-111.

[4] Hoon Jeong, Changwon Lee, Jaehong Ryu, Byung-Chul Choi, JeongGil Ko, and Jeongyeup Paek, "Reducing hops without extra power: Impact of deployment height on low-power multihop wireless network," International Journal of Distributed Sensor Networks, Vol.13 No. 9, July 2017.

[5] A. Dziri, A. Ben Ammar and M. Terre, "Performance analysis of MIMO cooperative relays for wireless sensor networks," 2017 13th International Wireless Communications and Mobile Computing Conference (IWCMC), Valencia, 2017, pp. 2029-2033.

[6] A. Bharti, C. Devi and V. Bhatia, "Enhanced energy efficient LEACH (EEE-LEACH) algorithm using MIMO for wireless sensor network," 2015 IEEE International Conference on Computational Intelligence and Computing Research (ICCIC), Madurai, 2015, pp. 1-4.

[7] M. Hefnawi, "Large-Scale Multi-Cluster MIMO Approach for Cognitive Radio Sensor Networks," in IEEE Sensors Journal, vol. 16, no. 11, pp. 4418-4424, June1, 2016.

[8] G. Liu, Z. Sun and T. Jiang, "Joint Time and Energy Allocation for QoS-Aware Throughput Maximization in MIMO-based Wireless Powered Underground Sensor Networks," in IEEE Transactions on Communications.

[9] J. Chung, J. Kim and D. Han, "Multihop Hybrid Virtual MIMO Scheme for Wireless Sensor Networks," in IEEE Transactions on Vehicular Technology, vol. 61, no. 9, pp. 4069-4078, Nov. 2012.

[10] G. Huang, D. Chen and X. Liu, "A Node Deployment Strategy for Blindness Avoiding in Wireless Sensor Networks," in IEEE Communications Letters, vol. 19, no. 6, pp. 1005-1008, June 2015.

[11] H. Yuan and J. Xie, "Node deployment strategy for a mobile sink in wireless sensor networks," 2011 IEEE 3rd International Conference on Communication Software and Networks, Xi'an, 2011, pp. 361-364.

[12] G. Xiong, L. Hong and Y. Guangyou, "Improving energy efficiency by optimizing relay nodes deployment in wireless sensor networks," 2017 IEEE 9th International Conference on Communication Software and Networks (ICCSN), Guangzhou, 2017, pp. 306-310.

[13] A. Rakavi, M. S. K. Manikandan and K. Hariharan, "Grid based mobile sensor node deployment for improving area coverage in Wireless Sensor Networks," 2015 3rd International Conference on Signal Processing, Communication and Networking (ICSCN), Chennai, 2015, pp. 1-5.

[14] R. Kotian, G. Exarchakos and A. Liotta, "Reliable low-power wireless networks over unstable transmission power," 2017 IEEE 14th International Conference on Networking, Sensing and Control (ICNSC), Calabria, 2017, pp. 801-806.

[15] S. A. Dobre, A. B. Kahng and J. Li, "Design Implementation With Noninteger Multiple-Height Cells for Improved Design Quality in Advanced Nodes," in IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems, vol. 37, no. 4, pp. 855-868, April 2018.

[16] J. Zhao and R. Govindan "Understanding packet delivery performance in dense wireless sensor networks," 2003 1st ACM international conference on embedded networked sensor systems, Los Angeles, 2003, pp.1–13.

[17] W. Heinzelman, A. Chandrakasan and H. Balakrishnan, “Energy efficient communication protocol for wireless microsensor networks,” the 33rd Annual Hawaii International Conference on System Sciences (HICSS), Maui, HI, Jan. 2000.

[18] I. Lee and D. Kim, "Probability of SNR Gain by Dual-Hop Relaying over Single-Hop Transmission in SISO Rayleigh Fading Channels," in IEEE Communications Letters, vol. 12, no. 10, pp. 734-736, October 2008.

[19] F. Alassery, W. K. M. Ahmed and V. Lawrence, "MDSA: Multi-dimensional slotted ALOHA MAC protocol for low-collision high-throughput wireless communication systems," 2015 36th IEEE Sarnoff Symposium, Newark, NJ, 2015, pp. 179-184.

[20] C. K. Marigowda, Thriveni J, Gowrishankar S, and Venugopal K. R, "An Efficient Secure Algorithms to Mitigate DoS, Replay and Jamming Attacks in Wireless Sensor Network," Lecture Notes in Engineering and Computer Science: Proceedings of The World Congress on Engineering and Computer Science 2018, 23-25 October, 2018, San Francisco, USA, pp166-171

[21] Venkatesh, Akshay A L, Kushal P, K R Venugopal, L M Patnaik, and S S Iyengar, "THGOR: Two-Hop Geographic Opportunistic Routing in WSNs," Engineering Letters, vol. 25, no.4, pp396-405, 2017.

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