IJETIE
International Journal of Emerging Technology and Innovative Engineering
Volume I, Issue 3, March 2015
ISSN: 2394 - 6598
www.ijetie.org

OPTIMAL NETWORK TOPOLOGY OF WIRELESS SENSOR NETWORK BASED ON UNIFORM DISTRIBUTION

P. Rajesh Kumar[1],S.Rajeswari[2]
[1]II M.E (Communication Systems) PSN College of Engineering and Technology, Tirunelveli.
[1]Email: rkrrajesh74@gmail.com
[2]Asst.professor,Department of ECE, PSN College of Engineering and Technology, Tirunelveli.
[2]Email: rajee.eswari2006@gmail.com

Abstract — **In this paper, we explore methods to generate optimal network topologies for wireless sensor networks (WSNs) with and without obstacles. Specifically, we investigate a dense network with n sensor nodes and $m = n^b (0 < b < 1)$ helping nodes, and assess the impact of topology on its throughput capacity. For networks without obstacles, Randomly distributed sensors cause weak signal and interference which affects the throughput capacity of the network. So we are using heterogeneous uniform sensor distribution which helps to overcome those problems instead of non-uniform random sensor distribution and the Poisson process is used here to distribute the sensors as uniformly. At finally we have found the optimal network topology is as hybrid topology according from the survey. It could only lead a favorable improvement in throughput capacity. Because in the hybrid topology there are so many multi centralizers are used, while in the case of any of one centralizer getting failure, then the entire network will be redirected and those sensors will be connected to the nearer centralizer. So the signal transmission will be continuous and there will be no signal losses.**

Index Terms— **Wireless sensor network, topology, throughput capacity, nodes' spatial distribution.**

I. I NTRODUCTION

Network capacity is a fundamental issue in wireless sensor networks (WSNs). A typical WSN involves little or no infrastructure and sensor nodes may communicate in an ad hoc manner. In Gupta and Kumar's seminal work, they adopt Protocol and Physical Model to describe a successful transmission and show the per-node throughput capacity scales as $\Theta(1/\sqrt{n \log n})$ in random networks, and the per-node transport capacity scales as $\Theta(1/\sqrt{n})$ in arbitrary networks, respectively [1]. Extensive research on the broadcast and multicast capacity for ad hoc network has been conducted in [2], [3]. These results provide us not only a theoretical bound but also a foundation in the network optimization and protocol design.

Following their work, more researches are conducted to understand the scaling laws in wireless sensor networks better. And in some applications, more powerful helping nodes are introduced to improve the performance, which can result in a heterogeneous network. In heterogeneous networks, the sensors which are used in that can sensing the various sets of signals. That's why we can use it for multi sensing and

different access control protocols are studied in [4], [5], [6], [7], routing protocols are studied in [8], [9], [10], [11], [12], [13], N. Li et al. studied topology control in [14] to maintain the network connectivity for improving network capacity. P. Li et al. studied the throughput capacity of heterogeneous networks with rectangular areas in [15], [16]. Many other schemes such as multicast, multiple-input multiple-output (MIMO), hierarchical region and adding infrastructure are also explored in literatures to improve the network capacity. However, most of works above are for networks with regularly or uniformly distributed sensor nodes. While in practice, sensor nodes may not be placed uniformly, which could have a huge impact on network properties, including the capacity. For example, if lots of nodes are confined in a small region, it would lead to great interference and deteriorate the capacity. Also, if nodes are too sparse in a particular area, communication might get difficult, which also harms network performance. To the best of our knowledge, only a few works have dealt with the capacity of networks with inhomogeneous node density. In [17], [18], [19], [20], [22], capacity of inhomogeneous clustered networks is analyzed. Corresponding scheduling and routing schemes to approach the upper bounds for both Cluster Grid and Cluster Random models are discussed in [21].

On the other hand, almost all the previous works dealt with flat network region. While in practice, sensor networks are often deployed in complex environments, such as battle fields or mountainous areas, and there are often many obstacles distributed in these regions. These obstacles may constrain the distribution of sensor nodes and the transmission of packets. For example, in a building monitoring WSN, electromagnetic wave signal can be attenuated significantly when passing through furniture, walls or floors, which could have a great impact on network performance.

Another example is WSNs deployed in a mountainous area, in which both routing strategy design and deployment of sensor nodes should consider the constraint of the complex landform. Generally, obstacles have a negative impact on the network capacity. However, if we design the network

IJETIE
International Journal of Emerging Technology and Innovative Engineering
Volume I, Issue 3, March 2015
ISSN: 2394 - 6598
www.ijetie.org

topology appropriately, it could lead to a favorable improvement. For example, in building monitoring WSNs, the capacity can be improved if we place fewer nodes in areas shadowed by obstacles. Also, in a mountainous region, if we deploy more nodes in open areas, network capacity can be much larger than that we put most of them in valleys or laps.
These motivate us to explore better network topologies for given network regions, especially for networks with obstacles. In this paper, we investigate how nodes' spatial distributions influence the throughput capacity and explore the optimal nodes distribution on given conditions. We firstly model three typical network spatial topologies, analyze the network capacity respectively and make comparison of the results. Based on intuitional explanation and derivation of the results, we draw some useful conclusions on generating the optimal topology for flat network areas. For networks with obstacles, it's difficult to derive a general solution for various obstacles distributions. However, a feasible algorithm with linear complexity can be proposed by dividing the whole network region into some small pieces and dealing with them respectively.

Our main contributions are as follows: ·

For one overall network consisting of many isomorphic sub-networks, the throughput capacity of the overall network is larger than that of one sub-network that has the same network scale.

For networks without helping nodes, uniform sensor nodes' distribution is ordered optimally on maximizing the throughput capacity.

For networks with non-uniformly distributed user nodes and without helping nodes, if the value range of user nodes distribution's PDF is limited, the gap in achievable throughput of non-uniform networks and uniform networks is at most a constant time.

For networks with uniformly distributed sensor nodes, we find that regularly distributed helping nodes are optimal to maximize the network throughput capacity.

For networks with non-uniformly distributed sensor nodes, though regularly distributed helping nodes are no longer optimal, any improvement on helping nodes' distribution cannot change the throughput capacity on scale.

For networks with obstacles, we introduce a novel algorithm of complexity $O(M)$ to generate the optimal sensor nodes' topology for any given obstacles' distribution.

We further analyze the algorithm's performance for networks with regularly distributed obstacles. The rest of the paper is organized as follows. Section II gives the network model. Section III studies the connectivity of networks with different nodes' distributions. In Section IV, we derive the throughput capacity of networks with different topologies. In Section V and VI, we explore some general properties of network topologies. In Section VII, we investigate the throughput capacity of networks with obstacles and introduce an algorithm to generate the optimal user nodes' topology for any given obstacles' distribution. Finally, we conclude the paper in Section VIII.

I. NETWORK MODEL

In this section, we introduce the heterogeneous wireless network model, definition of obstacles, routing strategy and scheduling scheme.

Network Components: A heterogeneous wireless network is a dense network with n user nodes and $m = n^b$ $(0 < b < 1)$ helping nodes. Here we assume that the network has asymmetric traffic as that defined in [15], [16], i.e., all the n user nodes are sources while only n^d $(0 < d < 1)$ user nodes are randomly chosen as destinations. User nodes can serve as relays if needed while helping nodes do not have information to transmit or receive and they only help relaying packets from other user nodes. We divide the network traffic into user mode and helping mode, according to whether user nodes' packets are forwarded by helping nodes. In user mode, packets are forwarded only by user nodes. While in helping mode, packets are firstly sent to the nearest helping nodes, and then forwarded to intended destinations in the helping network. Meanwhile, we assume that all the user nodes have a total bandwidth of 1 and split it into three parts as following

$$W_1 + W_2 + W_3 = 1$$

where W_1, W_2 and W_3 are for ad hoc transmissions in user mode, uplink transmissions in helping mode and downlink transmissions in helping mode, respectively.
Besides, we assume that ad hoc transmissions in helping network have an independent bandwidth of $W_4 = \Omega(1)$.

Definition of Obstacles: To describe networks with obstacles, we assume the network area is partitioned into $k = \Theta(n^w)(0 < w \leq 1)$ cells. When there is no user node in a cell, we assume at the cell's center there is a relay working in the same bandwidth as user nodes, which keeps the network's connectivity. Assume there are $M = \Theta(n^v)(0 < v \leq w)$ obstacle nodes in the network area, which can be arbitrarily or randomly distributed. Cells are blocked when there are obstacle nodes in them. Here, "blocked" has two implications: no user nodes can be distributed in blocked cells and communication between user nodes cannot cross blocked cells.

Interference Model: To bind the interference between different nodes, we suppose the system is based on a cellular network model. Assume that the network is a unit square and we divide it into non-overlapping cells. For user mode and helping mode, the length of cells will be different, and we will present a specific pattern study in the following section. Nodes can communicate with each other only when they are in the adjacent cells. Furthermore, we assume that communications between different cells has taken time division multiplexing (TDM) scheme. Therefore, to avoid

International Journal of Emerging Technology and Innovative Engineering
Volume I, Issue 3, March 2015
ISSN: 2394 - 6598
www.ijetie.org

interference between adjacent cells, we adopt a rotating scheduling scheme as that described in [15], [16]. Thus, at the same time, in all of the adjacent cells there is at most one that can transmit or receive packets and each cell has the same opportunity to be active. Following the power propagation model introduced in [23], the reception power at node X_j of the signal from node X_i is $P_{ij} = CP_i / d_{ij}^{\gamma}$ (1) where d_{ij} is the distance between node X_i and node X_j, γ is the path loss exponent and P_i is the power emitted by node X_i.

Routing Strategy: As user nodes can only communicate with Nodes in neighbouring cells, packets from source nodes may need to be forwarded to destination nodes through multi-hop transmissions. For networks with and without obstacles, we adopt following routing strategies, respectively.

Routing Strategy I - for networks without obstacles:
Suppose that a source node is located in cell S_i and that its destination is located in cell S_j . The packet sent from the source node firstly is forwarded along the cells in the same vertical line of cell S_i until it gets to the cell in the same horizontal line of cell S_j , then the packet is forwarded along the cells in the same horizontal line of cell S_j until it reaches the destination node.

Routing Strategy II - for networks with obstacles:
1) If packet sent from the source node can be relayed to its destination by Routing Strategy I, do it.
2) Otherwise, if there are only convex obstacles polygons, firstly forward the packet along the routing path generated by Routing Strategy I. When it can no longer be forwarded in current direction (vertical or horizontal), change the forwarding direction to another one (horizontal or vertical). Repeat this until it arrives at the destination node.
3) If there exist concave polygons obstacles and neither the source node nor the destination node is in the groove of a concave obstacles polygon, replace the concave obstacles polygons by their convex hulls, respectively, and then following Step 1) and 2) to forward the packet.
4) If source and destination nodes (or either of them) are in the grooves of concave obstacles polygons, we can find cells outside the corresponding convex hulls and nearest to source and destination nodes, respectively. Denote them by S_A and S_B, respectively. We firstly transmit the packet from the source node to cell S_A, then following Step 1), 2) and 3) to forward this packet from cell S_A to cell S_B, and finally we forward the packet from cell S_B to the destination node.

Network Topology: We first established coordinate system for the network region. As shown in Fig. 1, the coordinate origin is located at the centre of the network. As the edge length of the network region is 1, the maximal scales of x-axis and y-axis are both 1/2.

1) *Uniform Distribution* For networks with uniformly distributed nodes, the probabilities that nodes located at any place of the network is the same with each other, i.e., it has following probability density function.

$$\begin{cases} f(x) = 1 \left(-\frac{1}{2} < x < \frac{1}{2}\right) \\ f(y) = 1 \left(-\frac{1}{2} < y < \frac{1}{2}\right) \end{cases}$$

Uniformly distributed sensors avoid weak signal problems as well as signal interferences, because, if we place the sensors near to one another then it causes signal interferences and if we places the sensors far to one another then it will create the weak signal problem. The throughput capacity of the heterogeneous network is high when compare to the homogeneous network with random distribution and non-uniform distribution. Sensor deploying is low in the uniform distribution of sensors. Cluster is created in the uniform distribution for avoiding the route overhead and the time delay.

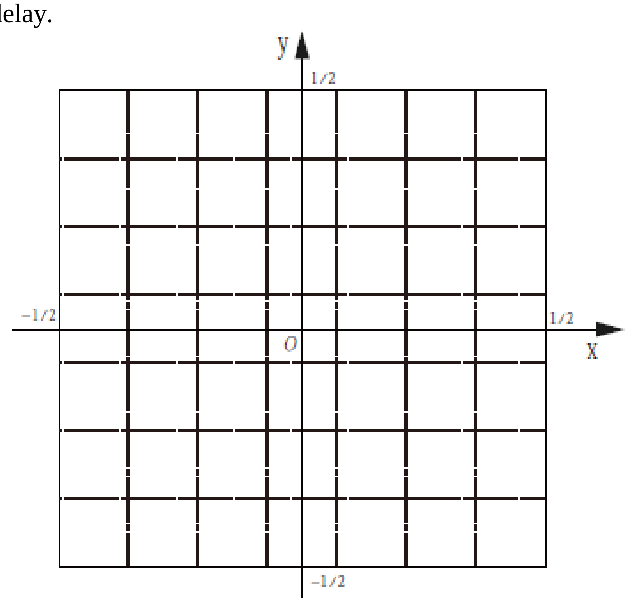

Fig.1.Coordinate system for the network region.

2) *Centralized Distribution* We first consider a simple case of the non-uniform distribution. As shown in Fig. 2, nodes density is large in the centre of the network and small at the edge. We call it "centralized distribution". One of its possible probability density functions can be shown as follows:

$$f(x) = (4a - 4)\,|x| + 2 - a \;(-1/2 < x < 1/2)$$
$$f(y) = (4a - 4)\,|y| + 2 - a \;(-1/2 < y < 1/2) \quad (4)$$

Where a $(0 \le a \le 1)$ is centralization coefficient and its value determines the extent that network nodes aggregate to the centre. The larger a is, the more uniformly the nodes are distributed, or vice versa. In particular, when $a = 1$ the nodes are uniformly distributed; when *a* = 0, the probability of nodes distributed at the edge of the network would become 0.

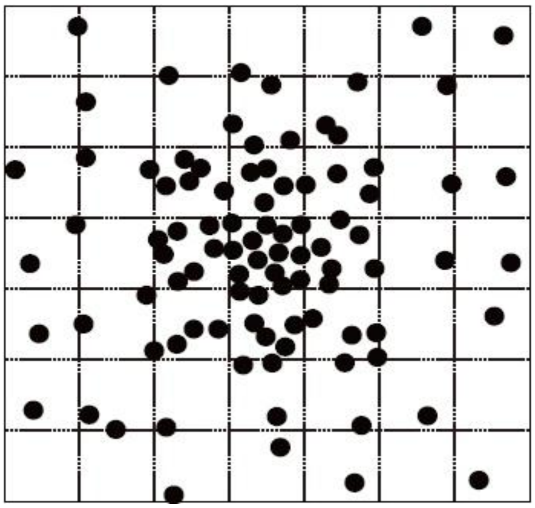

Fig.2.Centralized distribution networks.

3) *Multi-centralized Distribution* In practice, network nodes often aggregate in several locations of the network, not just the centre of the network. We call it "multi centralized distribution". As shown in Fig. 3, We can divide the whole network into many small sub-networks according to the aggregation centre and each sub network has similar network topology. In this paper, we assume that each sub-network is a small centralized distributed network as defined before, i.e., it satisfies the probability density function shown in (4).

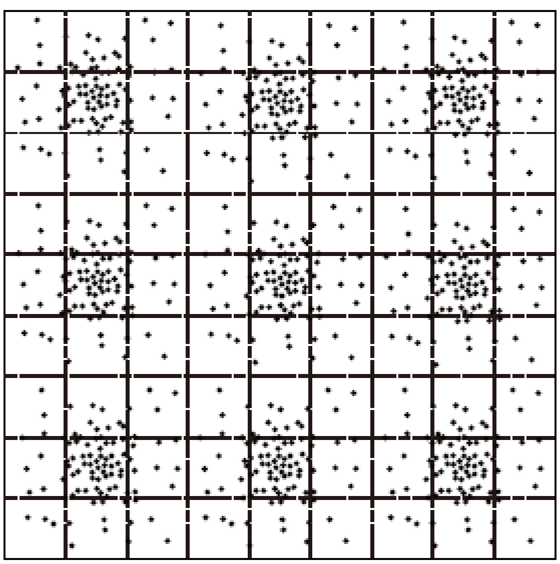

Fig. 3. Multi-centralized distribution networks.

II. PROPOSED SYSTEM

A. *Wall with gate algorithm*

B. *Heterogeneous network*

C. *Hybrid Topology*

D. *Cluster formation in Uniform distribution*

To design the optimization algorithm, we first consider a simple scenario. As shown in Fig. 5, assume that there is a "wall" with a "gate" in the network, which divides the network area into two parts. In this case, the area around the gate is the "hot spot" and the bottleneck of the network achievable throughput since any data flow passing from one side of the wall to another side must pass through the gate. To maximize the network throughput capacity, we can minimize the transmission burden of this area by the following algorithm.

A. Algorithm - "Wall with Gate":

1) Assume that there are $\hat{n}$, n_1 and n_2 number of nodes in the gate area, the left and the right part of the network, respectively, where $\hat{n} + n_1 + n_2 = n$. The expected number of data flows passing through the gate is $u = f(\hat{n}, n_1, n_2)$, where function $f(.)$ can be decided using the methods given in Section IV. Thus the transmission burden of the gate area is $B_0 = u/k_0$, where k_0 is the number of cells in the gate area (the nodes' distribution in the gate area is assumed to be uniform since this area is relatively small).

2) Ignore the wall and the right part of the network. Put $\varphi_1 = g_s(\hat{n}, n_1, n_2)$ number of virtual source nodes and $\phi_1 = g_d(\hat{n}, n_1, n_2)$ number of virtual destination nodes uniformly in front of the gate (i.e., the area illustrated in Fig. 5) to replace the ignored user nodes. Virtual source and destination nodes work as sources and destinations, respectively, generating virtual date flows. Functions $g_s(.)$and $g_d(.)$ are determined by the routing strategy so that this number of virtual nodes have the same influence on the left part of the network as the ignored parts.2 Then we obtain a degraded sub-network without any obstacles.

IJETIE
International Journal of Emerging Technology and Innovative Engineering
Volume I, Issue 3, March 2015
ISSN: 2394 - 6598
www.ijetie.org

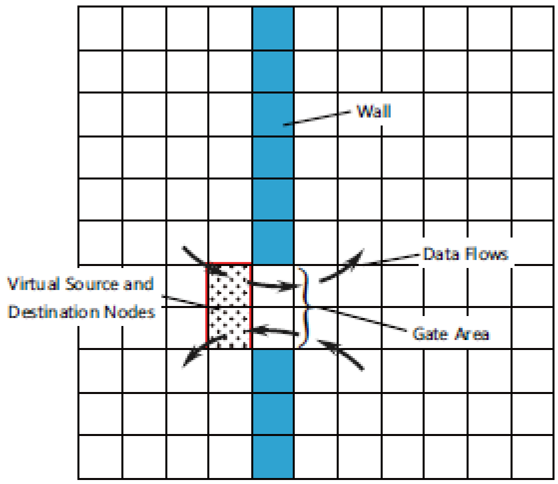

Fig.4. A Wall with gate in the network area.

3) For the degraded sub-network, use methods and conclusions given in Sections IV - VI to generate an optimal topology $\mathfrak{T}_1 = T_1(\hat{n}, n_1, n_2)$ and calculate the corresponding transmission burden $B_1 = h_1((n, m_1, m_2)$.

4) Repeat Step 2 and 3 to the right part of the network, respectively. Generate the optimal topology $T_2 = T_2((n, m_1, m_2)$ and calculate the transmission burden $B_2 = h_2((n, m_1, m_2)$.

5) Use appropriate optimization methods to minimize the cost function $B = \max(B0,B1,B2)$. Calculate corresponding (n, $n1$ and $n2$. Since the topologies obtained in 2For the routing strategy given in Section II, we can let $gs(\_n, n1, n2) = n1n2/n$ and $gd(\_n, n1, n2) = n1n2/n$, respectively.

Step 3 and 4 are functions of (n, $n1$ and $n2$, the optimal topology for the whole network can thus be determined by combining T1 and T2. This "Wall with Gate" algorithm can be generalized to obtain optimal topology for any given networks with obstacles. Firstly, divide the network area into pieces by the following method.

Divide the network by walls - Method I: As shown in Fig. 6, take blocked cells in a row (vertical or horizontal) as a wall and cells without obstacles in this row as gates. Then the network is divided into some sub-networks by these walls. After the network is divided into several sub-networks and gates, the optimal topology for this network area can be obtained by applying the idea of "Wall with Gate" algorithm for each sub-network and gate area. It is important to note that in this situation the gate areas may be relatively large, we can no longer assume that nodes' distribution for gate areas is uniform and also need to perform the algorithm in these gate areas.

The optimal topology for the whole network can be no longer obtained by simply integrating the optimal topology for sub-networks and gate areas using the "Wall with Gate" algorithm. For this network, a sub-network may be adjacent to different gates with other sub-networks. If per pair of adjacent sub-networks is applied by the "Wall with Gate" algorithm to obtain the optimal topology for the pair sub-networks and corresponding gate. It's very likely that there are different optimal topologies for one sub-network with different adjacent sub-network and corresponding gate. The optimal topology of the whole network can't be obtained in this case. The optimal topology of the whole network can be gotten by applying the idea of "Wall with Gate" algorithm, and we should apply the algorithm to the whole network. After the network is divided into several sub-networks and gate areas by walls, we can assume that there are S sub-networks and R gates. Step 2 is applied to all sub-networks and gate areas, and then we can obtain a degraded network without any obstacles, only including several degraded sub-networks and gates. The optimal topology and the transmission burden for degraded sub-networks and gate areas can be obtained by using methods and conclusions given in Sections IV - VI. We use Tk, $k = 1, 2, \ldots S$ and Bk, $k = 1, 2, \ldots S$ as the

B. HETEROGENEOUS NETWORK ARCHITECTURE

We propose a multichannel wireless network that supports heterogeneity with regard to each node's support of multiple channels. We envision a heterogeneous network consisting of single channel legacy nodes along with new emerging multichannel nodes. The emerging multichannel nodes will have a diverse set of multichannel transceivers. Some multichannel nodes can be implemented with a single transceiver, utilizing Software Defined Radio (SDR) technology, thereby enabling the node to "tune" to any of a set of multiple channels by changing some "soft" parameters in the transceiver. Existing alongside these can be nodes that support multiple channels by having transceiver arrays that are made possible by RF circuit integration advances.

This heterogeneous multichannel network will not impose any particular multichannel transceiver architecture on any node. The only requirement in our heterogeneous network architecture is that all nodes support a "base" channel that acts as the control channel and default data channel. This channel can be thought of as a "lobby" where nodes meet by default to negotiate a place to conduct their transmission. All nodes must be able to continuously monitor this channel to avoid the multichannel hidden terminal problem. For legacy single channel nodes, the "base" channel would be the only channel supported.

A method is needed to enumerate the channels. This enumeration scheme needs to be known by all nodes, so a standard should be developed. A detailed discussion of this is outside the scope of this paper. We simply assume that a common enumeration scheme exists.

C. HYBRID TOPOLOGY

We extend the idea of sub wavelength sharing to existing multicast demands. We provide a more flexible and practical framework where existing light-trees could be shared as well. A technical challenge in sub wavelength sharing of light-trees is that a light-tree is designed for a specific group and a wavelength is not desirable to be shared by different groups with different set of members. It is because the sharing of a light-tree for other multicast groups will cause all the destinations on the tree to receive data packets sent on the tree unnecessarily. We minimize the excess traffic due to light-tree sharing while optimizing all the resources. We bound the degree of sharing in order to meet the QoS of existing traffic. Our solution is aimed for a dynamic environment where new traffic demands need to be satisfied without disturbing the service of existing traffic. Our main contribution is that when new traffic demands, either unicast or/and multicast, arrive, they can be supported incrementally, taking available resources and existing traffic demands into consideration. If desirable or physical resources are lacking, we allow the use of existing light-paths or light-trees in conjunction with a possibly new (partial) light-tree. A challenging issue when light-trees are shared is to minimize excess traffic incurred by the different multicast demand from the existing tree(s). In order to address that, we formulate an optimization problem that includes the overhead of excess traffic. We find that this hybrid (light-trees and light-paths) virtual topology design enables us to establish multicast trees when it would otherwise be impossible. Thus, more traffic demands are supported under practical network condition of limited wavelength constraints.

There are essentially two types of fault-management techniques: protection and restoration. In protection, spare capacity is reserved during call setup. In restoration, the spare capacity available after the fault's occurrence is utilized for rerouting the disrupted traffic. Generally, restoration schemes are more efficient in utilizing capacity due to the sharing of the spare capacities, while protection schemes have a faster recovery time and provide guarantees on the recovery.

D.CLUSTER FORMATION IN UNIFORM DISTRIBUTION

Cluster analysis groups data objects based only on information found in the data that describes the object and their relationship the objects and their relationships. The goal is that the objects within a group similar to one another and different from the objects in other groups. The greater the similarity within a group and the greater the difference between the groups, the better or more distinct the clustering. In many applications, the notion of the cluster is not well defined. To better understand difficulty of deciding what constitutes a cluster membership. Cluster analysis is related to the another technique that are used to divide data objects into groups. For instance and clustering can be regarded as a form of classification in that it creates a labeling of objects with class labels. However, it derives these labels only from the data. In contrast, classification of cluster head and the cluster members. Clustering combined with in-network data aggregation is also seen as a useful mechanism to increase the energy efficiency of the system, another important design criterion of WSNs.

While clustering has many advantages regarding the operation of the WSN, we argue that it has some drawbacks with respect to security. In particular, each cluster usually has a controller node, called the cluster head that has a distinguished role. For instance, the cluster head may be responsible for controlling the operation of the sensor nodes in the cluster by setting their configuration parameters, and for aggregating the sensor readings collected from the cluster and storing the result or sending it to the sink or some higher level cluster head. If such a cluster head node is disabled by physical destruction or jamming, then the entire cluster becomes inoperable temporarily until the problem is detected and a new cluster head is elected. Hence, when clustering is used, the adversary can focus its effort and resources on attacking the cluster head nodes, which constitute only a small subset of the node.

In order to address this problem, one would like to make it difficult for the adversary to identify the cluster head nodes. For this, in turn, one needs to understand when and how the adversary may attempt such identification. Basically, the adversary can try to identify the cluster heads either (i) during the cluster head election process itself, or (ii) after the cluster head election during the regular operation of the network. In case (i), the adversary may passively observe the execution of the cluster head election protocol and learn, just like the cluster members, which nodes became cluster heads, or it may actively interfere with the execution of the protocol and try to manipulate its outcome such that it becomes easier for the adversary to figure out who the cluster heads are. In case (ii), the adversary may eavesdrop the messages and try to figure out from the addressing information who the cluster heads are, or, if such addressing information is hidden from the adversary, it may try to analyze the traffic patterns and identify the cluster heads as the sinks of the local traffic flows. The adversary may also try to tamper with an arbitrary sensor node and read from its stored state information (e.g., its routing table) who may be the cluster head that the node is associated with. In this paper, we focus on the prevention of the identification of the cluster head nodes during the execution of the cluster head election protocol, because this seems to be a completely neglected problem. Indeed, most existing cluster head election protocols use clear text cluster head announcement messages to broadcast the identifier of the cluster head within the cluster, and hence, trivially leak the identity of the elected cluster heads even to a passive observer. We propose the first private cluster head election protocol for wireless sensor networks that minimizes the information leaked out about the elected cluster heads to an external observer. We address both eavesdropping attacks and traffic analysis attacks against the cluster head election protocol. In addition, if the adversary tampers with an arbitrary sensor node, our protocol ensures that the adversary can identify only those cluster heads that the compromised sensor node can be potentially associated with but no other cluster heads in the network.

CONCLUSION AND FUTURE WORKS

In this paper, we investigate the throughput capacity of heterogeneous wireless networks with different network topologies and analyse the impact of topologies on the network properties. We find that compared to the sub-networks with the same network scales, overall networks have a larger network achievable throughput. We analyse the impact of user nodes' topology and helping nodes' topology on the network capacity. We find that for non-uniformly distributed user nodes, if the value range of nodes distribution's PDF is limited, the gap in achievable throughput of non-uniform networks and uniform networks is at most a constant time. Compared to regularly distribute helping nodes, any change of helping nodes' topology cannot improve the network achievable throughput on scale. We further investigate the impact of obstacles. An algorithm is introduced to divide the network with obstacles into several sub-networks and gate areas and forming the cluster. Then we study the performance of the algorithm for the regularly distributed obstacles. Moreover the in-depth analysis for network areas with different distributions is needed. Centralized network with node density which has a power law distribution, normal or Poisson distribution may be more in line with reality and should be analysed in the future. Then the optimal topology for these network models or the characteristic conditions for ensuring the optimal solution can be obtained according to these analyses. The optimal nodes' spatial distribution should be studied for specifically obstacles' distributions on the basis of practice with the algorithm and these optimal solutions for different nodes' distributions.

REFERENCES

[1] P. Gupta and P. R. Kumar, "The capacity of wireless networks," *IEEE Trans. Inf. Theory*, vol. 46, no. 2, pp. 388–404, Mar. 2000.

[2] A. Keshavarz-Haddad, V. Ribeiro, and R. Riedi, "Broadcast capacity in multihop wireless networks," in *Proc. 2006 ACM Mobicom*.

[3] C. Hu, X. Wang, and F. Wu, "MotionCast: on the capacity and delay tradeoffs," in *Proc. 2009 ACM MobiHoc*.

[4] P. Li, X. Geng, and Y. Fang, "An adaptive power controlled MAC rotocol for wireless ad hoc networks," *IEEE Trans. Wireless Commun.*, vol. 8, no. 1, pp. 226–233, Jan. 2009.

[5] P. Li, Q. Shen, and Y. Fang, "Power controlled network protocols for multi-rate ad hoc networks," *IEEE Trans. Wireless Commun.*, vol. 8, no. 4, pp. 2142–2149, Apr. 2009.

[6] M. McGarry, M. Reisslein, and V. Syrotiuk, "Access control in heterogeneous multichannel wireless networks," in *Proc. 2006 Int'l Conf. Integrated Internet Ad hoc and Sensor Networks*.

[7] H. Zhou, C. Yeh, and H. Mouftah, "Access control in heterogeneous multichannel wireless networks," in *Proc. 2004 IEEE Vehicular Technology Conference*.