Effect of Obstacles in the formation of FoV based Clusters in Wireless Multimedia Sensor Network

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Abstract: Wireless multimedia sensor network (WMSN) uses multimedia nodes to sense the area that are uncorrelated to the areas sensed by the neighboring sensors. Because of the extensive amount of data produced in wireless multimedia sensor network, clustering schemes eligible in wireless sensor network are not suitable for WMSN. For this very purpose, a number of clustering schemes are available in the literature and a clustering scheme based on overlapping FoVs of multimedia nodes is one of them. This paper analyzes the formation of obstructed clusters because of the obstacle encountered by the node as it is an inherent consideration to be brought while designing a routing scheme in WMSN. The main aim of this work is to analyze the effect of obstacles lying in front of multimedia nodes and thus forming the clusters accordingly.

I. INTRODUCTION

With the advent of efficient short range radio communication and advances in miniaturization of computing devices, a strong interest in wireless sensor network has been generated. Wireless Sensor Network [4][5] are formed of spatially distributed autonomous large number of small, inexpensive, battery powered MEMS-based sensor nodes with the ability to communicate to the external world via base station. The communication is either direct (single hop) or via other nodes (multi hop) around it in a cooperative manner.
In recent times there has been increased interest in video surveillance and environment sensing applications. Multimedia is media and content that uses a combination of different content forms. Multimedia sensors are generally used in wireless multimedia sensor network (WMSN) [2][6],for application monitoring and should be able to process in real-time, retrieve or fuse multimedia data. By using CMOS cameras embedded in wireless sensor nodes, visual information maybe captured from the environment.

The key challenge in the design and implementation of WSNs is the maximization of system lifetime and energy conservation. Node clustering is one of the subjects that have been proposed for enhancement in efficiency of applications associated with WSNs. The several objectives pursued by clustering in WSN are: (i) energy conservation, (ii) network scalability, (iii) network topology stabilization, (iv) optimized management strategies to prolong battery life and network lifetime, and (v) routing overhead minimization. Most of the time, distance from nodes to cluster-head or radio coverage (i.e., neighborhood) are the main criterions for node clustering in WSNs [7].

For WMSN, the sensing region of the nodes is different from the traditional nodes used in WSNs. The multimedia node has a defined field of view (FoV) and can capture objects within that region only. In traditional WSNs, the node collect the information of different phenomenon around them from the area determined by its sensing range; whereas, the image of the object captured by the video camera may not necessarily be in camera's vicinity. The camera's orientation and relative position towards the object will determine the captured image of object, which can also be distant from the camera. Now as it is clear, because of the difference between radio neighborhood and sensed region by the multimedia node, the coverage techniques and node clustering in WSNs do not satisfy WMSNs requirements.

Now, for this kind of WMSN it is like a challenge to make it energy-efficient & of longer life time. A survey on this WMSN is given in [2].In this paper, we are proposing a new scheme to check the various parameters of the network due to obstacles in the path of the sensing region as well as to make a network which will be energy efficient. We took the idea for making clusters by the algorithm described in[1] where the author made the clustering based on FoV. Two cameras would be in same cluster if their FoVs have a common area greater than threshold area.

The clustering algorithm to be reevaluated here is based on overlapping FoVs of the camera and accordingly evaluating intersection polynomial of FoVs of two nodes and computing the overlapped area are the keys to figure out the clusters and cluster membership.

There is a very common scenario that FoVs of nodes may be obstructed due to number of obstacles. In that case we need to re compute the obstructed overlapping areas to analyze the performance of the network i.e. how the formation of clusters gets affected.

II. RELATEDWORK

Clustering has been studied in wireless scalar sensor network. The surveys [7] present the clustering protocols in this field and provide main keys for the design of such algorithms. Some geometric calculations and algebra related to our research [11][12] represents different methods for checking the intersection of two triangles.

Multimedia sensors are powerful multidimensional sensors that can capture a directional view. We assume wireless sensor nodes with fixed lenses providing a θ angle FoV, densely deployed in a random manner. The monitoring area consists of N wireless camera sensors, represented by the set, $\{S = S_1, S_2 . S_3, \ldots, S_N\}$.

The following definitions are used in the paper[1]

Field of View (FoV)

refers to the directional view of a multimedia sensor and it is assumed to be an isosceles triangle (two-dimensional approximation) with vertex angle θ**,** length of congruent sides R_s(sensing range) of the sensor and orientation α. The sensor is located at point A (x_A, y_A).

Clusters ($C_j | j = 1, 2, 3 \ldots$)

consist of a subset of multimedia nodes with high overlapping FoV areas. The size of overlapping area between FoV of two nodes determines whether they can be in the same cluster.

Clustering threshold (γ)

defines the minimum percentage of node's FoV area that is required to be overlapped for membership in a cluster.

We have considered a clustered architecture based on WMSN[1].In the earlier paper[1], the author had proposed a WMSN clustering based on Field of View (FoV).The area overlapped between the FoV of each camera was found out. Then according to that the cameras whose overlapped area crossed a certain threshold value were placed in one cluster. So in each cycle if a camera from all the clusters were waken then the energy conservation for the entire network was enhanced.

A. Overlapping Areas Between FoVs of Multimedia Nodes with Obstacle

We propose that cameras can have obstacle in front of them, therefore, some modifications in the mathematical calculations of the paper[1] are made and then calculated the overlapped area with obstacle.

Now for this modification, the nodes should have some mechanism to calculate the lowest and highest point of the obstacle. For formation of cluster firstly we have to know about *Field of View (FoV).*It can be shown as *fig.1*

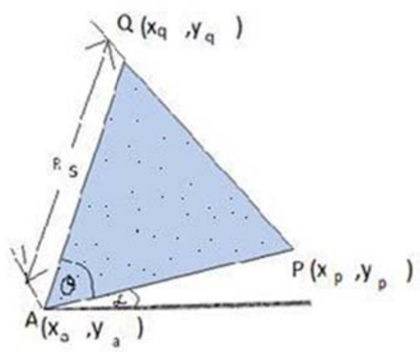

Figure 1(a).FoV of a node without Obstacle

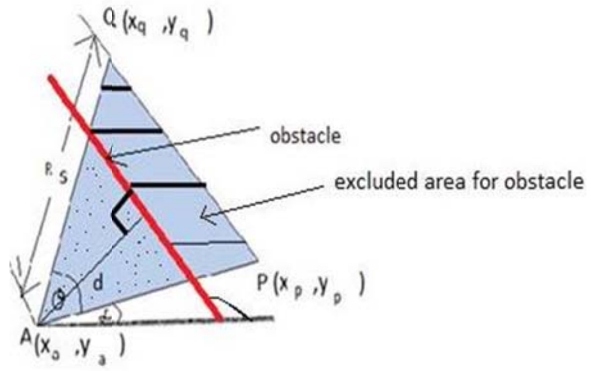

Figure 1(b). FoV of a node with Obstacle

We worked on basically with the FoVs having obstacles i.e represented in *fig.1 (b).*
Now we have some *assumptions* regarding our work. *Firstly* the thing which doesn't change it's position with time & which fully covers the FoV is considered as the *obstacle* for that node particularly.

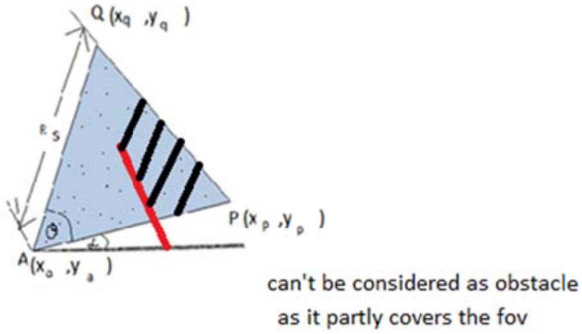

Figure 2. Node with Partial Obstacle

Secondly Our hypothetical application provides us such types of multimedia sensors which can detect these *obstacles* and can compute their perpendicular distance from it's own position and also the slope of that obstacle, i.e., *d and β*(as in fig. 1(b))are known to every node.
Now we make cluster on the basis of overlapping area of the FoVs.In the paper mentioned above the calculations are there for finding the overlapping area of the FoVs.But we have made it more practical by including the obstacles to the nodes.So, for us the *area of FoV*is reduced as it is shown in fig.1(b).
So, the *effective FoV area* is reduced as shown in the following diagram:

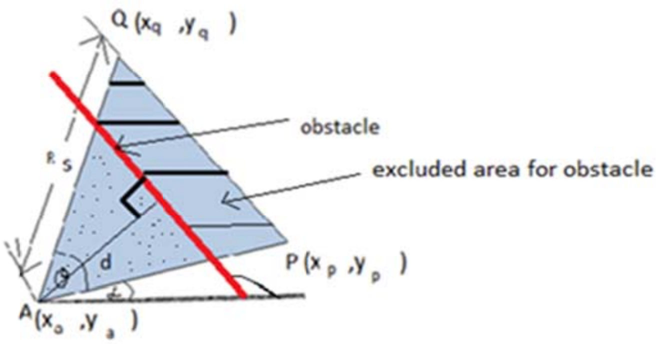

Figure 3. Affected FoV of a Node

Now as we have nothing to do with the excluded part so let's remove it.

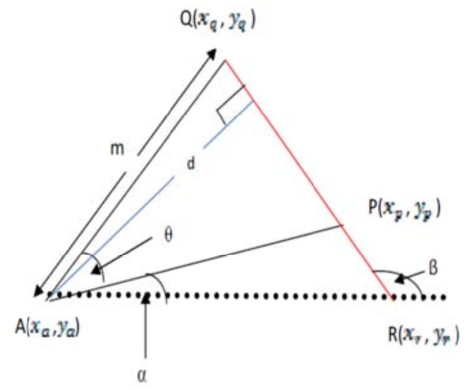

Figure **4**. Reduced FoV of a Node

After removing the excluded part, FoV of the camera

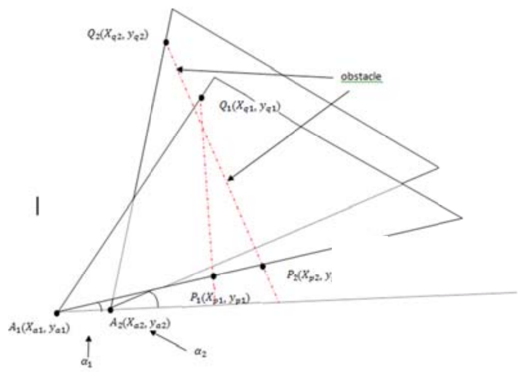

Figure 5. Overlapping FoVs of Nodes

Now the equation of the side of the triangle (from fig.4)

$AP \rightarrow \; y - Y_A = (x - X_A) tan\alpha$

$AQ \rightarrow y - Y_A = (x - X_A)\tan(\alpha + \theta)$

$$\tan\beta = \frac{y_q - y_p}{x_q - x_p}$$

$PQ \rightarrow y - Y_p = (x - X_p)\tan\beta$

Now to calculate the overlapped area of $\Delta A_1P_1Q_1$ and $\Delta A_2P_2Q_2$ (fig.5), one has to consider every side of $\Delta A_1P_1Q_1$ with respect to every other side of $\Delta A_2P_2Q_2$. Afterward, one needs to check the validity of every such intersection-point whether they lie on at least one line of any of two concerned FoVs. At last, area of the polygon formed with these points is computed and checked against a threshold area for making an appropriate decision regarding an eligible overlapping of nodes' FoVs towards cluster-formation.

B. Algorithm

This section explains the formation of clusters and cluster membership with and without obstacles in the sensing area. All sensor nodes have been configured with a FoV vertex angle θ=60º and R_s of 20 m. A sensing field spanning an area of 120m×120m has been used. Once a random deployment is done; clusters are formed in a centralized manner at sink which requires node's location, angle-orientation, and vertex-angle etc. Furthermore, another algorithm describes the cluster formation with obstacles in the path of camera's FoV.

Cluster Formation (Without Obstacle)

```
1. k=1
2. For i=1:n
  /*for every un clustered multimedia sensor node*/
3   Cluster(k).member=[node(i)]
4. For j=1:n
5. if i==j
6.   Continue;
7. else
8.        A=Overlapping _ FoV's_ intersection
area(node(i),node(j))
 /*Compute overlapping FOV area between the ith & jth node*/
9.if A>=γ                    /*γ-> Threshold Area*/
10.                              Cluster(k).member=[Cluster(k).member.
nodes(j)];
11.  else
12.      Continue;
13.      end if
14.      end if
15. end for
16. k=k+1
17. end for
```

Cluster Formation (With Obstacle)

```
1. k=1
2. For i=1:n
/*for every un clustered multimedia sensor node*/
3. Compute the reduced FoV for node(i)
4. Cluster(k).member=[node(i)]
5. For j=1:n
6. if i==j
7.     Continue;
8. else
9.    A=Overlapping _ Obstructed _ FoV's_
Intersection_ area(node(i),node(j))
 /*Compute overlapping FOV area between the ith
& jth node*/
10. if A>=γ                      /*γ-> Threshold Area*/
11.            Cluster(k).member=[Cluster(k).member. nodes(j)];
12. else
13.         Continue;
14. end if
15. end if
16. end for
17. k=k+1
18. end for
```

C. Simulation-Results

The following results are obtained with varying number of node deployment i.e. 50, 100, 150, 200, 250 and 300 in presence of different number of obstacles i.e. 25, 50,75, and 100 while keeping other parameters constant.

Sensing Range	20 m
Network Area	120 x 120 m²
Vertex angle	60º
Clustering Threshold	0.5

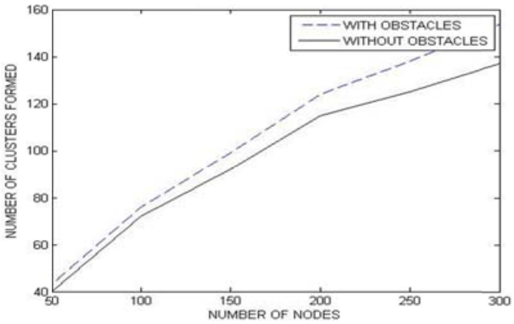

Figure 6.Formation of Clusters with varying number of nodes in the presence of 25 Obstacles

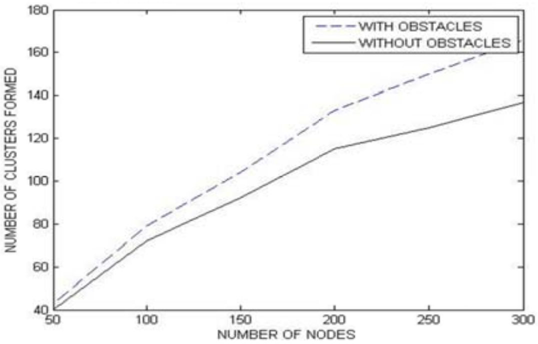

Figure7. Formation of Clusters with varying number of nodes in the presence of 50 Obstacles

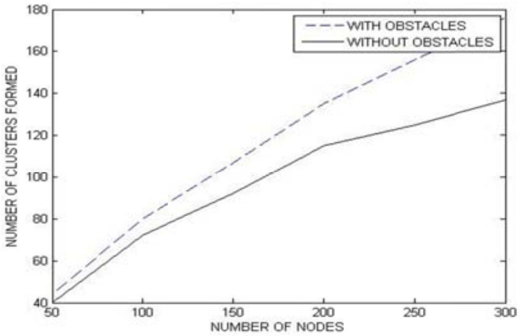

Figure 8. Formation of Clusters with varying number of nodes in the presence of 75 Obstacles

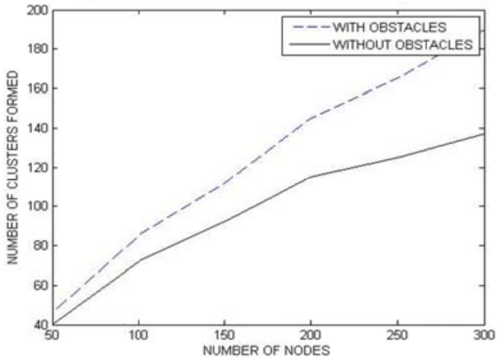

Figure 9. Formation of Clusters with varying number of nodes in the presence of 100 Obstacles

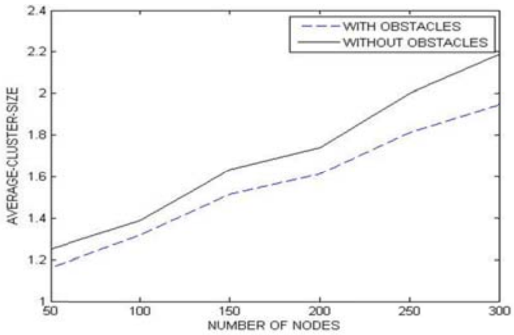

Figure 10. Average Cluster Size with varying number of nodes in the presence of 25 obstacles

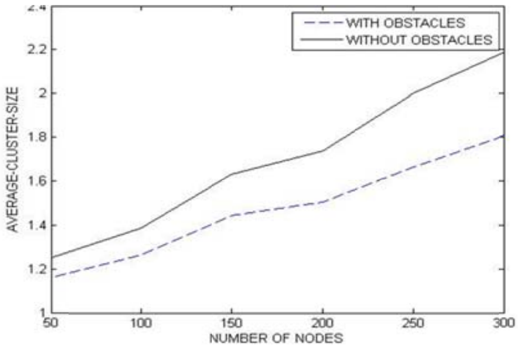

Figure 11. Average Cluster Size with varying number of nodes in presence of 50 obstacles

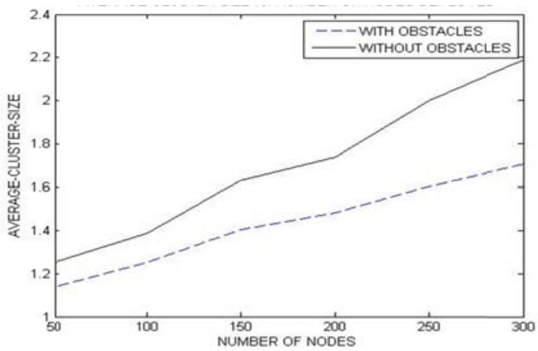

Figure 12. Average Cluster Size with varying number of nodes in presence of 75 obstacles

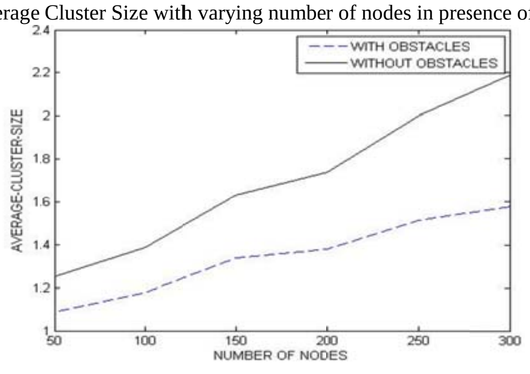

Figure 13. Average Cluster Size with varying number of nodes in presence of 100 obstacles

It can be easily observed from Fig. 6 to Fig. 9 that as the number of obstacles increases, the number of clusters increases as well. It happens because of the restricted overlapping of nodes' obstructed FoVs. Besides this, from Fig. 10 to Fig. 13, it can also be noticed that with the increase in the number of obstacles, average cluster-size is reduced, because some of the clusters are built with only one node i.e. isolated clusters; the same reason cited above causes the happening of this phenomenon also. Moreover, this degrades the performance of network.

III. CONCLUSION AND FUTURE WORK

As it can be verified from the above cited simulation-results, the presence of obstacles severely affects formation of the cluster. It can be merely stated that as the number of obstacles in the sensing field increases, the number of clusters increases and hence the average size of clusters decreases as well. The only reason is that obstacles limit and blocks the field of view of respective nodes and with such obstructed FoVs, the chances of FoV-overlapping get reduced; henceforth, number of clusters (isolated clusters i.e. clusters with single node) increases.

The same clustering scheme will be checked against heterogeneous and mobile multimedia sensor nodes in future and it will be observed that how the network-performance gets affected.

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