Constrained Passive Tracking Using Wireless Sensor Networks

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Abstract: *Wireless Sensor Network consists of sensor nodes, used for monitoring the environmental conditions such as pressure, temperature, etc. In order to provide efficient clustering and to increase the lifetime of the network the K-Medoids algorithm is used for clustering. As compared to K-Means K-Medoids is more effective for larger sensor networks. The Target Tracking is one of the important application in wireless sensor networks, where it follows steps as first senses the objects, provides the tracking algorithms and then communicates. Tracking is important in order to provide security in highly alert areas. In tracking we trace the path of object which is moving all over in the network. The object here we considered is an moving object. The Kalman Filterign algorithm is used for tracking, Kalman filter is one of the most important an common data fusion algorithm in use today, It keeps a track of estimated state of the system and variance of uncertainty of estimate. The kalman filter algorithm works in two steps. In the prediction step, the estimats of current state will be produced by the kalman filter and the uncertainties are also produced These estimates are updated using a weighted average once the outcome of next measurement is obtained. Kalman filter operates on stream of noisy data input. Kalman filter has many applications in technology, most common applications include guidance, navigation and control of vehicles particularly aircraft and spacecraft. Kalman filters are widely used in signal processing and econometrics*

I. Introduction
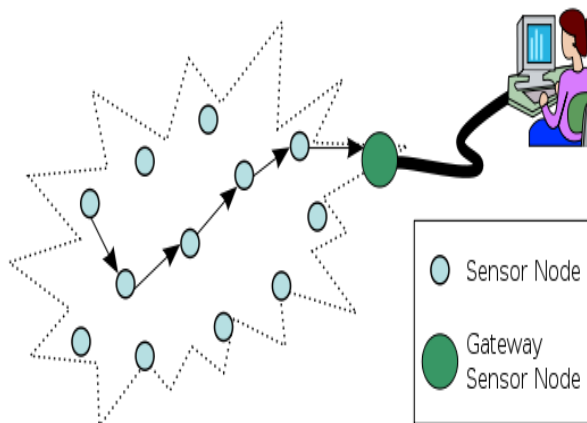
1.1 Introduction to Wireless Sensor Networks

Figure 1.1: Typical multi-hop wireless sensor network architecture.

Wireless Sensor Network consists of sensors distributed all over in the network, Used for monitoring the environment conditions like temperature, pressure, etc. and supportively pass their data through the network to main location. Because of the military applications such as battlefield surveillance wireless sensor networks demandingly have growth. These networks also used in consumer and industrial applications like machine health monitoring, industrial process monitoring, etc. The wireless sensor network build of thousands of sensor nodes, and each node is connected to one or more sensors. Each sensor node consists of transceiver with an internal antenna both for transmitting and receiving the data, microcontroller for processing of the data, sensors for sensing the information from the nodes, analog to digital converter for conversion analog data to digital data, power supply for the devices as sensors are battery operated they does not require any power supply electronic circuit for interfacing between the sensor nodes. The size of sensor node is constant or varying, it may vary from small grain of dust to larger one. The cost of sensors depends on the complexity in sensor nodes, it varies from few to hundred dollars. The parameters like computational speed, memory in the network, communication bandwidth, etc depends on the cost and size of the sensors. Routing or flooding are the propagation methods

used for communication between the hops of network. The topologies used may vary from simple to complex topologies like star to multi hop respectively.

Target Tracking

Target tracking is the most important application in wireless sensor networks whose aim is to trace the nomadic path of an object which is considered as a target and to detect the position of target. As wireless sensor network incessantly monitor the environment, it provides us space to improve the energy efficiency. Target tracking system comprises of three interrelated subsystems which are shown in below figure1.3.
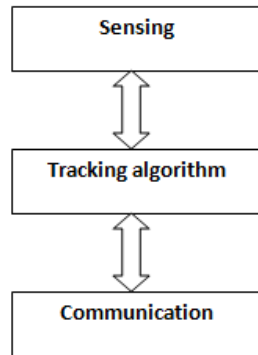
Figure 1.2: Target Tracking Scheme Classification.

The sensing subsystem is used to sense the target i.e. it of the node that first detects the target and other nodes which gradually take part in detecting the target. Second subsystem is the prediction based algorithm which is used to trace the path of the preferred target. The last one is communication subsystem which is used to send the information from one node to another. All these three subsystem works collaboratively and maintains the relationship among them. Since sensor networks are used for monitoring the environmental conditions, Location tracking is one major issue in wireless sensor network which is used for tracing the path of moving objects or individuals in the area in which sensors are deployed. This problem is demanding in two ways: no central control mechanisms and backbone network, here wireless communication is very limited. At present location tracking is done using GPS. It has its limitations like it cannot be used in most indoor environments because it depends on Line of Sight criterion and also in non-urban outdoor settings, GPS does not yield accurate results because it depends too much on factors such as terrain, foliage and topographical settings of the place where the object is located since, GPS receives may be too large, too costly or too power exhaustive, using wireless sensor networks provides us with a better alternate for location tracking since the nodes are relatively small, cheap and low power devices. They are much more feasible considering economic and ease constraints.

II.   Proposed System
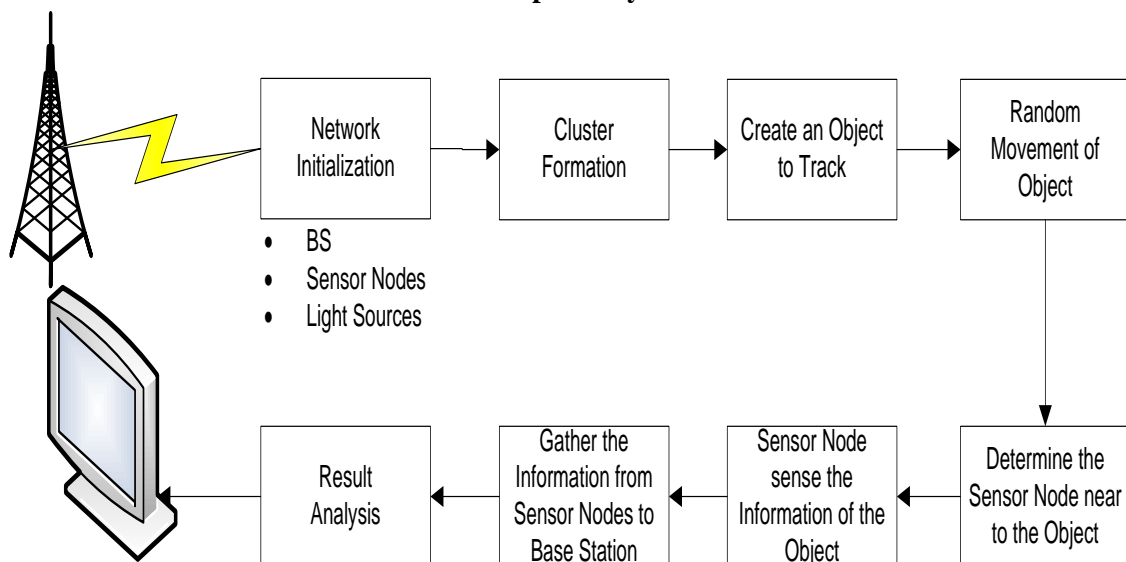
Figure 2.1: Block Diagram of the Proposed System.

Network Initialization

In our proposed system network initialization is the first step where will set an area of the network as 100*100 meters, then will mention the number of nodes as 20 and these nodes are static in nature. Define specific location for all the nodes, For each node print node id on the respected node location. Define location for the base station in the network, Calculating the distance to all the nodes from the location0 node, create base station by specifying location and finally stores all the node information and base station information as output.

Cluster Formation

Clustering is important in order to increase the lifetime and throughput of the network, There are many clustering algorithms like K-means, K-medoids, etc. In order to provide even clustering in the network we used an K-Medoids clustering algorithm, It is an effective and efficient clustering algorithm where we first select the centroids randomly and then calculate the distance to each of the nodes. Nodes which are closer to that centroid those will form an cluster. The centroids are called the medoids and each cluster will have one cluster head and information will be shared between the clusters through the cluster heads.K-medoids is a cluster partitioning technique which clusters data set of n objects into k clusters.

Create an Object to Track

Creating an object for tracking, as we have taken the passive tracking the target which is to be tracked is created manually.

Random Movement of Object

The object created here will be moved all around in the network and the movement of the object will be random in nature, the object is moved with respect to x and y axis.

Determine the Sensor Node near to the Object

In this stage will find the sensor node which is nearer to the object for gathering the information from the object. Sensor Node Sense the Information of the Object, Once we determine the sensor node nearer to the object, that sensor node senses the information of the object, the sensor node have the capability to sense the environment. Each sensor node will have one trance receiver both for transmitting and receiving, analog to digital converter for converting the analog information into digital data, a microprocessor for processing the data with an power supply. As the sensor nodes are battery operated they does not require any power supply it is required for the microcontroller, External Memory for storage of the data.

Gather Information from Sensor to Base Station

A network will have one base station and the information from the sensor nodes will be gathered in the base station, every kind of information will be present their in the base station and we can collect the information from the base station for further analysis.

Result Analysis

Finally the result analysis will be done. The information from the base station is stored in our system for further analysis.

III. Algorithms Used
3.1 K-Medoids Algorithm for Clustering

Clustering is important in order to increase the lifetime and throughput of the network, There are many clustering algorithms such as K-means, K-medoids, etc. In order to provide even clustering in the network we used an K-Medoids clustering algorithm, It is an effective and efficient algorithm where we first select the centroids randomly and then calculate the distance to all nodes. The nodes which are closer to that centroid those will form an cluster. The centroids are called the medoids and each cluster will have one cluster head and information will be shared between the clusters through the cluster heads. K-medoids is called a cluster dividing technique which clusters data set of n objects into k clusters. dividing around medoids is as follows

1. Initialize: randomly select K of data points as the medoids.
2. Calculate the distance from medoid to all the nodes using any distance metric, the nodes which are nearer to medoids will form cluster.
3. For each medoid m
a. For non medoid data point 0
1. Compute the total cost of the configuration by swapping m and 0.
4. With the low cost select the configuration.

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5. Until no changes in the medoids repeat steps 2 and 4.

Cost/Distance calculation:
Where cost between any two points is found using formula
Cost (x, c) = $\sum_{i=1}^{d} \left| xi - ci \right|$

Where x is any data object, c is medoid, and d is the dimension of the object.
The distance d1 between two vectors p,q in an n-dimensional real vector space with fixed Cartesian coordinate system.
d1(p, q)=$\left| p\text{-}q \right| 1 = \sum_{i=1}^{n} \left| pi - qi \right|$
where (p, q) are vectors
p=(p1, p2,……..,pn) and q=(q1, q2,………,qn)
the taxicab distance between (p1 ,p2) and (q1, q2) is $\left| p1\text{-}q2 \right| + \left| p2\text{-}q2 \right|$.

Strengths and Weaknesses of this Algorithm
Strengths:
In the presence of noise and outliers K-medoids is more robust than K –means, because K-medoid is less influenced by outliers or other extreme values than K-means.
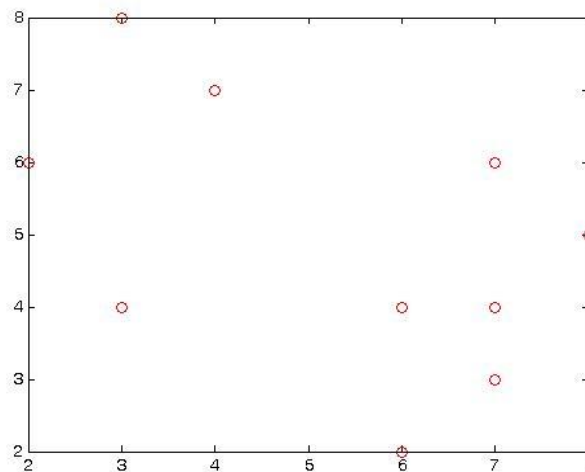

Figure 3.1: Distribution of data.

Weaknesses: Relatively more costly and complexity is more.

Example: Consider the following data set of 10 objects, cluster them into two clusters

X1	2	6
X2	3	4
X3	3	8
X4	4	7
X5	6	2
X6	6	4
X7	7	3
X8	7	4
X9	8	5
X10	7	6

Table 3.1: Data set of 10 objects

Step 1:
Initialize K centers
Select X2 and X8 as medoids, i.e. C1=(3,4) and C2=(7,4)
Distance to each center is calculated to associate data object to nearest medoid. Cost to the nearest medoid is shown in below table

Cost(distance) to C1					
i	C1		Data Objects(Xi)		Cost(distance)
1	3	4	2	6	**3**
3	3	4	3	8	**4**
4	3	4	4	7	**4**
5	3	4	6	2	5
6	3	4	6	4	3
7	3	4	7	3	5
9	3	4	8	5	6
10	3	4	7	6	6

Table 3.2: Costs to centroid C1

Cost(distance) to C2					
i	C2		Data Object(Xi)		Cost(distance)
1	7	4	2	6	7
3	7	4	3	8	8
4	7	4	4	7	6
5	7	4	6	2	**3**
6	7	4	6	4	**1**
7	7	4	7	3	**1**
9	7	4	8	5	**2**
10	7	4	7	6	**2**

Table 3.3: Cost to centroid C2

The clusters are
Cluster 1={(3,4)(2,6)(3,8)(4,7)}
Cluster 2={(7,4)(6,2)(6,4)(7,3)(8,5)(7,6)}
The points (2,6) (3,8) and (4,7) are closer to c1, they form one cluster.
The cost is 20.

Where cost between any two points is found using formula
Cost (x, c) = $\sum_{i=1}^{d} \left| xi - ci \right|$
where *x* is any data object, *c* is the medoid, and *d* is the dimension of the object which in this case is 2.
Total cost is the summation of the cost of data object from its medoid.
Total cost   ={cost((3,4),(2,6))+cost((3,4),(3,8))+cost((3,4),(4,7))}
+{cost((7,4),(6,2))+cost((7,4),(6,4))+cost((7,4),(7,3))
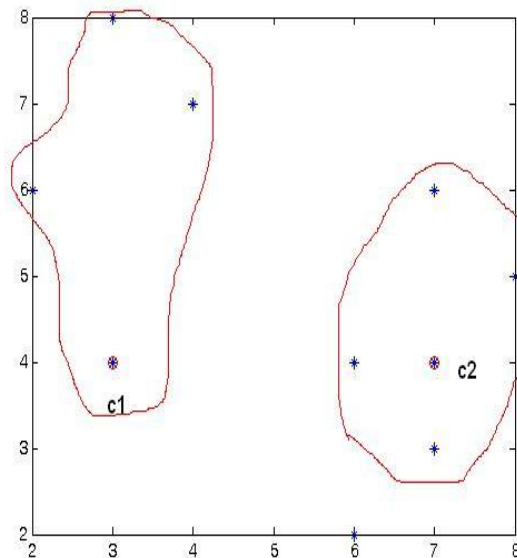+cost((7,4),(8,5))+cost((7,4),(7,6))}
=(3+4+4)+(3+1+1+2+2)
=20

Figure 3.2: Clusters after step 1.

Step 2:
Select one nonmedoid o'
Let us assume o'=(7,3), i.e.X7.
Now the medoids are C1(3,4)
Select one of the nonmedoids O′ and o'(7,3)
Now as C1 and o' are new medoids, calculate the total cost using formula in step 1.

i	C1		Data Objects(Xi)		Cost(distance)
1	3	4	2	6	**3**
3	3	4	3	8	**4**
4	3	4	4	7	**4**
5	3	4	6	2	5
6	3	4	6	4	3
7	3	4	7	4	4
9	3	4	8	5	6
10	3	4	7	6	6

Table 3.4: Cost to centroid C1

i	O'		Data Object(Xi)		Cost(distance)
1	7	3	2	6	8
3	7	3	3	8	9
4	7	3	4	7	7
5	7	3	6	2	**2**
6	7	3	6	4	**2**
7	7	3	7	4	**1**
9	7	3	8	5	**3**
10	7	3	7	6	**3**

Table 3.5: Cost to non medoid O'

Total cost =3+4+4+2+2+1+3+3
            =22
Cost of swapping medoid fromC2 to o' is
S= current total cost-past total cost
  =22-20
  =2>0
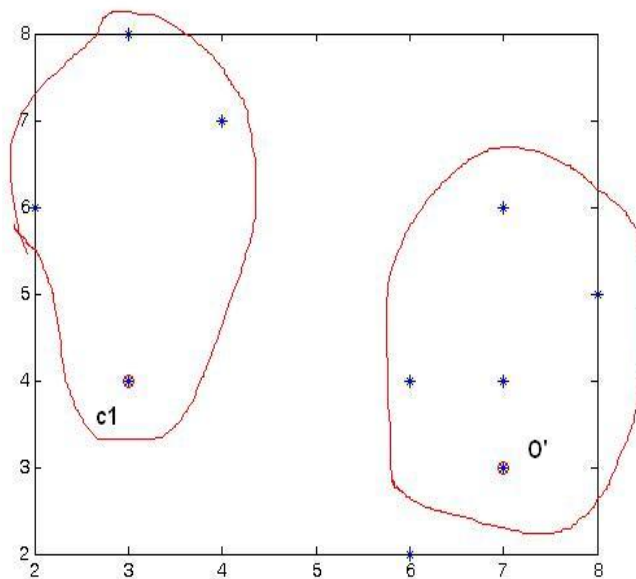So moving C2 to o' would be a bad idea, previous choice was good.

Figure 3.3: Clusters after step 2

3.2 Kalman Filtering Algorithm

Kalman filter is one of the most important an common data fusion algorithm in use today, It keeps a track of estimated state of the system and variance of uncertainty of estimate. The state transition is used for updating the estimates. Kalman filter is also known as Linear Quadratic Estimation(LQE), it uses series of measurements observed over time, containing noisy, other unaccuracies and produces estimates of unknown variables. Kalman filter operates on stream of noisy data input. Kalman filter has many applications in technology, most common applications include guidance, navigation and control of vehicles particularly aircraft and spacecraft. Kalman filters are widely used in signal processing and econometrics.

The kalman filter algorithm works in two steps. In the prediction step, the estimats of current state will be produced by the kalman filter and the uncertainties are also produced These estimates are updated using a weighted average once the outcome of next measurement is obtained. No additional past information is required as the algorithm can run in real time, using the present input and the past calculated values and their uncertainties.

By using a form of feedback control the filter estimates a process, the filter gets the input process it and obtains the output or feedback ion the form of noise, as such the equations for kalman filter are given in two groups time update and measurement update equations. Time update equations are responsible for keeping the update of next time step and the measurement update equations are responsible for feedback.

The time update equations work like predictor and the measurement update equations like corrector, so the entire estimation algorithm can be called as the predictor-corrector algorithm. The predictor used for predicting the next step and corrector will correct the predicted values.

IV.   Results And Discussions
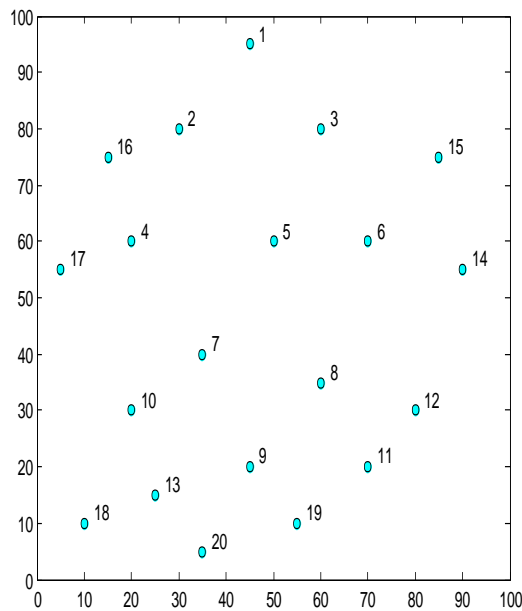
Network Initialization

Figure 4.1: Network Initialization

The above figure 5.1 shows network initialization, where the area defined is 100*100 meters, 20 nodes are statistically distributed in the network. Each sensor node will have its unique id.
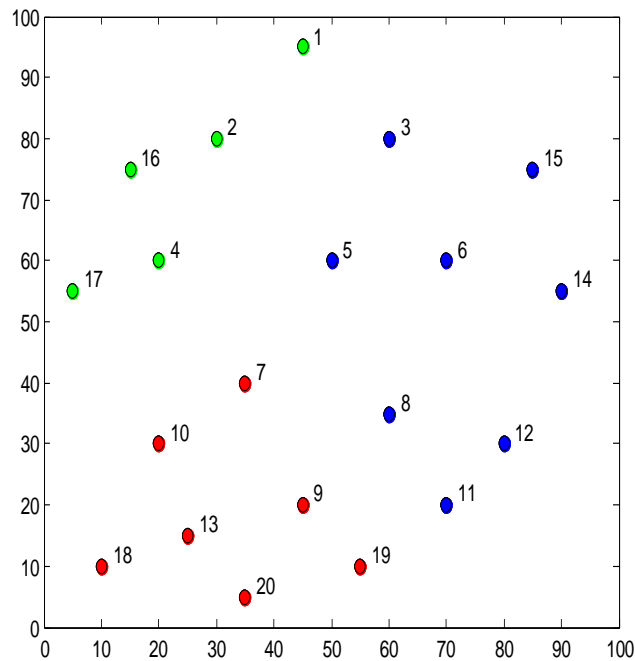
Figure 4.2: Cluster Formation

Above figure 5.2 shows cluster formation, there are three clusters with different colors for identification, Depending on the distance from centroid to sensor nodes will form clusters. The sensor nodes 1,2,4,16 and 17 will form one cluster, the sensor nodes 3,5,6,8,11,12,14 and 15 will form second cluster and finally sensor nodes 7,9,13,18,19 and 20 will form one cluster each cluster will have one cluster head. Here K-medoid algorithm is used for clustering.
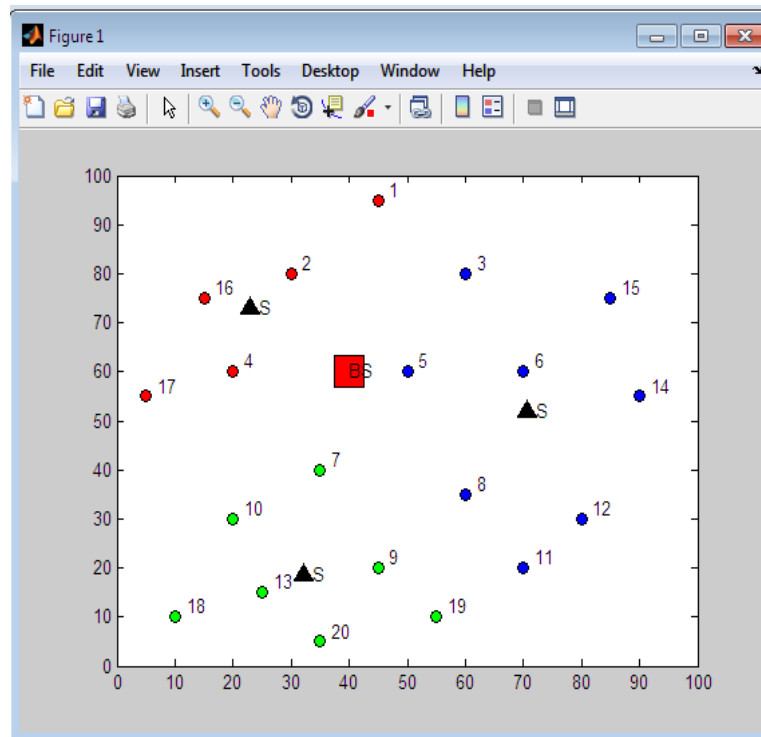

Figure 4.3: Identification of Base Station

Above figure 5.3 shows the identification of the station, where the station will be identified.
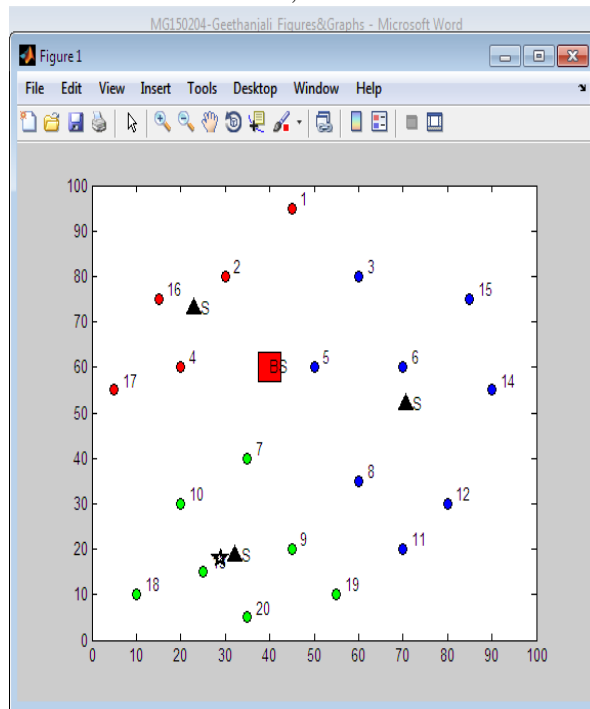

Figure 4.4: Object Creation

Above figure shows object creation, the object is created by defining the shape, color and location from x and y-axes. The object created here will be moved in the network.
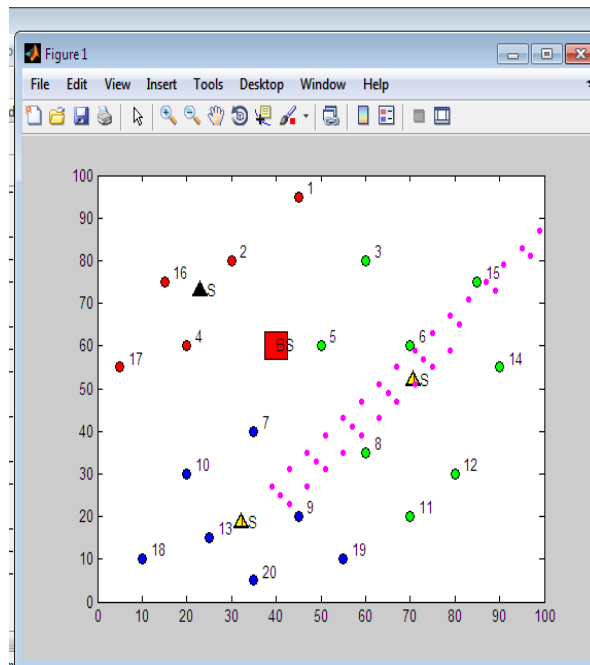

Figure 4.5: Moving Object Tracking

The above figure 5.5 shows tracking the path of moving object, The location of the target will be traced. As the object starts moving in the network it traces that path of the moving object. The kalman filtering algorithm is used. The information will be stored in the base station, first sensors will senses the information and through the cluster heads information will be moved to base station

V. Conclusion

Wireless Sensor Network consists of huge number of sensor nodes distributed all over in the network, capable of monitoring the environmental conditions. Target Tracking is an important application in wireless sensor networks, in order to provide security in highly alert areas the tracking is must. The K-medoids algorithm is used for clustering the sensor nodes in the network, the K-medoids algorithm is an efficient clustering algorithm for larger network consisting of thousands of sensor nodes. When compared with K-means algorithm K-medoids is more robust clustering method. Here we are tracking the moving objects, the kalman filtering algorithm is used for tracking the moving objects. Kalman filter is one of the most important an common data fusion algorithm in use today. By using a form of feedback control Kalman filter estimates the process.

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