Dynamic Clustering in WSN

Software Recommended: NetSim Standard v12.0 (32/64 bit), Visual Studio 2015/2017/2019, MATLAB (32/64 bit)

Follow the instructions specified in the following link to clone/download the project folder from GitHub using Visual Studio:
https://tetcos.freshdesk.com/support/solutions/articles/14000099351-how-to-clone-netsim-file-exchange-project-repositories-from-github-

Other tools such as GitHub Desktop, SVN Client, Sourcetree, Git from the command line, or any client you like to clone the Git repository.

Note: It is recommended not to download the project as an archive (compressed zip) to avoid incompatibility while importing workspaces into NetSim.

Secure URL for the GitHub repository:

https://github.com/NetSim-TETCOS/Dynamic_Clustering_Project_v12.0.git

Clustering in WSN:

Clustering is the process partitioning a group of sensors into small numbers of clusters. In environments where the sensors are mobile clusters cannot be static. Like cluster heads in each cluster are elected dynamically, the members in each cluster also need to be dynamically identified. Therefore, the size of each cluster is not fixed and can vary depending on the position of the sensors.

Dynamic Clustering helps in efficiently grouping sensors into clusters dynamically. There is no fixed cluster size and the sensors are divided into the required number of clusters with members of each cluster calculated dynamically.

Clustering using k-means algorithm:

kmeans(X,k) partitions the points in the n-by-p data matrix X into k clusters. This iterative partitioning minimizes the sum, over all clusters, of the within-cluster sums of point-to-cluster-centroid distances. Rows of X correspond to points, columns correspond to variables. kmeans returns an n-by-1 vector IDX containing the cluster indices of each point. By default, kmeans uses squared Euclidean distances. When X is a vector, kmeans treats it as an *n*-by-1 data matrix, regardless of its orientation.

The sensor positions and number of clusters,

X - a matrix containing the x, y coordinates of the sensors in the scenario

k- the number of clusters

are passed to k-means algorithm.

[IDX,C] = kmeans(X,k)

IDX – Contains the cluster id's of each sensor (i.e) the cluster to which the sensor belongs.

C – Centroids of each cluster

Clustering using Fuzzy C-Means Algorithm:

Fuzzy c-means (FCM) is a data clustering technique in which a dataset is grouped into n clusters with every data point in the dataset belonging to every cluster to a certain degree. For example, a certain

data point that lies close to the center of a cluster will have a high degree of belonging or membership to that cluster and another data point that lies far away from the center of a cluster will have a low degree of belonging or membership to that cluster.

Cluster head election based on distance from Centroid:

After grouping the sensors into different clusters, the cluster heads are determined based on the distance between the sensor and the centroid of the cluster to which it belongs.

The sensor which is closer to the centroid will be elected as the cluster head. Here the position values (i.e. value of x-coordinate and y-coordinate) of each sensor are passing from NetSim to MATLAB as a sole parameter.

Cluster head election based on distance and power:

After grouping the sensors into different clusters, the cluster heads are determined based on the distance between the sensor and the remaining power of each sensor. After that the sensors are assigned in respective cluster.

The sensor which is closer to the centroid and has the more power than other sensor will be elected as the cluster head. Here the position values (i.e. value of x-coordinate and y-coordinate) of each sensor and power are passing from NetSim to MATLAB as a sole parameter.

Dynamic Clustering in NetSim with MATLAB Interfacing:

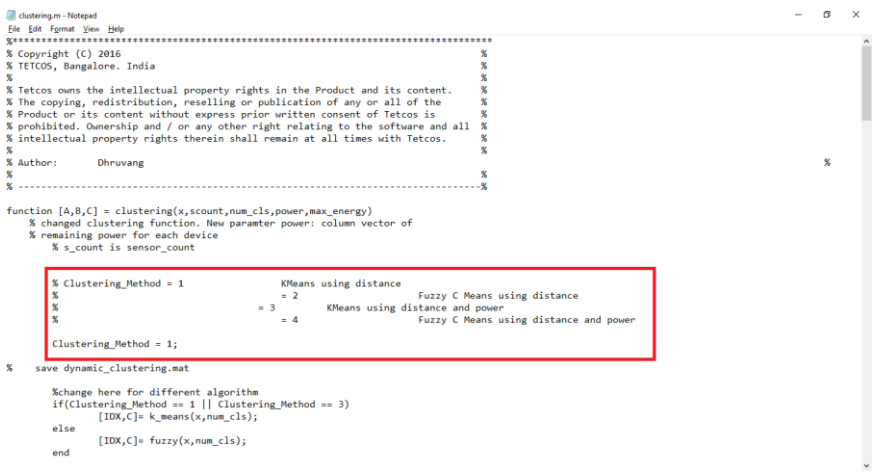
Dynamic Clustering is implemented in NetSim by Interfacing with MATLAB for the purpose of mathematical calculation. The sensor coordinates are fed as input to MATLAB and k-means algorithm that is implemented in MATLAB is used to dynamically perform clustering of the sensors into n number of clusters.

In addition to clustering we also determine the cluster head of each cluster mathematically in MATLAB. The distance of each sensor from the centroid of the cluster to which it belongs is calculated. Then the sensor which has the least distance is elected as the cluster head.

From MATLAB we get the cluster id of each sensor, cluster heads of each cluster and the size of each cluster.

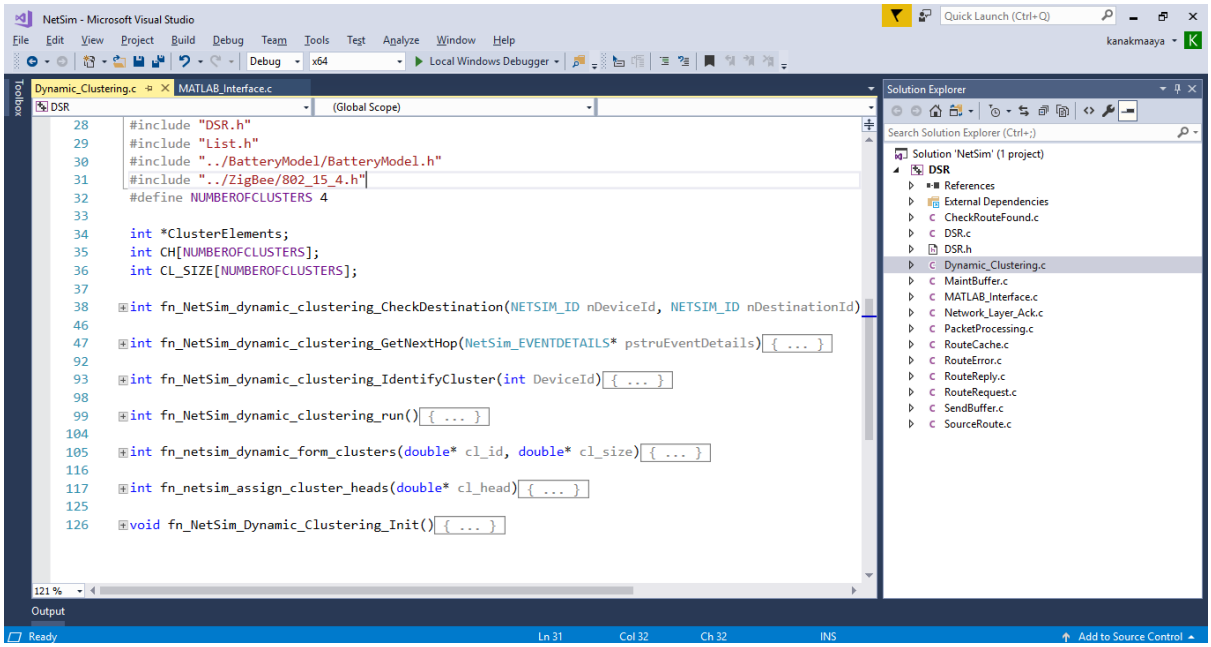
All the above steps are performed periodically which can be defined as per the implementation. Each time the cluster members and the cluster heads are determined based on the current position and they are not fixed.

The codes required for the mathematical calculations done in MATLAB are written to a **clustering.m** file as shown below:



The **clustering.m** file can be run in four different modes cluster head election.

A **Dynamic_Clustering.c** file is added to the DSR project which contains the following functions:



fn_NetSim_dynamic_clustering_CheckDestination()

This function is used to determine whether the current device is the destination.

fn_NetSim_dynamic_clustering_GetNextHop()

This function statically defines the routes within the cluster and from cluster to sinknode. It returns the next hop based on the static routing that is defined.

fn_NetSim_dynamic_clustering_IdentifyCluster()

This function returns the cluster id of the cluster to which a sensor belongs.

fn_NetSim_dynamic_clustering_run()

This function makes a call to MATLAB interfacing function and passes the inputs from NetSim (i.e) the sensor coordinates, number of clusters and the sensor count.

fn_netsim_dynamic_form_clusters()

This function assigns each sensor to its respective clusters based on the cluster id's obtained from MATLAB.

fn_netsim_assign_cluster_heads()

This function assigns the cluster heads for each cluster based on the cluster head id's obtained from MATLAB.

fn_NetSim_Dynamic_Clustering_Init()

This function initializes all parameter values.

Static Routing:
Static Routing is defined in such a way that the sensors in the cluster send the packets to the cluster head. The cluster head then directly sends the packets to the destination (sinknode).

If the current sensor is the source device and if it is not a cluster head then its next hop is its cluster head.

If the current sensor is the source device and if it is a cluster head then its next hop is the destination (i.e) the sinknode.

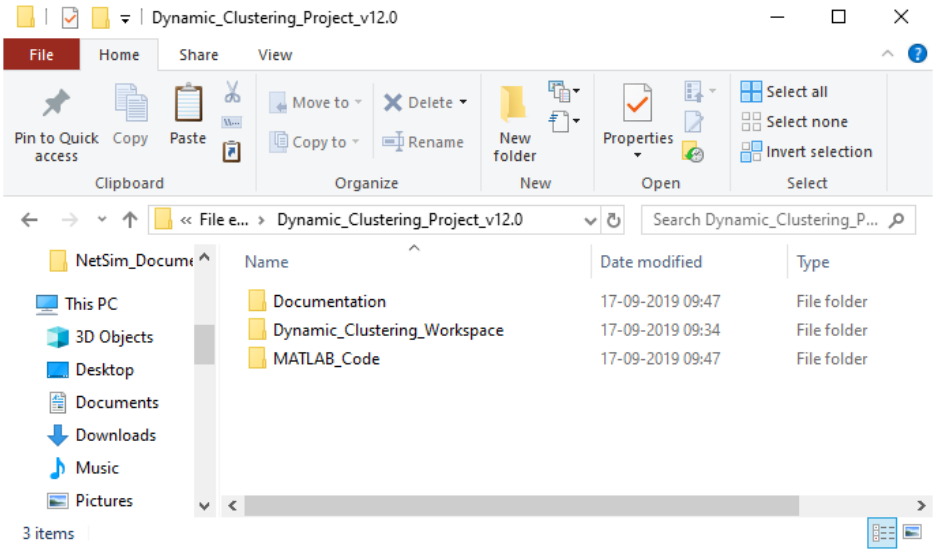
If the current sensor is not the source then the packet is sent to the destination (i.e) the sinknode.

NOTE:

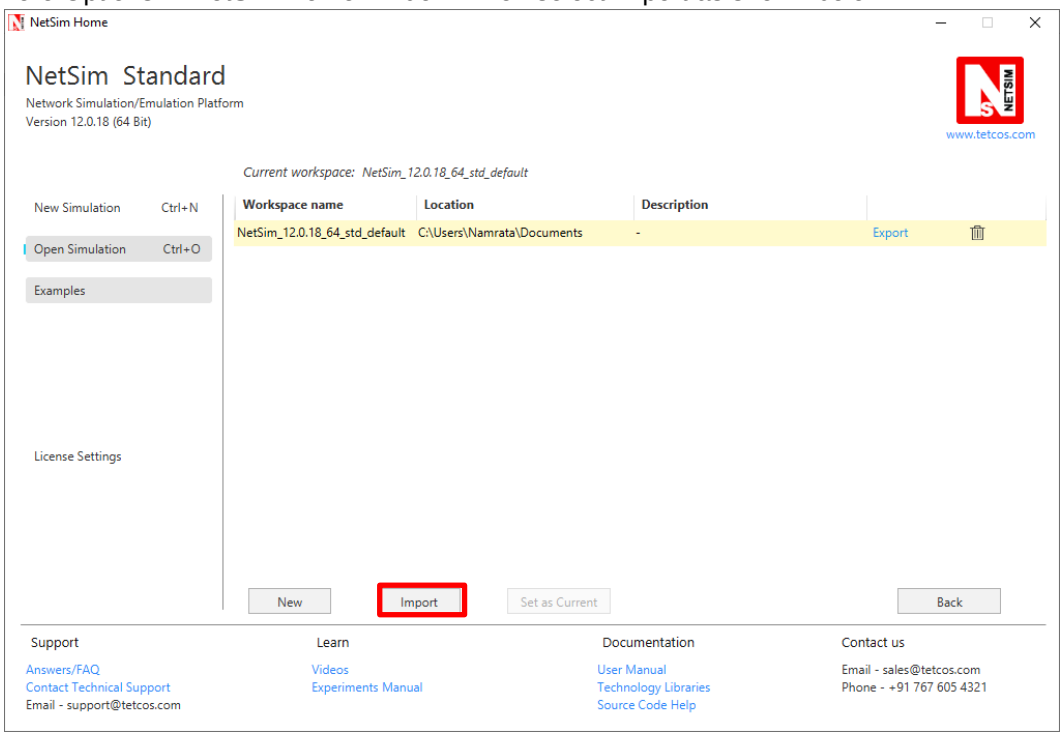
To run this code 64- bit version of MATLAB must be installed in your system.

Steps:

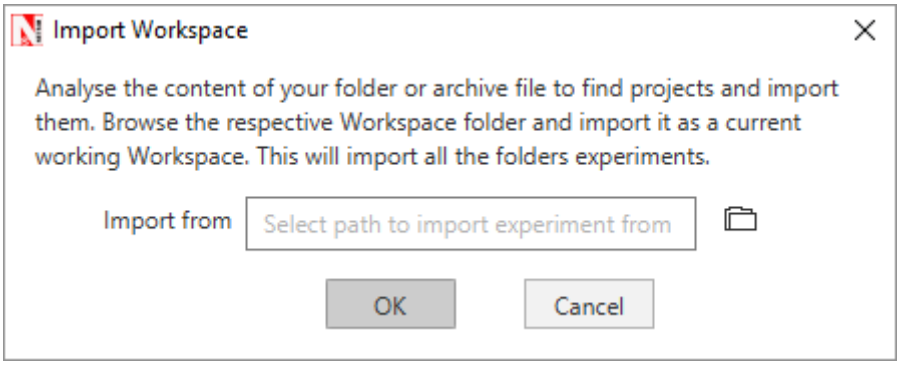
1. The downloaded project folder contains the folders Documentation, MATLAB_Code and Dynamic_Clustering_Workspace directory as shown below:



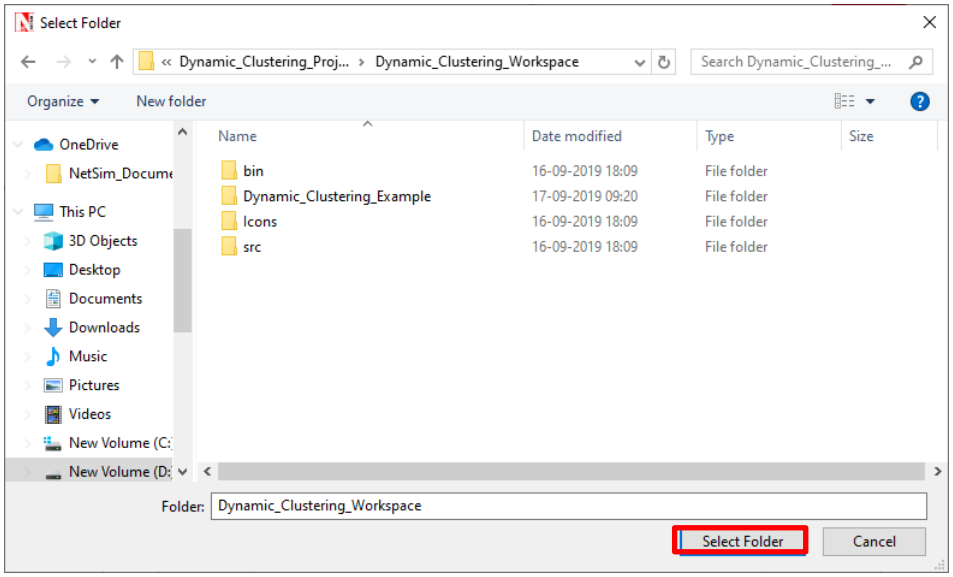
2. Import Dynamic_Clustering_Workspace by going to Open Simulation->Workspace Options->More Options in NetSim Home window. Then select Import as shown below:



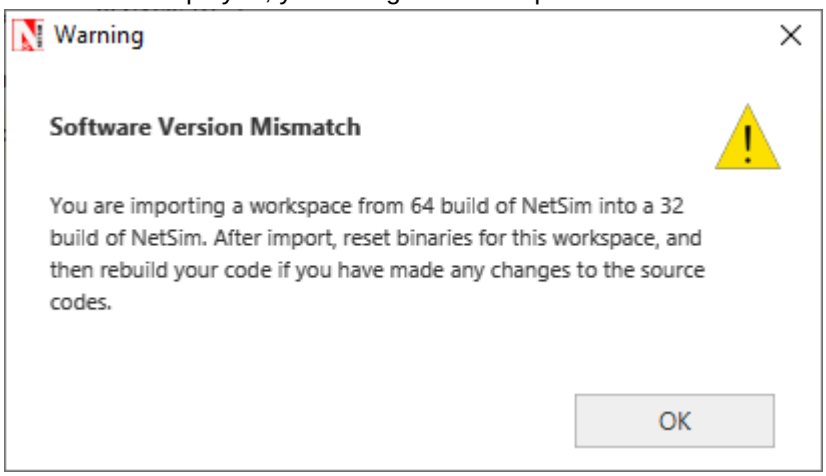
3. It displays a window where users need to give the path of the workspace folder and click on OK as shown below:



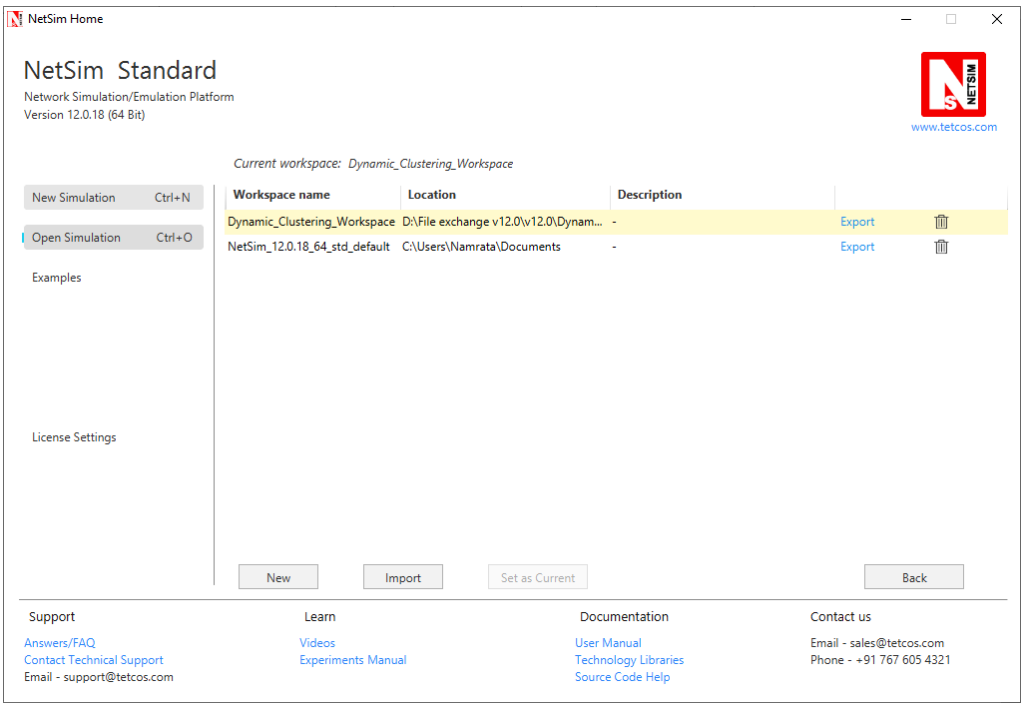
4. Browse to the Dynamic_Clustering_Workspace folder and click on select folder as shown below:



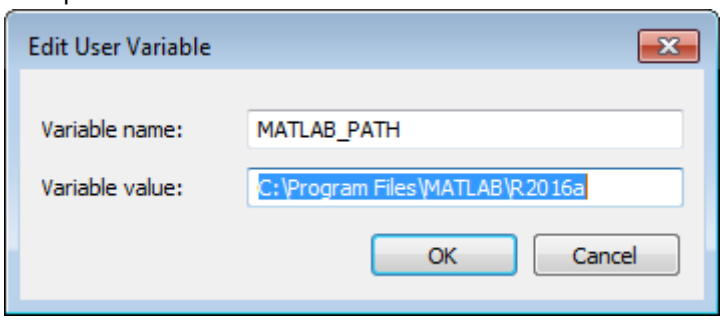
5. After this click on OK button in the Import Workspace window.
6. While importing the workspace, if the following warning message indicating Software Version Mismatch is displayed, you can ignore it and proceed.



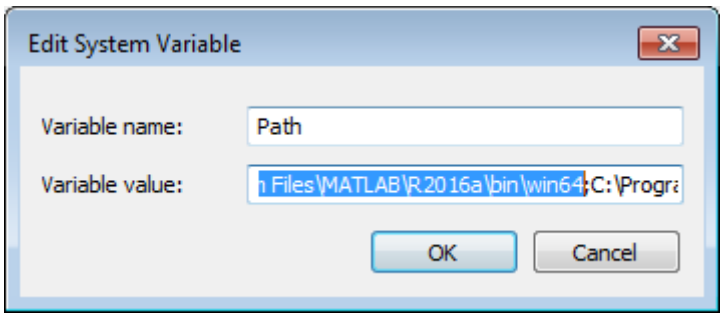
7. The Imported workspace will be set as the current workspace automatically. To see the imported workspace, click on Open Simulation->Workspace Options->More Options as shown below:



8. Create a user variable with the name of MATLAB_PATH and provide the path of the installation directory of user's respective MATLAB version.

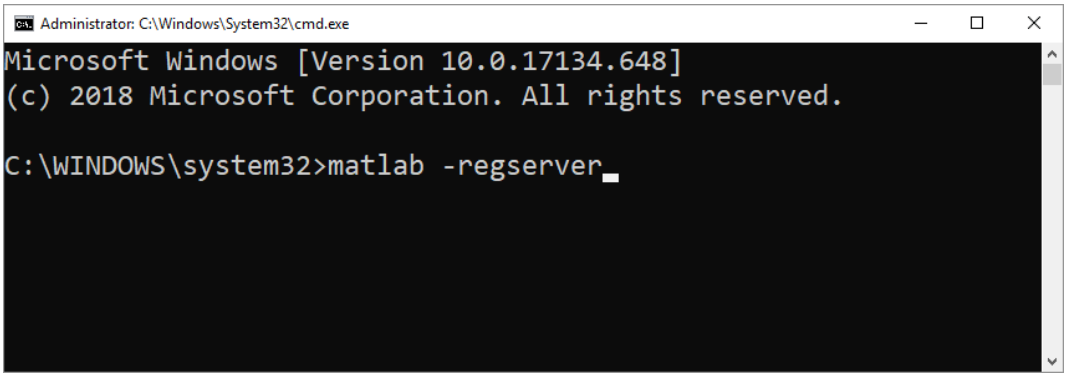


9. Make sure that the following directory is in the PATH(Environment variable)
<Path where MATLAB is installed>\bin\win64

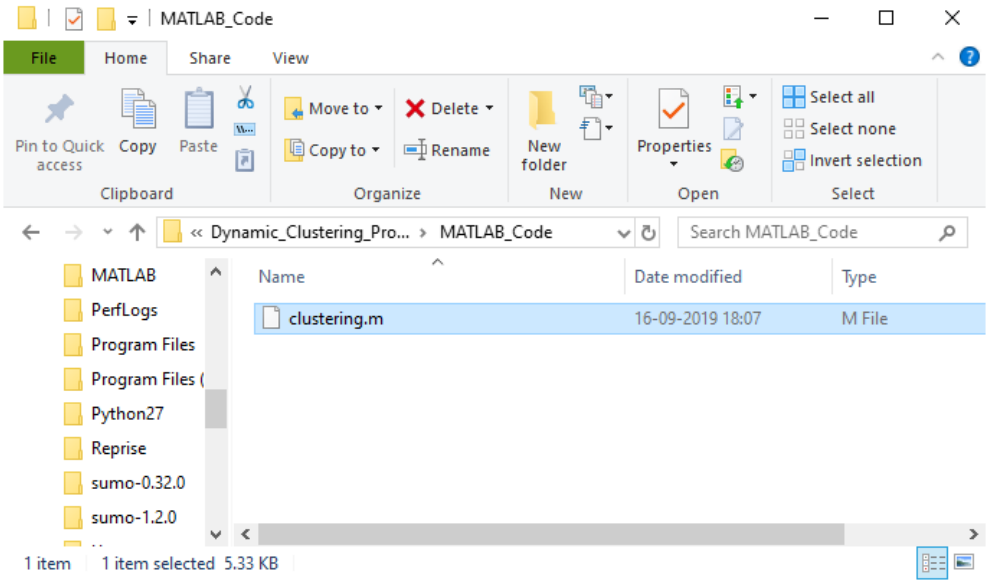


Note: If the machine has more than one MATLAB installed, the directory for the target platform must be ahead of any other MATLAB directory (for instance, when compiling a 64-bit application, the directory in the MATLAB 64-bit installation must be the first one on the PATH).

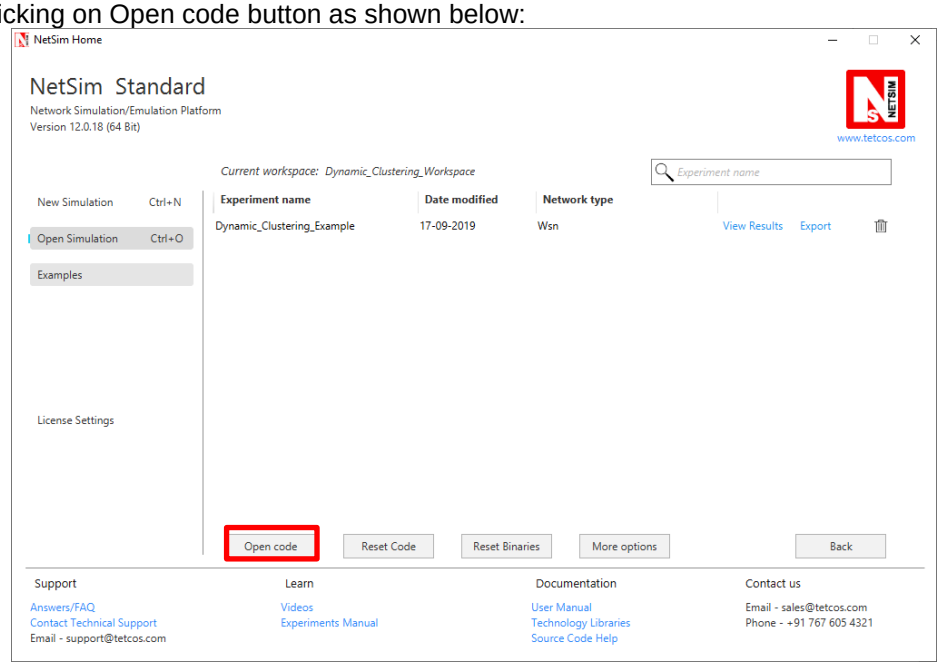
10. Open Command prompt as admin and execute the command "matlab -regserver". This will register MATLAB as a COM automation server and is required for NetSim to start MATLAB automation server during runtime.



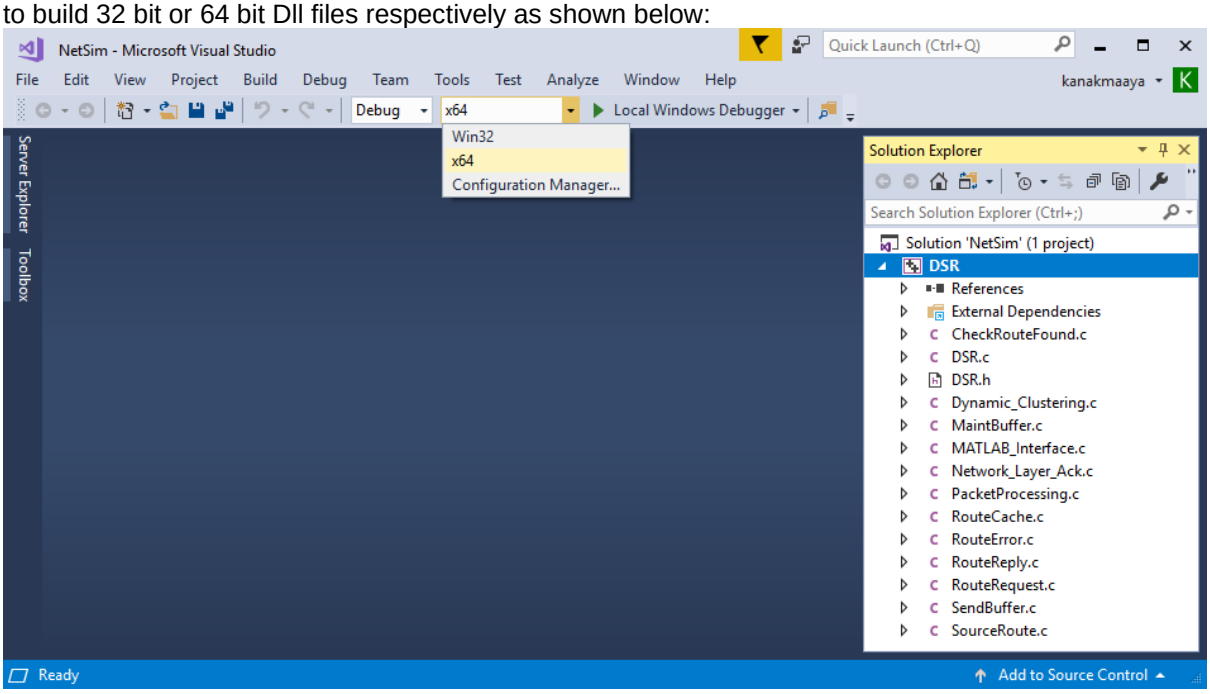
11. Place **clustering.m** present in the MATLAB_Code folder inside the root directory of MATLAB. For Example: **"C:\Program Files\MATLAB\R2016a"**.



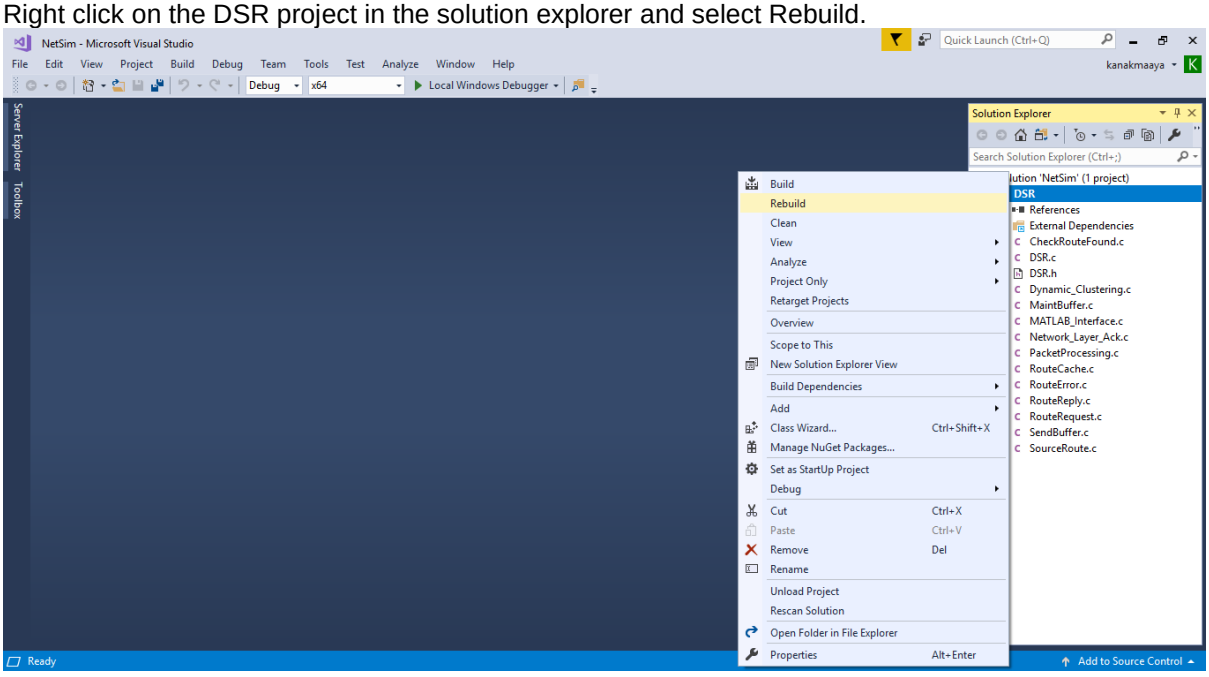
12. Open the Source codes in Visual Studio by going to Open Simulation-> Workspace Options and Clicking on Open code button as shown below:



13. Under the DSR project in the solution explorer you will be able to see that **MATLAB_Interface.c** and **Dynamic_Clustering.c** files which contain source codes related to interactions with MATLAB and handling clustering in NetSim respectively.
14. Based on whether you are using NetSim 32 bit or 64 bit setup you can configure Visual studio to build 32 bit or 64 bit Dll files respectively as shown below:



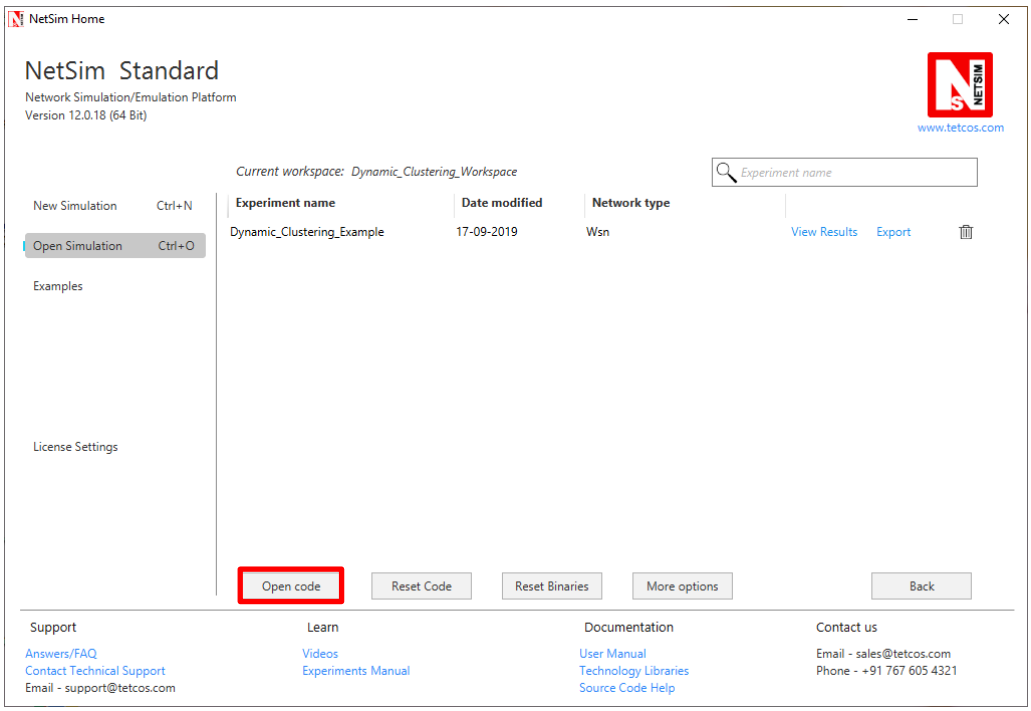
15. Right click on the DSR project in the solution explorer and select Rebuild.



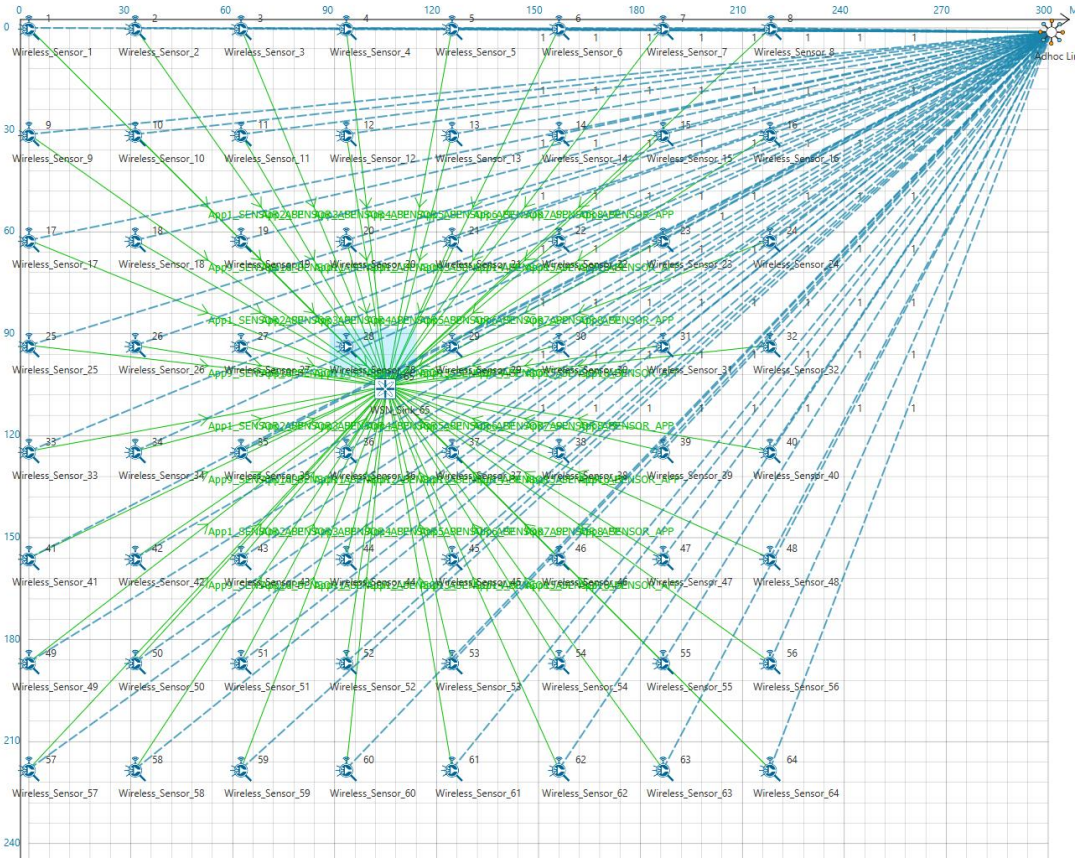
16. Upon successful build modified libDSR.dll file gets automatically updated in the directory containing NetSim binaries.

17. Run NetSim as Administrative mode.

18. Then Dynamic_Clustering_Workspace comes with a sample configuration that is already saved. To open this example, go to Open Simulation and click on the Dynamic_Clustering_Example that is present under the list of experiments as shown below:



19. The saved network scenario consisting of 64 sensors uniformly distributed in the grid environment along with a sink node forming a Wireless Sensor Network. Traffic is configured from each sensor node to the Sink Node.



20. Run the Scenario. You will observe that as the simulation starts in NetSim, MATLAB gets initialized and graph associated with energy consumption in the sensor network is plotted during runtime.

Analysis:

A total of 64 sensors are placed evenly on the grid environment and each sensor is set to have equal initial energy.

At the end of the simulation, NetSim provides Battery Model Metrics which provides detailed information related to energy consumption in each sensor node with respect to transmission, reception, idle mode, sleep mode etc as shown below:

Battery model_Table

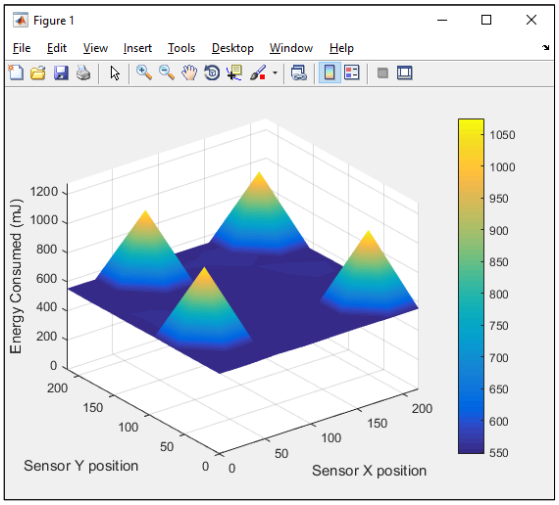
Batter model ☑ Detailed View

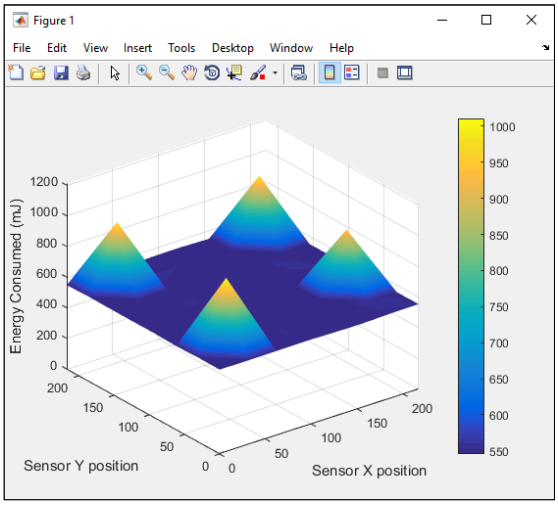
Device Name	Initial energy(mJ)	Consumed energy(mJ)	Remaining Energy(mJ)	Transmitting energy(mJ)	Receiving energy(mJ)	Idle energy(mJ)
WIRELESS_SENSOR_1	6480.000000	558.318835	5921.681165	20.038487	0.000000	538.280348
WIRELESS_SENSOR_2	6480.000000	556.923016	5923.076984	18.593404	0.000000	538.329613
WIRELESS_SENSOR_3	6480.000000	558.504945	5921.495055	20.231165	0.000000	538.273780
WIRELESS_SENSOR_4	6480.000000	557.202180	5922.797820	18.882420	0.000000	538.319760
WIRELESS_SENSOR_5	6480.000000	556.457743	5923.542257	18.111709	0.000000	538.346034
WIRELESS_SENSOR_6	6480.000000	557.853562	5922.146438	19.556793	0.000000	538.296770
WIRELESS_SENSOR_7	6480.000000	557.481344	5922.518656	19.171437	0.000000	538.309907
WIRELESS_SENSOR_8	6480.000000	555.806361	5924.193639	17.437337	0.000000	538.369024
WIRELESS_SENSOR_9	6480.000000	557.574399	5922.425601	19.267776	0.000000	538.306623
WIRELESS_SENSOR_10	6480.000000	629.662276	5850.337724	35.163691	58.563994	535.934592

This information can also be obtained at different points of simulation time either to log or to send to other external tools. The battery information and the position coordinates are passed to MATLAB periodically for clustering (number of cluster is set to 4), cluster head election and to obtain energy consumption plots.

Cluster head election using distance alone as a parameter:

Running simulations with Clustering Method set to 1 and 2 in the **clustering.m** file will provide energy consumption plots for kmeans and fuzzy c-means algorithms respectively as shown below:

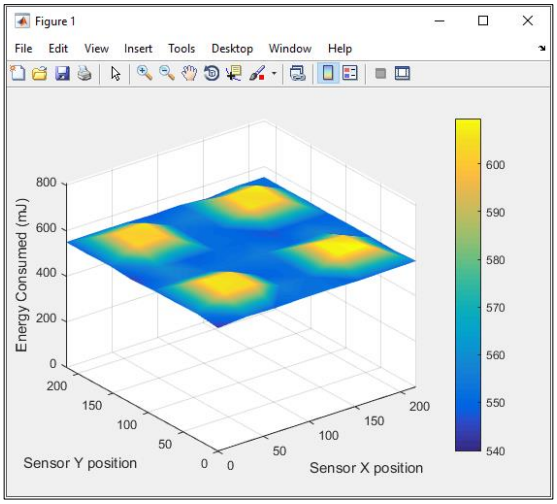


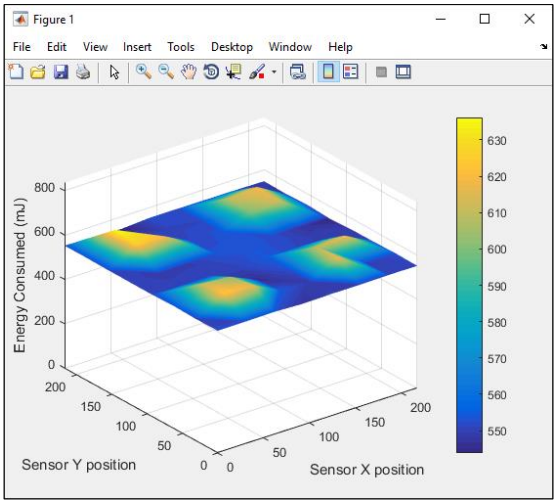


As it is seen from the plot, there are 4 peaks in the plot corresponding to higher energy consumption in the nodes in the center of the cluster, as they always become the cluster heads. This is because distance is used as a parameter for electing the cluster heads.

Cluster head election using distance and remaining energy as parameters:

Running simulations with Clustering Method set to 3 and 4 in the **clustering.m** file will provide energy consumption plots for kmeans and fuzzy c-means algorithms respectively as shown below:





In the initial phase the plot resembles the previous one. However as the time passes, it can be observed that the power is consumed by all the sensors at approximately the same rate.

There are no sharp peaks in this plot unlike the previous one because modified K-means takes into account the power level of each sensor and thus sensors other than those in the center of the cluster will also get a chance to be elected as the cluster head in its respective cluster.