

## 5G - UAV Network Communication (TR 36.777 pathloss)

**Software:** NetSim Standard v14.3 (64 bit), Visual Studio 2022, MATLAB R2020b or higher, Simulink, Robotics and System Toolbox.

### Project Download Link:

<https://github.com/NetSim-TETCOS/5G-UAV-v14.3/archive/refs/heads/main.zip>

Follow the instructions specified in the following link to download and set up the Project in NetSim:

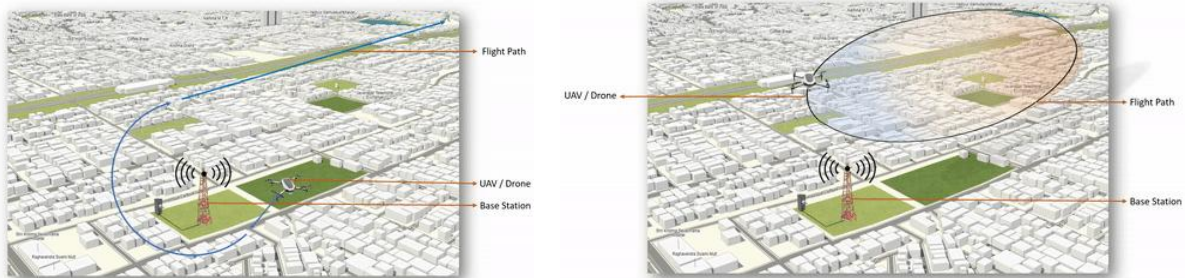
<https://support.tetcos.com/en/support/solutions/articles/14000128666-downloading-and-setting-up-netsim-file-exchange-projects>

### Objective

Performance analysis of UAV - Base station network communications. This involves interfacing NetSim and the UAV toolbox of MATLAB.

- For Each UE in NetSim, a UAV is instantiated in MATLAB as per the UE (UAV) ID.
- MATLAB calculates the flight path and passes the Mobility information to NetSim.
- In NetSim UE movement is modeled as per MATLAB UAV co-ordinates
- Pathloss calculations done in NetSim per 36.777.

### NetSim UAV Simulation model



**UAV Takes and moves away from eNB**

**UAV flies in a circular pattern over the eNB**

Pathloss calculations done in NetSim per 36.777 for Rural Macro

$$PL_{RMA-AV-LOS} = \max(23.9 - 1.8 \log_{10}(h_{UT}), 20) \log_{10}(d_{3D}) + 20 \log_{10}\left(\frac{40\pi f_c}{3}\right)$$

Figure 1: NetSim UAV Simulation model

### Code modifications

Files attached and their modifications are explained below.

1. LTENR\_PropagationModel.c - Added LTE-UAV propagation model for Rural macro as per 3GPP 36.777 Standard.

2. UAVBasedMobility.c - A newly created added to the Mobility Project. The interface with MATLAB happens here to get coordinates from MATLAB and to pass it to NetSim.
3. OpSimulink.m - To initiate Simulink.

### **NetSim - Simulink Interfacing**

Upon interfacing NetSim with MATLAB the following tasks are performed during the simulation start:

- MATLAB Engine process is initialized.
- MATLAB Desktop window is loaded.
- SIMULINK Model is loaded

Upon simulating a network created in NetSim the following tasks are performed periodically:

- SIMULINK Model is simulated
- SIMULINK Model is paused
- NetSim reads the data generated by SIMULINK from the MATLAB workspace.
- Appends the readings to the packet payload as packets are formed.

During the Simulation, the SIMULINK Model is started and paused several times for NetSim and SIMULINK simulations to run synchronously. The X, Y and Z coordinates obtained from SIMULINK are read from the MATLAB workspace and given as input to NetSim's Mobility model. In this example, coordinates are taken every second and updated to the device's mobility.

### **Output/Metrics specific to this example**

- Mobility of the devices configured in NetSim is given as input from MATLAB.
- Pathloss is implemented as per 3GPP Standard.
- NetSim Plot Results: Throughput analysis as the UAV moves away from the gNB

### **Modifications done to NetSim Source codes**

**Project:** Mobility

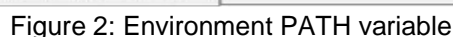
**Files:**

- Mobility.c,
- Mobility.h,
- Added - UAVBasedMobility.c
- Mobility.vcxproj (Project file)

### **Sections of source code modified**

- **Mobility.c**
  - **fn\_NetSim\_Mobility\_Init():** call to **init\_uav()** function
  - **fn\_NetSim\_Mobility\_Run():** Call to **uav\_run()** function
  - **fn\_NetSim\_Mobility\_Finish()**
- **Mobility.h**

1. In Control panel open>system>Advanced system settings>Edit the system environment variable>environment variables
2. Add the following MATLAB install directory path in the Environment PATH variable
  - a. <MATLAB\_INSTALL\_DIRECTORY>\bin\win64
  - b. For e.g.: C:\Program Files\MATLAB\R2020b\bin\win64



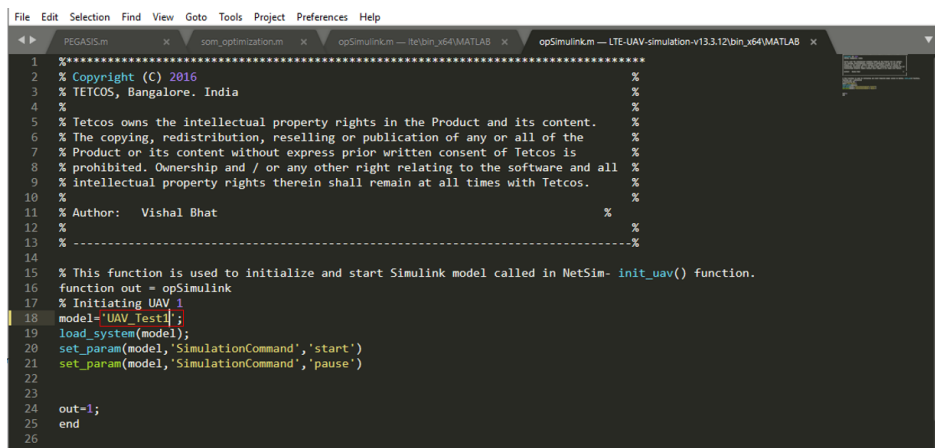
1. Open the Command prompt as admin and execute the command “Matlab -regserver”. This will register MATLAB as a COM automation server and is required for NetSim to start the MATLAB

automation server during runtime.

2. Copy the **UE.xml** file located in the NetSim\_Files folder of the downloaded directory to the <NetSim Installation Directory>\Docs\UI\_xml\Device\_Properties folder.
3. Open the Source codes in Visual Studio by going to Your Work-> Workspace and Clicking on Open code.
4. Under the Mobility project in the solution explorer, you will see that and UAV\_basedmobility.c files which contain source codes related to interactions with MATLAB and handling clustering in handling NetSim respectively.

## Examples

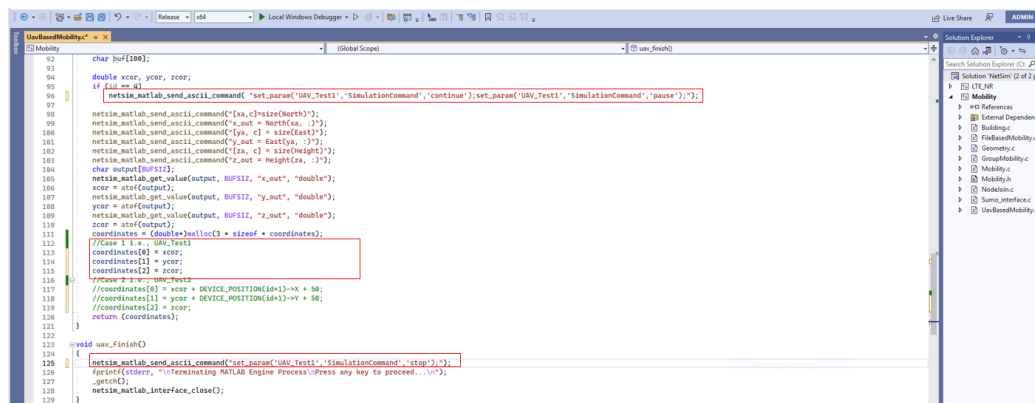
1. The **5G\_UAV\_Simulation\_Workspace** comes with a sample configuration that is already saved. To open this example, go to the Your Work option in the Home Screen of NetSim and click on the **5G\_UAV\_Example** from the list of experiments.
2. Before running Case 1 change the model name in the opsimulink.m file which is present in the workspace inside the bin 64 folder.



```

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9 % intellectual property rights therein shall remain at all times with Tetcos.
10 %
11 % Author: Vishal Bhat
12 %
13 % -----
14
15 % This function is used to initialize and start Simulink model called in NetSim- init_uav() function.
16 function out = opsimulink
17 % Initiating UAV-1
18 model='UAV_Test1';
19 load_system(model);
20 set_param(model,'SimulationCommand','start')
21 set_param(model,'SimulationCommand','pause')
22
23
24 out=1;
25 end
26
  
```

3. Uncomment the case-1 **UAV\_Test 1** section while running case 1 and Comment on the Case-2 **UAV\_Test 2** as mentioned below, then rebuild the project.



```

92 char buf[100];
93
94 double xcor, ycor, zcor;
95 if (i == 0)
96 {
97     netSim_matlab_send_ascii_command("set_param('UAV_Test1','SimulationCommand','continue');set_param('UAV_Test1','SimulationCommand','pause');");
98 }
99
100 netSim_matlab_send_ascii_command("x_out = North(xa, 3);");
101 netSim_matlab_send_ascii_command("ya_cj = size(East);");
102 netSim_matlab_send_ascii_command("y_out = East(ya, 3);");
103 netSim_matlab_send_ascii_command("za_cj = size(Height);");
104 netSim_matlab_send_ascii_command("z_out = Height(za, 3);");
105
106 char output[BUF12];
107 netSim_matlab_get_value(output, BUF12, "x_out", "double");
108 xcor = atof(output);
109 netSim_matlab_get_value(output, BUF12, "y_out", "double");
110 ycor = atof(output);
111 netSim_matlab_get_value(output, BUF12, "z_out", "double");
112 zcor = atof(output);
113
114 coordinates = (double*)malloc(3 * sizeof * coordinates);
115
116 //Case 1 i.e. UAV_Test1
117 coordinates[0] = xcor;
118 coordinates[1] = ycor;
119 coordinates[2] = zcor;
120
121 //Case 2 i.e. UAV_Test2
122 //coordinates[0] = xcor + DEVICE_POSITION(id+1)->x + 50;
123 //coordinates[1] = ycor + DEVICE_POSITION(id+1)->y + 50;
124 //coordinates[2] = zcor;
125 return (coordinates);
126
127
128 void uav_finish()
129 {
130     netSim_matlab_send_ascii_command("set_param('UAV_Test1','SimulationCommand','stop');");
131     fprintf(stderr, "Terminating MATLAB Engine Process!! Press any key to proceed...\n");
132     getch();
133     netSim_matlab_interface_close();
134 }
  
```

Figure 3: Source code changes for Case 1 in UAVBasedmobility.c

4. Run the simulation and press any key to continue.

- It will open the MatlabInterface.exe console window. You will observe that as the simulation starts in NetSim, MATLAB gets initialized and UAV Animation for all the devices in NetSim gets initialized as the simulation runs there will be continuous interaction between NetSim and MATLAB where the X, Y, and Z co-ordinates will be updated in NetSim from MATLAB.

### Case 1: UAV Drone Take off - Application throughput variation with Drone mobility.

#### NetSim Plot: Application Throughput vs. Time

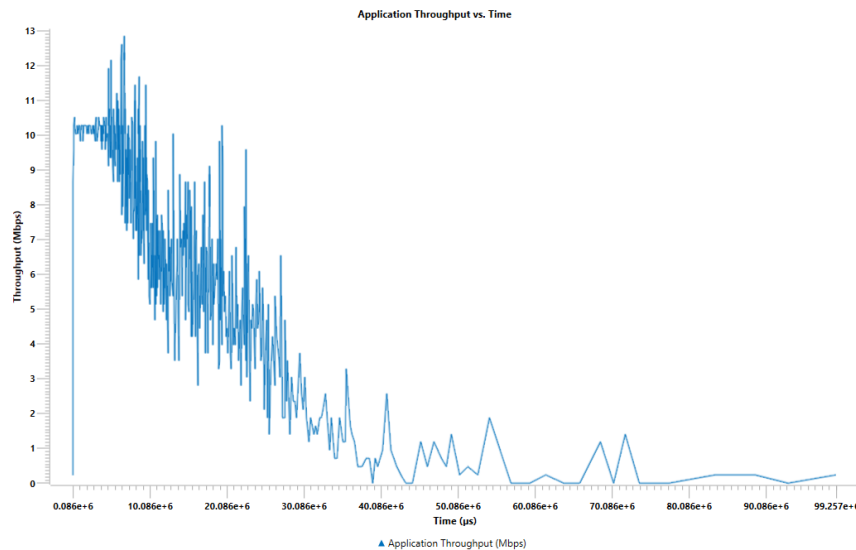


Figure 4: Application Throughput vs. Time from NetSim

#### MATLAB Flight Path

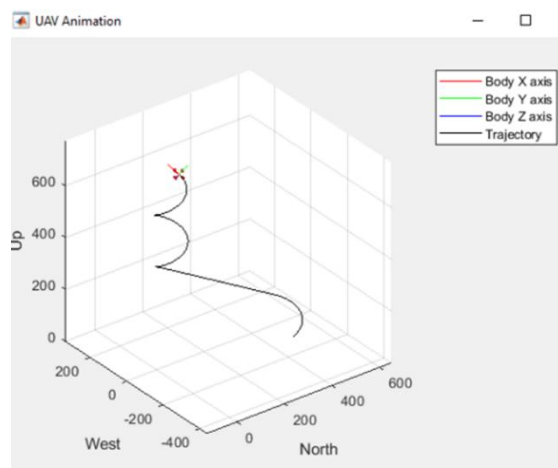


Figure 5: MATLAB Flight Path

### Case 2: UAV Drone rotation around LTE-eNB

- Before running Case 2 change the file name in the source code in UAV\_Basedmobility.c as mentioned below. change the Model name in the opsimulink.m file which is present in the workspace inside the bin 64 folder.

```

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10 % %
11 % Author: Vishal Bhat %
12 % %
13 % ----- %
14 %
15 % This function is used to initialize and start Simulink model called in NetSim- init_uav() function.
16 function out = opSimulink
17 % Initiating UAV_1
18 model='UAV_Test2';
19 load_system(model);
20 set_param(model,'SimulationCommand','start')
21 set_param(model,'SimulationCommand','pause')
22
23
24 out=1;
25 end
26

```

7. Uncomment the case-2 **UAV\_Test 2** section while running case 2 and Comment on the Case-1 **UAV\_Test 1** as mentioned below.

```

92 char buf[100];
93 double xcor, ycor, zcor;
94 if (id == 0)
95 {
96     netsim_matlab_send_ascii_command("set_param('UAV_Test2','SimulationCommand','continue');set_param('UAV_Test2','SimulationCommand','pause');");
97 }
98 netsim_matlab_send_ascii_command("isa_cj=size(North)");
99 netsim_matlab_send_ascii_command("x_out = North(isa_cj,:)");
100 netsim_matlab_send_ascii_command("isa_cj = size(East)");
101 netsim_matlab_send_ascii_command("y_out = East(ya,:)");
102 netsim_matlab_send_ascii_command("isa_cj = size(Height)");
103 netsim_matlab_send_ascii_command("z_out = Height(isa_cj,:)");
104
105 char output[BUFSIZ];
106 netsim_matlab_get_value(output, BUFSIZ, "x_out", "double");
107 xcor = atof(output);
108 netsim_matlab_get_value(output, BUFSIZ, "y_out", "double");
109 ycor = atof(output);
110 netsim_matlab_get_value(output, BUFSIZ, "z_out", "double");
111 zcor = atof(output);
112 coordinates = (double*)malloc(3 * sizeof * coordinates);
113 //Case 1 i.e. UAV_Test1
114 //coordinates[0] = xcor;
115 //coordinates[1] = ycor;
116 //coordinates[2] = zcor;
117 //Case 2 i.e. UAV_Test2
118 coordinates[0] = xcor + DEVICE_POSITION[id+1]*x + 50;
119 coordinates[1] = ycor + DEVICE_POSITION[id+1]*y + 50;
120 coordinates[2] = zcor;
121 return coordinates;
122 }
123
124 void uav_finish()
125 {
126     netsim_matlab_send_ascii_command("set_param('UAV_Test2','SimulationCommand','stop');");
127     fprintf(stderr, "Terminating MATLAB Engine Process! Press any key to proceed...\n");
128     getch();
129     netsim_matlab_interface_close();
130 }

```

Figure 6: Source code changes for Case 1 in UAVBasedmobility.

## NetSim Plot: Application Throughput Vs. Time

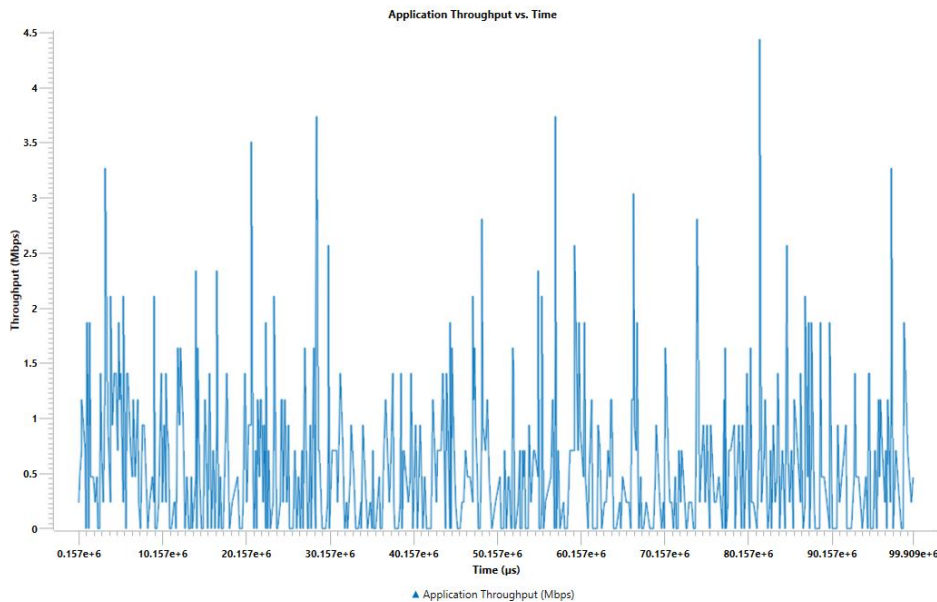


Figure 7: Application Throughput Vs. Time from NetSim

**MATLAB Flight Path:**

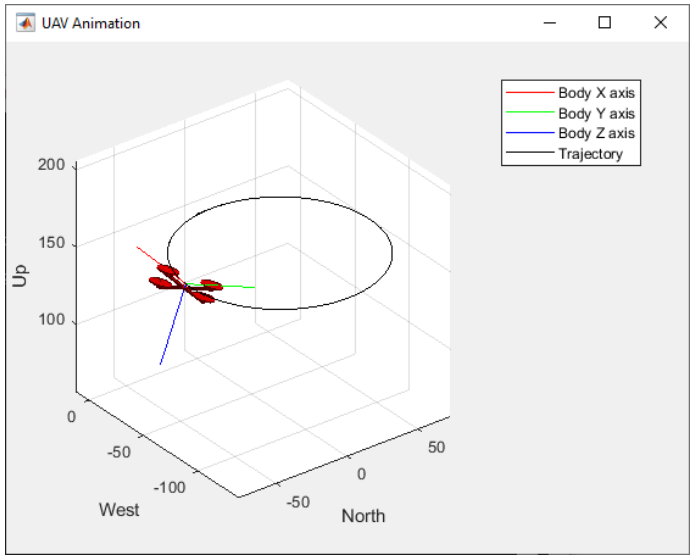


Figure 8: MATLAB Flight Path from NetSim