INTERNATIONAL HELLENIC UNIVERSITY
School of Science and Technology

Virtual Labs #5: "Routing Efficiency in Wireless Sensor Networks": Documentation

Referring to Courses:
Mobile Communication Networks,
MSc in Information and Communication Technology Systems

prepared by

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1.0 Preface

This report constitutes the documentation of the 5^{th} virtual laboratory environment that was developed for the "Mobile Communication Networks" and "Sensor Networks" courses of the MSc in Information and Communication Technology Systems, International Hellenic University.

Purpose of the present work is to provide a tool for the study of routing efficiency in Wireless Sensor Networks, with respect to node topology. The application is a modified version of the "prowler" simulator, created at School of engineering of the Vanderbilt University. Interface simplification for adaption to education purposes and expansibility have been the goals of the modification.

This documentation loosely relies on [1]. Documentation of the original simulator is scarce however, and this document attempts to present a simply functional substitute. The document consists of the following parts:

The fist section provide usage information for the simple user (student of an MSc program in Telecommunications). The second section targets the supervisor (academic assistant with some knowledge of programming in MATLAB).

Theoretical outline is not provided in the context of this report, as it would unnecessary increase its size. An excellent theoretical overview is given in [1], a published paper by the original authors.

September 12, 2010

Liaskos Christos, Electrical Engineer, Dpt. of Informatics, A.U.Th.

2.0 User's Manual

2.1 Requirements

- MATLAB version 2009b or 100% compatible. Consult the manual of your version of MATLAB for backwards compatibility, if you intend to use a more recent version of MATLAB.
- A version of Microsoft Windows capable of running the used MATLAB version.
- An installed version of Microsoft Excel, or any program able to handle .xls files in a fully compatible way.
- Dual core CPU with 2GB RAM.
- 2MB of hard disk space are required to hold the application files.

2.2 Installation Notes

The installation procedure follows that of the 1^{st} virtual lab "Antennas and Propagation":

- Place the provided application files in a folder that you specify, denoted as $USER\_DIR$. This folder will contain the files and folders that comprise the application.
- Add the $USER\_DIR$ and all contained subfolders to the MATLAB path. Consult the manual of your version of MATLAB for more details.
- Make sure that none of the application files are shadowed by same-named but irrelevant files already in the MATLAB path. It is advised to revert the MATLAB path to its factory default value before step 2, to avoid any shadowing problem. For more information on shadowing consult the manual of your version of MATLAB.

2.3 Application execution and usage

To start the application, change the current working path of MATLAB to *USER_DIR* and issue "simgui" at the MATLAB command prompt.

The main application form will appear:

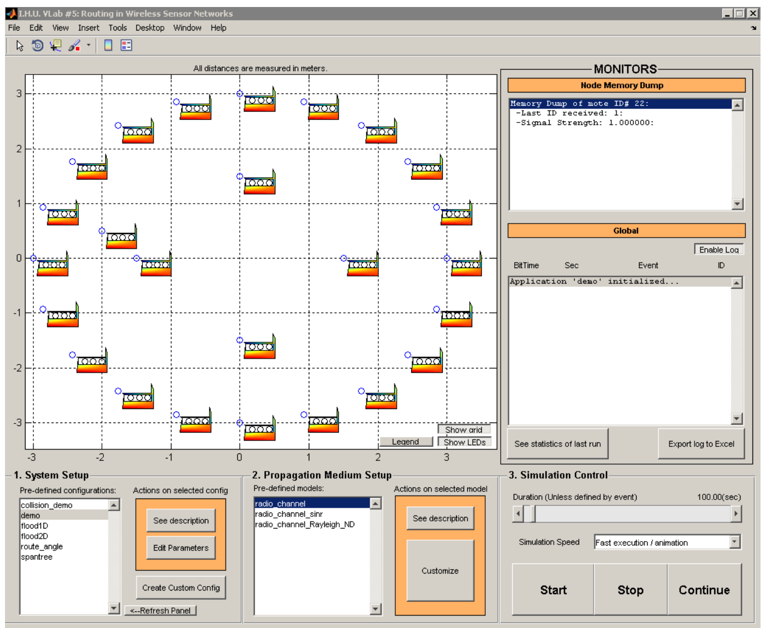

Figure 1: The main form of the application.

Understanding main form and related controls.

The menu and tool bars are the standard MATLAB figure components and the user should already be familiar with their meaning through the MATLAB documentation. Notice though that proficiency of usage is certainly not required in any part of the application.

Topology overview window

One of the most sizeable components of the main form is the topology overview:

A set of nodes is scattered over a flat, 2-D area. A node is represented by the encircled clip art of the previous figure. It consists of a box with three LEDs (small circles) and an

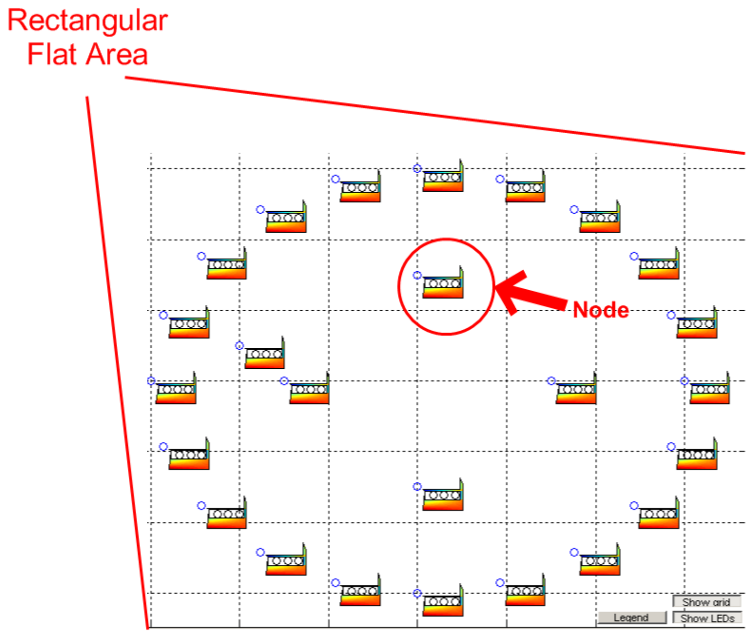

Figure 2: The topology overview window.

antenna:

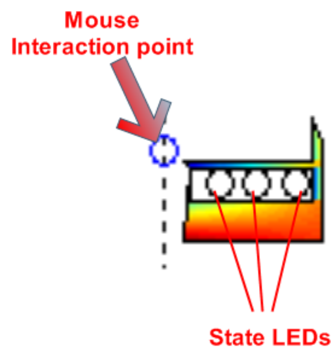

Figure 3: Graphical node representation.

Click on the designated point when interaction with a node is required (typically to extract node data, as described later).

When running a simulation, the colors of the LEDs may change, text messages may appear, as well as some animation effects. Click on the **Legend** button to get an explanatory window of these elements:

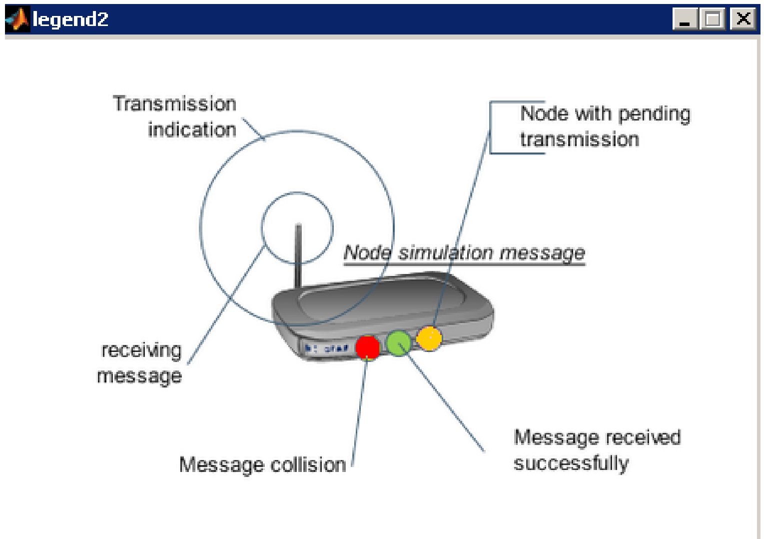

Figure 4: The topology overview legend window. An explanation of the color codes and animation is given.

Setup panels

The main form has several panels, lined up and numbered according to proper turn of use:

1. System setup panel

The student can access a series of available, parameterized scenarios which can be seen in the panel's listbox. Each scenario includes a specific topology, simulation animation, node behavior parameterizations. Choosing one scenario from the list box will automatically load it. This will become evident by the change in the topology overview window.

Click on the "**see description**" button to get specific information on the scenario, using the built-in MATLAN help system. This should contain all that is needed to understand the running setup of the system.

Click on the "**edit parameters**" button to configure the scenario through the options that its author has provided. Notice that a scenario may not support parameterizations. The topology of none of the scenarios may be edited for software maintenance reasons.

Should you require to create custom topologies, use the "**create custom config**" button. This procedure however is meant for the author to create custom scenarios which will be distributed to the students.

2. Propagation Medium Setup

In this panel, the student may choose different propagation models for the communication between nodes. This affects the communication and sensing radius of each node, the supported error and transfer rates.

Simply choose a model from the listbox, an it is immediately applied to the running scenario. For a full description on a model, click on the "see description" button with the corresponding model highlighted in the list box.

You may change the parameters of the chosen propagation model by clicking on "customize". An example of customization of the model "radio_channel" is shown below:

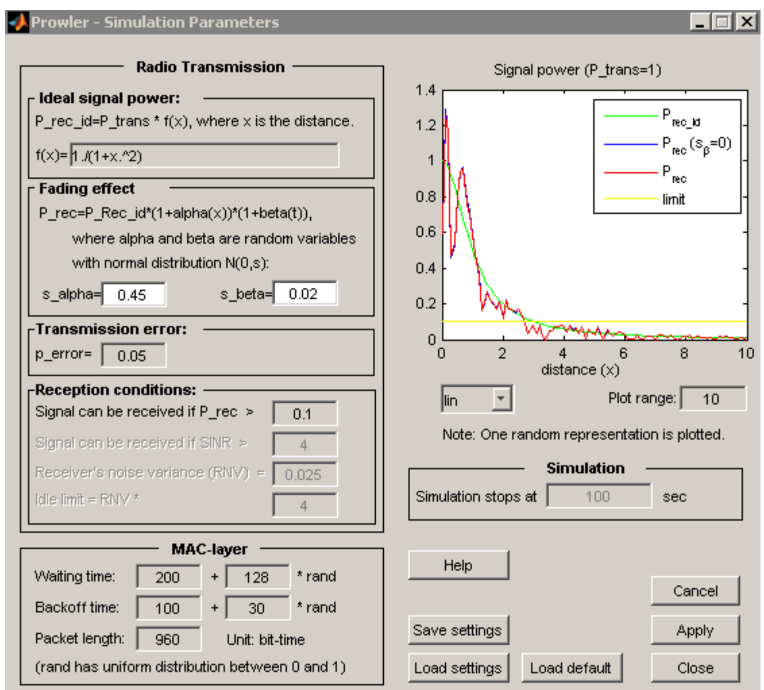

Figure 5: An example of customization of the model "radio_channel".

The shown form may differ from model to model.

The corresponding "description" contains all information regarding the meaning of the shown form and contained controls.

3. Simulation Control

The contained controls are self-describing:

- Use the "duration" slider to set the maximum duration of the simulation. Notice that the simulation may stop at an event defined by the scenario, e.g. a maximum number of colliding packets has been reached, etc.
- Use the "Simulation Speed" pop-up menu to slow down the execution speed of the simulation. Use it if you wish to observe an event better by slowing down is execution speed.
- Use the controls "Start", "Stop", "Continue" to perform the corresponding actions on the simulation.

Executing a simulation an collecting data

After setting up the simulation parameters as desired, click on the "Start" button in panel "3. Simulation Control". The "global monitor" begins to fill with data, while certain transmission events are being animated on the topology plot:

To extract node-specific, real-time data, click on the node's mouse interaction point described earlier. The "Node Memory Dump" monitor will fill with node-specific data. The information that will be extracted and shown in this monitor is defined by the running scenario:

You may pause the simulation in order to extract node data in a more coherent way.

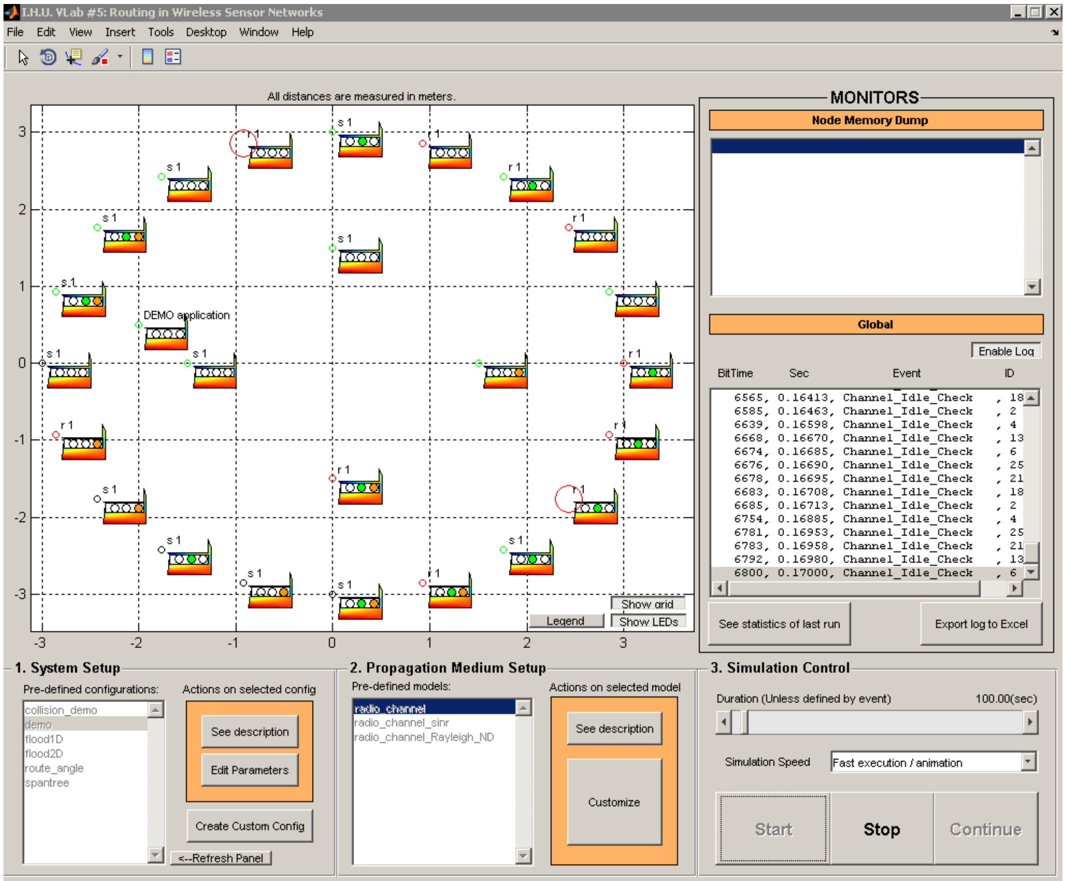

Figure 6: A running simulation.

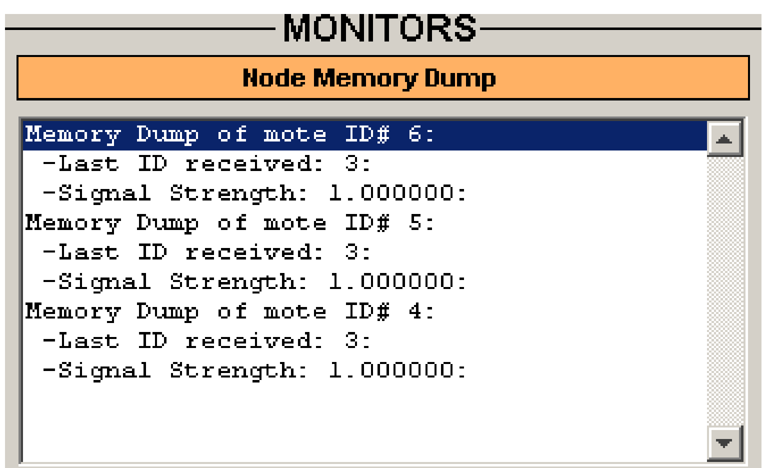

Figure 7: Getting node-specific data in real time.

The data displayed in the global monitor however, have the same format for any scenario. Events are logged as listbox lines. The time is logged in seconds and in bittime ($t_{sec} \cdot bps$).

The type of the event and the posting node are logged next.

When the simulation is stopped (either because the duration has been reached, or because the stopping event has been signaled, or simply it is paused/stopped by the user) you may press the "see statistics of last run" button to extract some statistical information of the simulation so far. The data will be shown in text form, so as to make it easier to copy and paste them form further external processing.

Finally, pressing the "Export log to excel" button will open the Microsoft Excel application and fill a datasheet with the complete log. You can then easily implement custom functions to extract efficiency data, as described by your instructor.

2.4 Uninstalling the application

The un-installation process is simple; no special utility is needed. Simply restore the MATLAB paths and remove all application files by deletion.

3.0 Supervisor's Manual

3.1 Extending the application

Features and limitations

It is possible to add new topologies for existing scenarios via an easy to use graphical interface. You may also change the animation type of all events. Changing the handling of the events however, requires some simple programmatic interventions.

Using the GUI to create new topology scenarios

On the "System Setup" panel click on the "create custom config" button. The following dialog appears:

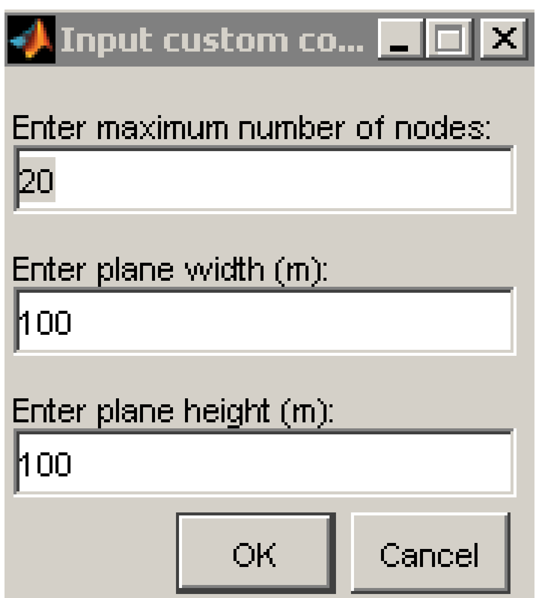

Figure 8: Custom config creation dialog.

You may enter the dimensions of the flat plane that will contain the nodes. You may define an upper limit for the number of nodes that will be placed. This is not restricting: you may place less nodes if you so choose without aborting and restarting the custom config creation.

Immediately after pressing OK, the following form appears:

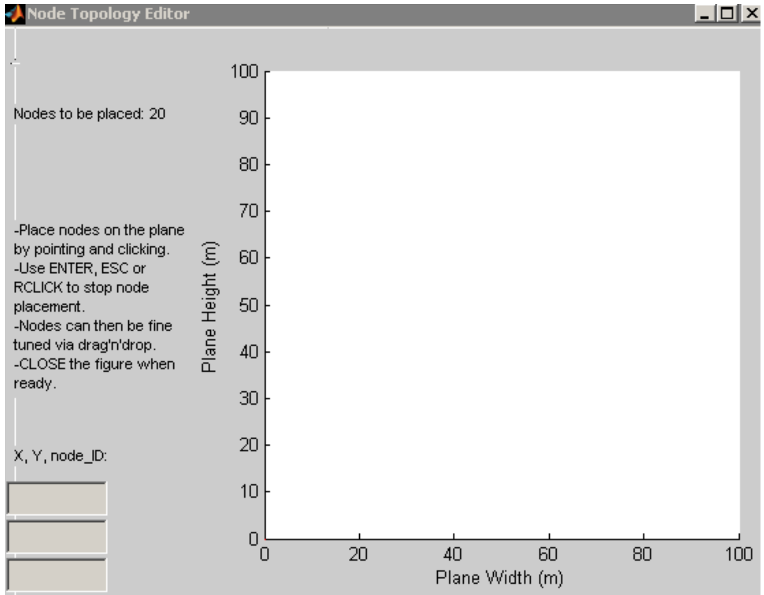

Figure 9: The node topology editor.

The mouse cursor has changed into cross-hair style, and you may place the nodes by pointing and clicking on the plot. The form's text notifies you on how to stop the node placement prematurely, and how many available nodes are left.

After the initial node positioning, you may drag and drop positioned nodes to other places as desired. *(NOTICE: You may NOT delete nodes or add additional ones form this point and on. This limitation stems from the fact that this interface is also available to students, who are supposed to use existing, tested and working scenarios and NOT create their own. Some degree of user-friendliness has been removed to discourage this practice.)*

While dragging nodes to other positions, the edit boxes at the lower-left of the form will be up updated to show the current coordinates and ID of the node that is being moved.

(NOTICE: Make sure that the nodes are placed at communicating distances, otherwise the topology may be useless.)

Once the topology is set, close the node positioning form. Immediately the following completion form appears:

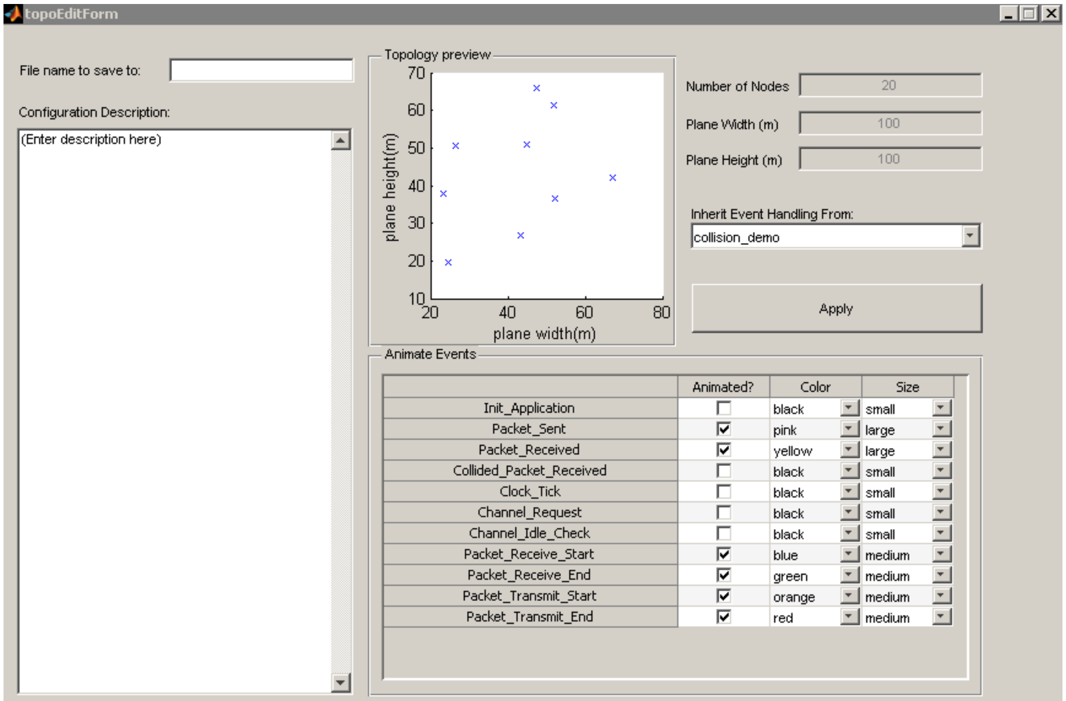

Figure 10: The custom config completion form.

Enter a unique filename (you will be notified if another file with the same name exists) for the new scenario and a description (will be shown when he user presses the "show description" button).

In the "animate events" panel, check all the events that you want to be animated on the topology overview panel of the main form. Choose appropriate colors. All events are animated as concentric cycles next to the node. Choose the size of each cycle via the third column listboxes. Notice that animating all events may produce results that are difficult to visually interpret.

Define how the simulation events will be handled, by choosing a scenario from the "inherit event handling form" pop-up menu. The event handling code will be directly copied from this scenario.

Finally, click on the "apply" button.

The config completion form will close, and control will be transferred to the main form once more.

Click on the "refresh panel" button of the "System setup" panel. The newly created scenario will become available in the scenario listbox. The prefix "user_" will be added to differentiate from the scenarios available by default. You may use it just like any other scenario, as already described.

Removing scenarios

Notice that no user-friendly way for removing scenarios has been added for security and maintenance reasons. To remove the scenario "user_MYSCENARIO" navigate to the directory "APPLICATIONS" in the application's install directory, and remove the following files:

- "user_MYSCENARIO_animation.m"
- "user_MYSCENARIO_info.m"
- "user_MYSCENARIO_params.m"
- "user_MYSCENARIO_topology.m"
- "user_MYSCENARIO_animation.m"

Adding Custom Event Handlers Adding custom event handlers is a rather straightforward but programmatic task. You must use one of the provided scenarios as a template and build upon it. For the scope of this example we will use the "route_angle" example. Use the previously described GUI and create a custom config which inherits from the "route_angle" scenario. We assumed that you have named you custom scenario as "MYCUSTOMSC".

Defining sinks and transmitters and random topologies In order to set receiving and transmitting nodes, edit the "user_MYCUSTOMSC_params.m" file. The contained entries define which parameters will be available for editing when the user clicks on the "Edit Parameters" button of the "System Setup" panel.

Enter the desired IDs in the 'StartMote' and 'StopMote' default values. Disable components (set(h,'Enabled','off')) that you do not want to be accessible for editing by the students.

As an extra, this scenario uses random node placement for topology creation. If you wish to go with this approach, overwrite the "user_MYCUSTOMSC_topology.m" file with the "route_angle_topology.m" and enter a default value for the topology creation algorithm.

Defining event handling

Edit the file "user_MYCUSTOMSC_application.m". An overview of the file's contents is shown below:

The custom code must be placed within the "application starts here"-"application ends here" tags. The contained switch is used to handle the events.

Use the provided default examples and their documentation to generate your custom code. You may also consult the original authors' documentation at the home-site of "Prowler: Probabilistic Wireless Network Simulator" at (http://www.isis.vanderbilt.edu/Projects/nest/prowler/).

```
function application(S)

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%                                           %%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%         APPLICATION STARTS                %%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%               HERE                        %%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%                                           %%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%vvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvv%

SENDER_ID=sim_params('get_app', 'StartMote');
if isempty(SENDER_ID), SENDER_ID=1; end

switch event
case 'Init_Application'
.......
case 'Packet_Sent'
.......
case 'Packet_Received'
.......
case 'Collided_Packet_Received'
.......
case 'Clock_Tick'
.......
case 'GuiInfoRequest'
.......
case 'Application_Stopped'
.......
case 'Application_Finished'
.......
otherwise
    error(['Bad event name for application: ' event])
end

%^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%                                           %%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%         APPLICATION ENDS                  %%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%               HERE                        %%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%                                           %%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

Figure 11: The application template.

References

[1] Gyula Simon, Peter Volgyesi, Miklos Maroti, Akos Ledeczi, "Simulation-based optimization of communication protocols for large-scale wireless sensor networks ", Aerospace Conference, 2003. Proceedings, pp. 1339-1346.