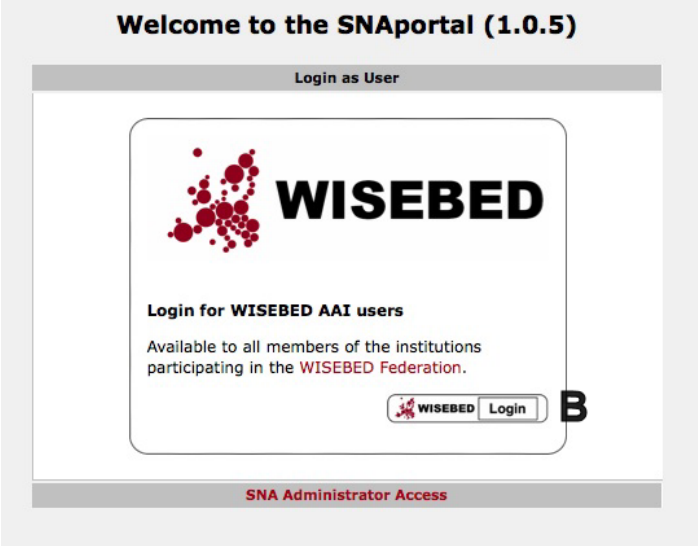

Figure 29: User roles: SNA portal login.

(A) By clicking on *register for roles* on the right top of the site (cf. Fig. 28), the user can register itself for roles.

(B) The user is directed to the SNA (Sensor Network Authorization) portal, shown in Fig. 29, where the user has to login again (using its wisebed login).

(C) The user can now subscribe for a role (cf. Fig. 30).

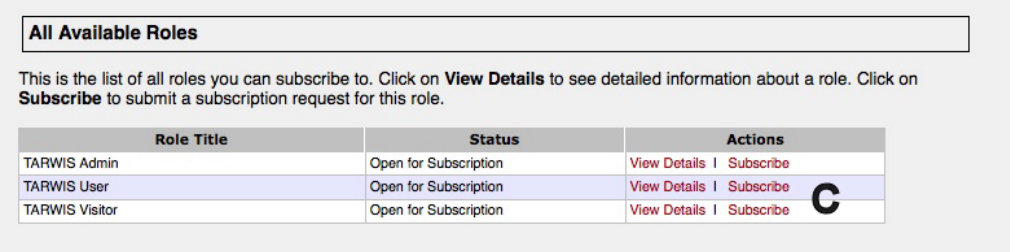

Figure 30: User roles: available roles.

(D) By clicking on the *Subscribe* button (cf. Fig. 31), the role administrator will get a notification about the request. The user gets informed by email, when it is accepted or not accepted for the requested role.

(E) By clicking on *List My Roles* in the left menu, the user can see its roles, including the status (cf. Fig. 32).

(F) The user can also *Unsubscribe* for a role.

7.3 Binary Code Image for Experiments

The behavior of the sensor nodes only depends on the software running on the nodes. This software is developed by the user. There is no pre-installed software.

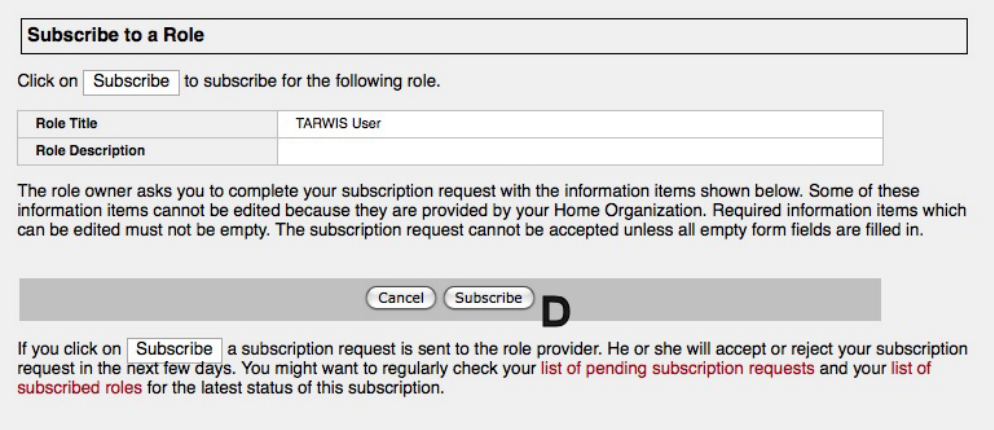

Figure 31: User roles: subscribe for a selected role.

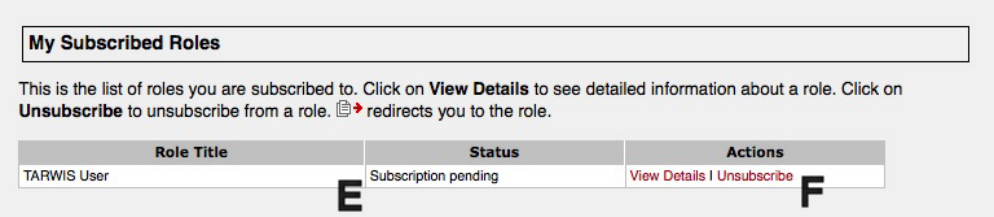

Figure 32: User roles: list of subscriptions.

Figure 33: Image: menu.

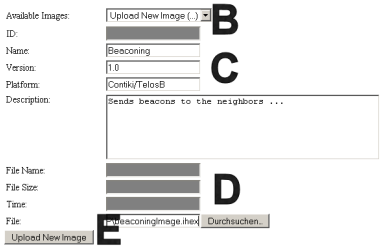

Figure 34: Image: upload.

(A) By clicking on the *Experiment Configuration* → *My Images* tab (cf. Fig. 33), the user can upload its software to the TARWIS GUI

(B) Selecting *Upload New Image (...)*, the user can upload its developed binary code image (cf. Fig 34).

(C) Afterwards, the user can enter the name, version, platform, and description of the image.

(D) Then, the user selects the file of the image.

(E) Finally, the user finish the form by clicking on the *Upload New Image* button. The image is now uploaded to the TARWIS GUI and can be used for the experiments (see Section 8.2).

(F) By selecting a previously uploaded image, the user can update the name, version, description, and the platform (cf. Fig. 35).

(G) By clicking on the according button, the user can update, delete or download the image.

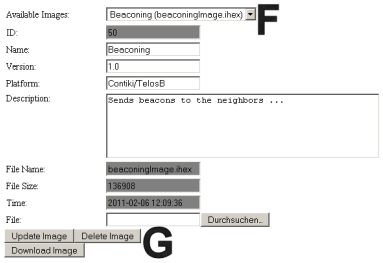

Figure 35: Image: update.

8 How to Perform an Experiment on TARWIS?

This Section describes the steps how a user can perform its experiment. It starts with the nodes reservation, and afterwards the experiment configuration. Finally it describes the experiment monitoring and downloading the experiment results.

8.1 Node Reservation

Figure 36: Reservation: menu.

(A) By clicking on the *Reservation* → *Reservation Overview* tab (cf. Fig. 36) the user can reserve nodes of the underlying testbed using the schedule sheet

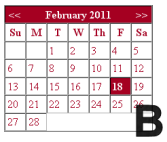

Figure 37: Reservation: calendar sheet.

(B) First, the user can select the day, when its experiment should performed (cf. Fig. 37). The current day is preselected.

(C) The available sensor nodes are listed on the left side of the schedule sheet (cf. Fig. 38). Different types of sensor nodes are separated by a white line.

(D) On the top of the schedule sheet the 24 hours of the day are listed (in UTC) and divided into 15 minute slots.

(E) The state of the nodes is depicted by the color of the sheet. Available slots are colored green, blocked ones red and own reservations blue. Slots in the past are gray colored.

(F) To reserve sensor nodes for an experiment the user can select nodes in the green area. To achieve this you can either click&drag to select a rectangle (nodes vs. time) and double-click on a node to remove this node from the selected nodes of the rectangle. Or the user can select (single-click) the first and the last time slots.

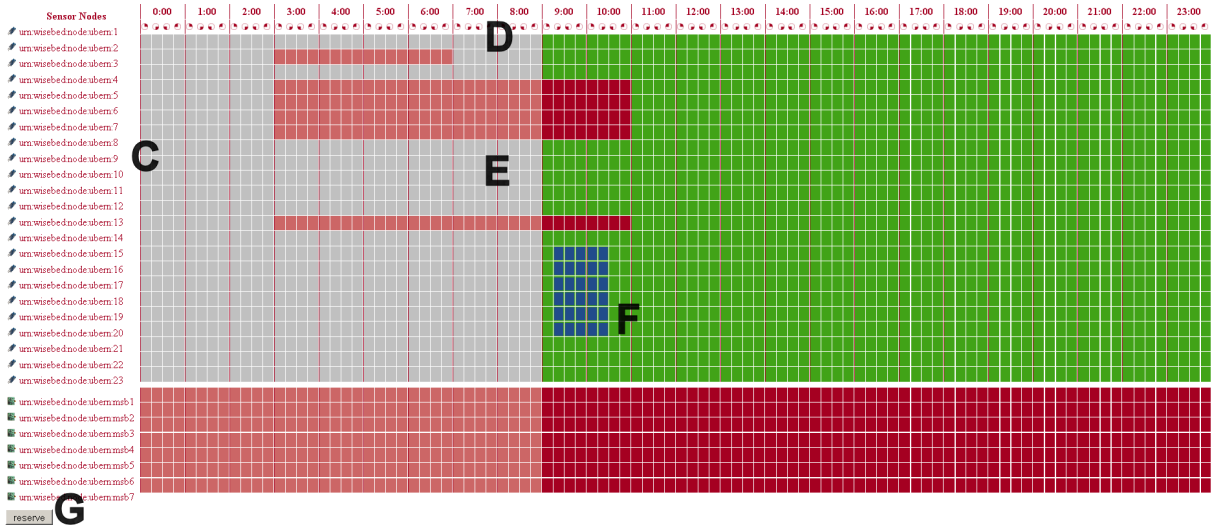

Figure 38: Reservation: overview.

Figure 39: Reservation: undo reservation or configure experiment.

(G) By click on the *reserve* button on the bottom of the page the reservation is finished.

(H) Afterwards it is depicted, if the reservations was successful or not. Now, the user can either undo the reservation (button *Undo Reservation*) or

(I) go directly to the experiment configuration tab, clicking the button *Configure Experiment for Reservation* (cf. Fig. 39).

Figure 40: Reservation: menu.

(J) By clicking on the *Reservation* → *My Reservations* tab, the user can find its own reservations (cf. Fig. 40).

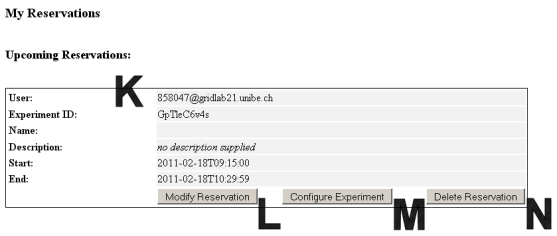

Figure 41: Reservation: my reservations.

(K) The unique ID of the experiment owner, the ID of the experiment, the name and description (if available), and the start- and end-time of the experiment are displayed.

(L) The user can modify the reservation (button *Modify Reservation*) or

(M) can configure the experiment (button *Configure Experiment*) or

(N) delete the reservation (button *Delete Experiment*), see Section 8.2.

Figure 42: Reservation: menu.

(O) By clicking on the *Reservation* → *Testbed Map* tab (cf. 42),

(P) the user can find the map of the positions of all nodes of the testbed (cf. Fig. 43).

(Q) On the right side, there are additional information about the nodes (ID, type, description, capabilities).

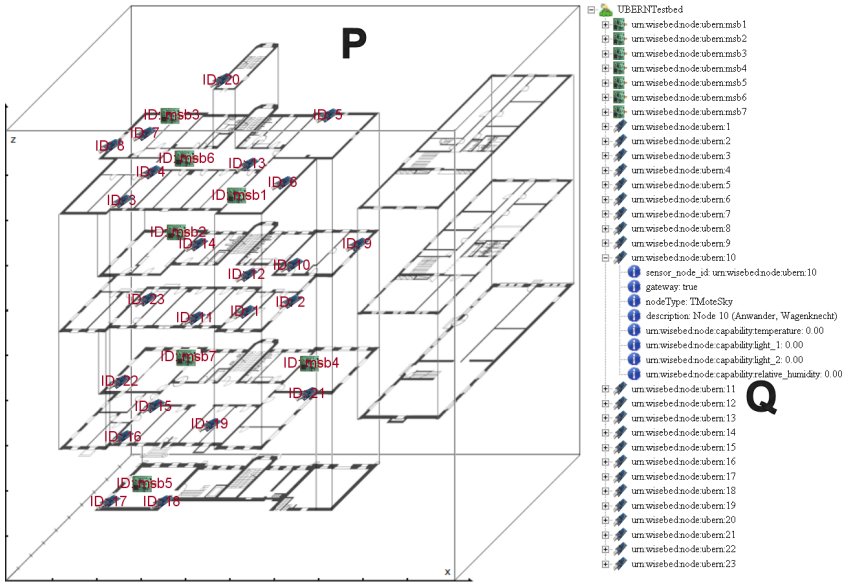

Figure 43: Reservation: testbed map.

8.2 Experiment Configuration

After the user has reserved nodes for certain time slots it has to configure the experiment. Configuration of an experiment includes binary code images and configuration commands for the sensor nodes, number of runs which the experiment should be performed, and additional information such as experiment description.

Figure 44: Configuration: menu.

(A) By clicking on the *Configure Experiment for Reservation* button (cf. **(H)** in Fig. 39) after reservation or via the *Experiment Configuration* → *My Experiments* tab (cf. Fig. 44 the user can configure its experiments using the dialog shown in Fig. 45.

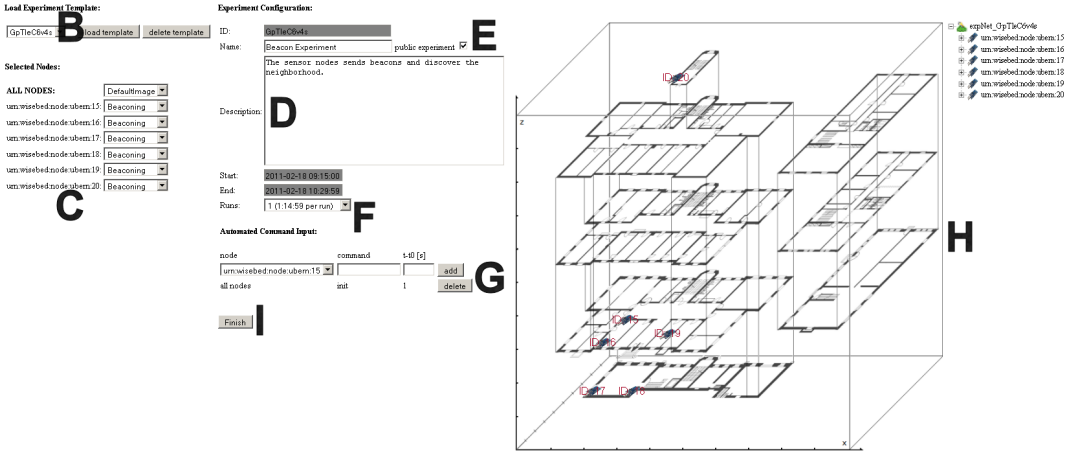

Figure 45: Configuration: image, description, number of runs, automated commands.

(B) First, the user can use a experiment template. This includes the images of the selected nodes, the description, the number of runs and the set of automated commands. Using a template could be utile, if the user wants to perform a series of similar experiments.

(C) The user can choose its binary code which will be uploaded to the selected sensor nodes. It can choose one image for all nodes or different images for different sensor nodes.

(D) A *Name* and a *Description* can be entered optionally by the user.

(E) If the user checks the *public experiment* checkbox, the experiment can be monitored by every TARWIS User and TARWIS Viewer.

(F) The user can select the number of runs, how often the experiment should be repeated. The time of a run is divided through reserved time. After a run the nodes are reseted and the experiment starts again.

(G) To configure the nodes or control the experiment the user may add commands which are transmitted to the sensor nodes at the chosen time. The commands are transmitted to the sensor nodes using the serial interface and have to be interpreted and executed by the operating system on the sensor node. A command can be send to all or only to selected sensor nodes.

(H) On the right side, the map with the selected sensor nodes and additional information (such as (ID, type, description, capabilities) are displayed.

(I) Clicking on the *Finish* button finish the configuration sheet.

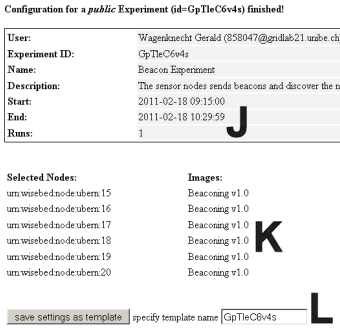

Figure 46: Configuration: configured experiment.

(J) After finishing, the configuration data of the experiment are depicted (cf. Fig. 46), like experiment ID, name and description of the experiment, start and end time and number of runs, and

(K) the selected sensor nodes with the selected images.

(L) Furthermore, the user can save the current configuration into a template for re-using with further experiments.

By clicking on *Experiment Configuration → My Experiments* (cf. Fig. 44 the user can finds its experiments, the unconfigured ones and the configured ones (cf. Fig. 47).

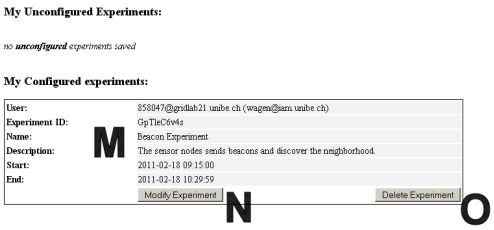

Figure 47: Configuration: my experiments.

(M) The user can find again the configuration data of all its experiments, like experiment ID, name and description of the experiments, and start and end time as well.

(N) To modify the experiment configuration, the user can press the *Modify Experiment* button.

(O) To delete the experiment configuration, the user can press the *Delete Experiment* button.

8.3 Experiment Monitoring

A configured experiment is performed during the reserved time slots. The user can monitor its own experiments (or public experiments). It can follow the output of the sensor nodes. If necessary, the user can send commands to the sensor nodes or reset the sensor nodes (if it is owner of the experiment). It is possible that two or more experiments running in parallel on the testbed and the user can switch between them.

Figure 48: Monitoring: menu.

(A) By clicking on the *Experiment Monitoring* tab the user can monitor the experiments (cf. Fig. 48).

(B) On top of the site (cf. Fig. 49), all running experiments are listed including the *Experiment ID*, the owning *User*, and the *Name* of the experiment.

(C) By clicking on the experiment ID, the user choose the experiment it wants to monitor.

(D) This experiment is listed with additional information such as experiment description, start and end time, and number of runs.

(E) Also displayed is the control output, which includes, e.g., status of flashing the images on the sensor nodes.

(F) By clicking on the *End Experiment, Save Result* button, the user cancel the experiment before the regular end. The user will get an email with the zipped experiment results.

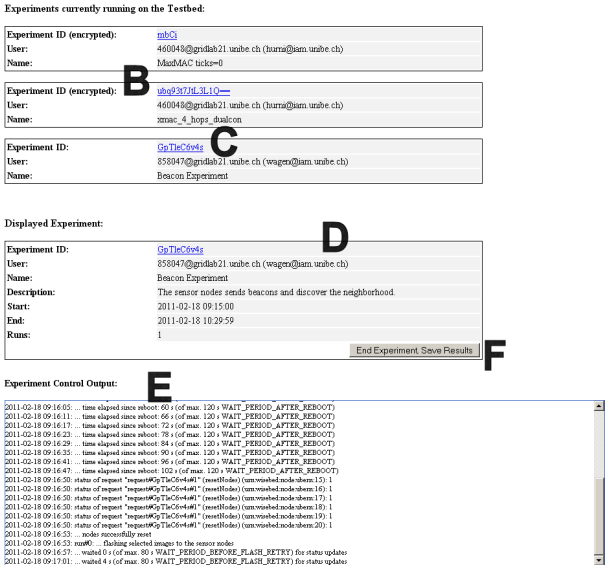

Figure 49: Monitoring: switching between parallel experiments.

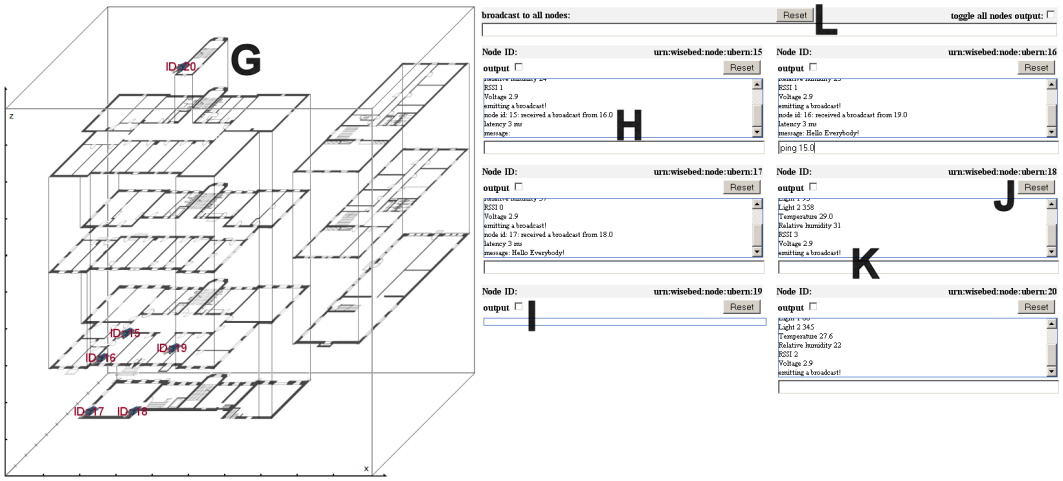

Figure 50: Monitoring: experiment output and map.

On the bottom of the site the output of the sensor nodes of the chosen experiment is displayed as shown in Fig. 50.

(G) On the left side the nodes' connectivity on the node map is displayed, as soon as nodes transmits packets and discover each other.

(H) On the right side an output window including a *Reset* button and a command line is displayed for each sensor node used in the experiment.

(I) The output window can be switched off for performance and clearness reasons by clicking in the *output* checkbox.

(J) If the user notices that a node misbehaves (e.g., is stuck in an endless loop or similar), it can reset the node using the *Reset* button.

(K) Furthermore the user can send commands to the sensor nodes using the command line. The set of commands which can be used is the same as for the control of a local physical testbed and depends on the operating system on the sensor nodes.

(L) It is also possible to reset all nodes with one click and send a command parallel to all sensor nodes.

8.4 Finishing Experiments

After finishing (or canceling) an experiment, all results are stored in the designated TARWIS database. The experiments' results and further information about the experiment are stored using WiseML (Wireless Sensor Network Markup Language) as described in the next Section.

Figure 51: Configuration: menu.

(A) The finished experiments can be found in the *Experiment Configuration → Finished Experiments* tab (cf. Fig. 51).

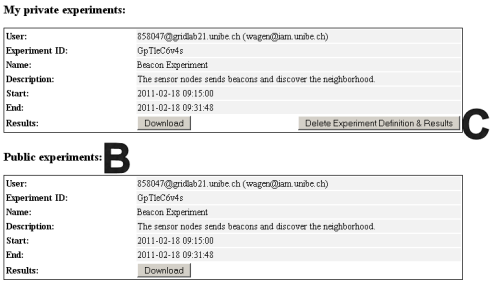

Figure 52: Configuration: finished experiments.

(B) On this site (cf. Fig. 52) all users' experiments are listed as well as all public experiments. The user can download the experiment results of its own experiments and of the public experiments

(C) For its own experiment, the user can delete the definitions and the results.

9 Data Acquisition and Representation

TARWIS integrates the WiseML (Wireless Sensor Network Markup Language) for several purposes. On one side, it uses WiseML for reading and parsing the necessary information about it's underlying *Network definition*. Furthermore, it uses WiseML for storing and generating the output of the *Experiment log and debug traces* in a common defined format.

Network definition: in order to read the network resources (node type, sensors, positions, etc), TARWIS calls the getNetwork() function of the SessionManagementService API, and retrieves a WiseML document listing the entire network endowment. It uses the retrieved positions to display the nodes of the network in the network graph. Listing 1 lists one *instantiation* of a node entry. The node type and endowment are described in the *defaults* section.

Listing 1: Node entry in SessionManagementService of Univ. of Bern testbed

```
<node id="urn:wisebed:node:ubern:1">
<position>
<x>69</x>
<y>20</y>
<z>52</z>
</position>
<gateway>true</gateway>
<description>Node 1 - Office 205 (2nd Floor)</description>
</node>
```

Experiment log and debug traces: As soon as an experiment is scheduled and configured, the TARWIS *ControllerService* retrieves experiment output (e.g. debug information, sensor values) over the *receive* function and stores it to the TARWIS internal database.

As soon as the experiment time has expired, the nodes are reflashed with a default image, and the network is prepared for the subsequent experiment. Every output of the finishing experiment is exported by TARWIS to a WiseML-file, zipped and saved to the TARWIS database. This WiseML-file hence comprises all important information about an experiment run, e.g., where the experiment took place geographically, what kind of nodes were used, what their sensor endowment was, and much more. Storing all this experiment-related information in one WiseML file offers many advantages, besides the possibility to easily use it for post-experiment analysis. As it defines essentially all crucial information of an experiment, it further allows to make the experiment data public to other research partners in a common well-defined language, giving them the opportunity to repeat the same or similar experiment, e.g. trying to improve the results. Hence, having integrated WiseML into the Testbed Management System inherently pushes research on wireless sensor networks one crucial step towards transparency and repeatability of sensor network experimentation.

Listing 2: Excerpt from a TARWIS-generated Experiment Trace

```
<wiseml> [...]
<trace id="experiment_UBERN_uniqueID_23453323">
  [...]
  <timestamp>3605.164612</timestamp>
  <node id="urn:wisebed:node:ubern:9">
  <position>
      <x>85</x>
      <y>80</y>
      <z>52</z>
  </position>
  <data key="textOutput">latency 15 ms</data>
  </node>
  <timestamp>3605.164612</timestamp>
  <node id="urn:wisebed:node:ubern:9">
  <position>
      <x>85</x>
      <y>80</y>
      <z>52</z>
  </position>
  <data key="textOutput">Light 1 202</data>
  </node>
  [...]
</trace>
[...]
</wiseml>
```

The WiseML code sample in Listing 2 lists two trace events retrieved in a small experiment at the University of Bern testbed. For each output line, one can determine the exact time (within the precision of some few milliseconds) relative to the experiment start time (c.f. the *timestamp* tag), the position of the node (hence, with mobile nodes, the node movement can also be captured) and the output itself. The WiseML-file generated by TARWIS can therefore describe to a very high degree what has happened at a certain time during the experiment.

10 TARWIS Testbed Management

To perform testbed administration tasks the user has to be a TARWIS Admin. How to become a TARWIS Admin is described in Section 5.

Figure 53: Testbed management: menu.

(A) By clicking on the *Testbed Management* → *Reservations and Experiments* tab, the administrator can modify the reservations and experiments (cf. Fig. 54).

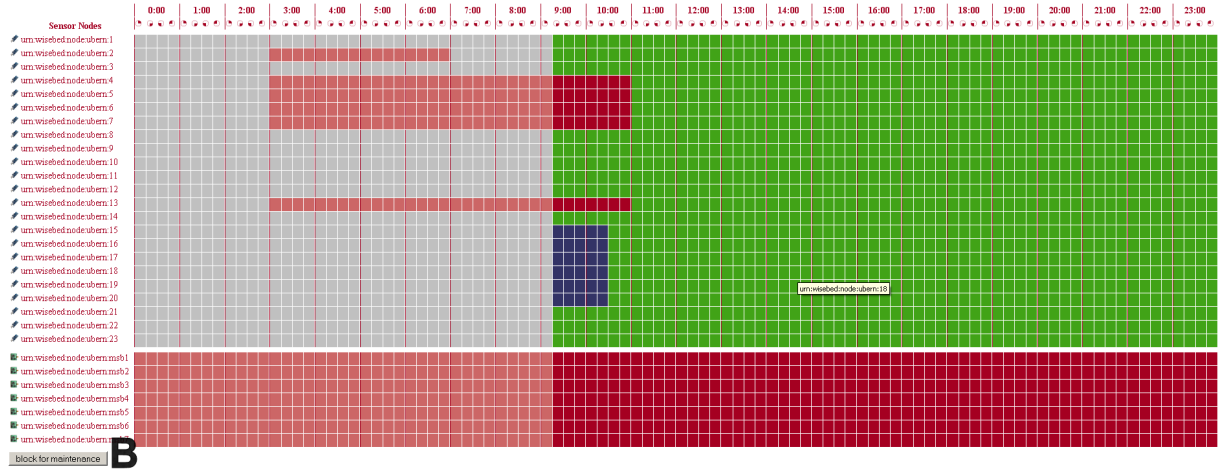

Figure 54: Testbed management: block for maintenance.

(B) The TARWIS Admin has the same reservation schedule sheet as the TARWIS user, but the administrator can block some nodes (or the whole testbed) for a certain time period due to maintenance reasons.

Figure 55: Testbed management: undo blocking.

(C) After blocking the administrator can also undo it.

(D) The administrator has a list of all maintenance blocks and can delete them.

(E) And, it has a list of all users' reservations and experiment configurations and can delete them as well.

(A) By clicking on the *Testbed Management* → *Reservations and Experiments* tab, the user can add new sensor nodes to the testbed (cf. Fig. 58), or update existing ones (cf. Fig. 59).

(B) By selecting *Add New Sensor Node(...)* from the drop-down menu, the user can enter the properties of the new sensor node into the form.

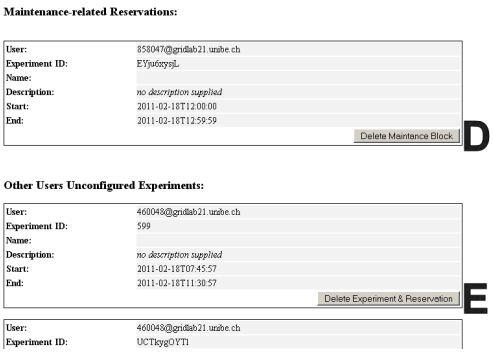

Figure 56: Testbed management: list of maintenance blocks and users' reservations.

Figure 57: Testbed management: menu.

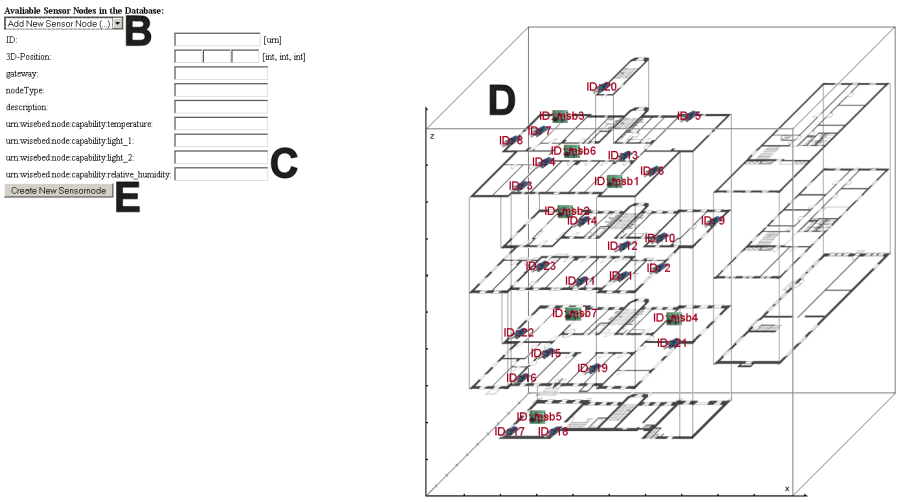

Figure 58: Testbed management: add new sensor node.

(C) This includes the ID (urn), position, gateway, type, description, and capabilities.

(D) The x-, y-, and z-value of the sensor nodes' position are between 0 and 100 according to the coordinates in the map.

(E) By clicking the *Create New Sensor Node* button, the node is added to the TARWIS database and depicted in the map.

(F) By selecting an existing sensor node from the drop-down menu, the user can update the properties of the new sensor node.

(G) The user can either update the properties for the selected sensor node or delete the sensor node from the database.

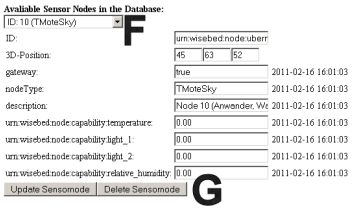

Figure 59: Testbed management: update sensor node.

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SEVENTH FRAMEWORK PROGRAMME
THEME 3
Information and Communication Technologies

Grant agreement for:
Collaborative project, Small and medium-scale focused research project (STREP)

Technical Report TR-TARWIS-USER-MANUAL:

TARWIS 4.0 User Manual v1.0

Project acronym: WISEBED
Project full title: Wireless Sensor Network Testbeds
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