Wireless Research with GENI:
Machine Learning for Wireless Sensor Networks Track

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Scenario

- Dr. Watson is a researcher in the field of artificial intelligence and machine learning.
- He's developed a novel approach to physical security systems.
- It collects ambient light measurements from distributed sensors and processes them with a machine learning algorithm.
- End result: estimates the probability of a certain security event (e.g., intruder in room).

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Scenario (continued)

- Dr. Watson's student wrote a Ruby application to implement the scheme that he developed.

What physical and computing resources does he need to evaluate this implementation?

Required Resources

- Distributed ambient light sensors that communicate with a measurement sink
- A measurement sink that he can configure to run the machine learning application

Optional Resources

- A way to set up and orchestrate complicated experiments with many parts
- Full control over all parts of the experiment, including measurement sources/sinks and all communication links
- Instrumentation and measurement tools for systematically collecting and comparing results

Experiment Topology

- Light sensors at one site communicate measurements over WiMAX network
  - NYU-Poly has thirteen physically distributed nodes equipped with temperature, light, humidity sensors
- Light readings travel over I2 link to a measurement sink at another site
  - NYU-Poly, BBN, WINLAB, all connected over I2
  - We'll configure WiMAX clients to use the I2 link
- Measurement sink receives measurements and processes using student's Ruby application

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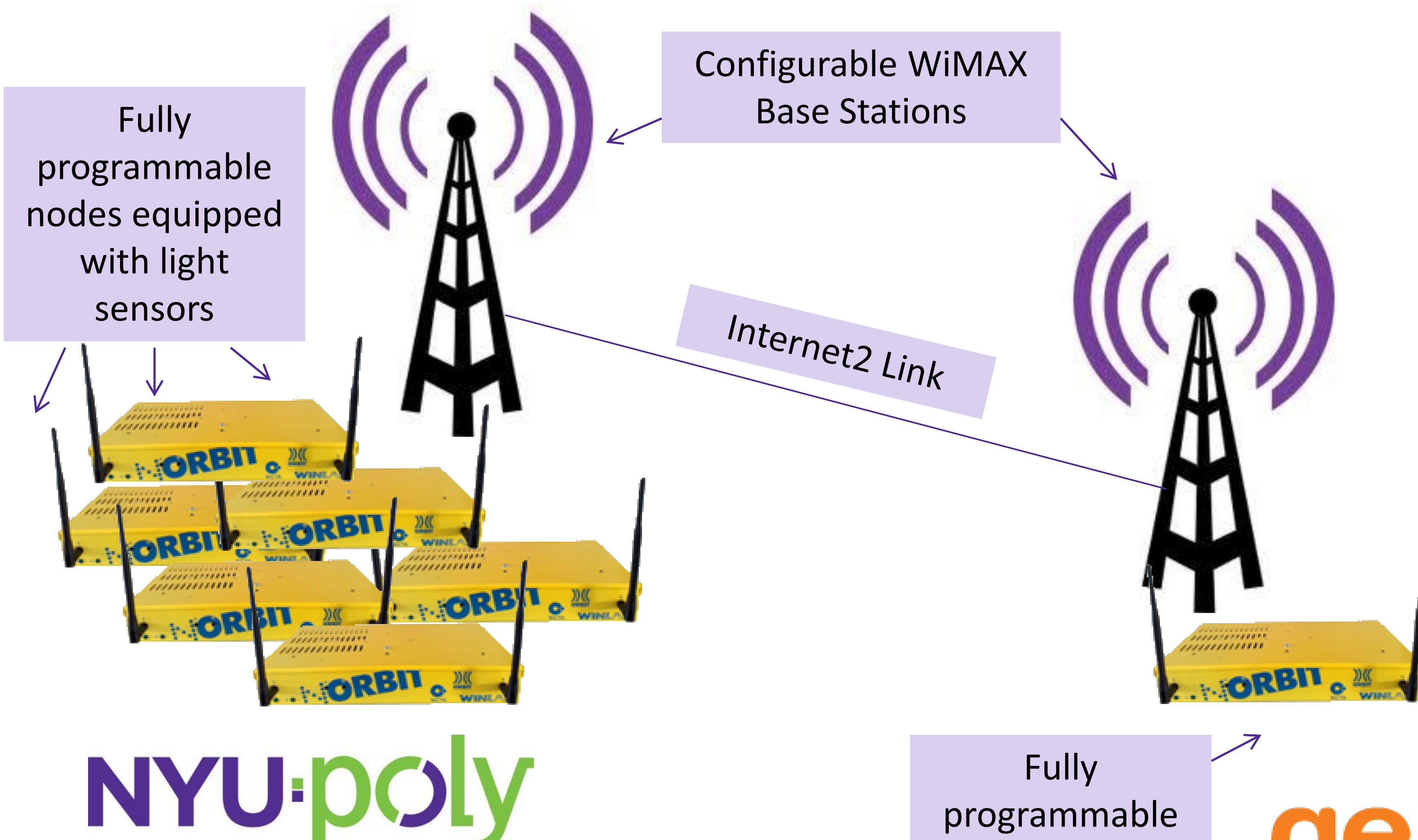
Experiment Topology, Illustrated



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Experiment

Does this experiment topology meet Dr. Watson's requirements?

- ✓ Distributed ambient light sensors that communicate with a measurement sink
- ✓ A measurement sink that he can configure to run the machine learning application.

and also

- ✓ Full control over all parts of the experiment, including measurement sources/sinks and all communication links

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Accessing a GENI WiMAX Testbed

- Register for an account and make a reservation to use a testbed ahead of time

Pro tip: Two WiMAX testbeds are currently open to experimenters.

- To register at NYU-Poly, visit http://witestlab.poly.edu and click "Register" in the top left corner – you'll get an email later than day with further instructions.
- To register at WINLAB, visit http://www.orbit-lab.org/userManagement/register

- At the designated time, use an SSH client to log in to the console of a WiMAX testbed, e.g.
  - `ssh ffund@omfserver-witest.poly.edu`

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Setting up Experiment

(Pre-configured BBN – demo this process at NYU-Poly)

- Reset base station to default settings
  - wget -qO- http://wimaxrf:5052/wimaxrf/bs/default
  - wget -qO- http://wimaxrf:5052/wimaxrf/bs/restart
- Configure datapath (connectivity endpoints) for WiMAX clients
  - wget -qO- "http://wimaxrf:5052/wimaxrf/datapath/config/load?name=bbn"

Pro tip: See more information about the pre-configured datapath options available at NYU-Poly at http://witestlab.poly.edu/index.php/instructions.html

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Setting up Experiment (cont.)

- Install disk images
  - `omf-5.3 load –i <image name> -t <list of nodes>`
  - The student started with a baseline image that already has WiMAX and sensor functionality set up (baseline-witest.ndz)
  - (Images are provided by testbed operators at each testbed)
  - He installed the machine learning application he built and its dependencies, some packaged artificial intelligence libraries (ai4r). Then he saved this disk image using `omf-5.3 save –n <node name>`
  - From now on, he can just load this saved image onto his nodes every session – no need to set up his environment every time

Pro tip: See more information about the prepared baseline images for NYU-Poly at http://witestlab.poly.edu/index.php/instructions.html

Experiment: Sequence of Events

- Dr. Watson’s student logs in to each node to begin the experiment
  - `ssh root@omf.witest.node1`
  - `wimaxcu connect network 51`
  - `ifconfig wmx0 10.37.35.151 netmask 255.255.255.0`
  - `sensor -d 10.37.35.175`
- Repeat for each of 13 nodes at NYU-Poly, then for measurement sink at BBN

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Experiment: Sequence of Events

- To save time, he learns to use OMF to configure the resources…

```
defProperty('hrnPrefix', "omf.witest.node", "Prefix to use for the HRN of resources")
defProperty('sender', "[13,12,11,10,9,8,7,6,5,4,3,2,1]", "List of IDs for the resources to use as senders")
defProperty('groupSize', 1, "Number of resources to put in each group of senders")

groupList = []
res = eval(property.sender.value)
groupNumber = res.size >= property.groupSize ? (res.size.to_f / property.groupSize.value.to_f).ceil : 1
(1..groupNumber).each do |i|
  list = []
  (1..property.groupSize).each do |j| popped = res.pop ; list << popped if !popped.nil?  end
  senderNames = list.collect do |id| "#{property.hrnPrefix}#{id}" end
  senders = senderNames.join(',')

  info "Group Sender #{i}: '#{senders}'"
  groupList << "Sender#{i}"
  defGroup("Sender#{i}", senders) do |node|
    node.net.x0.profile = '51'
    node.net.x0.ip = "10.37.35.#{i+150}"
    node.net.x0.netmask = "255.255.255.0"
    node.addApplication("test:app:sensor") do |app|
      app.setProperty('interval',5)
      app.setProperty('destination','10.37.35.175')
      app.measure('stats')
    end
  end
end
```

Set up WiMAX connectivity

Configure sensor application

Experiment: Sequence of Events

- .. and to define the sequence of events

```
onEvent(:ALL_UP_AND_INSTALLED) do |event|
  wait 10
  allGroups.startApplications
  wait 120
  allGroups.stopApplications
  Experiment.done
end
```

- He writes a similar script for BBN
- Now, to run the experiment, he only needs to do

  `omf-5.3 exec sensorapp-source.rb` *(at NYU-Poly)*

  `omf-5.3 exec sensorapp-sink.rb` *(at BBN)*

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Experiment: I&M

- The *sensor* applications saves measurements for him in a database, so he doesn't need to worry about capturing the results.

```
CREATE TABLE _experiment_metadata (key TEXT PRIMARY KEY, value TEXT);
CREATE TABLE _senders (name TEXT PRIMARY KEY, id INTEGER UNIQUE);
CREATE TABLE "sensor_predicted" (oml_sender_id INTEGER, oml_seq INTEGER, oml_ts_client REAL,
oml_ts_server REAL, "probability" REAL, "ts" INTEGER);
CREATE TABLE "sensor_received" (oml_sender_id INTEGER, oml_seq INTEGER, oml_ts_client REAL,
oml_ts_server REAL, "ts_server" INTEGER, "ts_client" INTEGER, "sender" TEXT, "source" TEXT,
"temperature" REAL, "humidity" INTEGER, "light" INTEGER);
CREATE TABLE "sensor_stats" (oml_sender_id INTEGER, oml_seq INTEGER, oml_ts_client REAL,
oml_ts_server REAL, "ts" INTEGER, "source" TEXT, "temperature" REAL, "humidity" INTEGER,
"light" INTEGER);
```

- He can retrieve these measurements as an *sq3* or *csv* anytime after the experiment runs, and plot them using standard data analysis tools like *gnuplot* or *R*.

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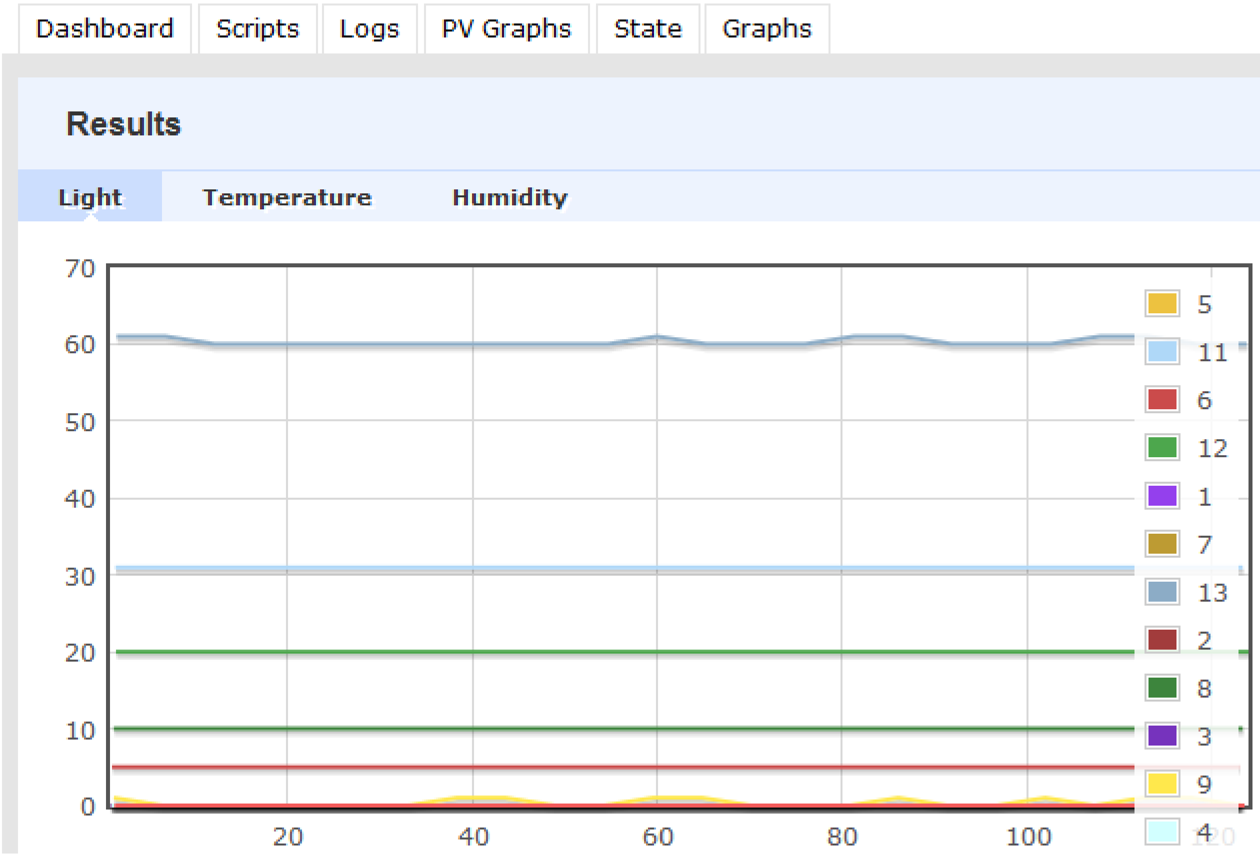
Experiment: I&M

- He even configured graphs in the experiment script, so he can view the visualization live and check on progress during the experiment



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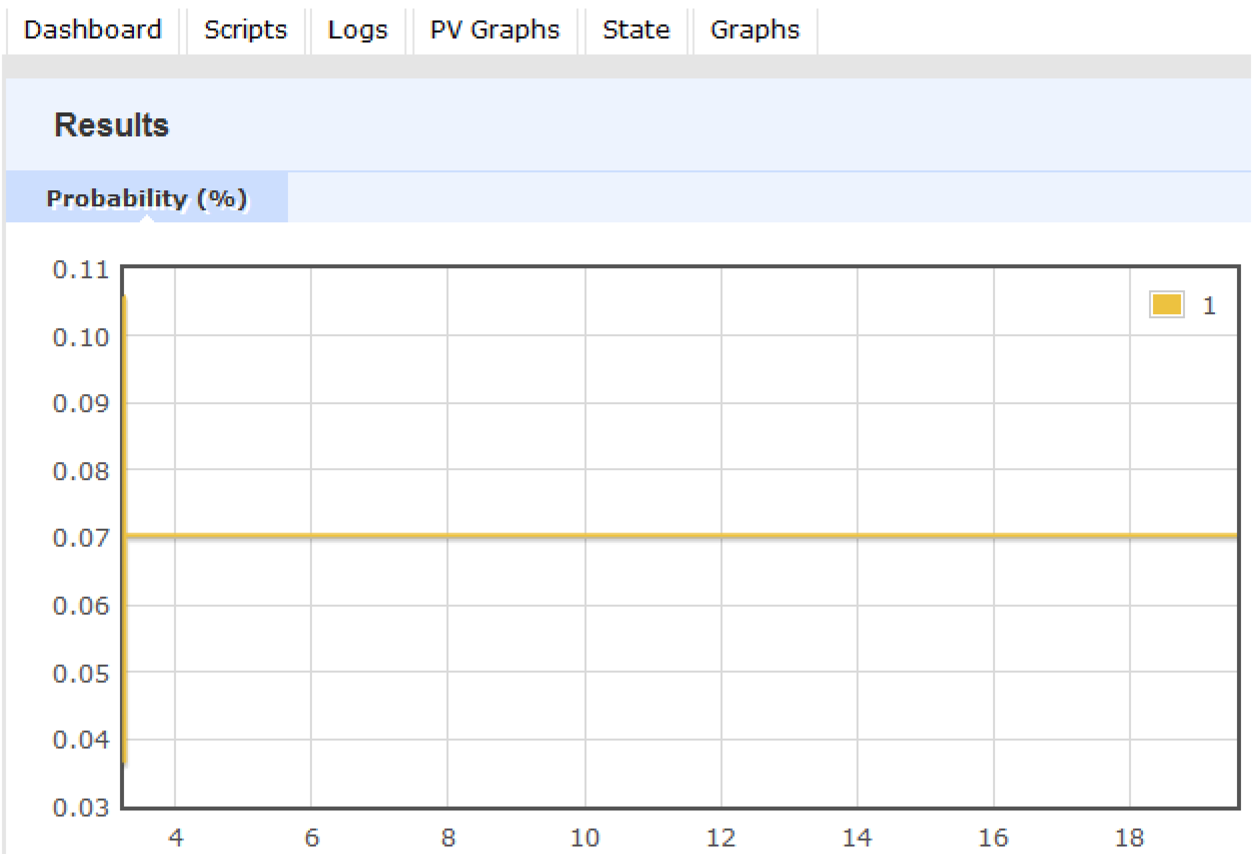
Experiment: I&M

Pro tip: Click on "Logs" to see the console output and "Scripts" to see the experiment script.



Experiment – with OMF

Does OMF give Dr. Watson useful functionality?

- ✓ A way to set up and orchestrate complicated experiments with many parts
- ✓ Instrumentation and measurement tools for systematically collecting and comparing results

Discussion

Questions?

(Someone will explain this experiment to the other groups –approximately 2 minutes)