Architecture and Framework for Supporting Open-Access Multi-user Wireless Experimentation

S.Ganu, I. Seskar, Max Ott, D. Raychaudhuri, S. Paul

http://www.orbit-lab.org

Project Rationale

- **Current wireless research**
  - Primarily simulation based or small in-house experimental setups
  - Difficult to repeat experiments
  - Excessive setup and data collection times may hinder rapid prototyping and experimentation
- **Key design goals**
  - Support multi-user wireless experimentation
  - Remotely accessible, lights-out operation
  - Facilitate choreographing of experiments
  - Automate measurement collection
  - Capture experiment description so as to repeat as often as necessary

ORBIT

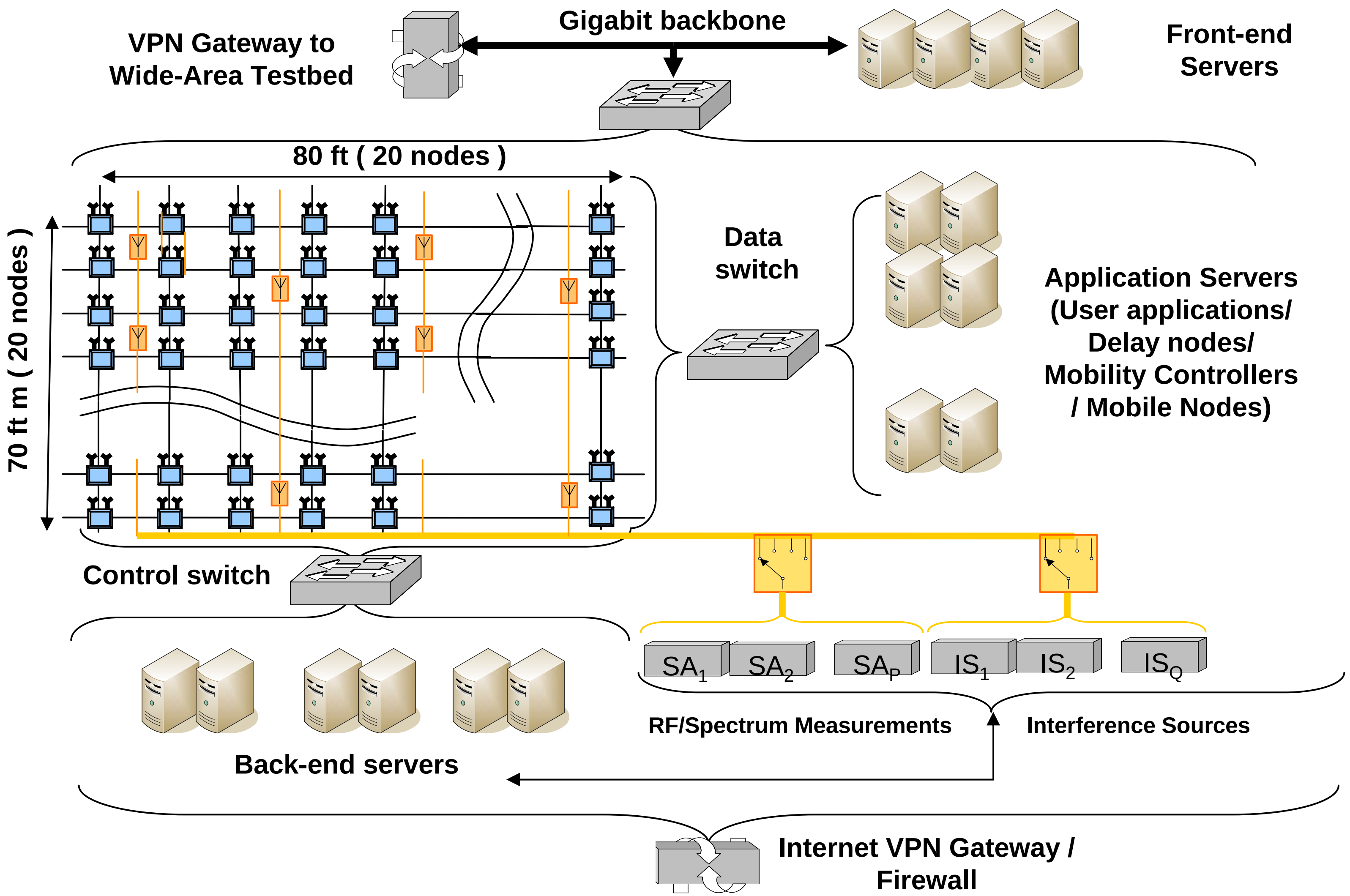
ORBIT Testbed: Background

- Seeded by NSF grant under the Networking Research Testbeds (NRT) program

- Collaborative effort: Rutgers, Columbia, and Princeton, along with industrial partners Lucent Bell Labs, IBM Research and Thomson

- Developed and operated by WINLAB, Rutgers University

ORBIT: Indoor Grid



Key Requirements

- ***scalability***, in terms of the total number of wireless nodes (~100's).
- ***reproducibility*** of experiments which can be repeated with similar environments to get similar results.
- ***open-access flexibility*** giving the experimenter a high-level of control over protocols and software used on the radio nodes
- ***extensive measurements capability*** at radio PHY, MAC and network levels, with the ability to correlate data across layers in both time and space
- ***remote access*** testbed capable of unmanned operation and the ability to robustly deal with software and hardware failures

ORBIT

Key Software Considerations

- Unlike wired testbeds, difficult to isolate experiments – mainly serial mode of operation
- Need to quickly offload users at the end of the slot
- Reduce start up and clean up times

Software components

Experiment Controller

- Choreograph experiments
- Capture experiment details to facilitate repetition

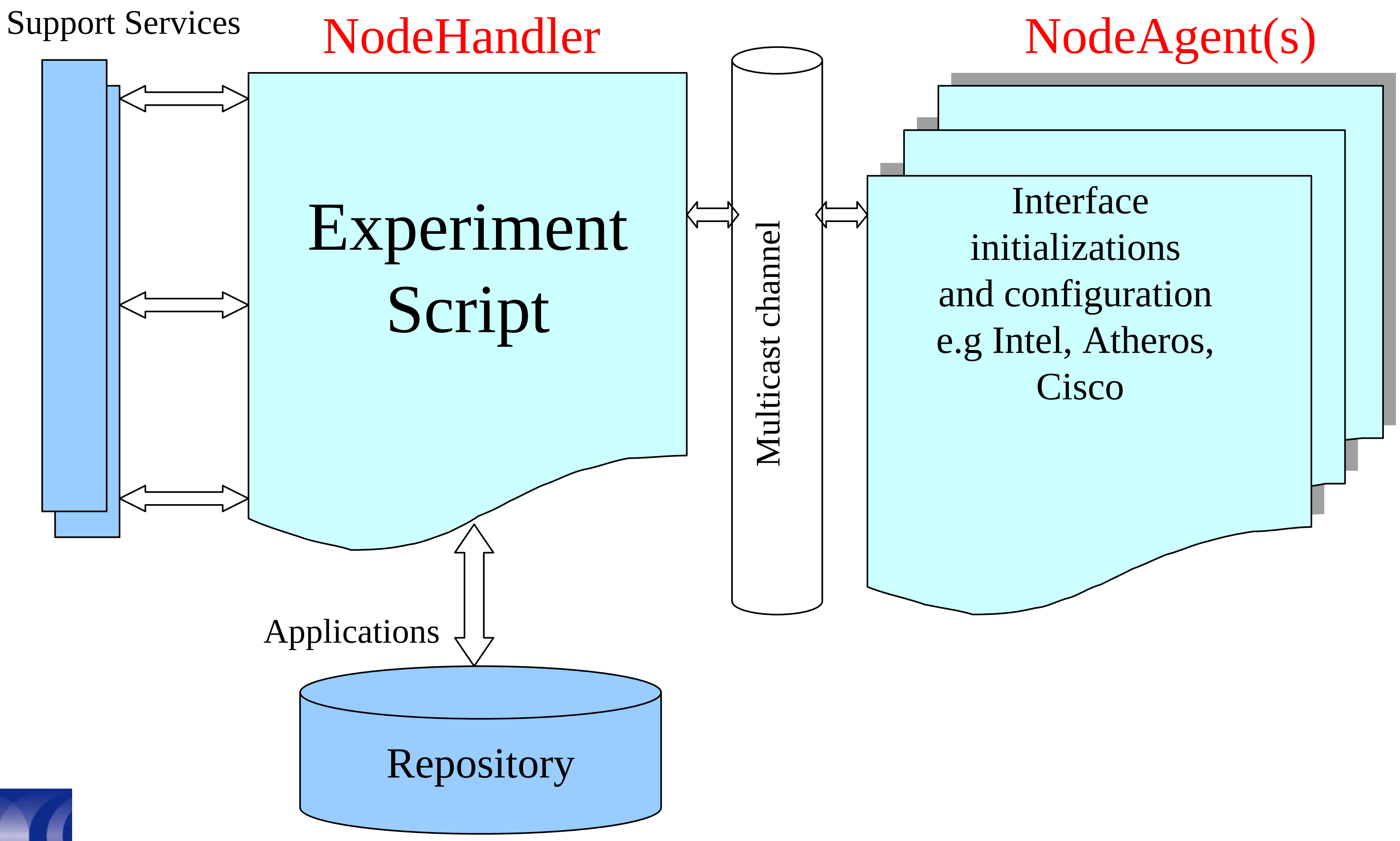
Measurement Framework

- Efficient measurement collection at run-time
- Avoids delays at end of experiment to collate measurements

Libmac

- Provides driver independent hooks to the application developers to collect measurements from at radio PHY, MAC layers

Experiment Controller (NodeHandler)



Experiment Controller

- A central **NodeHandler** process communicates with **NodeAgents** (present on each active node in the experiment)

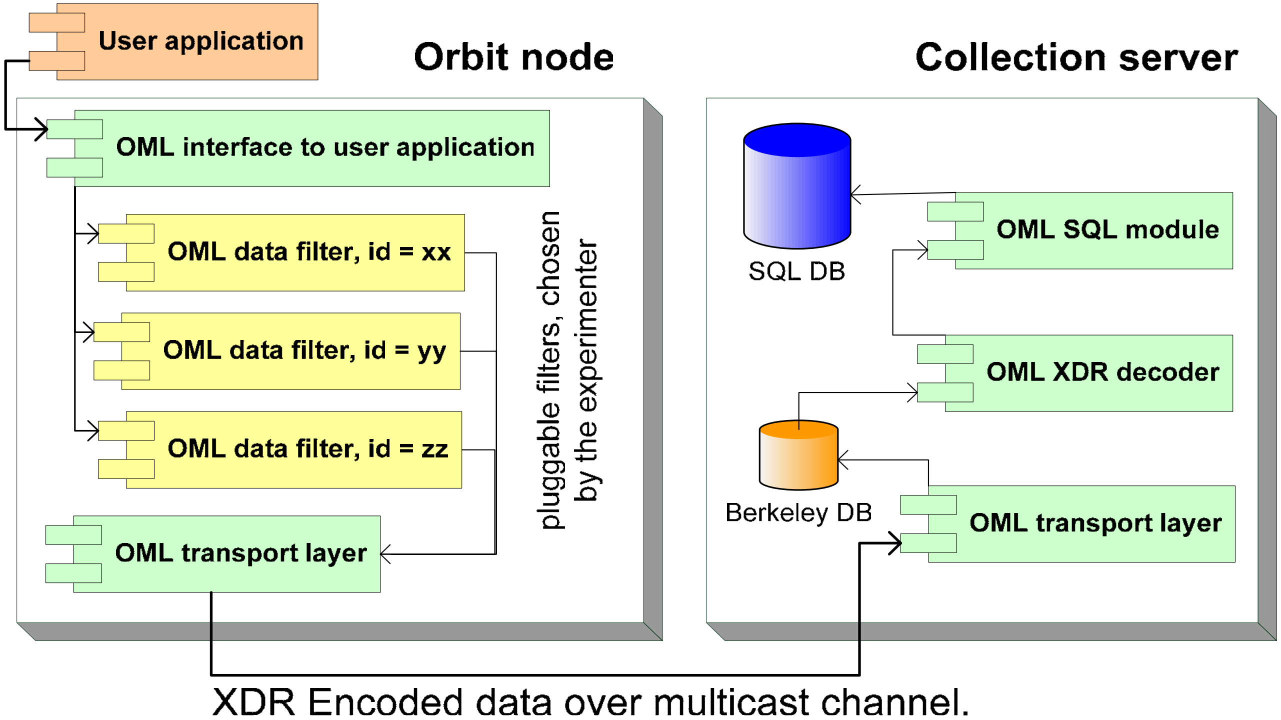
- Instructs nodes to configure interfaces, launch applications etc.

- Communication
  - Over multicast – scalable
  - Using experiment scripts

ORBIT

OML: Orbit Measurement Library

- Experiments are about collecting measurements
- How to collect them efficiently in a distributed environment like ORBIT?



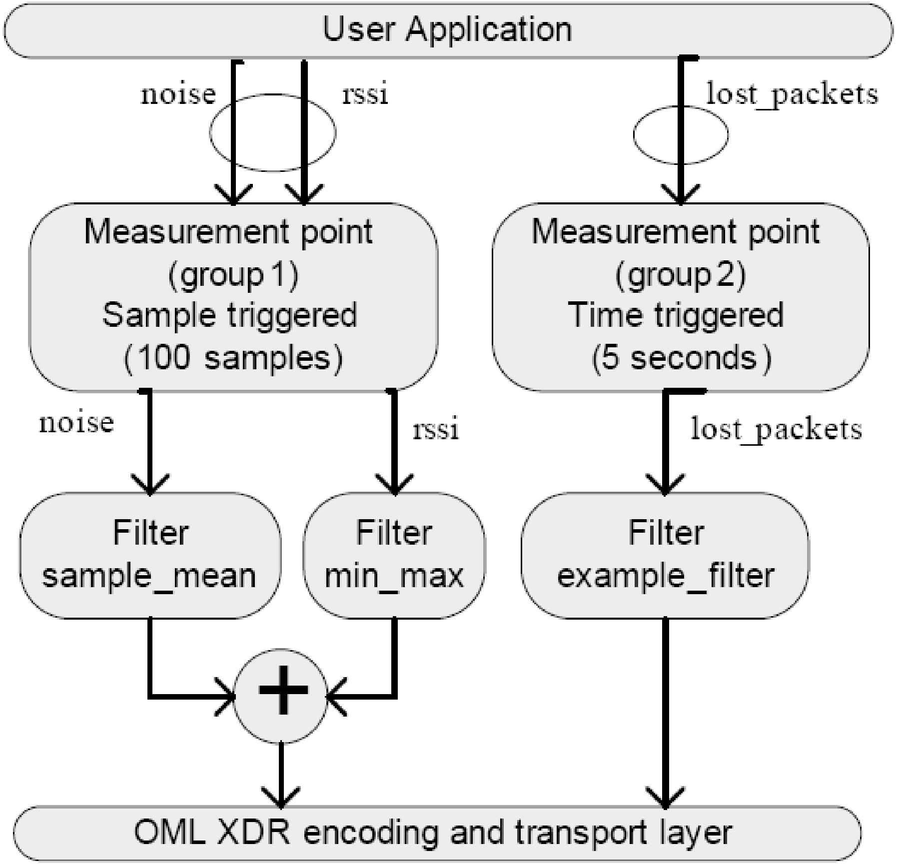
OML: Orbit Measurement Library

- Client
  - Simple API for application writers
  - Filters reduce the amount of reportable data
  - XDR encoded data over multicast channel
- Collection Server
  - Berkeley DB used for scalability
  - SQL database for persistent for data archiving
  - One multicast channel per experiment for logical segregation of data, and scalability

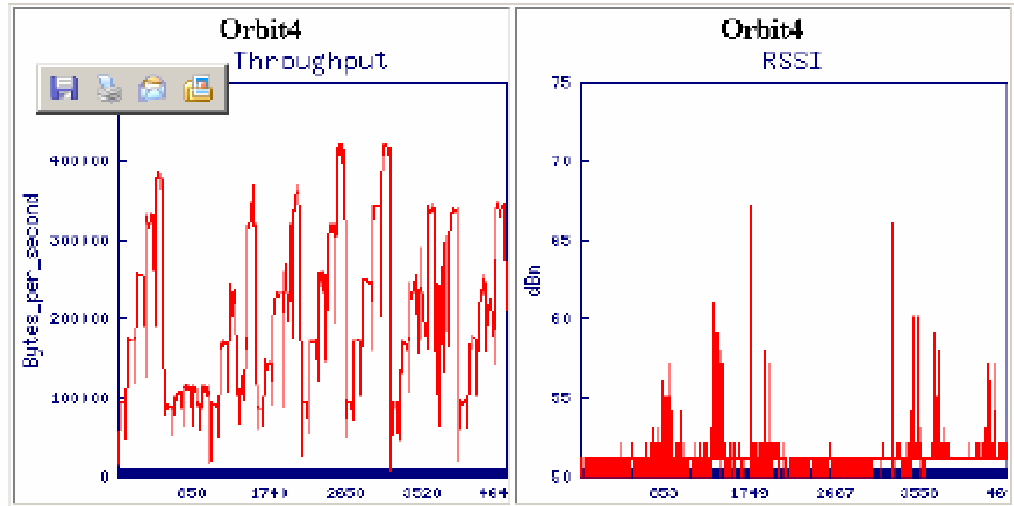
ORBIT

OML: Pluggable Filters

- Not all measurements may be needed
- Allow dynamic preprocessing before reporting to database
- Experimenter can choose the granularity (per packet or every N packets, per second or every N seconds)



Real time Statistics

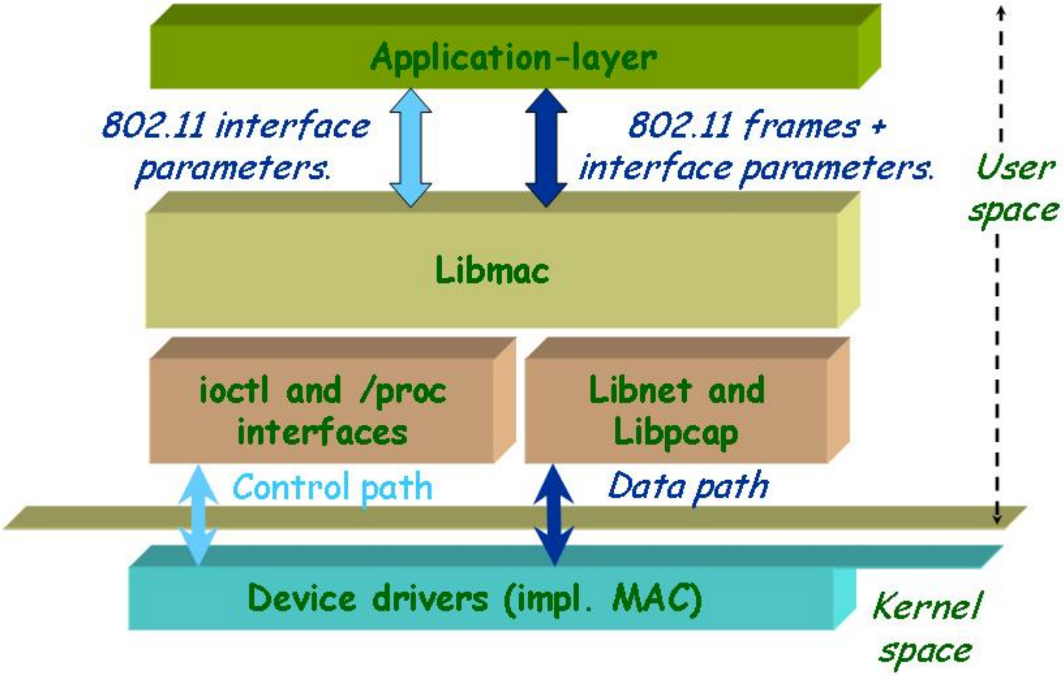



```
mysql> select * from metrics;
+----+--------------+-------+-------+
| id | metric       | units | type  |
+----+--------------+-------+-------+
|  1 | rssi         | db    | float |
|  2 | noise        | db    | float |
|  3 | throughput   | bps   | float |
|  4 | offered_load | bps   | float |
+----+--------------+-------+-------+
4 rows in set (0.00 sec)

mysql> select * from metrics_values where id=3 and node_id="orbit4";
+------+---------+-------------+---------+-------------+------------+
| id   | value   | packet_size | node_id | sequence_no | timestamp  |
+------+---------+-------------+---------+-------------+------------+
|    3 | 1086464 |         256 | orbit4  |           4 | 1084223553 |
|    3 | 1515520 |         256 | orbit4  |          10 | 1084223554 |
|    3 | 1503232 |         256 | orbit4  |          16 | 1084223555 |
```

MATLAB, Excel for Mysql allows easy post processing

ORBIT

Libmac

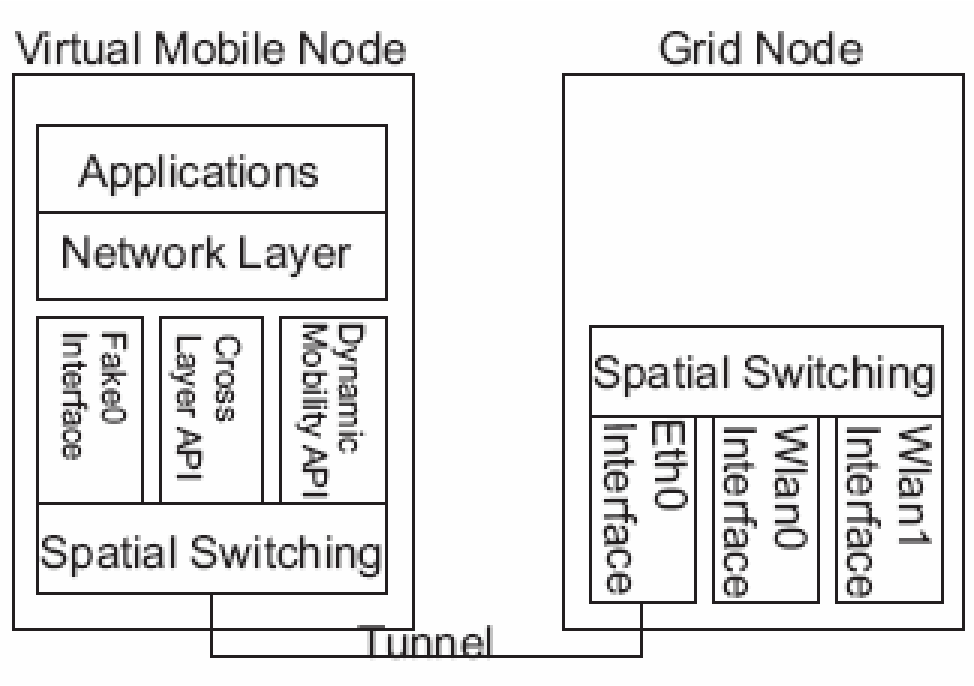


User-space C library

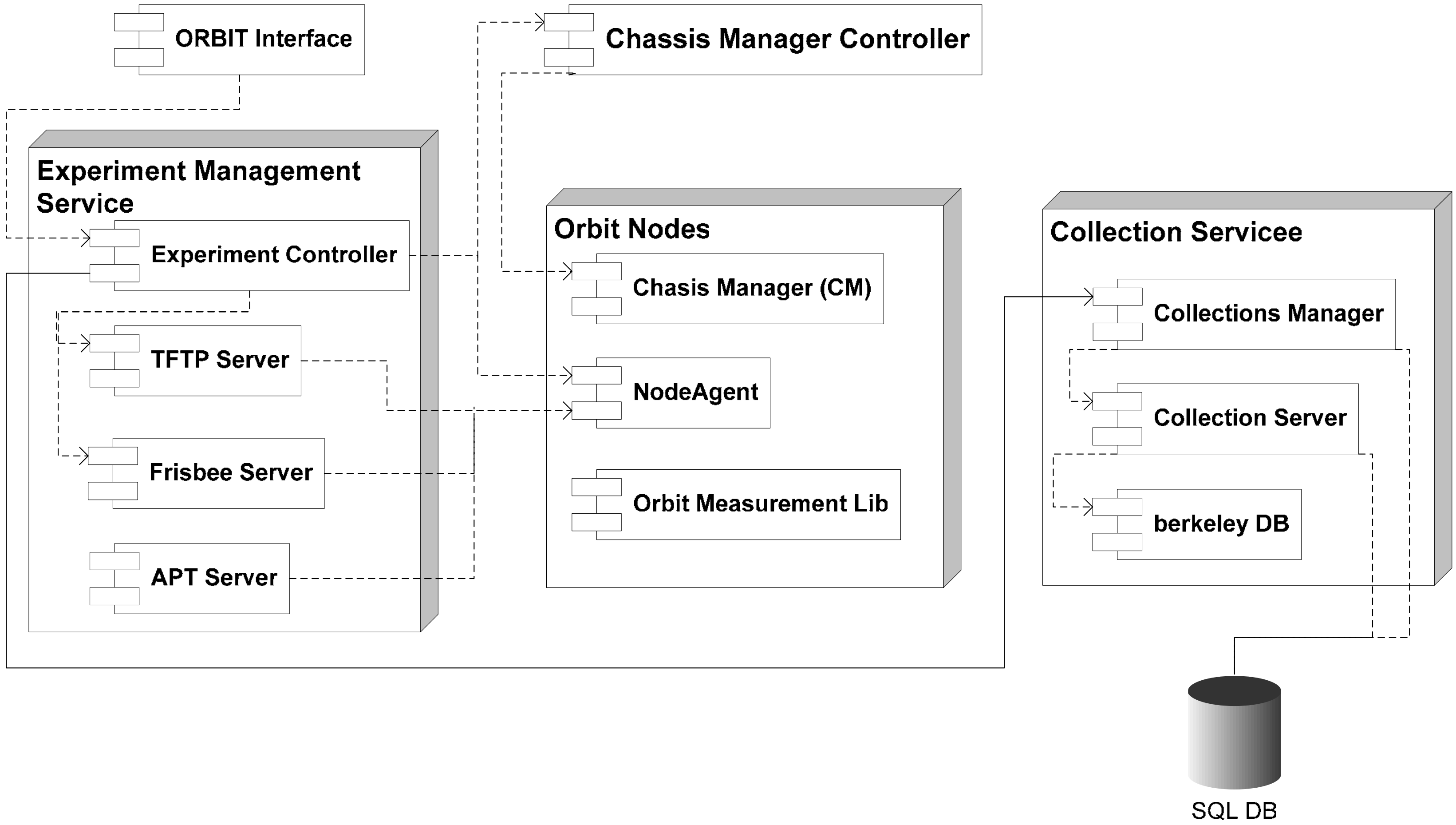
- To inject and capture MAC layer frames.
- To manipulate wireless interface parameters at both aggregate and per-frame levels.
- To communicate wireless interface parameters over the air, on a per-frame level
- Allows application developers to interface with driver measurements through simple function call

Mobility Emulation: Our Approach

- Uses software spatial switching
- Emulates trajectory by switching to different radio and antenna positions as time progresses

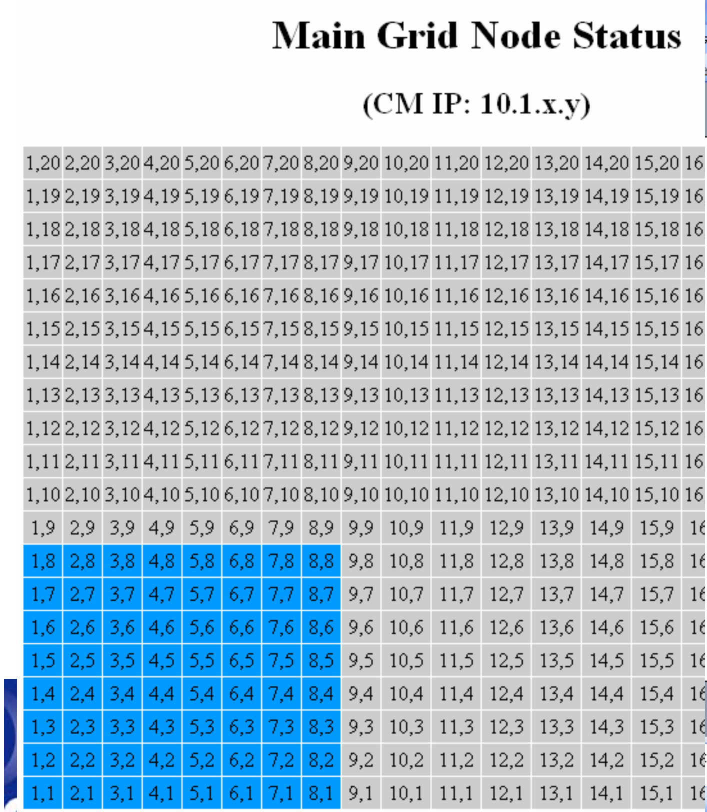


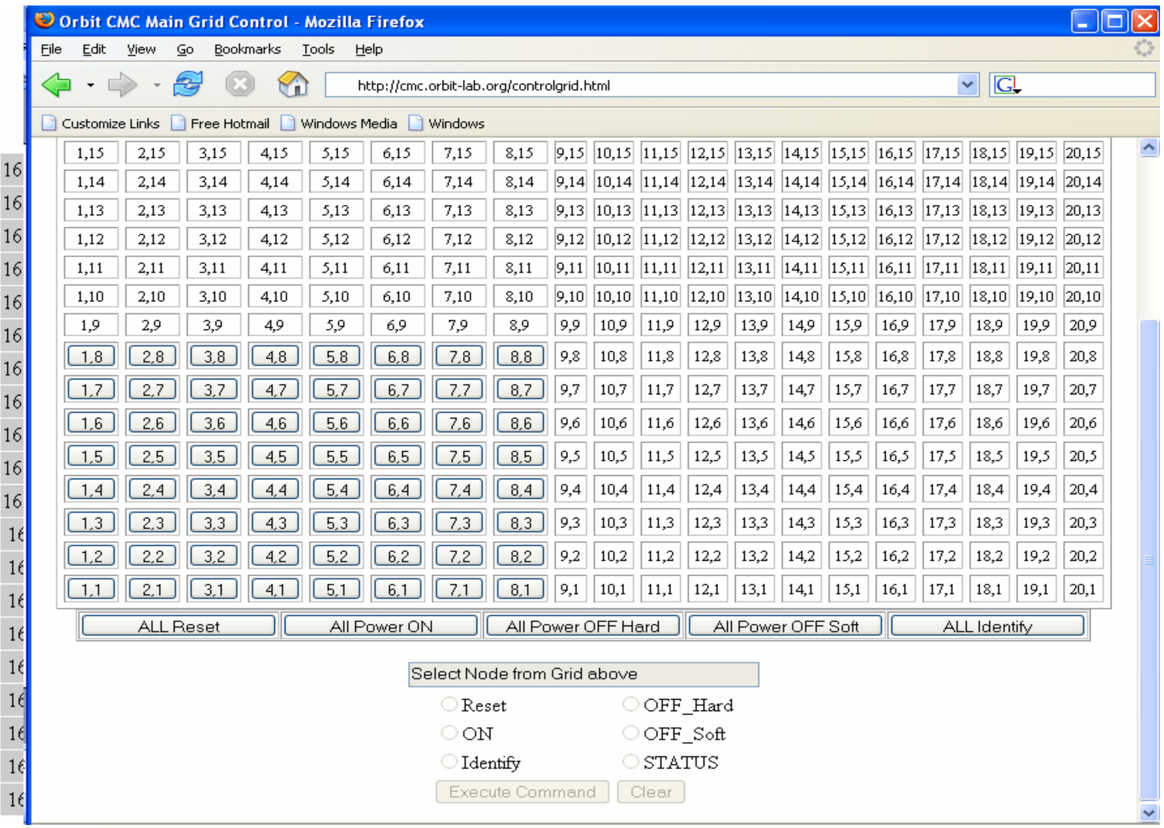
Essential Orbit Services



Chassis Manager Controller

- Web/Program interface for remote control of nodes
- Provides facilities for power on, reboot, hard/soft power off
- Console access to node
- Logging of node state (on/off), temperature, and voltage



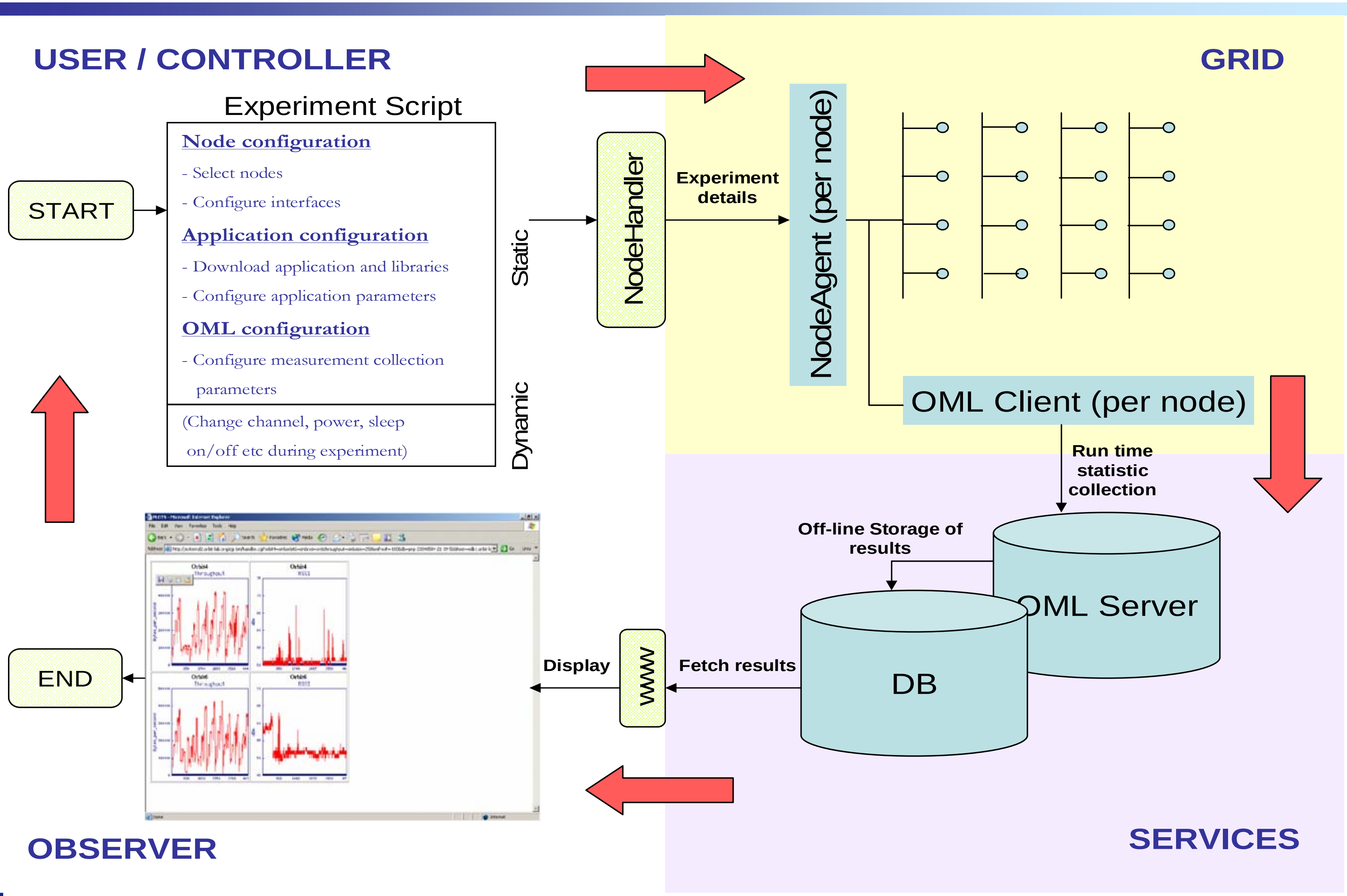


Frisbee*

- Fast and automated way to image any number of nodes
- Frisbee – Client/Server application that facilitates fast transfers of entire disk images.
    - Baseline Node Image (300 MB) currently takes ~5 minutes to install on all 64 grid nodes

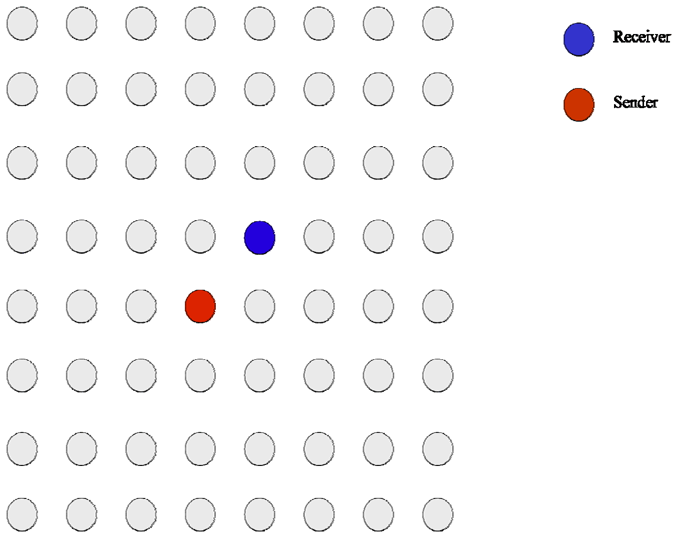
* From Emulab Testbed, University of Utah

Putting it all together



Sample Experiments using ORBIT

- Sender-Receiver Experiment
- Node 4-3 sends to Node 5-4
  - 11 Mbps
  - ‘b’
  - Ad-hoc (or Master-Managed)
  - 3 Mbps offered load
  - Measure RSSI, Throughput at receiver and offered load at sender



Define Sender

```
#
# Define nodes used in experiment
#
nodes([4,3], 'sender') {|node|
  node.image = nil  # Use default disk image

# experiment property space
  node.prototype("test:proto:sender",  {          # use prototype "sender"
    'destinationHost' => '192.168.5.4',           # Set it's property "destinationHost"
    'packetSize' => Experiment.property("packetSize"),
    'rate' => Experiment.property("rate")         # bind the remaining properties to defaults
  })                                              # Can be overridden later
  node.net.w0.mode = "master"
  node.net.w0.type = 'b'
  node.net.w0.essid = "helloworld"                # Set wireless parameters
  node.net.w0.ip = "%192.168.%x.%y"
  node.net.w0.rate = "11m"
}
```

w0, w1 are interpreted by nodeAgent according to the card being used
e.g Intel w0= eth2, w1= eth3
Atheros w0=ath0, w1= ath1

Define Receiver

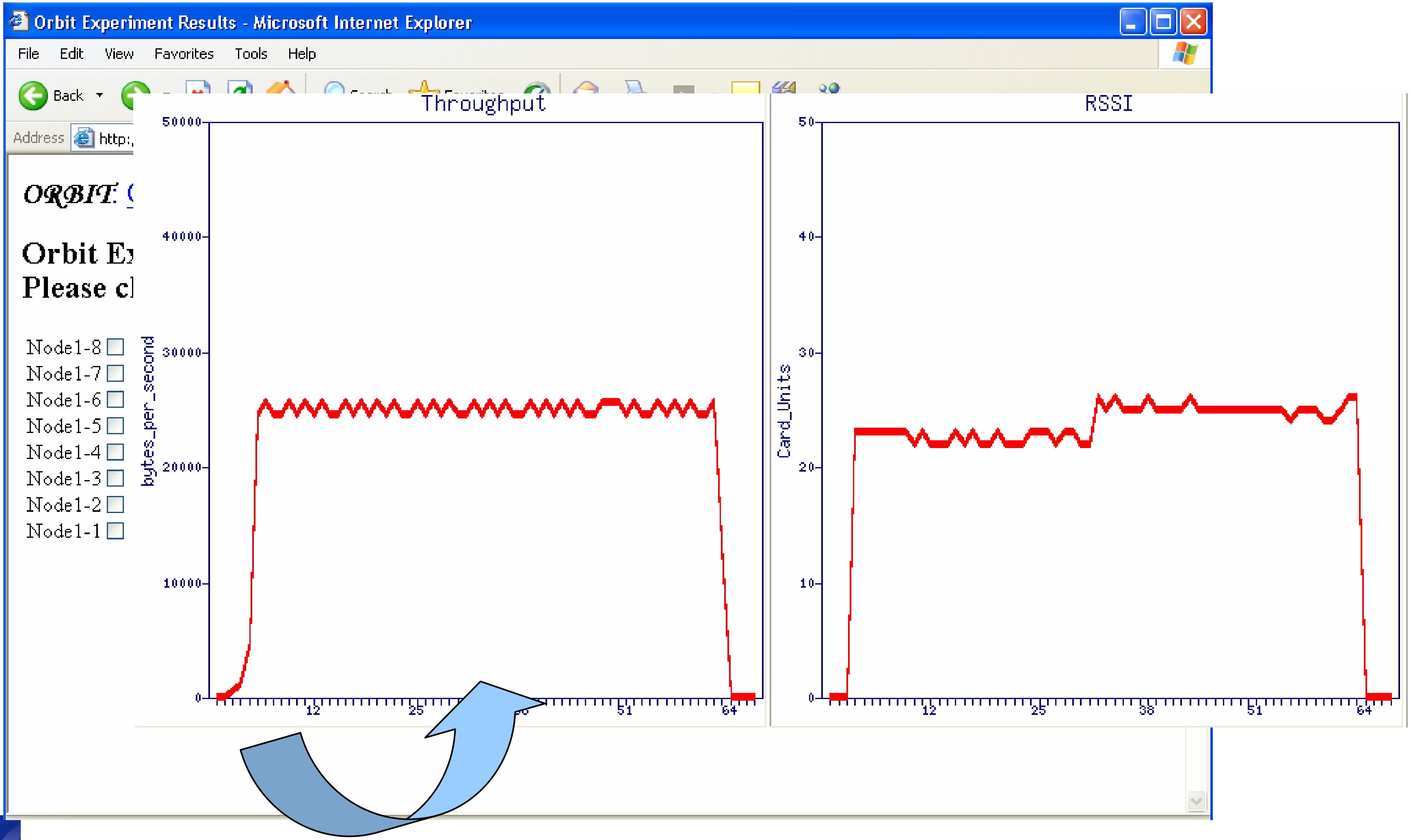
```
#
# Define nodes used in experiment
#
nodes([5,4], 'receiver') {|node|
  node.image = nil                    # assume the right image to be on disk
  node.prototype("test:proto:receiver" , {
  'hostname' => '192.168.5.4',
  'protocol' => 'udp_libmac'    # Use Libmac to report RSSI
  })
  node.net.w0.mode = "managed"
  node.net.w0.type = 'b'
  node.net.w0.essid = "helloworld"
  node.net.w0.ip = "%192.168.%x.%y"
}
```

Script..

```
# Now, start the application
whenAllInstalled() {
        allNodes.startApplications

          #Set packet size to 1024 bytes
        # and packet rate to 3000 Kbps
        NodeSet['sender'].send(:STDIN, 'proc/otg', 'size 1024')
        NodeSet['sender'].send(:STDIN, 'proc/otg', 'rate 3000')

        # Run the experiment for 60 seconds
        wait 60

        # Stop the applications
        allNodes.stopApplications
        Experiment.done
}
```

ORBIT

View Results (during exp.)



Cross layer effects! Throughput, RSSI vs time

www.orbit-lab.org