**DOME: Diverse Outdoor Mobile Environment**
**University of Massachusetts, Amherst**
**Brian Levine, Mark Corner, Brian Lynn**

**1. Provide an overview of the hardware systems in your contribution.**

Our test bed consists of 40 buses, each equipped with:

- A computer
  - 1GHz Intel Celeron processor
  - 1GB RAM
  - 60GB hard drive
  - Linux 2.6
- Mini PCI 802.11g card with an Atheros chipset
- 802.11 access point connect via 100Mb Ethernet port
- GPS device connected via USB
- 3G cellular modem connected via USB
- 900MHz Digi XTend radio connected via USB

**2. Discuss the GENI resources offered by your substrate contribution, and how they are shared, programmed, and/or configured. Include in this discussion to what extent you believe the shared resources can be isolated.**

The primary resource that we provide is access to the test bed. A researcher is getting access to all or part of the mobile network, including the mobile environment, as opposed to slivers or slices of a specific hardware resource. Initially, the granularity of a slice will likely be access to the entire network, i.e., all buses, over a period of time, such as a day or two. Over time, we hope to allow slices to define a subset of the buses, and then to eventually partition the resources on the buses.

With respect to the specific hardware defined in item 1 above, the following applies.

- The computer
  - Researchers will run experiments within an instance of a Xen Linux virtual machine, i.e., guest domain. The user will be able to execute as root.
  - We expect the host domain (dom0) to be relatively inactive, so most of the CPU cycles should be available to the guest domain.
  - We anticipate 512MB of the RAM being made available to the guest domain.
  - We will be responsible for uploading a user-supplied file representing a disk image, which will be mounted as a disk partition to the guest domain. We have not yet decided on the size limit of the partition.
- 802.11 PCI device
  - The PCI address of the 802.11 card will be exposed to the guest domain. By default, the Atheros madwifi driver will load when the guest domain

boots, though the user is free to replace driver modules. The guest domain will have full, unshared access to the device.

- 802.11 access point
  - The bus access points are recognizable by their SSIDs. The guest domain will have an IP address assigned to an Ethernet port on the same subnet as the access point.
  - We will provide a mechanism for a bus to determine the IP addresses of other buses.
- GPS device
  - The GPS device is owned by dom0. A standard gpsd daemon will run in dom0. The guest domain interfaces with gpsd via TCP to get GPS information.
- 3G cellular modem
  - This is a shared device managed by dom0. Since it is a mobile network, cellular connectivity is never assured. Dom0 will be responsible for maximizing the amount of time cellular connectivity is available.
  - The cellular link is the link used by the control plane.
  - The cellular link is not directly exposed to the guest domain, but instead traffic is routed through the guest domain's Ethernet link.
- 900MHz radio
  - This is not a shared device; it will be exclusively managed by the guest domain.
  - This is a Year 2 deliverable.

**3. Provide an overview of the physical connections within the substrate aggregate, as well as between the aggregate and the GENI backbones. Identify to the extent possible, non-GENI equipment, services and networks involved in these connections.**

*Bus to bus via 802.11*

There are two primary mechanisms for buses to directly communicate with each other. The first is for the Atheros PCI client to detect the access point on another bus and establish TCP/IP communication. This involves associating with the AP and joining the other bus's subnet. As mentioned above, we will provide a means to determine the IP address of each guest domain.

The second method is for the guest domain to place an Atheros PCI card in server/AP mode and for PCI cards on separate buses to directly interoperate. This allows the researcher to bypass the traditional TCP/IP stack and experiment with new protocols.

Note that the guest domain has complete control over, and responsibility for, the PCI WiFi device. This means that the guest domain can perform scans for SSIDs and BSSIDs, and it controls the policy for determining 802.11 associations.

*Bus to Internet via the 802.11 mesh*

Since the guest domain has complete control over the 802.11 association policy, experiments can also choose to connect to the Town of Amherst and UMass 802.11 meshes using TCP/IP. Once connected, traffic can be routed through the Internet (or Internet2) and be interconnected with other GENI networks.

*Bus to Internet via the cellular link*

As previously stated, the cellular link is a shared device to be used by the control plane. Dom0 uses the link for uploading log files, downloading GENI experiments, and providing status. The guest domain may also use the cellular link for similar functions while it is executing.

*Bus to bus via the 900MHz radios*

This will be available in Year 2. The 900MHz radios will provide a long-range, low-speed point-point link between buses.

**4. Identify the physical connections and software interfaces for integration into your cluster's assigned control framework**

As stated, the 3G cellular link is used by the control plane.

Since integration with the framework is a deliverable for the second half of the first year, the interfaces are TBD. Broadly, we will provide mechanisms to install experiments, reserve access to the test bed, and schedule experiments.

Note that the characteristics of a mobile test bed are quite different from other test beds. The computers often are not running, and when they do run they can be abruptly powered off. Even when the computer is running, there may be no available communication lines. Furthermore, cellular links are typically firewalled to prevent inbound connections, and the assigned IP addressees are very dynamic. Therefore, the staging of an experiment is a precondition for scheduling an experiment. The paradigm of assigning resources and then loading the experimental software is not the correct model. Furthermore, the standard operating procedure of ssh'ing into test systems does not apply (though intermittent ssh tunneling is conceivable). Experiments must be able to run unattended, and the ability to asynchronously offload experimental results is paramount.

**5. Identify any measurement capabilities, either embedded in your substrate components or as dedicated external test equipment.**

When the computers come up they do a self-check of their health and log the results to a UMass server. Once running, the computers on the buses continuously attempt to report their GPS coordinates so that we can determine a computer is running and track the bus's location.

Traditionally we have recorded a wealth of information, such as SSIDs discovered, whether a bus could communicate with the mesh or other buses, throughput information, etc. The control of the devices has now been ceded to the GENI experiments, and the GENI researchers are free to measure whatever they find useful. The information for 802.11 includes available SSIDs and BSSIDs, signal strength, noise level, and type of security that may be enabled. Since both the raw PCI device and root access is available, all traffic, including beacons, can be recorded using standard tools such as tcpdump.

With respect to the GPS device, both interpreted data and access to the raw sentences are available.

**6. Describe any tools or services which may be available to users and unique to your substrate contribution.**

We have two definitions of users: a GENI researcher who runs his or her own software on our computers, and bus riders that may indirectly use our computers for services such as Internet access.

With respect to the former, we offer the ability to pre-stage software on the computers. In other words, we will deal with the issues involved in distributing software to multiple, intermittently connected devices. However, we believe that the interface for this should eventually be provided by the framework, though the actual mechanism would be specific to the test bed. Another service that we provide is asynchronous logging. Due to intermittent connectivity, a GENI experiment cannot be assured that it can offload its collected data during its allocated time. Therefore, we will provide a mechanism to continue offloading data even though the experiment is no longer running.

As for the second type of user, we do provide Internet access to the bus riders. This is done by bus riders connecting to the access points, and dom0 routing traffic through the shared cellular link. We are also working with the UMass Transit Authority to provide bus tracking using the GPS coordinates that we report.

An opportunity for the GENI community is to run experiments that offer services to bus riders.