Research Desciption

This research aims to leverage a state-of-the-art IEEE 802.16e WiMAX base station product from NEC to prototype an open, programmable and virtualizable cellular base station node for GENI. This open GENI base station node ("GBSN") device is intended to support flexible experimentation in wide-area mobile network service scenarios similar to today's cellular systems. The GBSN will support programmability at both radio link and network routing layers via an "open API", and will work with off-the shelf WiMAX handsets and data cards. In addition, the project will demonstrate the GBSN integrated with backhaul access network options including Ethernet and NEC's emerging WDM PON technology. The overall goal is to leverage emerging carrier-class cellular wireless and access network platforms to provide a reliable, high-capacity and cost-effective solution for wide-area mobility in GENI.

Specific high-level goals/deliverables of the project are:

1. Develop an open/virtualizable WiMAX base station with external control and data API's.
2. Implement GENI-specific software on an external Linux-based PC controller for the WiMAX base station, demonstrating basic GENI compliance: virtualization, slice setup & resource management, L2/L3 programmability, and opt-in for off-the shelf terminals.
3. Integrate the GBSN with backhaul options including Ethernet and WDM PON to validate and demonstrate the total access networking solution.

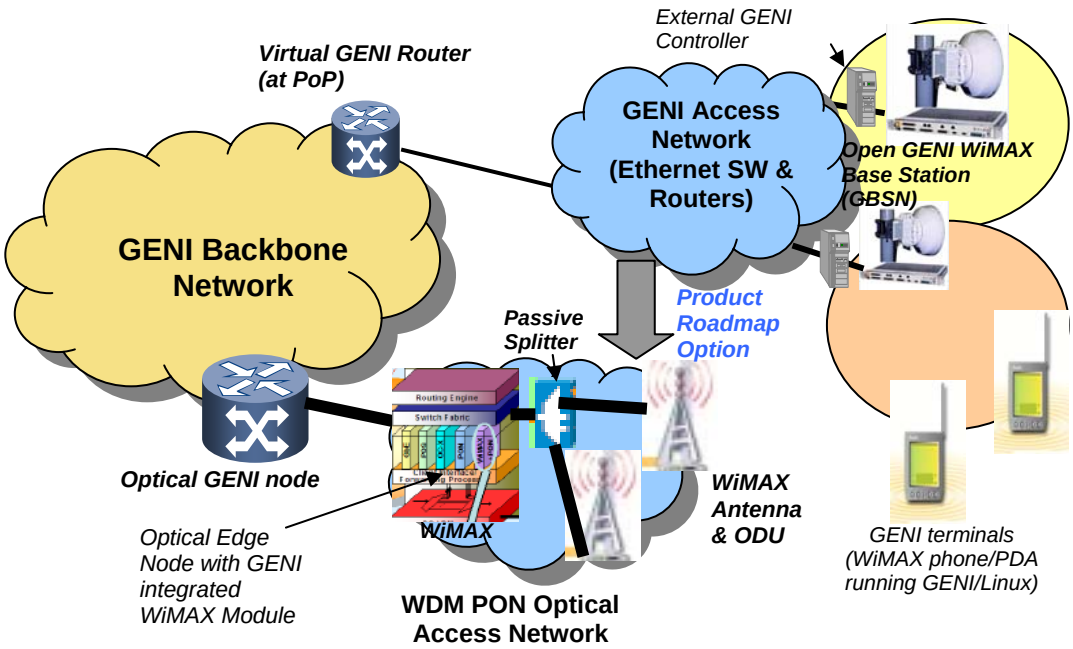

Fig. 1. Conceptual Overview of GENI Base Station Node and the Optical Backhaul Option

4. Demonstrate the GBSN capabilities in a phased manner, starting with controlled lab tests of each GENI feature and then migrating to a small-scale outdoor trial with off-the-shelf WiMAX terminal equipment.
5. Develop a deployment plan for multi-cell WiMAX services in GENI, including guidelines for site selection, frequency allocation, network backhaul and equipment/operating costs.

Methods and metrics used to evaluate the results of this project are as follows:

- Baseline equipment test results confirming capacity/coverage/service bit-rate properties of the basic NEC WiMAX base station platform.
- Validation and demonstration of external base station API using test software to exercise available control parameters and data paths.
- Validation and demonstration of GENI-specific software required to implement the GBSN, using a set of functional and performance tests for each of the key design features.
- A series of phased experimental evaluations for system level validation of the GBSN, including simple single-user test bench scenarios, to multi-user/multi-slice lab tests, and outdoor tests with multiple GENI-like experiments and mobile end users.
- Cost-performance analysis results for GENI deployments in both urban and suburban settings.

This project is structured as a collaborative effort between the proposing organization (WINLAB, Rutgers University) and its industry partner (NEC Labs America), with the objective of combining experimental networking expertise at WINLAB with core network product development and integration expertise at NEC. WINLAB will take primary responsibility for goals/deliverables (2,4,5) above including GENI-specific software (slice creation, virtualization, etc.), GBSN prototype integration, phased system-level demonstrations, and the GENI deployment plan report. NEC Labs personnel will collaborate closely on the technical aspects of goals (2,4) including optimization of virtualization software and system integration. NEC will take lead responsibility for goals/deliverables (1,3) including delivery of the WiMAX base station equipment, software modifications needed to implement the open API, and for subsequent demonstration of the WDM PON access network technology option. Note that this project offers significant leverage to the GPO in view of NEC's prior investments on WiMAX and WDM PON technology along with in-kind contribution of research staff labor towards the goals of this project. The project will also leverage a substantial base of existing testbed capabilities at WINLAB, including experience with GENI-like programmability and virtualization of wireless networks, ORBIT software for experiment execution and measurement collection, and the outdoor field trial infrastructure at Rutgers (base station site on campus, outdoor access points, vehicular nodes, etc.).

The open/programmable base station node to be developed in this project is a key enabling technology for GENI and the future Internet. In view of the rapid growth in cellular/mobile services worldwide, architectures for cellular-Internet convergence are of particular importance to the future Internet research agenda (see, for example, the NSF WMPG planning group report [1]). While the need for experimental cellular platforms is not in dispute, academic research has so far relied almost entirely on short-range WiFi devices because of their low cost and open-source Linux driver support. The availability of an open wide-area wireless network in GENI will encourage new categories of experiments directly addressing cellular-Internet convergence, while also making it easer to grow coverage and attract real end users. The importance of such research in GENI is reinforced by the much anticipated industry shift to "open" wireless data networks in the US [2,3], being promoted by Google in context of the 700 Mhz auction, and more recently endorsed by incumbent service providers such as Verizon Wireless.

Based on the above considerations, our goal for this project is to demonstrate the feasibility of an open "GENI-ized" 802.16e WiMAX base station that supports programmability and virtualization, and makes it possible to develop real-world mobile services with commodity end-user devices. The emerging WiMAX standard (802.16e) is a good technology base for such an open base station node because it represents the state-of-the-art in radio technology (high-speed OFDMA with QoS support, MIMO and mesh modes, etc.) with potential cost advantages relative to the cellular → 3G → LTE roadmap, particularly for small deployments. Also, initial WiMAX products are IP-based and are thus bundled with fewer vertical stack protocols than corresponding UMTS/CDMA options. NEC's Release 1 802.16e base station product is viewed as an excellent starting point for the addition of GENI features. Although the NEC base station was designed for use with an IP network gateway, we have been able to determine a

way to unbundle the basic layer-2 functionality of the device and make it accessible through an external control API. This makes it possible to develop Linux-based GENI code on an external PC controller, substantially meeting all the layer 2,3 programmability and virtualization requirements in a manner that is very similar to the software approach used for wired GENI routers.