WiMAX in the GENI Testbed

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I. INTRODUCTION

The Global Environment for Network Innovations (GENI) is a US National Science Foundation sponsored testbed building initiative intended to support a range networking research capabilities. Even though primary focus of the GENI deployment was on sliceability and programmability of the core network, significant effort was also focused on providing various edge related services including deployment of WiMAX (Worldwide Interoperability for Microwave Access) systems on a number of GENI-enabled campuses (Figure 1). WiMAX provides an avenue for the inclusion of researcher-owned and operated open cellular systems in GENI which have been proven suitable for a range of experiments including wireless-specific research, network research with a focus on mobility, and experiments in which wireless just happens to be an available connectivity option. In addition, availability of an open wide-area wireless network in GENI encourages new categories of experiments directly addressing cellular-Internet convergence, while also making it easy to grow coverage and attract real end users.

II. WIMAX IN GENI

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 Academic research on this topic has so far relied almost entirely on short-range WiFi devices because of their low cost and open-source Linux driver support while cellular system research was mostly focused on simulations (despite explosion of use of wide-area data services in the last couple of years).

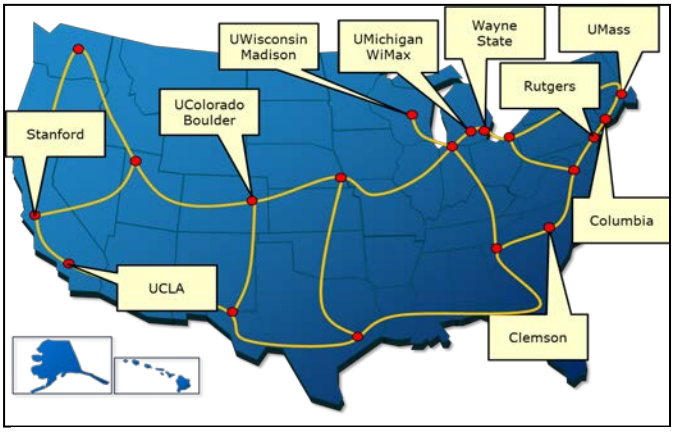

Figure 1: GENI WiMAX Deployment Sites

The importance of such research in GENI is reinforced by the recent industry shift to "open" wireless data services, starting with handset software initiatives such as Android. The WiMAX standard (802.16e) is a good technology choice for an open basestation (BTS) node because it represents the state-of-the-art in radio technology (high peak bit rates, QoS support, MIMO features, etc.) with potential cost advantages relative to standard cellular equipment, particularly for small deployments*. Also, WiMAX products are IP-based and are thus bundled with fewer vertical stack protocols than corresponding UMTS, CDMA or LTE options. Although standard WiMAX base station was designed for use with an IP network gateway, GENI Sprial 1 work focused on unbundling the basic layer-2 functionality of the device and making it accessible through an external control API.

A broad overview of GENI WiMAX kit architecture is as shown in Figure 2. The Profile A BTS hardware from the original WiMAX system is used as is and the original ASN-GW was extended with a control interface that enables interfacing with GENI Aggregate Manager (AM). To allow an independent control setup for individual slices, aggregate manager provisions multiple virtual machines that act as "virtual basestations" (vBTS). These vBTSs act as points of presence in the GENI framework for the experimenters. All packet switching from the vBTS to the wireless clients and

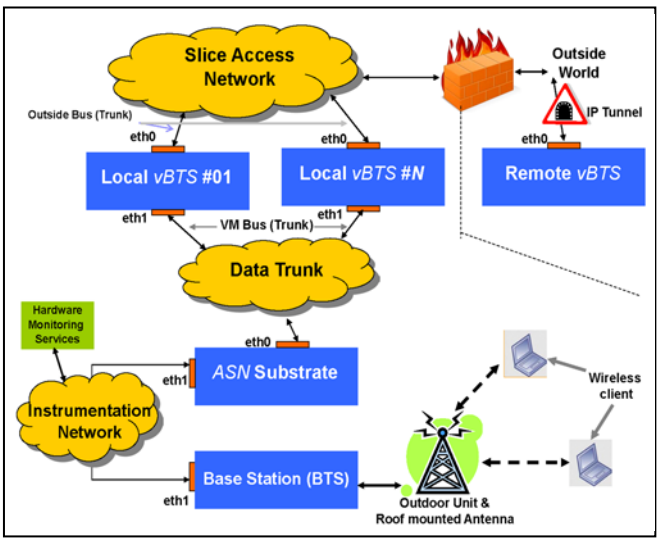

Figure 2: WiMAX Kit Architecture

* Some universities (particularly land-grant universities) actually own pieces of WiMAX spectrum.

vice versa is performed purely using layer 2. The architecture also supports a remote vBTS mode of operation where the slice point of presence runs remotely over the GENI access network. The main function of the vBTS substrate is to emulate an isolated private basestations for every slice.

The ASN substrate shown in Figure 3 is responsible for acting as a transparent gateway between the vBTSs and the actual air interface. The two main management components are the NEC ASN-GW Controller and a RF Aggregate Manager. The ASN-GW Controller was provided by NEC as part of the Wimax basestation and was extended to provide additional functionalities that are required as part of the design of a virtualized basestation.

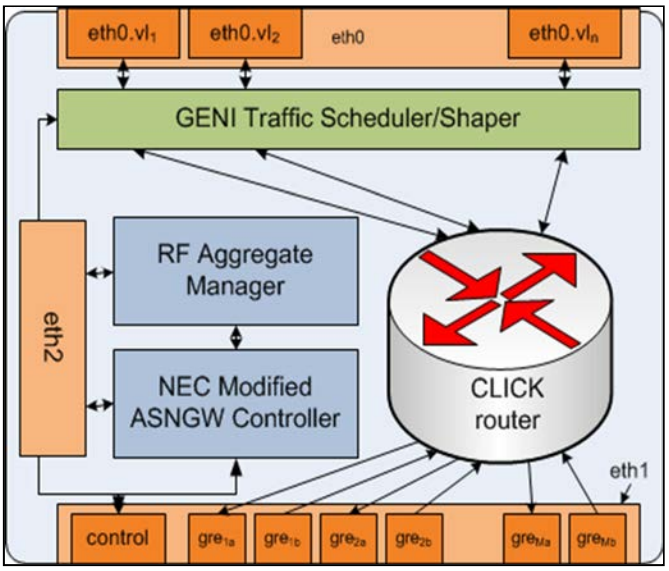

Figure 3: Modified ASN Substrate

The RF Aggregate Manager is responsible for establishment of the datapath between the slices and their respective clients. The datapath is setup based on control information from the NEC ASN-GW Controller. It is also responsible for configuring and executing a Scheduler/Shaper depending upon the QoS requirements of each service flow and the minimum reservation made by the respective slices. Two actual datapath component that is used to implement the bridging mechanism between slices and corresponding GRE tunnels can be chosen by the experimenter and can currently be either Click modular router or OpenVSwitch based. While Click based datapath implementation is intended for stand-alone operation of the WiMAX Kit, OpenVSwitch datapath implementation can be integrated into larger GENI SDN deployment.

The slice isolation engine is essentially a shaping mechanism that limits slice traffic irrespective of the clients and service classes used such that the fraction of radio resource used by each slice are based on per slice allocation policies. Since the slice is a logical entity maintained outside and independent of the BTS transceiver, the slice isolation engine helps maintain airtime fairness across individual slices.

Functionality of all GENI WiMAX AMs is provided through a customized version of the OMF service providing an easy web-based thus providing an interactive browser interface, which can also be accessed remotely. The framework also has an integrated data collection service based on OML that logs experiment metrics such as observed throughputs, client RSSI, retries and a host of other features.

This architecture provides layer 2,3 programmability and virtualization requirements in a manner similar to the software approach used for wired GENI routers; virtualization is achieved by mapping a slice's WiMAX channel(s) onto VLANs/flows and then to virtual machines, which provide the desired service to the mobile device. The resulting effect is essentially a sliced cellular system extending into a (wide-area) GENI slice. In Spiral 2 majority of effort was on increasing the number of campus deployments, while in Spiral 3, focus is on extending the framework to include more compact Profile C basestations and multi-sector/multi-basestation deployments.

Current WiMAX GENI sites were successfully used in a wide range of experiments starting with a simple single-site tutorials all the way up to a large-footprint deployment of MobilityFirst Future Internet Architecture (FIA) utilizing both core and edge programmability.

III. ACKNOWLEDGEMENTS

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