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NSF Project Reporting Format

This document has been developed to provide Principal Investigators (PIs), co-PIs, and research organizations with:

- A listing of the questions that will be asked in the new NSF project reporting format;
- Assistance in planning for the submission of the report; and
- A tool to help PIs collaborate with other contributors in answering these questions, if needed.

The project reporting service on Research.gov and the associated help documentation provides more detailed instructions and contextual assistance.

***Note**: NSF project reports are not cumulative and should always be prepared for the specific project reporting period only.*

PIs should NOT complete and upload this document to Research.gov in order to meet your reporting requirement. You are required to enter text in the text boxes available online.

Accomplishments

You have the option of selecting "nothing to report" in this section.

What are the major goals of the project?

SciWiNet is an exploratory NSF project. The project has built and trialed a large scale wireless network that supports the academic research community. We call the network the Science Wireless Network or SciWiNet. To accomplish a portion of the project goals, SciWiNet partnered with Sprint Wireless using a business model referred to as Mobile Virtual Network Operator (MVNO). An MVNO resells services from an actual wireless network operator (WNO). Typically, the MVNO caters to a group of users that have a specific need or set of requirements. SciWiNet represents the MVNO entity. Sprint is the WNO that owns the underlying spectrum and network infrastructure. We partnered with a third company (Arterra) to provide us with software systems that interface with Sprint's backend and that provide user management and billing. This partnership lowered the startup costs for SciWiNet.

The objectives of SciWiNet include:

1. Evaluate the efficacy of an MVNO model to provide a wireless testbed for the academic research community;
2. Integrate and build upon innovations and resources made available from the GENI community;
3. Develop appropriate support for the community of SciWiNet users that are from outside the networking research community;
4. Identify viable paths by which SciWiNet can evolve to become a self-sustaining, national resource.

The project was divided into 3 phases:

- **Phase 1** involves deploying the network and getting the GENI community involved to provide feedback.
- **Phase 2** extends the SciWiNet community to involve researchers outside the GENI community.
- **Phase 3** represents activities to be performed in year 3. We requested a no cost extension request that was approved. This allows the project to continue for one more year. (Until June 30 2016). We plan on finalizing the assessment of an MVNO during this phase. We also will package, document, and make available to researchers the tools and software developed. This includes an

Android App, several wireless performance assessment tools, cloud-based mobile data acquisition and visualization tools.

What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?

Major Activities:

For the time period 7/1/2014-6/30/2015, we report the following activities:

- Phase1
  - We completed a survey designed to provide feedback from the community to address our core issues/questions. We provide a summary of findings below. We also include a supplement PDF that contains the complete survey results.
  - Integration with GENI: we continued to work with GENI/Wireless to further integrate SciWiNet with GENI infrastructure. We demo'ed SciWiNet interacting with GENI instrastructure.
  - Explore advance network capabilities with collaborations with Arterra and Sprint. Working with Arterra and Sprint, we explored further options related to exposing advanced network capabilities to SciWiNet users.
- Phase 2
  - Extend SciWiNet to communities outside of GENI: We participated on several projects that were outside the immediate GENI community. These were to help identify potential capabilities that would be of assistance to other academic communities.

Specific Objectives:

Significant Results:

Survey results: We have attached a detailed summary of the survey results. Highlights include:

- 92% of participants use wireless technology for either education or research, and 50% for both.

- Android smartphones are the most widely used device (60%) followed by the iPhone (20%) and custom embedded devices (20%).
- The most popular data plans are unlimited plans

Integration with GENI: As a part of the GENI GEC23 (Washington DC, 2/2015), we demonstrated a connected vehicle application that used SciWiNet and GENI resources. The core idea was to demonstrate how a cloud (which was implemented by integrating SciWiNet and GENI capabilities) can support M2M devices (such as connected vehicles). We demonstrated an approach for building a cyberinfrastructure necessary to support the compute and delay requirements of M2M apps 'in the wild'. We have uploaded a PDF of the poster that was used for the demo.

Advanced network options: We have worked closely with Sprint and Arterra to identify additional network capabilities that SciWiNet could provide to the community. It is possible to deploy a SciWiNet management box within the carrier's network allowing us to manage MVNO traffic however we like. However, control of the traffic once it enters the wireless domain is out of our control with the following exception. Sprint does allow an MVNO to setup a number of service plan behaviors that their wireless network would support. For example, we could create a set of service plans that SciWiNet users could select for their set of devices. The MVNO arrangement that we had in place with Arterra/Sprint for the first two years of the SciWiNet project did not support these advanced network options.

Extend SciWiNet to communities outside of GENI: The majority of interest came from large scale sensing deployment projects (City of Provo, Utah USIgnite Climatology Study, Chicago's Array Of Things, Clemson's Intelligent River). Each project has unique needs: we helped Provo develop and use a modified version of our SciWiNet Android App and cloud data collection; the AoT and IR projects were both well established in terms of wireless technology, they were interested in the bucket model pricing, and the granular device management. All three projects shared one significant concern: they needed a single carrier that support 100% of their coverage area. All of these projects have struggled with this. Unfortunately, Sprint's coverage lags that of AT&T and Verizon in unpopulated areas.

Key outcomes or other achievements:

We will finalize our findings in next year's final report, however, an interim set of findings includes:

- Assess the wireless requirements of the academic community :

- The wireless requirements of the community is very diverse. The requirements of wireless network researcher needs the ability to observe or control the public cellular network in order to be useful. For other domain research, the wireless requirements are growing. It is clear that some communities that do not engage CS or ECE support will struggle carrying out innovative research in the wild.

- Assess the efficacy of an MVNO to support the academic community :
  - It is clear that the MVNO model used for year 1 and 2 of SciWiNet was not sufficient to support the needs to wireless researchers. Additional integration with the cellular network is required. To enhance and promote large scale wireless research, SciWiNet needs to be able to do the following:
    - Manage the aggregate MVNO traffic in meaningful ways,allowing experimenters to monitor or manage traffic in an experimental manner.
    - Allow a researcher to obtain 3GPP and IP information from the wireless network.
    - Allow a researcher to carve out a 'slice' of the wireless network allowing he/she to obtain a wireless service that offers a testbed-like capabilities.
    - Provide a researcher with one or more smartphone devices that are instrumented and/or fully customizable.
  - For the broader community, an MVNO model could be useful if it provides the following:
    - Low cost devices and services for normal student use
    - Appropriate service plans to meet the needs of short term projects
    - Support in the form of tools and cloud services that supports/promotes academic research 'in the wild'.

- Viable paths by which SciWiNet can evolve to become a self-sustaining, national resource:
  - One possible approach is to establish a non-profit entity. In addition to providing a customized MVNO, it provides an anchor for support for education or academic research involving cellular networks. To some degree, other disciplines already use this model. It is common for large grants such as in health to involve a third party to help carry out the funded research. As more government funded research (probably coming from areas such as NIH, DOE, or DOT) incorporates wireless technology, the need for evolved forms of the SciWiNet concept are likely viable.

What do we hope to accomplish next report period:

This represents Phase 3 of SciWiNet. We will work on the following:

- We will transition the following tools from internal project tools to useful tools and capabilities that researchers and students might find helpful
  - Android application
  - Connected vehicle applications and underlying hetnet wireless services
  -
- SciWiNet cloud services to be expanded to support
  - Connected Vehicle data
  - Cloud RAN services
- We will continue to make our tools available to the GENI/Wireless community.

How have the results been disseminated to communities of interest?

Through our publications, talks at conferences, and our community survey work, the results have been widely disseminated to the CS and ECE communities.

Publications include:

- R. Izard, A. Hodges, J. Liu, J. Martin, KC Wang, K. Xu, "An Openflow Testbed for the Evaluation of Vertical Handover Decision Algorithms in Heterogeneous Wireless Networks", Proceedings of TRIDENT 2014.
- K. Xu, R. Izard, K. Wang, J. Martin, "Cloud-based Handoff as a Service for Heterogeneous Vehicular Networks with OpenFlow (short paper)", Proceedings of the GENI Research and Educational Experiment Workshop (GREE'13), (Salt Lake City UT, March 2013).

Master student thesis:

- Adam Hodges (MSCS), “Broadband Mapping Emerging Heterogeneous Wireless Networks”, (August, 2014).