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14. ABSTRACT Mobility and security are two critical components of wireless networks. We request funding to enhance our Quail Ridge Wireless Mesh Network (QuRiNet) infrastructure for investigating fine-grained impact of mobility on network performance and security, and novel security mechanisms that exploit physical layer information and mobility to enhance network security. Our ultimate goal is to 1) build comprehensive and realistic models which can be used to analyze the impact of mobility on the network performance, quality of information, and security, and 2) develop robust and novel security mechanisms.
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Report Title

Final Report: QuRiNet Testbed for Security and Mobility Research

ABSTRACT

Mobility and security are two critical components of wireless networks. We request funding to enhance our Quail Ridge Wireless Mesh Network (QuRiNet) infrastructure for investigating fine-grained impact of mobility on network performance and security, and novel security mechanisms that exploit physical layer information and mobility to enhance network security. Our ultimate goal is to 1) build comprehensive and realistic models which can be used to analyze the impact of mobility on the network performance, quality of information, and security, and 2) develop robust and novel security mechanisms that exploit lower-layer characteristics.

The equipment requested and their usage are summarized as follows.

- IEEE 802.11n nodes. They will greatly enhance the value of QuRiNet by increasing its network capacity. They will also allow us to study the impact of MIMO (multiple-input multiple-output) technology on our mobility modeling and security mechanisms.
- Signal analyzer. It provides analog demodulation and digital modulation analysis, which will allow us to pull out the physical layer information of the wireless channel. It will enable us to investigate fine-grained impact of mobility on physical layer metrics and study how these information can improve the performance of the proposed physical-layer security mechanisms.
- Gators. The gators will allow us to conduct large scale mobility test under different mobility patterns and speeds at QuRiNet.

Our research, that will rely on the QuRiNet infrastructure enhanced by the requested instrumentation, will make remarkable contributions to the two of our (PI Dr. Mohapatra's) DoD projects. One is the MURI project ARSENAL (W911NF-07-1-0318) funded by the ARO on directly addressing the primary issues of mobility and security in tactical networks. The other is the NS-CTA project (W911NF-09-2-0053) funded by the ARL. NS-CTA aims at developing a computational approach to trust geared toward enhancing the quality of information (QoI) in tactical networks.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received Paper

TOTAL:

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received Paper

TOTAL:

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

12/04/2015 2.00 Victor Omwando, Amit Pande, Yunze Zeng, Prasant Mohapatra. Evaluating Perceptual Video Quality for Mobile Clients in 802.11n WLAN, ACM WinTech. 10-JUN-13, . . . ,

12/04/2015 1.00 Daniel Wu, Dhruv Gupta, Prasant Mohapatra. QuRiNet: A Wide Area Wireless Mesh Testbed for Research and Experimental Evaluations, Ad Hoc Networks. 01-FEB-11, . . . ,

TOTAL: 2

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received Paper

TOTAL:

Number of Manuscripts:

Books

Received Book

TOTAL:

Received Book Chapter

TOTAL:

Patents Submitted

Patents Awarded

Awards

Graduate Students

<u>NAME</u>	<u>PERCENT SUPPORTED</u>	<u>Discipline</u>
Dhruv Gupta	0.25	
FTE Equivalent:	0.25	
Total Number:	1	

Names of Post Doctorates

<u>NAME</u>	<u>PERCENT SUPPORTED</u>
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

<u>NAME</u>	<u>PERCENT SUPPORTED</u>	National Academy Member
Prasant Mohapatra	0.00	
FTE Equivalent:	0.00	
Total Number:	1	

Names of Under Graduate students supported

<u>NAME</u>	<u>PERCENT SUPPORTED</u>
FTE Equivalent:	
Total Number:	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 0.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:..... 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):..... 0.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields: 0.00

Names of Personnel receiving masters degrees

<u>NAME</u>	
Victor Omwando	
Total Number:	1

Names of personnel receiving PHDs

<u>NAME</u>	
Dhruv Gupta	
Total Number:	1

Names of other research staff

<u>NAME</u>	<u>PERCENT SUPPORTED</u>
FTE Equivalent:	
Total Number:	

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

We have deployed the Quail Ridge wireless mesh network, which provides wireless coverage for 2,000 acres of the Quail Ridge Natural Reserve. Quail Ridge Natural Reserve is used for environmental research by the Department of Ecology at UC Davis and is part of the UC Natural Reserve System (NRS). The mesh network is used for ecological research studying the flora and fauna in the region. The network helps in collecting audio, video, and ecological data from the sensors deployed in the reserve. We have several different types of equipments attached to various mesh nodes, including audio sensors, video cameras, and weather data equipment. Currently, the mesh network consists of about 40 mesh nodes. The network also includes a node located on a buoy in a lake. This network was deployed under great geographical (varying topology and forest environment) and technological (lack of power lines) challenges. Except for the gateway node, all other mesh nodes are powered using solar energy. This sets us apart from most existing test-beds.

In addition with providing network coverage for ecological researchers, the Quail Ridge wireless mesh network also provides us with a unique test-bed for carrying out research in wireless networking. Quail Ridge wireless mesh network is different from other wireless test-beds both in terms of its location and its usage. Unlike most other test-beds, which are implemented in controlled laboratory environments, our test-bed is in an outdoor wild life reserve, which gives us a better opportunity to understand the nuances of wireless networks. The Quail Ridge natural reserve is free from wireless interference and electromagnetic noise from electronic devices, which enables us to have fairly accurate signal strength measurements. Since the test-bed is used for ecological research, the test-bed continuously carries real data traffic such as weather data and wild life monitoring data, which helps us in better analyzing and evaluating the network performance.

The deployment of the Quail Ridge test-bed has provided us with excellent insights and important knowledge regarding wireless mesh networks. The test-bed gives us the opportunity to test the various theoretical ideas and their validity in practice. We have implemented a software system that measures quality metrics in the network, such as delay, which we used to design and implement novel admission control mechanisms in the network experiments. We have also implemented a software system that measures wireless link quality, which we will use in our future research.

In terms of broader impact, QuRiNet design and deployment provided very valuable experience for multiple graduate and undergraduate students at UC Davis. It also facilitates the research and training activities of ecological researchers working at the reserve.

Details about the QuRiNet project are at: <http://qurinet.ucdavis.edu>

Technology Transfer