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14. ABSTRACT This is a proposal for research equipment under the Defense University Research Instrumentation program. The Computer Engineering and Systems Group at Texas A&M University consists of fifteen faculty members and about fifty Ph.D. students conducting research under Department of Defense and other funding on a number of areas, including wireless networking, programmable medium access control, software defined networking, cyber-physical systems, and systems for emerging storage-class memory. This proposal is addressed towards procuring equipment to support this research with equipment in networking, computing and storage.
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Report Title

Final Report: Equipment for Research in Networks and Systems

ABSTRACT

This is a proposal for research equipment under the Defense University Research Instrumentation program. The Computer Engineering and Systems Group at Texas A&M University consists of fifteen faculty members and about fifty Ph.D. students conducting research under Department of Defense and other funding on a number of areas, including wireless networking, programmable medium access control, software defined networking, cyber-physical systems, and systems for emerging storage-class memory. This proposal is addressed towards procuring equipment to support this research with equipment in networking, computing and storage.

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)

<u>Received</u>	<u>Paper</u>
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TOTAL:

Number of Papers published in peer-reviewed journals:

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

<u>Received</u>	<u>Paper</u>
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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

TOTAL:

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>
FTE Equivalent:	
Total Number:	

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>
FTE Equivalent:	
Total Number:	

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

NAME

Total Number:

Names of personnel receiving PHDs

NAME

Total Number:

Names of other research staff

NAME

PERCENT SUPPORTED

FTE Equivalent:

Total Number:

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

We have completed all necessary purchase of equipment as described in the proposal. All equipment has been installed as part of the new CESG cluster on Jan. 18, 2017. Faculty members and PhD students are using this cluster to pursue research on networks and computer systems. Specific research projects include:

Towards Provably Timely and Reliable Battlefield Networks: This project aims to develop scheduling policies for unicasting and broadcasting real-time flows with heterogeneous requirements vis-a-vis deadlines and reliability, distributed algorithms for self-configurations and random access, as well as joint routing and scheduling policies to provide stringent end-to-end service guarantees. A new system of intra-tank wireless communications will also be investigated. The cumulative result will be a rich suite of solutions that provides stringent delay and reliability guarantees for important army networks, including intra-tank networks and battlefield networks with timing constraints.

A Holistic Approach to Networked Information Systems Design and Analysis: This addresses critical problems in secure networking, service guarantees in networks, real-time systems, correct and safe design of multi-vehicle systems, software defined networking, information extraction from sensor networks.

Emerging Frontiers of Science of Information: The overarching vision of this project is to develop rigorous principles guiding all aspects of information, integrating elements of space, time, structure, semantics, cooperation and value, through a new paradigm in the quantitative understanding of the representation, communication, and processing of information.

Measurement in Software Defined Networking: Exploits the flexibility of the controller switch combination in SDN for efficient measurement.

Network tomography and network resilience: Uses collaborative measurement to route traffic around network impairments without interior visibility.

Creating an Ecosystem for Enhanced Spectrum Utilization Through Dynamic Market Mechanisms: The main goal of this project is to bridge the disconnects between user preferences and allocated resources by the use of dynamic market mechanisms that allow for packet-level value determination over time. The objective is to study both primary markets in which service providers sell network access to end-users, as well as secondary markets in which end-users share resources via hot spots and device-to-device networking.

Analyzing social contexts to detect malicious behavior: Looking at analyzing the social context in communication patterns to detect malicious behavior. This includes the study of social networks and infrastructure networks. Protocol behavior and application behavior is being analyzed to understand normal traffic patterns to enable the creation of anomaly detectors.

Malware and spammer detection in social networks: Analyzing communication patterns in social networks and mobile networks. Correlating network level behavior with intrusions and malware. Analyzing traffic patterns in wireless and wired networks to understand the differences, with a view to design suitable anomaly detectors.

Towards a Theory of Self Organizing Networks for Countering WMD Attacks: Develop fundamental theories and algorithms for the creation of self-organizing D2D networks in which mobile devices automatically discover each other and form a network; collect and disseminate critical information in real-time; and communicate with outside to report damage information and receive C-WMD instructions.

Beyond Akamai and BitTorrent: Information and Decision Dynamics in Content Distribution Networks: The objective of this project is the development of a systematic analytical framework to achieve coordination across peers, across information, and across shared resources available to the peers, for the design of efficient content distribution systems. The main analytical tools are drawn from game theory, learning and stochastic networks. The aim is to capture the fundamental properties of large-scale content distribution systems using analytical models, and bind together applications such as file sharing, streaming, cloud-based services, and device-to-device wireless networks by employing this framework.

Strategic Analysis and Design of Robust and Resilient Interdependent Power and Communications Networks: Takes an important step towards the principled understanding of the interdependent power and communication networks, and the development of practical solutions that can be used to enhance their robustness. The goal of this project is to develop and validate a fundamentally new paradigm for capturing the complexity of interdependency between networks in a tractable yet accurate manner, and to utilize its predictive power to determine outcomes of network stresses and to provide prescriptive solutions to mitigate cascading failures by strengthening critical network elements.

Tools for Design and Analysis of Provably Correct Networking Systems: The project includes three major goals: (i) Identify abstractions present in network protocols and system design which allow for closer correspondence between design and construction; present a programming language, compiler, and runtime supporting these abstractions that target the large existing systems programming community; (ii) Enable the design of provably correct protocol constructions that systematically eliminate entire vulnerability classes; (iii) Identify program transformation algorithms that provide at least as good of

performance as hand optimizations present in existing low-level network programs.

Boolean Grid: Addresses how to employ digital techniques in the delivery of power so as to ensure a programmable smart grid.

Streaming algorithms for Big Graph Data: Develops algorithms to summarize streams of graph data (e.g. flow records or social network updates) that are both efficient and statistically optimized for classes of graph database query.

Hardware based machine learning: Aims to develop efficient hardware-based processors and accelerators for compute-intensive machine learning algorithms. Both statistical learning algorithms and biologically inspired spiking neural networks are targeted in this work.

Emerging storage-class memory architectures for big memory applications: Development of new memory systems architectures and system software, designed for the challenges of big memory applications, leveraging emerging non-volatile memory technologies together with traditional DRAM.

Client interfaces for object storage systems: Designing client interfaces for novel object based storage systems. Client interfaces, including POSIX, that enable current applications to talk to novel servers are being designed. This provides backward compatibility with newer server features. The primary target of this work is the parallel file systems for future exascale systems.

Conformance Verification and Software-Defined Flow Control Frameworks in Cloud Networks: Focuses on the design of a specification driven protocol firewall application that screens the protocol validity. Uses formal methods and correct-by-construction techniques to guarantee that no invalid packet (i.e., packet that violate structural or semantic constraints) can get through.

Reliability Assessment and Modeling of Cyber-Enabled Power Systems with Renewable Sources and Energy Storage: Focuses on developing a methodology for evaluation of the power system reliability in a holistic manner. Our methodology will enable the utilities to analyze the implications on power system reliability due to the introduction of advanced monitoring and control systems, renewable integration, and energy storage.

Technology Transfer