PROGRAMMABLE NETWORK ALGORITHMS & MODELS FOR CLASSICAL & QUANTUM NETWORKS

Project Description

Software defined programmable network abstractions and control plane intelligence is leading the much awaited network innovation. Programmable networking offers device agnostic communication framework to encode new network functions. Externally centralized control plane intelligence allows programmers to write network applications and to build functional network designs and it can even be extended to interconnect emerging computing architectures like quantum computers. We are using programmable network principles to create intelligent and adaptable network functions to solve problems of army interest in wired, wireless and quantum networks.

We are working to build a programmable 3-node quantum network by extending the OpenFlow protocol to support quantum metadata attributes to build such a network. We have previously defined required OpenFlow abstractions and created a simulation of the 3-node quantum network topology (1-2).

Programmable networks OpenFlow protocols to interact with other messaging protocols like MPI in HPC. While MPI is a very reliable protocol for scheduling, it is stateless, has scalability problems creates rich user feedback messaging regarding the performance, network usage without interfering with the ongoing jobs. Programmability allow users to write HPC specific applications to make use of the network intelligence to better prepare the work load. Programmable network fabrics will also allow efficient resource utilization and prepare the HPC network for future extensions and modifications to accommodate dynamic integration of mobile HPC systems into tactical edge networks. In this project, we propose and encode OpenFlow extensions to interact with MPI protocol and encode control plane application necessary to create a programmable HPC network fabric.

Programmable HPC network fabric will be critical to develop self-healing network interfaces required for tactical HPC systems to integrate into edge networks either directly or through cloudlet orchestration as needed. Continuous operation of tactical HPC systems in mobile edge networks require distributed programmable control plane intelligence resistant to frequent state disruptions

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We are working on the design and encoding of key programming libraries required to enable the on-demand control function framework for tactical ad hoc networks. Also working on design and implementation of a compiler and runtime to automatically generate local-decision algorithms to enable automatic operation the proposed

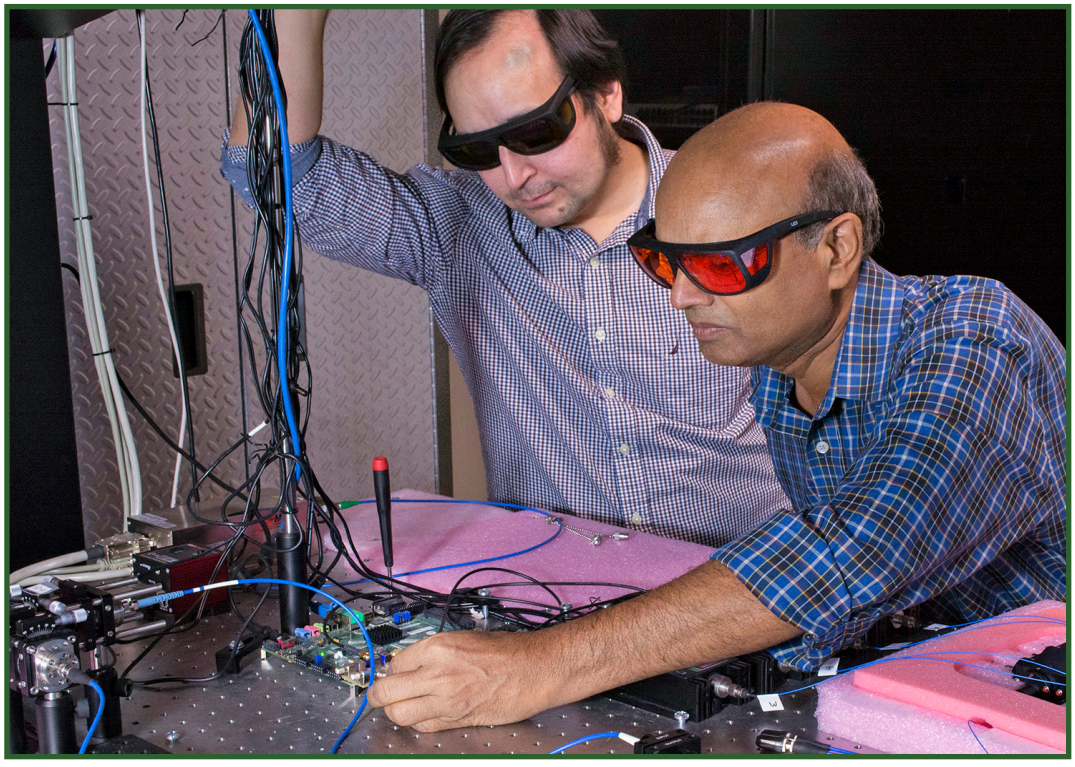
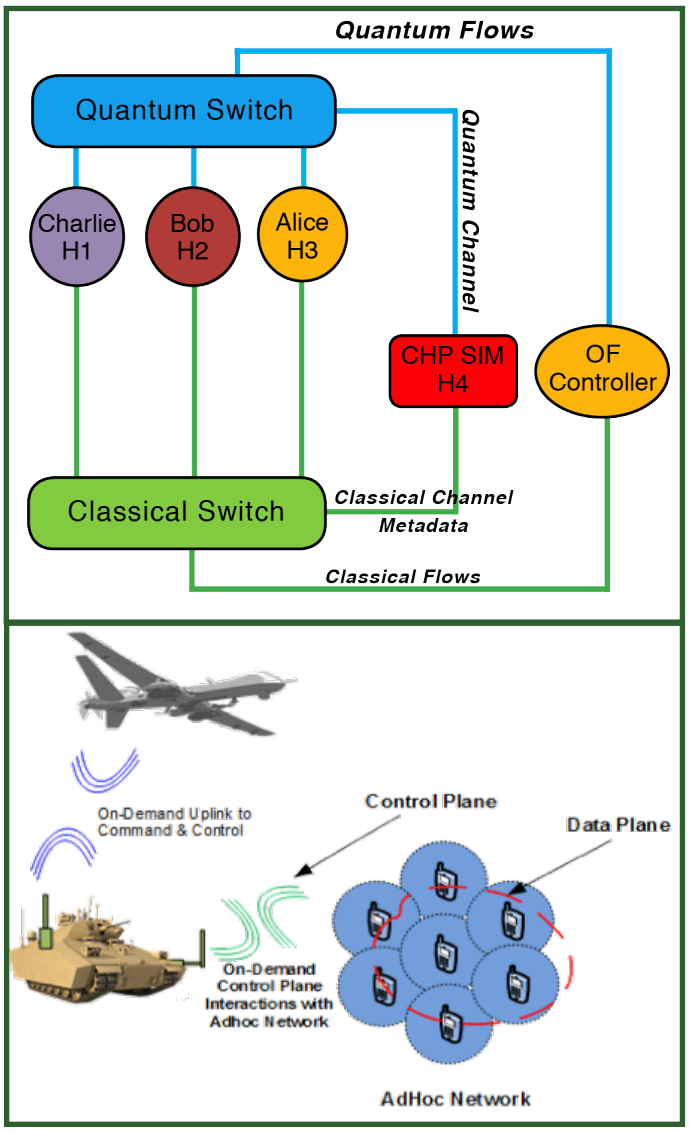


Figure 1: (top) Programmable Quantum Network Model
Figure 2: (bottom) On-Demand Control plane overview



on-demand control channel in ad hoc wireless network and to integrate the decision making functions with OpenFlow protocol.

Relevance of Work to DOD

Development of programmable network abstractions will contribute to the ARL's goal of creating 3-node quantum network. Creating programmable network fabric for interconnecting HPC clusters leads to the development of flexible, distributed HPC systems for building federated HPC systems that can share CPU cycles. Programmable network interface to communicate with MPI will allows users to interrogate the HPC nodes for status. The end result of all of this is more efficient use of these costly and rare computational resources, and more productivity of the HPC users. On-Demand control plane intelligence substantially improve flexibility and efficiency of adhoc network communications that are widely used by the Army and it will make it easy to integrate other sensor networks with the adhoc networks. On-demand control plane network abstractions could provide mechanisms for various coalition networks to form a global topology, coordinated global convergence, notification, command and control of army tactical wireless networks

Computational Approach

Extend the software defined programmable network architecture, algorithms and network abstractions to for adapting SDN architectures to existing Army networks. Develop programmable network fabrics for interconnecting HPC clusters and nodes. Subsequently integrate MPI with OpenFlow for development of a unified control plane.

Results

We have completed the encoding of OpenFlow data structures for building programmable quantum networks. We also successfully have created a 3-node quantum network simulation. We have finalized the design specification to integrate MPI with OpenFlow for creating programmable HPC network fabrics.

Future

We will plan on extending our programmable quantum network design to interconnect other qubits systems like trapped ions. Plans underway to produce HPC prototype with programmable network fabric and slicing functions. On-Demand control plane integration with tactical wireless adhoc networks will be carried out. We will integrate OpenFlow with the MPI protocol, and we will build a flexible federated experimental HPC testbeds to promote collaborative research within the DOD research community.

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