**Overview**:

Wireless cellular infrastructure is becoming dense and heterogeneous. Software-defined networking (SDN) has brought new opportunities for enhancing network planning and administration. When applied in geographically large-scale radio access networks (RANs), SDN suffers from the intrinsic scalability and survivability problems due to high centralization. Therefore in this project, a hierarchical software-defined radio access network (HSDRAN) is proposed and designed. The proposed research aims to address fundamental problems and challenges in creating a HSDRAN at the edge, with emphasis on a novel architecture design and network-wide resource allocation strategies.

**Intellectual Merit**:

The intellectual merit originates from the interdisciplinary incorporation of different technologies including SDN, wireless communications, software-defined radio, machine learning, and game theory. It addresses challenging issues of coexistence of interfering clusters and elastic resource allocation for a large-scale RAN, and proposing theoretically novel frameworks to tackle these challenges. The research activities are summarized in the following four thrusts:

1. Proposed Architecture for HSDRAN at the edge: In contrast to a flat version of software defined RAN which has large control overhead and system latency for large scaled networks, the proposed HSDRAN has reduced control overhead and system latency via the exploration of locality, and thereby enhances system scalability. In addition, the tree structure of the HSDRAN can easily deal with single point of failure. The plan is to investigate the architecture design of the HSDRAN, the protocol design for the control network, survivability, and locality and optimization.
2. Large-Scale Elastic Approaches: By using hierarchical stochastic game formulations, the optimal resource allocation strategies of the involved entities are investigated, under dynamic network situations. It is also planned to show that all the involved entities achieve better long-term utility performance, and the network performance is improved by exploiting the proposed resource allocation framework.
3. Machine Learning Based Approaches: A learning-based optimization framework is proposed to develop a set of strategies in locally-coupled networks for an optimal network-wide performance. The overarching goal is to maximize the sum of the local objective functions of all network nodes under limited information. Iterative randomized algorithms will be constructed, with provable convergence and optimality properties stemming from the framework of Markov random fields.
4. Matching Theory Based Approaches: Matching is proposed between radio resources (e.g. three-dimensional grid of space, time and frequency slots) and temporally & spatially fluctuating traffics, so as to achieve spectral efficiency or energy efficiency. Distributed and parallel computing can be achieved for large heterogeneous networks with near optimal performances.

This research will lead to simpler and more efficient resource allocation schemes for wireless networks by exploring the power of SDN. The transformative project involves a complementary mix of network architecture design, theoretical modeling and analysis, and experimental simulations quantifying performance benefits.

**Broader Impacts**:

The outcomes will be made available to research community through high quality journal articles and conference presentations which may be used by industries for network development and impact future industrial standardizations. This project will strengthen collaboration in the research field of wireless communication between the United States and Finland/Europe. The proposed research activities will complement and enrich the growing curriculum on game theory and optimization at the University of Houston and Arizona State University through course development and special topic seminars. Highly skilled personnel in related areas will be trained in carrying out the proposed research tasks. Special efforts will be made to engage minority and underrepresented groups. African-American and female graduate students will be involved in the project. The K-12 Outreach Programs will also be participated to inspire the interests of high school students in science and engineering.