Performability of Virtualized Wireless Networks of Things

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As more and more of human activity and endeavor converge at growing cities, as computing becomes increasingly pervasive in all facets of such activities, and as more and more of those computers cut the cord to become mobile and even airborne, future wireless cities becomes the perfect challenge scenario for computing and networking research and development. There are many research directions that fit into this grand vision. We focus on three inter-related areas, that of performabilty analysis of virtualized wireless environments, enabling a mobile and airborne network of things, and enabling deep monitoring of network state for these environments.

One of the key enabling technologies, as a broader range of devices share each spectrum band of an increasingly crowded heterogeneous wireless medium, is virtualization of the wireless space, and great strides have been made recently in this area. As the enablement of the sharing of wireless spectrum in various systematic ways is being explored by this research, the question of how the performance received by wireless devices is affected by their coexistence also needs to be explored. Wireless network performance has often been characterized by pure performance measures such as throughput or access delay, and considered on an aggregate basis. But the volatility of the wireless medium, reflected in the agility of the wireless networking techniques evolving across the layers (physical, MAC, network and even higher) in approaches such as dynamic spectrum access, means that such stationary measures are no longer suitable. Instead, measures such as performability, which measures overall service received integrated over time, are more appropriate. In [Pathak, Dutta, IEEE Trans Mob Computing 14(3)], we have recently shown how this metric is distinct from commonly understood metrics such as availability in the context of wireless mesh networks, and that it may not be possible to simultaneously maximize both metrics in this context. However, the study of how such metrics behave in various virtualized wireless medium remains a worthwhile future research area, especially when some or most of the nodes are mobile.

Mobility reaches a new level with the advent of urban airborne nodes. Airborne networking has gained a lot of attention in recent years, but much of it has been directed at large-scale aircraft and multi-tier zoned networks, as with the military’s 3-tier architecture that integrates with SATCOM. More recently, it is becoming clear that flying computers, at altitudes low enough to form part of terrestrial wireless networks, or at least interfere with them, at velocities that introduce more dynamics in the wireless medium than speeding cars, and less constrained in their routes through urban space than any other previous mobile nodes. At NCSU, our research group had designed and deployed an outdoor permanently installed wireless mesh network entirely dedicated to research and teaching called CentMesh (http://centmesh.csc.ncsu.edu), and in the last two years we have hosted programming and research challenges for NCSU students through the NCSU CentMesh Drones Challenges (http://go.ncsu.edu/drones_challenge). From the insight obtained by these practical experiences, we can state that the study of network dynamics, as well as protocol architectures to stabilize network behavior and performance of heterogeneous terrestrial/airborne networks is an important research area to enable the vision of future wireless cities.

Lastly, the information system underlying the wireless city of the future must be highly reflective – it must monitor and verify itself continuously at a high spatial and temporal frequency. In the context of the ChoiceNet project, we proposed an economy plane for the Internet, based on the postulate that all service, if worth having, is worth paying for. The general architecture has been described in [Wolf et al, SIGCOMM CCR 44(3); Wolf et al ICC 2015]. Measurement and verification inside the network can be seen as examples of such value-added services, and can be realized by third-party providers. In [Babaoglu, Dutta, ICCCN, 2013; Babaoglu, Dutta, GREE, 2014] we have shown how such third-party monitoring services can render trivial problems previously intractable, such as jitter apportionment. In [Udechukwu, Dutta, ICNP 2014], we have demonstrated a practical way in which such services may be provided on an application-aware per-flow basis by inserting arbitrary processing and monitoring in the path of traffic in a scalable manner, by using a combination of the OXM capabilities of OpenFlow, and an innovative offloading approach. Similar approaches can be used to monitor the wireless medium in the wireless city. This in turn can be used to monitor node mobility and network topology, and feed techniques to maintain routing stability or improve performance measures of the complete information system.