White Paper for Future Wireless Cities Workshop-NSF "Looking Beyond the Internet" Planning Group

Future Cities – Wireless Services for Applications Beyond Communications

by Zoran Kostic, Columbia University, zk2172@columbia.edu

The focus of this paper are wireless services capable of supporting applications which go beyond communications, and cover real time control and management. Urban environments are particularly suitable for experimentation with and deployment of such services since numerous physical fixtures which can anchor gateway devices, as well as citi communication networks, are both abundant and dense. By early 2016 the number and variety of miniature wireless-enabled low power sensors, computing devices and platforms is overwhelming. Internet of things (IoT) platforms in form of cloud services are mushrooming. Wireless service providers have learned how to reliable provide communications and are in the throngs of transitioning to a software defined network architecture.

We focus our investigations on issues of management, control and adaptable deployment of unbounded applications suitable for metropollises, on the example of New York City. "Wireless" NYC will benefit substantially from services improving safety and health of city dwellers and managing traffic logistics of the city.

We believe that making progress requires a holistic approach, founded on system-level expertise covering the complete eco-system: sensors, computing devices, hubs/gateways, network, cloud, data analytics – including feedback for purposes of control. The complete flow is presently functional for the Internet of Things eco-system, with important missing pieces needed for the emergence of the true future wireless city.

We propose research on the following topics, directed at making wireless cities a reality:

Redefining Latency Measurements and Requirements: Reduction of (time) latency in wireless networks is essential for enabling a large swath of new control/management-focused services, to name traffic management and autonomous cars as examples. The often stated goal of 1ms latency needs to be properly understood by reiterating that in 1ms the light can travel no more than 300 kilometers. For today's networks, we see a gaping hole in understanding true values of latencies, ability to associate latency contributions with individual network devices, paths and end components. Therefore latency QoS requirements can today only be used in the most crude ways in real deployments. We offer the following research targets: (1) Creation of dedicated protocols for continuous monitoring and reporting of latencies for arbitrary paths in a network; including the standardization of such protocols; (2) Re-definition of latency-based QoS requirements, where latency measurements will be continuously collected in forms of histograms rather than fixed values. Latency QoS will not be expressed as a fixed threshold, but rather as a histogram mask, not unlike spectral masks for modulations. Sophisticated machine-learning based algorithms will be dispatching data packets to meat latency histogram masks rather than overachieving fixed latency targets at the expense of other packets never to make it through the system. This topic requires theoretical evaluation, protocol development, and significant test-bed based experimentation.

Application focused integrated device:: We see a need and a clear opportunity for integration of devices which exist today into integrated systems, for application needed for city management and control. One practical example is the design of a gateway containing a fish-eye video sensor (camera), multiple wireless devices and multi-core computing units, to serve as a hub residing at the edge of a fixed network (possibly at the bottom of a traffic light in the center of intersection) capable of massive data collection, feature extraction, triage and dissemination. Mere combining of individual devices is a simple task, but coordinated operation of such multi-sensor units which can control/coordinate surrounding humans and things is a research problem of notable complexity. Real time requirements make it especially challenging. Where majority of this work represents systems and integration research, an example of research in a focused area is the creation of a language for efficient representation of features relevant to traffic control, extracted from video, such as motion vectors and traffic density estimators. This research will take advantage of concepts and platforms from both Internet of Things and Cellular eco-systems.

Testbed: We posit that the proposed research can not be done in form of paper studies or computer simulations. Rather, this research requires building test beds residing in real environments. We propose to architect and build a testbed surrounding one or more colleges in NYC. This testbed will be built in coordination with city government, wireless service operators, and with assistance of a number of startups operating in this domain.

Author's background: Wireless communications, systems and networks; low power devices; Internet of Thing eco-system; parallel computing for mobile devices. See short CV.