UCLA – NSF Cloud support of vehicular applications

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At UCLA we have conducted research and experiments on several vehicular projects under NSF sponsorship, initially as part of the GENI experimental testbed program and more recently under the NSF NeTS Large Project "*Closing the loop between traffic/pollution sensing and vehicle route control using traffic lights and navigators*", nicknamed ***Green City Project***. During the course of our research, we have identified important roles that the ***Cloud*** will play in the development and deployment of urban vehicle application and services, from two parallel and synergistic viewpoints: ***Mobile Computing Cloud***, and ***flexible access to the Internet Cloud***.

The need for a ***Mobile Computing Cloud*** in the vehicular grid is revealed by three important trends in the way vehicles will be used in the future. **First,** a typical vehicle has hundreds of sensors (including several video cameras) that enable it to become more autonomous and eventually self drive itself. At the same time, sensors and cameras capture an incredible amount of environment data that can be utilized to improve navigation, reduce pollution and also assist in surveillance making the city more livable and safe. **Second**, the sheer amount of data collected by cars cannot all be uploaded to the Internet Cloud for processing. There is not enough wireless bandwidth, and besides not all the data is meaningful. **Third,** the technology advancements will provide sufficient storage and processing power in vehicles (and on drivers' smart phones) and adequate short range V2V wireless bandwidth to support local distribution, filtering and preprocessing of all data before it is sent to the Internet Cloud for final processing and global optimization.

In this picture, the ***Internet Cloud*** serves the function of post processor of the data collected in the ***Mobile Vehicular Cloud***. There must be a subdivision of responsibilities between the two clouds, similar to what was already observed in the interaction between mobile phone and cloud. The major difference is that the Vehicular scenario deals with many mobiles (the vehicles) collaborating to provide real time services (eg, prevention of congestion, prevention of DDoS attacks, prevention of major accidents, etc). Such real time requirements demand Cloud access with more predictable QoS than currently offered by commercial Clouds. Thus the need for a next generation of experimental Clouds like the ***NSF cloud***.

In the section below, we describe an extension of our Green City project research that leverages the NSF Cloud.

Cooperative Mobile and NSF Cloud Computing

Application: Efficient, scalable, pollution aware vehicular routing

Goal: develop advanced urban vehicular routing techniques that are scalable to urban size and are ecologically sustainable (ie prevent uncontrolled increase of pollution in the city)

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Background and Experimental Scenario: Future, advanced vehicular routing in a complex urban environment can be viewed as the combination of: (a) sort range routing, say over a few blocks, and up to 1Km, and; (b) long range routing (above 1Km). Short range routing can be managed by collaboration among peers in the Mobile Vehicle Cloud. Long range routing is best handled by a Traffic Manager in the Internet Cloud. Today, vehicular routing is based on coarse grain traffic information offered by services like Google, WAZE and commercial navigators. It does not prevent route flapping nor congestion. Future, advanced routing will be more efficient, providing load balancing among multiple paths; congestion control via dynamic congestion pricing, green waves, fast track lanes, option of other transport modes (when available); pollution control. Human drivers may refuse to be routed by the Internet Cloud, but the gradual introduction of the autonomous car will eliminate this obstacle. The major dilemma of the traffic engineer is how to test a proposed vehicle routing strategy before introduction to the public.

The NSF Cloud infrastructure will help solve this problem. In a **small scale experiment,** the UCLA Campus testbed with 6 vehicles, say, will run the sort range routing component locally, in the Mobile Cloud using its services. The long range routing algorithm (optimized for minimal congestion and pollution, and supporting congestion control) will include realistic traffic and pollution conditions observed in the local testbed and will run in a *NSF Cloud* virtual slice. Connected to the routing model and running in the NSF Cloud are: (1) the atmospheric model that can predict the dispersion of pollutants in the air, and; (2) the congestion control model that regulates traffic signals and green waves, and adjusts congestion fees.

In a **large scale experiment**, the C-Vet tesbed will operate side by side with a Cloud based NS-3 Vehicular Emulator developed by the Green City project at UCLA. In this emulator, real vehicles will monitor and collect measurements to be used and extrapolated in the experiment. Namely, the Emulator will extract traffic and radio propagation parameters from the real testbed. The Emulator will run the short range routing scheme replicated over many localities. A *Global Route Coordinator* implemented in the NSF Cloud provides the long range route computation across localities.

To facilitate the connection between NSF Cloud and Mobile Cloud, special utilities will be developed to supervise the allocation of local and Cloud computing resources to achieve the required routing efficiency. More precisely, these utilities will interface the C-VET vehicles as well as the virtual vehicles in the Emulator to the NSF Cloud based Global Route Coordinator traffic management and pollution modeling applications. Long term plans include the extension of this project to support other mobile and vehicular applications that can benefit from joint local and NSF Cloud processing, like urban surveillance, safe navigation and cooperative content downloading.