Smart Mobility: Next Generation Transportation System (position paper)

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I. INTRODUCTION

The goal of any transportation system is to increase safety and efficiency of transportation infrastructure without expanding the current infrastructure. Therefore, Intelligent Transportation System (ITS) was received great effort in recent years targeting at applying well-established technologies in communications, control, electronics, and computer hardware and software to improve surface transportation system performance. In doing so, Traffic Management Systems receive main concerns and focuses among other ITS areas. Such systems consists of: a) Sensing and monitoring traffic in networks, b) Estimating, through the use of traffic models, the current traffic flow and predicting future traffic flow, and c) Optimizing the control strategy of the phase timing for single or series of traffic controller.

Current schemes of traffic management are based on batch/platoon/bulk/aggregated information and statistics for adaptive traffic control. We envision that with the availability of smart vehicles equipped with sensing and communication capabilities, smart infrastructures with sensors, and smart communications between infrastructure and vehicles; transportation systems will be able to: 1) acquire more accurate information and consequently eliminate uncertainty for short period predictions, 2) acquire new type of information and statistics about individual vehicles and trips (personalized information), and 3) predict traffics for longer periods (e.g., hours) with minimal uncertainty. The availability of such accurate and new information will enable us to develop and apply more efficient control strategies aiming at optimizing mobility and satisfying individual passengers. In addition, communicating useful information concerning the multimodal transportation system's conditions to the public in a timely manner will enable drivers to optimize their trips to their satisfaction. We name this envision as **Smart Mobility**.

II. ENABLING TECHNOLOGIES FOR SMART MOBILITY

Several key technologies stand to serve the objectives of Smart Mobility. We can categorize these enabling technologies to the following major categories:

- Smart Infrastructure and Sensors: Smart infrastructure would allow more efficient systems for managing, among other things, commuter traffic. The crucial technological ingredients of smart infrastructures include low-cost sensors and clever software for analytics and visualization, as well as computing power. Sensor networks are at the heart of all sorts of smart infrastructure. Each sensor node will integrate specific sensing capabilities with communication, data processing and power supply. Sensors can now collect and transmit information from roads and traffic conditions. And the improved software helps interpret the huge flow of information, so raw data becomes useful knowledge to monitor and optimize transport and other complex systems. Examples of sensors for smart infrastructure include: Wireless Detectors, Smart Pavements, Passenger Counters, RFID Tags, Probe data-collection technologies, Eco Sensors, Automatic Vehicle Location, Weather Sensors, Vehicle Re-identification, Pay-as-Go units, and Smart Cameras & Video processing.
- Smart Vehicles: examples of vehicle's on-board technologies include: Navigation System, Inertia Navigational Unit, On-board V2X Communication Box, In-Vehicle Network, Smart Display, Smart Camera, Driver Awareness Monitoring, Eco Sensors, Electronic Billing Unit, Streaming unit, Carputer, Safety Driving System, In-vehicle information systems, and Driver Identification.
- Smart Communications: Various forms of wireless communications technologies have been proposed for intelligent transportation systems. Radio modem communication on UHF and VHF frequencies are widely used for short and long range communication within ITS. Short-range communications

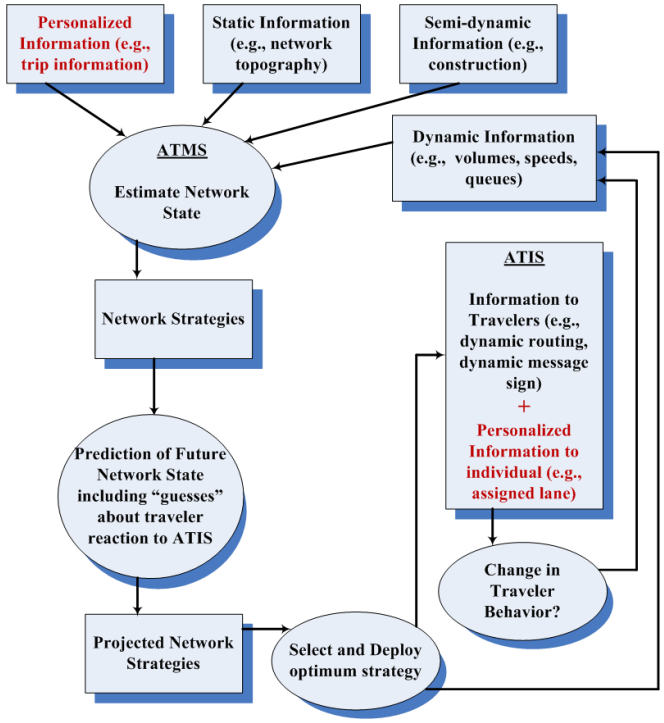

Fig. 1. Proposed Smart Mobility Framework

(less than 500 yards) can be accomplished using IEEE 802.11 protocols, specifically WAVE or the Dedicated Short Range Communications standard being promoted by the Intelligent Transportation Society of America and the United States Department of Transportation. Theoretically, the range of these protocols can be extended using Mobile ad-hoc networks or Mesh networking. Longer range communications have been proposed using infrastructure networks such as WiMAX (IEEE 802.16), Global System for Mobile Communications (GSM), or 3G. Long-range communications using these methods are well established, but, unlike the short-range protocols, these methods require extensive and very expensive infrastructure deployment. Examples of wireless communication standards to be exploited by ITS include: Cellular, RFID, WAVE/DSRC, Bluetooth, WiMax, and Zigbee.

III. Smart Mobility: Proposed System

With the availability of enabling technologies discussed earlier, new and accurate measurements are possible and more data can be managed and processed. Therefore, Smart Mobility could be achieved due to **Detailed**, **Accurate**, Real-time, and **Personalized information**, smarter traffic management systems (ATMS) that interact with traveler information system (ATIS) by providing multimodal information and account for customer response to ATIS-provided advice. Smart Mobility leads to both optimized network performance and optimized individual routes. Figure 1 describes the interaction and components of smart mobility framework. In the following subsections, we describe major element of our framework in brief.

A. Smart Mobility- "More Detailed and Accurate Information is available for better traffic management"

With the finalization of wireless DSRC standards, falling sensor prices, improved methods/equipment/machinery for rapidly and cheaply installing/deploying sensors, improved and cheaper processing and display technology for in-vehicle units, and current plans of major car manufacturer to begin shipping vehicles with OBUs, we believe more detailed and accurate information will be available. Figure 1 shows that among the different data types that is used by the ATMS, is the dynamic information. High accuracy dynamic information could be acquired with the use of some the current enabling technologies we discussed before.

Note that static and semi-dynamic information are known in advance and changes infrequently that usually acquired through transportation agencies and operation centers.

In addition to more accurate dynamic information, the spread of in-vehicle smart technologies such as on-board communication box, more detail information about vehicle, driver, and the trip could be acquired and used by ATMS for better optimization. We refer to this new detailed information as Personalized Information. Examples of personalized information include: Vehicle Information (e.g., passengers info, gas level, vehicle profile), Driver Info (e.g., driver profile, road preference, fatigue level, history information), and Trip Info(e.g., destination, arrival time, inter-modal transportation requirement, schedules for current trip, specific requirements of current trip).

B. Smart Mobility - "Interaction and Integration of ATMS & ATIS for better traffic management"

Currently, ATMS provides information to the aggregated drivers instead of individuals regardless of their interests. This is due to the technology limitation in current technologies (e.g., Dynamic Message Signs). With smart communications and smart in-vehicle display, integration of ATMS and ATIS is possible. In such integration, ATMS provides travelers (via ATIS services) with more optimized and personalized messages and information that increases user satisfaction and optimizes individual mobility. Several challenges need to be addressed for an efficient integration. Examples of such challenges such as: What is the value of the information provided to the travelers? How to measure it? Complete understanding of variables influencing travel behavior, and Does ATIS interact with ATMS in a positive or negative way?

C. Smart Mobility- "Better prediction for better traffic management"

Major component in traffic management (ATMS) is prediction of future network state. With more detailed and accurate information, prediction uncertainty is minimized. Consequently, optimum control strategy will be selected and deployed. Several challenges need to be addressed for an efficient prediction. Examples of such challenges include: What information/parameters are significant in prediction? How significant minimizing prediction uncertainty enhances total network performance? How information accuracy and availability affect prediction process? Study the effect new sensor modality (wireless detection sensors) on prediction phase and control strategy performance, and more comprehensive data and understanding on the intermodal nature of the transportation system.

D. Smart Mobility- "Account for traveler behavior for better traffic management"

Selecting optimum strategy needs to account for driver response to ATIS-provided advice. With provided personalized information and learning driver history, travel behavior in response to ATIS information could be well predicted.

IV. Biography

Dr. Tamer Nadeem, Assistant Professor, Old Dominion University, Department of Computer Science, email: "nadeem@cs.odu.edu" - received his Ph.D. in Computer Science from University of Maryland, College Park in 2006. Before joining ODU in Spring 2011, he spent five years as research scientist at Siemens Corporate Research (SCR) in Princeton, USA. He led several projects in the areas of IntelliDrive as well as radio management for enterprise wireless networks. His research interests span the following areas: wireless networks, vehicular networking, pervasive computing, social networks, sensor networks, and peer-to-peer systems. He has been on the organizing and technical program committees of different conferences and regularly invited to chair conference's sessions and to participate on panels. He has two granted patent and several pending patents. He has published over 40 technical papers in refereed conferences and journals including Journal on Selected Areas of Communication (JSAC), IEEE Transaction on Mobile Computing, IEEE Infocom, and ACM International Measurement Conference (IMC)