Virtual Lab of Connected Vehicle Technology

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Abstract

This paper presents a virtual lab of connected vehicle technology. The virtual lab features an interactive website where remote users, who are unable to learn connected vehicle technology at expensive real labs, can interact with the virtual environment. A team of traffic engineers, computer scientists/engineers, and electrical engineers propose this integrated and high-fidelity simulation platform to evaluate the timeliness and reliability of network design for vehicle-to-vehicle, vehicle-to-infrastructure, and vehicle-to-handheld device wireless communications. The work pioneers the interdisciplinary research of transportation cyber-physical systems by combining microscopic traffic simulation and computer network simulation. The model incorporates driving maneuvers, traffic dynamics, and control strategies to provide a realistic environment. The influence of transportation features on data rate and channel access of communication network is closely examined to evaluate the timing and reliability requirements. The paper also examines the effectiveness of virtual labs comparable to real labs in engineering education and training.

Keywords: Traffic engineering and measurements, virtual environments for training, simulation tools for computer communications and vehicular networks

1. Introduction

Connected Vehicle research has the potential to transform usual paradigm of transportation. Using leading edge technologies including wireless communications, embedded computer systems, advanced vehicle-sensors, GPS navigation, smart infrastructure, and others, Connected Vehicle Technology (CVtech) provides intelligent transportation. Modern vehicles equipped with CVtech can identify hazards on the roadway and to communicate this information over wireless networks to give drivers alerts and warnings. Drivers can now be informed with the dynamic status of traffic condition to avoid congestion [1].

Figure 1 illustrates the fundamentals of CVtech and the enabling technology. The core is a networked environment supporting very high speed transactions between vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and vehicle-to-handheld devices (V2D) to enable numerous safety and mobility applications. This connectivity offers the opportunity to know much more about traffic and roadway conditions than ever before. Equipped vehicles could anonymously send information that includes travel time and environmental conditions, making it possible one day to know traffic conditions along every major street in urban areas as well as along every interstate highway across the nation. This information could lead to improved traffic signal control, ubiquitous traveler information, better transportation plans, and reduced cost for existing transportation data collection methods, among other benefits [2].

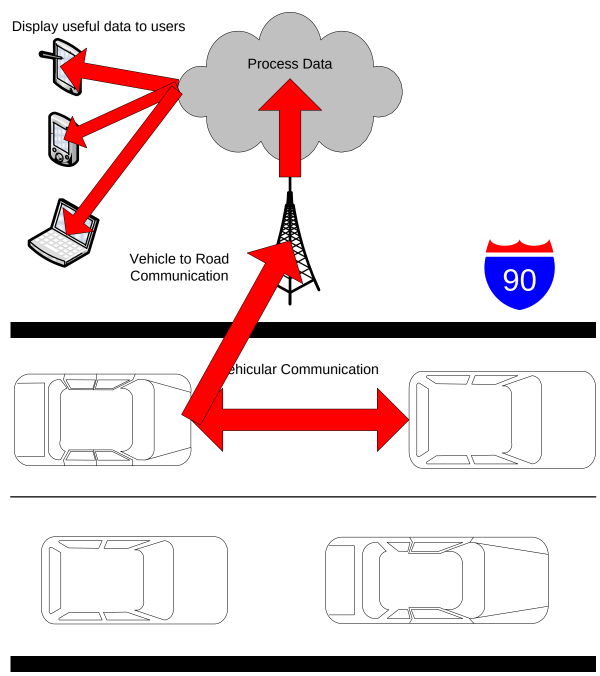

Figure 1. Connected Vehicle Technology

The rest of the paper is organized as follows: Section 2 presents the current status of CVtech study via simulations. We propose a virtual lab for CVtech study in Section 3, and its effectiveness compared with real labs is examined in Section 4. Section 5 concludes the work.

2. State of the Art in CVtech Simulations

In the past few years, CVtech research has attracted tremendous attention. Many simulation packages have been developed, including TraNS, GrooveNet, NCTUns, and

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MobiReal. However, existing studies are done almost exclusively by researchers from computer science/engineering and electrical engineering. Most do not include a high-fidelity traffic simulation component to accurately model the complicated interactions among vehicles, infrastructures, and devices, such as car-following and lane-change maneuvers, adaptive traffic signal control, and gap acceptance. Only a few of them integrate the wireless communications simulation models (e.g., NS-2 and QualNet) with mature microscopic traffic simulation tools (e.g., VISSIM and CORSIM) [3].

3. Implementation of Virtual Lab

This research proposes an integrated and high-fidelity simulation platform, accessible via a website [4], to accurately model CVtech enabled transportation applications in a realistic setting. The simulation focuses on timing, the most important parameter for efficient and reliable V2V, V2I, and V2D communications.

As shown in Figure 2, a real-time control engine will be developed to achieve real-time communications with four components: mobility prediction, resource reservation, network traffic congestion control, and real-time MAC protocol. The proposed MAC protocol is a time-bounded protocol. The prerequisite of V2V communication for traffic safety applications is timely medium-access.

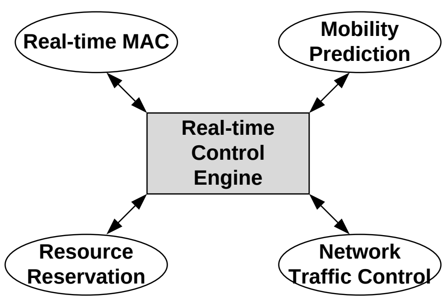

Figure 2. High-Level Model of Real-Time Communications

The team jointly designs a time-bounded medium-access control protocol with traffic control and resource reservation in a cross-layer manner [5]. Mobility predictions are done based on the history of vehicle locations and vehicle speeds. The limited bandwidth resources are pre-reserved through time slot assignments to achieve guaranteed time-bounded message delivery among vehicles. High-level congestion traffic control is implemented through traffic classification and priority-based delivery. Safety-related messages are always prioritized for delivery.

4. Real Lab vs. Virtual Lab

The University of Massachusetts system possesses several real labs that facilitate education of CVtech [6]. These include Amherst's Regional Traveler Information Center as shown in Figure 3, Diverse Outdoor Mobile Environment, and Dartmouth vehicle tracking. It is anticipated that the virtual lab offers a cost-effective way to teaching CVtech.

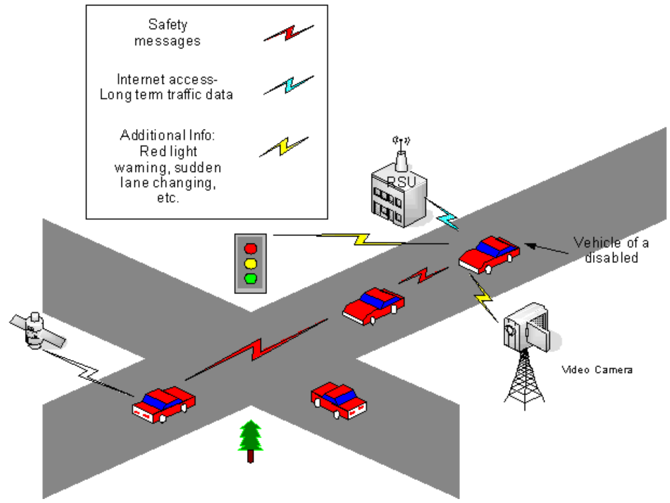

Figure 3: DSRC in a Transportation Network

5. Conclusion

This paper presents a simulation platform accessible online to compromise the study of CVtech for those without the resources for real labs. The comparative study of real lab vs. virtual lab on CVtech is encouraging. This unique multi-disciplinary research integrates transportation simulation with communication simulation and sheds lights on CVtech study. Future work includes design enhancement of simulation models and statistical evaluation of learning via virtual lab.

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