ACM HotMobile 2013 Poster: Vehicular Inter-Networking via Named Data

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In this paper we apply the Named Data Networking, a newly proposed Internet architecture, to networking vehicles on the run. Our design, V-NDN , illustrates NDN's promising potential to providing a unifying architecture that enables networking among all computing devices independent from whether they are connected through wired infrastructure, ad hoc, or intermittent DTN.

I. Introduction

In near future, a car will be equipped with a variety of wireless interfaces such as 3G/LTE, WiMAX, WiFi, or DSRC/WAVE. Our vision is to enable vehicles to communicate with each other and with the infrastructure over any and all physical communication channels, as soon as any channel comes into existence and as long as it is available. Today, in reality and by large vehicles are connected only through cellular networks to centralized servers. Many years of research in VANETs and delay tolerant networking are still far from completion and less likely to deploy. We believe the root cause of this problem in networking vehicles is IP's communication model. IP creates its own addressing space, assigns IP addresses to every communicating end point, and then encapsulates each piece of application data into an IP packet thus insulating applications from data delivery layer. Taking the named-data networking (NDN) as the starting point, we are developing a *single framework* to realize our vision. NDN identifies named data as the focal point in communication. NDN lets individual nodes to request the desired data using application data names directly. This enables data to exist in the absence of connectivity, and to be exchanged over *any* physical connectivity once it comes into existence. We have designed and developed a prototype implementation and demonstrated that our design indeed allowed vehicles to utilize all available channels to effectively communicate using different technologies and cope with disruption.

II. A Sketch of Our Design

We developed the first instantiation of NDN [1, 2, 3] for vehicle networking namely Vehicular Named-Data Network (V-NDN), as described below. In a V-NDN

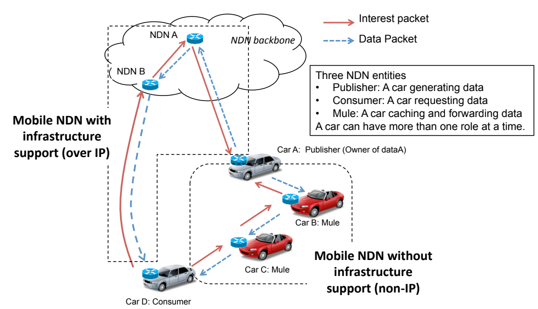

Figure 1: V-NDN Vehicular Named-Data Network : supporting infrastructure and -less networks

network, a car can play any of the four roles: a consumer, a producer, a forwarder when it is connected to other vehicles, and a "data mule" when it is moving but has no connectivity to anyone else. A node generates data, requests data, caches data, helps forward received data, including physically carring cached data. Since the name space used in communications is independent from connectivity or communicating parties, V-NDN can fully utilize any interface. Figure 1 shows the elasticity of V-NDN through different communication scenarios. If a car connects to infrastructure the car exchanges NDN interest and data packets with NDN routers located in wire-connected infrastructure. Cars can also exchange NDN packets through WiFi/DSRC ad-hoc mode in an infrastructure-free manner. In the figure, Car-D sends an Interest packet to the neighboring car (Car-C). The Interest packet is propagated hop-by-hop, using name-prefix matching, and eventually reaches a car with the requested data. The highly dynamic ad hoc environment makes running a conventional routing protocol infeasible. To forward Interest packets towards probable data producers, our pilot application, traffic information inquiry, encodes geolocations into data names, so that Interest packets can be forwarded towards the geolocation where the desired data is produced. [1] It is entirely possible, and even likely, that an Interest packet meets a car with the requested data long before approaching the named location. V-NDN leverages wireless broadcasting nature and takes advantage of vehicles resource properties (adequate storage capacity and power supply). Our design lets every node in the broadcasting range cache the received data regardless of whether it has a matching PIT entry or whether it needs the data itself. Either Interest or Data packets can be literally carried by running cars, when they do not have wireless connectivity to anyone else. Data can move out of the production location by requests or by car movements. In our design the NDN daemon provides the core named data networking capabilities and holds the key data structures such as the PIT and the Content store. The Local Face provides bridges Applications and the NDN daemon, supporting application registration, Interest request, and content delivery. The Network Face provides specific adaptation functions for layer-2 technology used in the communication; we use IEEE802.11 based wireless technology in Ad Hoc mode for V2V, and several wireless technologies i.e. WiMax, 3G, and WiFi, for V2I communications (see figure 2). It is worth

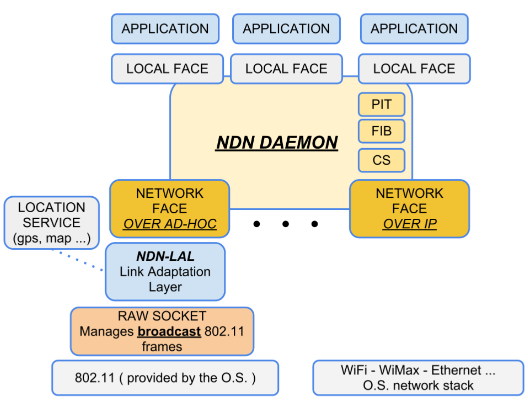

Figure 2: V-NDN logical architecture.

noting that the current IEEE802.11 standards practically do not support broadcast: broadcast transmissions are not protected (*i.e.*No RTS/CTS), and there are no collision avoidance/detection, nor acknowledgment/retransmission mechanisms. Thus wifi broadcast communications may suffer high loss rates. This is exacerbated by the nature of vehicular networks with short link durations and fast changing topologies [4]. To remedy this defect in today's WiFi we designed and implemented a simple set of mechanisms in the Link Adaptation Layer to reduce broadcast collisions in WiFi-based VANET communications; the details are omitted here.

[1] Note that, although the data may be produced at a given location its name identifies the data rather than the location.

III. Experimental Demonstration

V-NDN has been implemented as proof of concept prototype at UCLA and tested using UCLA Vehicular Testbed. Several experiments were performed during November and December 2012. We designed and implemented two NDN applications for the vehicular domain; **Traffic-Info** and **Road-Photo**. The Traffic-Info application emulates the request of traffic information at a specific area, any vehicle at the specified area or recently passed the area can send a reply. Likewise the road-photo application lets any car request a picture for a specific area and whichever car with the requested data can reply. The area is encoded in the data name, and is specified as intersections and streets stemming from that intersections *i.e.*/traffic/westwood-at-strathmore/ would refer to the traffic information from the area close to the Westwood-Strathmore intersection in the UCLA campus.

We conducted experiments to investigate V-NDN behavior for **V2V**, **I2V**, and **V2I** communications. Our results show that not only V-NDN enables vehicles to effectively communicate through any channels that become available, the system also exhibits a high resiliency to disruptions: the link duration is relatively short, the topology is constantly changing, and even the original data producers may go offline. Yet the in-network storage function of NDN, the cache in each vehicle, insures that data always gets propagated from the producer to other areas which enables high data availability.

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