Poster: Comparison of RAN Technologies for Delay-Tolerant Downloads in Vehicular Networks

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Abstract—**We study the performance of different radio access technologies for downloading delay-tolerant content in vehicular networks. Using realistic urban road network and vehicular mobility models, we show that short-distance, high data rate technologies can provide better average performance than large scale cellular networks for delay-tolerant downloads. The downside of such technologies is potentially long interruptions in connectivity, making them feasible only as part of a heterogeneous networking solution.**

I. Introduction

Providing wireless Internet access to vehicular networks still poses a significant challenge. The large-scale coverage offered by cellular systems forms an excellent foundation for low bitrate informational services and control traffic. However, applications such as video downloads will require higher throughputs than can easily be managed by especially macrocellular networks without significant densification [1], [2]. In this poster paper we present initial results from a performance comparison of radio access technologies for specifically delivering *delay-tolerant* content. Examples of such content include pre-caching of commonly visited web-pages as well as downloaded video formats such as utilized by Youtube.

For delivering delay-tolerant data, constant connectivity is not required. Instead, high instantaneous throughput with short, intermittent connections might be preferable if this leads to higher average throughput. Because of this, we focus on complementing the cellular network coverage with short-range high-bitrate technologies. As representative examples we have chosen modern Wi-Fi systems such as IEEE 802.11n and IEEE 802.11ac [4], and LMDS (local multipoint distribution service) like technologies providing very high bitrates in line of sight conditions using higher radio frequencies [3].

II. Modeling and Simulation

In order to obtain realistic results we have used street networks obtained from OpenStreetMap [5] as a foundation of both modeling vehicular mobility and the structure of the radio access networks (RANs) involved. We consider three RAN technologies in our study. LTE network is modeled based on existing cellular networks in terms of base station density, with performance characteristics modeled following the 3GPP recommendations. For Wi-Fi access we assume an outside deployment of IEEE 802.11n access points using both the 2.4 GHz and 5 GHz bands with deployment density similar to existing outside mesh network deployments. Similar path-loss based performance model as for the LTE case is used to obtain the achieved bitrates for the Wi-Fi links. Finally, for the LMDS / 60 GHz network we assume access points being deployed in the road infrastructure, and in particular street lights. Figure 1 shows an example snapshot from our simulations with simulation region in downtown in the city of Aachen, Germany, and with the access points for the different RANs shown. For performance modeling we use the technological properties of the Wireless HD standard as the baseline [7]. This ensures that our results are conservative, as upcoming 60 GHz wireless technologies are expected to have significantly improved performance figures compared to this already finalized standard. We assume that line of sight is needed for coverage for these higher frequencies, again to ensure conservative estimates. For mobility modeling we use the intelligent driver model of Sumo [6], in particular taking into account realistic behavior at intersections and traffic lights.

III. Results

Figure 2 shows the usage of the different RANs in the downtown Aachen scenario assuming a simple connection management scheme of handing over to the RAN offering best performance. We see that the LTE network is only used a small fraction of the time, with the shorter range technologies being utilized the largest amount of time. The actually realized throughput for these is highly varying, though. Figure 3 illustrates the downlink throughput for the 60 GHz downlink for a randomly selected vehicle throughout a single simulation run. We see that while very high throughput is occasionally achieved especially when the vehicle is at an intersection, these periods of high throughput are separated by complete lack of connectivity. Thus for general networking use such technologies are feasible only as part of a heterogeneous networking solution.

Despite the intermittent nature of the service offered by the 60 GHz "information showers" [3], the temporarily very high throughput results in significant increase in the overall downlink data rate observed in the simulations. Table I summarizes the performance achieved by different RANs in the downtown Aachen scenario in terms of the physical layer bitrate both for individual vehicles as well as for the network as a whole. We see that due to the relatively large number of intersections, the

(a) LTE (b) Wi-Fi (c) LMDS / 60 GHz

Fig. 1. Deployment models for the three considered radio access technologies.

60 GHz RAN has a dominant role in the overall throughput performance. Of course these results are highly idealized, and should be taken as initial results for guiding future research. In particular, the realism of the channel models used especially for the higher frequency technologies can be improved as more measurement data becomes available, and the handover latencies here assumed to be simple constants can be extended for full models of handover protocols. The most significant and important extension, however, would be to consider the backhaul capacity as well. For the very high data rates potentially offered by next generation RAN technologies with tiny cells, very high aggregate capacities are needed in the backhaul in order for the fixed network to cope with the volume of data transferred. The economic cost of such a backhaul can easily end up playing a dominant role in deployment considerations for wireless access infrastructure of future vehicular networks.

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TABLE I
Example results for the Aachen scenario.

	Downlink throughput	
Access technology	Aggregate	Per vehicle
Wi-Fi	816.7 Mbps	2.71 Mbps
LTE	210.4 Mbps	0.7 Mbps
LMDS / 60 GHz	196608 Mbps	653.2 Mbps

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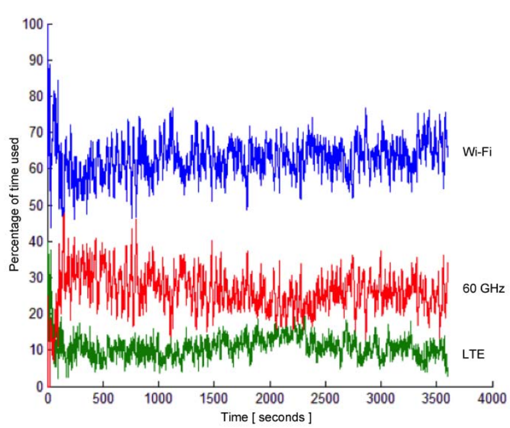

Fig. 2. Percentage of time given radio technology is used in the simulation.

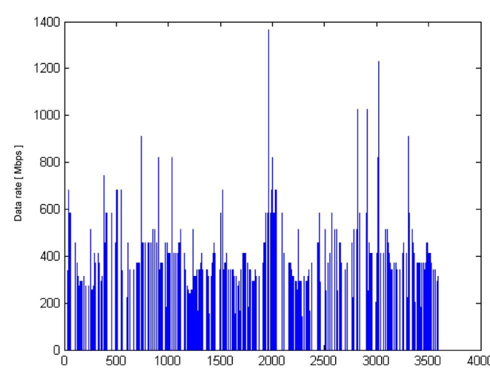

Fig. 3. Example throughput achieved using LMDS / 60 GHz hotspots.