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Leveraging on Electric Vehicles for Big Data Transfers

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Both governments and car manufacturers have recently made huge investments in electric vehicles (EVs) to turn them into a viable solution to cope with problems such as pollution due to internal combustion engines and increasing gas prices. For instance, the Renault-Nissan Alliance has invested 4 billion in EVs since 2010. In particular, they signed a partnership with Better Place, a company that operates battery swapping stations in both Israel and Denmark.

At the same time, 2.8 Zettabytes of content were created or replicated in 2012, and is forecasted to explode to 40 ZB by 2020, according to IDC [1]. Part of these numbers includes data generated by applications that can tolerate delivery delay in the order of hours or days (e.g., virtual machine migration in cloud architectures or content replication among a content provider network).

In this paper, we advocate the *opportunistic use of electric vehicles as carriers for delay-tolerant big data transfers*. In this scheme, EVs are equipped with one or more removable memory storage devices attached to the battery module. Vehicles use battery swapping stations as *offloading points* (OPs), where data are either loaded onto the vehicle, switched from one vehicle to another, or unloaded from the vehicle into the Internet. The decision on whether to load or not load data on the vehicles is made at the offloading points, depending on the destination of the data combined with the traffic expected on the roads adjacent to the OP. In a companion work, we focused on showing the feasibility of this scheme by considering a single road segment using the average daily traffic [2].

Here, we introduce a new formulation of the problem. We raise new challenges by taking into account new elements such as routing and data losses occurring when EVs show unexpected behaviors between two OPs (*data leakage*). As shown in Figure 1, we consider an overlay to formally define our framework, which is composed of the *underlaying road infrastructure* (layer 1) and the *network of offloading points* (layer 2).

We denote the underlaying road infrastructure by a directed graph $G^R = (N^R, L^R)$ where N^R refers to road junctions and swapping stations (nodes in the graph) and L^R refers to roads (links in the graph). We denote by $\mathcal{P}^R$ the set of all paths in the road infrastructure. We denote the network of OPs by another directed graph $G^O = (N^O, L^O)$, where N^O refers to the set of OPs and L^O refers to the set of "virtual" links between the OPs. We characterize the overlay with a mapping $\mathcal{M}$ of the virtual network of OPs onto a subset of the underlaying road infrastructure G^R:

$$\mathcal{M} : \begin{cases} \mathcal{M}_N : N^O \longmapsto N^O \subset N^R & \text{Node mapping} \\ \mathcal{M}_L : L^O \longmapsto \mathcal{P} \subset \mathcal{P}^R & \text{Link mapping} \end{cases}$$

Our problem is to jointly maximize the achievable data throughput and minimize the delivery delay by deciding, at each OP, if any given data should be loaded or not onto the EV. We propose that such a decision be based on the computation of a *confidence* value; this confidence, to be formalized and evaluated in a future work, is related to the probability that an EV will reach the destination OP using the attributes of the EV itself and of the nodes and links of the underlaying road path.

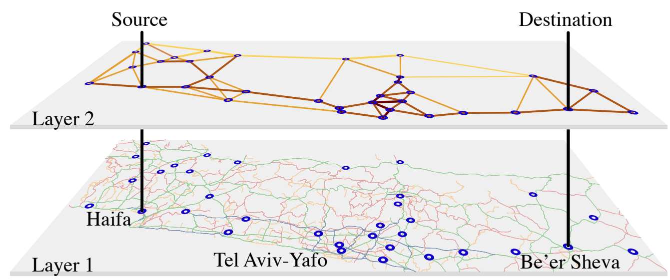

Fig. 1. Representation of the framework based on Better Place battery swapping stations locations in Israel, where data flow from Haifa (Source) to Be'er Sheva (Destination). The blue dots on the maps are the battery swapping stations (offloading points) and the palette of orange colors of the links between the OPs represents the strength of the links (the darker, the stronger) and was determined according to annual daily traffic measured in 2011.

References

[1] J. Gantz and D. Reinsel, "The digital universe in 2020: Big data, bigger digital shadows, and biggest growth in the far east," tech. rep., 2012.

[2] R. Gorcitz, Y. Jarma, P. Spathis, M. Dias de Amorim, R. Wakikawa, J. Whitbeck, V. Conan, and S. Fdida, "Vehicular carriers for big data transfers (poster)," in *Vehicular Networking Conference (VNC), 2012 IEEE*, pp. 109–114, 2012.