Router deployment of Streetside Parking Sensor Networks in Urban Areas

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Abstract

Urban traffic congestion has drawn a lot of attention to the parking seeking and management problem in recent years. Several parking solutions have been proposed to ease drivers' pain. In which, crowdsourcing-based is the easiest and cheapest to implement, however, its published content could be outdated or false due to insufficient participants or malicious users. In view of this fact, wireless networked sensors, which help obtain the real-time parking availability information and assure of the accurate measurement, is favorable for city municipalities. For example, the SFpark project in San Francisco and FastPrk in Barcelona both require the installation of large urban-scale parking sensors on street parking grid so as to monitor the occupancy information continously. These networked parking sensors form a wirless sensor network (WSN) and certainly inherit its energy and delay constraints. Such a so-called parking sensor network (PSN) is a specialized form of WSN and has the following characteristics: First, parking sensors are stationary and in-ground with a minimum adjacent distance. Second, the network topology is linear and limited by urban street layout. Third, the network traffic model is mainly affected by vehicles' activities, namely urban mobility. Fourth, the communication between in-ground sensors is restricted as well as the router's coverage due to various urban environment. Fifth, PSN, as a part of urban infrastructure which provides drivers real-time service, requires the robustness, acceptable information delay and extremely energy-efficiency.

With respect to these aforementioned characteristics, how to deploy such an efficient large-scale PSN in urban areas? Since the sensor technology is limited, each parking sensor can merely detect the arrival and departure of one vehicle at a time. That is to say, multiple detection is not available yet. Also, ”in-ground” parking sensor cannot integrate with a mini solar panel. From some existing implementation in SFpark's report in 2011, we consider that parking sensor is always one-hop away from the nearest router so that none of them has to forward any network packet to achieve the maximum energy-saving, but router does instead. Router and gateway are both full function devices, mounted in street lights or traffic signs and supplied by solar panel or power cable. Here we assume that a router is simply a relay in parking sensor network, and a gateway is the device

with richer functions which can distribute the collected information to mobile users or internet. Some studies have shown that the placement of routers and gateways shall be in crossroads considering the maximum coverage distance. Hence, we get the following questions: How many intersections shall be chosen to install routers? After that, how many routers shall be replaced by gateways which provide urban services to drivers directly?

The evaluation of our model is based on a real street parking map in Lyon, network traffic according to vehicle's interarrival, maximum capacity of routers and load balance. First, we obtain the latitude and longitude coordinates of all the intersections as nodes and then define the relationship between them from the parking map. Second, network traffic is strongly related to on-street occupancy estimation but still not available in Lyon due to the absence of detectors. However, from Vlahogianni's report with the data from the PSN in 4 different regions in Santander, we boldly assume the occupancy and vacant time are both Weibull distributed with a heavy tail (shape parameter is smaller than 1) and estimate the available time by the the average turnover of different parking policies. Hence, the router's traffic model will be the sum of the generated packets from different sensor nodes. Weibull distribution is much suiable to describe the burstiness of network traffic when the network density is high. The maximum capacity of routers is limited by bandwidth allocation method. With the above constraint, we define the equations and solve them in Sage (free open-source mathematics software system) with GLPK solver.

While taking the parking map in 2^{nd} arrondissement of Lyon in figure 1, the purple and yellow lines stand for the location of street parking with different pricing. After transferring the parking map to the adjacency matrix of graph $\mathsf{CITY}(\mathsf{V}, \mathsf{E})$, the result shows that the red crosses are the selected intersections for deployment of routers. The selection of gateway is not shown here due to the lack of traffic flow in Lyon which can help to choose appropriate position.

As the technology of PSN is more and more striking in different urban contexts, the large urban-scale deployment is the first concern to deal with. In this paper, we studied the router deployment with a real parking map in Lyon and other network parameters. The gateway deployment is also studied but lack of some vehicle trajectories in order to choose the most passing intersections. Our contribution is twofold. First, we introduced a model to assess the preliminary deployment of PSN as an engineer's guideline. Second, we studied a real parking map which can be considered later as a tutorial for the PSN deployment in Lyon. Other important parameters can also be included to improve the caluation accuracy and some better economic considerations, for example, link quality and traffic flow information. The work can also help the urban service providers to optimize their resouce allocation, and later for the information dissemination in vehicular networks or distributed algorithms.

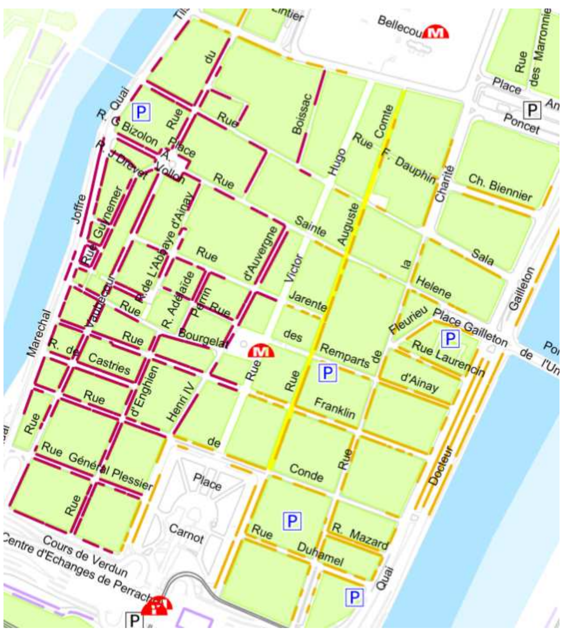

Figure 1: parking map

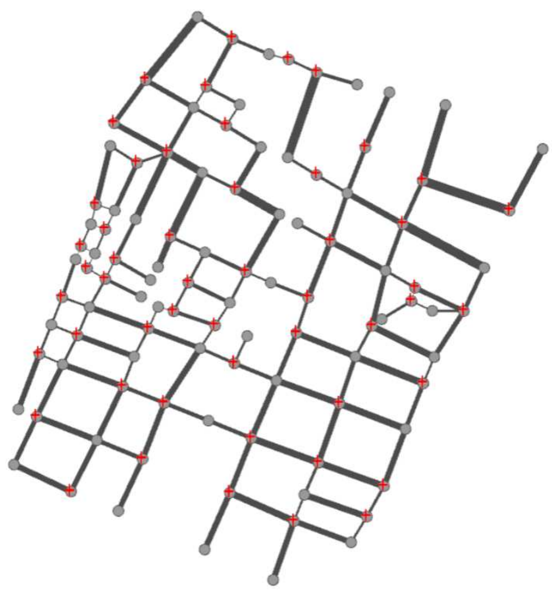

Figure 2: graph