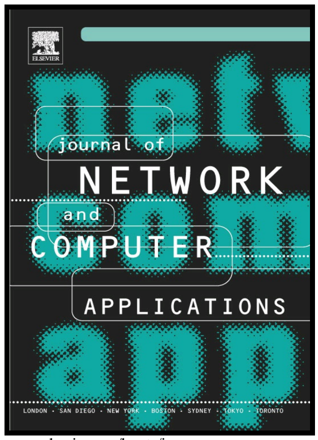
Author's Accepted Manuscript

MDP: Minimum Delay Hot-spot Parking

Peng Liu, Biao Xu, Guojun Dai, Zhen Jiang, Jie Wu



www.elsevier.com/locate/jnca

PII: S1084-8045(17)30098-X
DOI: http://dx.doi.org/10.1016/j.jnca.2017.03.002
Reference: YJNCA1874

To appear in: *Journal of Network and Computer Applications*

Received date: 4 October 2016
Revised date: 2 February 2017
Accepted date: 5 March 2017

Cite this article as: Peng Liu, Biao Xu, Guojun Dai, Zhen Jiang and Jie Wu MDP: Minimum Delay Hot-spot Parking, *Journal of Network and Compute Applications,* http://dx.doi.org/10.1016/j.jnca.2017.03.002

MDP: Minimum Delay Hot-spot Parking

Peng Liu*, Biao Xu *, Guojun Dai*, Zhen Jiang†‡, and Jie Wu†
*Institute of Computer Application Technology, Hangzhou Dianzi University
†Dept. of Computer and Information Sciences, Temple University
‡Dept. of Computer Science, West Chester University

***Abstract*—Hot-spot parking is becoming the Achilles' heel of the tourism industry. The more tourists that are attracted to the scenic site, the more often they will encounter a hassle of congestion to find a parking place; while those existing facilities for daily traffic are not supposed to support the excessive volume outburst. In this paper, we present a new parking guidance information system (PGI). By taking advantage of the technical advances of today in wireless communication of vehicular ad-hoc network, each vehicle will request and obtain a relatively fair opportunity to park. The competition and the corresponding allocation on the available slots emerging along the time scale are considered, in order to ensure that no vehicle enters a state of starvation. This is the first attempt to solve the spatiotemporal problem of resource assignment based on our extensive work on the Hungarian algorithm. The contribution as one part of the sustainable development of big historic cities is to minimize the idle driving and waiting, without increasing the parking supply, which could be costly and unnecessary to build in those urban areas. Both analytical and experimental results demonstrate the success of our effort, in terms of the average cruising/waiting time in each individual parking case and its upper bound. The data is compared with the best results known to date and shows a new direction to improve the resource assignment.**

Index Terms: Hungarian algorithm, parking guidance information system (PGI), traffic performance optimization, vehicular ad-hoc network (VANET), wireless communication.

I. Introduction

West Lake was made the UNESCO World Heritage Site in 2011 [16]. It has been the best-known hot-spot over centuries to attract many tourists. But during the travel season, such as the Golden Week Holiday, a high parking volume usually exceeds the capability of existing facilities, incurring the so-called hot-spot parking problem (e.g., [30]).

The delay in searching and occupying a parking slot might cause congestion and environmental issues as indicated in [19]. The time includes the period a vehicle drives towards the target place according to the reservation. It also includes the idle driving around the scenic site when the vehicle waits for the vacant slot to emerge. In our hot-spot parking, such a delay has a direct impact on municipal reputation and revenue, while tourism has become one of the world's fastest growing industries as well as the major source of earning and employment for many developing countries.

Unlike the problem of residential parking [1] that can resort to new construction of parking facilities [25], this is a resource allocation problem, but in an extremely critical circumstance where those slots constituted for daily traffic are required to allocate for the volume outburst (e.g., [35]). When the slots currently available are not enough to support all parking demands, the capacity of each place growing along the time scale must be considered for the vehicle to capture the future parking opportunity. This introduces the spatiotemporal resource allocation problem discussed here.

Many existing parking guidance information systems (PGI), either reservation based (e.g., [19]) or greedy (e.g., [8]), provide parking guidance by allowing every vehicle to reach the nearest available slot. However they overlook the competition of limited slots in the resource-critical scenarios and cannot provide a fair chance for those runner-ups to reenter the parking competition. The corresponding slot allocation to the closest vehicle ignores the fact that many vehicles behind it are runner-ups from the early parking competitions, which have cruised for a long time since they lost the parking opportunities. Due to the distance existing for a runner-up to approach the next available slot, its priority of parking reservation will be depleted by any vehicle ahead that newly joins the competition. Such a depletion will force those runner-ups back to the idle driving. As often seen in the reality, when an overwhelming amount of vehicles frequently join the parking competition from everywhere, one loss usually leads to a sequence of consecutive losses and even a starvation.

Remark. Considering that the above starvation creates an endless delay effect, the aforementioned spatiotemporal resource assignment (dispatching all m vehicles to n places where $m >> n$) becomes non-trivial. Existing PGI strategies (e.g., [8, 12, 19, 21]) or similar assignment-based schemes for vehicle dispatching (e.g., [5, 18, 23, 24]) are applied on a sufficient number of targets only. As we will demonstrate later, the starvation cannot be avoided completely when the demands exceeds the supply.

In this paper, we present a solution for the PGI system under its common structure (e.g., [19, 31]). The proposed assignment of parking slots is derived from the Hungarian Algorithm [14]. We first consider the extension from the solution for the traditional quadratic assignment problem (QAP) [32]. Such a weighted bipartite matching takes both weights on edges and vertices but does not increase any time complexity as we will prove it later. Then we present our assignment by utilizing the capacity growth along the time scale. The corresponding complexity is bounded within a linear-time incremental structure, in order to achieve a practical system implementation. As the result, the total time needed for all parking processes (i.e., the average of an individual case) can be minimized in both the above assignment solutions. Meanwhile, the worst case can be bounded within a certain period. Such minimum parking scheme is denoted by MDP. Its key is to capture the potential