Demo Abstract: SmartParcels - A What-If Analysis and Planning Tool for IoT-Enabled Smart Communities

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ABSTRACT

We present a tool, SmartParcels, that assists urban planners in deploying applications in smart communities. The deployment involves the mapping from information units (generated from data analytics), infrastructures (sensing, networking, and computing devices), to geophysical locations. SmartParcels provides two design schemes, clean-slate (planning from scratch) and retrofit (exploiting existing devices). Moreover, SmartParcels allows users to control the trade-off between optimality (sensing coverage and accuracy) and efficiency (execution time) for the design results. Finally, users can perform a dynamic traffic simulation with different background network traffic to study the result plan's ability to handle the community's dynamic traffic. SmartParcels then allows users to fine-tune the results according to the user's domain knowledge.

CCS CONCEPTS

• **Software and its engineering → Layered systems**.

KEYWORDS

IoT planning, urban planning tool, placement problem

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1 INTRODUCTION

Smart communities emerge with the rapid growth of consumer-grade sensing, communication, and computing devices. The devices are instrumented in the communities and form an IoT ecosystem to provide intelligent applications, such as (i) public safety, e.g., smart streetlights, (ii) environmental monitoring, e.g., air quality and noise, and (iii) hazard detection, e.g., wildfire and gunshot. The smart city market is at $83.9 billion in 2019, and it is expected to keep growing at the rate of 24.7% annually between 2020 and 2027 [2]. Hence, the demand for unified IoT planning is urging, especially when several stakeholders, e.g., governments, business owners, residents, involve in such smart spaces.

However, existing urban planning tools, such as umi [3] and CitySim [4], are incapable of creating a plan, i.e., selecting and deploying devices for applications required by smart communities. Umi and CitySim aim to reduce the environmental impacts, such as energy consumption, from buildings/structures. What is missing for planning smart communities is to facilitate intelligent applications via instrumenting heterogeneous sensing and communication devices. Moreover, stakeholders usually deploy devices individually and manually, which leads to an ad-hoc and sub-optimal plan.

In this work, we prototype SmartParcels [1], a tool for urban planners to design smart communities cost-effectively. SmartParcels allows users to input the related profile data, such as locations requiring applications and for instrumenting devices, costs, budgets, etc. Besides, SmartParcels provides a control knob for users to trade off the optimality (coverage and accuracy) and efficiency (execution time) while generating the plan. Finally, two types of design are provided, clean-slate (builds the plan from scratch) and retrofit (exploits existing devices to reduce costs). In the demonstration, we will show how to derive results from different settings/scenarios.

2 APPROACH AND SYSTEM OVERVIEW

Fig. 1 shows the overview of SmartParcels [1], which divides the input into layers of information, infrastructure, and geophysical location. SmartParcels outputs a planning graph consisting of information and infrastructure layer, which indicates the mapping from information units to infrastructures and then to geophysical locations. A ***database*** (MongoDB) stores the inputs for each user; meanwhile, a ***data handler*** at the front-end provides users the ability to input and modify the data. The ***planning tool-kits*** provides the following design schemes: (i) ***clean-slate***, which builds the plan from scratch, (ii) ***retrofit***, which exploits the existing devices for the plan, and (iii) ***optimality control***, which trade offs the optimality and execution time. At the back-end, a ***design agent*** processes the user's queries to execute corresponding modules for each scheme. First, ***Geophysical Mapping selection (GM)*** identifies a set of possible locations to install devices, and then ***Planning Graph generation (PG)*** generates a planning graph by examining GM's outputs to maximize the total utility (coverage and accuracy)

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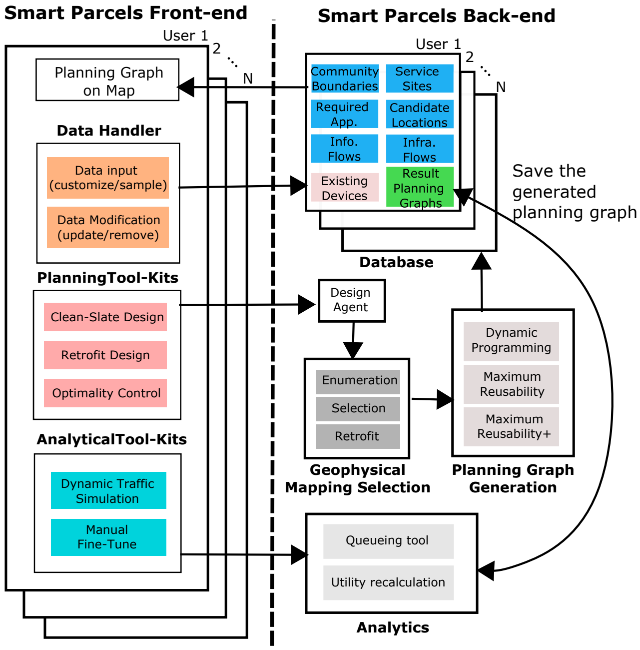

Figure 1: System architecture of SmartParcels.

under limited budgets (deployment and operational). By using different combinations of GM and PG models can derive various levels of optimalities [1]. SmartParcels also provides ***analytical tool-kits***, allowing users to perform quick analysis on the result planning graph. First is the ***dynamic traffic simulation*** that analyzes the planning graph's ability to handle different background network traffics by a ***queuing tool***. Besides, SmartParcels allows users to ***fine-tune*** the result ***manually***, such as adding/moving/deleting a device. Then, the utility is recalculated by SmartParcels.

3 DEMONSTRATION

We use two real settings for the demonstration: (i) a smart streetlights testbed at National Tsing Hua University (NTHU), Taiwan and (ii) four communities in Irvine, California, USA.

1. **NTHU.** The testbed includes 8 smart streetlights (in mirrored L-shape region in Fig. 2) and 63 regular streetlights. The following devices are installed on the smart streetlights: (i) 5 cameras, (ii) 1 motion sensor, (iii) 4 WiFi routers, and (iv) 2 edge servers. An auto-dimming application is deployed for the streetlights to save energy by image-based object detection and motion sensor detection methods. The streetlights are both ***candidate locations***, locations for installing devices, and ***service sites***, locations requiring the application.
2. **Irvine.** The four communities are (i) Irvine Spectrum, an outdoor shopping center, demanding for gunshot detection, (ii) Quail Hill, a residential area near a highway, demanding for air quality and noise monitoring, (iii) Shady Canyon, a residential area next to a wildland, demanding for wildfire detection and air quality monitoring, and (iv) Shady Canyon Open Space Preserve, a wildland, demanding for wildfire detection. Shady Canyon and Shady Canyon Open Space Preserve are identified as *very high fire hazard severity zones* by Orange county fire authority. We assume public facilities, such as traffic signals, power poles, as candidate locations.

We then demonstrate SmartParcels in the following scenarios.

1. **Clean-slate in Irvine.** Each community is divided into several grids, and the center of each grid represents a service site. SmartParcels then deploy the applications by instrumenting the infrastructures to the candidate locations with the clean-slate scheme.
2. **Retrofit at NTHU.** SmartParcels exploits the existing devices on smart streetlights at NTHU to implement the auto-dimming application. Different from the clean-slate scheme, the exploitation of existing devices can reduce the costs and further increase the utility for the output planning graph.
3. **Optimality control at NTHU.** We show that SmartParcels can derive the optimal solution by using enumeration for GM and Dynamic Programming (DP) for PG. Besides, the trade-off between optimality and efficiency is shown by executing maximum reusability+ for PG, which executes DP for a user-specified period, and then uses maximum reusability.
4. **Analytical tool-kits at NTHU.** After deriving the result planning graph from SmartParcels at NTHU, the dynamic traffic simulation evaluates the planning graph's capability of holding different types/distributions of background network traffic. Furthermore, users can manually fine-tune the result planning graph according to the interested region's traffic pattern and their domain knowledge.

Fig. 2 shows a sample result at NTHU, where 3 cameras, 2 motion sensors, 2 WiFi APs, and 2 edge servers are deployed. Then the deployed devices form a planning graph, where red circles and lines represent devices and the connectivity between devices.

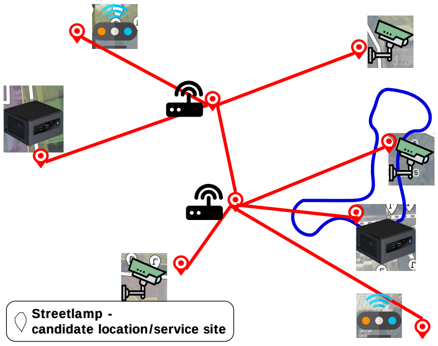

Figure 2: Sample result at NTHU with streetlamps as inputs.

REFERENCES

[1] Chang, T.-C., et al. Smartparcels: Cross-layer iot planning for smart communities. In *IoTDI* (2021).

[2] Grand View Research. Smart cities market size & analysis, industry report, 2020-2027, 2020. https://www.grandviewresearch.com/industry-analysis/smart-cities-market.

[3] Reinhart, C., et al. Umi-an urban simulation environment for building energy use, daylighting and walkability. In *13th Conference of International Building Performance Simulation Association, Chambery, France* (2013), vol. 1.

[4] Walter, E., et al. A verification of citysim results using the bestest and monitored consumption values. In *Proceedings of the 2nd Building Simulation Applications conference* (2015), Bozen-Bolzano University Press.