Towards Secure Smart Parking System Using Blockchain Technology

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***Abstract*—Over the last few years, finding vacant parking spaces has become a hassle for drivers especially in crowded cities. This problem leads to wasting drivers' time, traffic congestion, and air pollution. Recently, smart parking systems aim to address this problem by enabling drivers to have real-time parking information about vacant parking spaces. However, the existing parking systems rely on a central third party to organize the service, which makes them subject to a single point of failure and privacy breach concerns by both internal and external attackers. In this paper, we propose a secure smart parking system using blockchain technology. Specifically, a consortium blockchain is made of parking lots to ensure security, transparency, and availability of the parking system. Then, to protect the drivers' location privacy, we use cloaking technique to hide the drivers' locations. The blockchain validators return available parking offers with in the cloaked area. Finally, the driver selects the best offer and makes reservation directly with the parking lot. Evaluations are conducted to evaluate the proposed scheme, and results indicate practicality of our scheme.**

***Index Terms*—Smart parking, blockchain, and security and privacy preservation.**

I. Introduction

With the increasing number of vehicles over the last few years, finding a vacant parking space has become a major problem for drivers especially in crowded cities. According to the report in [1], more than 1.3 million drivers struggle every day to find available parking spaces in Shanghai city. This problem can lead to wasting drivers' time, traffic congestions, and extra fuel consumption. For example, in Cairo, Egypt, drivers waste more than 20 minutes each time they search for available parking spaces. In addition, 30 percent of traffic congestions are attributed to the problem of finding available parking spaces [2]. Moreover, in Los Angeles, the amount of gasoline consumed in finding vacant parking spaces is around 47,000 gallons per year, producing 728 tons of carbon dioxide per year [3].

Due to the advancement in wireless communications and Internet of Things (IoT) devices [4], smart parking systems have been emerging to facilitate finding available parking spaces. Specifically, an IoT device is installed in each parking spot to detect the availability of the spot and send status information to a service provider. The service provider allows drivers to check the available parking spaces and make online reservations.

However, the existing smart parking systems suffer from critical security and privacy concerns. These systems [5], [6] rely on a centralized authority to manage parking services, which makes them prone to an inherent single point of failure and distributed denial of service (DDoS) attacks [7]–[9], which could disrupt the parking services. Moreover, driver's sensitive information is stored on the centralized service provider, which has the risk of privacy breaches by both internal and external attackers.

In contrast to existing centralized solutions, in this paper, we propose a blockchain-based smart parking management system. First, a consortium blockchain created by different parking lots is introduced in order to securely store parking availability, rates, and available services (e.g., charging for electrical vehicles). Each parking lot sends its parking offers to the blockchain network, which records the offers in a distributed shared ledger. Then, a driver sends a transaction to the blockchain network to retrieve parking offers in a cloaked cell to preserve his/her privacy. Then, the driver selects the best offer based on his preference, such as, parking location, price, services, etc. Finally, the driver pays for the parking services using Bitcoin to preserve privacy.

II. System Architecture

As depicted in Fig. 1, the considered system architecture has the following entities.

- *Key Distribution Center (KDC)*. The KDC is a government agency that is responsible for registering parking lots.
- *Consortium Blockchain Network*. At the heart of our system is the blockchain network that process and records all parking offers transactions. The consortium blockchain network is managed by authorized parking lots.
- *Parking Lots*. Parking lots periodically send parking offers to the blockchain network.
- *Drivers*. Each driver can use his/her smartphone to reserve a parking space.

III. Proposed Scheme

In this section, we present our blokchain-based smart parking scheme. The blockchain network in our scheme consists of authorized validators (parking lots), which manage the parking services.

Our scheme has two main phases: submitting parking offers and parking offers retrieval and reservation.

A. Submitting Parking Offers Phase

In this phase, a parking lot $\mathcal{PL}_j$ submits its parking offers to the blockchain network.

First, we assume the area $\mathcal{A}$ (e.g., a city) where the smart parking system will be deployed, is divided into a set of cells $C = \{C_1, C_2, ,,, C_m\}$.

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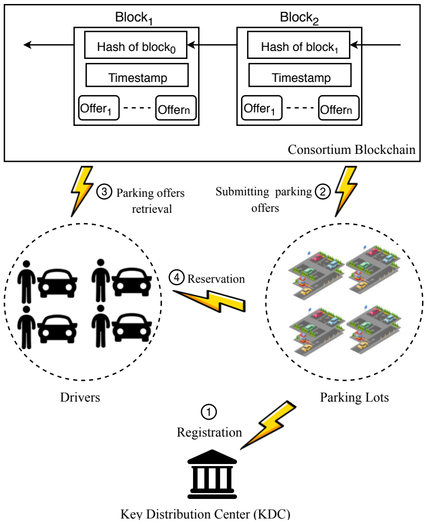

Figure 1: System Architecture.

To submit a parking offer, each parking lot $\mathcal{PL}_j$ constructs a blockchain transaction that includes the following information: identity ID_j, certificate $Cert_j$, location loc, cell identifier C_m, number of available spaces $\mathcal{N}$, available services $\mathcal{S}$ (e.g., charging station, car wash, etc.), parking price p, and availability times t_v.

$$Offer :< ID_j, Cert_j, loc, C_m, \mathcal{N}, \mathcal{S}, p, t_v > \quad (1)$$

Note that each transaction offer is signed using the secret key of the $\mathcal{PL}_j$ and is broadcasted on the blockchain network. The validators of the blockchain network verify the parking offers by verifying the $\mathcal{PL}_j$ signatures. Then, the validators add the offers to the ledger based on the cell identifier C_m. Then, a secure consensus protocol is run by all validators to agree on the content of the ledger. For example, the validators run the Raft consensus algorithm. The Raft is a leader-based algorithm, where the consensus is achieved via a leader election. The leader is responsible for updating the ledger content and has the right to append a new block to the existing chain of blocks. The Raft provides fast consensus time for the blockchain nodes compared to proof-based consensus algorithms, such as proof of work or proof of stake [10].

B. Offers Retrieval and Parking Reservation Phase

In this phase, a driver $\mathcal{D}$ retrieves available parking offers in the desired cloaked cell from the blockhain and make online reservation.

The driver $\mathcal{D}$ sends a query to the slot leader of the blockchain network in order to download all parking offers in the desired cloaked cell. Note that retrieving the parking offers in a cloaked cell preserves the privacy of the driver's desired parking location.

After retrieving the parking offers in the desired cloaked cell, the driver $\mathcal{D}$ selects a parking offer based the distance from the desired destination, price, available services, etc. Then, the driver uses his smart phone to contact the parking lot and make reservation. After the reservation, the driver $\mathcal{D}$ drives his/her vehicle to the selected parking lot and park his/her vehicle. At the end of the parking period, the driver can use any existing cryptocurrecny system (e.g., Bitcoin [11]) to pay the parking fees. The Bitcoin is used for parking payments in order to preserve drivers' privacy since using credit/debit card payment allows banks to track users' locations from the transactions they make.

IV. Performance Evaluation

In this section, we discuss the storage cost overhead (i.e., size of parking offers) on the validators. Based on the information included in the parking offer, the size of the offer should be equal to 110 bytes. We assume the number of the submitted offers is 500, the size of block header and tailer is 80 byte, and blocks are generated frequently every 5 minutes. Then, the size of the ledger after one year would be $(110 \times 500) \times 12 \times 24 \times 365 = 5.8$ GB. For these parameters, we assume that parking lots free up their storage on annual basis to reduce the storage overhead. Note that the data content of the blocks needs to be backed up and the storage should be released periodically.

V. Conclusion

In this paper, we have proposed a blockchain-based smart parking system using blockchain. A consortium blockchain is created by parking lots to store the parking offers on a shared ledger to ensure security, transparency, and availability. To preserve the drivers' location privacy, we used cloaking technique to hide the drivers' exact parking locations. In our future work, we will implement the proposed scheme using Hyperledger Fabric that interacts with drivers through a mobile application. Also, we will evaluate the implemented system efficiency in terms of on-chain performance.

VI. ACKNOWLEDGEMENT

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References

[1] South china morning post. [Online]. Available: https://www.scmp.com/
[2] T. Giuffrè, S. M. Siniscalchi, and G. Tesoriere, "A novel architecture of parking management for smart cities," *Procedia-Social and Behavioral Sciences*, vol. 53, pp. 16–28, 2012.
[3] D. C. Shoup, "Cruising for parking," *Transport Policy*, vol. 13, no. 6, pp. 479–486, 2006.
[4] M. Baza, M. Nabil, N. Lasla, K. Fidan, M. Mahmoud, and M. Abdallah, "Blockchain-based firmware update scheme tailored for autonomous vehicles," *Proc. of the IEEE Wireless Communications and Networking Conference (WCNC), Marrakech, Morocco*, April 2019.
[5] L. Zhu, M. Li, Z. Zhang, and Z. Qin, "ASAP: An anonymous smart-parking and payment scheme in vehicular networks," *IEEE Transactions on Dependable and Secure Computing*, in press 2018.
[6] J. Ni, K. Zhang, Y. Yu, X. Lin, and X. S. Shen, "Privacy-preserving smart parking navigation supporting efficient driving guidance retrieval," *IEEE Transactions on Vehicular Technology*, in press 2018.
[7] M. Baza, M. Mahmoud, G. Srivastava, W. Alasmary, and M. Younis, "A light blockchain-powered privacy-preserving organization scheme for ride sharing services," *Proc. of the IEEE 91th Vehicular Technology Conference (VTC-Spring), Antwerp, Belgium*, May 2020.
[8] M. Baza, N. Lasla, M. Mahmoud, and M. Abdallah, "B-ride: Ride sharing with privacy-preservation, trust and fair payment atop public blockchain," *arXiv preprint arXiv:1906.09968*, 2019.
[9] M. Baza, A. Salazar, M. Mahmoud, M. Abdallah, and K. Akkaya, "On sharing models instead of data using mimic learning for smart health applications," *Proc. of the IEEE International Conference on Informatics, IoT, and Enabling Technologies (ICIoT'20) , Doha, Qatar*, Feb. 2020.
[10] D. Ongaro and J. Ousterhout, "In search of an understandable consensus algorithm," in *proc. of USENIX Annual Technical Conference (USENIX ATC 14)*, pp. 305–319, 2014.
[11] S. Nakamoto, "Bitcoin: A peer-to-peer electronic cash system," 2008.

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