VirCh: Virtual Mobile Charger-based Wireless Power Transfer for Large-Scale Internet-of-Things Systems

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1. Introduction

Wireless power transfer has emerged as a promising technology to prolong the lifetime of Internet-of-Things (IoT) systems by wirelessly charging distributed IoT devices. To improve its effectiveness, mobile charger (MC) is employed to travel inside an IoT system. However, most of current mobile charging algorithms assume that an MC has infinite energy reserve to charge all deployed IoT devices, which is impractical particularly for large-scale IoT systems [1]. While the solution in [2] considers this drawback and employs multiple energy-constrained MCs , it neglects the relative locations of IoT devices, which dramatically degrades system charging efficiency. Therefore, this paper presents a virtual mobile charger-based wireless power transfer strategy, *VirCh*, that aims to improve the charging efficiency for a large-scale IoT system composed of a base station (BS), multiple energy-constrained MCs, and massive IoT devices. *VirCh* dispatches several virtual MCs to charge the IoT devices near the BS while employing other MCs to move along the shortest Hamiltonian cycle to charge the remote ones.

2. Design of *VirCh*

We consider massive IoT devices distributed around a BS in an IoT system. Multiple energy-constrained MCs are employed to guarantee full charging of all the deployed devices. Particularly, MCs start from the BS, fully charge each device, and return to the BS. To improve the system charging efficiency, *i.e.,* the ratio between obtained energy at devices and consumed energy by MCs, we adopt minimum spanning tree-based algorithm to find the global shortest Hamiltonian cycle (GSHC) according to the topology of the IoT system. Based on it and MC energy constraint, we aim to *find a local Hamiltonian cycle for each MC whose energy is sufficiently transferred to the devices before returning to the BS.*

Fig. 1 shows a topology example of an IoT system. The number $s_{(\cdot)}$ associated with each device indicates its order for being charged along the GSHC. To describe the details of *VirCh*, we take the charging path of MC 2 in Fig. 1 as an example. Given that $L(s_8, s_9) + L(s_9, s_{10}) > L(s_8, s_{10}) + 2L(\text{BS}, s_9)$ and $L(s_8, s_{10}) + L(s_{10}, s_{11}) > L(s_8, s_{11}) + 2L(\text{BS}, s_{10})$, we observe that when MC 2 completes the charging of s_8, it does not need to charge s_9 along the GSHC. Instead, it directly travels to s_{10} while the BS employs another MC to fully charge s_9 and return. Similarly, MC 2 can pass s_{10} and turn to charge s_{11} while the BS employs another MC to cover s_{10}. As a result, we can then *virtualize* the use of the two additional MCs and finally shorten the GSHC path of MC 2 to the one shown in Fig. 1. In this way, we can also find shorter charging paths than the GSHC for MC 1 and MC 3, thereby reducing the total charging path length for system charging efficiency boost.

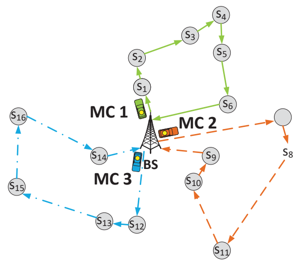
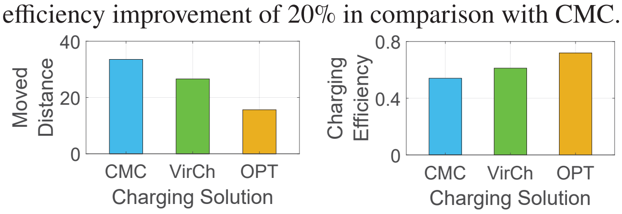


Fig. 1: *VirCh* example.

3. Preliminary Results

We conduct MATLAB-based simulation to compare *VirCh* with CMC, the most similar work to ours [2]. We also refer to the theoretical boundary (OPT) as our performance benchmark. Fig. 2 (a) shows that *VirCh* < CMC in terms of the totally moved distance of dispatched MCs. From Fig. 2 (b), we observe that *VirCh* achieves the system charging efficiency improvement of 20% in comparison with CMC.



(a) Totally moved distance of MCs (b) System charging efficiency

Fig. 2: Performance comparison among charging solutions.

4. Conclusion

This paper has proposed *VirCh*, a novel wireless power transfer strategy for large-scale IoT system charging based on multiple MCs. Simulation results show that *VirCh* can significantly enhance the charging efficiency of a whole system.

References

[1] N. Wang, J. Wu, and H. Dai, “Bundle charging: Wireless charging energy minimization in dense wireless sensor networks,” in *Proc. of IEEE ICDCS*, July 2019.

[2] S. Zhang, J. Wu, and S. Lu, “Collaborative mobile charging,” *IEEE Trans. Comput.*, vol. 64, no. 3, pp. 654–667, Mar. 2015.

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