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PPDO: a privacy-preservation-aware delay optimization task-offloading algorithm for collaborative edge computing

Key words: Collaborative edge computing; Task offloading; Privacy protection; Markov decision process

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Motivation

1. By appropriately offloading tasks, collaborative edge computing (CEC) can greatly improve the performance of mobile edge computing (MEC). However, most of these studies either focused on finding trade-off between cost optimization and privacy protection, or concentrated on protecting location privacy by ignoring the importance of usage pattern during offloading.

2. To ensure privacy during offloading, it is essential to enhance the protection of both location and usage pattern by integrating the concept of privacy tasks. Also, due to the high time consumption of traditional Markov decision processing (MDP), it is important to optimize the efficiency of the proposed algorithm.

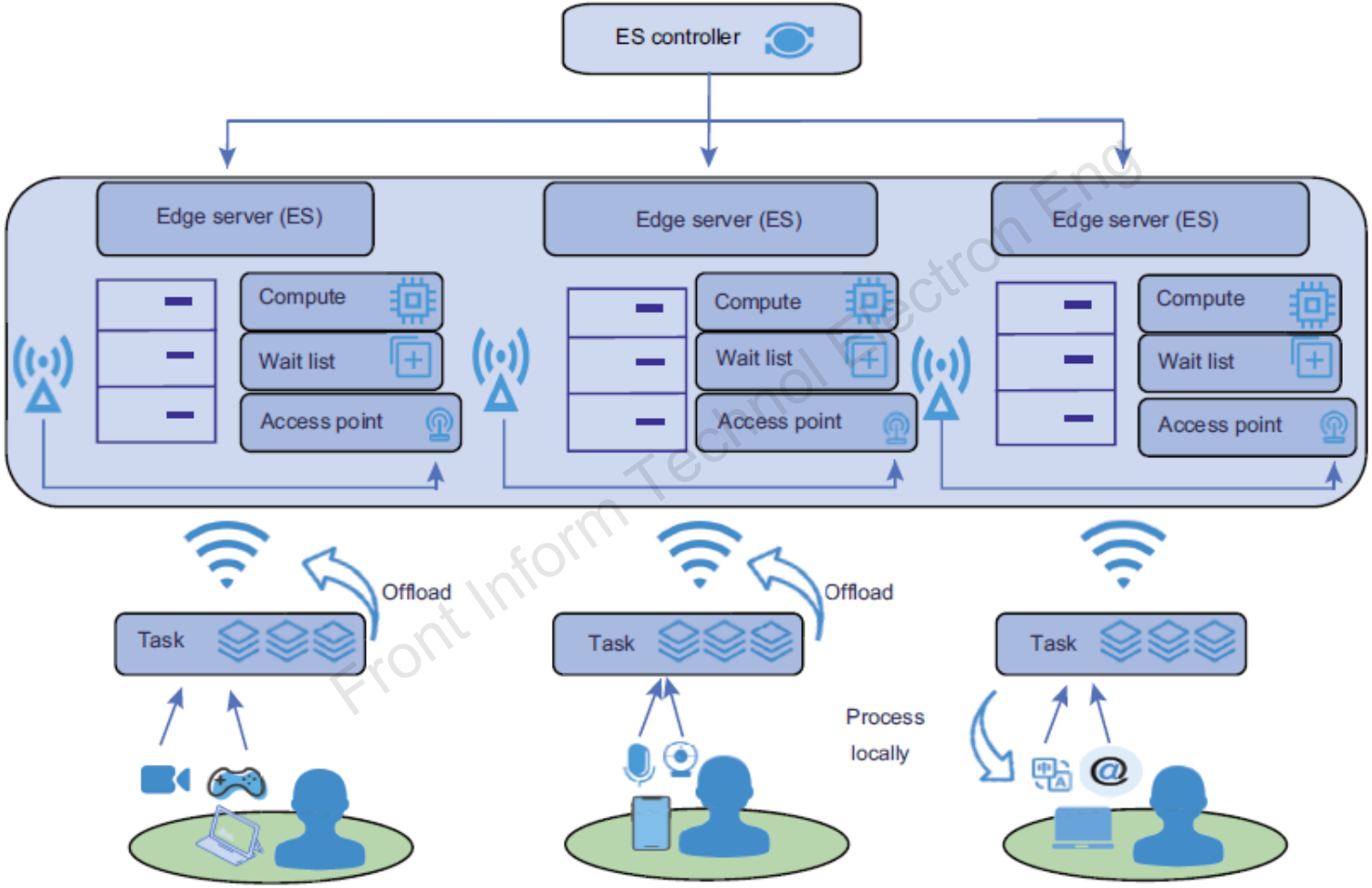
Main idea

1. We establish a multi-user CEC that minimizes the delay of task offloading without compromising privacy preservation. Specifically, we enhance the privacy protection scheme with respect to location and usage pattern. We also define privacy tasks to interfere with edge server (ES) operations to prevent privacy leaks.

2. We develop an improved MDP-based privacy-preservation-aware task-offloading algorithm in CEC under the enhanced privacy protection scheme by eliminating the redundant action set.

3. We conduct a simulation using the edge user allocation (EUA) dataset. Several competitive algorithms are selected for comparative purposes. The results demonstrate that the proposed algorithm outperforms comparative algorithms in minimizing delay under the consideration of privacy preservation.

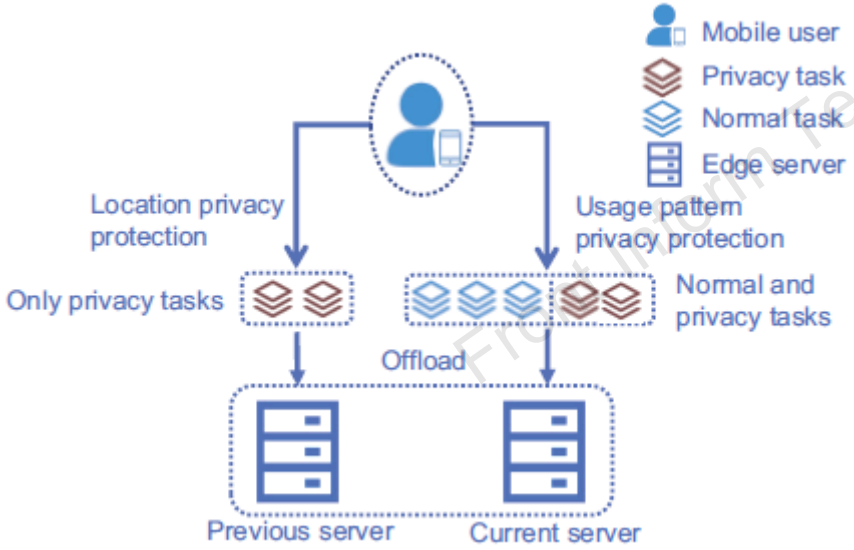
Problem formulation



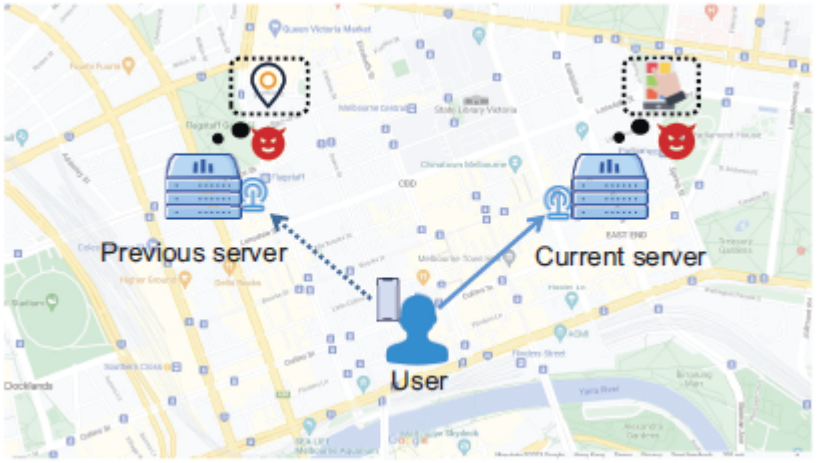
Overview of the collaborative edge computing systems with multi-mobile users, tasks, and edge servers

Method

1. Privacy-task-based privacy preservation: To protect the users' location and usage pattern privacy during task offloading in CEC, we implement privacy tasks, which are offloaded to interfere with the ES responsible for task execution, inhibiting the attacker from analyzing privacy information.



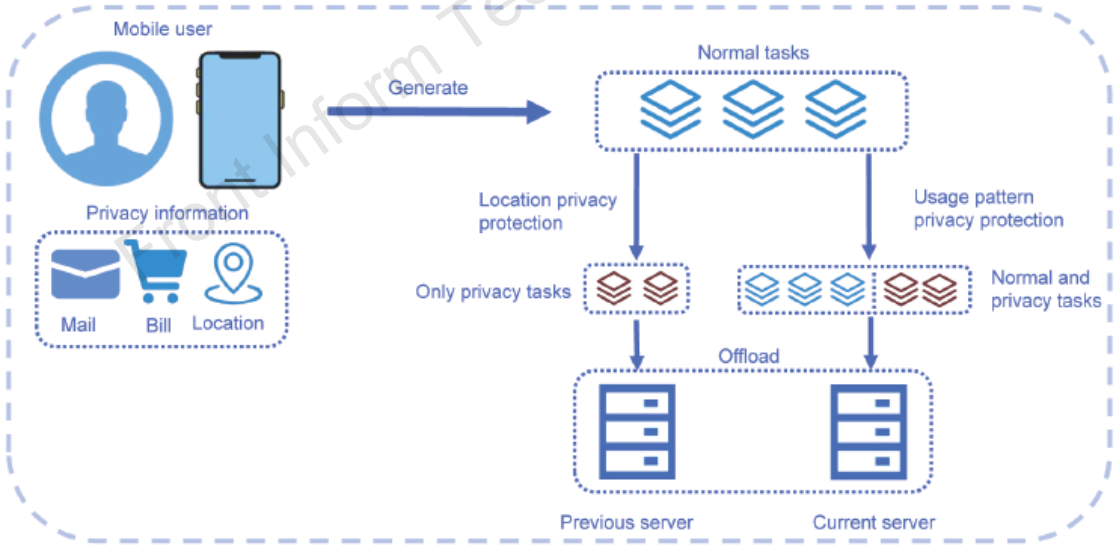
Privacy task protection for location privacy and usage pattern



Location and usage pattern leakage risks

Method

2. Location privacy protection: Edge servers can infer user location information through offloaded tasks.
3. Usage pattern privacy protection: The privacy tasks interfere with the edge severs during the evaluation of task data, thereby protecting the usage pattern.



A general procedure on privacy-task-based privacy preservation

Method

4. In the MDP model, because the CEC system has to engage in the collaborative computation of local devices and ESs, we implement privacy tasks to guarantee the protection of privacy. This leads to exploration with a high temporal overhead during policy iteration. To address this issue, we accelerate the policy iteration by reducing action set *A*.

Algorithm 3 Improved policy iteration algorithm

Input: action set A, task number u_k, edge CPU capability f^{ES}, and local CPU capability f^{local}
Output: updated action set A
loop
  for all $a \in A$ **do**
    if $u_k \leq u_{\mathrm{thr}}$ or $f^{\mathrm{ES}} \geq f^{\mathrm{ES}}_{\mathrm{thr}}$ **then**
      Remove action a for local execution of tasks
    end if
    if $f^{\mathrm{local}} \geq f^{\mathrm{local}}_{\mathrm{thr}}$ **then**
      Remove action a for $d_{ij} > d_{\mathrm{thr}}$
    end if
  end for
  return $A \leftarrow A^*$
end loop

Major results

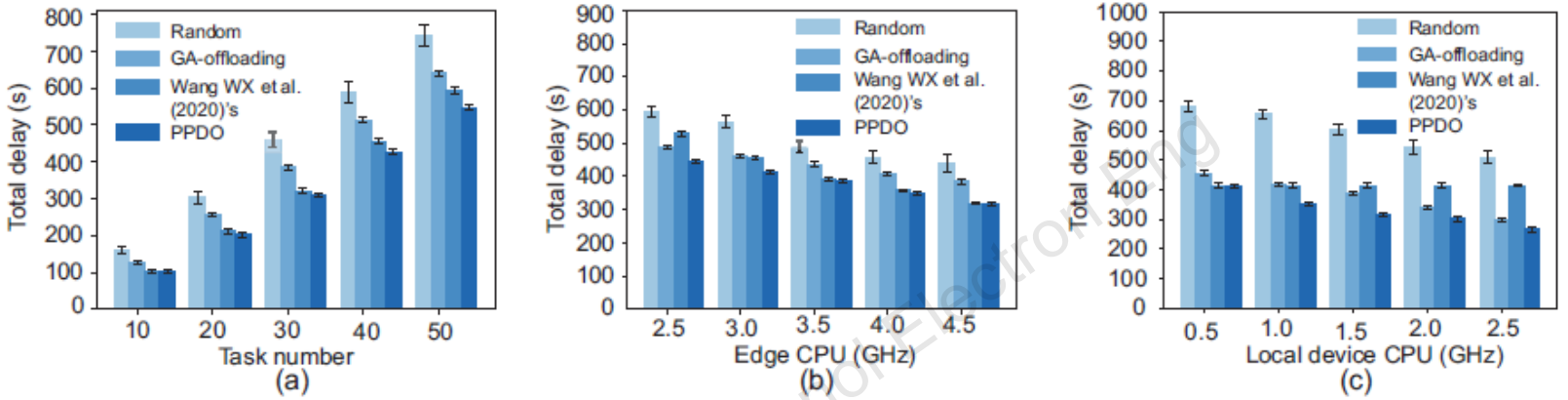


Fig. 5 Impact of the number of tasks (a), CPU of the ES (b), and CPU of the local device (c) on the total delay

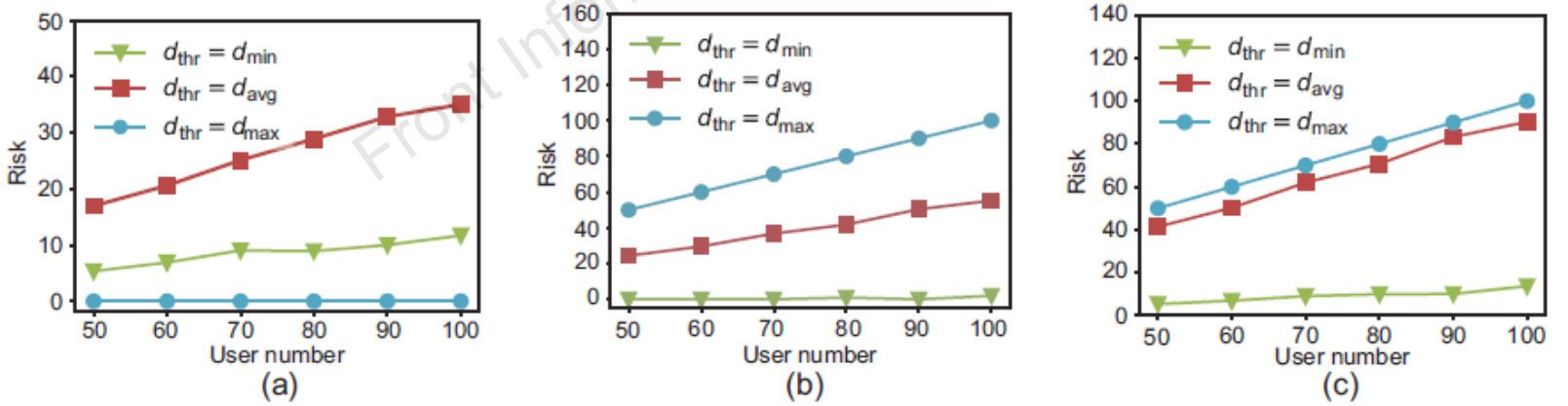


Fig. 6 Risks of privacy leakage under different $d_{\mathbf{thr}}$'s: (a) risk of usage pattern privacy leakage; (b) risk of location privacy leakage; (c) total risk of privacy leakage

Conclusions

1. In contrast to prior studies, we investigated the problem of privacy preservation with the objective of minimizing the total delay in task offloading. The preservation scheme calculated the privacy leakage risk and offloaded privacy tasks accordingly. Subsequently, the issue of minimizing the delay incurred by task offloading was formulated as an MDP problem.

2. We developed a policy-iteration-based privacy-preservation-aware offloading algorithm to reduce the total latency of task offloading while protecting user privacy. Furthermore, we extended the proposed algorithm by decreasing the exploration time in the action set.

Chao JING received the PhD degree in computer science from Shanghai Jiao Tong University, China in 2014. From 2017 to 2018, he was a visiting scholar with Prof. Sherief Reda's Group at Brown University, USA. Currently he is a full-time professor of Guilin University of Technology, China. He has published over 50 academic papers in major international journals and conferences. His main research interests include intelligent edge computing, cloud-edge-end collaborative systems, and artificial intelligence.

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