Design of the Advanced Artificial Intelligence Algorithms for the Autonomous Mobility Based on Edge Computing Paradigm

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Motivation and Goals

According to estimates, **a single connected autonomous vehicle (CAV) is projected to generate a minimum of 3 gigabits of data per second** [1]. A significant portion of this data will require rapid processing with minimal latency. Multi-access Edge Computing (MEC) emerges as a well-suited solution for managing such data processing demands. Consequently, the computational and radio infrastructure of 5G MEC networks will face substantial requirements.

Goals of the work:

- Create a **5G MEC network simulation environment** with support for autonomous vehicle mobility.
- Design a **route selection algorithm with regard to the available radio and computing resources** of the 5G MEC network.
- Design an **effective distribution of radio and computing resources** of the 5G MEC network.

Related Works

1. Route Planning Considering 5G MEC Resources

- **SQRSA** [2] - This method involves route selection that hinges on signal quality, gauged through SINR values.
- **VaRSA** [3] - This approach focuses on route selection based on available capacity within the radio resources of the 5G MEC network.

However, **both these strategies overlook the computing resources** of the 5G MEC network during route selection.

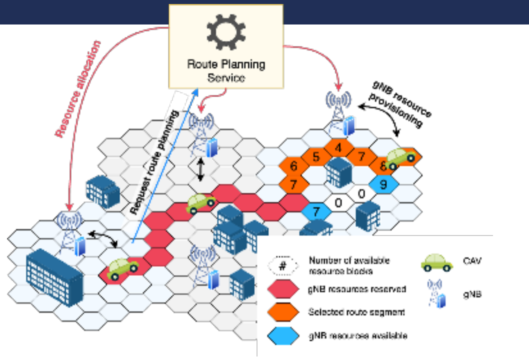
2. Dynamic allocation of 5G MEC resources

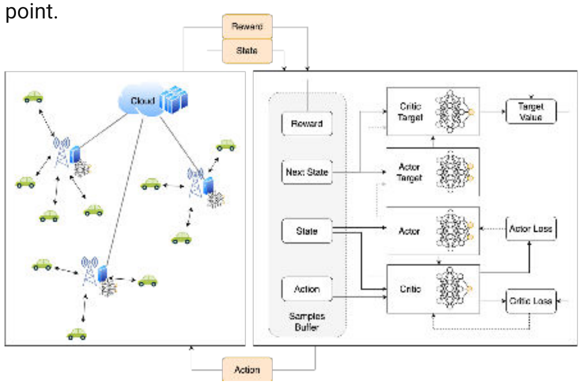
- **DECO** [4] - Method involves continuous optimization of both 5G MEC radio and computing resources, however this solution is constrained by a predetermined count of CAVs and 5G New Base Stations (gNBs).
- **DQN method** [5] - This approach facilitates the adaptable allocation of computing resources, yet it too is constrained by a predetermined count of CAVs.

Methods **do not consider continuous optimization** of 5G MEC radio and computing resources, and/or the methods are **confined to a fixed number of CAVs or gNBs** within the environment.

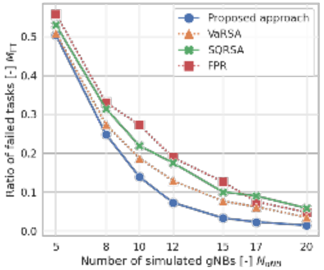
Proposed Methods

The route selection problem was tackled using a **custom-designed lexicographic A* algorithm**. The main objective was to minimize the ratio of failed tasks, while a secondary aim was to reduce route prolongation. The A* algorithm's cumulative value consists of a tuple of three items. The first item, assigned the highest priority, signifies the count of route segments where CAV's requirements cannot be met by the MEC system. The second item indicates the number of resource blocks required to fulfill CAV's requirements, and the third, of the lowest priority, represents the distance traveled. The heuristic function's value is derived solely from the third element, representing the distance to the destination point.

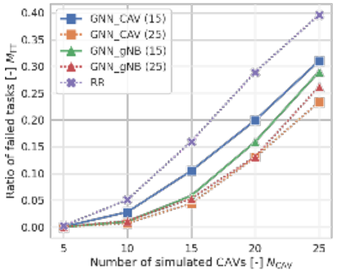




We tackled the dynamic allocation problem using the **Deep Deterministic Policy Gradient algorithm (DDPG) in conjunction with Graph Neural Networks** as feature extractors. Through the strategic selection of these methods, we've formulated a **solution that isn't constrained by a specific count of CAVs or gNBs** within the environment as CAVs are represented as nodes within a graph. Remarkably, our method **simultaneously optimizes the allocation of computing and radio resources** within the 5G MEC infrastructure. The strength of this solution lies in its generalisability; it is not bound to a fixed size of CAVs or gNBs and the training samples can be collected from the entire environment. The DDPG training can occur within the cloud, and subsequently, the DDPG actor can be efficiently distributed to each gNB for execution.



(a)



(b)

Results & Conclusion

The proposed route selection method **significantly reduces the number of required gNBs to fulfill CAV requirements, showcasing a potential reduction of up to 30%** when compared to other cutting-edge methods, as illustrated in Figure a. In Figure b, a comparison between our method and the equitable redistribution of MEC resources (RP) is presented, focusing on the ratio of failed tasks as the metric. Impressively, our approach achieves a substantially **improved ratio of failed tasks, with reductions of up to 60%** in comparison to the RP approach.

Simulations have demonstrated that the proposed methods hold the capacity to curtail both infrastructure and operational costs for service providers. Through the dual optimization of route selection and the dynamic allocation of MEC resources, these methods exhibit the potential to enhance both the safety of autonomous vehicles and the overall efficiency of the 5G MEC infrastructure. **The outcomes of the proposed lexicographic A* algorithm have been formally published in the esteemed *IEEE Transactions on Intelligent Transportation Systems*** [6], solidifying the credibility of the approach.

References

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