# Bankruptcy Game based Computational Resource Scaling in Mobile Edge Computing

Sarder Fakhrul Abedin, Choong Seon Hong

Department of Computer Science and Engineering, Kyung Hee University, Korea

Email: {saab0015, cshong}@khu.ac.kr

## Abstract

The rapid growth of different compute-intensive IoT applications is mainly dependent on computational ability at the Mobile Edge Computing (MEC). However, the computational capacity of the mobile edge servers is scarce. Therefore, it is vital for the mobile edge servers to scale and allocate the computational resource to the offloaded IoT tasks in a fair and efficient manner. In this paper, we model a bankruptcy game for the computational resource scaling at the mobile edge servers considering the IoT application-specific resource demand. In the simulation, we evaluate the fairness level of the proposed bankruptcy game based computational resource scaling at the Mobile Edge Computing network under different task density.

## 1. Introduction

The notion of Mobile Edge Computing (MEC) has enabled numerous computationally intensive IoT applications [1][2] with edge computing. The benefit of deploying MEC servers greatly outperforms the Cloud computing paradigm in terms of low-latency computation and location awareness, mobility and accessibility [3]. However, the number of IoT devices and applications are increasing significantly [4] where a great number of those devices/applications will offload the computationally intensive tasks to the nearby MEC servers. As a result, the computational capacity of the MEC servers will be scarce with respect to the computational demand of the IoT applications. Therefore, it is crucial to ensure fairness in computational resource scaling for the tasks at the closely located MEC servers.

In [5], the authors proposed a bankruptcy game for network resource allocation in the cooperative femtocell network. In [6], the authors proposed task allocation and computational frequency scaling in Mobile Edge Computing where the problem is NP-hard. In [7], the authors proposed a learning-based task offloading and resource allocation in UAV-assisted fog network. In [8], the authors proposed a distributed reinforcement leaning based code
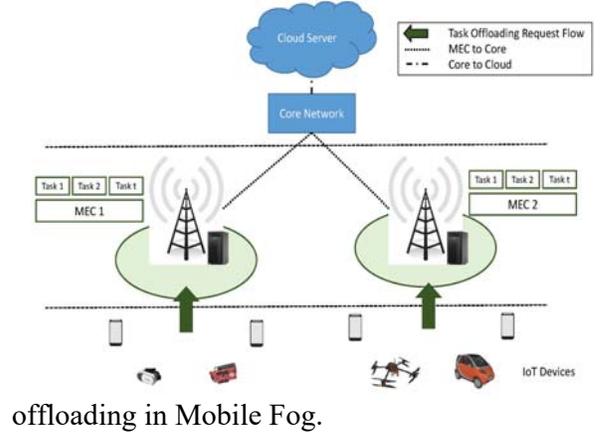
offloading in Mobile Fog.



Fig. 1: System Model

## 2. System Model

In Fig 1., we consider a three-tier mobile edge network where there are $M$ number of Mobile Edge Computing (MEC) server $\mathcal{M} = 1, \cdots, M$ and $T$ number of tasks from the IoT devices $\mathcal{T} = 1, \cdots, T$. Each MEC server $m \in \mathcal{M}$ has a set of computing resource block (CRB) $\mathcal{C} = 1, \cdots, C$. The IoT devices offload their computing tasks to the nearest MEC server where tasks can be allocated to multiple CRBs based on the application specific requirements. The capacity of the MEC servers are denoted as $\alpha_m$ whereas the computational demands from

different tasks at each MEC server are represented in vector $\Gamma_m = 1, \cdots, \gamma_t$ where $\gamma_t$ is the task load of task t. The CRB allocation valuation of the MEC is calculated as Jain' Fairness Index in Eq. 1. In Eq. (1), the network fairness depends on the allocation of the tasks. High valuation indicates better and fair CRB scaling at the MEC server.

$$\mathcal{V}_m = \frac{(\sum_{t \in \mathcal{T}} \frac{\gamma_t}{\alpha t})^2}{T \sum_{t \in \mathcal{T}} (\frac{\gamma_t}{\alpha t})^2} \qquad (1)$$

## 3. Bankruptcy Game for CRB Scaling

We assume that, the tasks from the IoT devices are initially assigned to the nearby MEC server under given task/player loads and the MEC server is responsible for performing the cooperative game for fair task allocation. The best coalition is grand coalition where the MEC serve capacity $\alpha_m$ is scaled and allocated fairly to the set of tasks depending on the task specific resource demand The characteristics function to

$$v(S) = max(a_m - \sum_{t \in \mathcal{T}-S} \gamma_t, 0) \qquad (2)$$

evaluate the coalition $S$ is defined as,

In (2), the coalition value of S is the part of the benefit that remains after paying the aggregated tasks in $\mathcal{T}-S$. For the bankruptcy game, we then calculate the Shapley value and define the function based on characteristics function in (2) to for fair CRB allocation as,

$$\phi_t(v) = \sum_{S \subset \mathcal{T}} \frac{(|S|-1)!(t-|S|)!}{t!}(v(S) - v(S-t)) \qquad (3)$$

In (3), the Shapley value is based on three axioms, symmetry, efficiency and additivity which ensures Pareto efficiency in computational resource scaling.

## 4. Simulation Results

In the simulation, we consider M=5, T= [1,20], $\alpha = [5, 100]$, $\Gamma = [1, 20]$. The values are uniformly distributed.

In Fig. (2), we observe, the fairness in the network wide CRB scaling in which the task density at each MEC increases significantly. The figure also states that with increased task density, the fairness index also increases.

## 5. Conclusion

In this paper, we have proposed a bankruptcy game based task allocation and computational resource scaling at the Mobile Edge Computing network. The simulation results show the fairness of the proposed method under various task density scenario. In future, we will extend the research with learning based proactive resource allocation.
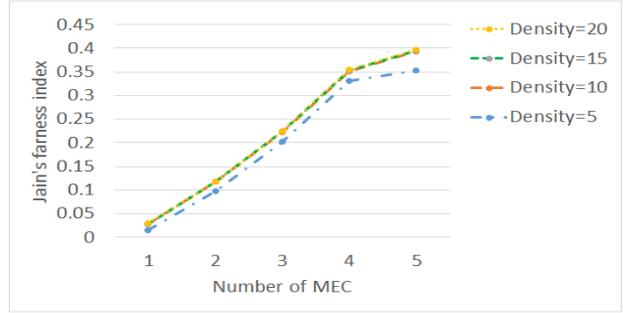


Fig. 2: Fairness Index for different task density

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