Department of Electrical Engineering,
Iqra National University Peshawar

Digital Twin Assisted Task Offloading beyond 5G Wireless Networks

Group Students
Abdul Samad (18305)
Sangeen Khan (21028)

Supervisors
Dr. Engr Sohail Imran Saeed
Dr. Engr Muhammad Waqas

Table of Contents

INTRODUCTION

Introduction

- Task offloading is an approach to transfer compute-intensive tasks from mobile devices to nearby edge servers or cloud for high speed computation.

- Mobile devices are equipped with limited battery life and processing capabilities, hindering their ability to handle substantial data storage and compute-intensive tasks.

- Examples of Task Offloading: Rendering graphics for AR/VR, Running inferences for machine learning, remote surgery, and data processing in autonomous cars and UAVs.

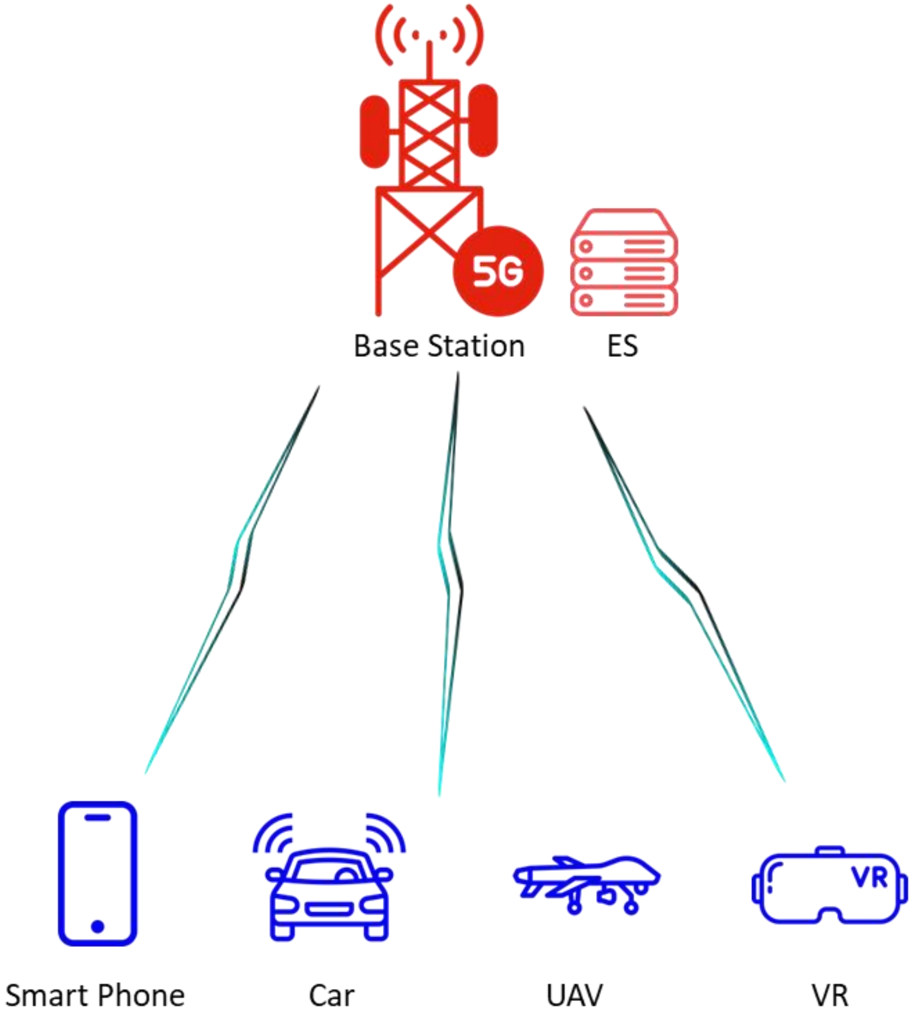


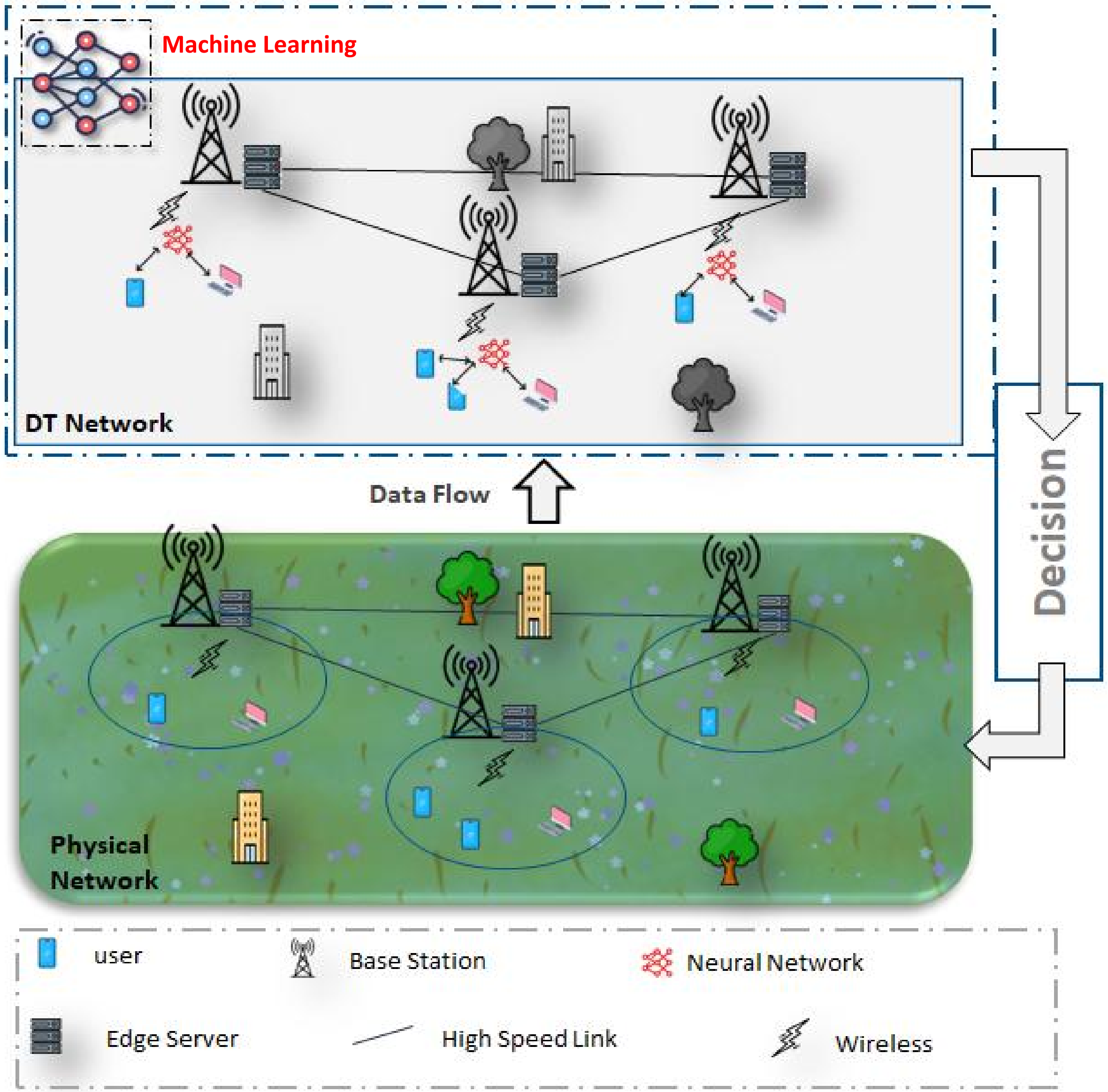
Fig 1 Task Offloading

Introduction

- Mobile Edge computing (MEC) is the processing of data near to the users.

- Digital Twin (DT) is an electronic replica of a physical system in which the changes in the physical system synchronizes with the replica in almost no time.

- The combination of AI and DT improves the efficiency, cost reduction, and performance of the network by proactive response, automated management, and intelligent prediction & allocation.



Literature Review

Literature Review

Sr.no + Year	Journal	Contribution	Outcome	weakness
1 [2024]	IEEE Internet of Things	• Proposed multiple radio access technologies (Wi-Fi, Wi-Fi direct, 5G) for offloading tasks in MEC to optimize load distribution and scheduling.	• Gained over 70% in terms of delay. • Ensured in order packet delivery.	• Resulted in increased energy consumption in the system. • Security concern in multi RATs • Cloud is not considered. • Bad resource allocation management.
2 [2023]	Electronics	• Introduced Emergency factor to Ensure task of different size compute efficiently, especially small size. • Enhanced Resource allocation and offloading decision	• Prioritize small size tasks offloading achieved. • Systems work on OFDMA	• No DRL method is used. • Mostly focus on small tasks size to offload.
3 [2023]	IEEE Transactions on Consumer Electronics	• Designed an algorithm to obtain possible solutions for task offloading • Proposed an algorithm to select best MEC server and optimize task.	• Reduced task latency about 15%. • MEC execution reduce energy consumption. • Total energy cost average.	• Doesn’t considered cloud system. • Trade off between latency minimization and energy consumption. • Local execution did worst in energy consumption reduction.
4 [2023]	IEEE Transactions on Mobile computing.	• Innovative algorithm for task partitioning and offloading • Prediction: delay calculation model at MU and ES • Pricing strategy of MU for efficient task scheduling.	• Proposed algorithm TPOS-UAI did well in reducing delay and energy consumption. • Subtask of 4 different devices are computed in parallel.	• Single ES in MEC network. • Parallel computing up to for 4 different devices, if > sequential execution. • Local (MU) execution included. • Mobility is not considered.

Literature

Sr. no + Year	Journal	Contribution	Outcome	Weakness
5 [2023]	IEEE TRANSACTIONS ON MOBILE COMPUTING	• COFE algorithm automatically assign tasks to ES and cloud based on the description of task. • Multi application task offloading.	• COFE reduced average makes pan and deadline violation reduction.	• 1 UE is considered • Mobility of user is not considered • No parallel computing • Near ideal, simulated
6 [2023]	IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS	• Novel framework for task offloading with migration and merging scheme. • Prioritized task to optimize task offloading in the MEC environment.	• DVRMO outperformed other algorithms in terms of minimizing deadline violation ratio (DVR) • Results showed that proposed algorithm reduced DVR about 65%	• No cloud Computing • Mobility not considered • Poor resource management • Chance that the task may be dropped.
7 [2022]	IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS	• Proposed a distributive algorithm that addresses the unknown load level at ES node. • DRL based distributed algorithm	• The average delay of proposed algorithm increases less dramatically. • Effectively addresses the load dynamics.	• Non divisible task is considered, which may lead to high delay. • No cloud execution. • High intensive task beyond MEC computing capacity may not be executed.
8 [2023]	IEEE TRANSACTIONS ON COGNITIVE AND DEVELOPMENTAL SYSTEMS	• Introduced novel architecture for vehicle micro-clouds. • Presented Triple Check Offloading algorithm (TCOA) to balance cost effectiveness in system. • Considered dynamic scaling rule for vehicular instances leaving the system at any time.	• TCOA outperformed other schemes and achieved better balance between cost effectives and delay. • Resulted in dynamic scaling rule to maintain system effectiveness when vehicle leaves the micro-cloud.	• TCOA might have problem predicting performance under extreme conditions. • Have complexities that might prevent from deploying in real-world.

Problem Statement

Problem Statement & Solution

- Traditional task offloading struggled in the following areas:
  - Dynamic resource management.
  - Resource Wastage: Due to the lack of AI inefficient use of computation power, network bandwidth, and storage results in high operational costs and lower customer satisfaction.

Proposed Solution

- DT-powered task offloading offers a more proactive and optimized solution to the mentioned issues of task offloading in the setting of resource constrained devices and changing network circumstances.
- Implanted AI for predictive analysis and to decide action (a_inj=[0,1], a_icj=[0,1]) based on the network resource and environment conditions.

Research Objectives

Research Objectives

- Developed a robust AI and DT integrated framework capable of dynamically optimizing task offloading strategies in complex environment
- Evaluated the performance of DT-enabled MEC architecture, focusing on following metrics
  - Latency
  - Energy consumption
  - Quality of service

METHODOLOGY

Methodology

- Both Edge Servers (ES) and cloud resources is considered for task offloading.
- Task offloading decisions will be determined via decision variables.
- Our primary objectives include minimizing both the data access delay for each subtask and the overall energy consumption of the system in mobility scenario.
- A deep Reinforcement Learning algorithm A3C is employed to iteratively optimize task offloading strategies, with the goals of reducing system energy consumption and minimizing.

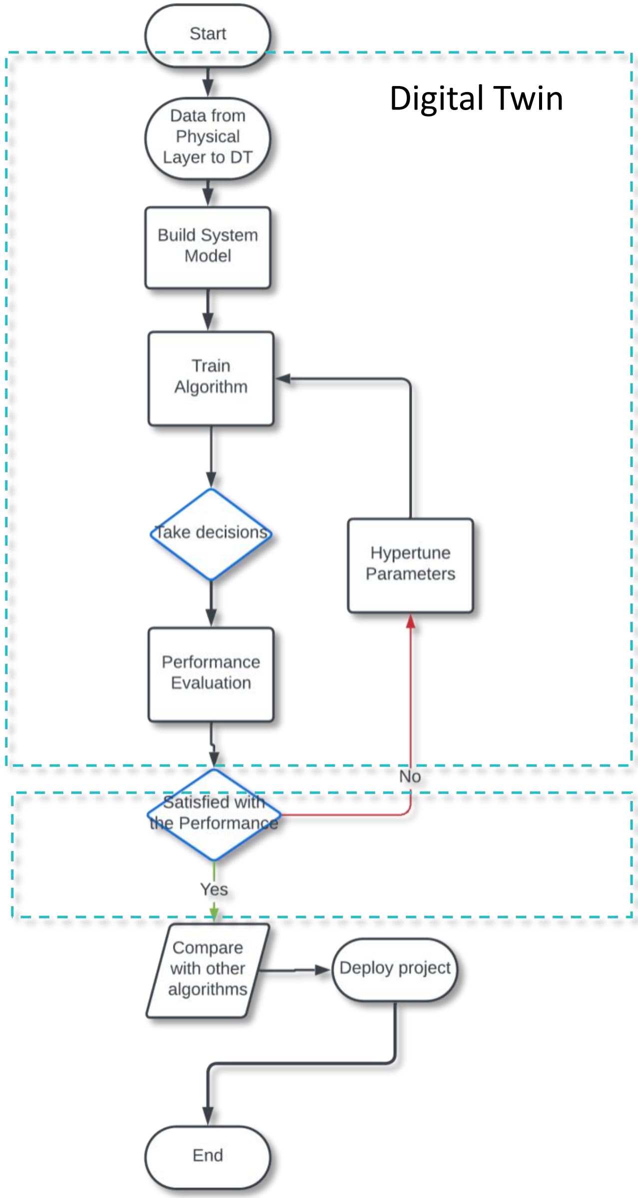
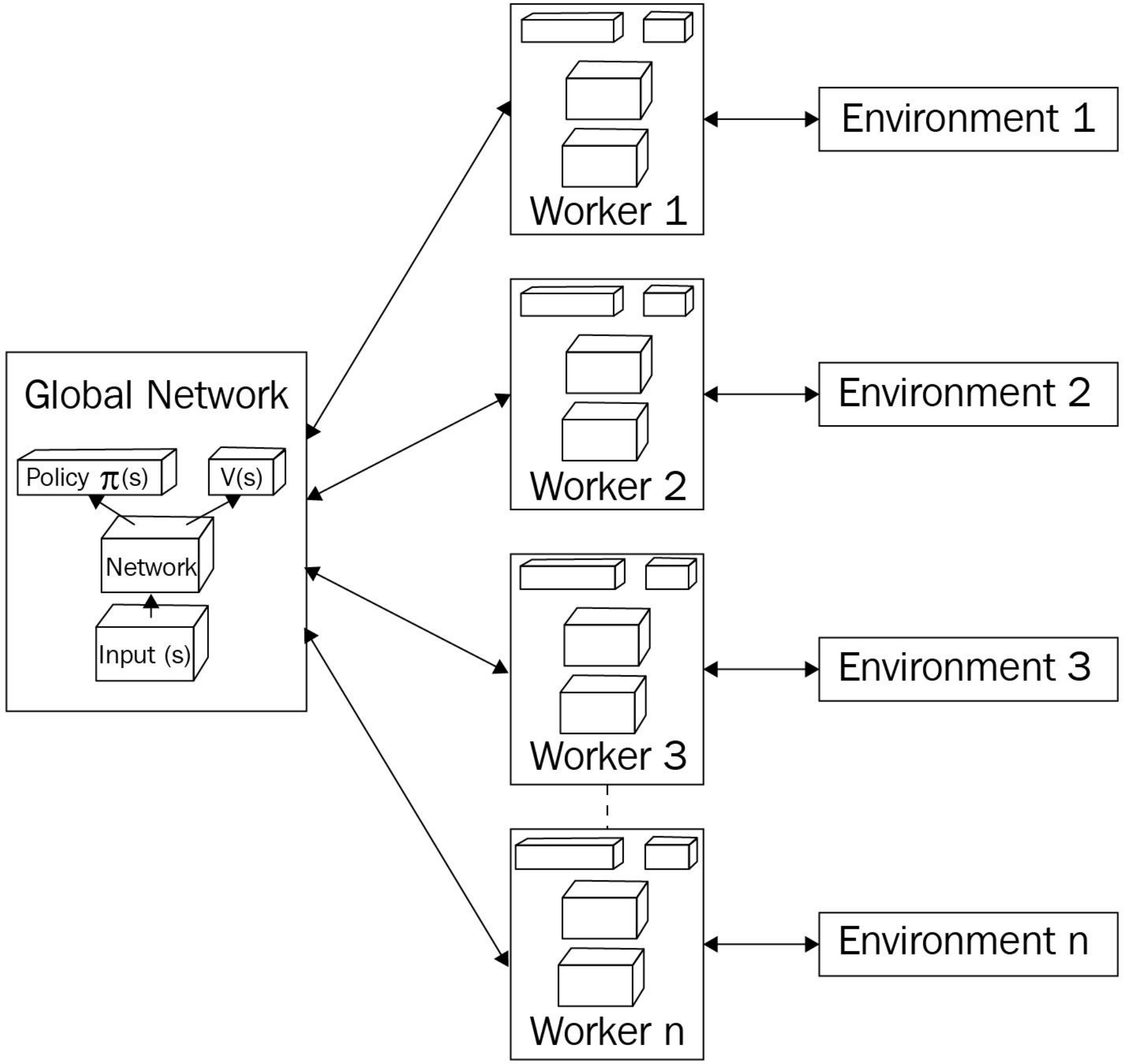


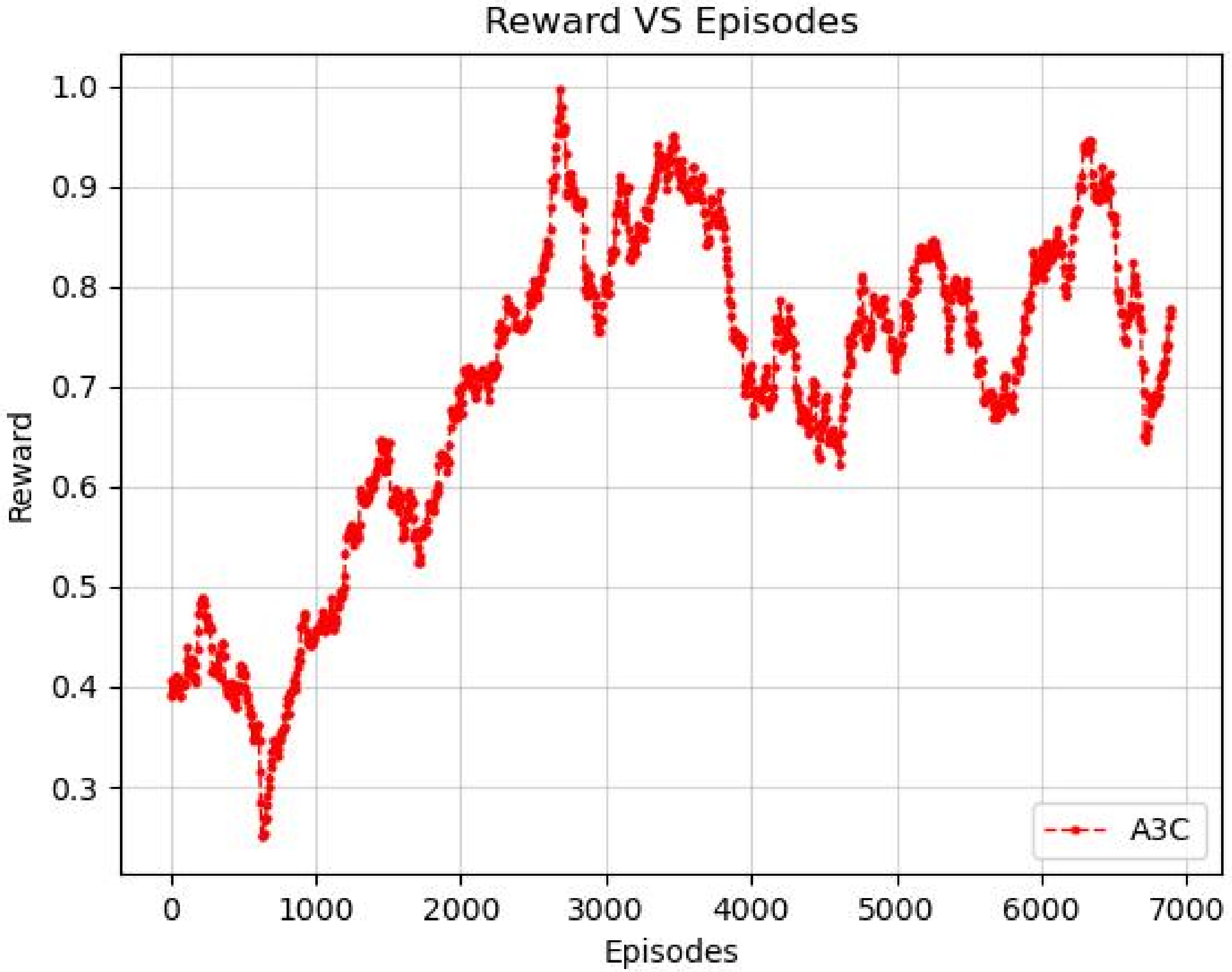
Fig.2 Flow chart Diagram

Architecture of A3C

- **Actor & Critic (Two Neural Networks)**
- **Train in Parallel**
- **Multiple Workers (CPU Cores)**

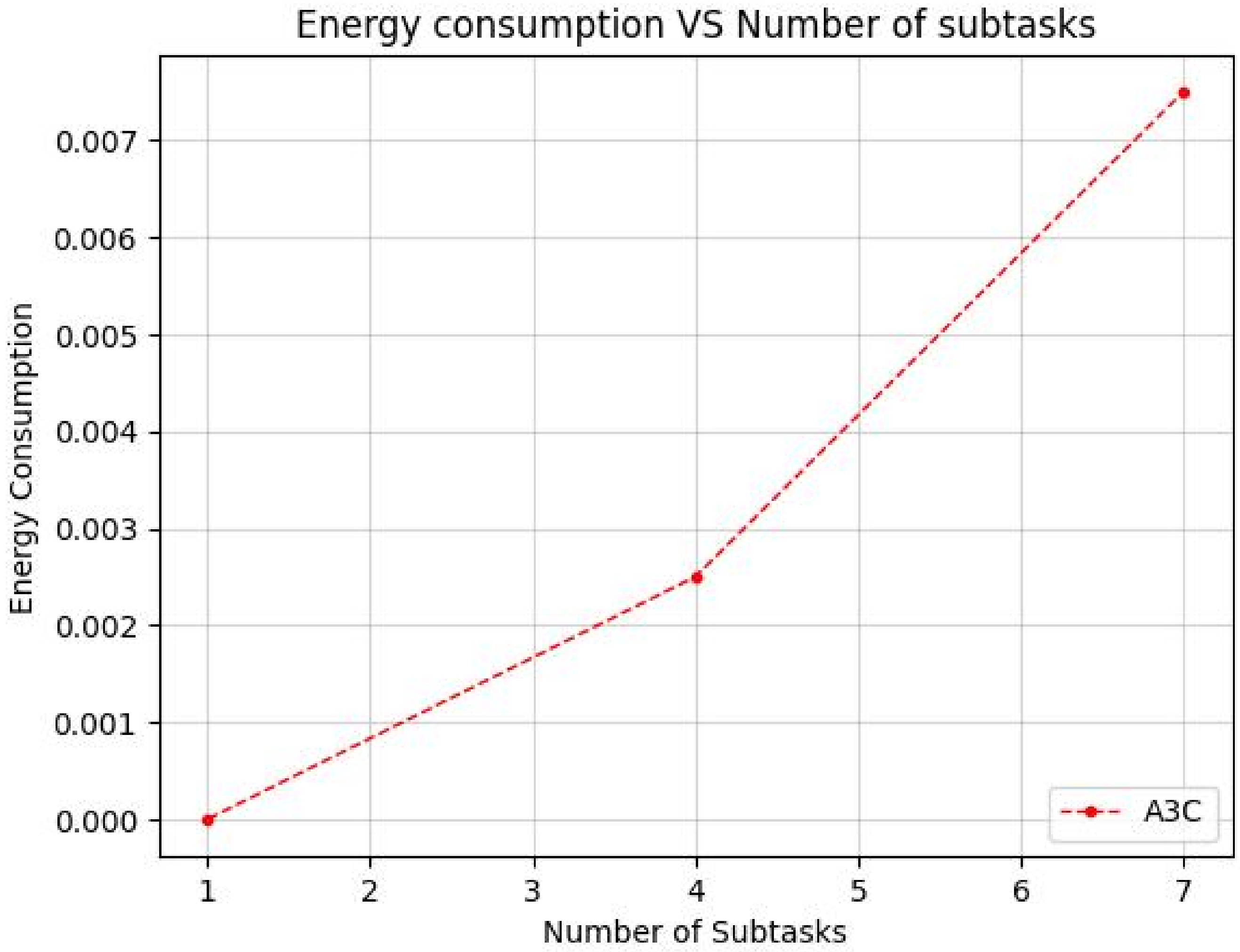


Reward Vs Episodes



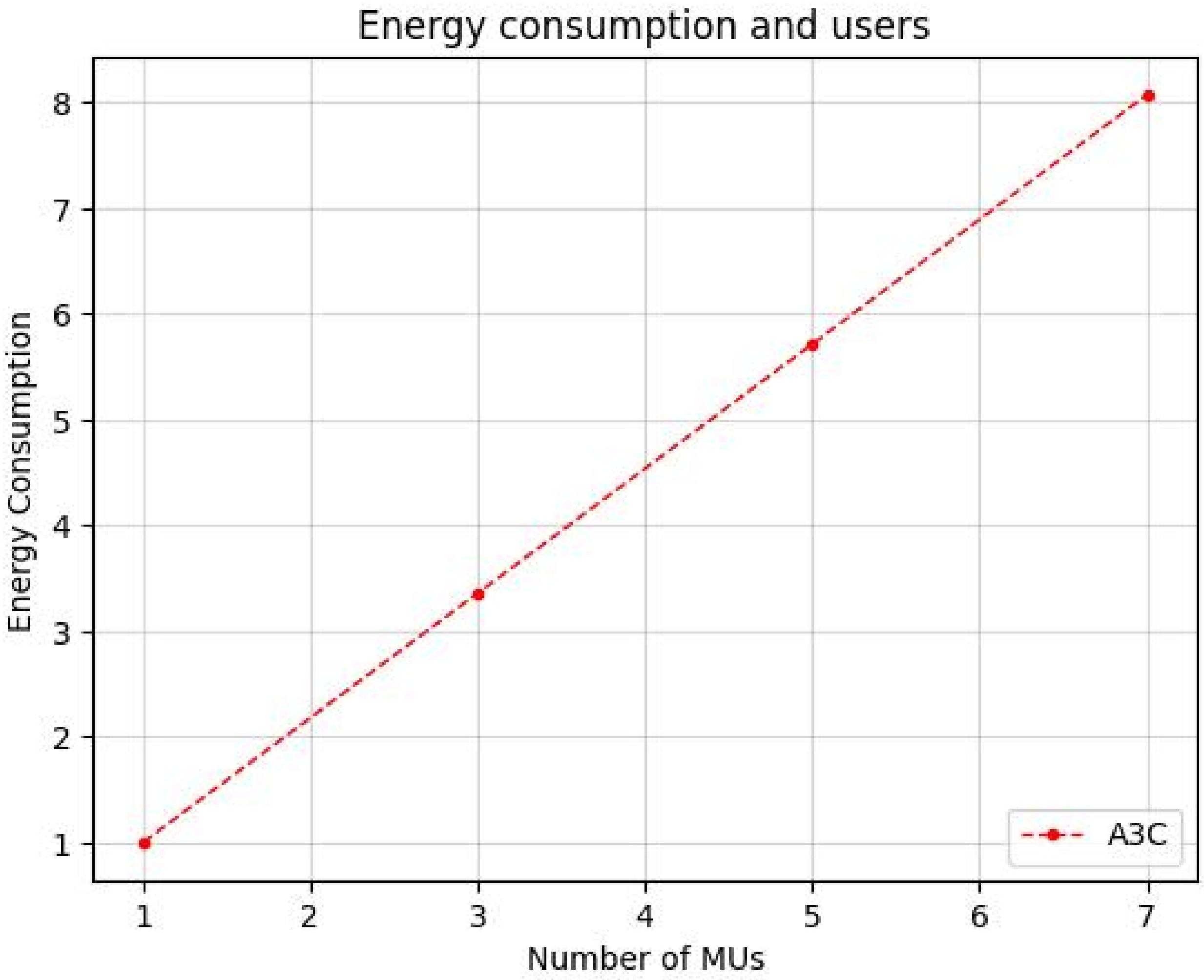
Results

Energy Consumption Vs Number of subtasks



Results

Energy Consumption Vs Number of Mobile Users



Tools & Technology

python™

OpenAI Gym

PyTorch

UN SDGs


7
AFFORDABLE AND CLEAN ENERGY


9
INDUSTRY, INNOVATION AND INFRASTRUCTURE


11
SUSTAINABLE CITIES AND COMMUNITIES


13
CLIMATE ACTION

THANK YOU