**Hybrid Walrus with Lemurs Optimization Algorithm for Multi-Objective Constraints-based Secured Edge-Cloud Task Offloading in IoT Environment**

**Introduction**

Internet of Things (IoT) is an integrated platform connecting hundreds of wireless sensors, smart meters, electronic equipment, and mobile devices [9]. These IoT entities collect, share, and transfer data to network nodes and connected devices for further processing. In recent years, the remarkable advancements in IoT and wireless networks have emerged as a solution for ubiquitous connectivity and intelligent data transfer [10]. IoT applications contribute to a number of sectors, including smart healthcare, autonomous vehicles, industrial automation, monitoring ambient environment, and so on [11]. The value of the IoT market is expected to outreach $8.9 trillion by 2020. These computation intensive IoT applications have created enormous workloads on the existing networking systems. The bandwidth-greedy and delay-sensitive tasks for IoT applications not only result in excessive energy demand, but also cause significant environmental consequences [12]. Mobile devices with limited battery capacity and computational resources are not suitable to address such computing demand. Globally, the number of per day battery replacements is anticipated to be 913 million considering three-year battery lifetime [13]. The IoT services also put forward diverse quality of experience (QoE) requirements, including, but not limited to, low latency, intensive computation capability, and high data rate. Therefore, industries, researchers, and policy makers are constantly looking for high-performing, cost-effective, and energy-efficient strategies for IoT applications [14].

Conventionally, cloud computing is considered for offloading and remote execution of computing tasks. This is because the migration of tasks to the cloud servers can overcome the limitations in computation capability and battery lifespan of the user devices [15]. However, the long distance between the users and the cloud servers is a major problem in adapting cloud-based services. Offloading of the IoT tasks to the cloud servers not only causes backhaul congestion, but also fails to meet the delay requirements of the applications. Hence, cloud computing cannot provide best services to the IoT systems [16]. To confront these technical requirements, mobile edge computing (MEC) has been introduced as an efficient solution for task offloading. MEC achieves low transmission delay compared to cloud computing by reducing the distance between the servers and end users [17]. In MEC, mobile devices can send their computation-intensive tasks to the MEC servers placed at the network edge. This strategy not only reduces the task computation time, but also overcomes the problem related to limited battery capacity of the mobile devices. Computation offloading at different edge nodes can reduce the task latency as well as communication load [18]. Furthermore, optimal allocation of the computational resources also exhibits significant potential to reduce energy consumption while maintaining latency requirements [19]. As a result, thousands of computation intensive IoT applications will require uninterrupted connectivity and high-data rate. Conventional approaches are not efficient to fulfill these requirements. Thus, MEC is anticipated as a key solution in designing low-latency and energyefficient solutions for IoT task offloading [20].

Privacy and security concerns of the offloaded tasks are major threats in MEC [21]. The MEC servers, which are located at the network edge, are in close proximity to the attackers and vulnerable to hostile attacks [22]. Furthermore, the security protections at the edge nodes are less stringent because of the limited computational capability compared to the cloud servers [23]. IoT applications deal with different types of confidential information. Potential security breach can lead to system failures and cause life threatening consequences for the end users. The security requirements of different applications are also diverse in terms of authentication, confidentiality, and integrity process [24]. However, the preventive services for security threats inevitably originate computation overheads and lead to additional computing delay and energy consumption [25]. Therefore, in IoT task offloading, addressing these conflicting issues simultaneously is a major research challenge.

**Related works**

In 2020, Zahed *et al.* [1] have proposed a green and secure MEC technique combining caching, cooperative task offloading, and security service assignment for IoT networks. The study not only investigated the synergy between energy and security issues, but also offloads IoT tasks to the edge servers without violating delay requirements. A resource-constrained optimization model was formulated, which minimized the overall cost combining energy consumption and probable security-breach cost. They also developed a two-stage heuristic algorithm and find an acceptable solution in polynomial time. Simulation results proved that the proposed technique achieved notable improvement over other existing strategies.

In 2019, Ren *et al.* [2] have suggested multiple deep reinforcement learning (DRL) agents deployed on multiple edge nodes to indicate the decisions of the IoT devices. On the other hand, with the aim of making DRL-based decisions feasible and further reducing the transmission costs between the IoT devices and edge nodes, federated learning (FL) was used to train DRL agents in a distributed fashion. The experimental results demonstrated the effectiveness of the decision scheme and federated learning in the dynamic IoT system.

In 2022, Ko *et al.* [3] have proposed a location privacy-guaranteed offloading algorithm (LPGA) in cache-enabled edge cloud environments. In LPGA, an IoT device decides where to offload the task (i.e., edge cloud or central cloud) with the consideration of the privacy level on the location and the cache hit probability. To minimize the generated traffic volume while maintaining low energy outage probability and providing a sufficient level of location privacy, a constrained Markov decision process (CMDP) problem was developed and which was converted into an equivalent linear programming (LP) model to achieve the optimal policy for offloading. Evaluation results demonstrated LPGA can reduce the traffic volume up to 39% compared to a central cloud-based offloading scheme while maintaining the energy outage probability below a certain level and providing required location privacy level.

In 2019, Deng *et al.* [4] have designed the Green and Sustainable Mobile Edge Computing (GS-MEC) framework based on Energy Harvesting Technologies (EHT), to make IoT devices self-powered by utilizing the green energy in the IoT environment. In the developed framework, the problem of minimizing response time and packet losses of tasks under the limitation of energy queue stability was formulated to improve the timeliness and reliability of task processing. Additionally, the dynamic parallel computing offloading and energy management (DPCOEM) algorithm was designed to solve the problem based on the Lyapunov optimization technology. Finally, theoretical analysis demonstrated the effectiveness of the proposed algorithm, and the numerical result of simulation showed that the average performance of the proposed algorithm was an order of magnitude better than state-of-the-art algorithms.

In 2022, Heidari *et al.* [5] have suggested a new deep Q-learning approach to address the IoT-edge offloading enabled blockchain problem using the Markov Decision Process (MDP). There was a substantial gap in the secure online/offline offloading systems in terms of security, and no work had been published in the arena thus far. The system could be used online and offline while maintaining privacy and security. The proposed method employed the Post Decision State (PDS) mechanism in online mode. Additionally, the edge/cloud platform was integrated into IoT blockchain-enabled networks to encourage the computational potential of IoT devices. The system could enable safe and secure cloud/edge/IoT offloading by employing blockchain. In the system, the master controller, offloading decision, block size, and processing nodes may be dynamically chosen and changed to reduce device energy consumption and cost. TensorFlow and Cooja’s simulation results demonstrated that the method could dramatically boost system efficiency relative to existing schemes. The findings showed that the method beats four benchmarks in terms of cost, computational overhead, energy use, task failure rate and latency.

In 2018, Lyu *et al.* [6] have presented new integration architecture of the cloud, MEC, and IoT, and propose a lightweight request and admission framework to resolve the scalability problem. Without coordination among devices, the proposed framework could be operated at the IoT devices and computing servers separately, by encapsulating latency requirements in offloading requests. Then a selective offloading scheme was designed to minimize the energy consumption of devices, where the signaling overhead could be further reduced by enabling the devices to be self-nominated or self-denied for offloading. Simulation results showed that the proposed selective offloading scheme could satisfy the latency requirements of different services and reduce the energy consumption of IoT devices.

In 2020, Yousafzai *et al.* [7] have proposed a lightweight process migration-based computational offloading framework by analyze the effect of platform-dependent native applications on computational offloading in edge networks. The proposed framework does not require application binaries at edge servers and thus seamlessly migrated native applications. The proposed framework was evaluated using an experimental test-bed. Numerical results reveal that the proposed framework saved almost 44% of the execution time and 84% of the energy consumption. Hence, the proposed framework showed profound potential for resource-intensive IoT application processing in MEC.

In 2019, Hong *et al.* [8] have recommended a game-theoretic approach to achieving Quality of service (QoS)-aware computation offloading in a distributed manner by studied the multi-hop computation-offloading problem for the IIoT–edge–cloud computing model. First, they developed the computation-offloading and communication-routing problems with the goal of minimizing each task’s computation time and energy consumption, formulating the joint problem as a potential game in which the IIoT devices determine their computation-offloading strategies. Second, a free–bound mechanism wasa applied to ensure a finite improvement path to Nash equilibrium. Third, a multi-hop cooperative-messaging mechanism was proposed and developed two QoS-aware distributed algorithms that can achieve the Nash equilibrium. The simulation results showed that the algorithms offered a stable performance gain for IIoT in various scenarios and scale well as the device size increases.

**Problem Definition**

Recently, the offloading of workloads to Edge-Cloud in IoT environment plays a vital role. Bit it faces many challenges like limited capacity for computational, increased delay and this make lead to increase the computational latency. The features and challenges of the existing offloading of workloads to edge-cloud in IoT model is depicted in Table 1. Green and secure MEC technique [1] permits high bandwidth and very low latency and provides rapid performance for IoT in different applications and also increases the size of the devices. However, cannot show best performance in security, cost and power savings. DRL [2] can effectively handle the stochasticity and noise and has the ability to tackle the more challenging tasks with less knowledge. However, it needs more data and computation process to offer best outcome and the cost for maintenance is high. LPGA [3] can effectively lessen the traffic volume while maintains the same level of energy and more suitable to provide require level of privacy. But, the speed of the system is little slower than other models and requires more time to compute. GS-MEC [4] offers more flexibility and has the difficulty for any malevolent assaults. It enforces more security on the data. However, it has inadequate storage and less power for processing. Deep Q-learning [5] shows outstanding performance by considering the future actions and easily converges to the global optimal solution. However, it has high-dimensionality challenges which cannot solve in this model and sometimes it prone to make errors. Three-layer integration model [6] minimizes the network congestion and usage of the data centre (DC). The data traversing amount could be minimized effectively. However, it has standardization shortages and cannot provide adequate storage capacity when obtaining more data. Process migration-based computational offloading (PMCO) [7] can save the time of execution and consumption of energy. However, it cannot approach the offloading mechanism based on "edge-to-edge computation" to save the time of migration and solve the issues. Multi-hop Cooperative Computation offloading Game (MCCG) [8] can reduce the computing time for all the tasks, consumption of energy and ensure the finite enhancement and select optimal strategy to offload the tasks. However, it cannot permit the throughput to be assigned based on the size of the data. As a result, we designed new offloading of workloads to edge-cloud model in IoT environment to resolve the existing challenges.

**Table 1:** Features and challenges of the existing offloading of workloads to edge-cloud Model in IoT sector

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| --- | --- | --- | --- |
| **Author [citation]** | **Methodology** | **Features** | **Challenges** |
| Zahed *et al.* [1] | Green and secure MEC technique | * It permits high bandwidth and very low latency. * It provides rapid performance for IoT in different applications and also increases the size of the devices. | * It cannot show best performance in security, cost and power savings. |
| Ren *et al.* [2] | DRL | * It can effectively handle the stochasticity and noise. * It has the ability to tackle the more challenging tasks with less knowledge. | * It needs more data and computation process to offer best outcome. * The cost for maintenance is high. |
| Ko *et al.* [3] | LPGA | * It can effectively lessen the traffic volume while maintains the same level of energy. * It is more suitable to provide require level of privacy. | * The speed of the system is little slower than other models. * It requires more time to compute. |
| Deng *et al.* [4] | GS-MEC | * It offers more flexibility and has the difficulty for any malevolent assaults. * It enforce more security on the data | * It has inadequate storage and less power for processing. |
| Heidari *et al.* [5] | Deep Q-learning | * It shows outstanding performance by considering the future actions. * It can easily converge to the global optimal solution. | * It has high-dimensionality challenges which cannot solve in this model. * Sometimes it prone to make errors. |
| Lyu *et al.* [6] | Three-layer integration model | * It minimizes the network congestion and usage of the data centre (DC). * The data traversing amount could be minimized effectively. | * It has standardization shortages. * It cannot provide adequate storage capacity when obtaining more data. |
| Yousafzai *et al.* [7] | Process migration-based computational offloading (PMCO) | * It can save the time of execution and consumption of energy. | * It cannot approach the offloading mechanism based on "edge-to-edge computation" to save the time of migration and solve the issues. |
| Hong *et al.* [8] | Multi-hop Cooperative Computation offloading Game (MCCG) | * It can reduce the computing time for all the tasks, consumption of energy and ensure the finite enhancement. * It can select optimal strategy to offload the tasks. | * It cannot permit the throughput to be assigned based on the size of the data. |

**Research Methodology**

The ever-increasing number of diverse and computation-intensive Internet of things (IoT) applications is bringing phenomenal growth in global Internet traffic. Mobile devices with limited resource capacity (i.e., computation and storage resources) and battery lifetime are experiencing technical challenges to satisfy the task requirements. Thus, with the idea of offloading intensive computing tasks from them to edge nodes (ENs), edge computing emerged to supplement these limited devices. Benefit from this advantage, IoT devices can save more energy and still maintain the quality of the services they should provide. However, computational offload decisions involve federation and complex resource management and should be determined in the real-time face to dynamic workloads and radio environments. Therefore, the assignment of security services to the offloaded tasks is a major requirement to ensure confidentiality and privacy. In this proposal we develop a secured task offloading model in IoT environment. The task offloading process will be done by the support of Hybrid Walrus Optimization Algorithm (WaOA) [26] and Lemurs Optimizer (LO) [27] (H-WoLo). The multi-objective constraints for the developed H-WoLo-based task offloading model will be resource utilization, makespan, energy consumption, cost and security. The developed model is explored with several popular tasks offloading models and showed the effectiveness over other models. Figure 1 explains the pictorial view of the developed task offloading model.

Edge-Cloud in IoT environment

Secured Task Offloading

Objective constraints like resource utilization, makespan, energy consumption, cost and security

Developed H-WoLo

Task scheduled output

Figure 1: Pictorial View of the Developed Task Offloading Model

**Expected Outcome**

The developed task offloading scheme in IoT environment will be evaluated through Matlab software, where the performance analysis will be carried out to ensure the effectiveness. The convergence and statistical analysis will be performed to validate the goodness.

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