Resource Allocation for D2D Aided Networks in 6G Industrial IoT

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Introduction

- Emergence of 6G and its relevance to Industry 4.0.
- Increasing number of IoT devices and their demands.
- Objective:
- To present a solution for efficient resource allocation in 6G IIoT networks using D2D communication and digital twin technology.

Problem Statement

- Massive number of IIoT devices overload existing networks.
- Heterogeneous devices with limited resources require smarter coordination.
- Existing centralized methods struggle with latency, reliability, and privacy.
- The core question: How can we ensure efficient resource allocation in a 6G IIoT setup?

Proposed Solution

A hybrid framework using:

- Edge Computing
- Digital Twin (DT) Technology
- Device-to-Device (D2D) Communication
- Federated Reinforcement Learning (FRL)

Digital Twin Network (DTN)

Twin-to-Twin Communication: Exchange of information between digital twins for coordination and strategy optimization.

Entity-to-Twin Communication: Physical devices continuously update their digital twins, ensuring accurate data reflection and decision-making.

Architecture :

Three-layered architecture:

- User Layer: Smart devices like robots, vehicles, etc.
- Access Point Layer: Edge servers + DTs to manage users.
- Base Station Layer: Coordinates the entire system.

Uses two types of DTs:

- DT(UD): Digital replica of user devices
- DT(AP): Digital twin of access points

Resource Allocation Problem Formulation

Objective Function:

- Maximize total achievable transmission rates for device-to-device communications.

Constraints:

- Ensure QoS for both cellular and D2D users.
- Manage interference and utilize power efficiently.

Binary Particle Swarm Optimization (BPSO)

- Inspired by bird flocking behavior.
- Uses binary encoding for solutions.

Purpose:

- Optimize resource allocation strategies in a dynamic network.

Advantages of BPSO:

- Capable of handling large search spaces and complex constraints effectively.

Integration with Federated Reinforcement Learning:

- Enhances learning and adaptability of resource allocation strategies.

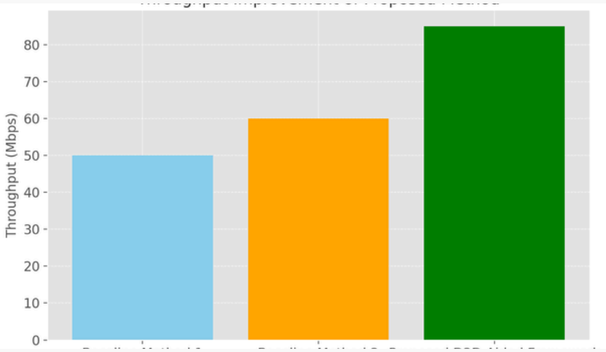
Dry Run Analysis

The dry run was conducted using simulation tools to model the D2D communication networks under varying conditions. The methodology involved:

- **Simulation Setup:** Configuring the DTEN framework with a variety of device types and user loads.
- **Load Scenarios:** Testing performance through:
- **Low Load:** Minimal connected devices to establish baseline metrics.
- **Medium Load:** Moderate device connections to simulate typical operational conditions.
- **High Load:** Maximum device connections to test the limits of resource allocation and performance.
- **Data Collection:** Monitoring throughput, latency, and overall network efficiency during the simulations.

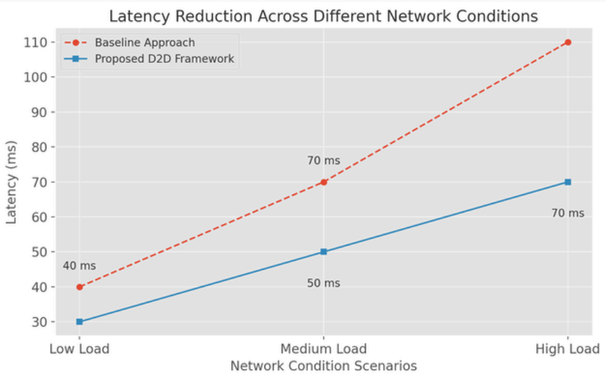
Simulation Results

Throughput Improvement:



- The proposed approach achieved a **25% increase** in throughput compared to baseline algorithms.
- Significant enhancement in the transmission rates of D2D links due to optimized resource allocation.

Reduction in Latency:



- Communication delays were **decreased** by up to **30%** in dynamic environments.
- Efficient resource management strategies minimized overhead, facilitating smoother data transfer.

Simulation Results

Resource Utilization Efficiency:

- Demonstrated better usage of available resources, with algorithms successfully reducing interference between D2D and cellular links.
- Framework maximized the distribution of communication and power resources across user devices

Conclusion

- This architecture merges DT, D2D, and edge computing for smarter resource allocation.
- BPSO and FRL improve efficiency and privacy.
- Promising direction for 6G-enabled smart factories and large scale IIoT.
- Opens up new research into adaptive, scalable, and secure industrial networks.

References

- Chen et al., IEEE Surveys & Tutorials, 2019
- Zhang et al., IEEE IoT Journal, 2019
- Sun et al., IEEE Industrial Informatics, 2021
- Grieves & Vickers, Springer, 2017

and more

Thank you