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Communication efficiency optimization of federated learning for computing and network convergence of 6G networks

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Key words: Computing and network convergence; Communication efficiency; Federated learning; Two architectures

Yizhuo CAI
E-mail: caiyizhuo@bupt.edu.cn
ORCID: https://orcid.org/0000-0002-6662-3767

Motivation

- In traditional federated learning, users synchronously transmit model parameters and compete with each other for communication resources.
- Meanwhile, the computing power resources of the training devices are imbalanced, resulting in inconsistent training times and a decrease in the training efficiency of federated learning.
- Computing and network convergence (CNC) of sixth-generation (6G) networks provides a certain turning point for solving the above problems.
- Relying on the ability to sense the computing power of devices in real time and synchronize various resource information in the network, CNC can flexibly schedule the clients in federated learning and make better decisions for the network topology and the allocation of resources. This guides the training process of federated learning and improves communication efficiency.

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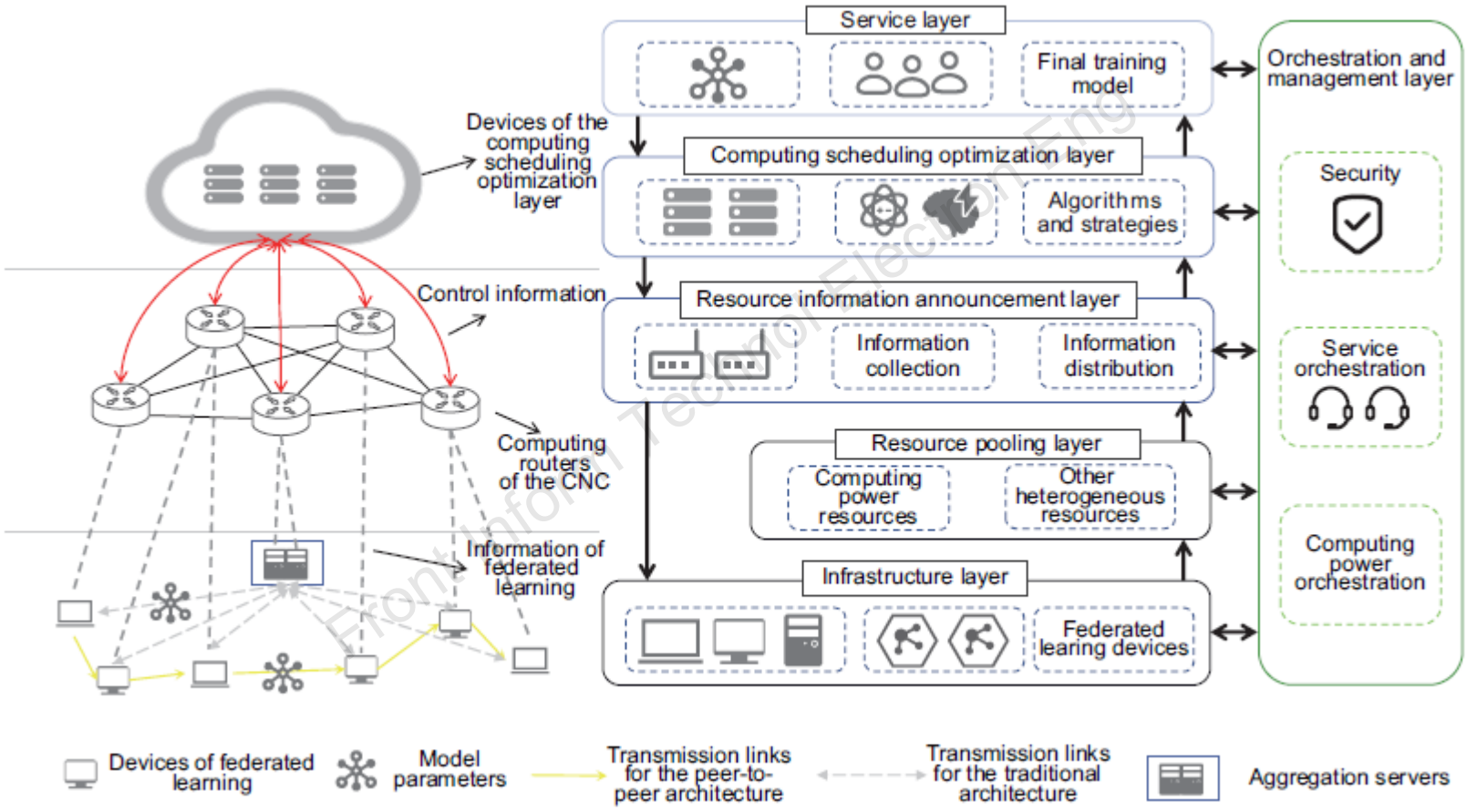
Main idea

- Design the communication optimization system based on each layer of the CNC, combined with the mechanism of federated learning
- Propose corresponding optimization algorithms for traditional/ peer-to-peer architectures in federated learning
- Use real-time computing power resource information obtained from the CNC to achieve orchestration and scheduling of client devices in federated learning
- Allocate communication resources based on real-time updated network information in CNC to improve communication efficiency

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System architecture

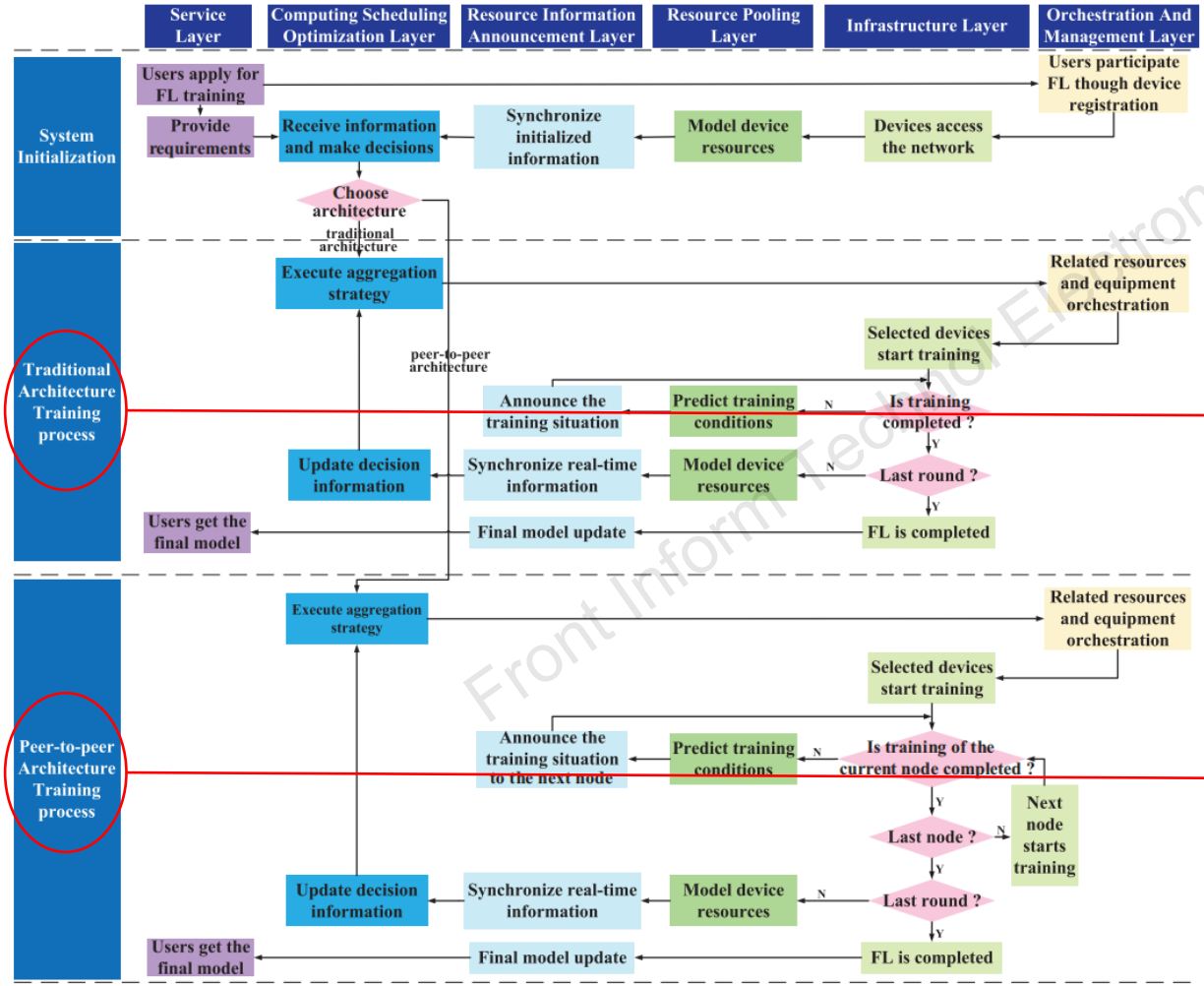
- Implement a federated learning communication efficiency optimization system by combining the architecture of the CNC



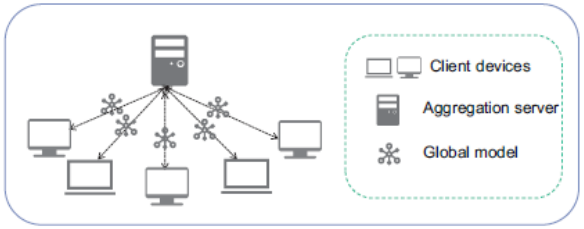
Communication efficiency optimization system for computing and network convergence (CNC) of 6G networks

Operational process

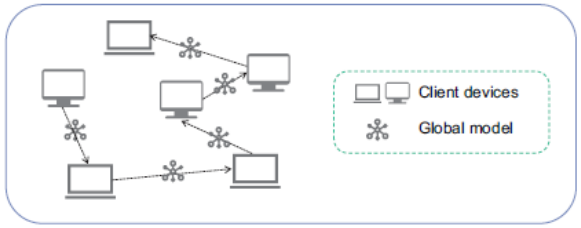
- Corresponding workflow for the two architectures in the communication efficiency optimization system



System operation flowchart



Traditional architecture

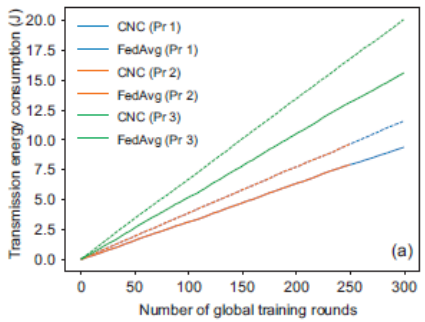


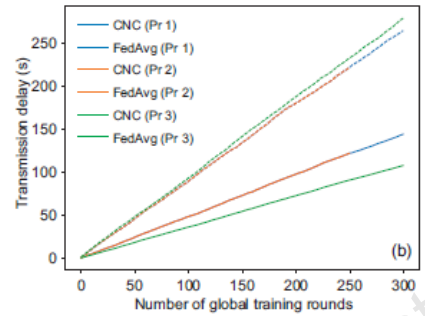
Peer-to-peer architecture

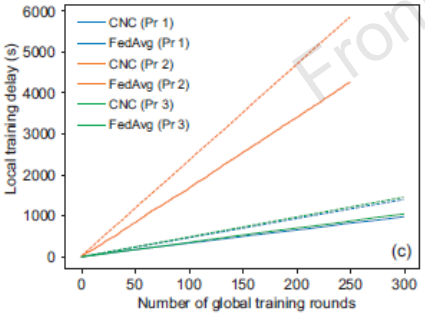
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Simulation results under the traditional architecture

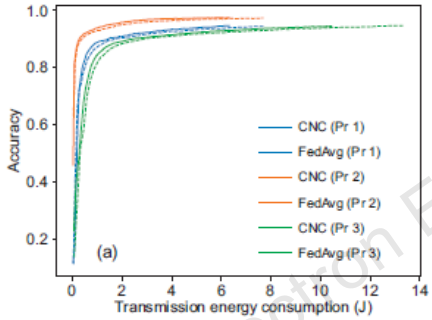
- Communication performance comparison / Test accuracy comparison (under different communication indicators)

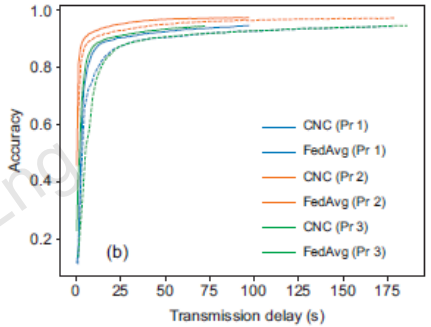


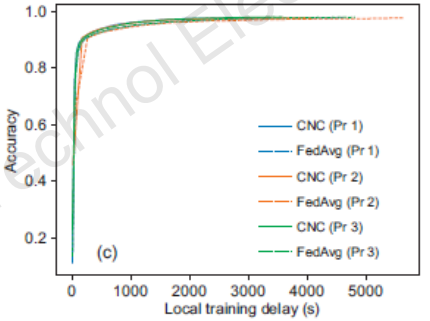


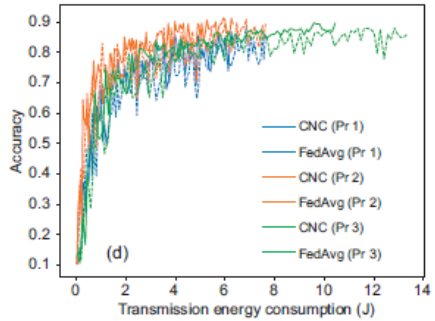


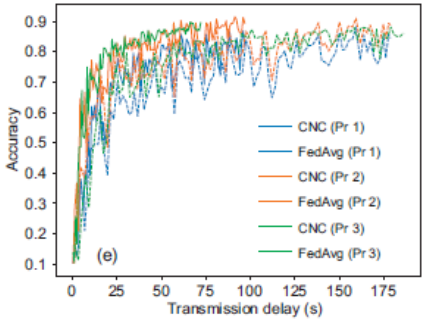
Communication performance comparison under the two algorithms: (a) transmission energy consumption; (b) transmission delay; (c) local training delay (CNC: computing and network convergence; FedAvg: federated averaging)

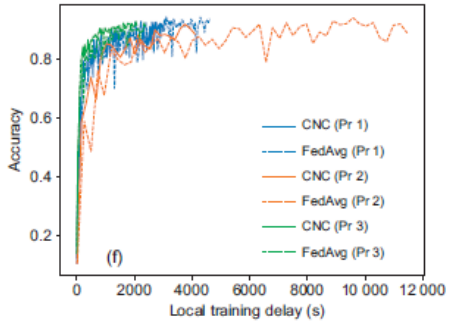










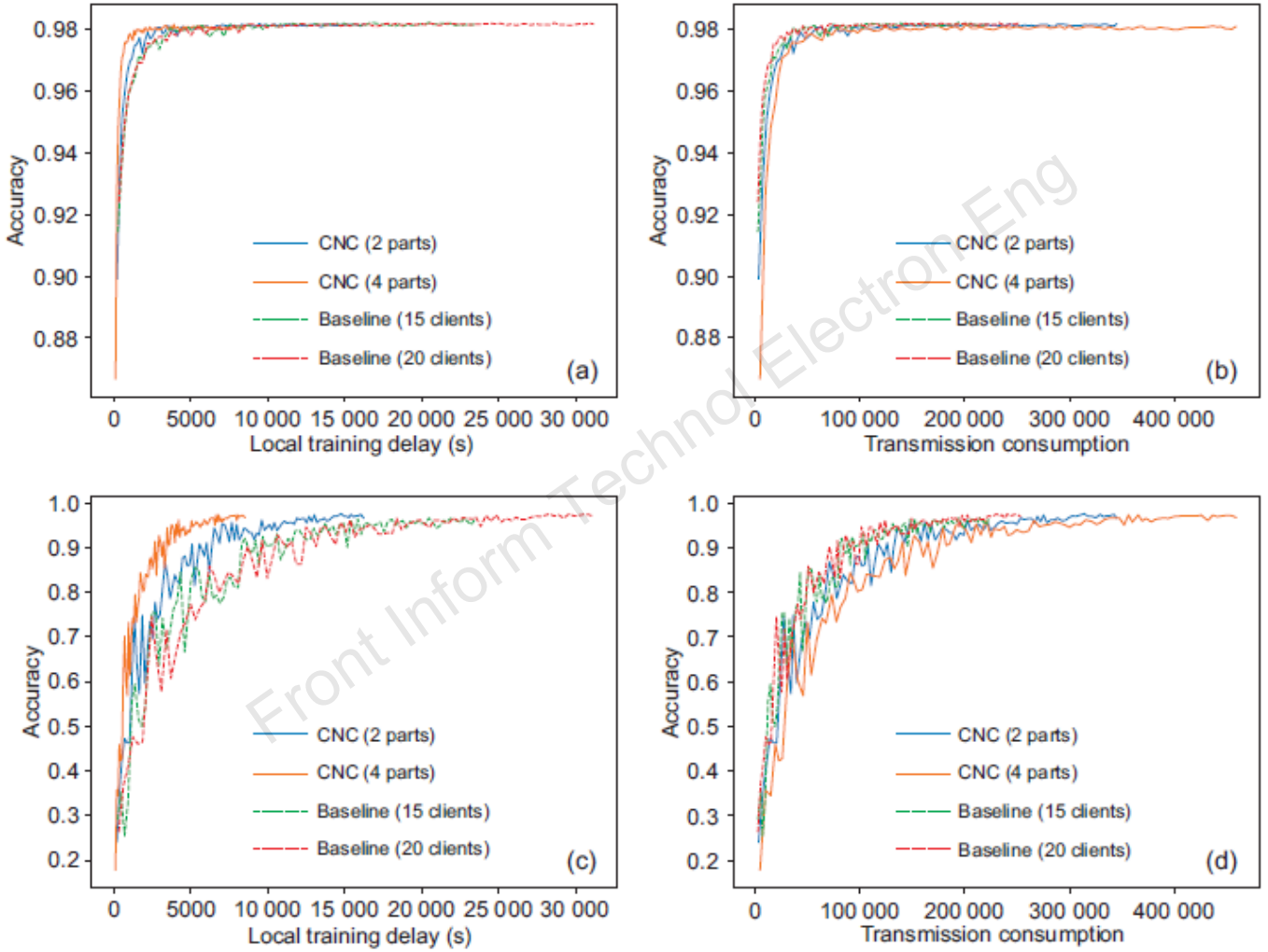


Test accuracy comparison under the two algorithms: (a) transmission energy consumption (IID); (b) transmission delay (IID); (c) local training delay (IID); (d) transmission energy consumption (non-IID); (e) transmission delay (non-IID); (f) local training delay (non-IID) (CNC: computing and network convergence; FedAvg: federated averaging; IID: independent and identically distributed)

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Simulation results under the peer-to-peer architecture

- Test accuracy comparison (under different communication indicators)



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Test accuracy comparison under the peer-to-peer architecture in experiment 1: (a) local training delay (IID); (b) transmission consumption (IID); (c) local training delay (non-IID); (d) transmission consumption (non-IID) (CNC: computing and network convergence; IID: independent and identically distributed)

Conclusions

CNC of 6G networks is a new network architecture and paradigm. Federated learning can show better performance with its support, especially in terms of communication efficiency. In this case, we propose communication efficiency optimization of federated learning for CNC of 6G networks. As the simulation results shown, it has great potential to improve the federated learning process, especially in balancing heterogeneous computing power and improving communication efficiency.

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Yizhuo CAI received the B.S. degree in Communication Engineering from Beijing University of Posts and Telecommunications (BUPT) in 2022. He has been pursuing his master degree in Wireless Signal Processing and Network Laboratory at BUPT since 2022. He has mainly conducted research in federated learning, and his main research interests are focused on communication challenges in federated learning.



Bo LEI is now a director of Future Network Research Center of China Telecom Research Institute. He received his Master's degree in Telecommunication Engineering from Beijing University of Posts and Telecommunications, Beijing, China, in 2006. His currently research interests include future network architecture, new network technology, computing power network and 5G application verification. Now he leads the Future Network Research Center focusing on future network. He is the first author of two technical books and has published more than 30 papers in top journals and international conferences, and filed more than 30 patents.

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Xing ZHANG (M’10-SM’14) is currently a full professor with the School of Information and Communications Engineering, Beijing University of Posts and Telecommunications, China. His research interests are mainly in 5G/6G networks, edge intelligence, and Internet of Things. He has authored or co-authored three technical books and over 200 papers in top journals and international conferences and holds over 50 patents. He received more than six Best Paper Awards in international conferences. He is a Senior Member of IEEE and a member of CCF. He has served as a General Co-Chair of the third IEEE International Conference on Smart Data (SmartData-2017), as a TPC Co-Chair/TPC Member for a number of major international conferences.

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