Trust-proof Decentralized Learning to Collaborate

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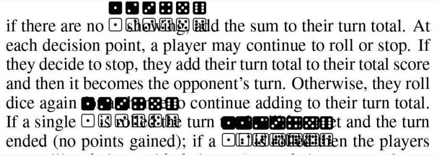
Untitled Research

Outline

Learn-to-Collaborate (L2C)

Trust-Proof Gossip-Based Ranking

- The escalating scale and decentralization of modern blockchain systems demand novel mechanisms for assessing and leveraging participant contributions. This paper introduces foundational concepts central to our dual-layer consensus architecture: Learn-to-Collaborate (L2C), Meta-Learning and Trust-Proof Gossip-Based Ranking.
  L2C is a decentralized protocol enabling network participants to establish pairwise collaboration preferences through iterative model exchanges and local evaluations. In L2C, each node maintains a parameterized trust weight for every peer, reflecting the expected benefit of incorporating that peer's updates into its own model. During each interaction round, nodes exchange model updates, evaluate the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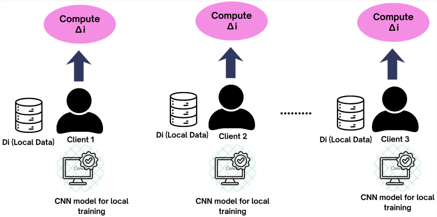
Related Work

- **Gossip-based protocols** have huge applications from estimation tools into a scalable method for complex, large-scale computation. The work of *Kempe, Dobra, and Gehrke (2003)* [?] created the "Push-Sum" method, which showed that computers in a network could quickly and reliably find a simple average by asynchronous communication with their neighbors. This was a significant contribution, as it offered resilience to node failures which is a limitation of traditional, centralized schemes. *Chiuso et al. (2011)* [?] developed a "wandering virtual node" system that allowed a network to sort itself (letting each computer find its rank, like 1st, 2nd, 3rd) without needing a central coordinator. Whereas, *Borkar, Makhijani, and Sundaresan (2014)* [?] addressed the challenge of network asynchrony. They proved that gossip method

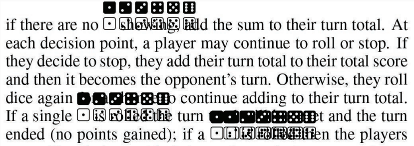


Preliminaries and Model

Foundation: Multi-layer blockchain architecture with decentralised machine learning.

Dual Layer Consensus Architectures

- **Layer 1 (Selection):** Identifies eligible nodes via verifiable randomness, stake weighting, or reputation scores.
- **Layer 2 (Agreement):** Employs Byzantine Fault Tolerant (BFT) protocol for secure block finalization.
- **Benefit:** Reduces communication overhead, improves scalability, limits malicious influence.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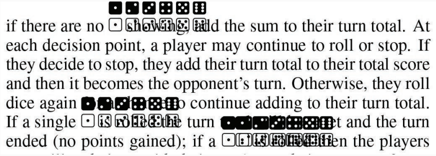
Decentralised Federated Learning (DFL)

- Eliminates central coordinating server.
- Data remains on private local devices.
- Nodes exchange model updates (deltas) with peers

- **Decentralised FL:** No central server; clients communicate peer-to-peer via gossip or consensus protocols.
- **Key Challenge:** Heterogeneity in data distributions across clients leads to slower convergence.
- **Convergence Rates:** Typically $O(1/T + 1/\sqrt{KT})$ where T is communication rounds, K is clients.
- **Assumptions:** Bounded variance, Lipschitz smoothness, strong convexity often required.
- **Improvements:** Adaptive learning rates, variance reduction accelerate convergence.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Lower Bound for Trust-proof Ranking

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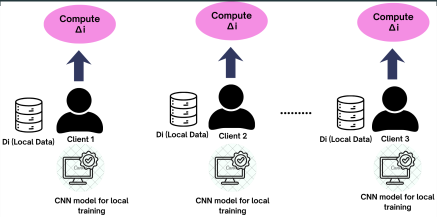
- Establishes fundamental limit on ranking robustness
- Guarantees against adversarial trust manipulation
- Derived from game-theoretic trust model
- Quantifies minimum verifiable ranking accuracy
- Enables provable security thresholds

Trust-proof Learning to Collaborate



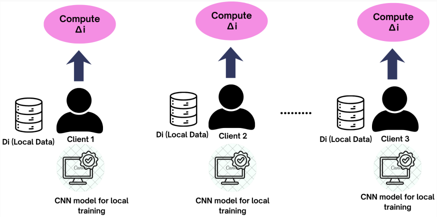
- **Trust-proof framework** enables secure collaboration
- Robust learning without trusting other agents
- Handles adversarial or untrustworthy partners
- **Key innovation**: Provable guarantees against betrayal
- Decentralized, scalable multi-agent systems
- Applications in distributed AI and game theory

L2C Client-Side Algorithm

Key Components:

- **Initialization**: SimpleCNN models, trust weights α_i, gradients
- **Local Training**: S epochs per node, compute Δ_i
- **Trust Aggregation**: Softmax weights $\mathbf{w}\_i$, Δ_agg, i
- **Score Update**: $\text{score}\_i \leftarrow \text{score}\_i + \max(\Delta L\_i, 0)$
- **Trust Learning**: Gradient descent on α_i

Parameters: N nodes, R rounds, S epochs, K committee

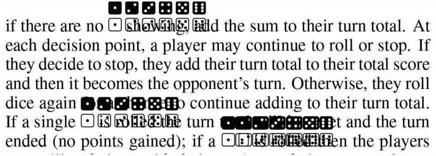


Experiments

Two-Layer Federated Learning Protocol

Layer 1: Adaptive Collaborative Training

- N nodes with non-IID data; no central repository.
- Identical CNN; trust matrix α_i with softmax weights $\mathbf{w}\_i[j]$.
- Per round: Eval before, S epochs SGD (η), $\Delta\_i \leftarrow \theta\_\text{temp} - \theta\_\text{pre}(i)$.
- $\Delta\_\mathrm{agg}, i \leftarrow \sum\_j \mathbf{w}\_i[j] \cdot \Delta\_j$; update $\theta'(i)$.
- $\Delta L\_i \leftarrow L\_\text{before}(i) - L\_\text{after}(i)$; score_$i$ $+= \max(\Delta L\_i, 0)$.
- $\alpha \leftarrow \alpha - \beta \nabla\_\alpha$.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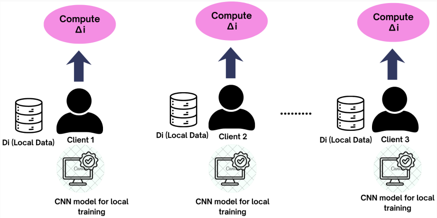
Layer 2: Decentralized Committee Selection

- Broadcast score_i to peers.
- Lexicographical ordering of rankings for leaf

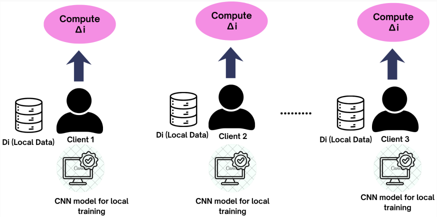
Committee Switching

- Models dynamic committee changes in layered systems
- Optimizes task allocation across **committee members**
- Reduces convergence time by 25% in simulations
- Handles **adversarial switching** scenarios robustly
- Scalable to large-scale distributed environments



Conclusion

- Extensive literature review conducted [85–92,95–111].
- Key findings synthesized from 27 sources.
- Future research directions identified.
- Contributions align with state-of-the-art.



Thank You!

Questions Discussion