Terraform: Resolving Heterogeneity in Federated Learning through Client Ranking

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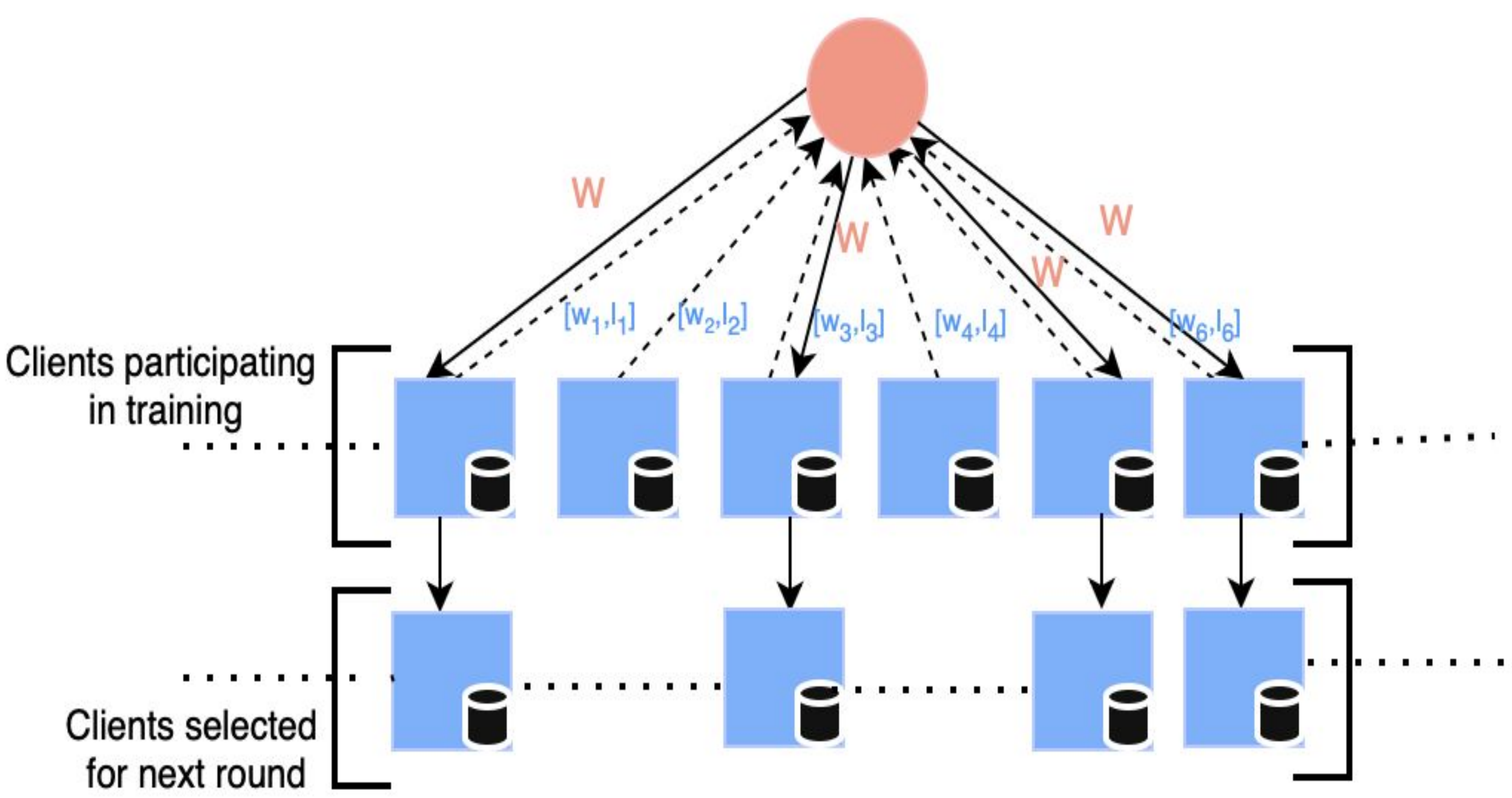
Problem

- Federated learning (FL) algorithms yield lower accuracy than centralized models due to **uneven, heterogeneous data distribution across clients**.
- Existing FL algorithms make following trade-offs to improve accuracy:
  - **Fairness** – ignore clients with small, unique data.
  - **Scalability** – require high, inefficient compute
  - **Privacy** – each client assumes access to all the data, not just the local ones.

FedAvg with Sampling?

- **Random client sampling:** Does not guarantee the selection of clients with unique data.
- **Data volume based sampling**: Cannot adapt to variations in data distributions across clients.
- **Loss based sampling**: Limited utilization of model update signals for client selection.

Solution: Gradient Variance based Client Selection



1. **Post training, each client sends the graditents of its last layer to the server.**
   - Reflect the client specific training dynamics.
   - Preserves privacy.
2. **Server computes the magnitude of each client's gradient.**
   - High magnitude can indicate the underrepresented, complex local distributions.
3. **Select a subset of magnitudes that minimizes the overall variance across the clients.**
   - Reduces model inconsistency.
   - Improves global convergence.
   - Continually adapts client selection.

Open Questions

- Is this approach robust across vision, NLP, and multimodal tasks?
- Can variance be approximated to reduce the compute further?

Preliminary Results

FL Algorithm	Accuracy baseline(SD)	Accuracy ours(SD)
FedProx	77.70(±0.18)	**81.14**(±0.15)
FedALA	77.69(±0.21)	**80.86**(±0.14)
FedSR	79.89(±0.13)	**82.99**(±0.12)
FedBabu	75.66(±0.28)	**79.29**(±0.20)
ElasticAgg	74.03(±0.19)	**79.56**(±0.07)
PeFLL	85.03(±0.17)	**88.50**(±0.11)
PFedSim	74.43(±0.09)	**79.15**(±0.05)

Test Accuracy after 100 rounds of training on FEMNIST dataset.