NEURAL INFORMATION PROCESSING SYSTEMS

Personalized Subgraph Federated Learning with Differentiable Auxiliary Projections

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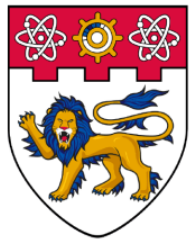

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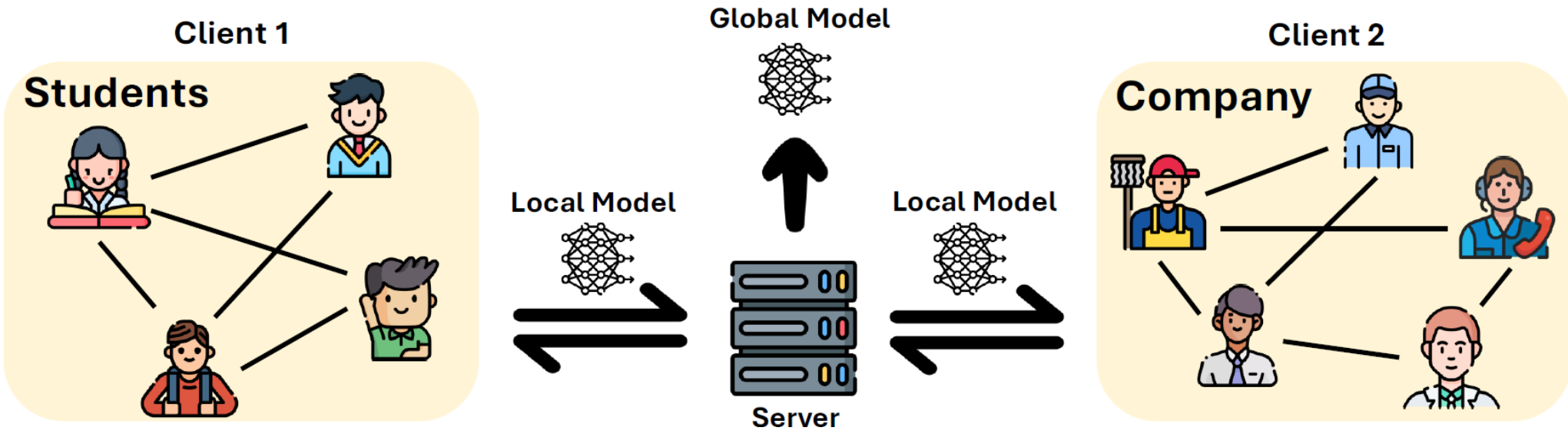
Subgraph Federated Learning

Subgraph federated learning involves K clients, each holding a local subgraph from a larger global graph.



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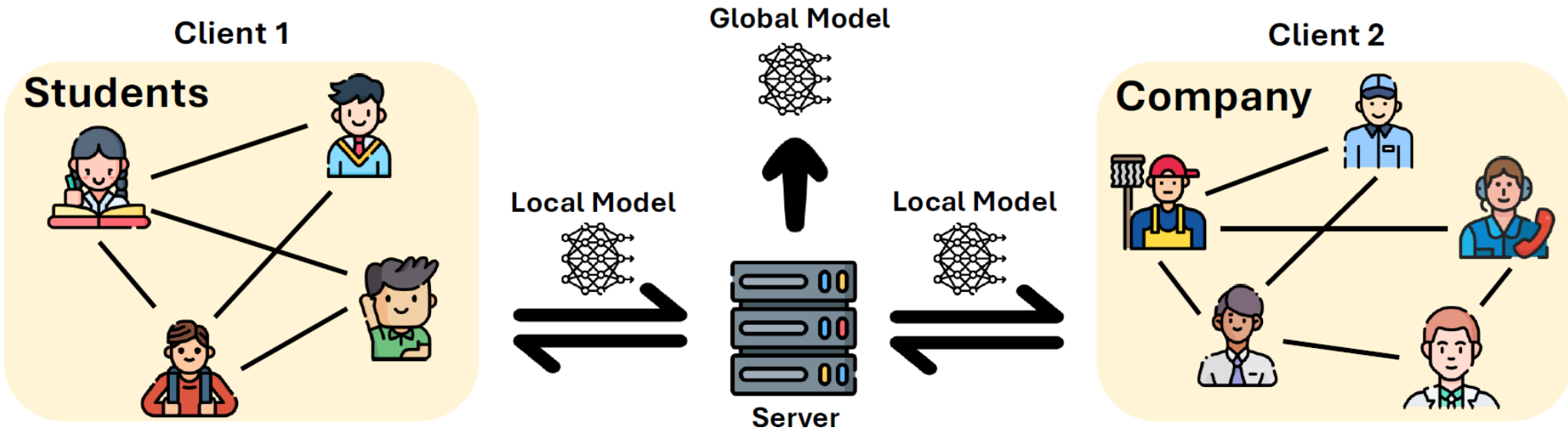
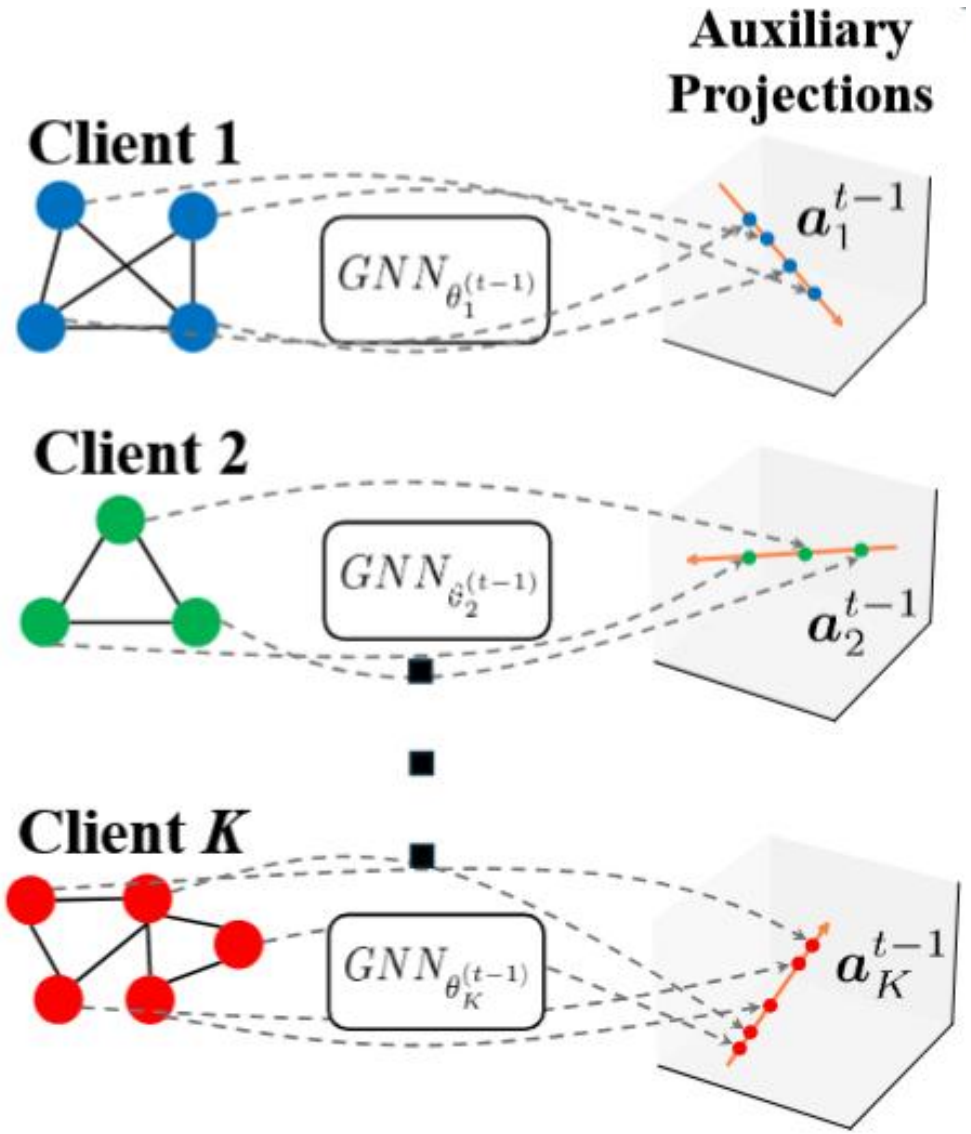
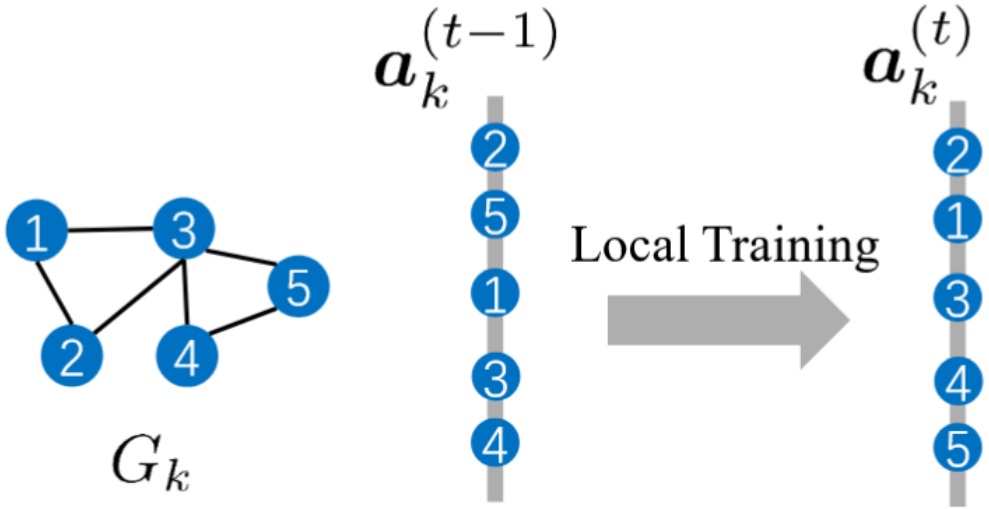


The key challenge is that these subgraphs exhibit significant heterogeneity in their structures, features, and label distributions, making traditional federated averaging ineffective.

Auxiliary Projection Vectors

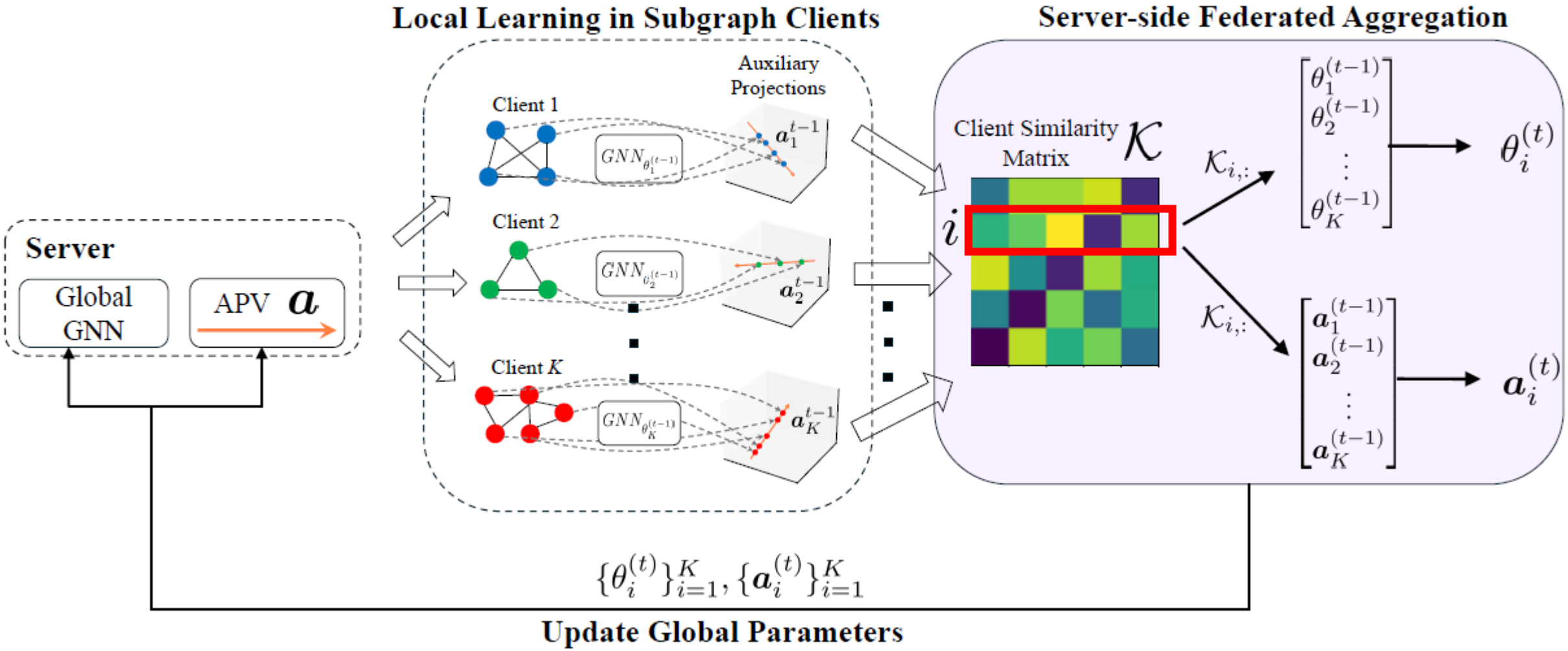




APV client-specific similarity proxies on the server

APV serves as a privacy-preserving latent space that retains relative subgraph structure while concealing absolute node positions and raw features.

Overall Framework



Theoretical Analysis

Theorem 3.1 (Fidelity of the APV $\boldsymbol{a}$). *Let* $\mathbf{C} := \frac{1}{N}\sum_{i=1}^{N} h_i h_i^\top$ *be the empirical covariance of node embeddings in the current client with size* N. *The gradient of the local loss* $\mathcal{L}$ *w.r.t. the* APV $\boldsymbol{a}$ *satisfies:*

$$\nabla_a \mathcal{L} = -\frac{2}{\sigma^2}\mathbf{C}\boldsymbol{a} + \mathcal{R}(\sigma), \tag{9}$$

where the remainder term obeys $\|\mathcal{R}(\sigma)\| = \mathcal{O}(\sigma^0)$ *as* $\sigma \to 0^+$. *Define* $\mathbb{S}^{d-1} = \{x \in \mathbb{R}^d : \|x\|_2 = 1\}$ *as the unit Euclidean sphere embedded in* $\mathbb{R}^d$, *then the gradient descent on* $\mathcal{L}$ *with unit-norm re-normalization reproduces Oja learning rule [22]:*

$$\boldsymbol{a} \leftarrow \Pi_{\mathbb{S}^{d-1}}(\boldsymbol{a} - \eta\mathbf{C}\boldsymbol{a}), \tag{10}$$

whose unique stable fixed points are the eigenvectors of $\mathbf{C}$, *and the global attractor is the principal eigenvector (largest eigenvalue).*

Experiments

Methods	Cora			CiteSeer			Pubmed		
	5 Clients	10 Clients	20 Clients	5 Clients	10 Clients	20 Clients	5 Clients	10 Clients	20 Clients
Local	81.30±0.21	79.94±0.24	80.30±0.25	69.02±0.05	67.82±0.13	65.98±0.17	84.04±0.18	82.81±0.39	82.65±0.03
FedAvg	74.45±5.64	69.19±0.67	69.50±3.58	71.06±0.60	63.61±3.59	64.68±1.83	79.40±0.11	82.71±0.29	80.97±0.26
FedProx	72.03±4.56	60.18±7.04	48.22±6.81	71.73±1.11	63.33±3.25	64.85±1.35	79.45±0.25	82.55±0.24	80.50±0.25
FedPer	81.68±0.40	79.35±0.04	78.01±0.32	70.41±0.32	70.53±0.28	66.64±0.27	85.80±0.21	84.20±0.28	84.72±0.31
GCFL	81.47±0.65	78.66±0.27	79.21±0.70	70.34±0.57	69.01±0.12	66.33±0.05	85.14±0.33	84.18±0.19	83.94±0.36
FedGNN	81.51±0.68	70.12±0.99	70.10±3.52	69.06±0.92	55.52±3.17	52.23±6.00	79.52±0.23	83.25±0.45	81.61±0.59
FedGTA	71.26±2.93	68.33±1.27	69.24±0.91	69.39±0.75	67.34±1.08	65.29±1.92	78.47±0.25	82.79±0.20	81.92±0.60
FedSage+	72.97±5.94	69.05±1.59	57.97±12.6	70.74±0.69	65.63±3.10	65.46±0.74	79.57±0.24	82.62±0.31	80.82±0.25
FED-PUB	83.72±0.18	81.45±0.12	81.10±0.64	72.40±0.26	71.83±0.61	66.89±0.14	86.81±0.12	86.09±0.17	84.66±0.54
FedAux	**84.57±0.39**	**82.05±0.71**	**81.60±0.64**	**72.99±0.82**	**73.16±0.29**	**68.10±0.35**	**88.10±0.16**	**86.43±0.20**	**84.87±0.42**

Methods	Amazon-Computer			Amazon-Photo			ogbn-arxiv		
	5 Clients	10 Clients	20 Clients	5 Clients	10 Clients	20 Clients	5 Clients	10 Clients	20 Clients
Local	89.22±0.13	88.91±0.17	89.52±0.20	91.67±0.09	91.80±0.02	90.47±0.15	66.76±0.07	64.92±0.09	65.06±0.05
FedAvg	84.88±1.96	79.54±0.23	74.79±0.24	89.89±0.83	83.15±3.71	81.35±1.04	65.54±0.07	64.44±0.10	63.24±0.13
FedProx	85.25±1.27	83.81±1.09	73.05±1.30	90.38±0.48	80.92±4.64	82.32±0.29	65.21±0.20	64.37±0.18	63.03±0.04
FedPer	89.67±0.34	89.73±0.04	87.86±0.43	91.44±0.37	91.76±0.23	90.59±0.06	66.87±0.05	64.99±0.18	64.66±0.11
GCFL	89.07±0.91	90.03±0.16	**89.08±0.25**	91.99±0.29	92.06±0.25	90.79±0.17	66.80±0.12	65.09±0.08	65.08±0.04
FedGNN	88.08±0.15	88.18±0.41	83.16±0.13	90.25±0.70	87.12±2.01	81.00±4.48	65.47±0.22	64.21±0.32	63.80±0.05
FedGTA	85.06±0.82	84.27±0.71	79.46±0.28	89.70±0.67	76.53±3.21	82.02±0.78	65.42±0.09	64.22±0.08	63.75±0.18
FedSage+	85.04±0.61	80.50±1.30	70.42±0.85	90.77±0.44	76.81±8.24	80.58±1.15	65.69±0.09	64.52±0.14	63.31±0.20
FED-PUB	90.25±0.07	89.73±0.16	88.20±0.18	93.20±0.15	**92.46±0.19**	90.59±0.35	67.62±0.11	66.35±0.16	63.90±0.27
FedAux	**90.38±0.08**	**89.92±0.15**	88.35±0.96	**93.37±0.26**	92.30±0.29	**90.91±0.60**	**68.83±0.15**	**68.50±0.27**	**65.52±0.10**