Privacy Mechanisms

Address Anonymization

$\tilde{a}_j = \text{HMAC}_k(a_j) \oplus \mathcal{L}(0, \lambda_a)$

Price Fuzzing

$\tilde{p}_j = p_j + \mathcal{L}(0, \Delta p/\varepsilon_p)$

Temporal Perturbation

$\tilde{ts}_j = \text{Quantize}(ts_j, \delta_t) + \mathcal{L}(0, \lambda_t)$

Transaction Embedding

$e_j = W_{\text{trans}}[W_{\text{addr}}(a_j^s \oplus a_j^r); W_{\text{price}} p_j; W_{\text{time}} ts_j]$

e_1 e_2 e_3 ... e_t

Transaction Sequence $X^t = \{tr_1, tr_2, ..., tr_t\}$

tr_1	tr_2	tr_3	...	tr_t
a_1^s, a_1^r	a_2^s, a_2^r	a_3^s, a_3^r		a_t^s, a_t^r
p_1, ts_1	p_2, ts_2	p_3, ts_3		p_t, ts_t

Sequence Processing
Longformer Architecture

Window1 Window2 Window3

$$M_{ij} = \begin{cases} 0, & \text{if } |i-j| \le w \text{ or } g_i = 1 \text{ or } g_j = 1 \\ -\infty, & \text{otherwise} \end{cases}$$

$$\text{Attention}_{Longformer}(Q, K, V) = \text{softmax}\left(\frac{QK^T \odot M}{\sqrt{d_k}}\right)V$$

Global Attention Tokens

[Global tokens for significant price changes]

Graph Processing
Graph Convolutional Networks

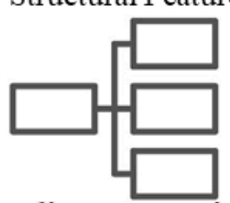
Node i ⟷ Node j

$$H^{(l+1)} = \sigma\left(\tilde{D}^{-\frac{1}{2}}\tilde{A}\tilde{D}^{-\frac{1}{2}}H^{(l)}W^{(l)}\right)$$

$\tilde{A} = A + I$ (adjacency matrix with self-loops)

$\tilde{D}$ = degree matrix of $\tilde{A}$

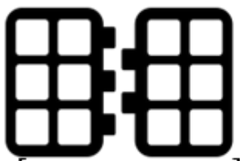
Structural Features



[Network centrality, community structure, etc.]

Feature Aggregation

Concatenation & Projection



$h_t = W_{\text{out}}[h_{\text{sequence}}; h_{\text{graph}}] + b_{\text{out}}$

Privacy-Preserved Transaction Features

$\tilde{h}_t = h_t + \mathcal{L}(0, \lambda_t \cdot \Delta_t/\varepsilon_t)$