Variational Label-Correlation Enhancement for Congestion Prediction

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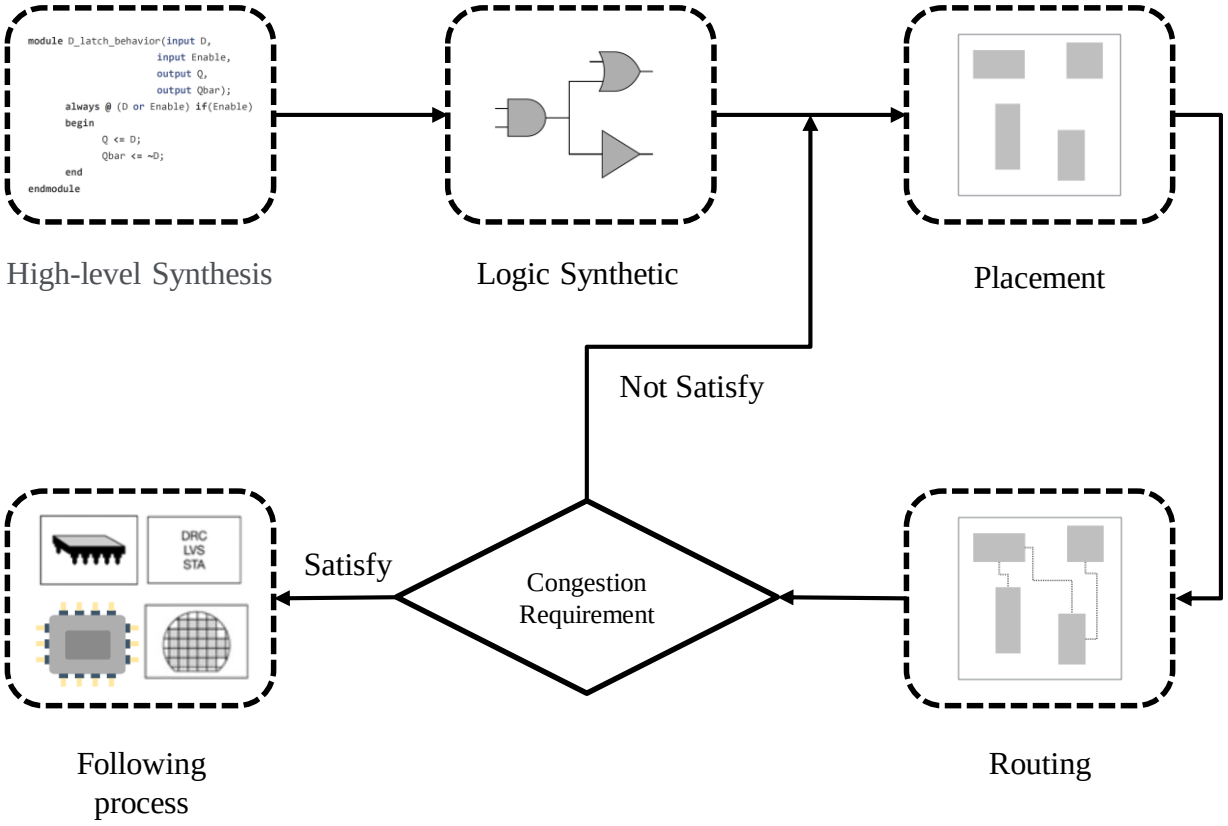
Congestion Prediction



Problem Setup

Settings

$\mathcal{X}$: q-dimensional feature space $\mathbb{R}^q$

$\mathcal{Y}$: congestion map space with $H \times W$ positive real labels

Inputs

$\mathcal{D}$: training set with n examples $\mathcal{D} = \{(\boldsymbol{X}_i, \boldsymbol{Y}_i) | 1 \leq i \leq n\}$

$\boldsymbol{X}_i \in \mathcal{X}$ is a q-dimensional feature vector

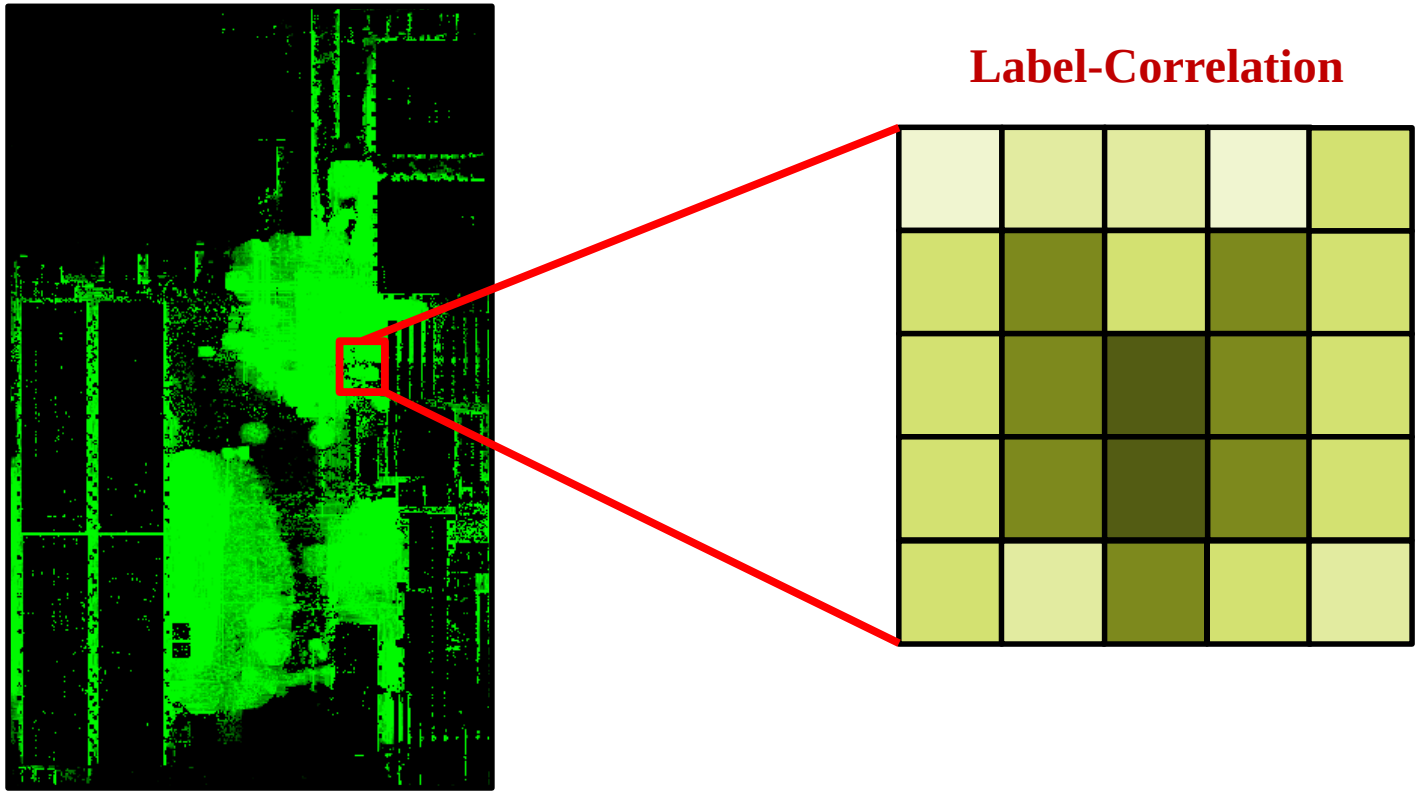
$\boldsymbol{Y}_i = [\boldsymbol{y}_i^1, \boldsymbol{y}_i^2, \ldots, \boldsymbol{y}_i^H] \in \mathcal{Y}$ is the congestion map associated with $\boldsymbol{X}_i$

$\boldsymbol{y}_i^j = \left[y_i^{j,1}, y_i^{j,2}, \ldots, y_i^{j,W}\right]^\intercal$

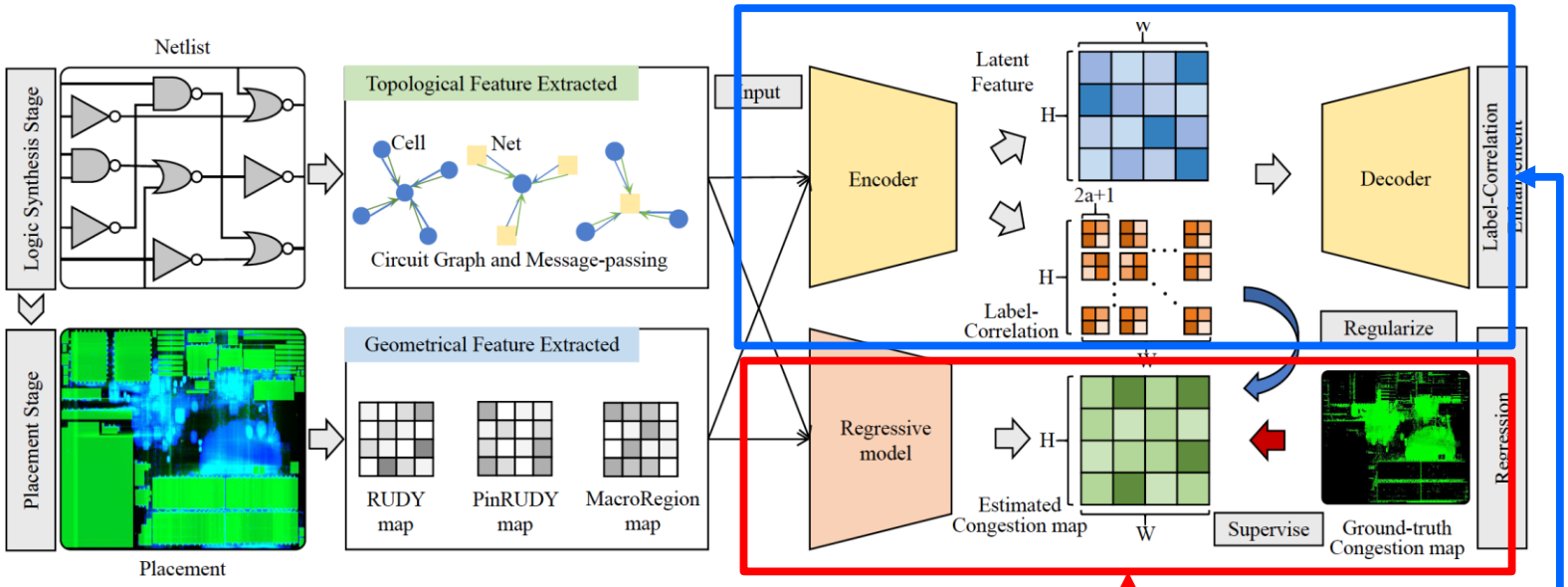
Outputs

f: congestion map regression model $f: \mathcal{X} \mapsto \mathcal{Y}$

Label-Correlation in Congestion Prediction

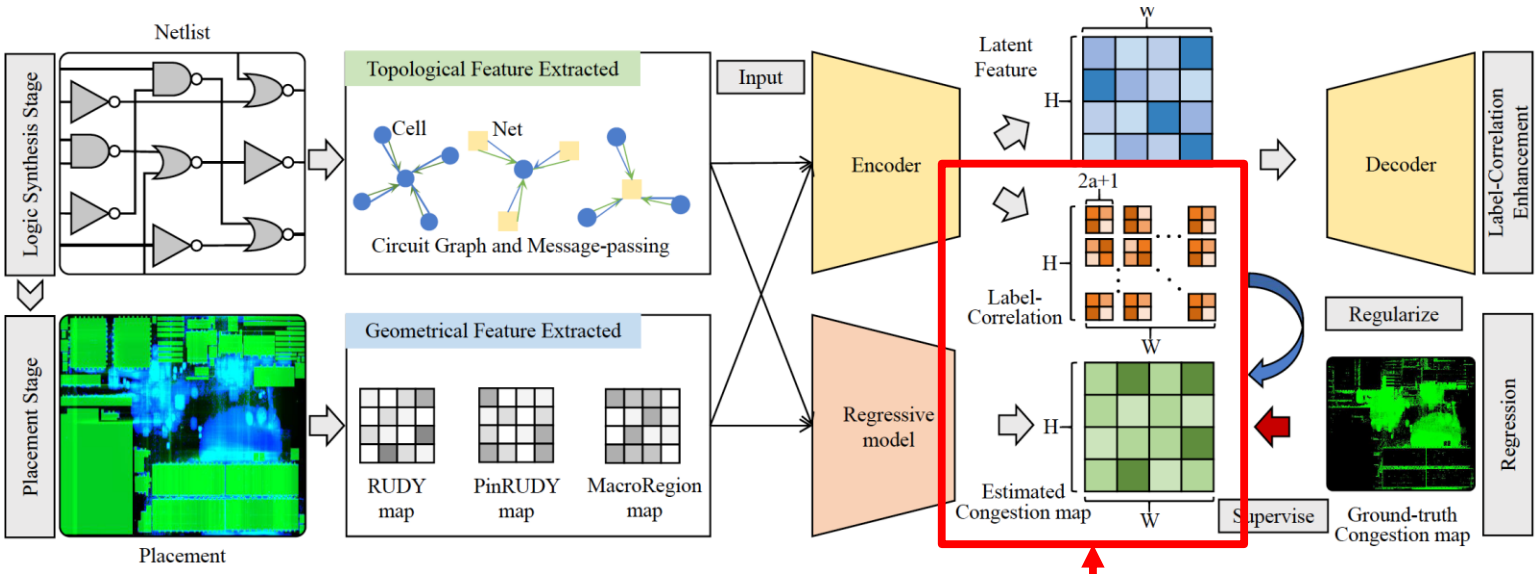


The overall framework



$$\hat{R}(f) = \frac{1}{n}\sum_{i=1}^{n}\left(\mathcal{L}_{\text{sup}}\left(f(\mathbf{X}_i), \mathbf{Y}_i\right) + \lambda\mathcal{L}_{\text{reg}}(f(\mathbf{X}_i), \mathbf{M}_i)\right)$$

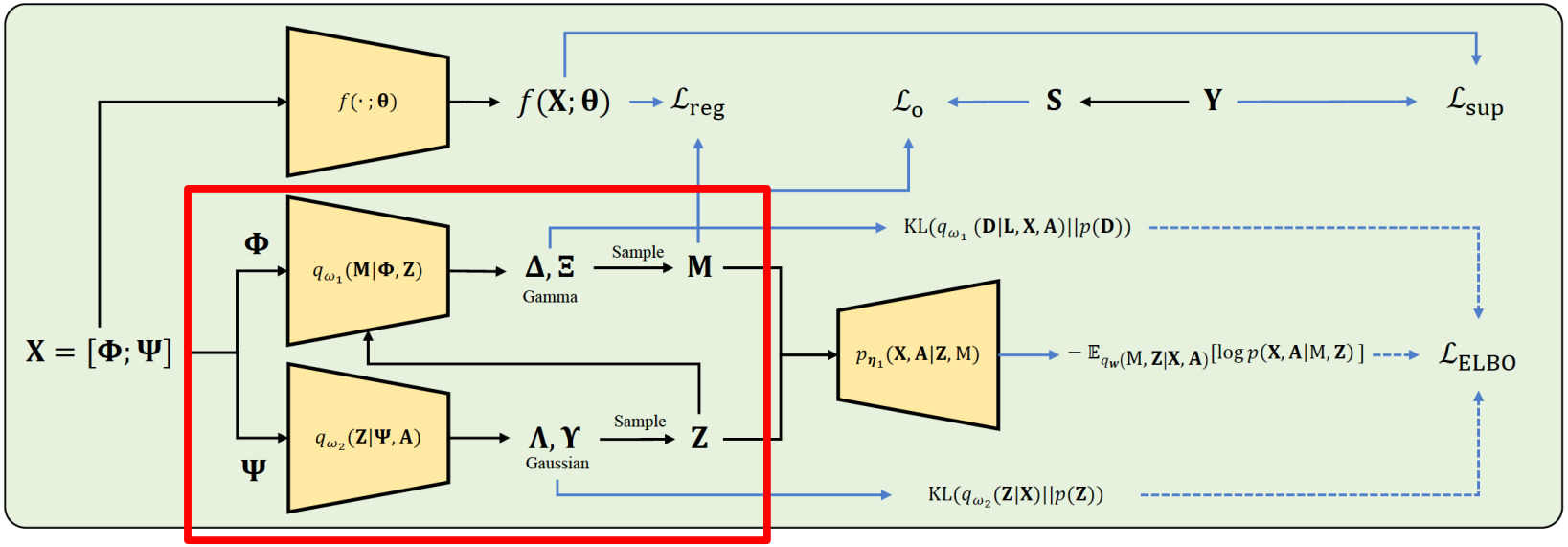
Label-Correlation Enhancement



$$\mathcal{L}_{\text{reg}}(f(\mathbf{X}_i), \mathbf{M}_i) = \sum_{j=1}^{H} \sum_{k=1}^{W} \ell_{\text{lc}}\left(f^{j,k}(\mathbf{X}_i), \mathbf{M}_i^{j,k}\right)$$

$$\ell_{\text{lc}}\left(f^{j,k}(\mathbf{X}_i), \mathbf{M}_i^{j,k}\right) = \sum_{h=1}^{2a+1} \sum_{w=1}^{2a+1} m_{i,j,k}^{h,w} \cdot \left\| f^{j,k}(\mathbf{X}_i) - f^{r,v}(\mathbf{X}_i) \right\|$$

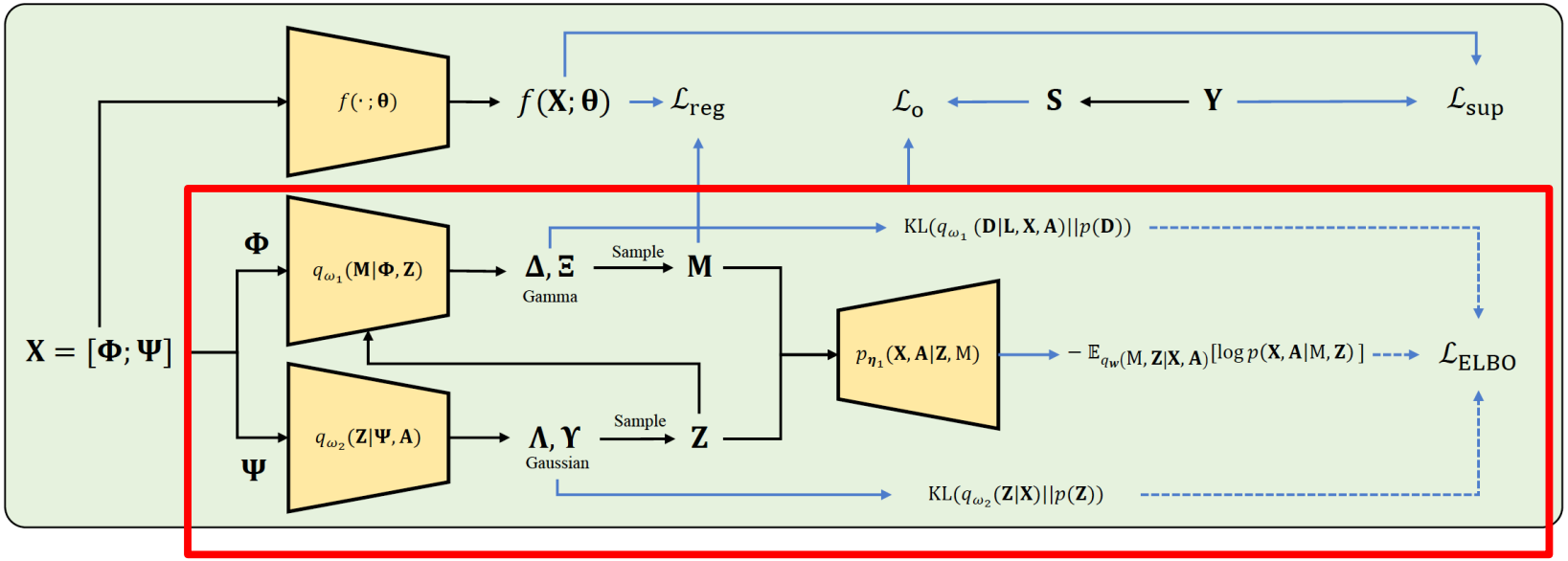
Variational Label-Correlation Enhancement



$$q_{\boldsymbol{\omega}_1}(\mathbf{M}_i \mid \boldsymbol{\Phi}_i, \mathbf{Z}_i) = \prod_{j=1}^{H} \prod_{k=1}^{W} \prod_{h=1}^{2a+1} \prod_{w=1}^{2a+1} \text{Gamma}\left(m_{i,j,k}^{h,w} \mid \alpha_{i,j,k}^{h,w}, \beta_{i,j,k}^{h,w}\right)$$

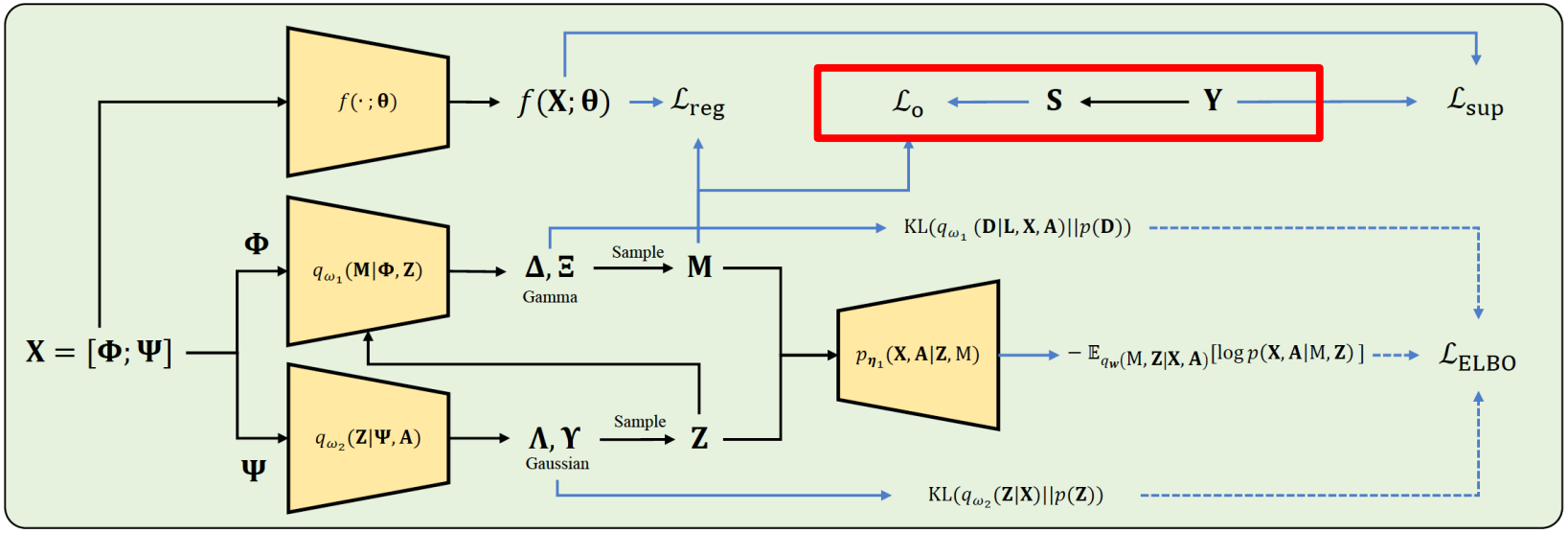
$$q_{\boldsymbol{\omega}_2}(\mathbf{Z}_i \mid \boldsymbol{\Psi}_i, \mathbf{A}_i) = \prod_{j=1}^{C} \prod_{k=1}^{b} \text{Gaussian}\left(z_i^{j,k} \mid \mu_i^{j,k}, \sigma_i^{j,k}\right).$$

Variational Label-Correlation Enhancement



$$\mathcal{L}_{\text{ELBO}} = \mathbb{E}_{q_{\boldsymbol{\omega}_1,\omega_2}(\mathbf{M},\mathbf{Z}|\boldsymbol{\Phi},\boldsymbol{\Psi},\mathbf{A})}\left[\log p_{\boldsymbol{\eta}}(\mathbf{X},\mathbf{A}|\mathbf{M},\mathbf{Z})\right]$$
$$-\mathrm{KL}\left(q_{\boldsymbol{w}_1}(\mathbf{M}|\boldsymbol{\Phi},\mathbf{Z}) \parallel p(\mathbf{M})\right)$$
$$-\mathrm{KL}\left(q_{\boldsymbol{w}_2}(\mathbf{Z}|\boldsymbol{\Psi},\mathbf{A}) \parallel p(\mathbf{Z})\right)$$

Variational Label-Correlation Enhancement



$$\mathcal{L}_o = \sum_{i=1}^{n} \| \mathbf{M}_i - \mathbf{S}_i \|$$

$$\mathbf{S}_i^{j,k} = \left[s_{i,j,k}^{1,1}, \dots, s_{i,j,k}^{1,2a+1}; \dots; s_{i,j,k}^{2a+1,1}, \dots, s_{i,j,k}^{2a+1,2a+1} \right]$$

$$s_{i,j,k}^{h,w} = e^{-\frac{\|y_i^{j,k} - y_i^{h,w}\|}{2\sigma^2}}$$

Experimental results

TABLE III: Congestion prediction result in placement stage of ISPD2011.

Baseline	Cell-level			Grid-level		
	pearson	spearman	kendall	pearson	spearman	kendall
GAT (w. geom.)	0.959	0.568	0.524	0.112	0.803	0.717
PIX2PIX	-	-	-	**0.419**	0.399	0.318
LHNN	-	-	-	-0.030	0.019	0.016
CIRCUITGNN (w/o. topo.)	0.969	0.573	0.539	0.134	0.813	0.726
CIRCUITGNN	0.965	0.571	0.538	0.182	0.809	0.722
VALCE	**0.974**	**0.579**	**0.545**	0.352	**0.823**	**0.737**

TABLE IV: Congestion prediction result in placement stage of DAC2012.

Baseline	Cell-level			Grid-level		
	pearson	spearman	kendall	pearson	spearman	kendall
GAT (w. geom.)	0.704	0.135	0.107	0.029	0.189	0.134
PIX2PIX	-	-	-	0.337	0.304	0.238
LHNN	-	-	-	0.246	0.167	0.135
CIRCUITGNN (w/o. topo.)	0.189	0.249	0.187	0.091	0.298	0.207
CIRCUITGNN	0.223	0.237	0.178	0.128	0.321	0.225
VALCE	**0.830**	**0.547**	**0.428**	**0.481**	**0.644**	**0.458**

Experimental results

TABLE V: Inference time (second/epoch) results in logical synthesis stage.

Baseline	ISPD2011	DAC2012
GCN	10.85	10.55
GRAPHSAGE	11.60	12.00
GAT	12.24	11.28
CONGESTIONNET	11.58	11.36
MPNN	36.17	30.44
CIRCUITGNN	22.78	18.51
VALCE(w/o. geom.)	10.21	10.41

TABLE VI: Inference time (second/epoch) results in placement stage.

Baseline	ISPD2011	DAC2012
GAT (w. geom.)	11.93	11.22
PIX2PIX	1.40	1.33
LHNN	63.15	102.41
CIRCUITGNN (w/o. topo.)	14.93	14.03
CIRCUITGNN	15.37	16.04
VALCE	11.48	10.81

THANK YOU