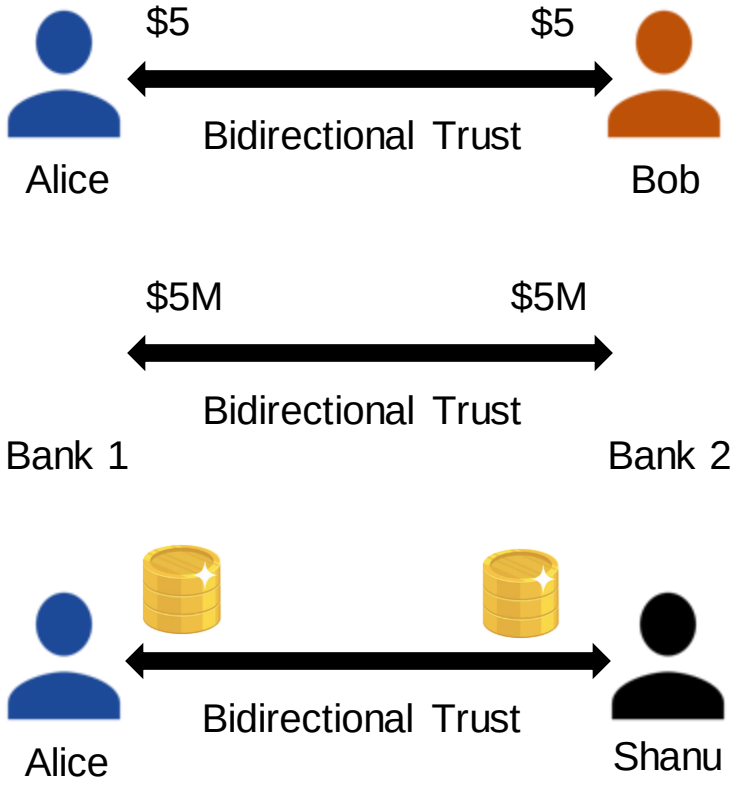
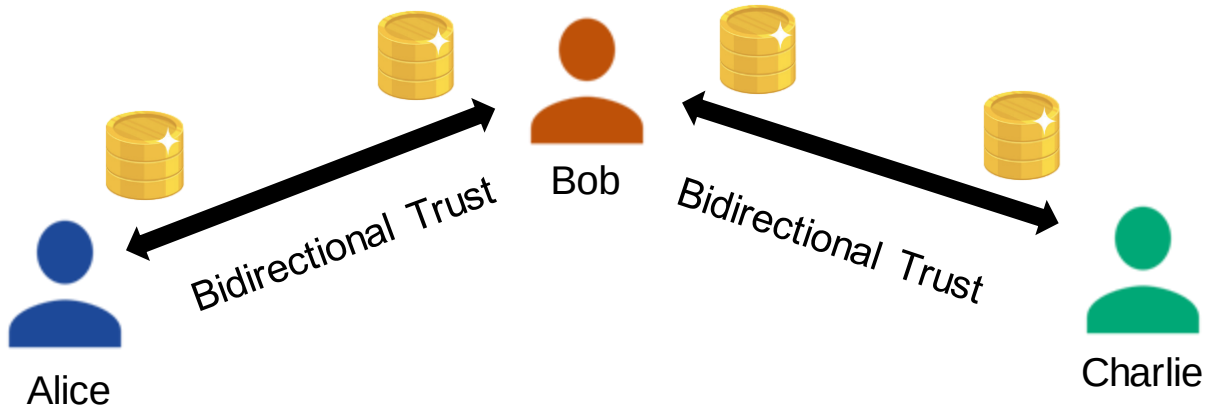
The Effect of Network Topology on Credit Network Throughput

Vibhaalakshmi Sivaraman, Weizhao Tang, Shaileshh Bojja Venkatakrishnan, Giulia Fanti, Mohammad Alizadeh

Credit Networks

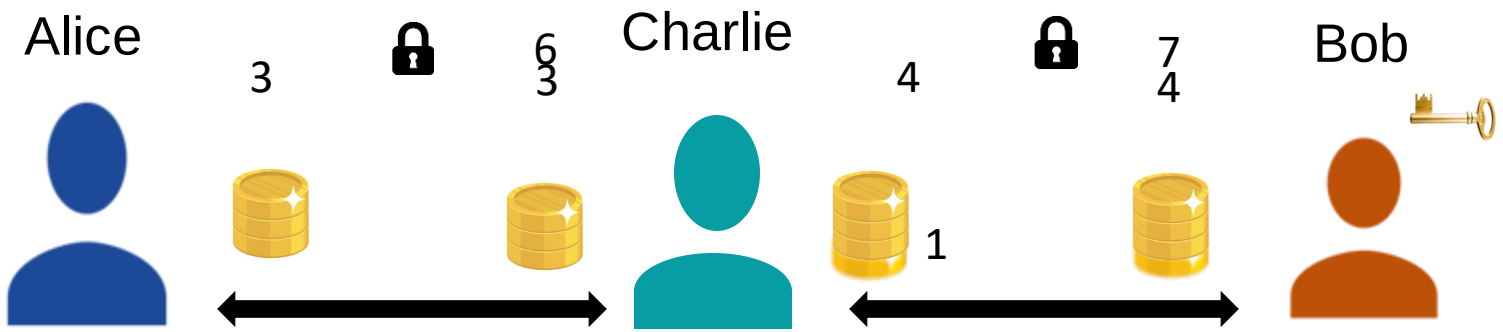
Networks enabling transfer of money, goods, or services through trust lines





Payment Channel Networks

Alice wants to send
3 coins to Bob

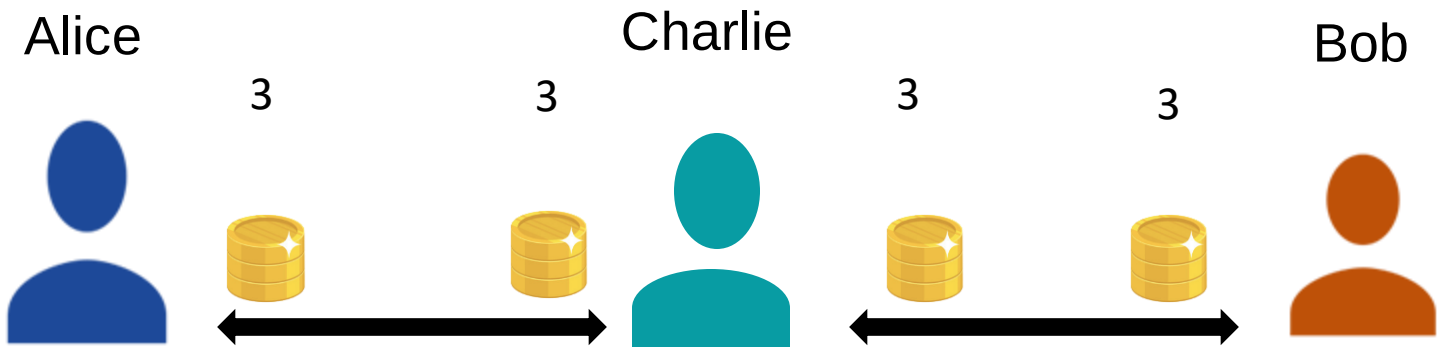


Alice can no longer pay Bob

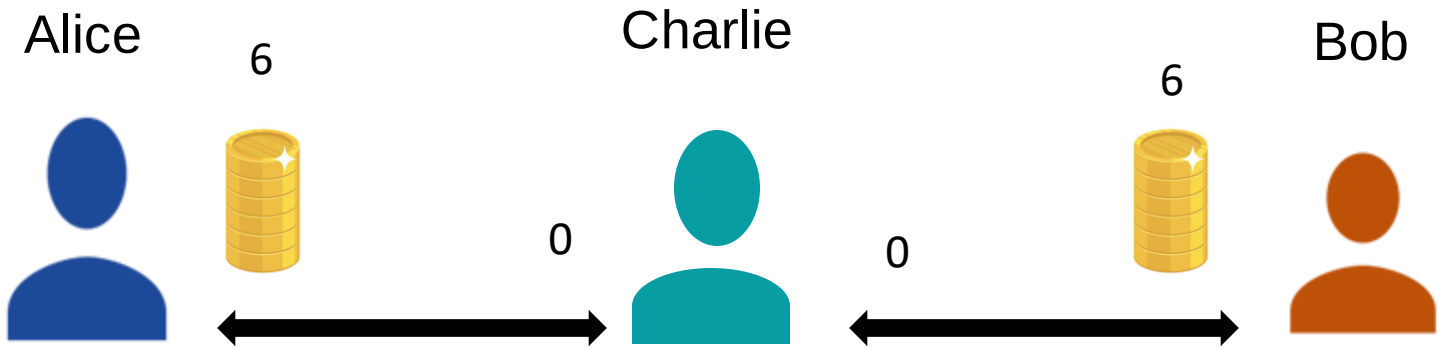
How does the configuration affect credit network throughput?

Comparing Configurations

Alice → Bob
Bob → Alice



Alice and Bob can pay each other



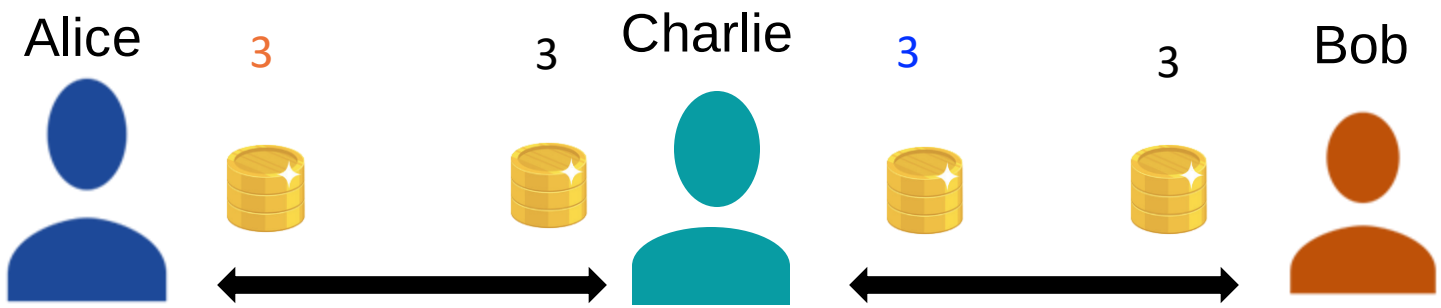
Deadlock !

Alice and Bob can no longer make payments

Simplified Model

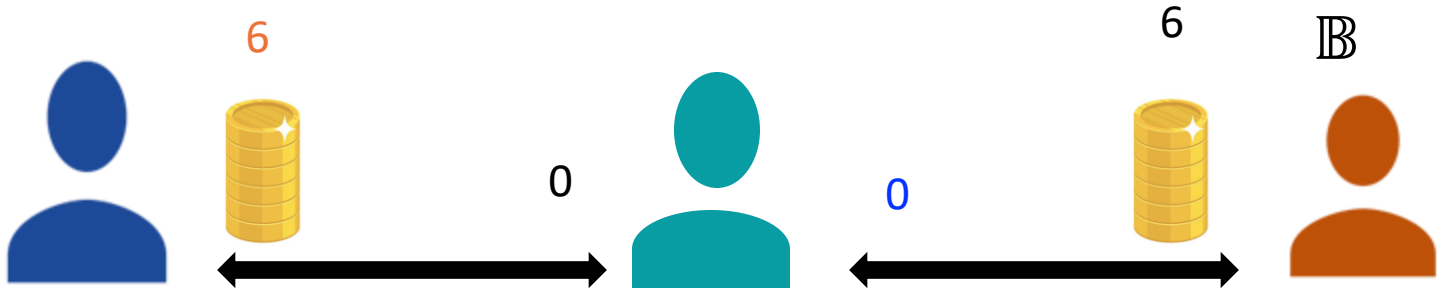
$G(E,V)$

$b = \begin{bmatrix} 3 \\ 3 \end{bmatrix}$



$\text{Capacity} = \begin{bmatrix} 6 \\ 6 \end{bmatrix}$

$b = \begin{bmatrix} 6 \\ 0 \end{bmatrix}$

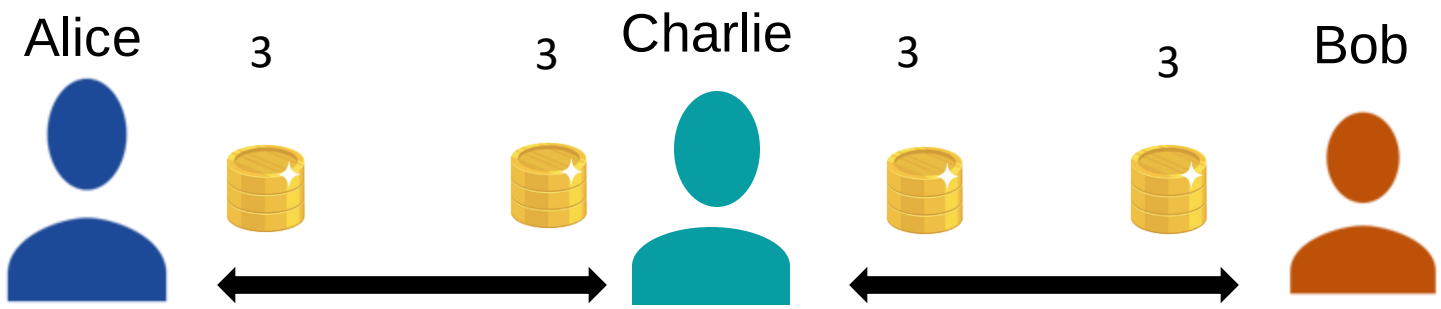


Balance State Space $\mathbb{B}$

Demand D:
Alice → Bob
Bob → Alice

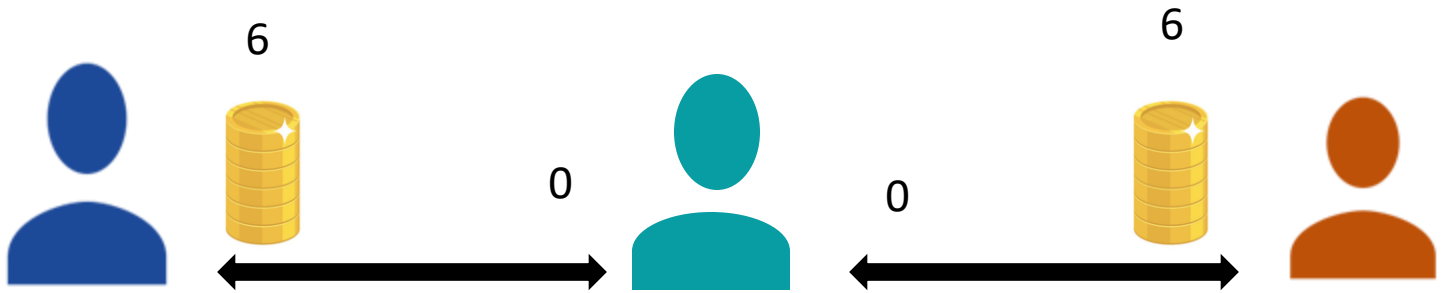
Steady-state Throughput $\phi(b) = \lim_{T\to\infty} \frac{\sum_{t=0}^{T} Throughput(t)}{T}$ (Subject to Demand D and topology)

Throughput Sensitivity



$$\phi_{max} = \max_{b \in \mathbb{B}} \phi(b) = 6$$

Throughput Sensitivity



$$\phi_{min} = \min_{b \in \mathbb{B}} \phi(b) = 0$$

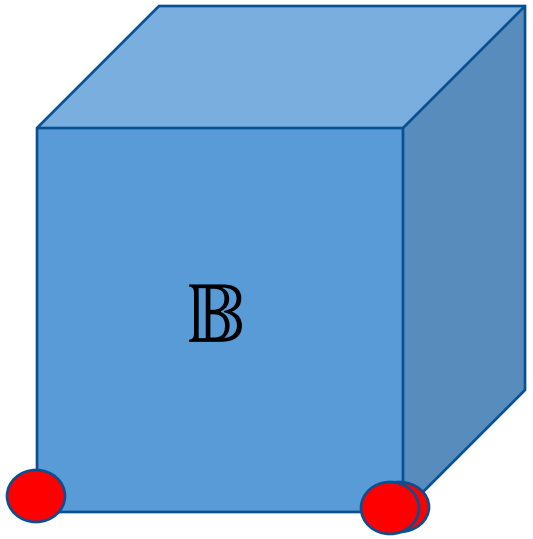
$$\phi_{min} \neq \phi max$$

When is $\phi_{min} \approx \phi max$?

Throughput Insensitivity

Deadlocks and Throughput Sensitivity

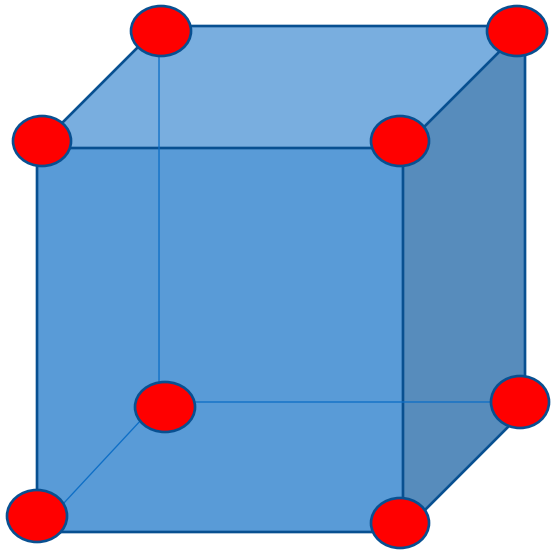
Theorem 1: No deadlocks ⇒ Throughput Insensitivity



Deadlocks and Throughput Sensitivity

Theorem 1: No deadlocks ⇒ Throughput Insensitivity

Theorem 2: Minimum throughput ϕ_{min} achieved at state with most deadlocked channels



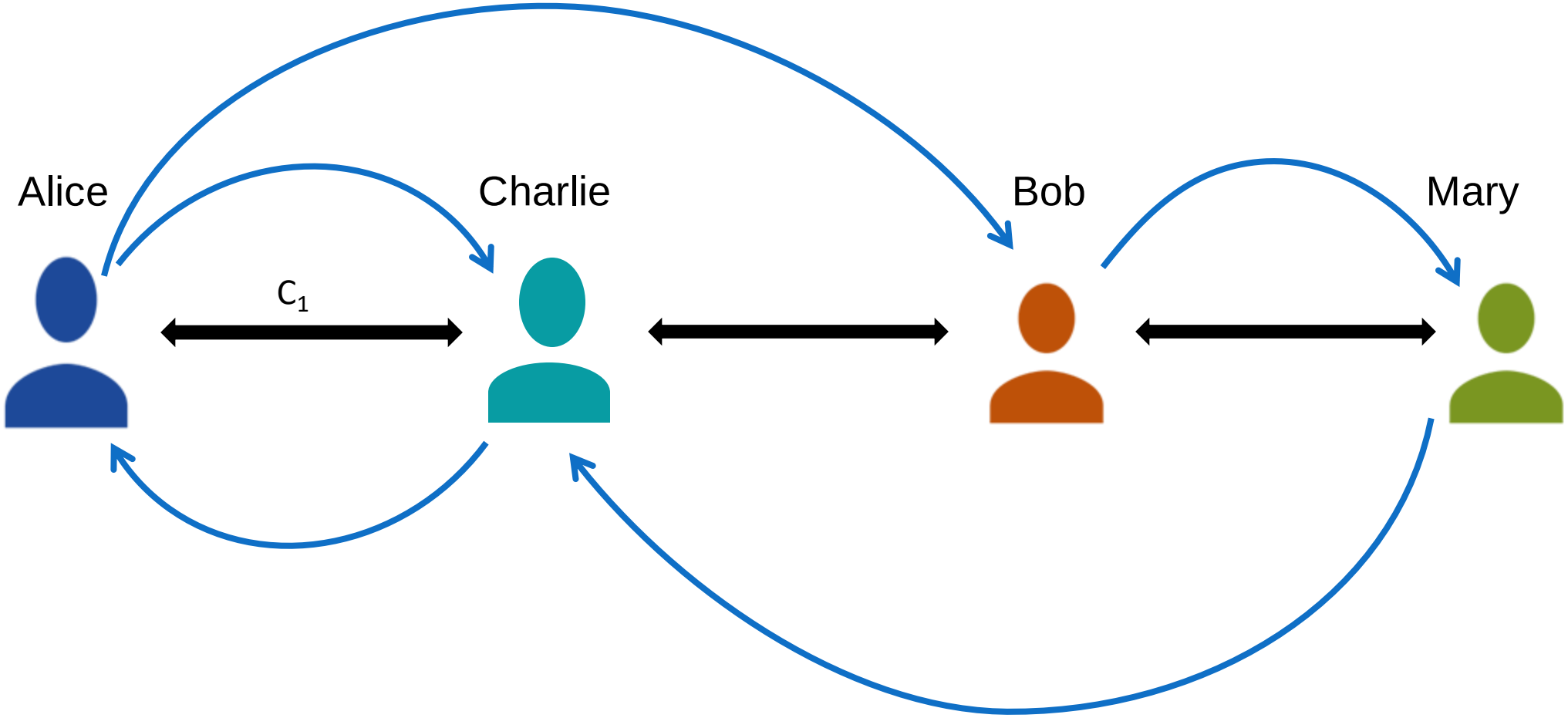
Deadlocks and Throughput Sensitivity

Theorem 1: No deadlocks ⇒ Throughput Insensitivity

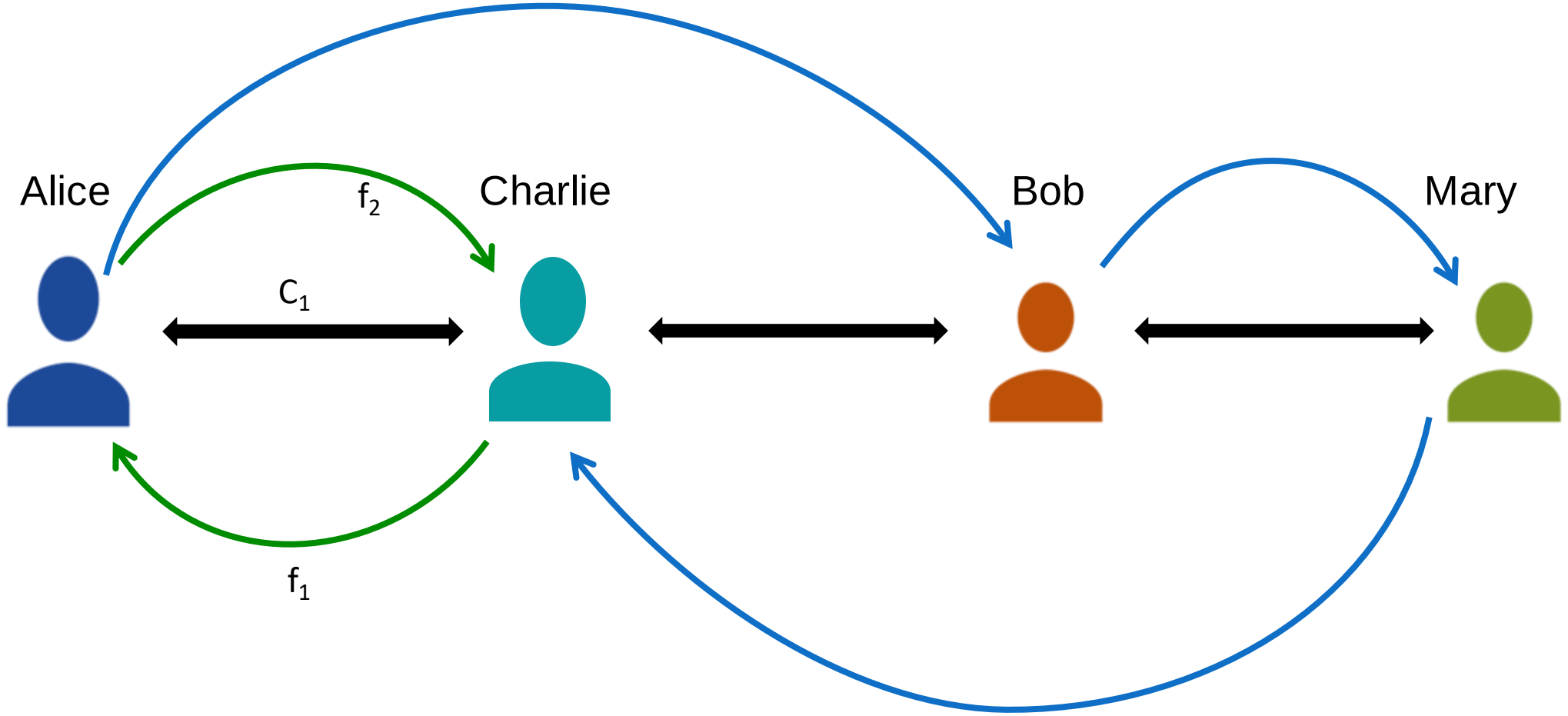
Theorem 2: Minimum throughput $\phi_{\mathbf{min}}$ achieved at state with most deadlocked channels

Theorem 3: Deadlock detection is NP-Hard

Detecting Deadlocks



Detecting Deadlocks



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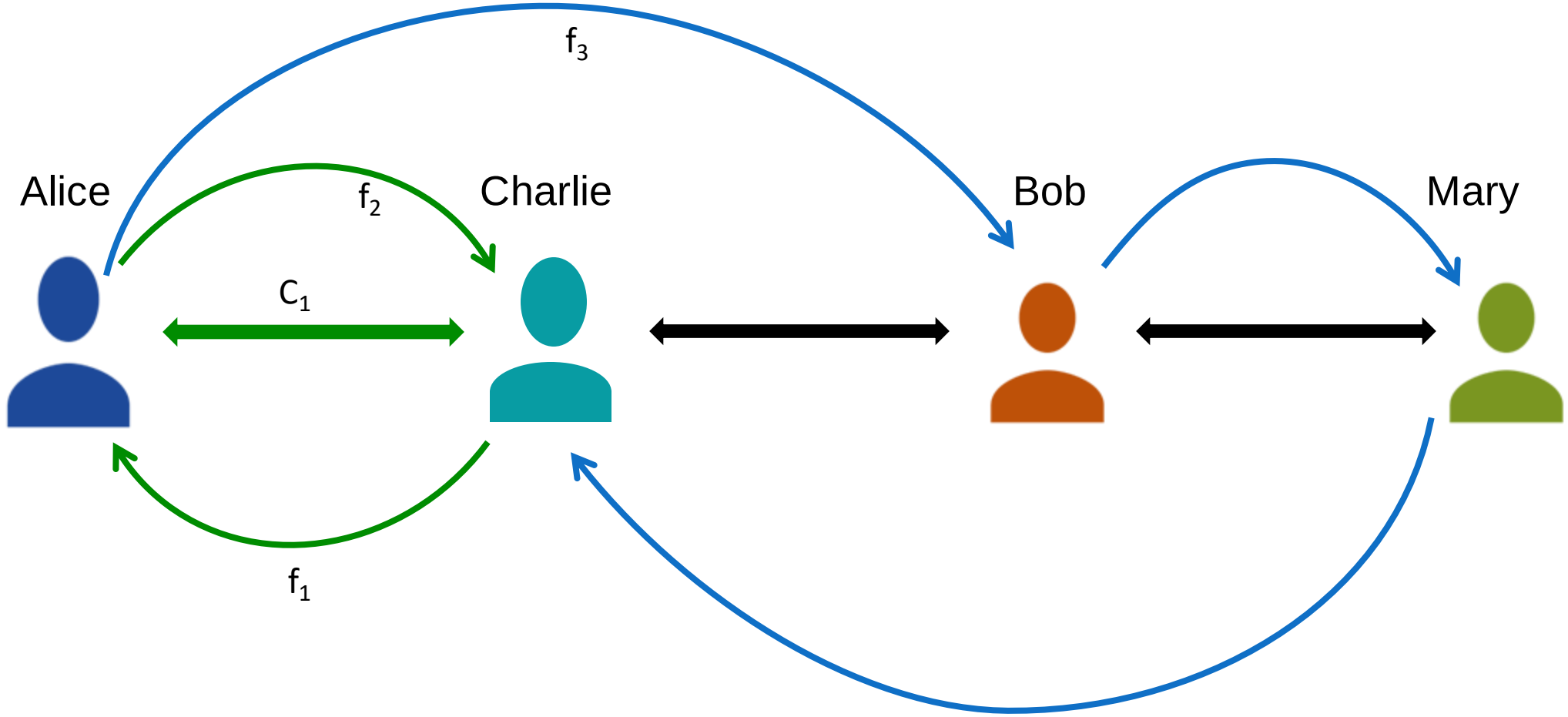
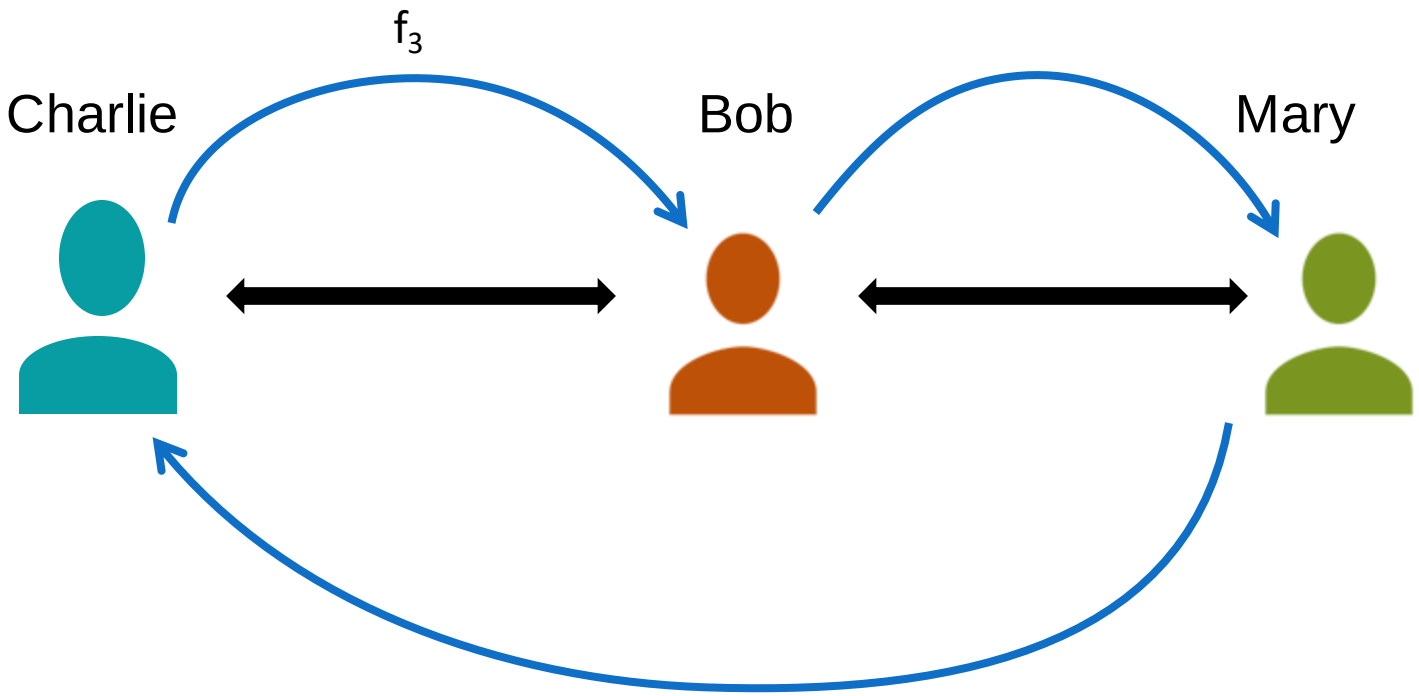
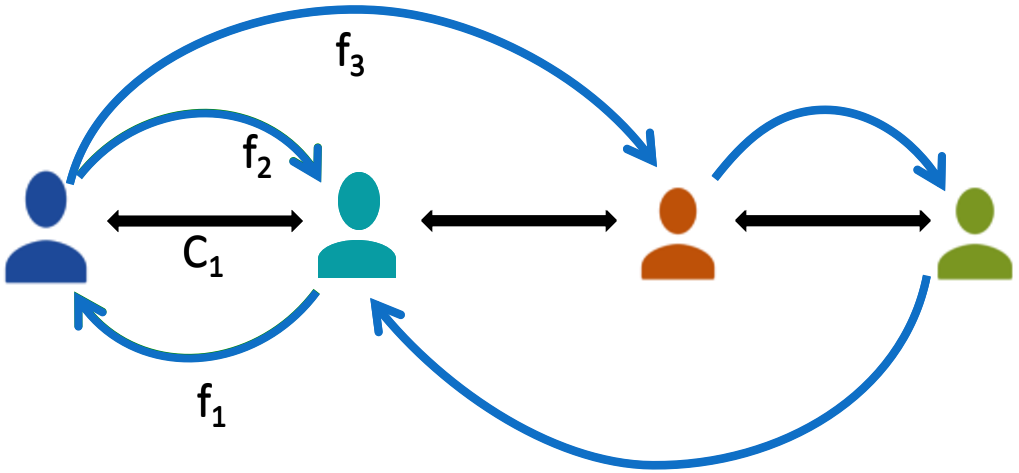
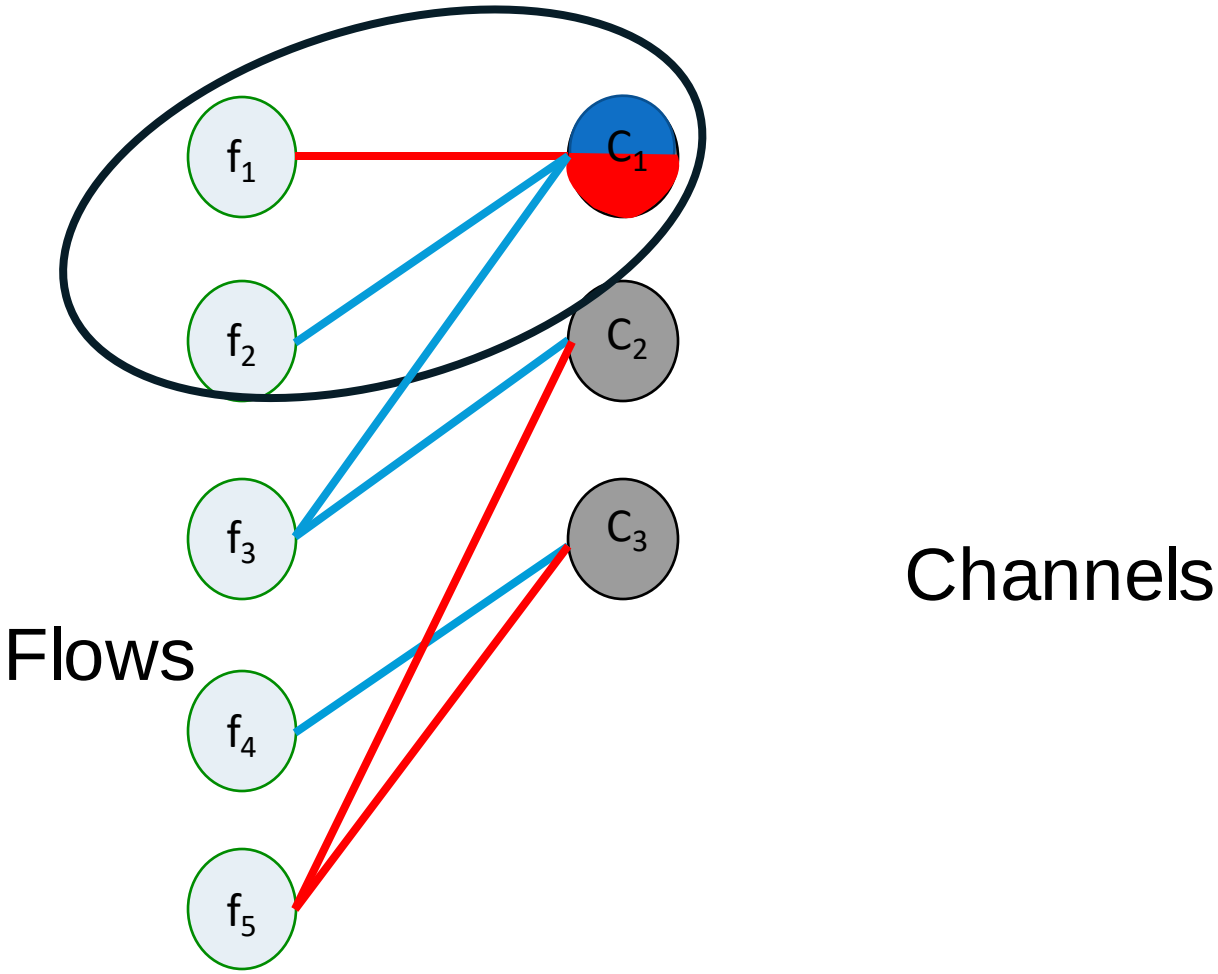


Detecting Deadlocks



Deadlock Peeling Algorithm





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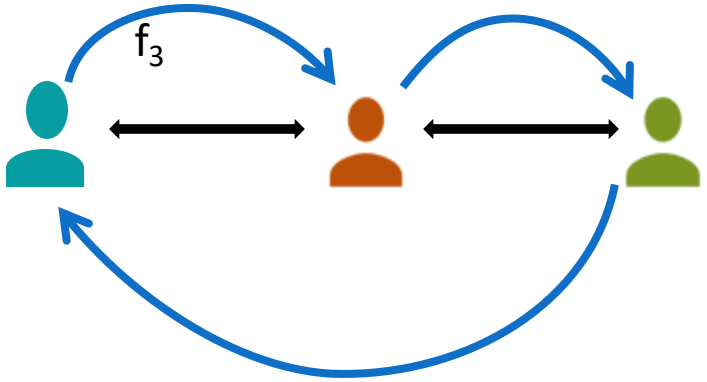
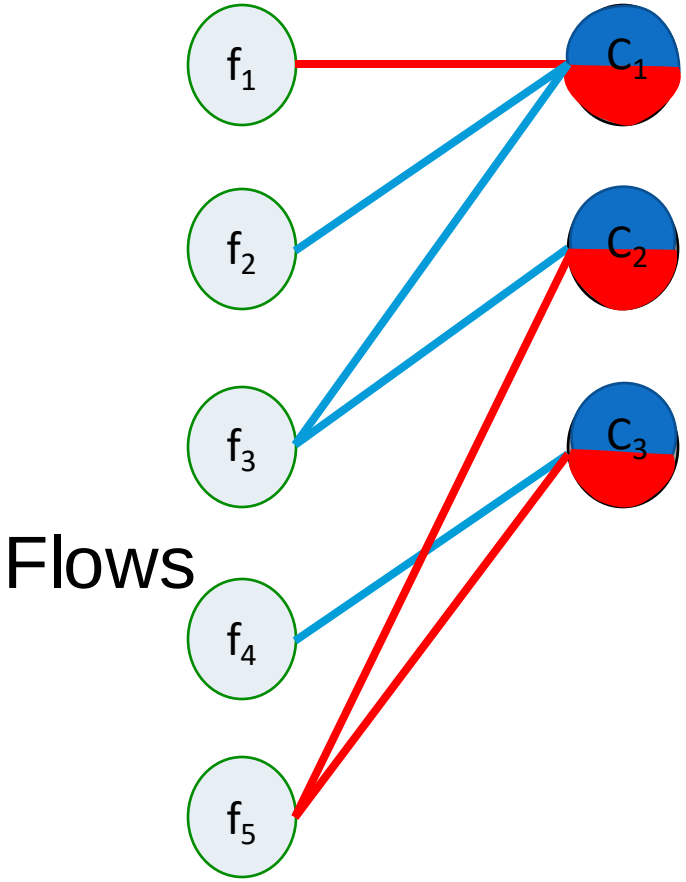


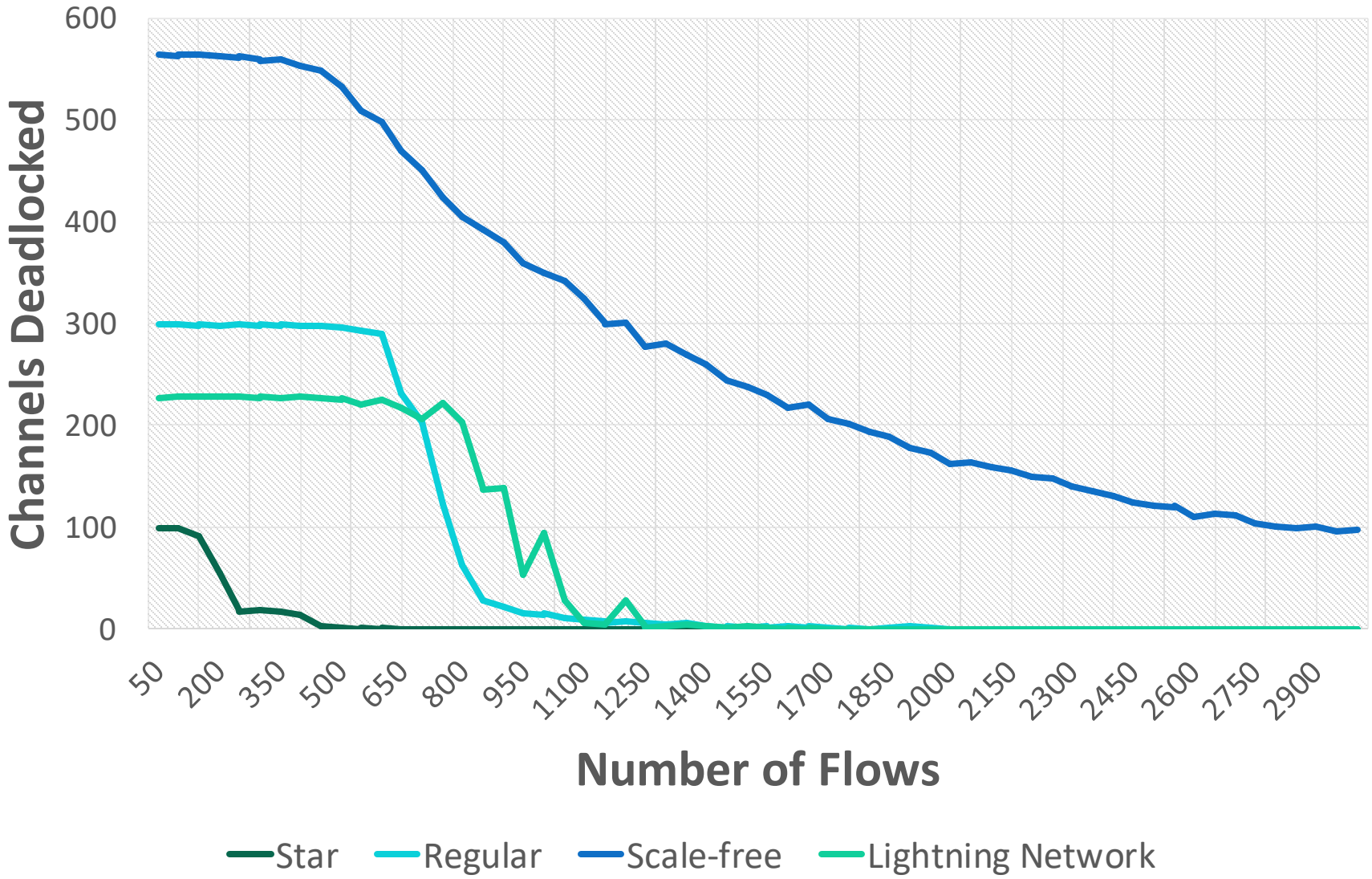


Flows

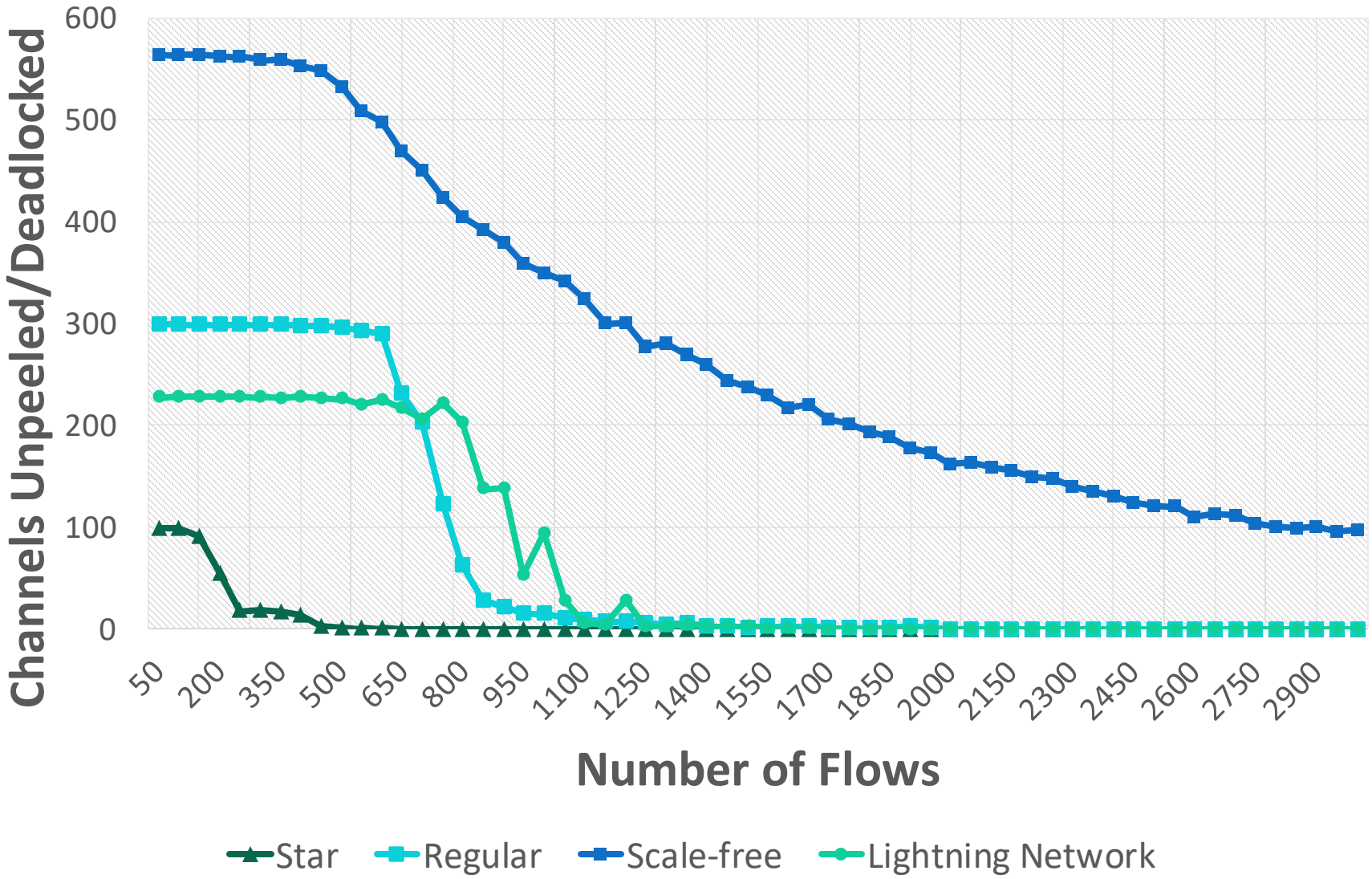
Channels

Termination depends on path length distribution

Peeling Algorithm Accuracy



Peeling Algorithm Accuracy



Topology Synthesis

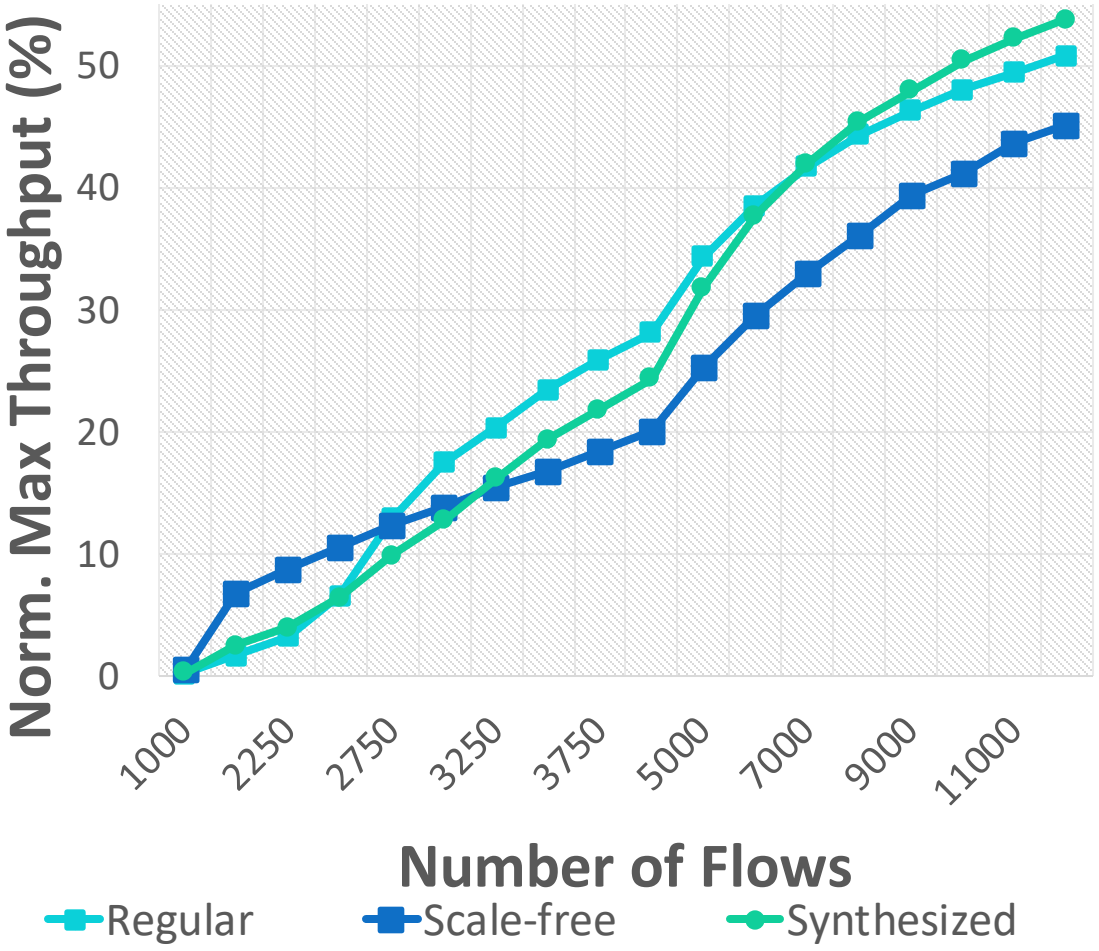
Peeling algorithm finds deadlock-free channels and helps compute ϕ_{min}

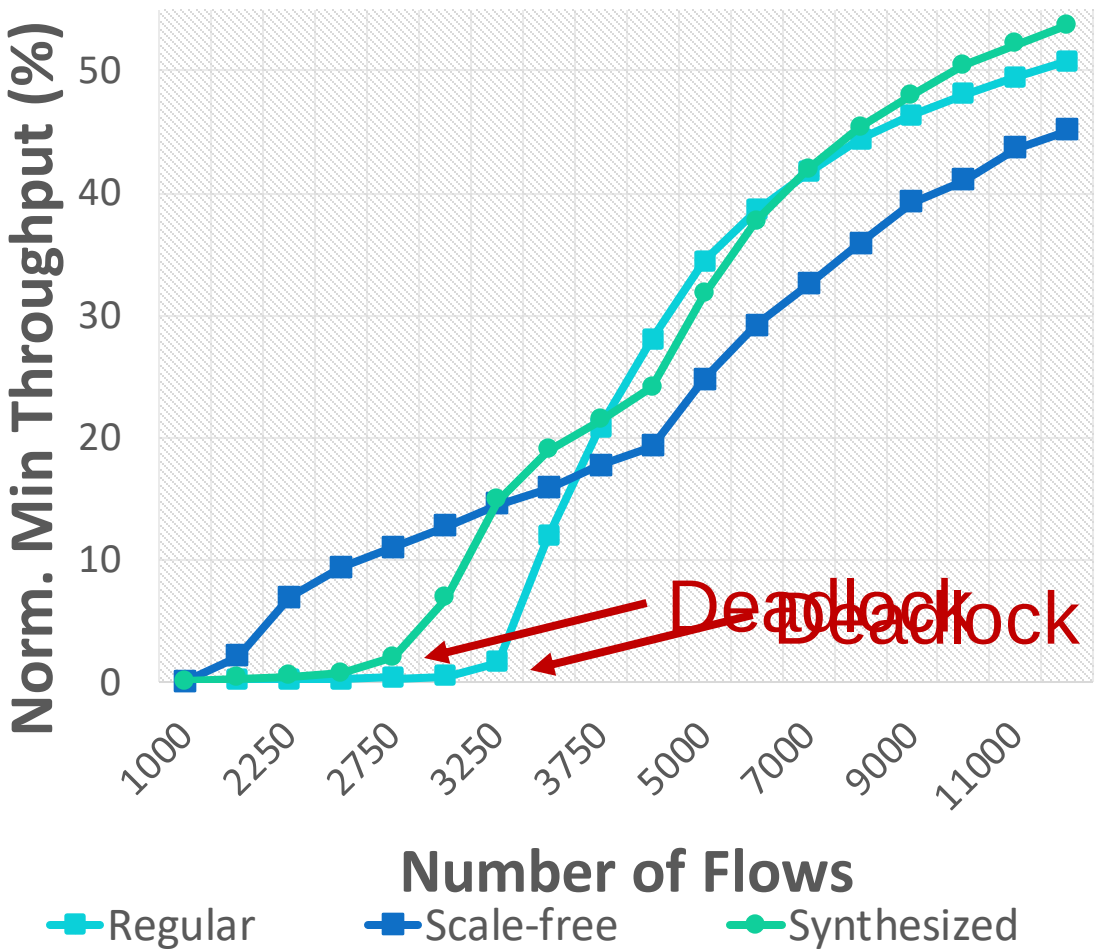
Synthesize robust topologies with good peeling behavior

Insight: Termination depends on path length distribution

Leverage peer-recommendation services such as “autopilot”

Topology Synthesis





Summary

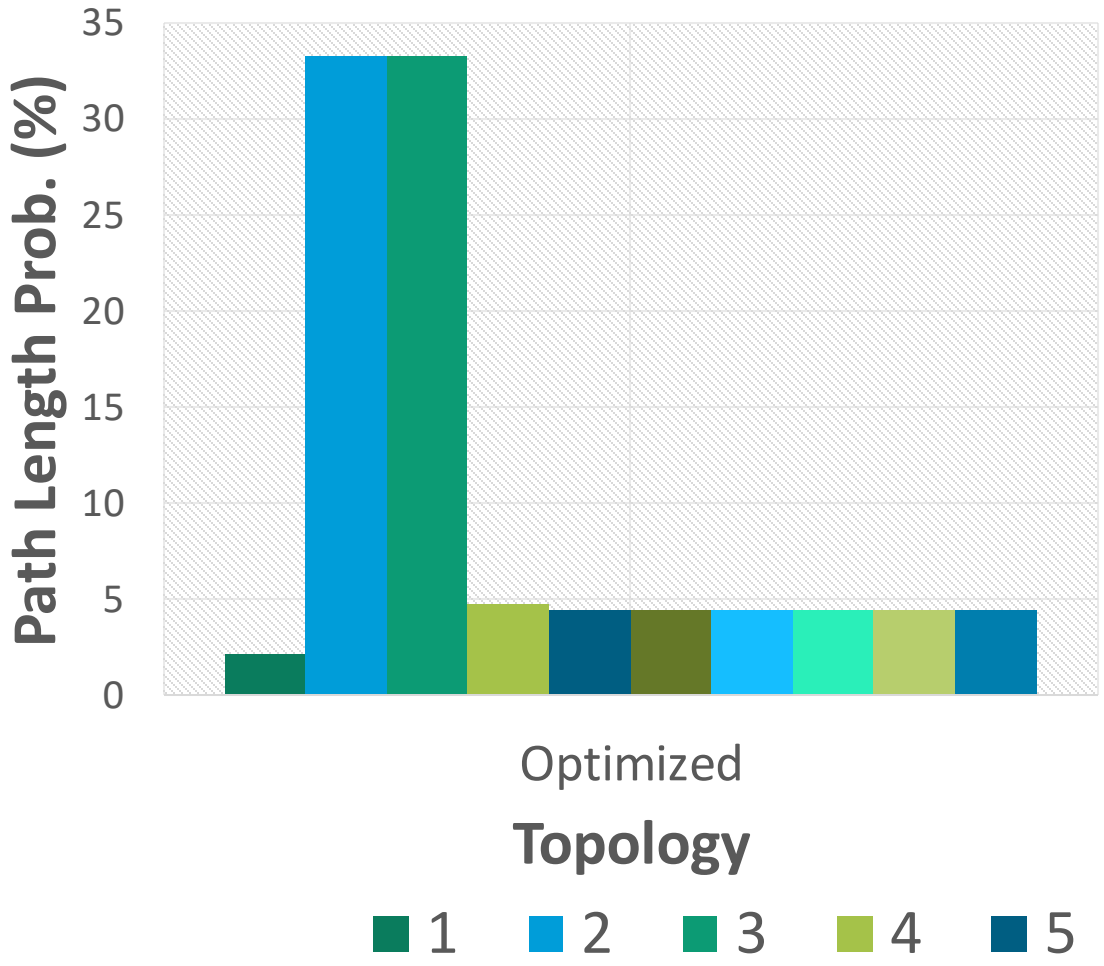
Credit networks enable money transfer through trust relationships

Potential for imbalance and deadlocks can cause discrepancies in throughput based on the starting configuration

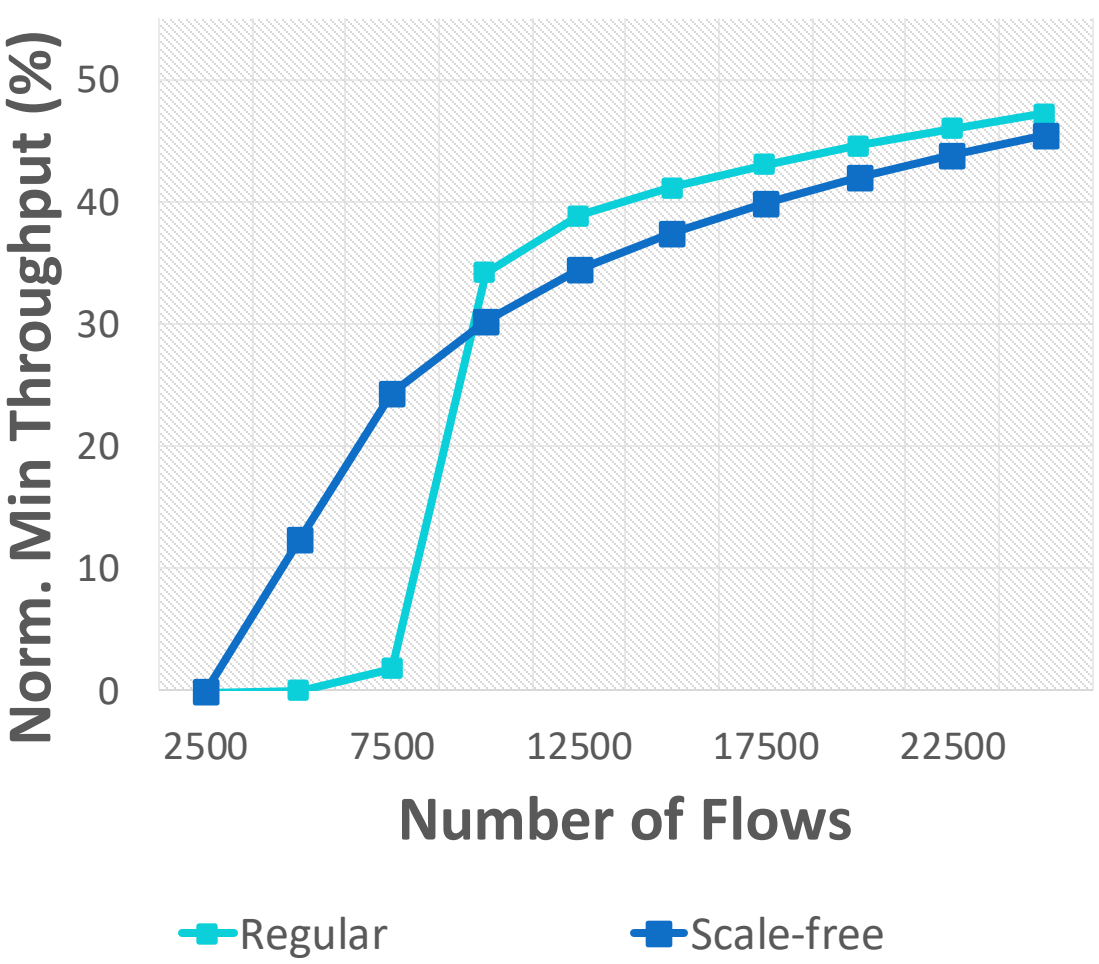
Topology synthesis techniques can further improve the worst-case throughput behavior

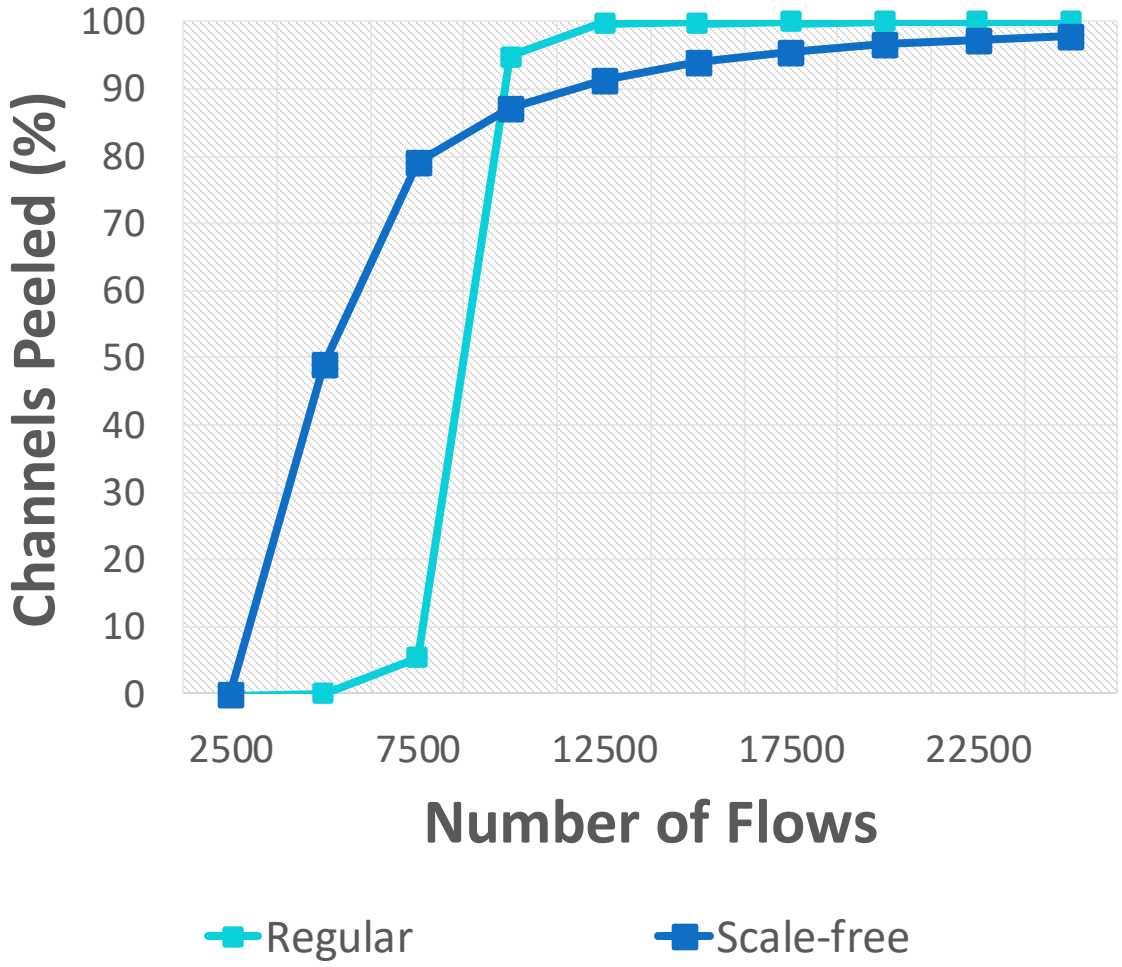
Contact: vibhaa@mit.edu

Optimized Distribution



Topology Comparison





Topology Comparison