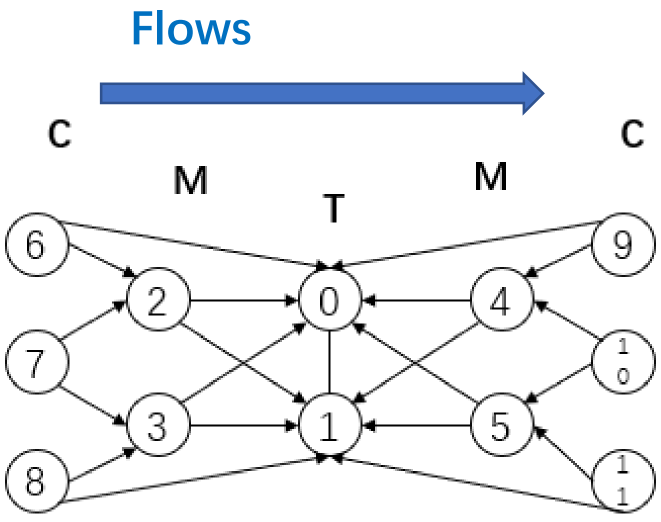
Flow based routing

2018 2.14

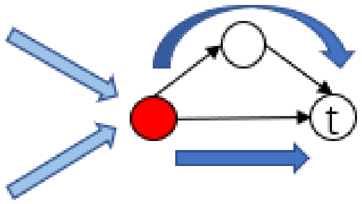
Network Environment

- Topology and traffic

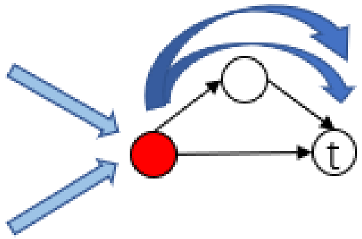


Ten flows with some repeated destinations.

- Focus on specific flow to choose action.



Get larger throughput.



Cause difference between global optimal and resulting state.

Experiment Design

- Cut down action space for each agent.

In one time epoch:

inject flow one**:**

agents get local **state** and take **actions.**

update *network state*

inject flow two**:**

agents get new local **state** and take **actions**.

update *network state*

…

All flows determined, **rewards** obtained.

Train each agent for each flow.

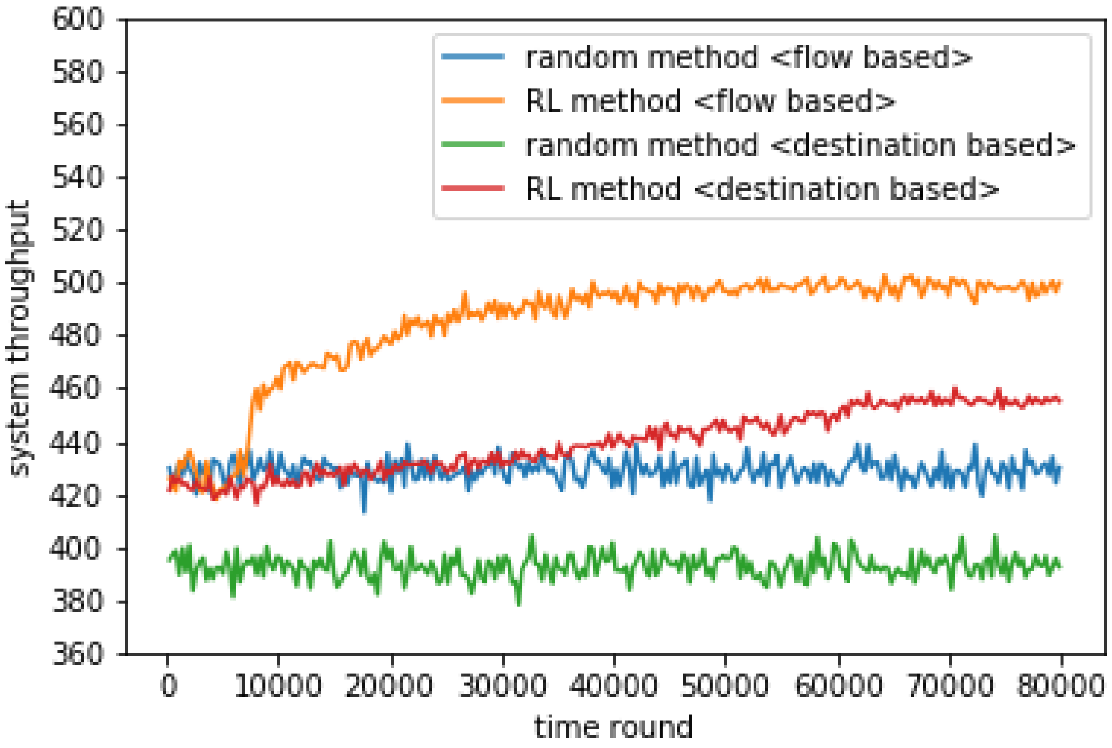
flow profile, neighbor links status, reachable end-to-end throughputs

Next hop for this flow; ε-greedy

Average of reachable end-to-end throughputs

AC model; Experience replay

Experiment Results



The global optimal is 600

Flow based RL has 19.05% improvement compared to Random.

Destination based RL has 13.31% improvement compared to Random.

Confirm solver for global optimal

- Objective and constrains:

Objective Function $\max(\sum v^f, f \in F)$

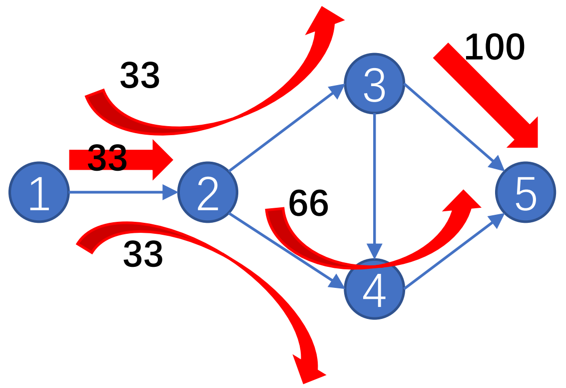
$$\sum_{j:(i,j)\in E} x_{ij}^f - \sum_{i:(j,i)\in E} x_{ji}^f = \begin{cases} 0, & for\ all\ i \in V - s^f - t^f \\ 1 & for\ i = t^f \\ -1 & for\ i = s^f \end{cases}$$

$$x_{ij}^f \in \{0,1\}, \quad for\ \forall f \in F, (i,j) \in E$$

$$0 \leq \sum_{f\in F}(v^f x_{ij}^f) \leq u_{ij}$$

$$v^f \geq \min\{\frac{u_{ij}}{\sum_{f\in F} x_{ij}^f}\}_{f\ across\ ij}, \qquad \text{for } \forall f \in F$$

- Example for test: (link capacity 100)



Global optimal = 33+33+33+66+100 = 265
Flow based.

Dual Problem to solve (ref on Stephen Boyd, Stanford University)

- Setting:

  topology with n flows, m links. Link capacity c.
  flow j with rate f_j. Routing matrix R (fixed)

$$R_{ij} = \begin{cases} 1 & \text{flow } j \text{ passes over link } i \\ 0 & \text{otherwise} \end{cases}$$

- Original problem

$$\begin{aligned} &\text{minmize } -U(f) = -\textstyle\sum_{j=1}^{n} U_j(f_j) \\ &\text{s.t.} \qquad Rf \leq c \end{aligned}$$

  write into Lagrange: $L(f,\lambda) = -U(f) + \lambda^T(Rf - c)$

  If objective function is separable: $L(f,\lambda) = \sum_{j=1}^{n} (-U_j(f_j) + (r_j^T\lambda)f_j)$

- Original problem with constrains is changed into solving Lagrange function:

$$\begin{aligned} &maximize\ g(\lambda) = -\lambda^T c + \sum_{j=1}^{n} \inf_{f_j}(-U_j(f_j) + (r_j^T\lambda)f_j) \\ &\lambda \geq 0 \end{aligned}$$