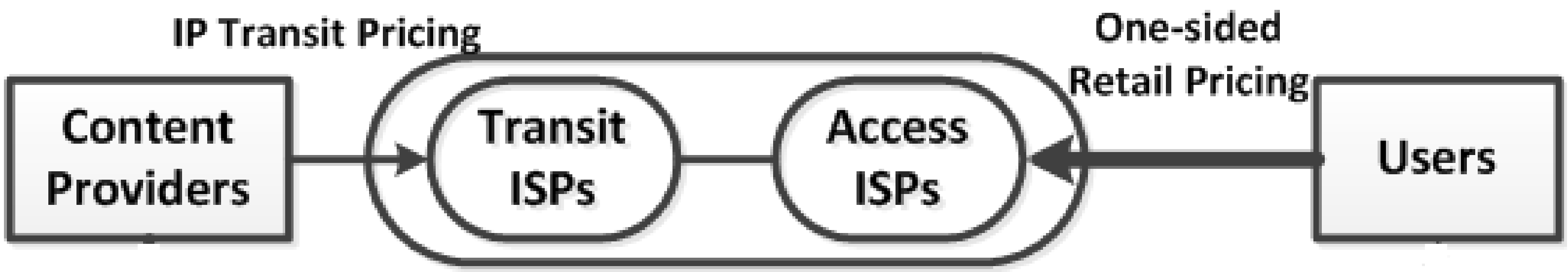
Subsidization Competition: Vitalizing the Neutral Internet

Richard T. B. Ma
School of Computing
National University of Singapore

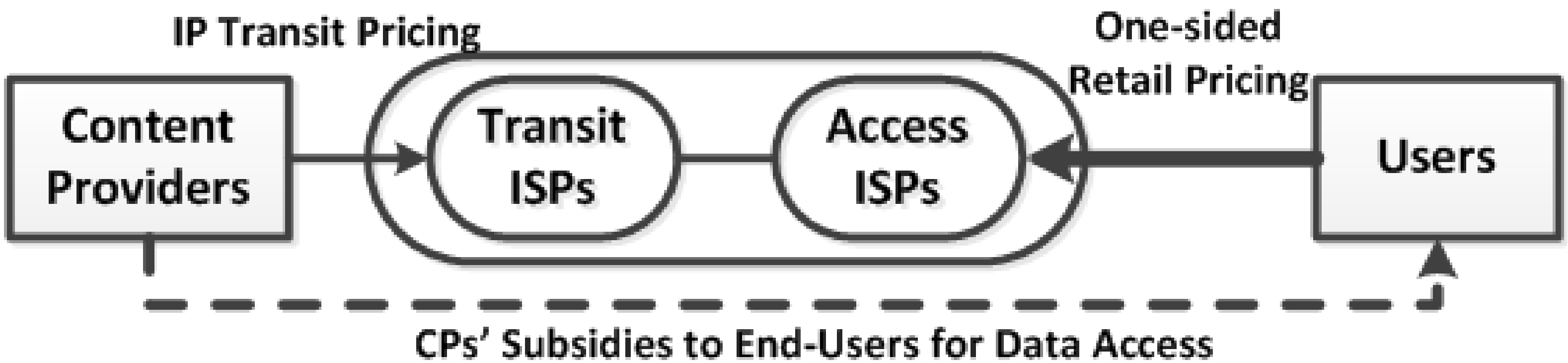
WIE 2014

Internet's two-sided market



- Problem is not in the transit market
  - Fiber optics backbone, rare congestion
  - Competitive market with declining prices
  - CPs bypass Tier-1 ISPs to improve performance
- But in the mobile access market
  - High mobile infrastructure costs
  - One-side pricing from end-users
  - Lower profit margin than those of the CPs
  - Few incentives for investments

About this work

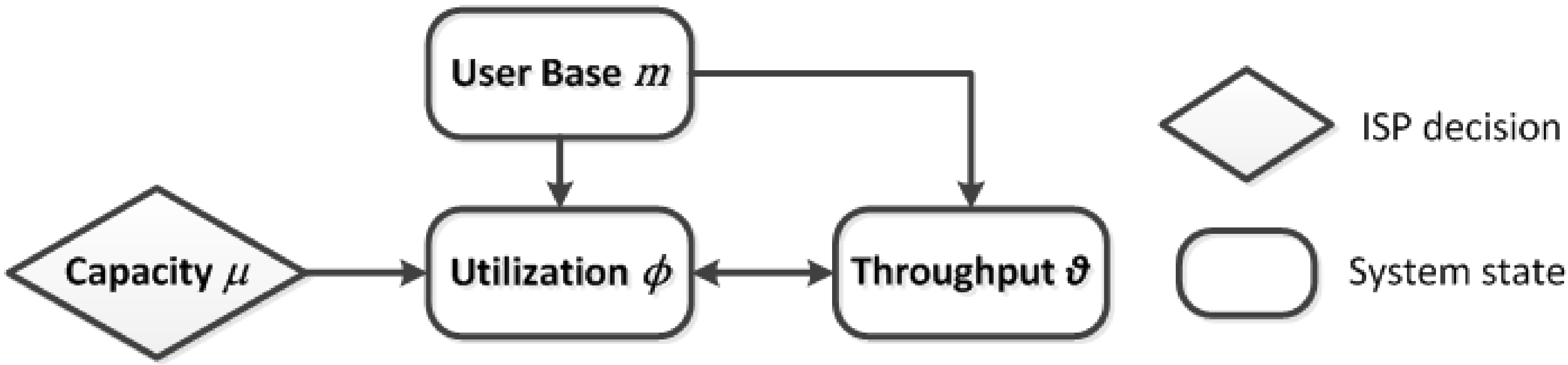


- Propose and study "subsidization competition"
  - CPs could voluntarily subsidize its users' usage costs
- Differences to sponsored data plan/"zero rate"
  1. Partial subsidization is allowed
  2. ISPs charge the same per-unit rate, regardless the source of revenue (no secret deals with CPs)

Basic system model $(\boldsymbol{m}, \mu)$

- Focus on an access ISP with capacity μ and a set $\mathcal{N}$ of CPs. For each $i \in \mathcal{N}$, denote
  - m_i: user size, λ_i: avg per user throughput
  - $\theta_i \triangleq m_i \lambda_i$ as throughput and $\theta \triangleq \sum_{i \in \mathcal{N}} \theta_i$
- Define $\phi \triangleq \Phi(\theta, \mu)$ as the system utilization
  - $\Phi(\theta, \mu) \nearrow \theta$; $\Phi(\theta, \mu) \searrow \mu$
  - can be seen as system congestion
- User throughput satisfies $\lambda_i \triangleq \lambda_i(\phi) \searrow \phi$

Basic system model $(\boldsymbol{m}, \mu)$



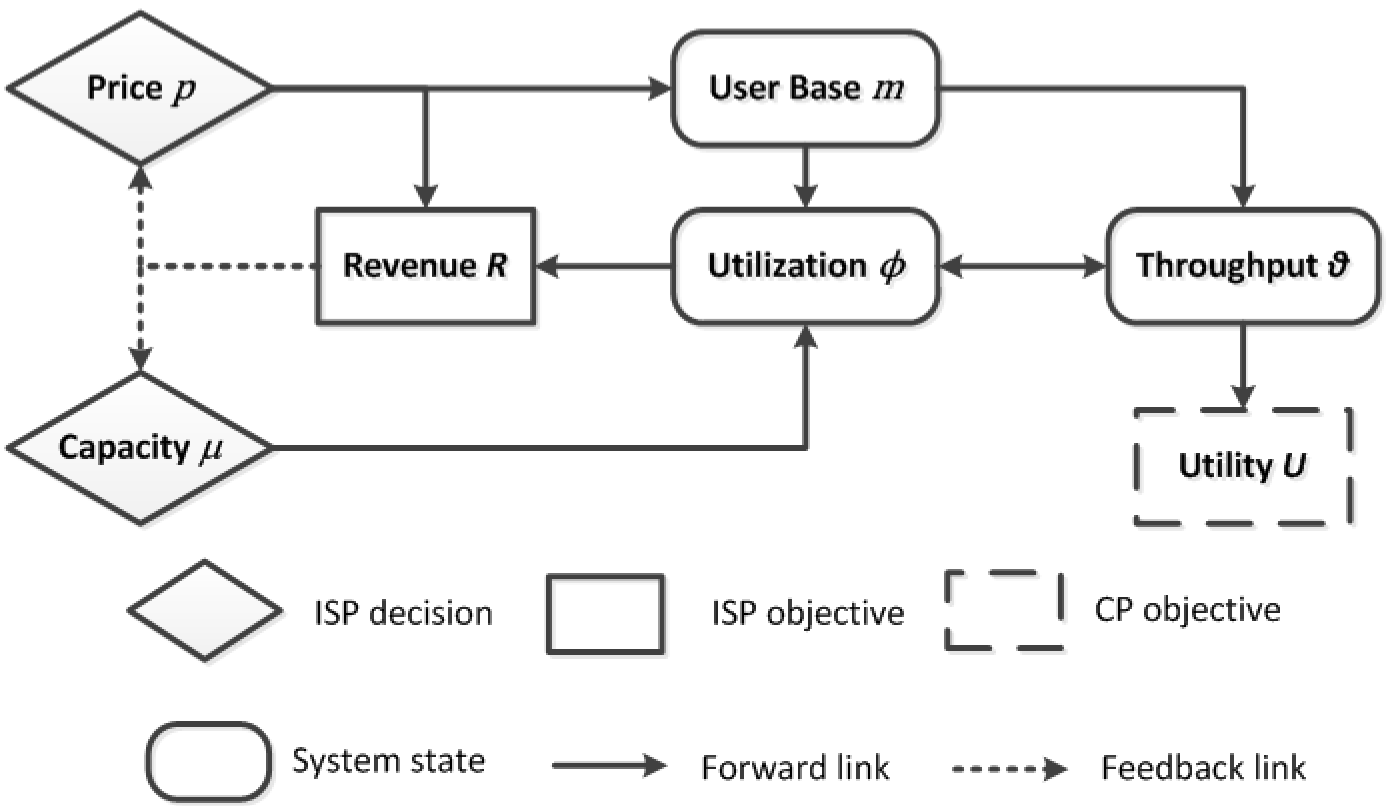
- ϕ is the utilization of a system $(\boldsymbol{m}, \mu)$ iff

$$\phi = \Phi\left(\sum_{i \in \mathcal{N}} m_i \lambda_i(\phi), \mu\right)$$

- utilization is unique ➔ throughput of CPs

One-sided pricing model

- If ISP charges p, its revenue is $R \triangleq p\theta$
- User size: $m_i \triangleq m_i(p) \searrow p$



One-sided pricing model

- Price effect:

$$\frac{\partial \phi}{\partial p} \le 0; \quad \frac{\partial \theta}{\partial p} \le 0.$$

- CP i's throughput θ_i increases with price p iff

$$\epsilon_p^{m_i} / \epsilon_\phi^{\lambda_i} < -\epsilon_p^\phi$$

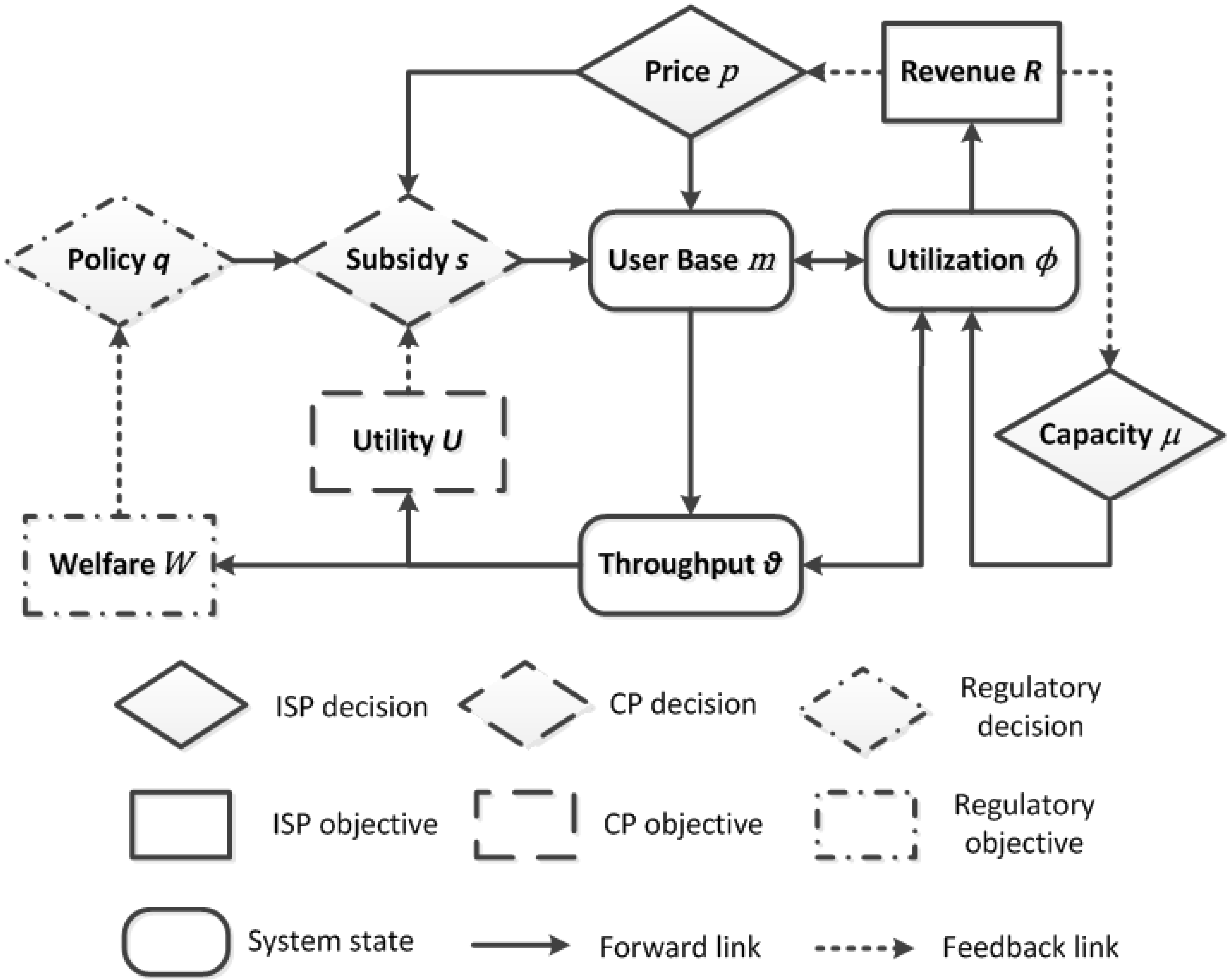
where $\epsilon_x^y \triangleq \frac{\partial y}{\partial x}\frac{x}{y}$ denotes the x-elasticity of y.

  - $\left|\epsilon_p^{m_i}\right|$ small: users are not price sensitive
  - $\left|\epsilon_\phi^{\lambda_i}\right|$ large: traffic is very sensitive to congestion

Subsidization model

- Denote q as a policy that limits the subsidy, each CP i choose to subsidize $s_i \in [0, q]$
- Denote $\boldsymbol{s}$ as the strategy profile of the CPs
- User size becomes $m_i = m_i(t_i) = m_i(p - s_i)$
- CP's utility becomes $U_i = (v_i - s_i)\theta_i$
- Define social welfare $W = \sum_{i \in \mathcal{N}} v_i \theta_i$

Subsidization model



Nash equilibrium

- For price p and policy q, a strategy profile $\boldsymbol{s}$ is a Nash equilibrium iff each s_i solves

$$Max\ U_i(s_i;\boldsymbol{s}_{-i}) = (v_i - s_i)\theta_i(\boldsymbol{s})$$
$$s.t.\ 0 \le s_i \le q.$$

- There exists a unique Nash equilibrium if for any $s' \neq s$, there always exist CP i such that

$$(s_i' - s_i)(u_i(\boldsymbol{s}') - u_i(\boldsymbol{s})) < 0$$

where $u_i = \partial U_i(\boldsymbol{s})/\partial s_i$ defines the marginal utility.

Dynamics of equilibrium

- If a CP i's profitability increases unilaterally from v_i to v_i', under Nash equilibrium, $s_i' \geq s_i$.
- Dynamics of the Nash equilibrium:

$$\frac{\partial s_i}{\partial q} = \begin{cases} 0 & if\ s_i = 0 \\ 1 & if\ s_i = q \\ \dots & otherwise \end{cases}$$

$$\frac{\partial s_i}{\partial p} = \begin{cases} 0 & if\ s_i = 0\ or\ s_i = q \\ \dots & otherwise \end{cases}$$

Policy implications

- Result: Under fixed price p, if marginal utility matrix is off-diagonally monotone,

$$\frac{\partial \phi}{\partial q} \geq 0, \qquad \frac{\partial R}{\partial q} \geq 0 \ \ and \ \ \frac{\partial s_i}{\partial q} \geq 0 \ \forall i \in \mathcal{N}$$

- Deregulation incentivize CPs to subsidize, increase system utilization and ISP revenue

- Implications: deregulation is desirable for improving investment incentives for ISPs

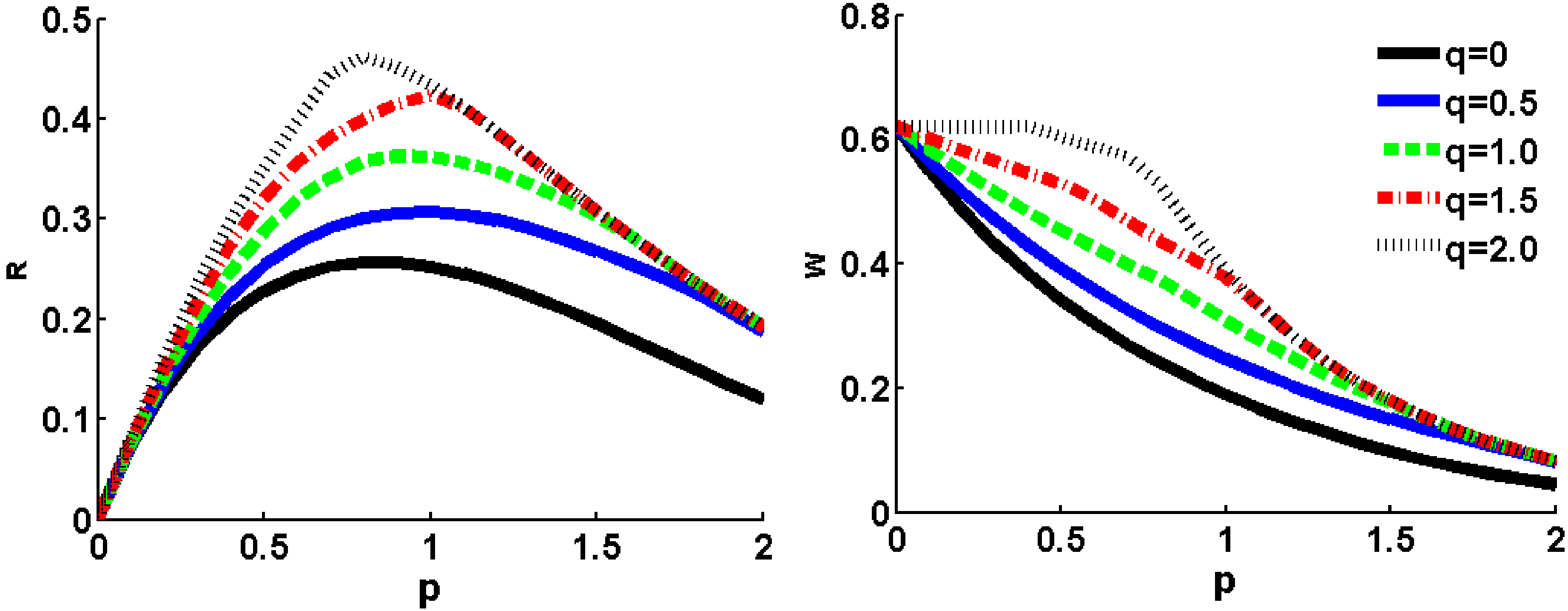
Policy under ISP's optimal price

- Consider a 3-stage game:
  1. Regulator chooses policy q
  2. ISP chooses optimal price $p(q)$
  3. CPs choose subsidies s
- Policy effect: $\frac{dm_i}{dq} = \cdots, \frac{d\phi}{dq} = \cdots, \frac{d\lambda_i}{dq} = \cdots$
- CP i's θ_i decreases with relaxed policy q iff

$$\epsilon_{t_i}^{m_i} \epsilon_q^{t_i} / \epsilon_\phi^{\lambda_i} = \epsilon_q^{m_i} / \epsilon_\phi^{\lambda_i} > -\epsilon_q^\phi$$

  - $\left|\epsilon_{t_i}^{m_i}\right|$ small: users are not price sensitive
  - $\left|\epsilon_\phi^{\lambda_i}\right|$ large: traffic is sensitive to congestion
  - $\left|\epsilon_q^{t_i}\right|$ small: CP is less profitable

Revenue and social welfare



- Relaxed policy induces higher R and W
- Price regulation might be needed

Conclusions

- Study subsidization competition among CPs,
  - ISP uses the same per-unit charge
  - Partial subsidy is allowed
- Properties
  - the network is physically neutral
  - it creates a feedback loop for CPs to compete
  - increase access revenue and attract investment
- Caveats
  - Utilization will increase, some CPs have lower rates
  - ISP's price might need to be regulated if the market is not competitive enough

FCC Open Internet Order

- Transparency
  - must disclose network management practices, performance characteristics, and …
- No blocking
  - may not block lawful content, applications, services, non-harmful devices …
- No unreasonable discrimination
  - may not unreasonably discriminate in transmitting lawful network traffic …

How do we want to regulate?

- It is about "no unreasonable discrimination"
- Existing solution
  - impose an absolute minimum requirement for ordinary class
  - however, ISPs have different capacities …
- Our proposal
  - restrict the maximum gap in service quality
  - implication: if you make premium class better, you need to make ordinary class better too.

References

- Richard T. B. Ma. "Subsidization Competition: Vitalizing the Neutral Internet." *ACM CoNEXT Conference 2014*
- Jing Tang and Richard T. B. Ma. "Regulating Monopolistic ISPs Without Neutrality." *IEEE ICNP Conference, 2014.*