Cellular Radio:
User-perspective Design and Economics

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Cellular Business
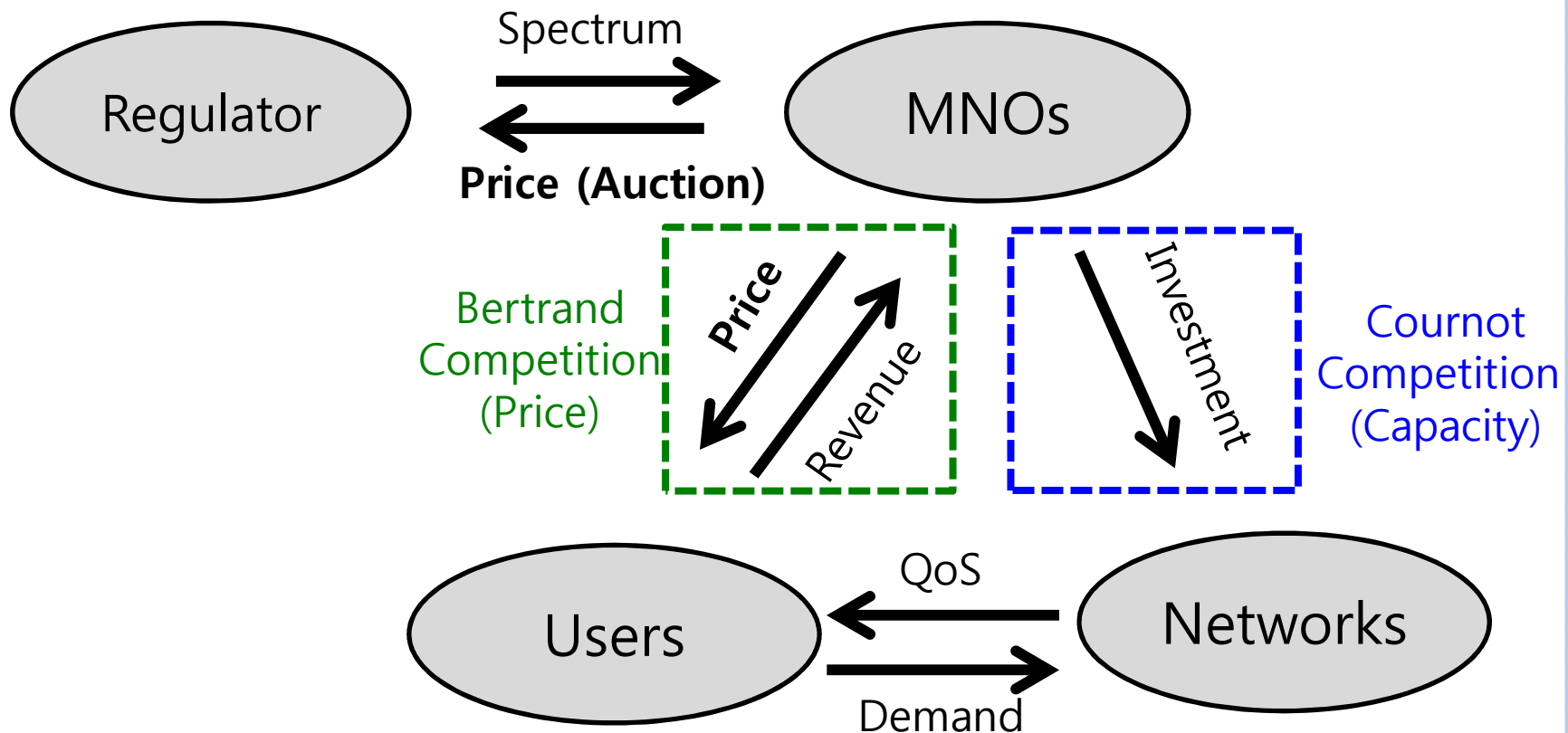
Spectrum Auction Results (Korea, 2013.8)

주파수 대역	대역폭	사업자	낙찰가	시초가
주파수 경매 최종 결과 (단위:원)				
1.8GHz	15MHz	KT	9001억	2888억
1.8GHz	35MHz	SKT	1조 500억	6738억
2.6GHz	40MHz	LG U+	4788억	4788억
합 계			2조4289억	1조4414억

자료: 미래창조과학부

- **90 MHz = 2,297,928,637 (USD)**
- **45 USD = 2,297,928,637 (USD)/51,098,531 (Persons)**
- **You pay for using what is yours**

Why?

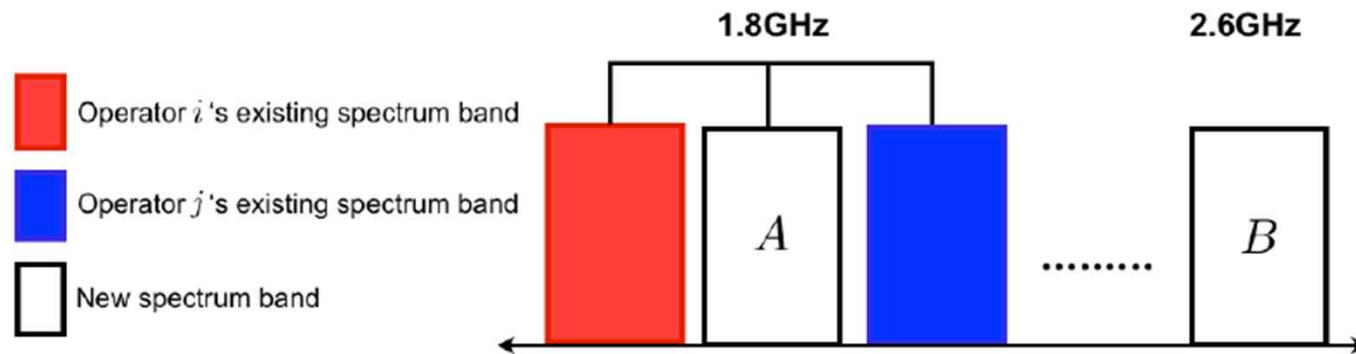| 주파수 경매 최종 결과 (단위:원)				
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Spiteful Action

- **Bidding behavior of a spiteful MNO who not only maximizes his own profit but also minimizes his competitor's profit.**

Asymmetric–valued Spectrum Auction (Korea, 2013.8)

- **Two MNOs compete in a first-price sealed-bid auction where two spectrum blocks A and B are auctioned off to them**
- **A and B are the same amount of spectrum (i.e., 10 MHz spectrum block).**

Multi-stage Games

Stage I - Spectrum auction game

Player: operator i and operator j

Decisions: spectrum bidding A and B

Objective: joint profit maximization and weighted difference of profits minimization

Stage II - Service price game

Player: operator i and operator j

Decisions: service price $p_i(t)$ and $p_j(t)$

Objective: revenue maximization in asymmetric and symmetric phase

Stage III - User responses

Player: end users

Decisions: to stay in operator $i(j)$ or to switch to operator $j(i)$

Objective: utility maximization in asymmetric and symmetric phase

The leader, despite charging higher price, achieves more market share and profit.
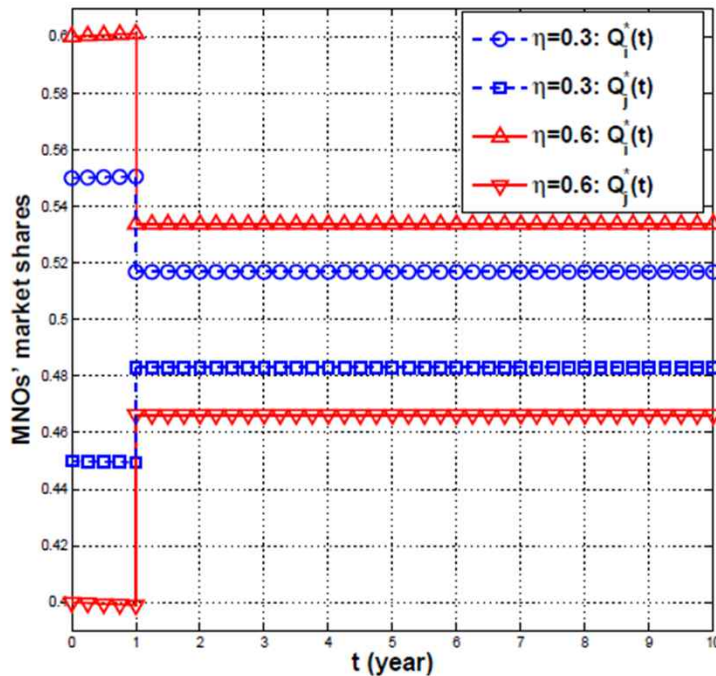

Fig. 5. User responses in asymmetric and symmetric phase under two different user sensitivities ($\eta=0.3$, $\eta=0.6$). Other parameters are $u_o=1$, $\lambda=0.01$, $t_1=1$ and $t_2=10$.
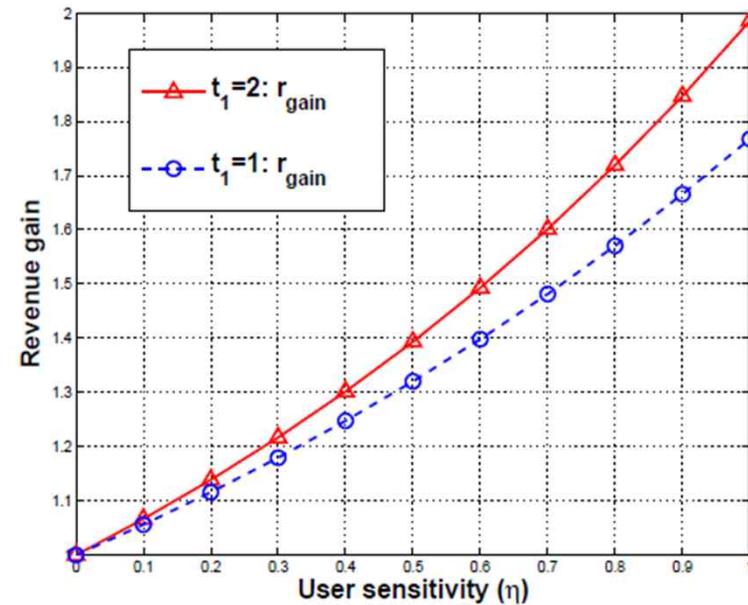

Fig. 6. Revenue gain as a function of η under two different times($t_1=1$ and $t_1=2$). Other parameters are $u_o=1$, $\lambda=0.01$ and $t_2=10$.

Results

- **MNOs announce different equilibrium prices to the users, even when providing the same quality in services to the users.**

- **The market share leader, despite charging a higher price, still achieves more market share.**

S. Y. Jung, S. M. Yu, and S.-L. Kim, "Asymmetric-valued Spectrum Auction and Competition in Broadband Wireless Services," submitted for publication. http://arxiv.org/pdf/1307.7838v1.pdf

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Cellular System Design
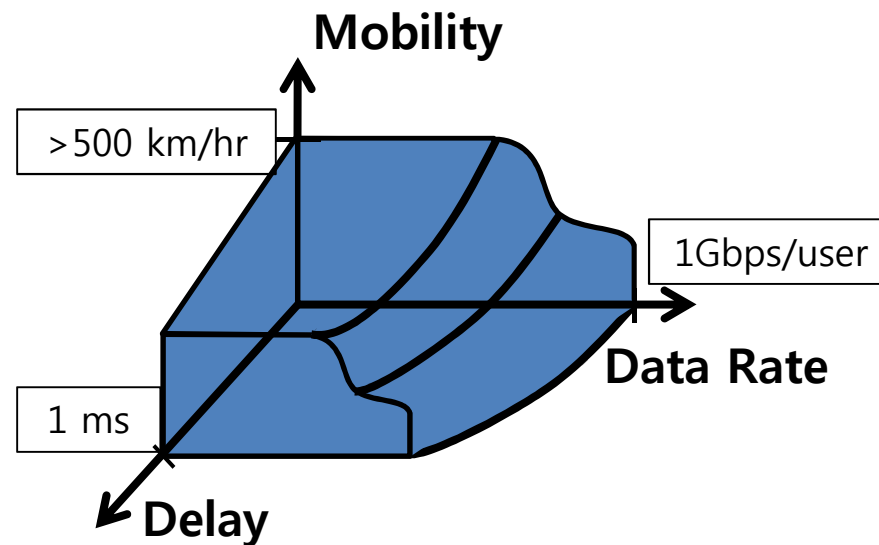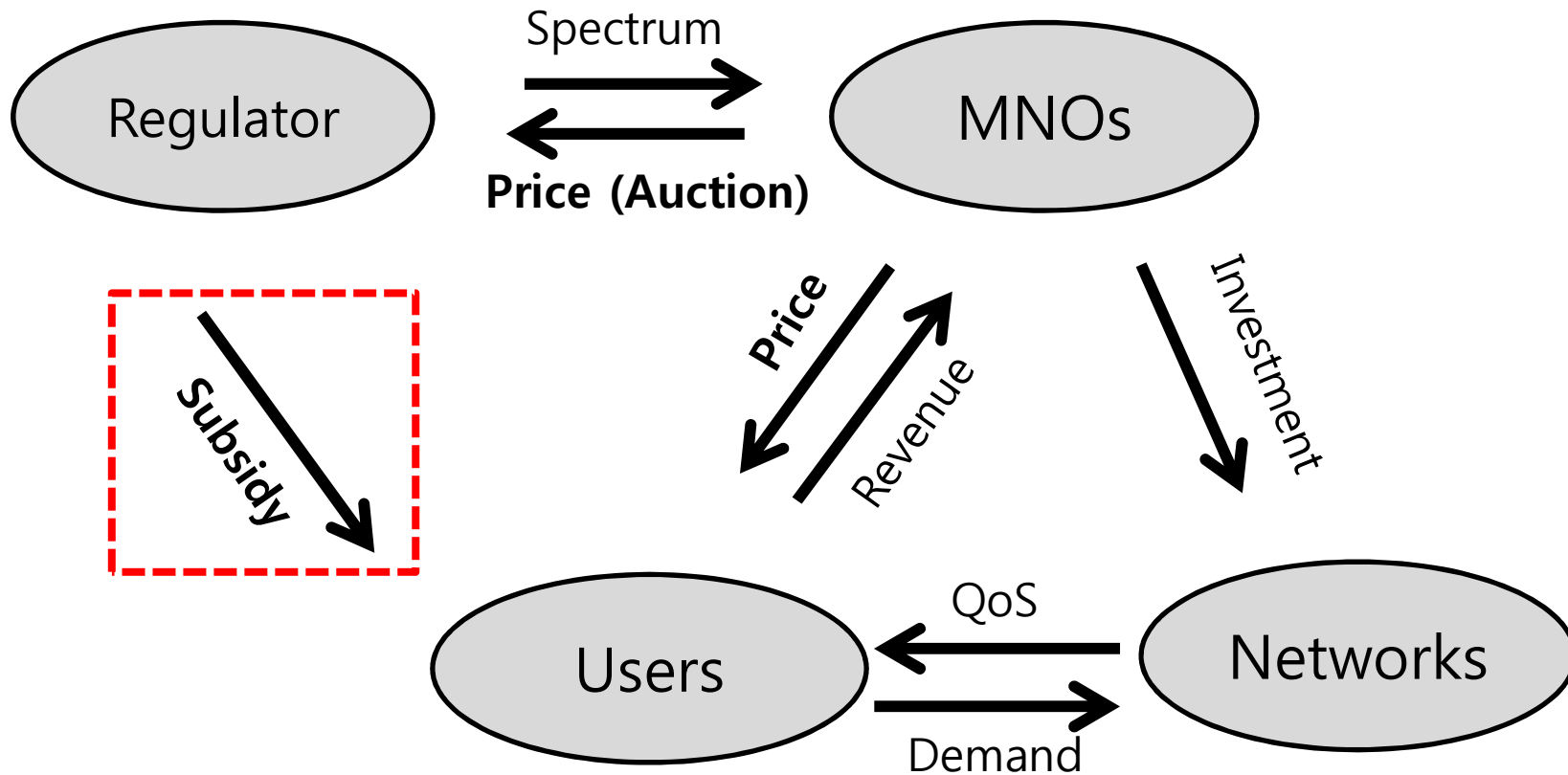
Cellular Users

The users care more about economical benefit (bits/payment)

Subsidy

Two Subsidy Schemes
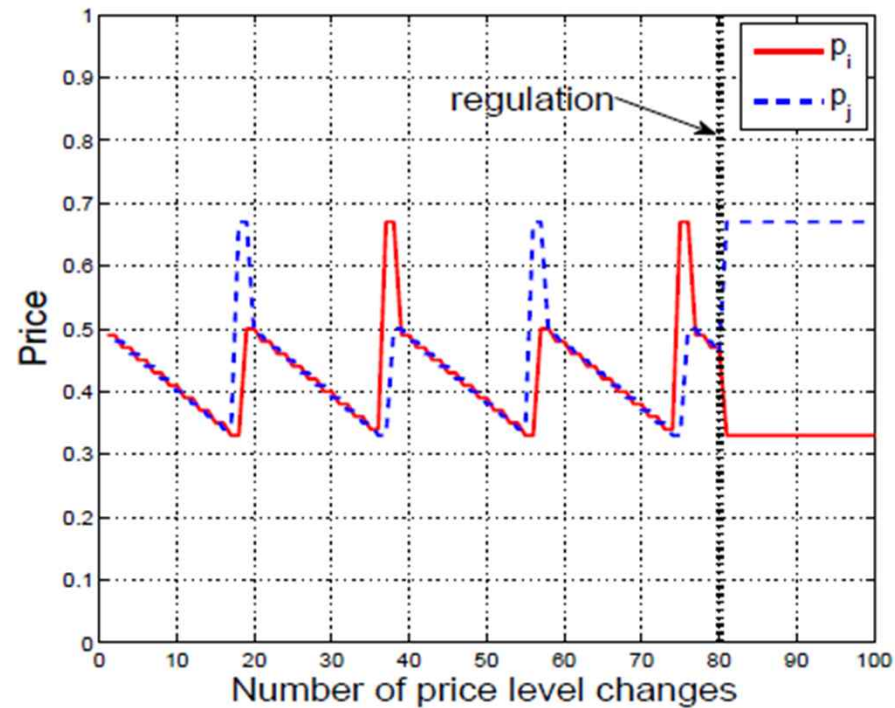
- **Price Subsidy**
  - Giving price discount to users accessing network service.

- **Data (QoS) Subsidy**
  - Providing a predefined amount of data (QoS) to users without any charge.
  - Free Wifi?

S. M. Yu and S.-L. Kim, "Guaranteeing User Welfare in Network Service: Comparison of Two Subsidy Schemes," Proc. *ACM SIGMETRICS/Performance Workshop* W-PIN (*First Workshop on Pricing and Incentives in Networks*), London, UK, 2012.
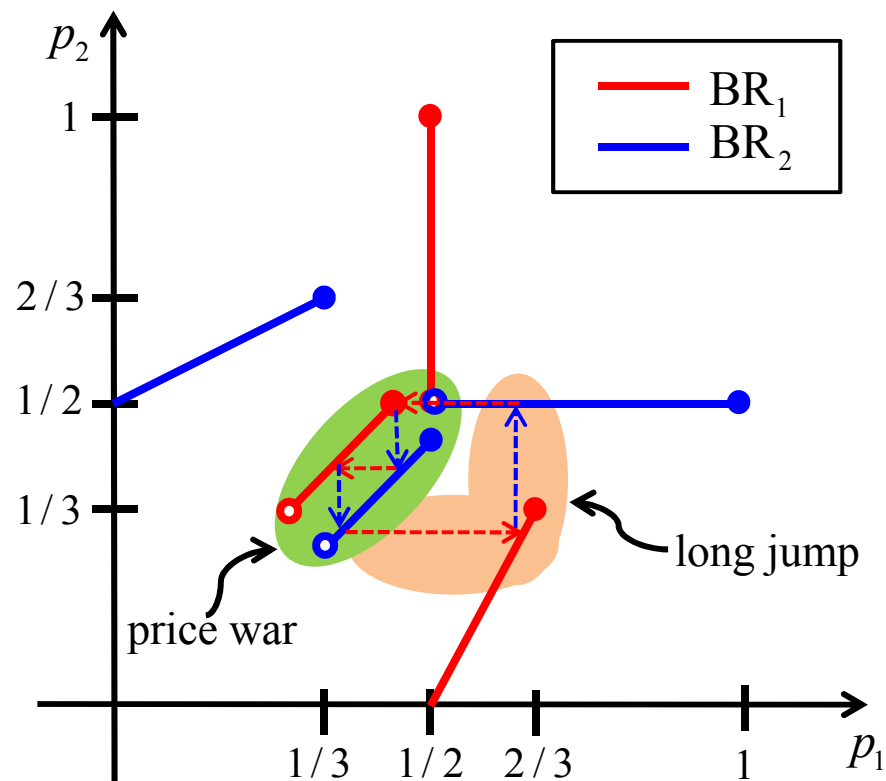
Price (Subsidy) Competition

S. M. Yu and S.-L. Kim, "Game-theoretic Understanding of Price Dynamics in Mobile Communication Services," submitted for publication, http://arxiv.org/abs/1304.3875

Game-theoretic Understating of Price (Subsidy) Competition

- **Best Response Functions of Two Operators (No Equilibrium)**
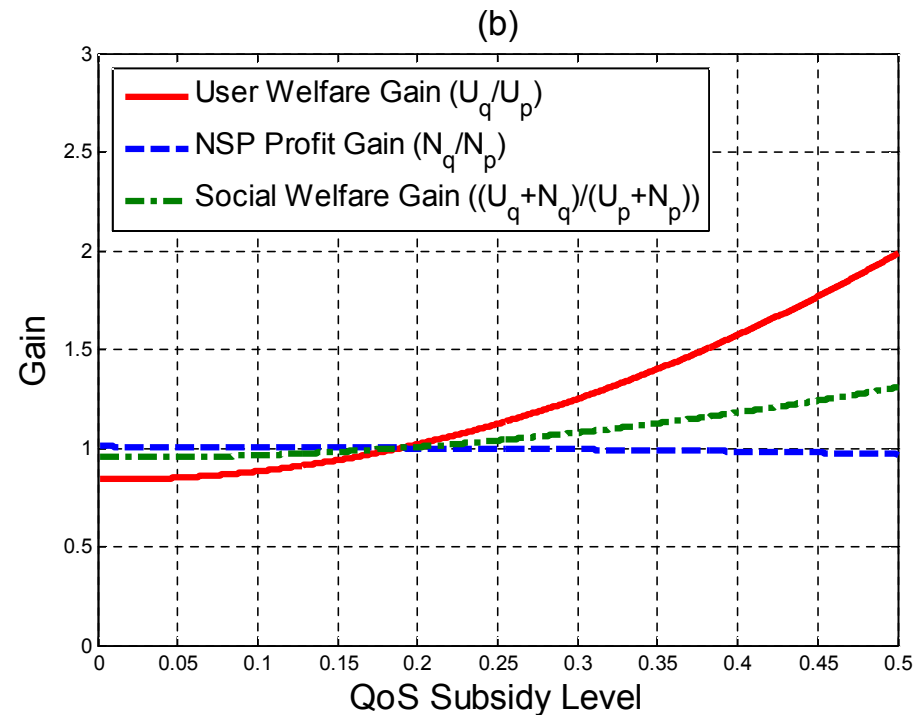
Data (QoS) Subsidy Scheme

- **Data (QoS) Subsidy Scheme (Type 1)**
  - The regulator gives all of the available spectrum amount to mobile network operators (MNO) for free in return for providing a predefined amount of data (QoS) to users without any charge.

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Price- vs. QoS Subsidy

(b)

- **If the regulator has sufficient spectrum for the network service, then the QoS subsidy scheme will be a good choice for all players in the network service market.**

S. M. Yu and S.-L. Kim, "Guaranteeing User Welfare in Network Service: Comparison of Two Subsidy Schemes," Proc. *ACM SIGMETRICS/Performance Workshop* W-PIN (*First Workshop on Pricing and Incentives in Networks*), London, UK, 2012.
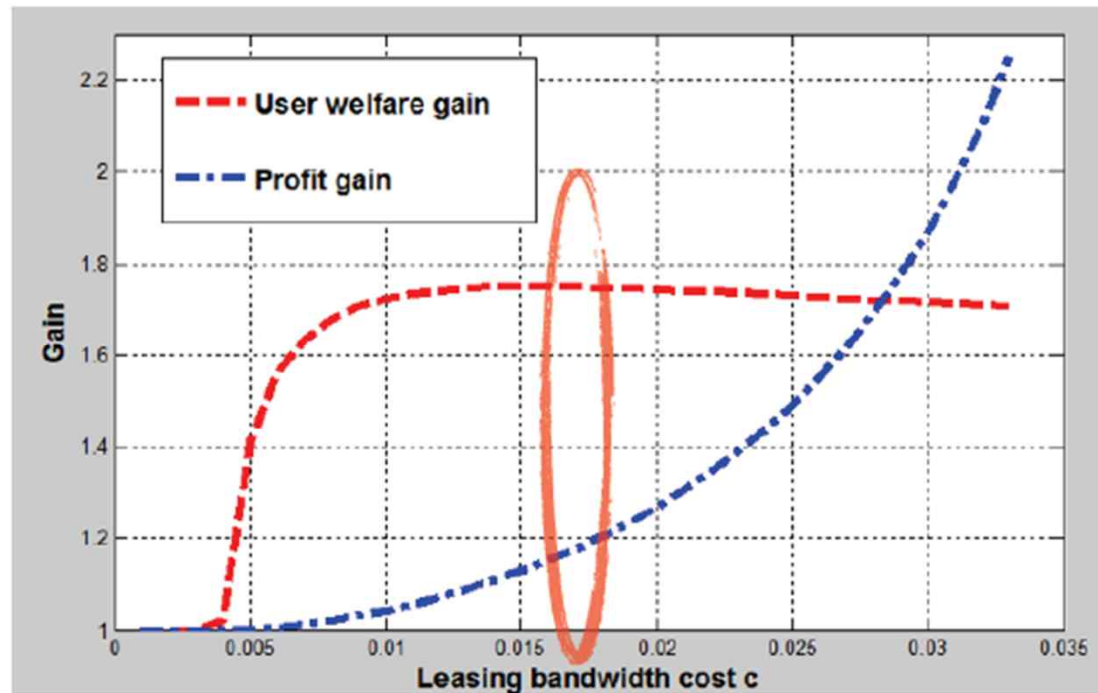
Partial Spectrum Leasing
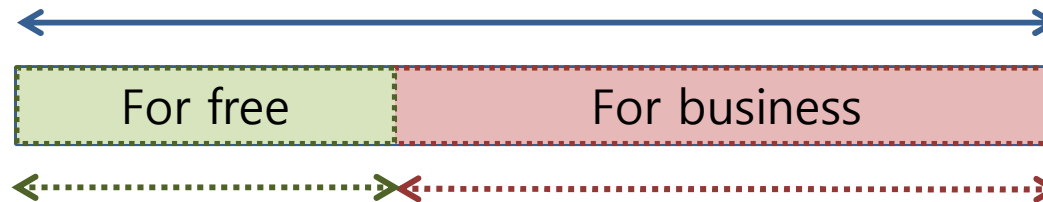
- **Data (QoS) Subsidy Scheme (Type 2)**
  - Dynamic control of the amount of leasing bandwidth ➡ "free services" to all users in a leftover bandwidth.
  - MNO: Joint leasing and pricing decisions.
  - Regulator: "Optimal spectrum price" for maximal profit and user welfare.

User Welfare and Profit Gain

S. Y. Jung, S. M. Yu, and S.-L. Kim, "Utility-optimal Partial Spectrum Leasing for Future Wireless Networks," in Proc. IEEE Vehicular Technology Conference, Spring, Dresden, Germany, 2013 (**Best paper award**).

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Discussion