Vertical Handover Decision Strategies
A double-sided auction approach

Working paper

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Content

- Introduction
- Handover in heterogeneous networks
- Auctions in Handover Decision Strategies
- Conclusion
Introduction

- The evolution of various wireless technologies
  - 3G, 4G, WLAN, WMAN
  - Difference of wireless access, bandwidth, cost, latency

- Connectivity to IP services anytime, anywhere

- QoS is a crucial issue
  - Always Best Connected (ABC) concept
Handover in heterogeneous networks

- Mobility management involves
  - Horizontal handover
  - **Vertical handover**: a process help MT maintaining connectivity while moving between heterogeneous networks

- Major challenges in vertical handover
  - Seamless
  - *Automation aspects in network switching*

- Focus on the vertical handoff decision problem
  - Decision criteria, policies, algorithms, control scheme
  - Decision criteria may include user preference, network conditions, application requirement, and terminal capabilities.
Handover in heterogeneous networks

Handover management process

- Enforce handover
- Determine when, and how to handover by selecting suitable network.
- Handover initialization/
  System discovery
Handover decision strategies

- Function-based strategies
  - Measurement of the benefit obtained by handing over particular parameters

Handover decision strategies classification

- Objective function
  - Koudourakis et al.
- Profit function
  - Liu et al.
- Customer surplus
  - Ormon et al.
- Degradation utility
  - Yang et al.
Handover decision strategies

- Discussion on previous schemes
  - Derived from different factors to make decision
  - Who is better in control of handover?
    - Mobile-assisted handover
    - Network-assisted handover
  - Difficult to make an evaluation comparison
  - Ultimately goal is to provide good bandwidth allocation, with optimization of QoS handover (in term of cost, delay, application requirement, etc).
  - Computational constrains to Mobile-assisted handover
Auctions in Handover Decision Strategies

- What’s auction
  - An important application of *mechanism design*
  - Implement *social choice* in strategic setting
  - Auctioneer, seller, and buyer

- Type of auctions
  - Single-sided auction, Double-sided auction
  - First price auction
  - Second price sealed-bid auction
  - VCG auction
    - VCG payment is the opportunity cost that their presence introduces to all the other players.
Auctions in Handover Decision Strategies

- Motivation
  - Second proposal: apply auction to vertical handover
  - Double-sided auction is more efficient than one-sided auction
  - Benefit nice properties from VCG auctions
    - Incentive-compatible
    - Individually rationality
    - Efficiency (in term of total social welfare)
  - Optimization of bandwidth using at both mobile terminal and network providers
  - Can be applied on both mobile-assisted handover and network-assisted handover
Auctions in Handover Decision Strategies

- **Mathematical model**
  - There is a set of $n$ networks, $m$ mobile nodes
  - User/Mobile node submits a buy bid $(b_i, \tau_i)$
  - Network $j$th provides a sell bid $(a_j, \lambda_j)$
  - Handover is determined as an handover allocation $(x^*, y^*)$ as following optimization

$$
\max_{x, y} \sum_i b_i x_i - \sum_j a_j y_j
$$

subject to

$$
\sum_j y_j - \sum_i x_i \geq 0
$$

$$
x_i \geq \tau_i > 0 \quad \text{and} \quad 0 < y_j \leq \lambda_j
$$
Auctions in Handover Decision Strategies

VCG payment determined at buyers/sellers

\[
\rho_{\text{buyer}} = \left( \sum_{k \neq i} b_k \tilde{x}_k^i - \sum_j a_j \tilde{y}_j^i \right) - \left( \sum_{k \neq i} b_k \tilde{x}_k - \sum_j a_j \tilde{y}_j \right)
\]

\[
= \sum_{k \neq i} b_k (\tilde{x}_k^i - \tilde{x}_k) - \sum_j a_j (\tilde{y}_j^i - \tilde{y}_j)
\]

\[
\rho_{\text{seller}} = \sum_i b_i (\bar{x}_i^j - \bar{x}_i) - \sum_{k \neq j} a_k (\bar{y}_k^j - \bar{y}_k)
\]

where

\((\tilde{x}, \tilde{y})\) is the solution outcome from optimization

\((\tilde{x}_i^i, \tilde{y}_i^i)\) is the solution from optimization without buyer i

\((\bar{x}_i^j, \bar{y}_i^j)\) is the solution from optimization without seller j
Auctions in Handover Decision Strategies

- **Theorem 1**: Solution outcome of the optimization is an efficient Nash equilibrium of our pricing game.

- **Theorem 2**: Truth-telling is the dominant strategy in our pricing game.
Conclusion

- **Advantages**
  - Optimization of cost, bandwidth using at mobile nodes and network routers
  - Benefit from nice properties from auction theory
    - Efficiency, individual rationality, incentive compatibility
    - Converge to a Nash equilibrium
  - Can be applied to Mobile-assisted handover and Network-assisted handover schemes
  - Support multi-homing
    - Mobile node can maintain IP-connectivity with more than one AP of different technologies

- **Drawbacks**
  - Limited input parameters
  - Budget-balance problem