Dynamic Resource Management for Next Generation Wireless Communications

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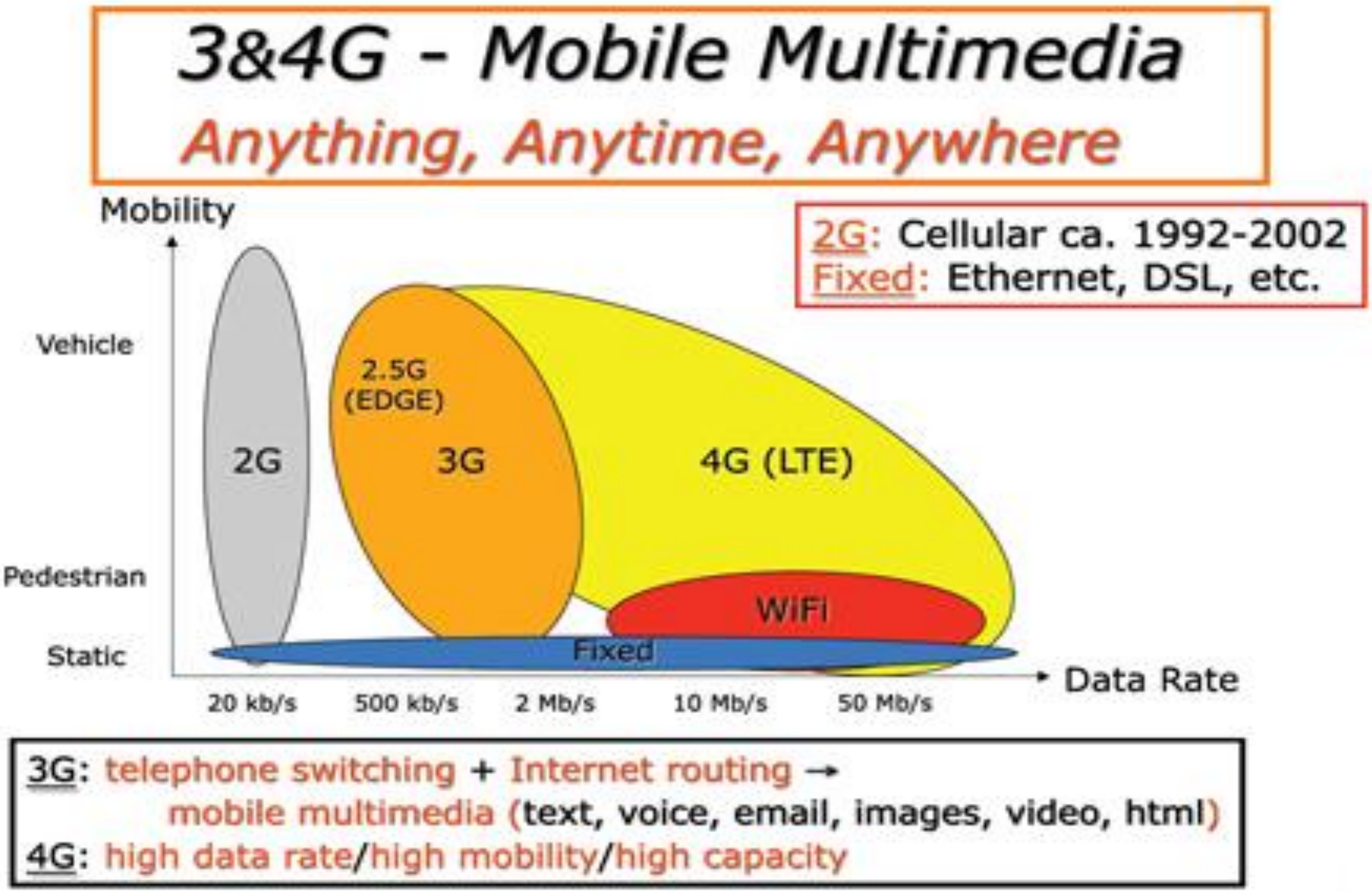
Evolution of Wireless Communications

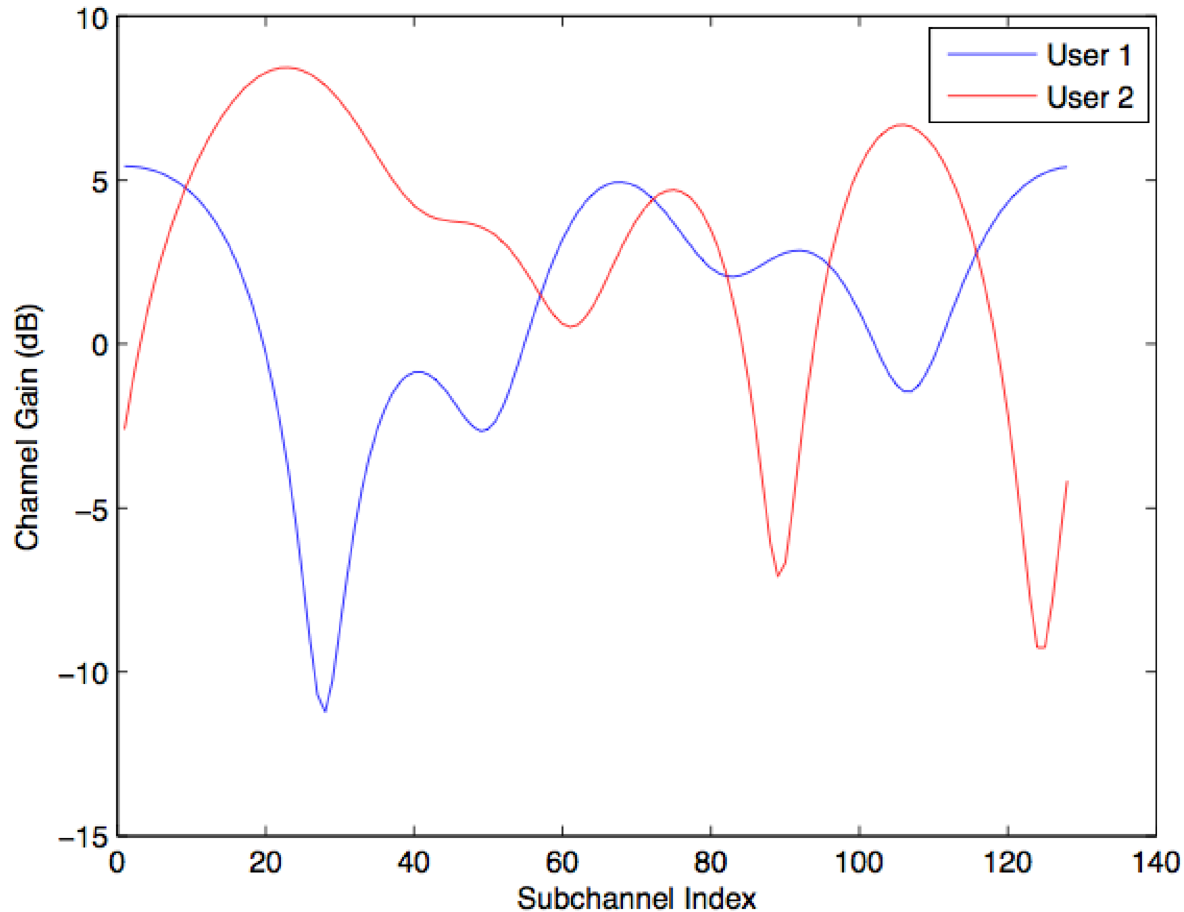


Wireless Communication Resources

- Resources to be allocated across multiple users
  - Time
  - Frequency (Sub-channels)
  - Transmission Power

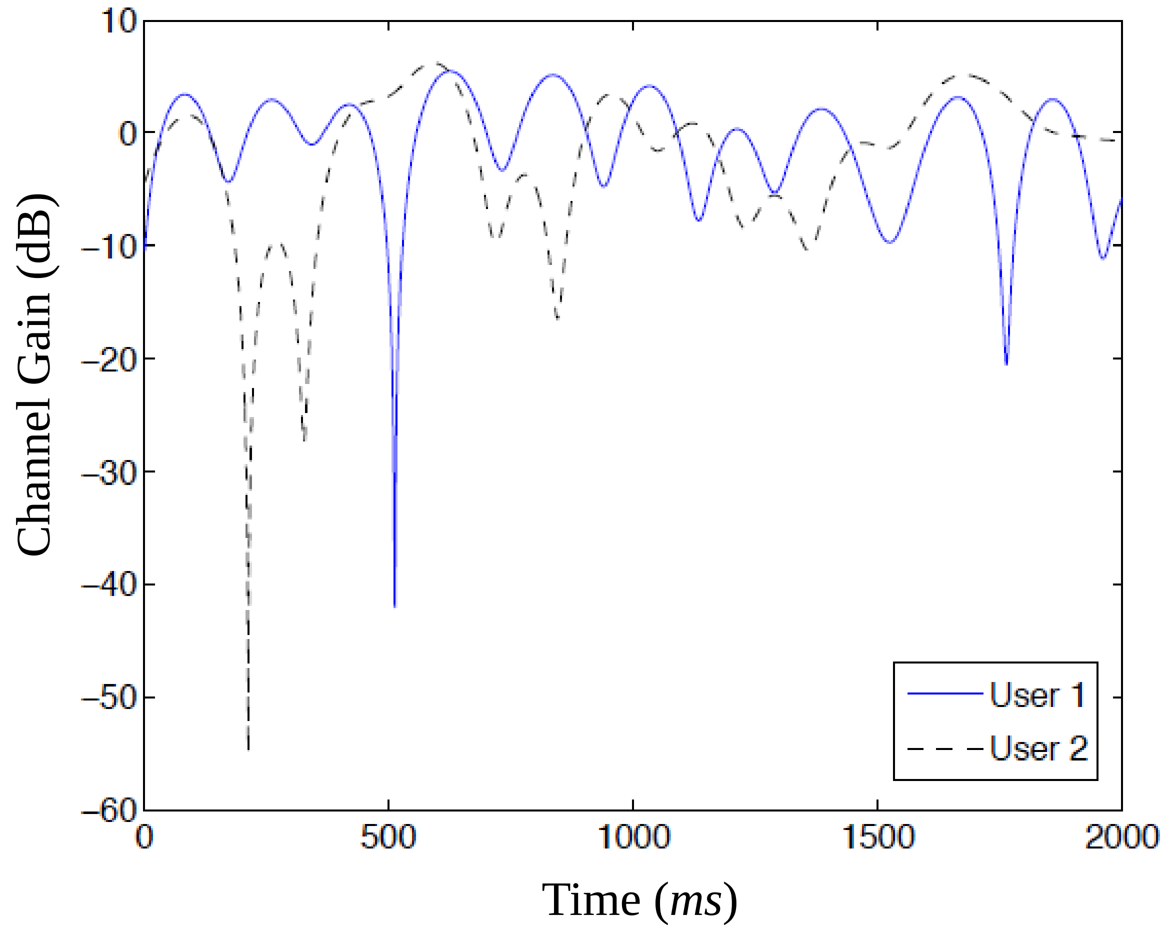
Challenge 1: Frequency Diversity

- Frequency-selective channel: caused by multipath



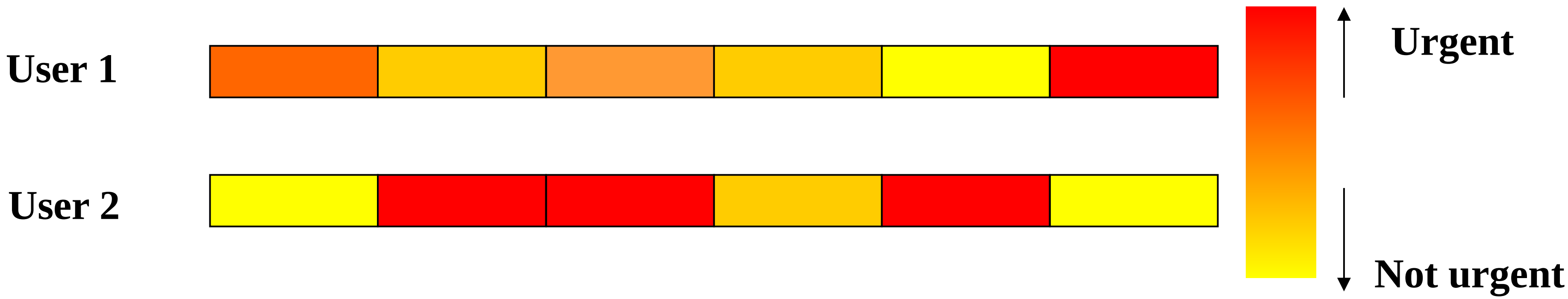
Challenge 2: Time Diversity

- Time-varying channel: caused by movement of mobile terminals



Challenge 3: Data Diversity

- Different traffic types
- Different quality of service requirements

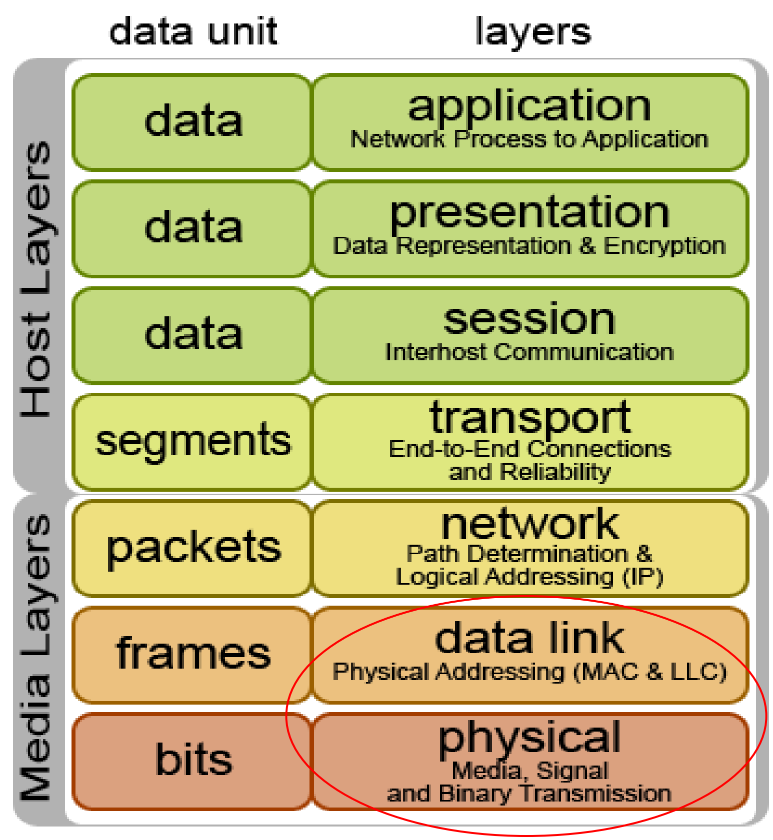


Resource Allocation Strategy

- How to allocate limited and expensive resources across a large number of users?
- Things to consider:
  - Quality of service
  - Fairness
  - Dynamic
  - Real-time processing
  - …
- Proposed solution: cross-layer design

Cross-Layer Design

- Conventional communication networks have independent layers, which is not efficient.
- Objective: to enhance the network performance by dynamic resource allocation, using the information across two or more layers.



Cross-Layer Resource Allocation

- Previous method: maximum sum capacity at PHY layer only.

$$\max \sum_k R_k \longleftarrow$$

Maximum data rate of user k determined at the **PHY** layer

- Proposed method: maximum **weighted** sum capacity (MWSC) scheme cross PHY and MAC layers.

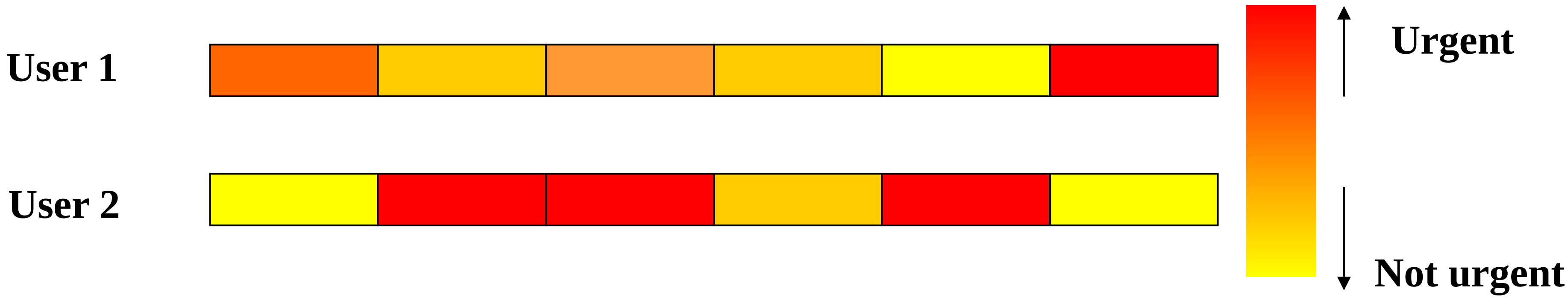
$$\max \sum_k W_k R_k$$

Weight of user k determined at the **MAC** layer

subject to fixed total transmission power

Scheduling at the MAC Layer

- Previous scheduling methods
  - All packets for the same user are given the same weight.
  - Not efficient
    - Urgent and less urgent packets are treated with the same priority;
    - Some packets in the waiting queue may be dropped.

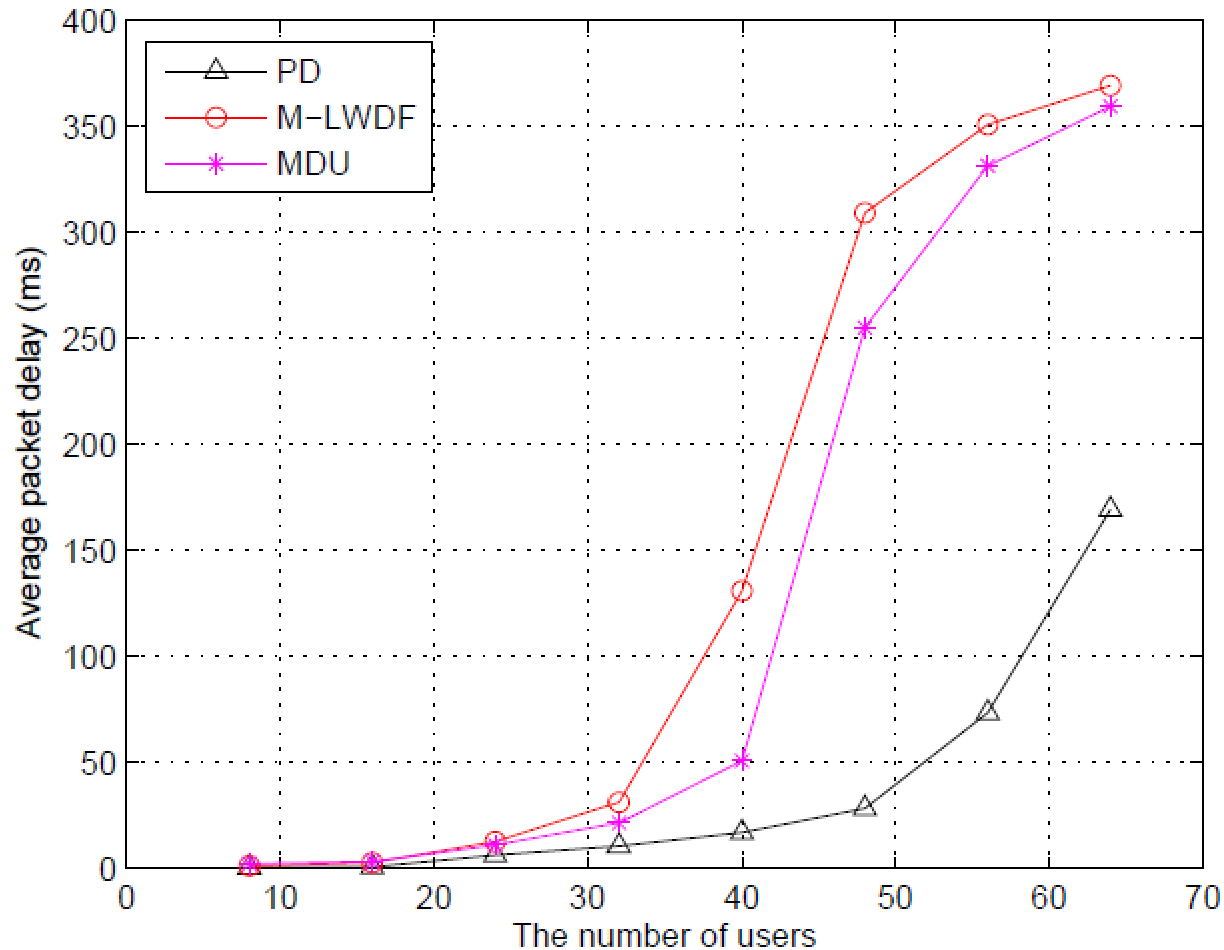


Packet Dependent (PD) Scheduling

- Proposed method: **packet dependent (PD)** scheduling—different packets for the same user may be assigned different weights.
- The packets with higher weights are served first--more flexible and efficient.
- The quality of user experience (QoE) is taken into account in weight calculations
  - Packet delay
  - Packet size: bigger data to serve first
  - Traffic type (voice, video, text)

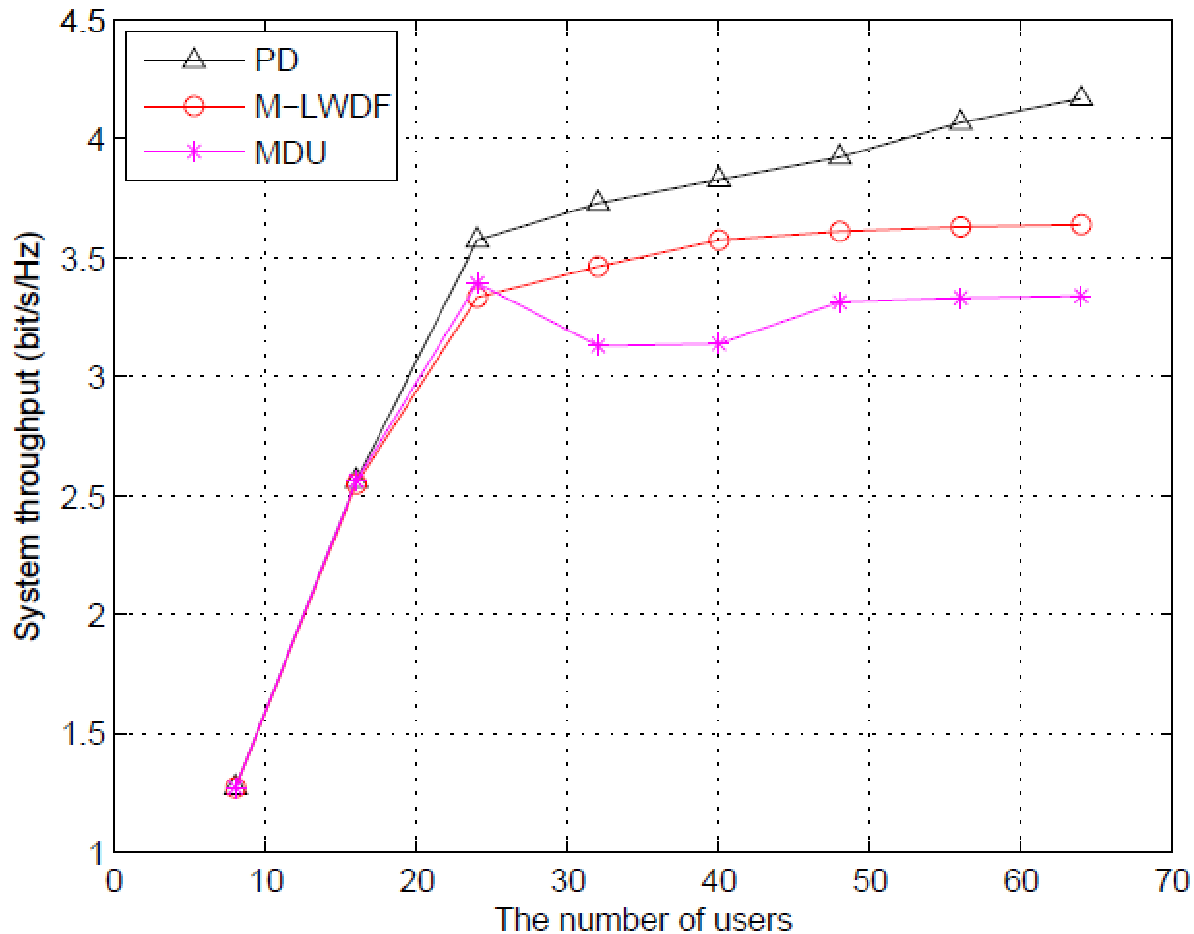
Average Delay Performance

- PD scheduling achieves a much lower average delay than the previous methods.



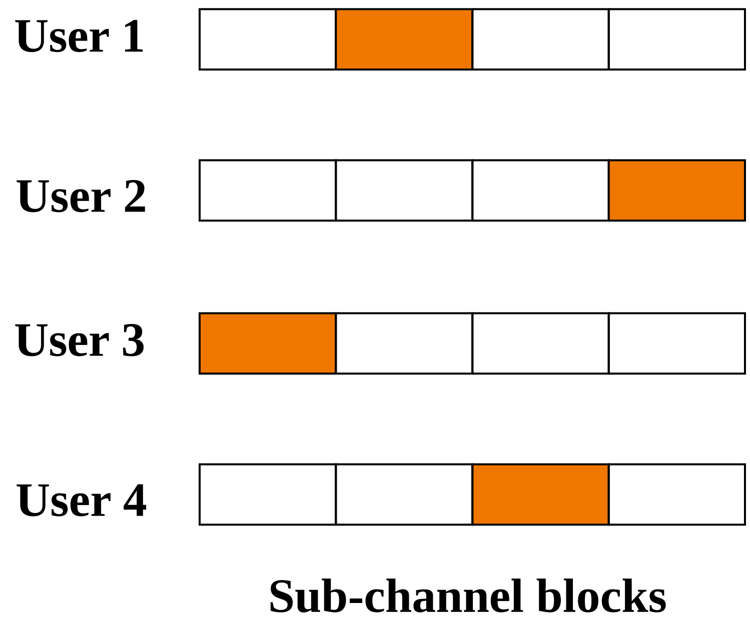
System Throughput Performance

- The PD cross-layer design achieves a higher throughput than the previous methods.



Sub-Channel Allocation at the PHY Layer

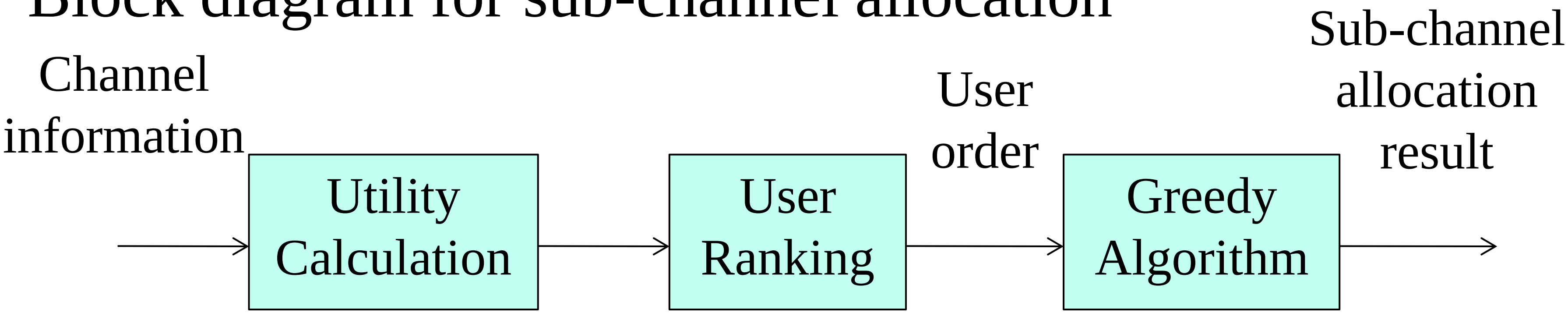
- Optimal solution: exhaustive search is computationally prohibitive ($100! \approx 10^{158}$ possibilities for 100 users)
- Suboptimal solution: greedy algorithm with a reduced search space.
- The greedy algorithm searches across sub-channels with a given user order (e.g., [3,2,4,1]) each time.



$$\max \sum_k W_k R_k$$

Greedy Algorithm based Sub-Channel Allocation

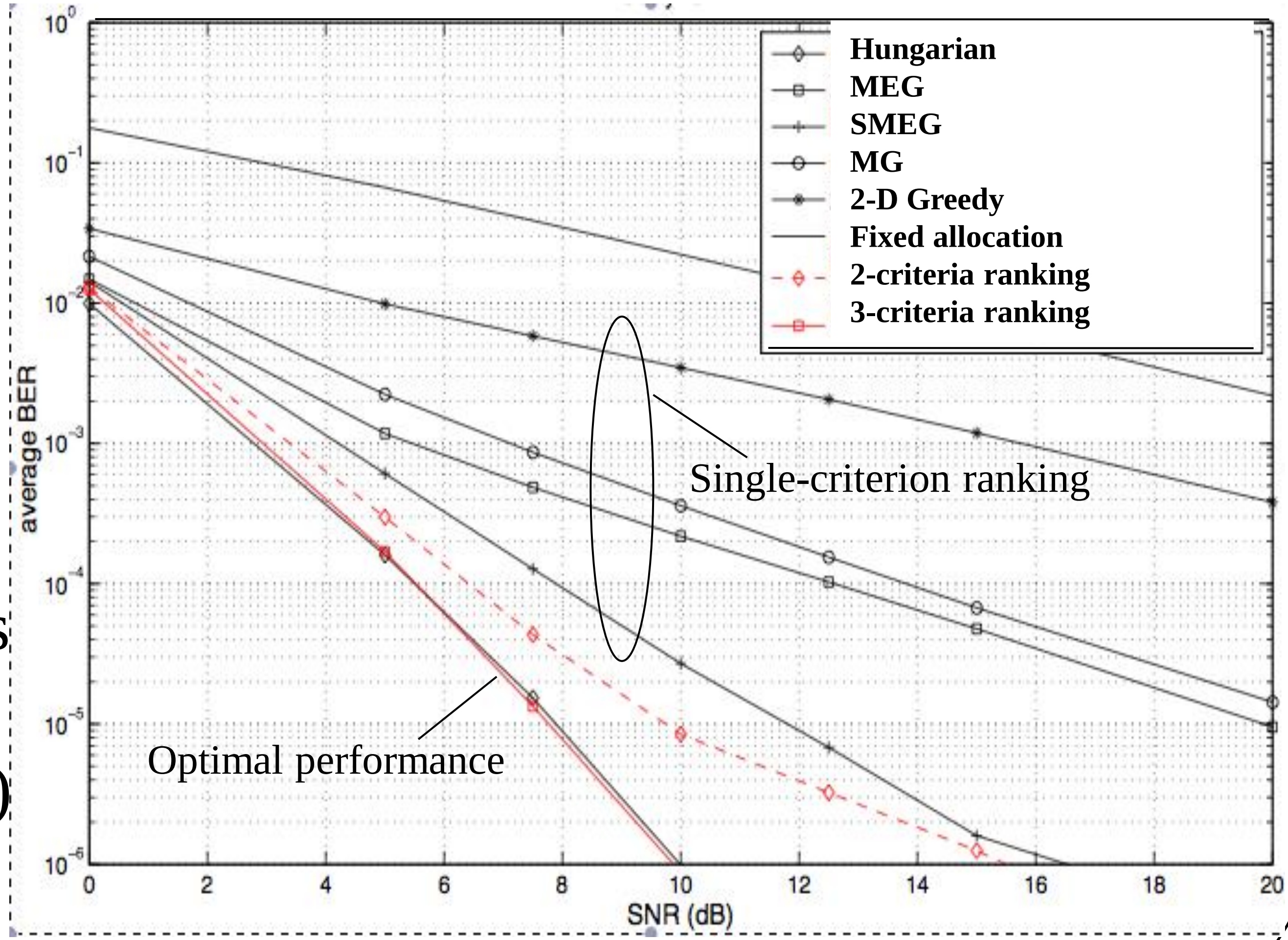
- Block diagram for sub-channel allocation



- We only select a small number (e.g., 100) of user orders. Thus, user ranking is important in reducing the search space
  - Previous work was based on single criterion ranking
  - Proposed method: multi-criteria ranking, using the mean, standard deviation etc. of a user's performance across different sub-channels

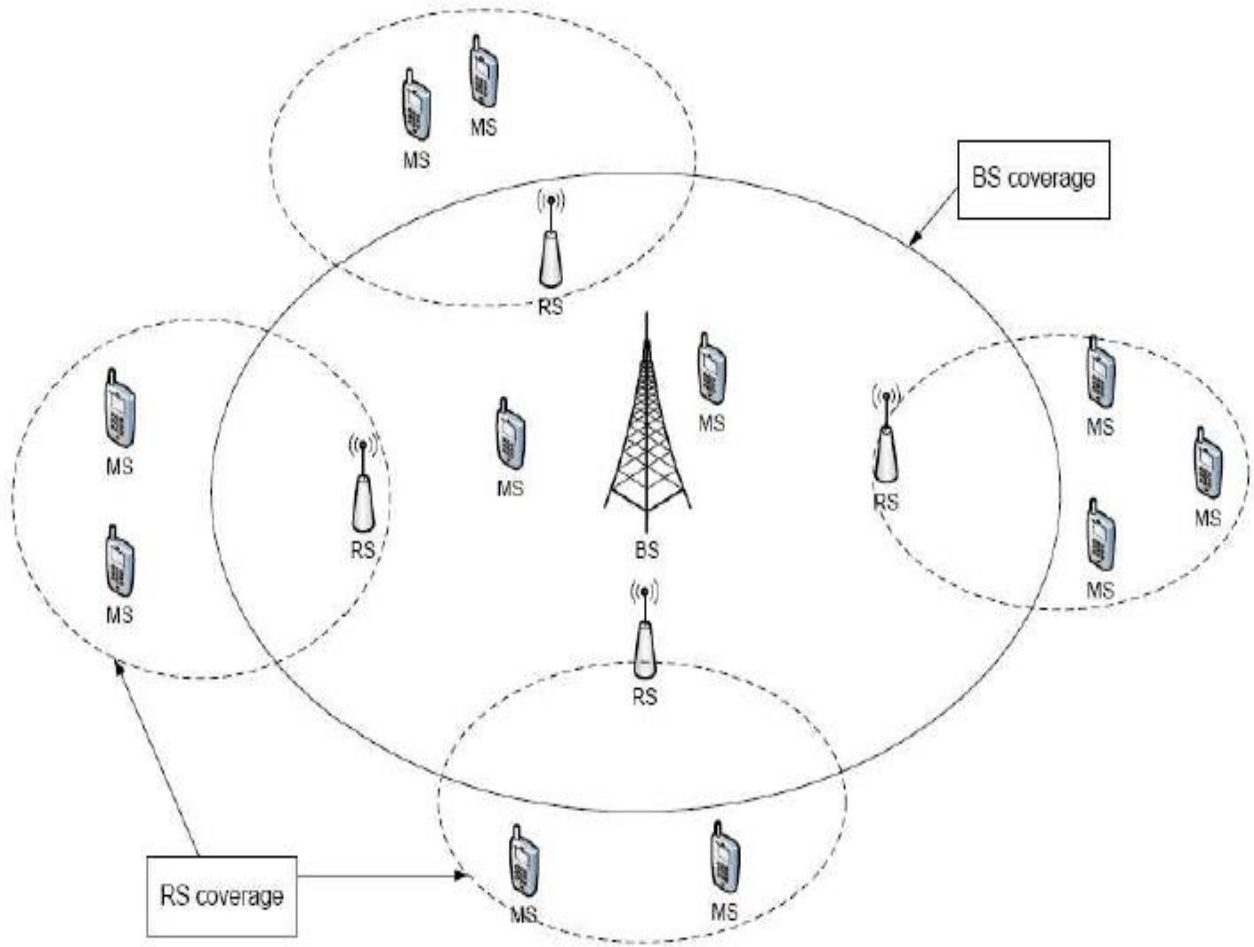
Bit Error Rate Performance of the Greedy Algorithm

- Multi-criteria ranking achieves near optimal performance
- Lower complexity compared to some single-criterion ranking algorithms (e.g., 10 times less complex than MG)



Relay based Wireless Network

- Higher energy efficiency
- Extension of cell coverage
- More reliable and longer lasting network connectivity
- Cost effective



Resource Allocation for Relay based Wireless Networks

- Objectives of the further work
  - Improved user quality of experience
  - Real-time processing
  - High network performance (throughput etc.)
- Methods
  - Cross-layer resource allocation
  - Positioning + resource allocation
- This is applicable to vehicular communications.

Conclusion

- Low-complexity and dynamic cross-layer resource allocation across multiple users
  - Scheduling: better quality of service than previous methods.
  - Sub-channel allocation: near-optimal performance.
- Further work
  - Relay based wireless networks