Cooperative and Opportunistic Transmission for Wireless Ad Hoc Networks

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Jeng-Long Chiang

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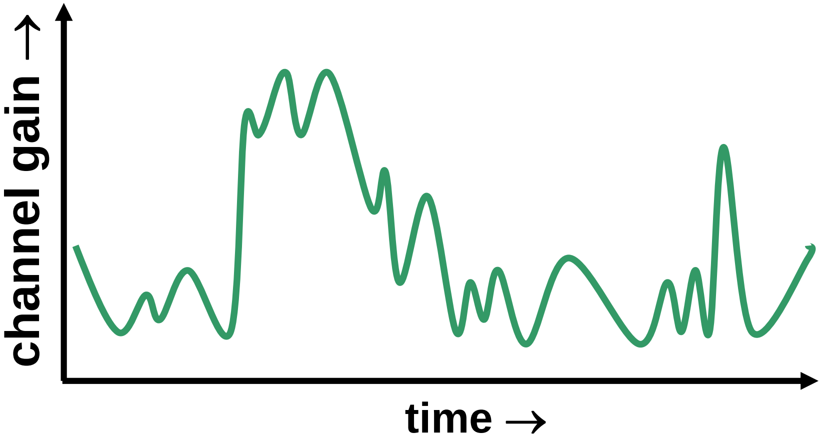
Outline

- Introduction
- Distributed Cooperative Rate Adaption (DCRA)
  - – DCRA Performance
- Cooperative and Opportunistic Scheduling (COS)
  - – COS Performance
- Conclusion

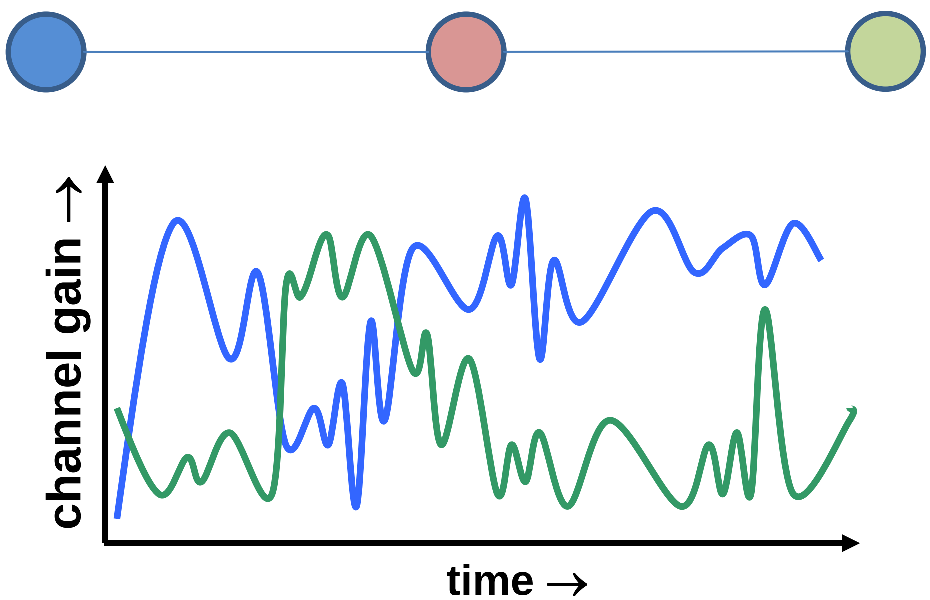
Introduction

- Opportunistic Transmission
  - Time diversity: Transmit more packets at higher rates when the channel condition is better.



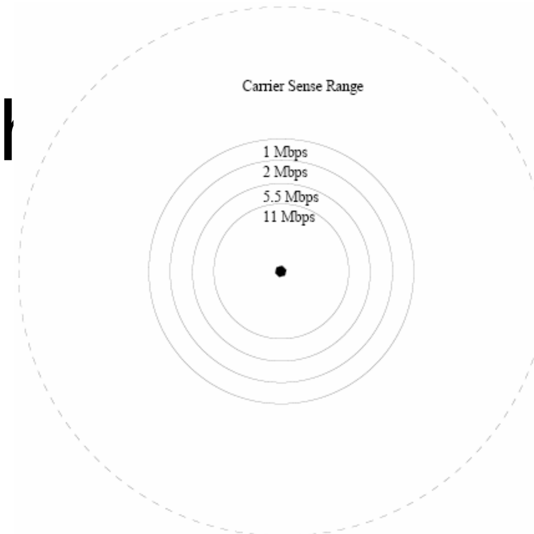
Introduction

- Opportunistic Transmission
  - Multi-user diversity: Select instantaneously an on-peak receiver with the best channel condition.



Motivation

- Local decision is not enough
  - Hidden terminal
  - Co-channel interference



- Neighboring transmitter should jointly determine the on-peak flows.
  - Rate selection
  - Flow scheduling

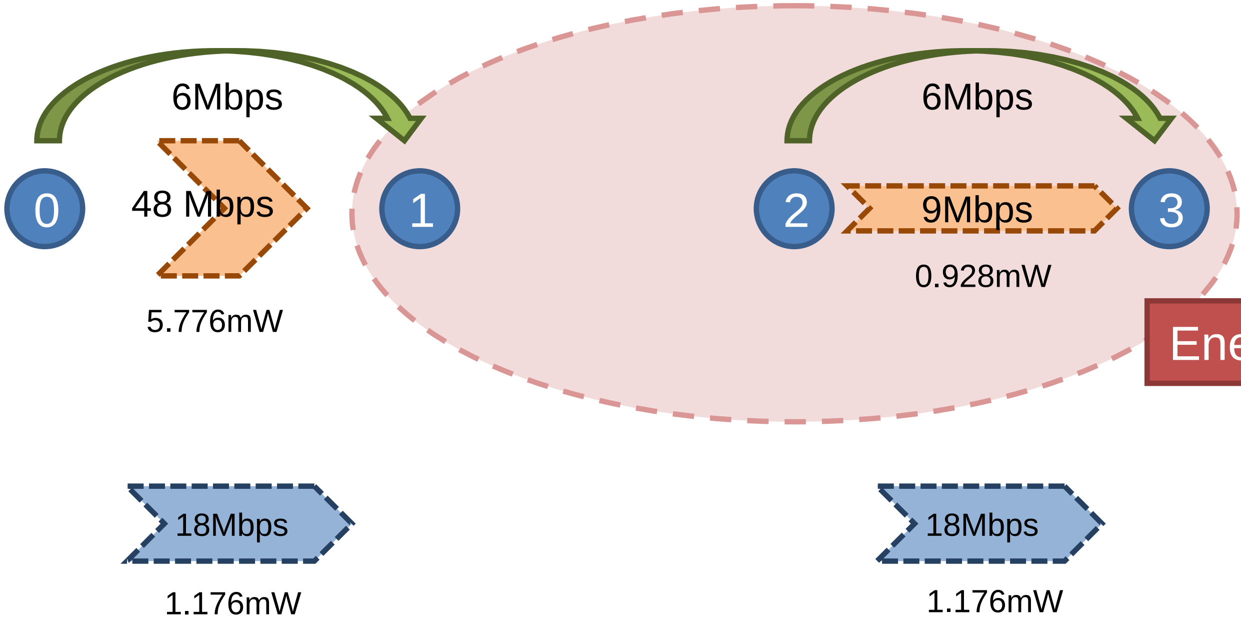
Design Goals

- Cooperative and opportunistic transmission

- Cooperative rate adaptation (CRA)
  - Energy efficiency
- Cooperative and opportunistic scheduling (COS)
  - Throughput maximization
  - QoS provisioning

Inequality of Channel Access

- Inequality of channel access results from hidden terminals.



Total Power Consumption:

6.704mW

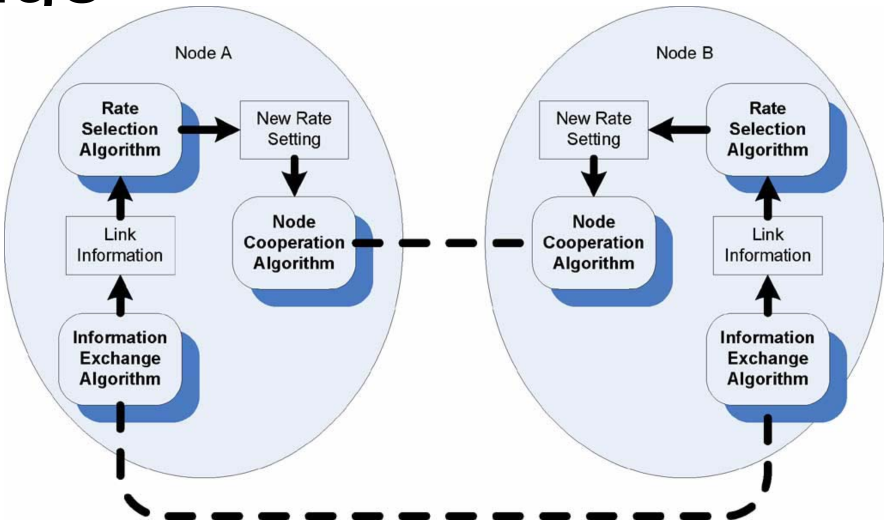
Energy inefficiency!

2.352mW

Distributed CRA

- Nodes cooperate in rate adaption for high overall energy efficiency.

- Information exchange
- Rate selection
  – (NP-complete)
- Node cooperation



DCRA (Heuristic Algorithm)

Step 1 Set the rate for each link in node A's maximum interference range to the highest value as the initial setting.

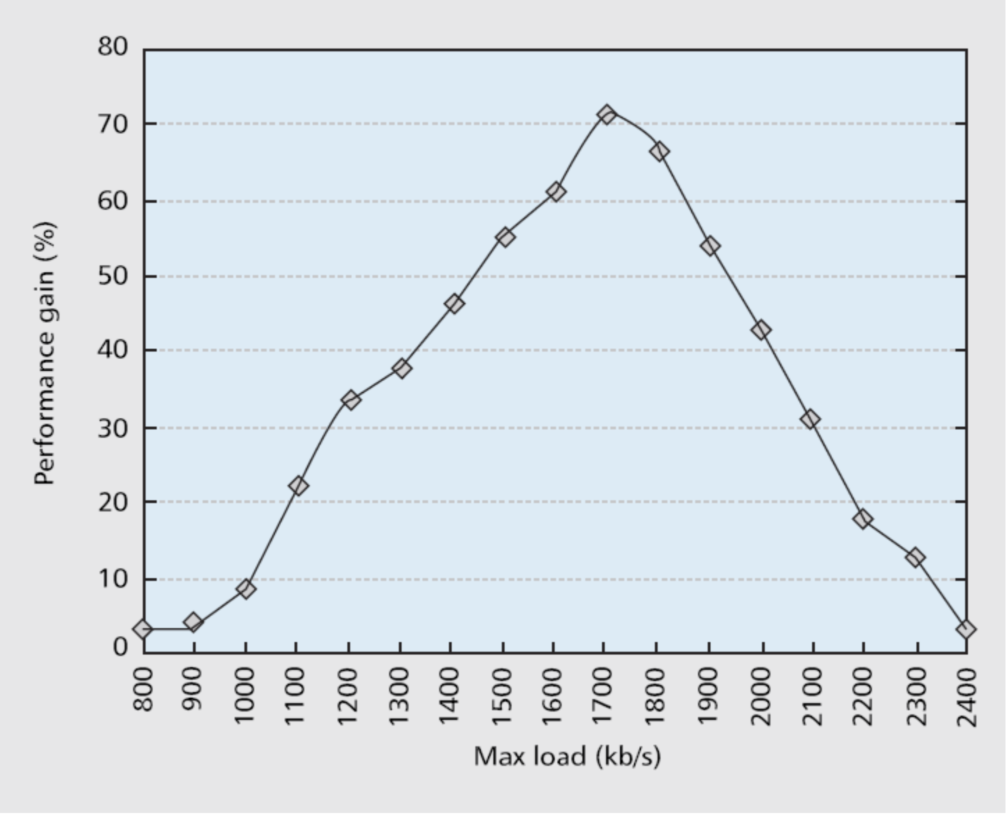
Step 2 For each link within A's maximum interference range, select a rate that has the largest $\Delta E/\Delta T$, where ΔE denotes energy reduction and ΔT denotes the channel time increase, as compared to the current setting. Then, choose the link that has the largest $\Delta E\ \Delta T$ among all the links within A's maximum interference range. If we can not find a setting that results in $\Delta E > 0$, the algorithm ends.

Step 3 Check whether the new rate of the link is feasible. If it is feasible, select the new rate setting; otherwise, reset to the previous setting.

Step 4 Go to step 2.

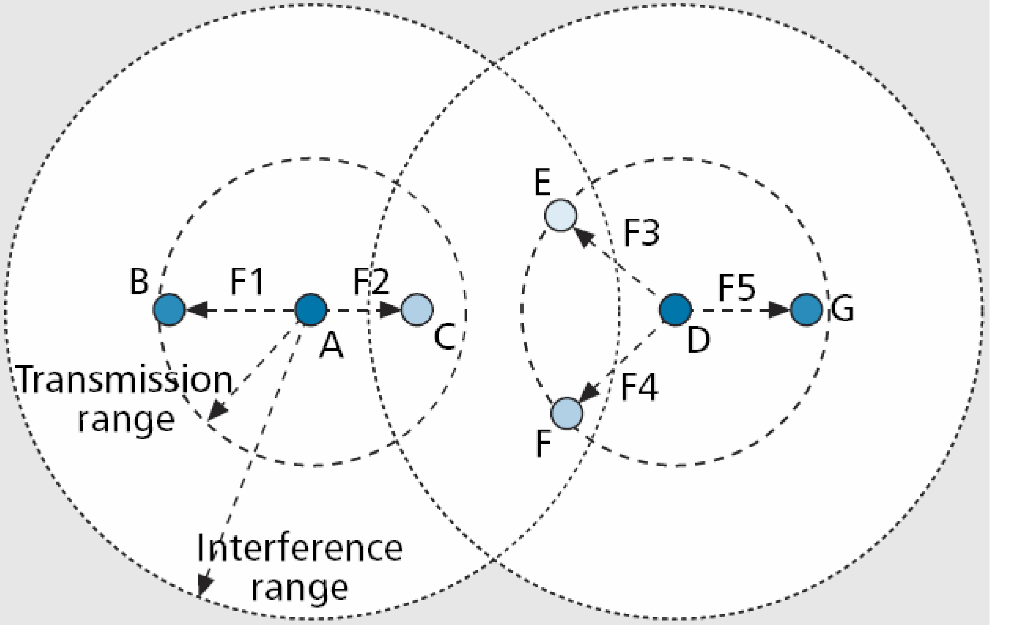
DCRA Performance

- 1000m * 1000m / 50 * 50-node random topologies / 15 traffic requests (rate: 0 ~ max. load)



Flow Contention

- Link contention
- QoS consideratio
- Resource coordination



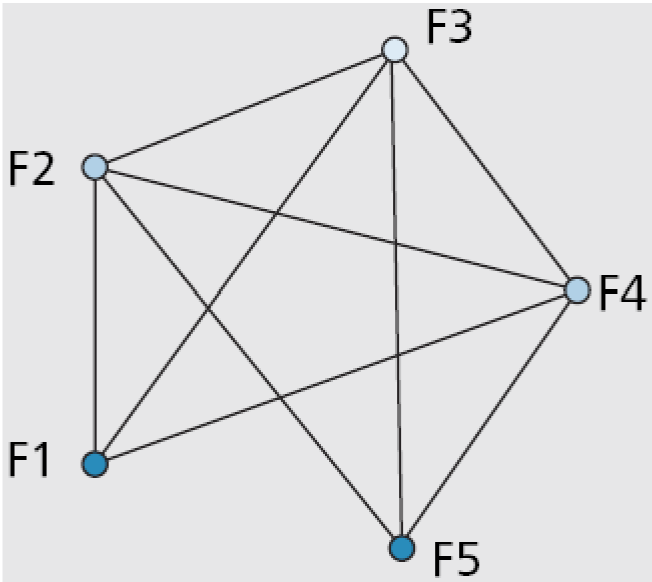
Spec. of ORiNOCO 802.11b PC Card

Rates (Mbps)	11.0	5.5	2.0	1.0	CS
Range (m)	399	531	669	796	1783

COS

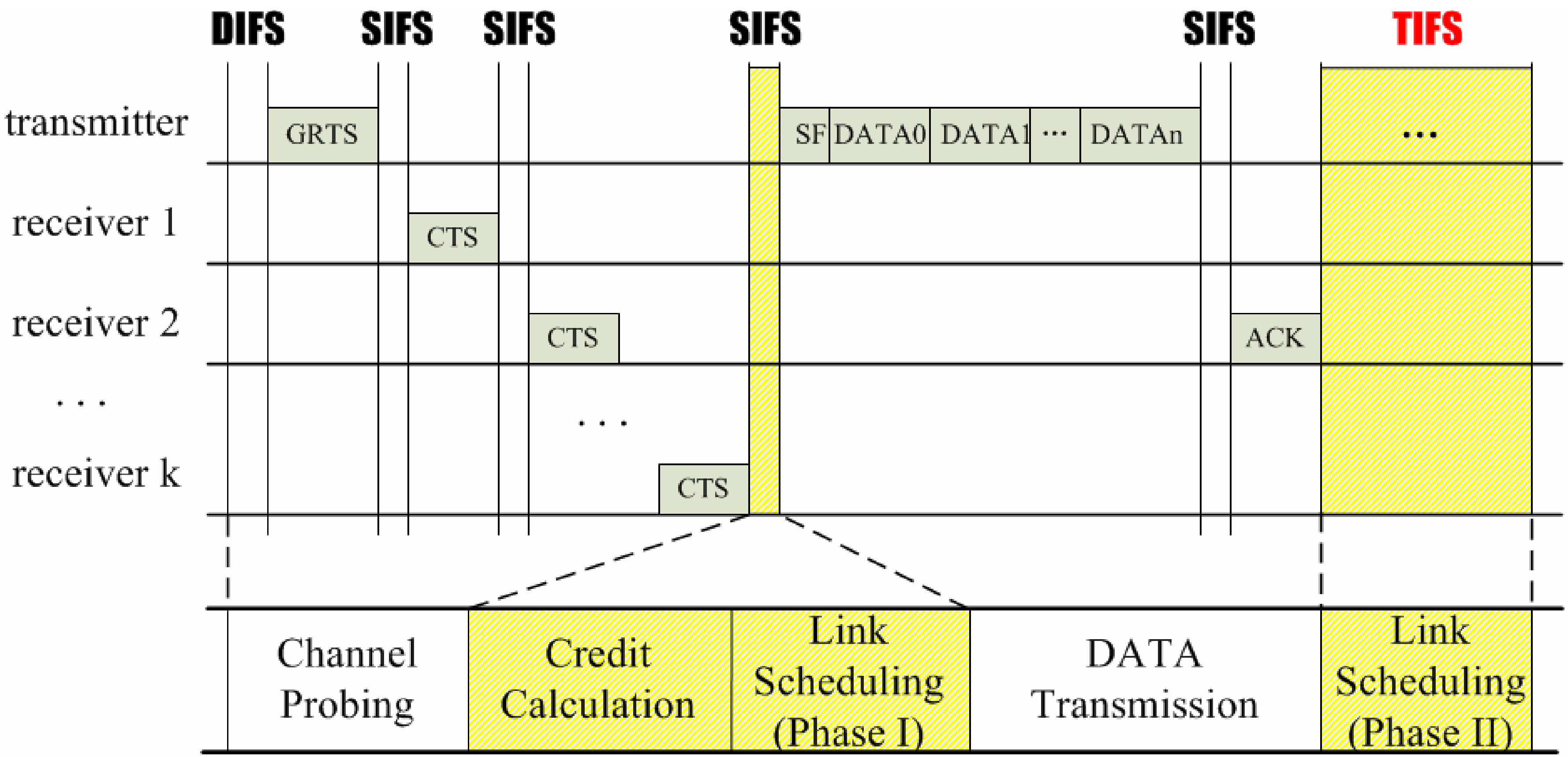
- Find the globally best set of flows that can transmit simultaneously and maximize overall system performance.

- Channel probing
  - LCG
- Credit calculation
- Data transmission
- Flow scheduling



Local Contention Graph (LCG)

The 4 Procedures of COS

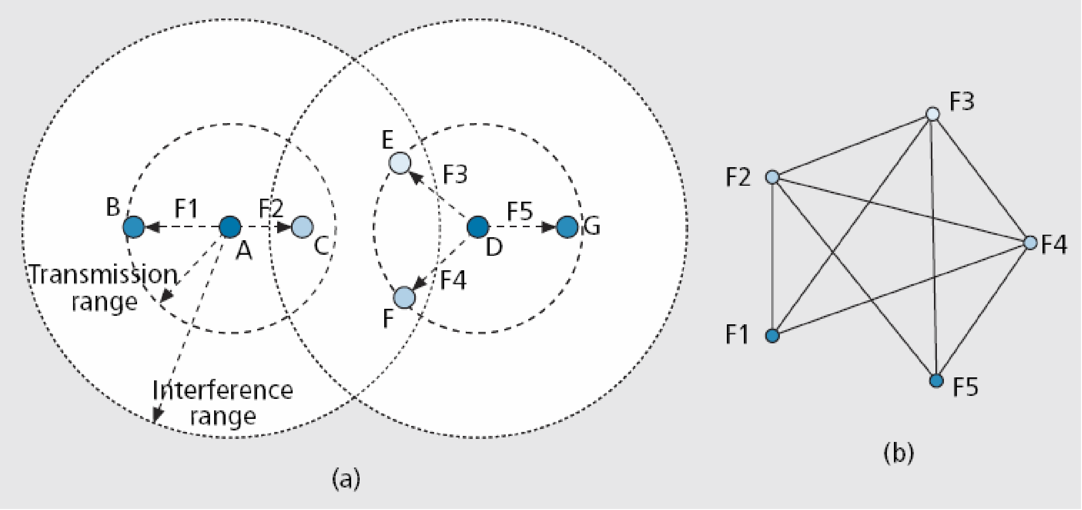


Credit Calculation

- *The CR* of the MIS (Maximal Independent Subset)
  - {*Sm*}={{F1, F5}, {F2}, {F3}, {F4}}
  - CR(Sm) = $\sum_{i \in S_m} \mu_i (1 + \lambda_i)$
    - μ *i*: the highest rate the *i*-th link supports
    - λ *i*: the QoS factor of the *i*-th flow
- *The CR* of the flow: for flow selection
- *The CR* of the transmitter: for TIFS caculation

An Example

- CR's of MIS's
  - {F1, F5}=7, {F2}=6, {F3}=5, {F4}=4.
- CR of flows
  - {F1, …, F5}={7, 6, 5, 4, 7}.
- CR of Transmitters
  - A=7, D=7.



Credit Update

- After each transmission, the QoS factor is updated according to:

$$\lambda_i^{k+1} = \begin{cases} \lambda_i^k + a^k (G_i - C_i^k), & \text{if } G_i > C_i^k \\ 0 & \text{otherwise} \end{cases}$$

  - *Gi*: the long-term QoS requirement of the *i*-th flow
  - C_i^k: the throughput achieved until time slot *k*
  - $\alpha^k = 1/k$

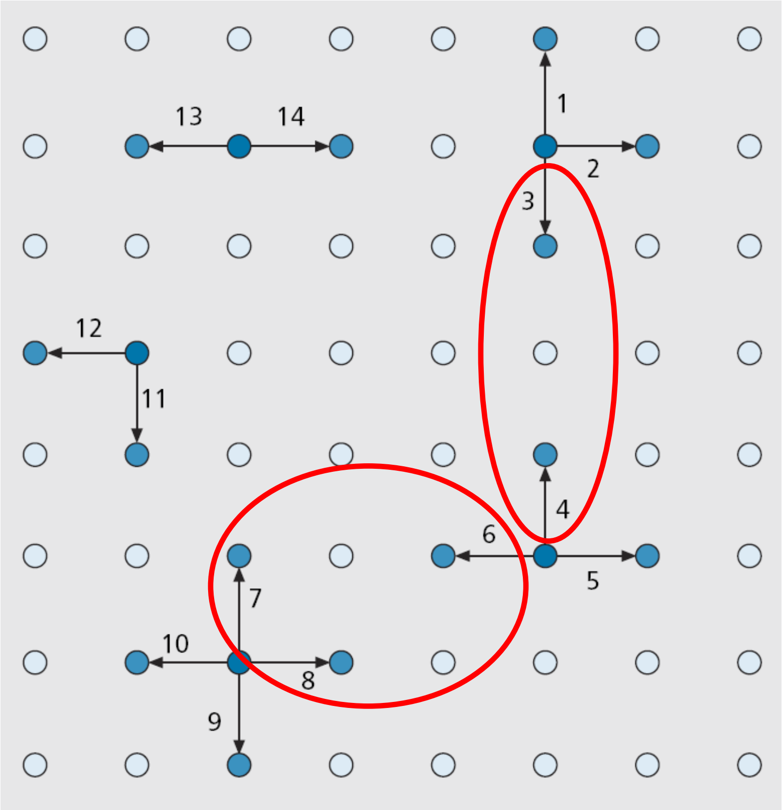
Flow Scheduling

- Traffic control InterFrame Space
  - Defer non-transmitter's attempt to access for approximate the optimal time scheduling

$$TIFS = \begin{cases} 0, & \text{if } seq = 1 \\ TIFS_{min}, & \text{if } TIFS = 0 \text{ and } seq > 1 \\ \min(TIFS \cdot seq, TIFS_{max}), & \text{otherwise} \end{cases}$$

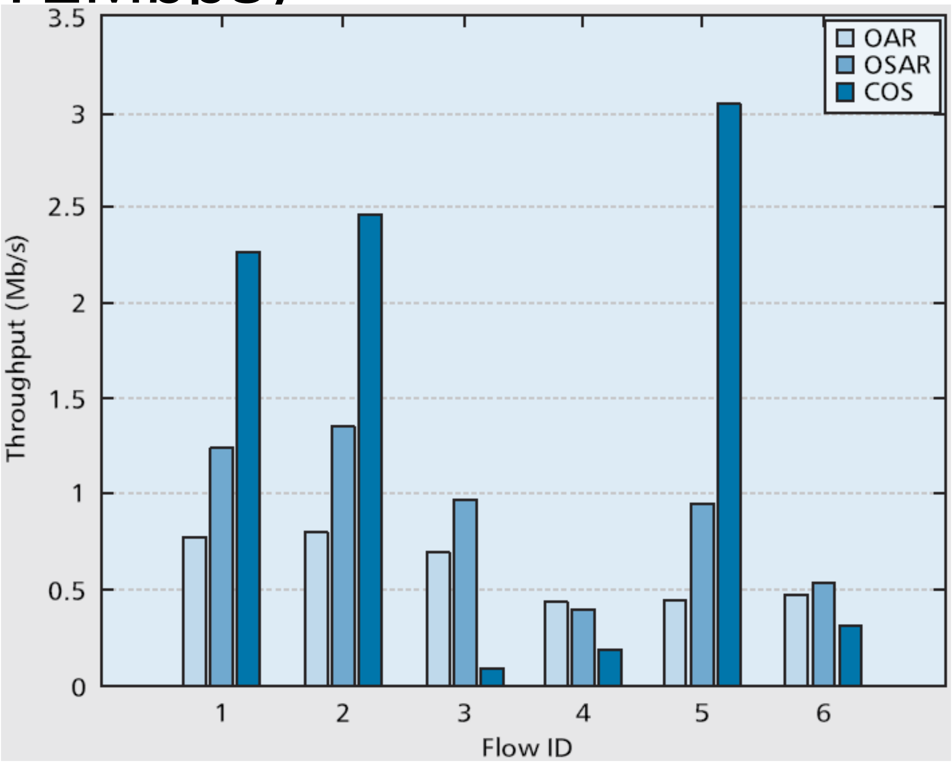
COS Performance

- 1, 2, 5.5, 11 Mbps / QSAR with flow credit / 8x8-grid=64 nodes / 14 flows



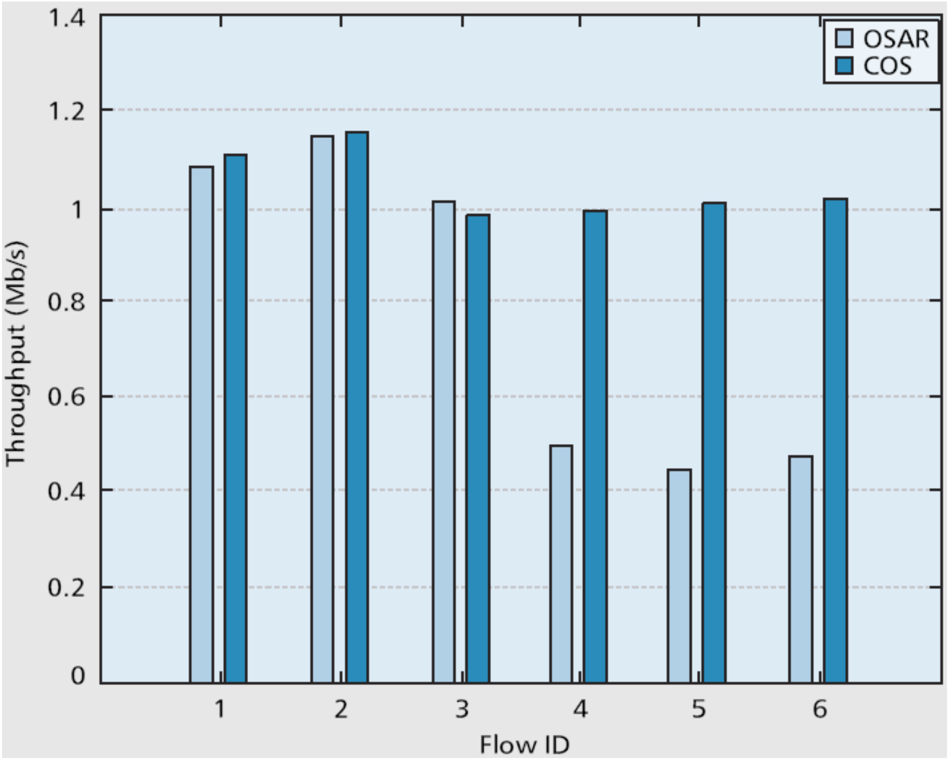
Throughput w/o QoS

- OAR(8.7Mbps) / OSAR(10.16Mbps) / COS(13.72Mbps)



Throughput w/ QoS

- G1=G2=…G6=1.0Mbps



Conclusion

- Opportunistically accessing the varying wireless channel opens a new direction for wireless networking related researches.
- Types of diversity that can be considered:
  - Time diversity
  - Multiuser diversity
  - Channel diversity
  - Path diversity
  - Space diversity

References

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