Opportunistic Relaying in Wireless Networks

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Outline

1. Motivation
2. System Model
3. Two-Phase Protocol and Throughput Analysis
4. Discussion and Conclusion

Overview of Throughput Capacity of Ad Hoc Networks

motivation of the work

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- We address these practical issues and propose a two-hop relaying scheme which:
  - does not require any cooperation between relays
  - requires only CSIR and limited feedback from receivers to senders
  - ... without sacrificing throughput scaling

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- n ad hoc nodes and m relay nodes
- I.i.d. Rayleigh connections
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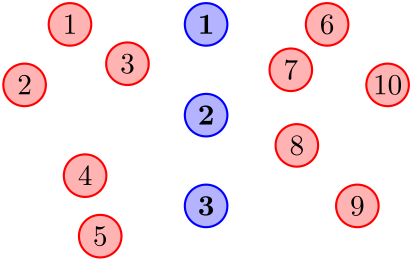

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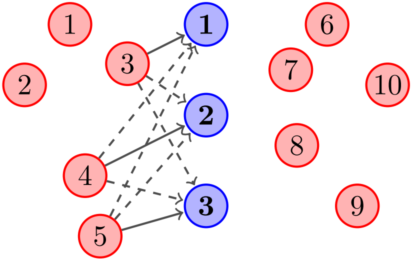

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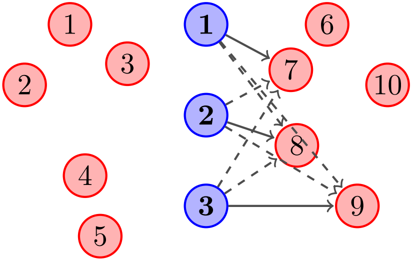

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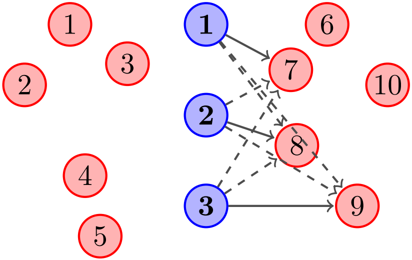


- Key idea: exploit multiuser diversity!

System Model

recall: multiuser diversity in cellular systems

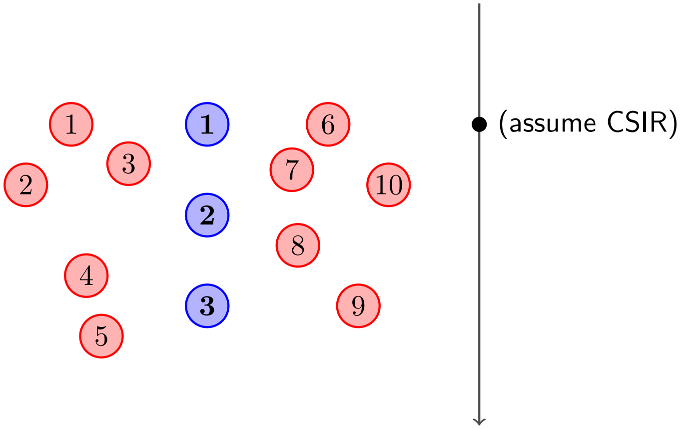
- Knopp and Humblet (1995)
- Transmits to the best user only
- Optimal in IT sense
- Implemented in IS-856 and HSDPA (with limited CSI feedback)

Multiuser Diversity Gain

$$\{h_i\} \text{ i.i.d.} \sim \mathcal{CN}(0,1)$$
$$\{\gamma_i\} \text{ i.i.d.} \sim \mathrm{Exp}(1)$$
$$\max\{\gamma_1,\ldots,\gamma_n\} \sim \log n$$

Phase 1

specific scheme for Phase 1



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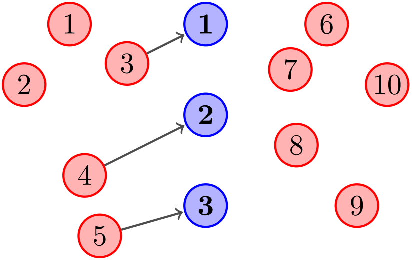

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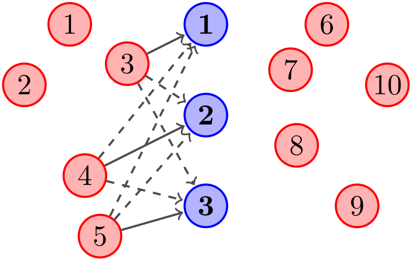

- (assume CSIR)
- each relay will schedule the best source independently
- the scheduled sources transmit at 1 bits/sec/Hz

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system throughput of Phase 1

Lower Bound of R_1

For any ρ, m, $s > 0$, and large n, the achievable throughput of the opportunistic relay scheme at Phase 1 is lower-bounded by

$$\begin{aligned} R_1 &\geq m \cdot \Pr[N_m] \cdot \Pr[S_m] \\ &\geq m \frac{n(n-1)\cdots(n-m+1)}{n^m} \left(1 - (1 - e^{-s})^n\right) F_Y(s - \tfrac{1}{\rho}) \end{aligned}$$

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$\Rightarrow R_1 \to m$ as $n \to \infty$ and m fixed.

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numerical results ($n = 1200$, $\rho = 10$ dB)

$$R_1 \geq m \cdot \Pr[N_m] \cdot \Pr[S_m]$$
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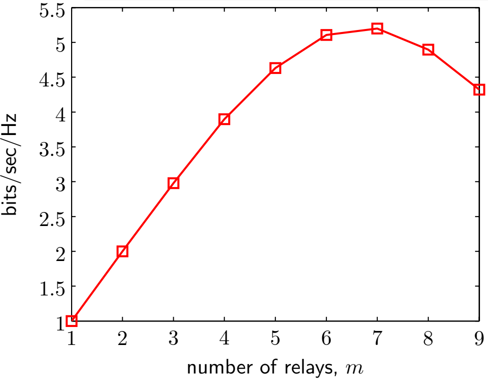

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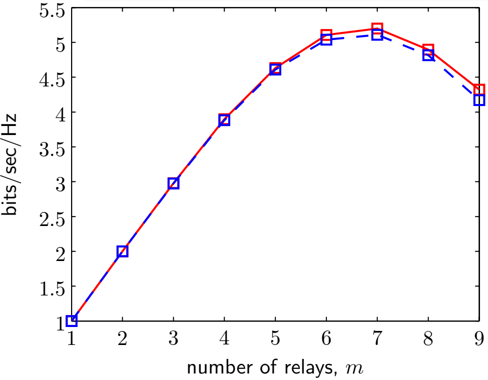

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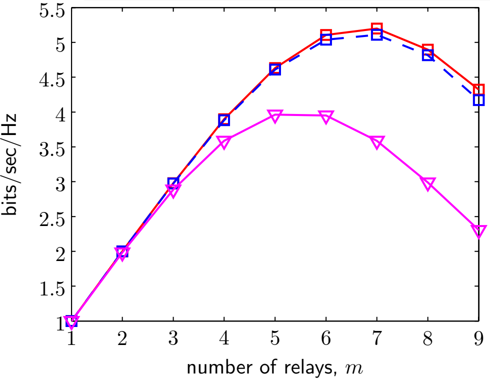

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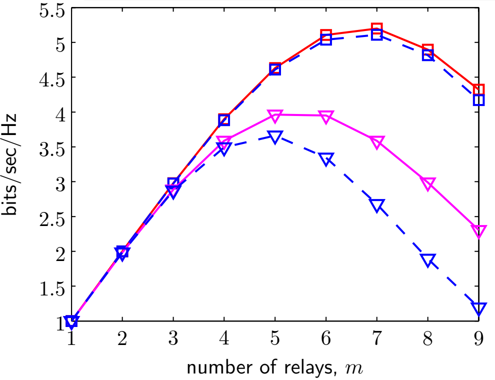

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- lower bound with optimized $s = \log n - \log\log n$

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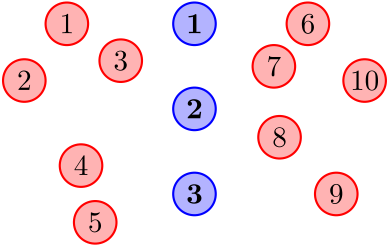

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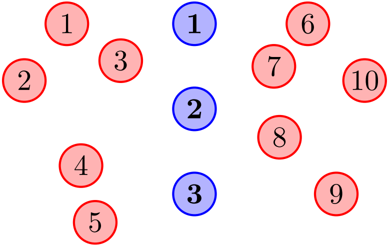

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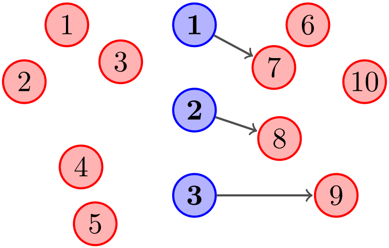

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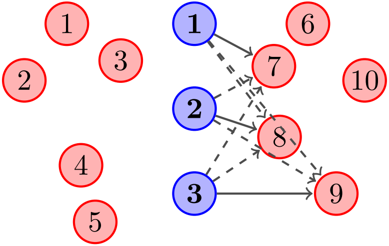

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Exact R_2

For any ρ, m and n, the achievable throughput of the opportunistic relay scheme at Phase 2 satisfies

$$R_2 = \sum_{k=1}^{m} 1 \cdot \Pr\left[\exists\, \mathsf{SINR}_{k,j}^{\mathrm{P2}} \geq 1,\ \forall 1 \leq j \leq n\right]$$
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- When $n \to \infty$, both R_1 and $R_2 \to m$
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- ... thanks to multiuser diversity gain

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If we allow m to grow as a function of n, how large can m be, while still satisfying the linearity of system throughput with m?

How Large Can m Be?

Large n and Fixed m

$R_1 \to m$ and $R_2 \to m$.

$m = \Theta(\log n)$ (Allerton 2007, submitted)

If $m = \Theta(\log n)$, then R_1 and R_2 are still $\Theta(m)$; If $m = \Omega(\log n)$, then R_1 and R_2 are $o(m)$.

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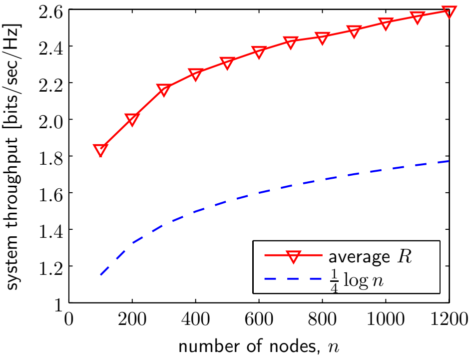

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  1. for Phase 1, $\Theta(n)$ is possible
  2. for Phase 2, still $\Theta(\log n)$ (due to lack of CSIT!!!)

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  - does not require cooperation between relays
  - does not assume CSIT
- Extends the philosophy of multiuser diversity from cellular systems to wireless ad hoc networks.
- Characterized the system throughput to be $\Theta(\log n)$, the same as Gowaikar, Hochwald and Hassibi (2006).