Discussion of “Capacity Regions for Wireless Ad Hoc Networks”

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Outline

- Ad Hoc Nets Special Challenges
- System Model
- Transmission Schemes and Schedules
- Rate Matrices
- Capacity regions
- Results for Specific Configurations

Special Challenges of Ad Hoc Nets

- No infrastructure
- Decentralized control (power, routing, data rates, etc)
- Dynamic topology
- Wireless channel impairments

System Model-1

- nodes : $A_1 \ldots A_n$
- Each A_i
  - has transceiver with infinite buffer
  - maximal power output is P_i
  - canNOT simultaneously send and receive
  - may send data to any A_j (multihop routing possible)
  - occupy ALL bandwidth (W) while transmitting
  - NO broadcast

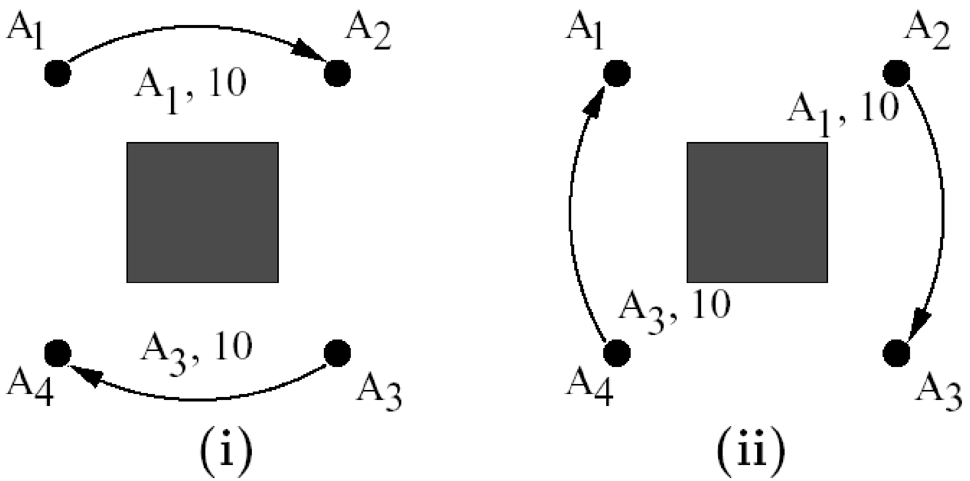
System Model 2

- Gains: $G = \{G_{ij}\}$; AWGN: $H = \left[\eta_1 \cdots \eta_n\right]$
- Each node knows "everything": G, H, P
- $t \in \mathcal{J} \Rightarrow A_t$ is transmitting with power P_t
- If A_i ($i \in \mathcal{J}$) transmits to A_j ($j \notin \mathcal{J}$),
  - $$\text{SINR: } \gamma_{ij} = \frac{G_{ij}P_i}{\eta_j W + \sum_{k\in\mathcal{J},k\neq i} G_{kj}P_k}$$
  - data rate: $R_{ij} = f(\gamma_{ij})$ pre-agreed for performance; e.g., $f(\gamma_{ij}) = W \log_2(1+\gamma_{ij})$

Transmission Schemes

T-scheme $\mathcal{S}$: describes info flow at given time

- all transmit-receive node pairs, and data rates
- originating node of data



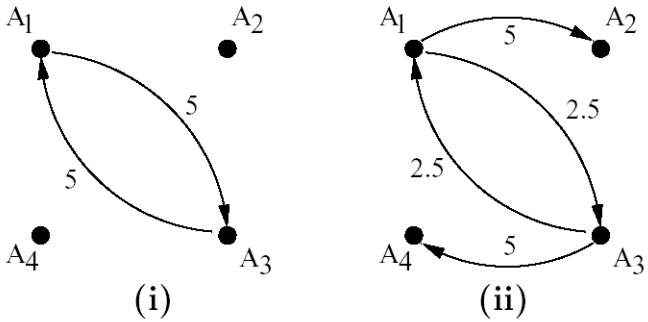
Time Division Schedules

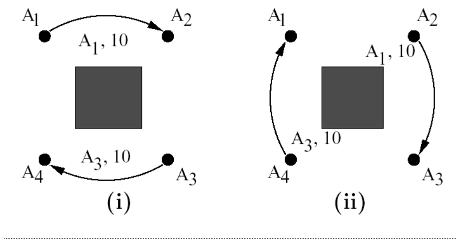
Network may alternate various schemes. Ex:

(i) $\mathcal{T}_1 = 0.5\mathcal{S}_1 + 0.5\mathcal{S}_2$ or

(ii) $\mathcal{T}_2 = 0.75\mathcal{S}_1 + 0.25\mathcal{S}_2$

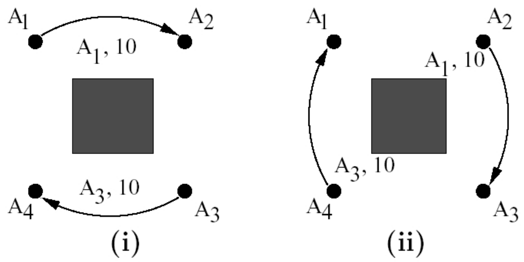
See resulting info flow:





Rate Matrices–1

For given scheme $\mathcal{S}$, $R(S)$ is $n \times n$ matrix such that $R_{ij} = \pm r \Rightarrow A_j$ receives/send r bps originating at A_i

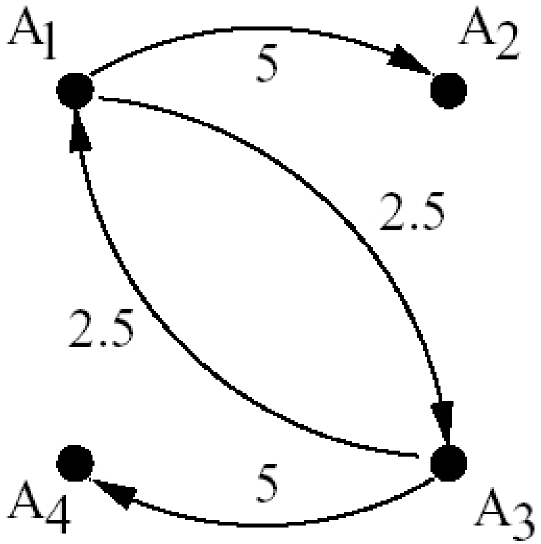


$$R_1 = \begin{bmatrix} -10 & 10 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & -10 & 10 \\ 0 & 0 & 0 & 0 \end{bmatrix} \qquad R_2 = \begin{bmatrix} 0 & -10 & 10 & 0 \\ 0 & 0 & 0 & 0 \\ 10 & 0 & 0 & -10 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

Rate Matrices–2

They work for time-division schedules also:

$$K_2 = R(\mathcal{T}_2 = 0.75\mathcal{S}_1 + 0.25\mathcal{S}_2) = 0.75R_1 + 0.25R_2$$

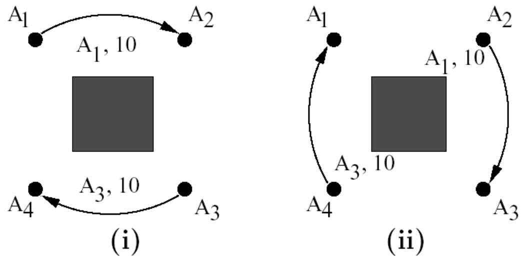


(ii)

$$K_2 = \begin{bmatrix} -7.5 & 5 & 2.5 & 0 \\ 0 & 0 & 0 & 0 \\ 2.5 & 0 & -7.5 & 5 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

Protocols and basic matrices

- Trans. protocol: rules for transmitting nodes
  Ex: only transmit own info; use max power; simultaneous trans. OK; etc.
- Given a protocol, many schemes are possible



- Each has a rate matrix $\Rightarrow$"basic matrices"

Capacity Region : Definition

- Capacity region: Convex Hull of all basic rate matrices such that the weighted sums have NO negative off-diagonal elements
- Uniform Capacity, $C_u = R_{max} \times n(n-1)$ with R_{max} largest R s.t. this matrix is in the capacity region:

$$\begin{bmatrix} -(n-1)R & R & \cdots & R \\ R & -(n-1)R & \cdots & R \\ \vdots & \vdots & \ddots & \vdots \\ R & R & \cdots & -(n-1)R \end{bmatrix}$$

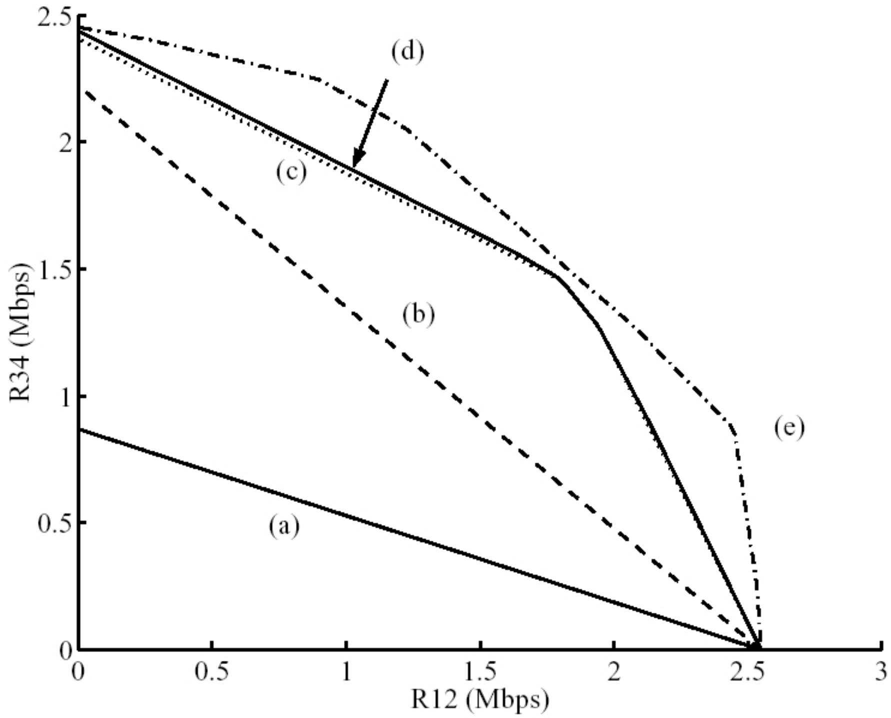
Specific physical parameters

- Nodes: 5 uniformly distributed in box [-10m , 10m]$\times$[-10m , 10m]
- $G_{ij} = 10^2 d_{ij}^{-\alpha} S_{ij}$
- S_{ij} (shadowing) lognormal with $\mu = 1$ and σ= 8 db
- $P_i = 1W$; $\eta_i = 10^{-11}$ W/Hz
- bandwidth $W = 10^6$ Hz

Capacity: No multi-hopping, No spatial reuse

- Only one transmits $\Rightarrow$# of schemes is $N^a = n(n-1)+1$
- Choose rates by $f(\gamma_{ij}) = W \log_2(1+\gamma_{ij})$
- Associated rate matrices : $R_k^a, \quad k = 1 \dots N^a$
- uniform capacity : $C_u^a =$0.83 Mbps
- Slice of capacity region ($R_{ij} = 0$ if $(i,j) \neq$ (1,2), (3,4)) (see fig)

Several capacity results



(a) Single-hop, No spatial reuse

(b) Multihop, no spatial reuse

(c) Multihop, spatial reuse

(d) 2-levl power cntrl added to (c)

(e) Succs. interference cancellation

	a	b	c	d	e
C_u	0.83	2.85	3.58	3.61	4.31