Cooperating with Smartness Using Heterogeneous Smart Antennas in Ad Hoc Networks

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INFOCOM 2007

Outline

- Introduction
- Node Co-operation in HSANs
- Adaptive Co-operation mechanism
- The MACH protocol
- Performance evaluation of MACH
- Conclusions

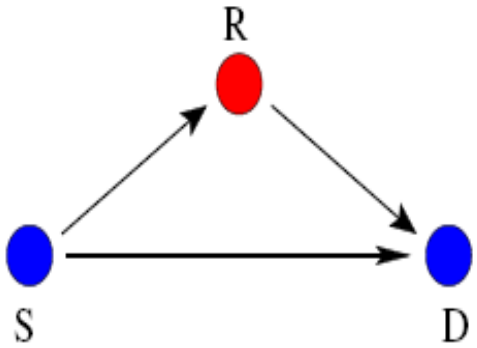
Introduction

- Smart antennas
  - Switched beam -> LOS
  - MIMO (adaptive array antenna) -> NLOS
- Motivation
  - Economic feasibility
  - Mesh networks (arbitrary)
- Retransmit diversity

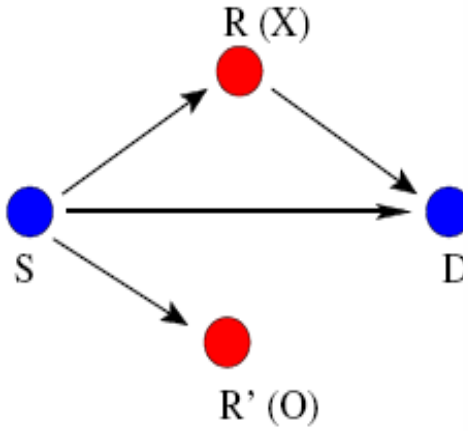
Smart node

- In switched beam antennas , a pre-defined set of weights is used , each of which results in a beam pointing to a particular direction with a high SNR gain (LOS)
- For strong multipath scattering (NLOS) environments , it is the adaptive array antennas that are capable of adapting their weights and hence beam pattern to maximize the resulting SNR

Node cooperation in HSANs



a) Node Cooperation



b) Node Cooperation in HSAN

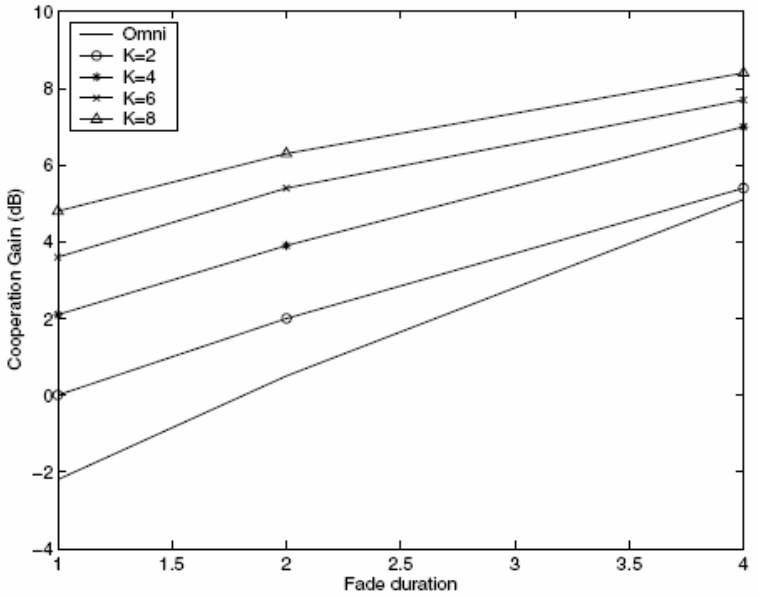
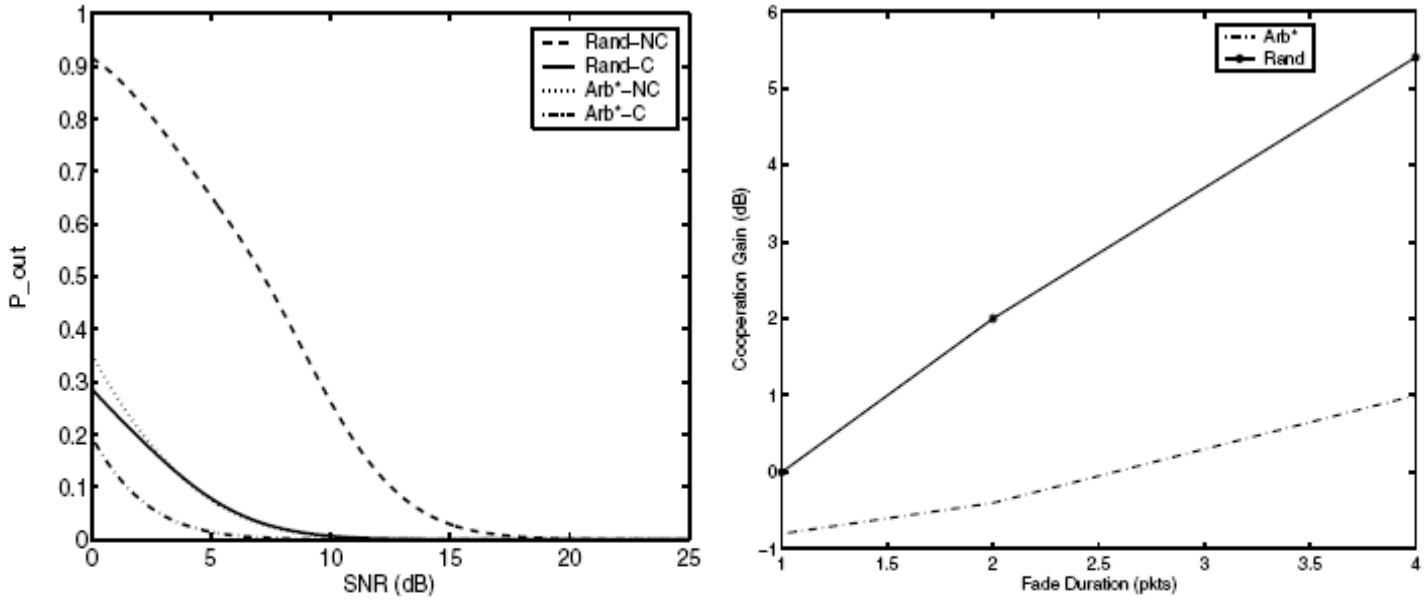


Fig. 2. Cooperation Gain

Properties

Lemma 1: $G_{c\_R} \geq G_{c\_A}$

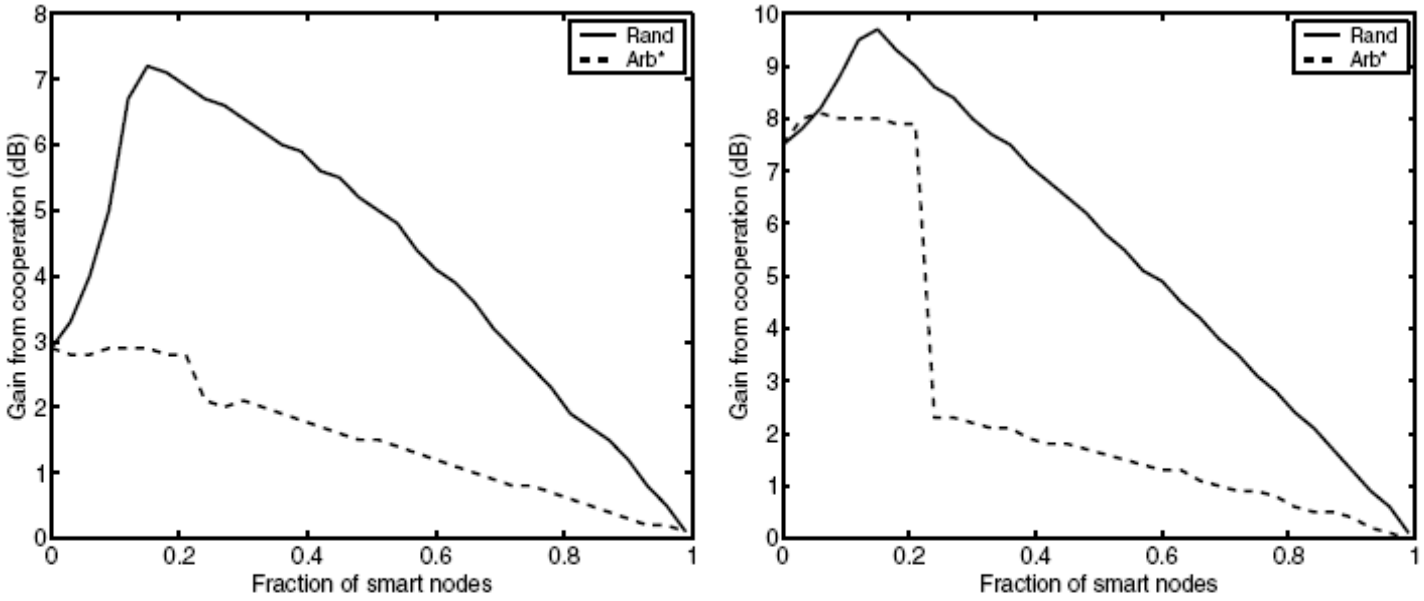


a) P_out: p=30, f=1 b) Gain: p=20, K=2

Fig. 3. Outage and Gain Results

Properties

Lemma 2: **G_{c_R} is a concave function in the (fractional) number of smart nodes in the network, $p_x \in (0,1]$.**



a) f=1 b) f=3

Fig. 4. Cooperation Gain Results

Adaptive Co-operation mechanism

- C_{ant} : basic cooperation which favors antenna gain
- C_{coop} :after experiencing a fading loss , switches to omni-directional mode to favor cooperation

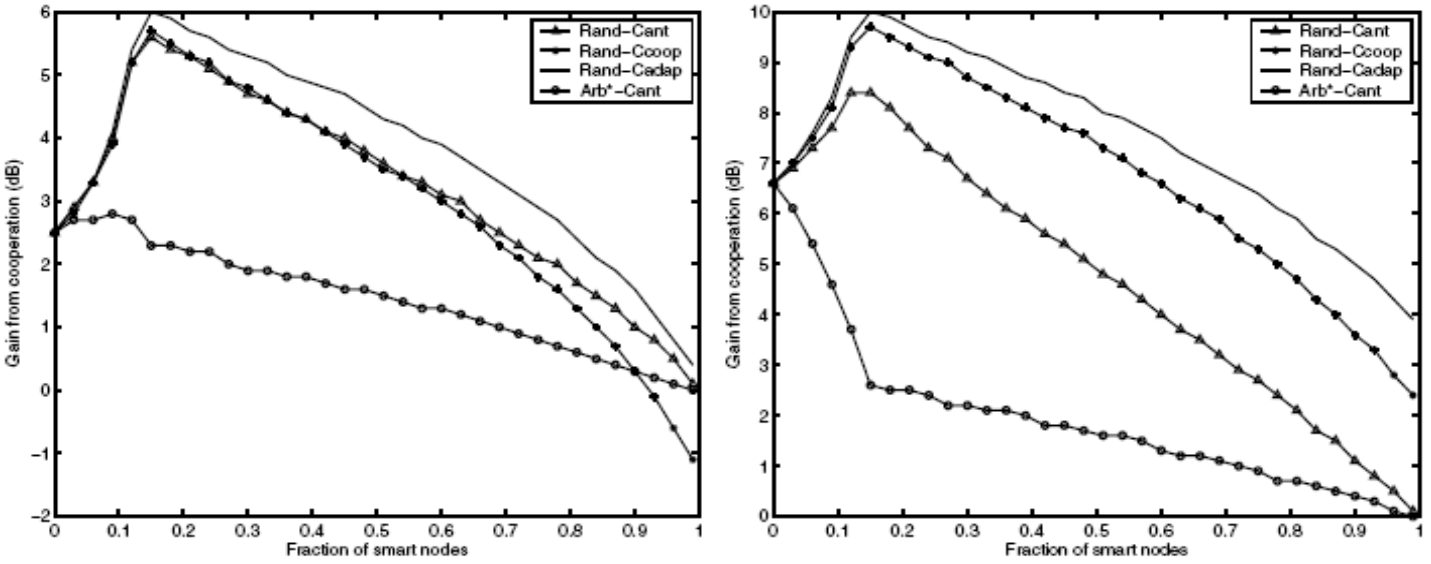
Lemma 3: When $p_x \to 1$,

$$G_{C_{ant}} \geq G_{C_{coop}}, \quad f = 1$$
$$G_{C_{coop}} \geq G_{C_{ant}}, \quad f = F$$

Mechanism C_{adap}

- If there are multiple neighbors, the one with the largest link gain will take part in the cooperation
- Transmitter reduces its rate to omni rate and starts exploiting the antenna gain for reliability from the second trial onwards
- If the transmitter is a smart node
  - Elements for rate switch to reliability
  - Switches to using three elements for reliability
  - omni-directional transmission

Proposition 1: If q_o and q_3 are probabilities of finding a relay in the case of an omni transmission and a spatially sensitive tranmission made with three elements respectively, then $\frac{1}{3} \leq \frac{q_3}{q_o} \leq 1$. [Proof in [9]]



c) Gain: f=1 d) Gain: f=3

Fig. 5. Performance of Different Strategies

The MACH protocol

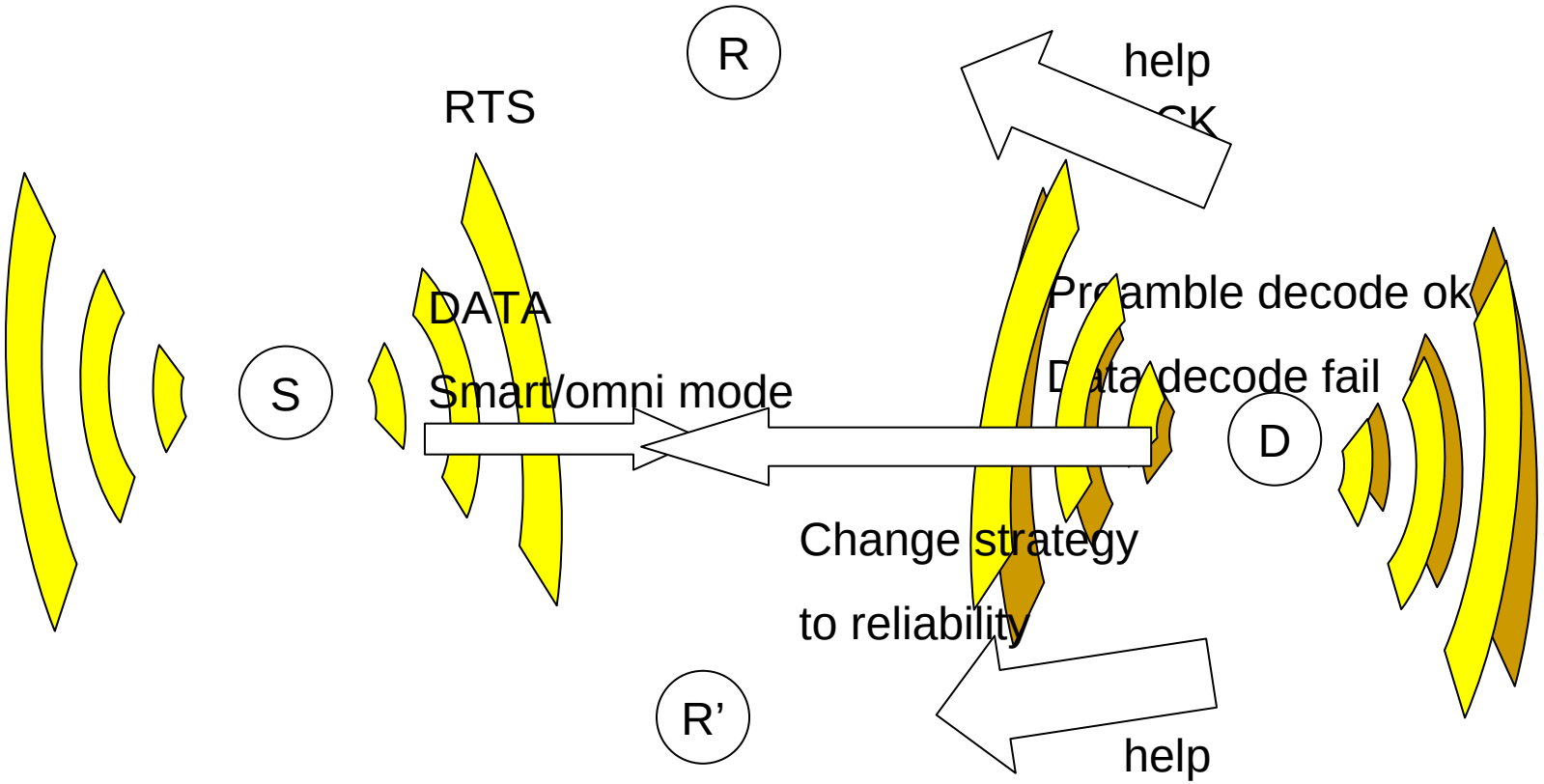
- Weighted proportional fairness model
- Distributed persistence algorithm

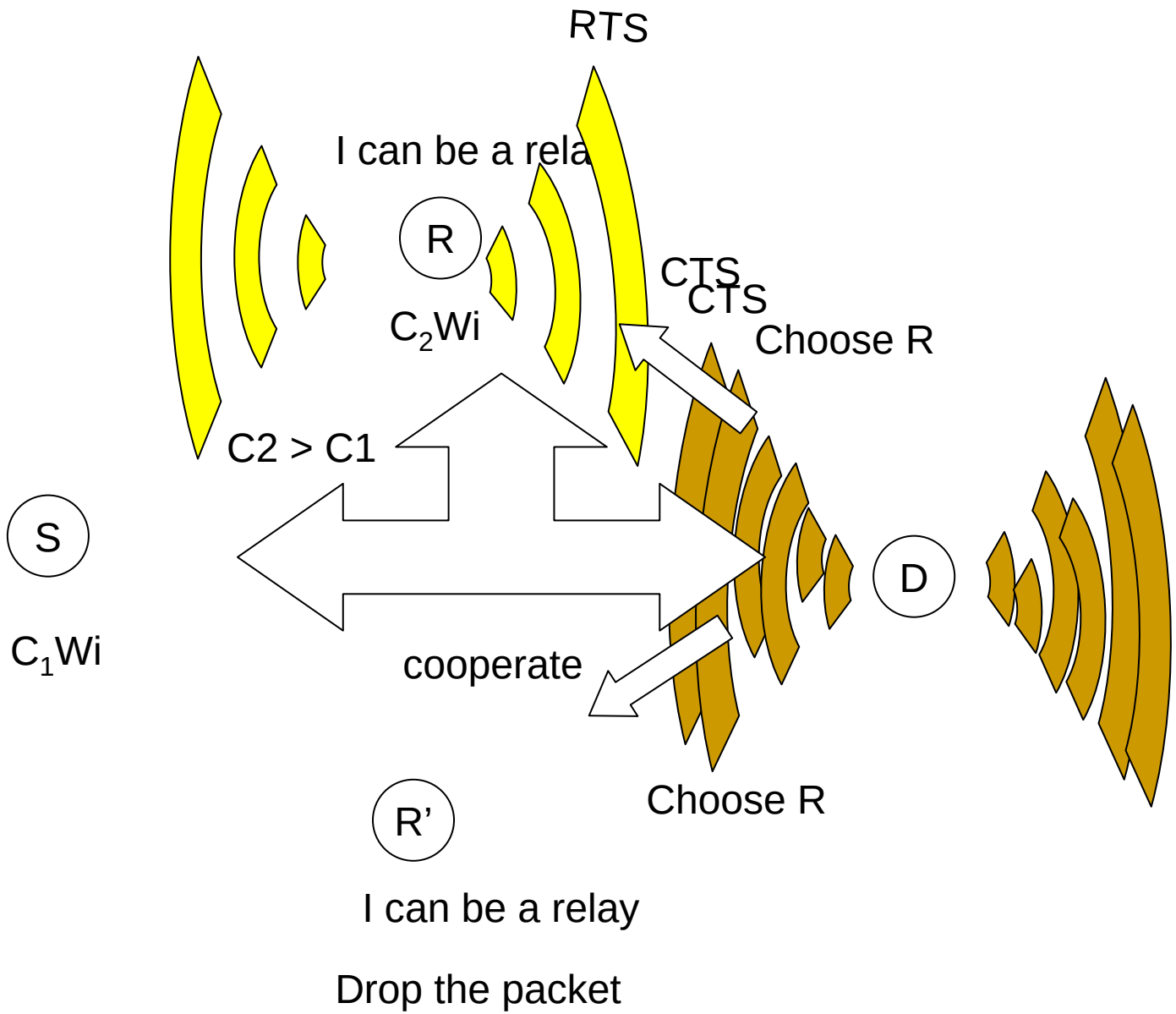
$$\dot{a}_i = \alpha w_i - \beta p_i a_i$$

- P_i :loss probability of the flow i
- W_i :the weight assigned to the flow (SNR gain)
- a_i: persistence probability
- α : utility constant
- β : penalty constant

Protocol details

- Fading loss detection
  - Source append a short preamble to the DATA packet
  - For identifying fading loss
  - High reliability
  - Low rate
  - Small size (avoid overhead)

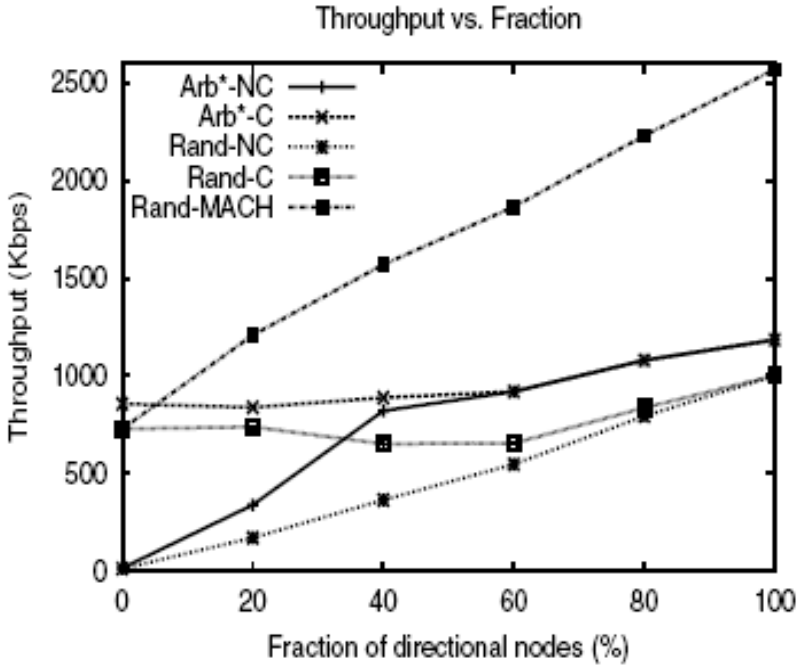

R
help
RTS
DATA
Preamble decode ok
Data decode fail
S
Smart/omni mode
D
Change strategy
to reliability
R'
help


RTS
I can be a rela
R
CTS
CTS
C_2Wi
Choose R
C2 > C1
S
D
C_1Wi
cooperate
Choose R
R'
I can be a relay
Drop the packet

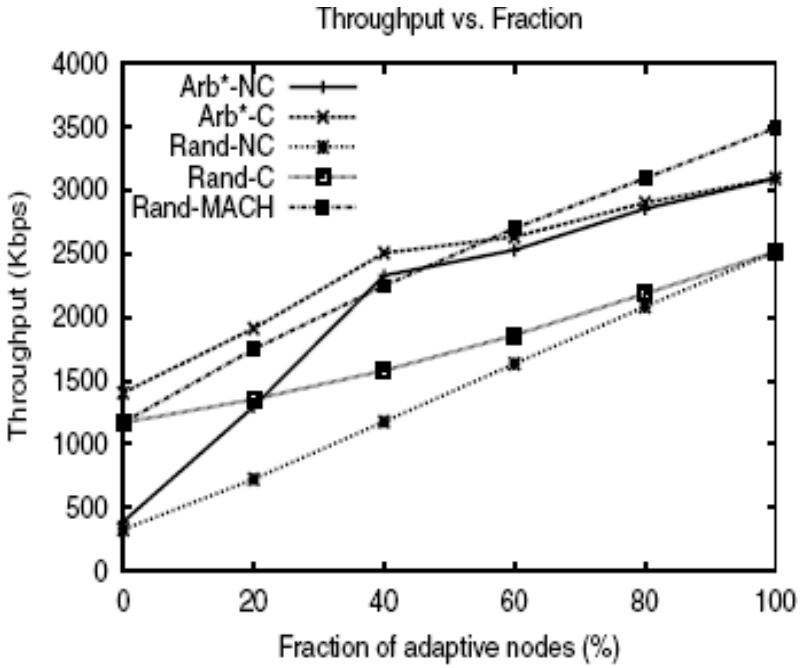
Performance evaluation

- Throughput

1000m *1000 m 100 node
UDP protocol
100 seconds
10 times

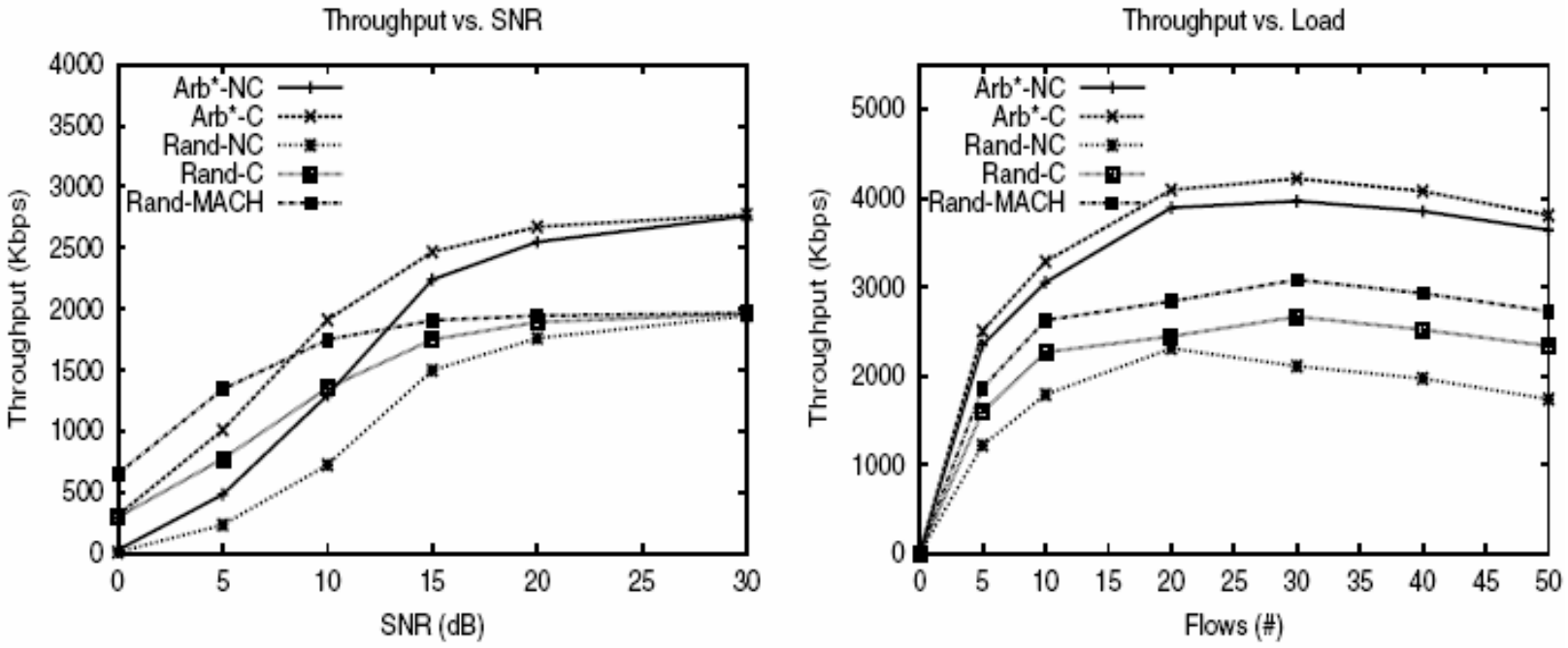


a) LOS: Fraction (x,4,5,30)



b) NLOS: Fraction (x,6,10,30)

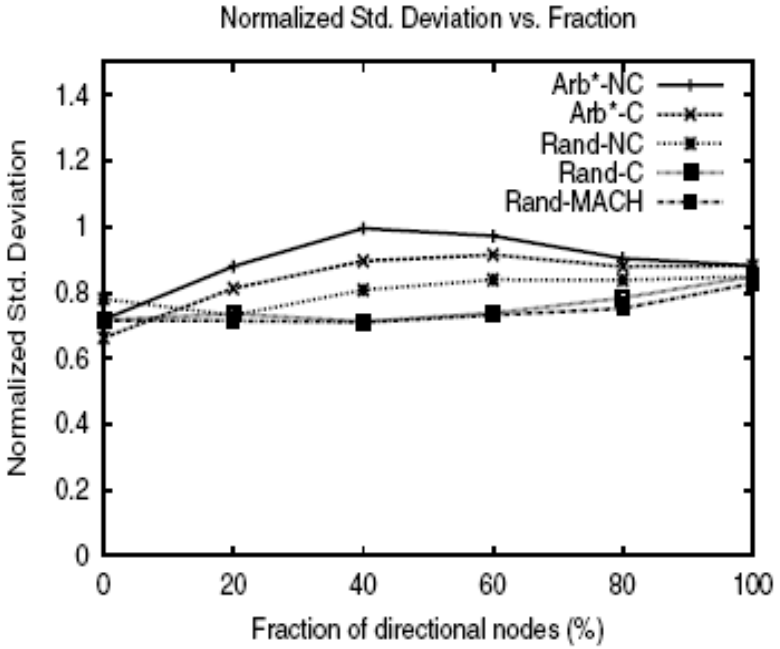
Throughput



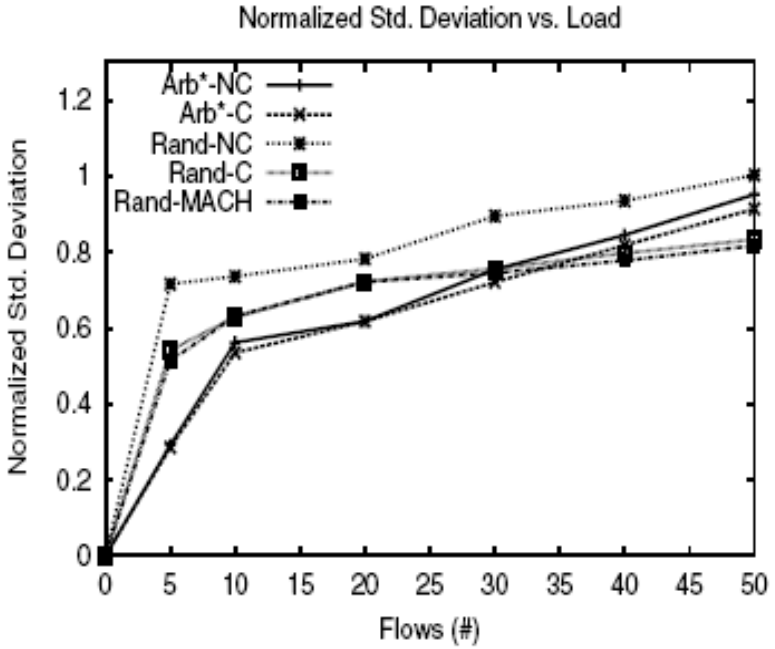
c) NLOS: SNR (20,6,x,30) d) LOS: Load (40,4,15,x)

Fig. 6. Throughput Results: (Fraction,Elements,T_SNR,Flows)

Fairness



c) LOS: Fraction (x,4,10,30)



d) NLOS: Load (40,4,10,x)

Conclusions

- We considered the problem of ad-hoc networks with heterogeneous antenna technologies
- The MACH protocol that incorporate the proposed cooperation mechanism makes the performance better