Peering in Infrastructure Ad hoc Networks

EE 228a Course Project

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Presentation Outline

- Introduction to the problem
- Objectives
- Problem Formulation
- Analysis of approaches
- Experimental Results
- Conclusions

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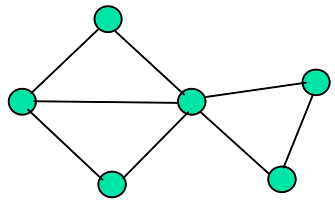
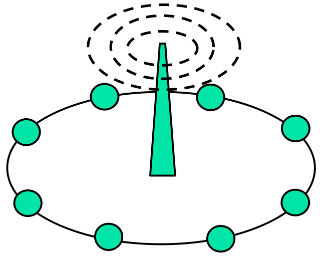
Ad hoc Networks : Current Modes of Operation

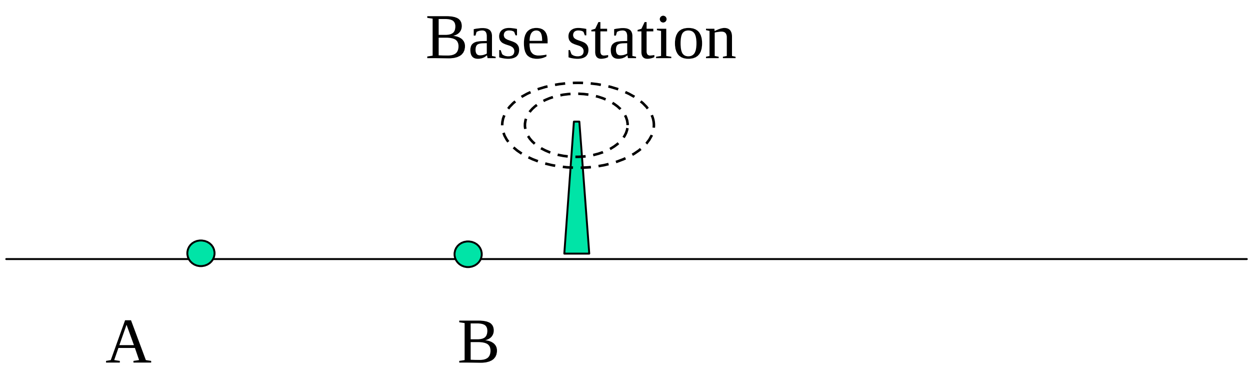
- Peer-to-Peer Mode
  - Nodes relay each other's traffic



- Infrastructure Mode
  - No relaying between nodes
  - Nodes directly communicate with Base Station

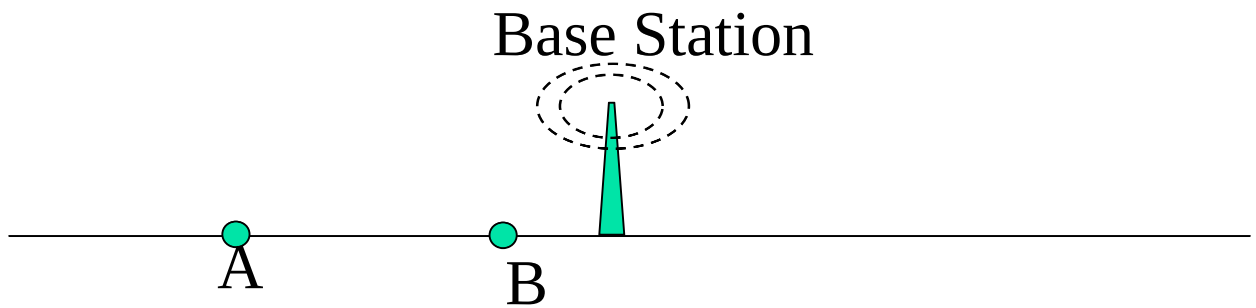


A Hybrid Approach



- Does Peering in Infrastructure Mode make sense?

Scenario : Reduced Power



- A and B both want to communicate with the base station.
- Using direct connections, A ends up using more power. With B agreeing to peer, A can reduce its power consumption while B can increase its throughput.

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Objectives

- Analyze the advantages of peering in infrastructure mode based on two approaches:
  - Individual User Centric: Each user tries to maximize its own performance
  - System Centric: Users collaborate to maximize overall system performance
- Show improvement in network performance with experimental results

Assumptions

- Base Station distributes tokens to each user in every cycle
- The number of tokens, *T*, distributed by BS in every cycle equals the no of transmission slots in each cycle
- A user can transmit in a slot only if it has a token
- Underline MAC layer resolves contention for slots

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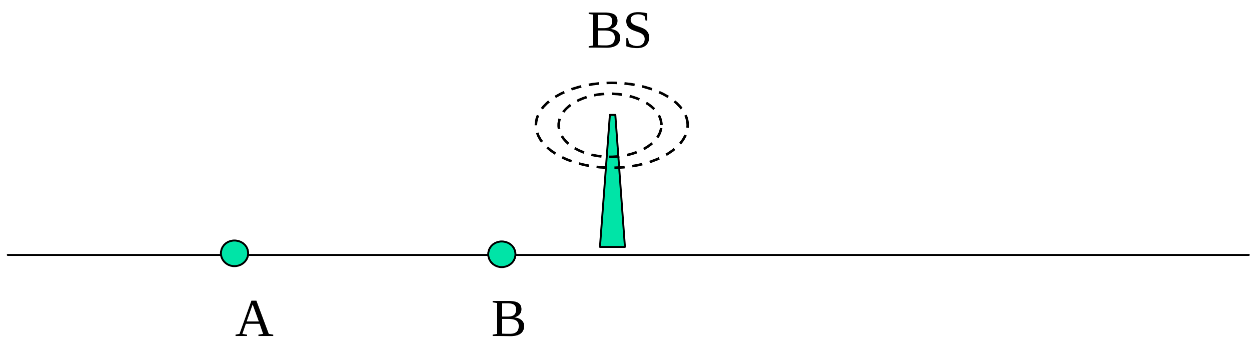
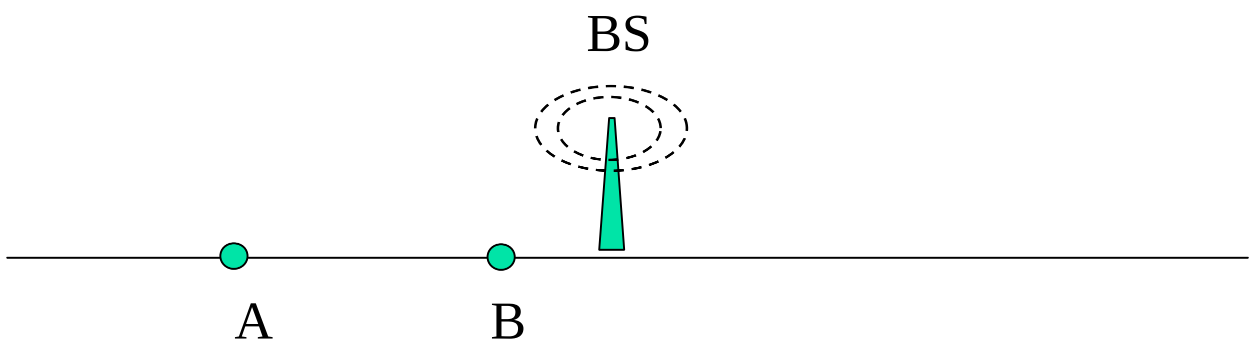
Problem Formulation



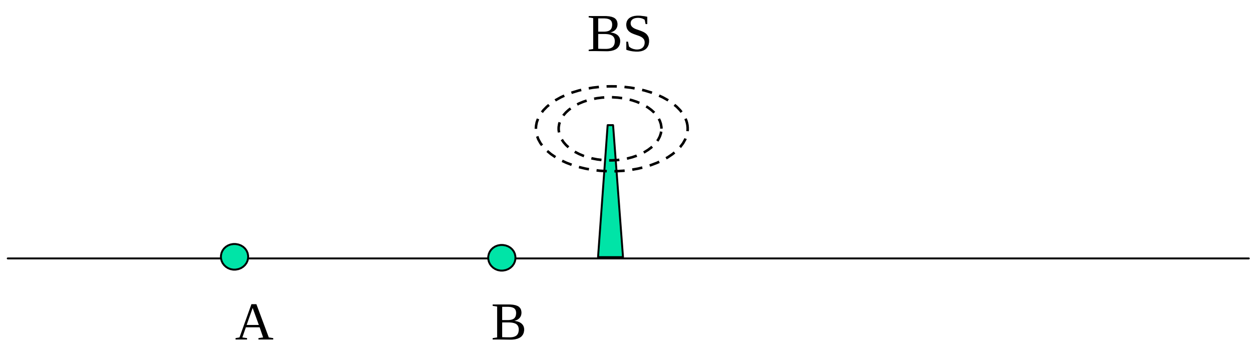
- Total tokens in system - T
- Node A has T_A tokens
- Node B has T_B tokens
- $T_A + T_B = T$
- Power level of transmission is same for each user, P_T

Problem Formulation (contd.)



- Data rate/slot for A→BS = $r_A \propto 1/(d_A)^\alpha$
- Data rate/slot for B→BS = $r_B \propto 1/(d_B)^\alpha$
- Data rate/slot for A→B = $r_{AB} \propto 1/(d_{AB})^\alpha$

No Peering (Relaying)



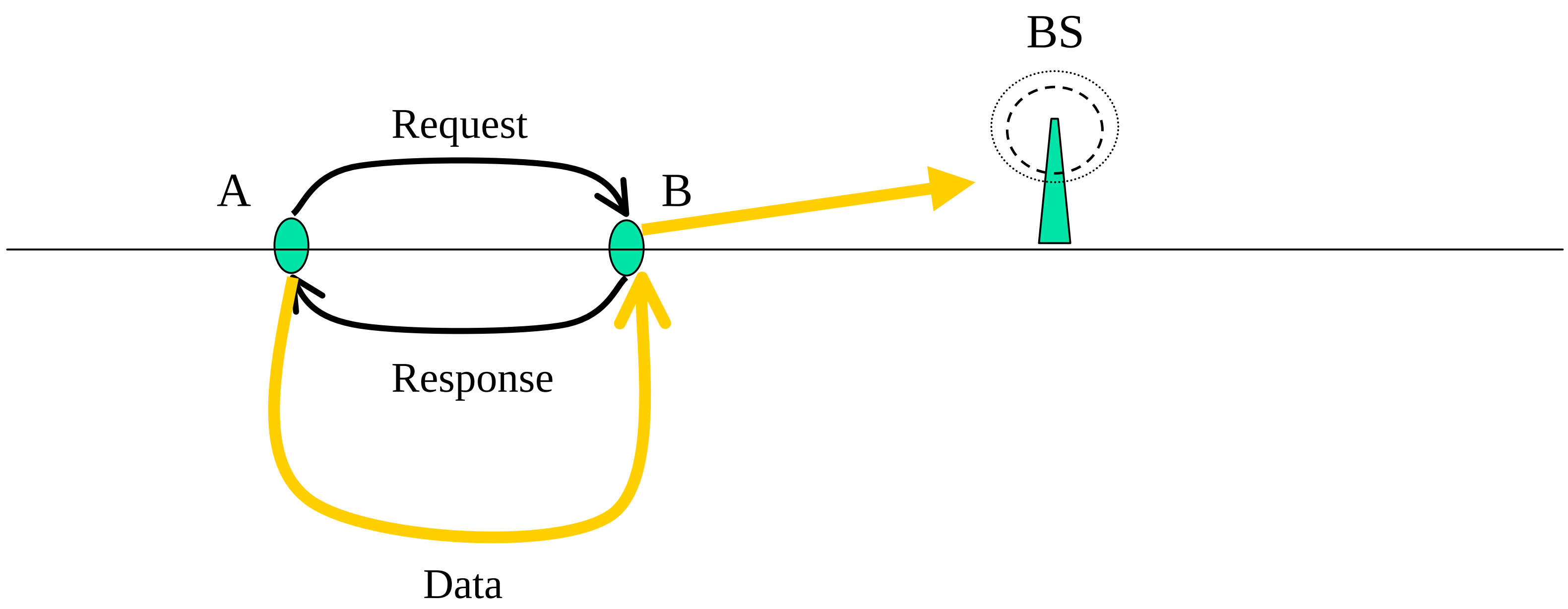
- Throughput of node A = $T_A.r_A$
- Throughput of node B = $T_B.r_B$
- Throughput of the whole system = τ = $T_A.r_A + T_B.r_B$
- Power consumption for above throughput = $(T_A + T_B)P_T$

Node B Relays Node A's traffic

- Node A sends a request to node B for relaying its data. Information of total data to be relayed is sent with this the request
- Node B analyzes the cost of relaying (in terms of power spent and throughput gained) and sends a response to node A asking for the no of tokens it wants in lieu of relaying
- Node A analyzes this response and decides to relay its traffic through node B if it can meet node B's demand

Assumption: Protocol setup time is negligible

Node B relays Node A’s traffic



Problem formulation (contd.)

- Throughput of node A = $T_{AB}.r_{AB} = T_A.r_A$
- No of tokens available for distribution = $T_A - T_{AB}$

  where $T_{AB} = T_A(d_{AB}/d_A)^{\alpha}$

- Throughput of node B = $(T_B+T_{B'}).r_B$

  where $T_{B'}$ is the minimum no of tokens gained by node B to justify the relay i.e. to satisfy its utility function

Problem formulation (contd.)

- No of tokens saved in the system = $T_A - (T_{AB} + T_{B'} + T_{B''})$

  where $T_{B''}$ is the no of tokens needed by node B to transmit node A's data i.e. $T_{B''} = (T_{AB}.r_{AB})/r_B$

- Power spent by the system for same throughput as in the case of no relay = $(T_{AB} + T_B + T_{B''})P_T$

Token Distribution Strategies

- Equal tokens
  - Both nodes get half of the total tokens
  - $T_A = T_B = T/2$
  - [Not Fair]
- Equal Bandwidth
  - Both nodes get equal throughput
  - $T_A.r_A = T_B.r_B \rightarrow T_A/T_B = (d_A/d_B)^{\alpha}$
  - [Doesn't optimize overall system throughput]

Token Distribution Strategies ...

- Equal normalized rate of change in throughput w.r.t. no of tokens

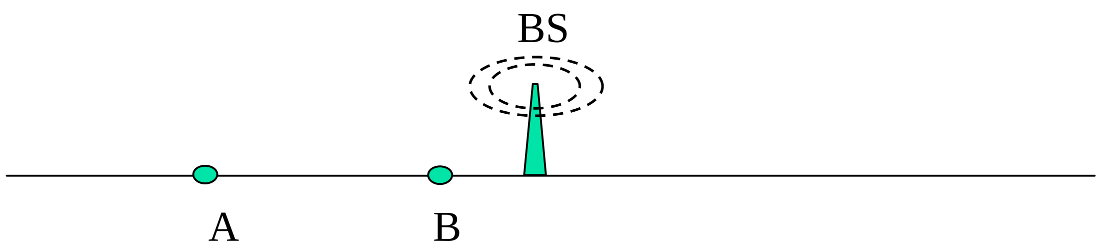
Throughput of node A = $T_A.r_A \propto T_A/(d_A)^\alpha$

➔ $d(T_A.r_A)/d(T_A) \propto 1/(d_A)^\alpha$

Similarly, $d(T_B.r_B)/d(T_B) \propto 1/(d_B)^\alpha$

$[d(T_A.r_A)/d(T_A)]/T_A = [d(T_B.r_B)/d(T_B)]/T_B$

➔ $T_A/T_B = (d_B/d_A)^\alpha$



[Optimizes overall system throughput and seems fair]

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User Centric Approach

- In this system, each user tries to improve its own performance i.e. it doesn't relay any data for social cause, it relays only to improve its own performance

- We define the utility function of relaying node as:

  $$U(T, P) = T[1 + C(\log P)/P]$$

  where T and P are the no of tokens and battery power of relaying node (available for itself) respectively

- Captures the token gain and energy payoff of relaying node very well

User Centric Approach (contd.)

- Value of utility function of node B before relaying is:

  $$U(T_B , P_B) = T_B[1 + C(\log P_B)/P_B]$$

- If $T_{B'}$ is the no of tokens gained by relaying the data and $P_{B'}$ is its new residual power , then new value of node B's utility function is:

  $$U((T_B+T_{B'}), P_{B'}) = (T_B + T_{B'})[1 + C(\log P_{B'})/P_{B'}]$$

  where $P_{B'} = P_B – (P_T.T_{B''})$ and $T_{B''} = T_{AB}.r_{AB}/r_B$

User Centric Approach (contd.)

Since relaying node wants to maximize its performance, its utility value shouldn't decrease after relaying the date i.e. :

$U((T_B+T_{B'}), P_{B'}) - U(T_B, P_B) > 0$

➔ $T_{B'} > T_B C\, [(\log P_B/P_{B'})/ P_B]$

$T_B C\, [(\log P_B/P_{B'})/ P_B]$ is the minimum no of tokens needed by node B for its own usage in order to justify relaying node A's data.

System Centric Approach

- The users in this system try to enhance the overall system performance rather than their own.
- A user relays the traffic from another node if the ratio of residual battery power of relay node and source node is greater than the ratio of energy spent per bit by the relay node and the source node for transmission i.e. :

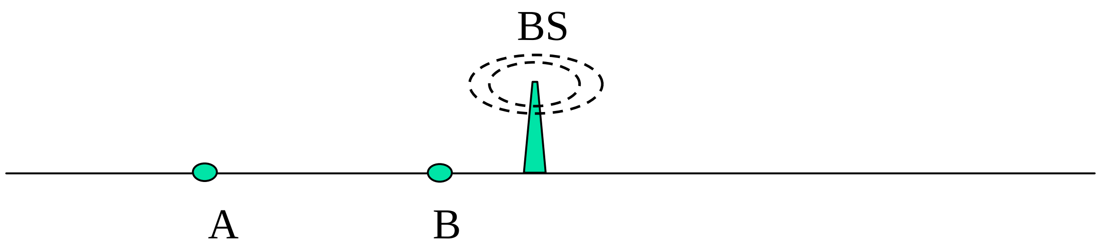
$$\frac{P_{Relay}}{P_{Direct}} > \frac{E_{Relay}}{E_{Direct}}$$

where E_{Direct} and E_{Relay} are the energies spent by source node and relay node to transmit one bit to the Base Station

System Centric Approach (contd.)

- In our 2-node case,

$$\frac{E_B}{E_A} = \left(\frac{d_B}{d_A}\right)^{\alpha}$$



- Hence, node B will relay node A's data if,

$$\frac{P_B}{P_A} > \left(\frac{d_B}{d_A}\right)^{\alpha}$$

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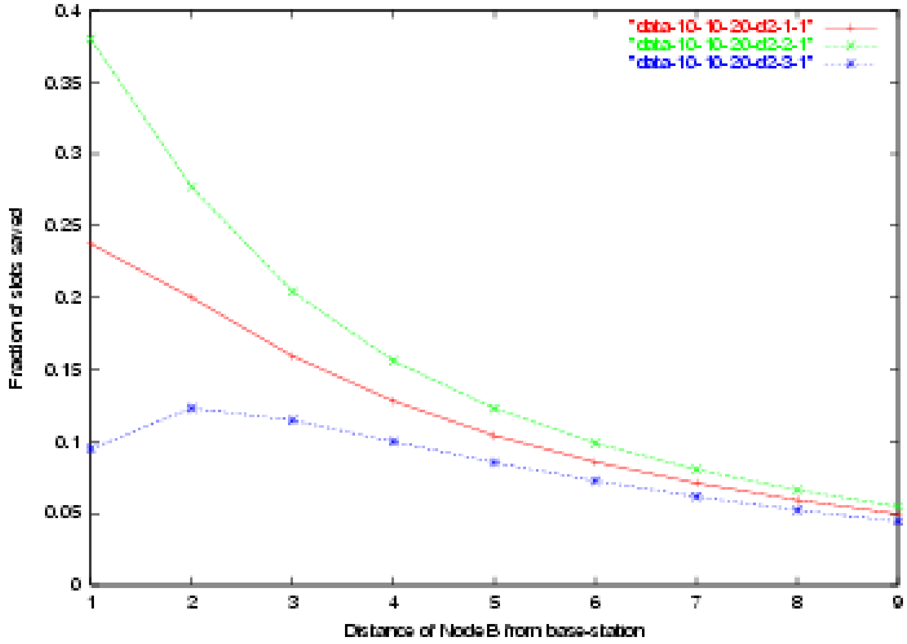
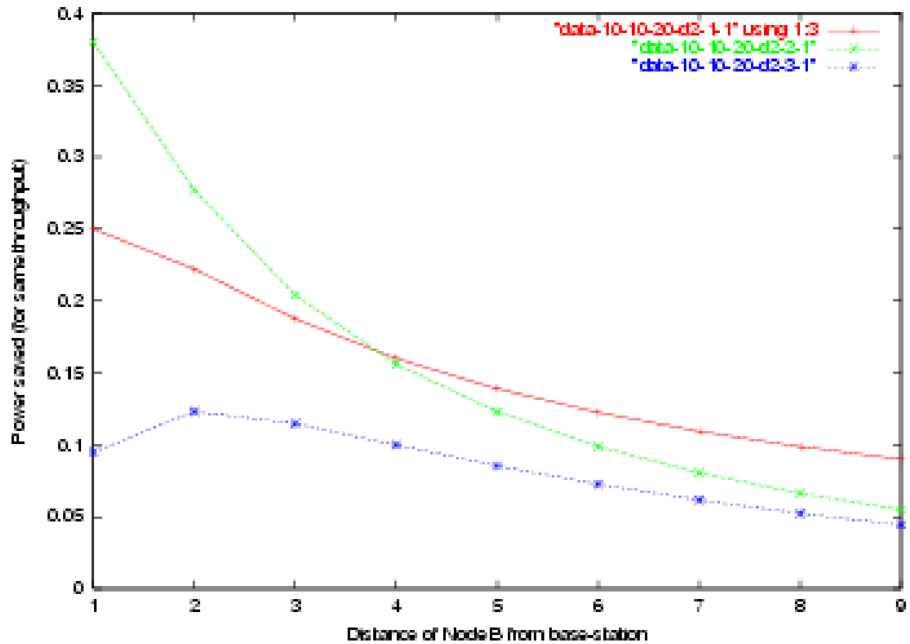
Experimental Results



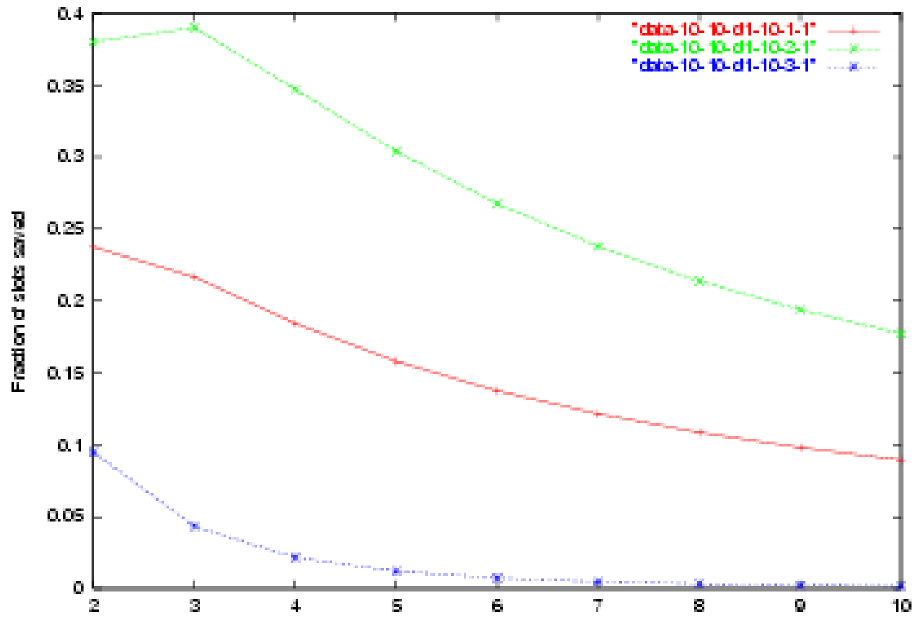
Approach 1: Varying position of node B, power of B fixed

Experimental Results



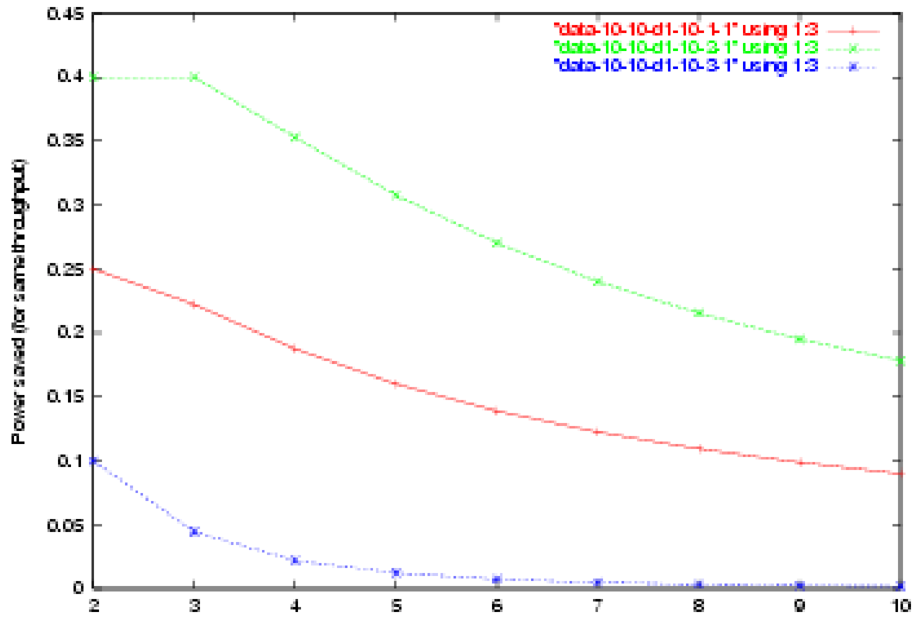
Approach 1: Varying position of node B, power at B fixed

Experimental Results



Approach 1: Varying position of node A, power at B fixed

Experimental Results



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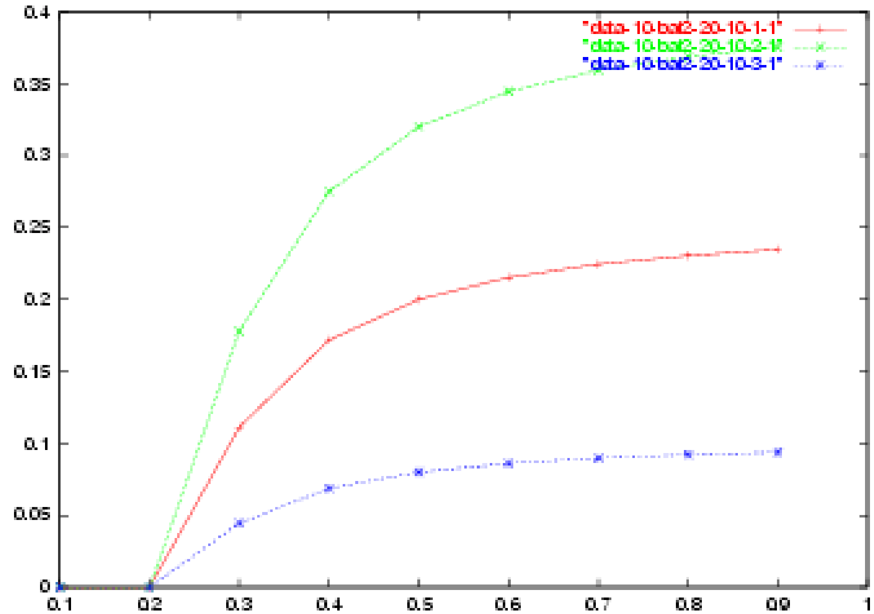
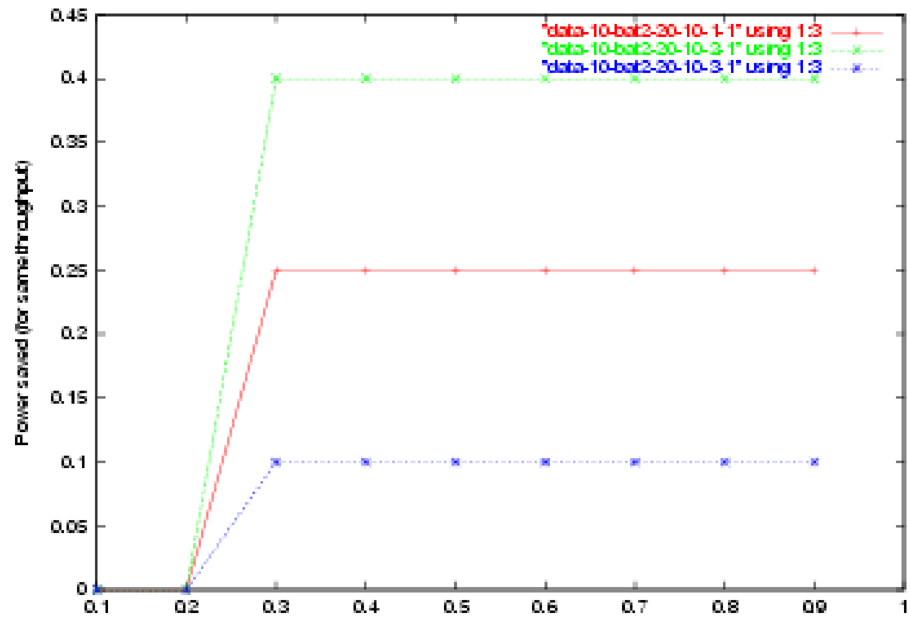


Fraction of slots saved Vs power at node B

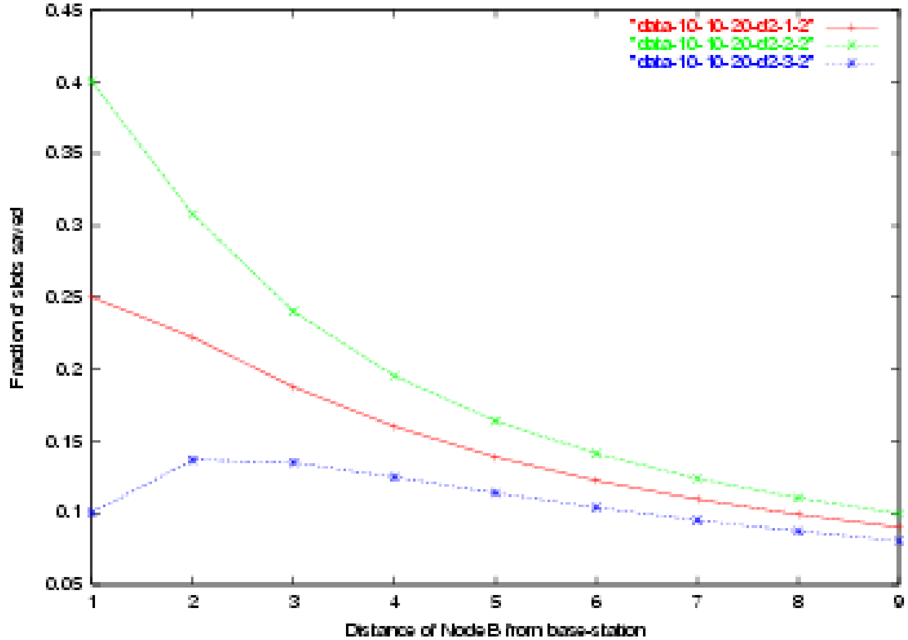
Approach 1: Varying Power at node B, positions of A & B fixed

Experimental Results



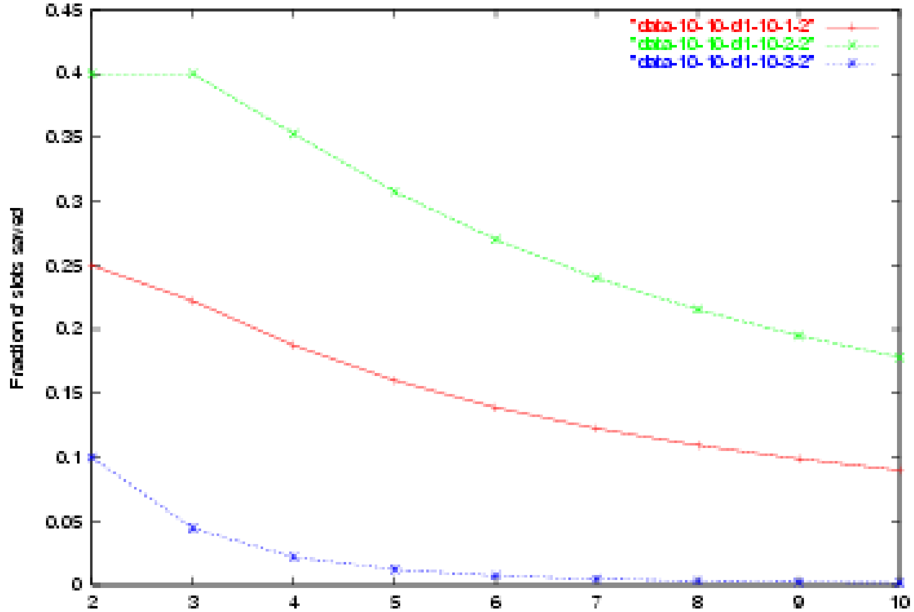
Approach 1: Varying Power at node B, positions of A & B fixed

Experimental Results



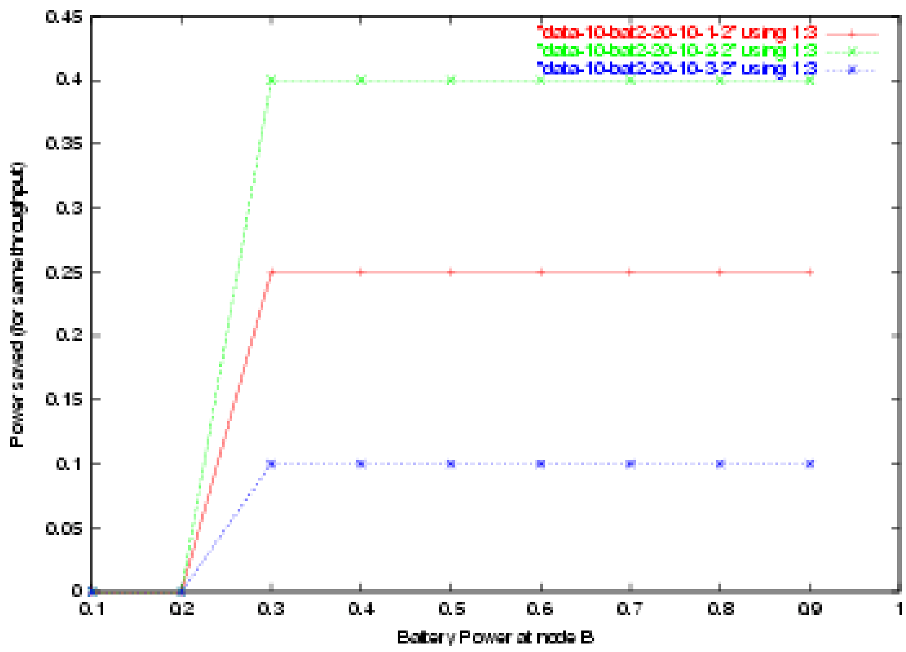
Approach 2: Varying position of node B, power at A & B fixed

Experimental Results



Approach 2: Varying position of node A, power at A & B fixed

Experimental Results



Approach 2: Varying Power at node B, positions of A & B and power at A fixed

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Conclusions

- Relaying can reduce power consumption in the system, increase throughput of the system or do both
- The amount of improvement achieved depends on the token distribution strategy and the topology of the system and battery power of constituents

Future Work

- Extend the analysis and experiments for N nodes
- Fine tune the model
- Analyze the system with different fairness notions

References

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THANK YOU !