Dynamic Rate-Selection for Extending the Lifetime of Energy-Constrained Networks

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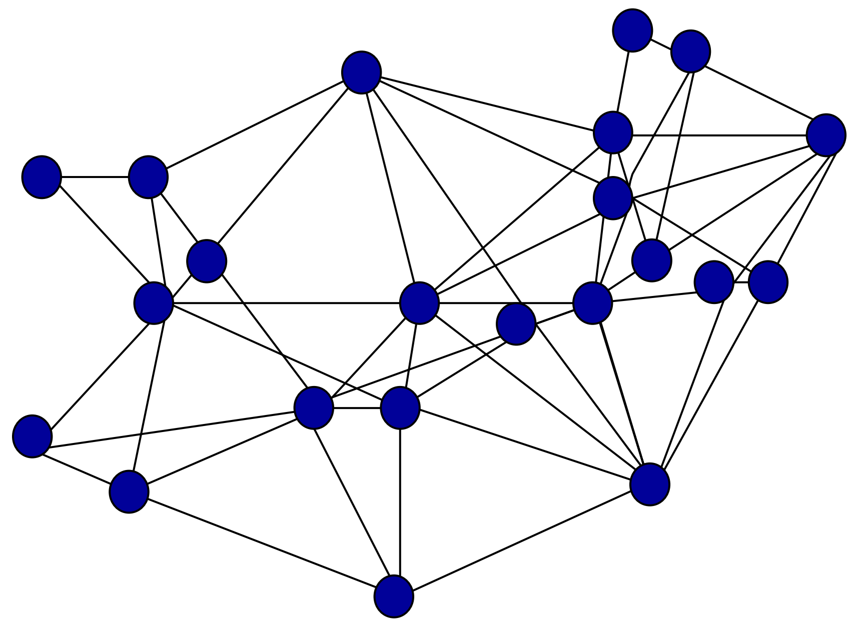
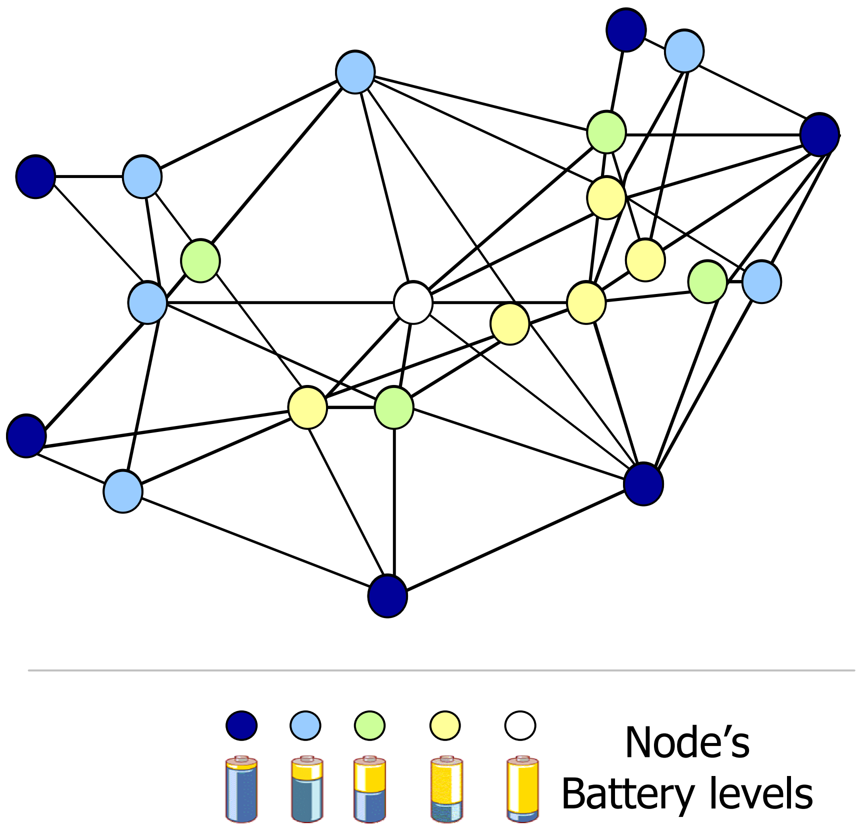
Introduction

- Energy constraints in ad-hoc and sensor networks



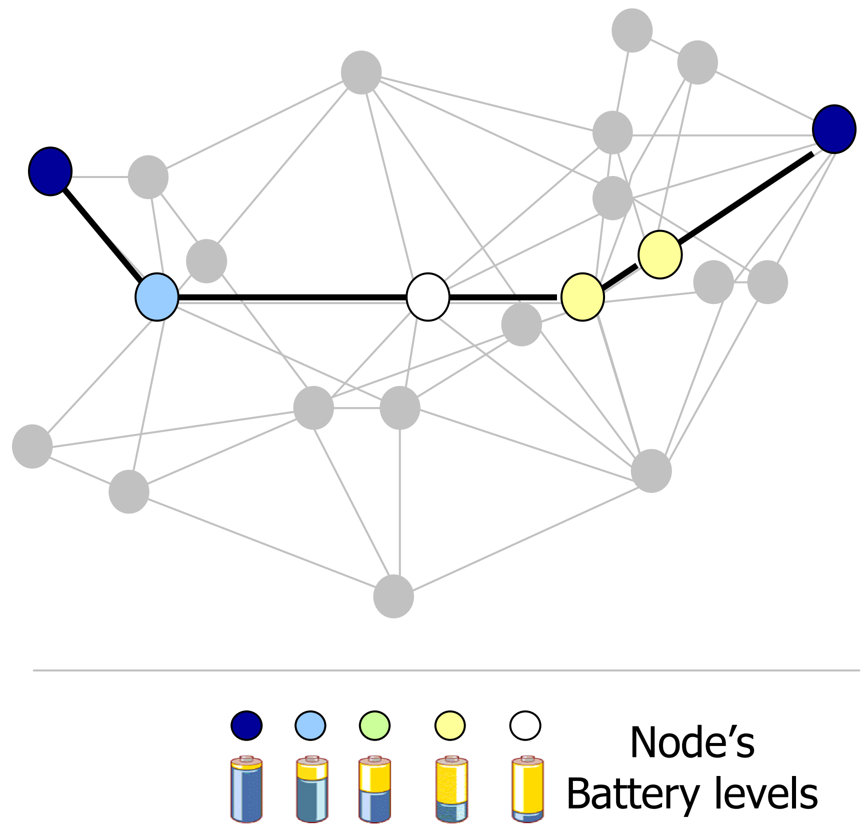
Introduction

- Energy constraints in ad-hoc and sensor networks
- Different traffic-load for different flows varies the battery level at each node.



Introduction

- Energy constraints in ad-hoc and sensor networks
- Different traffic-load for different flows varies the battery level at each node.
- Within the same flow, nodes with low battery exerts more relative energy.



Connection-Flow Lifetime

Problem: extend the lifetime of flows (networks)

Cause of problem: nodes with low battery level deplete faster than other nodes causing path disconnection.

Solution: explore the tradeoff between transmission energy and transmission rate; the rate computed is based on the energy level of the node.

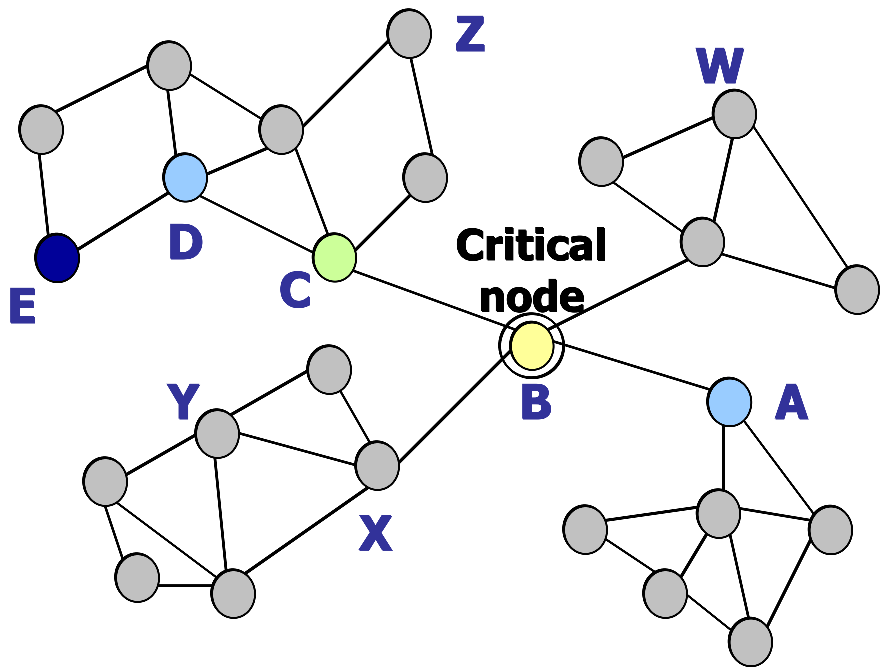
Example

For flow A-E:

- All nodes transmit with highest energy→
B dies after <u>12739</u> packets

- Node B transmits with ½ the power of others →
B dies after <u>59378</u> packets

5x Lifetime improvement for flow A-E



Models

- Each flow has:
  - total propagation time T_{tot}
  - other estimated delays d_{other}
    - ex: interference, collision
  - delivery time constraints for its packets D

$$D \geq T_{tot} + d_{other}$$

- A path is disconnected when any of its nodes fail → *flow lifetime*
- Minimal processing in nodes

Energy Models

In QAM model: $$P = (C \cdot R_s (2^b - 1) + F \cdot R_s)$$

$$t_{bit} = 1/R = 1/R_s b$$

Where:

R_S is the symbol rate, b is the bits per symbol

C and F are quality of transmission and electronic circuitry constants

$$E_{bit} = P \cdot t_{bit}$$

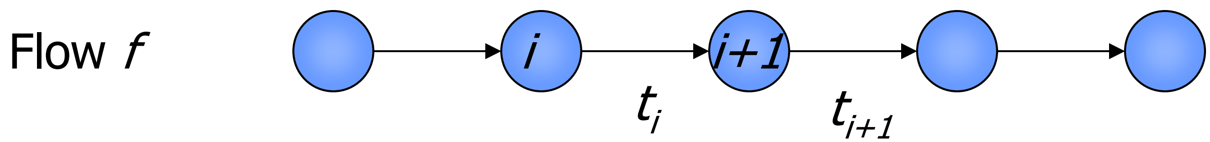
$$= (C(2^b - 1) + F)\frac{1}{b}$$

b is typically even integer value

$$E_{bit} \;\alpha\; R$$

Dynamic Rate Selection

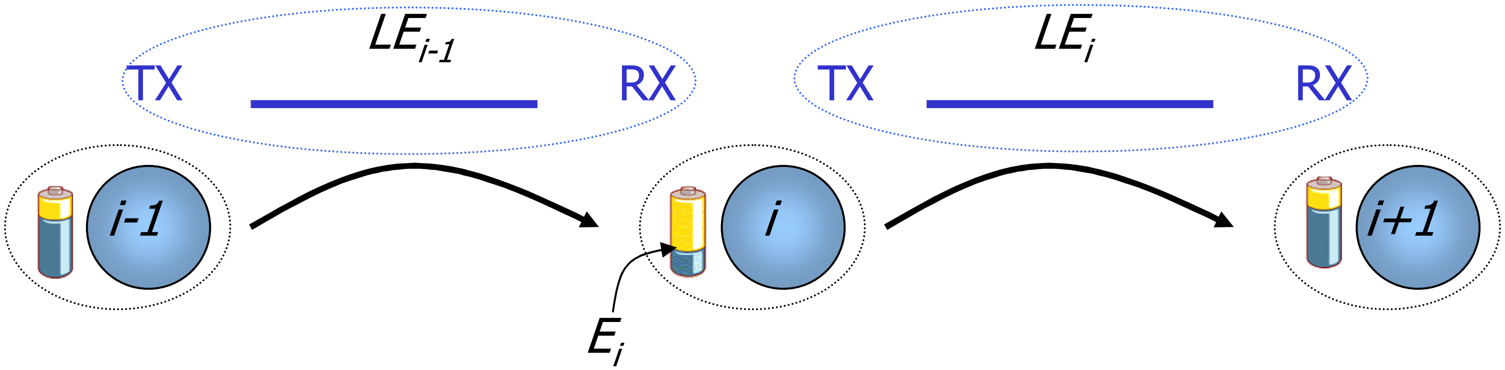
Find R_i for each node $i \in$ flow f s.t. packets in f meet time constraint $\sum t_i \le T_{tot}$



Steps:

- Compute Energy Budget
- Rate computation & discretization
- Communicating the rate values

Energy Budget Modeling



$$LE_i = \omega_{tx} E_i + \omega_{rx} E_{i+1}$$

$$\omega_{tx} = \frac{P_{tx}}{P_{tx} + P_{rx}} \qquad \omega_{rx} = \frac{P_{rx}}{P_{tx} + P_{rx}}$$

Rate Selection

Allocate t_i according to LE_i

$$t_i = T_{tot} \frac{1/LE_i}{\sum_{k=0}^{n-2} 1/LE_k}$$

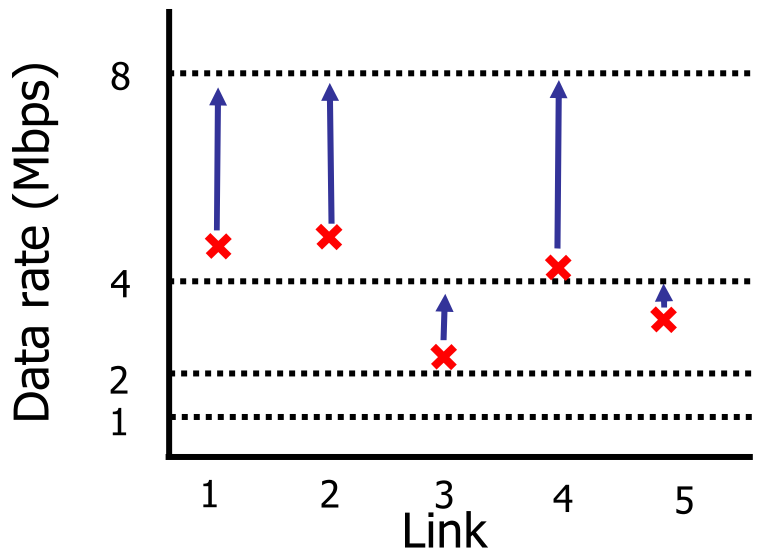
To avoid buffer overflow :

$$R_i = \max\left\{ \frac{t_{\max}}{t_i} R_{\max}, R_{src} \right\}$$

Discrete Rate Setting

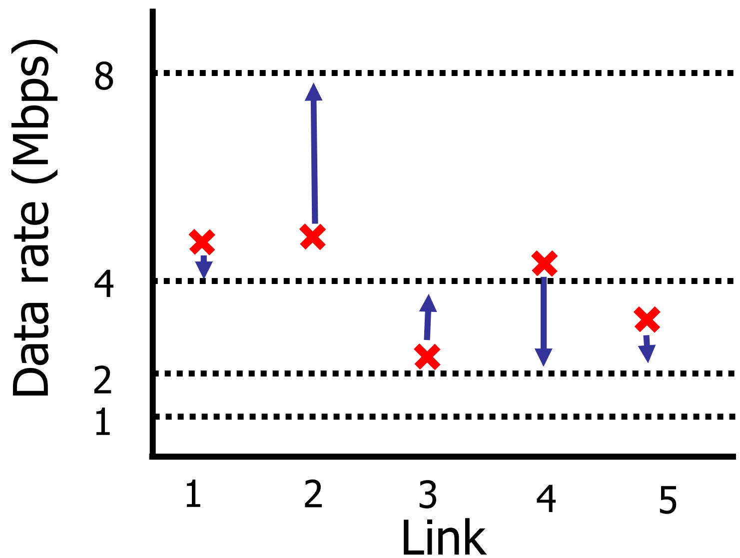
Simple scheme:

Round rate to the next highest discrete rate.



Iterative scheme:

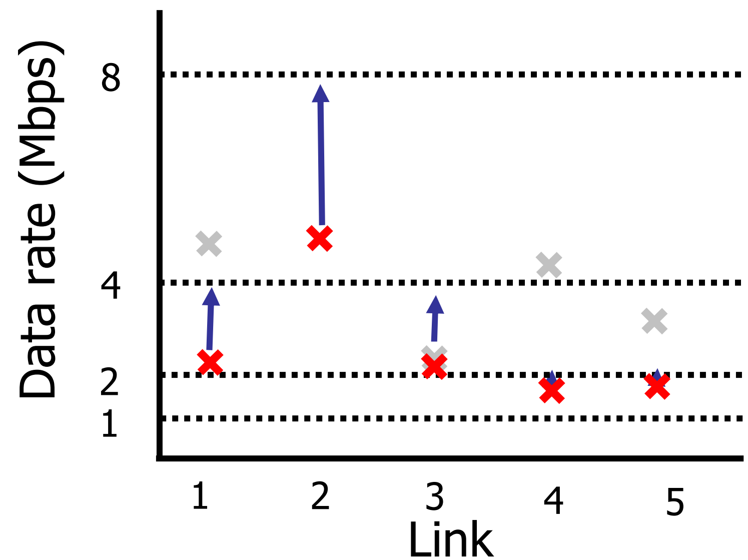
Exploit the slack time from other node's discretized nodes.



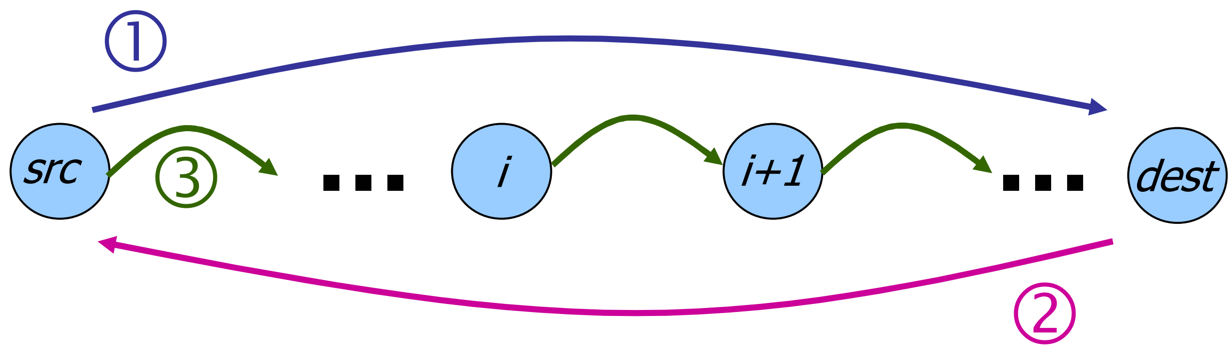
Iterative Rate Discretization

Simple Heuristic

1. Iteratively select the highest link energy
2. Round the rate
3. Recompute available T_{tot}
4. Repeat from 1



Rate Notification



step	Original protocol	Added support
①	DSR route discovery	Collect battery level
②	Return of discovered route	Notify src node
③	Packet transmission	Notify nodes with rates in packet's header

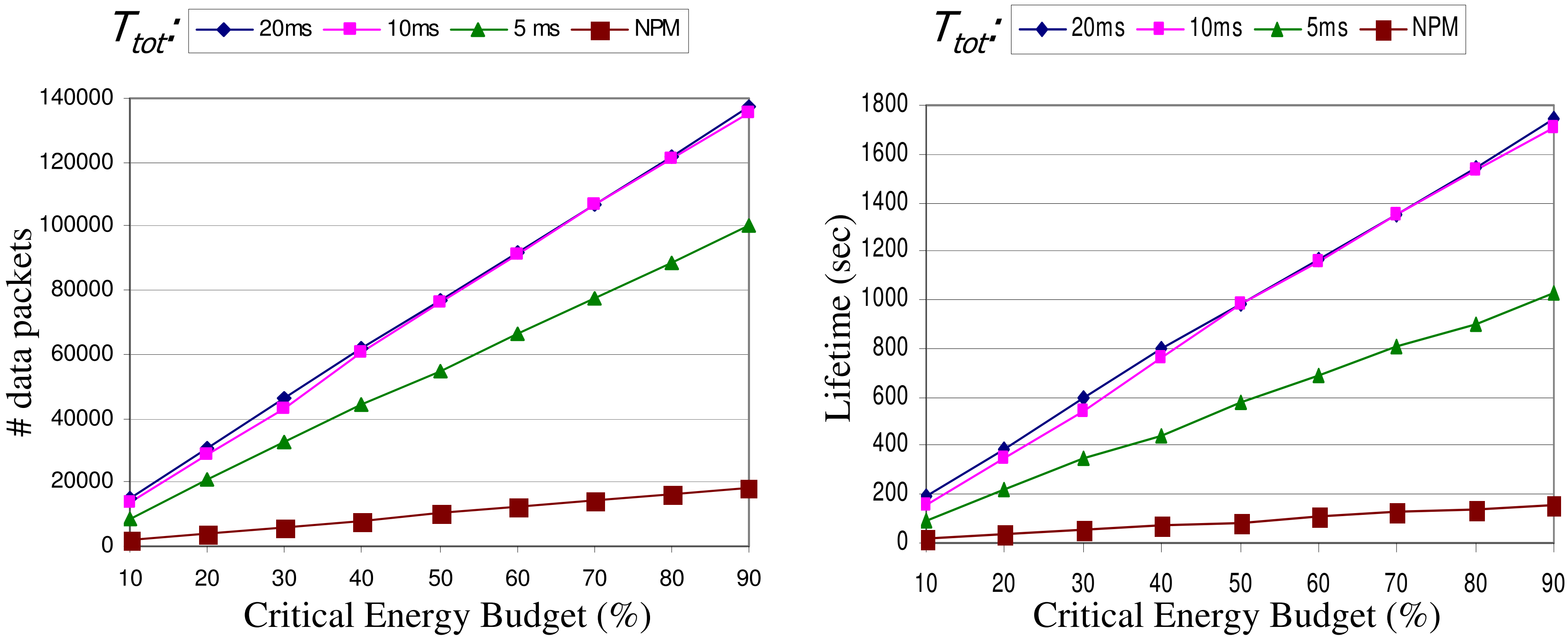
Evaluation Setup

- Trace driven ns-2 simulation
- UDP traffic
- Discrete Rates 2, 4, 6 & 8 Mbps
- Single path (5 nodes) & single critical node
- Control packet transmitted at 2Mbps

Lifetime Extension Evaluation

- Study the effect of
  - Varying the traffic load
  - Different discretization schemes
- Compared schemes:
  - Dynamic rate selection (DRS)
  - No power management (NPM)
  - Static rate selection (Static)

Varying the Traffic Load

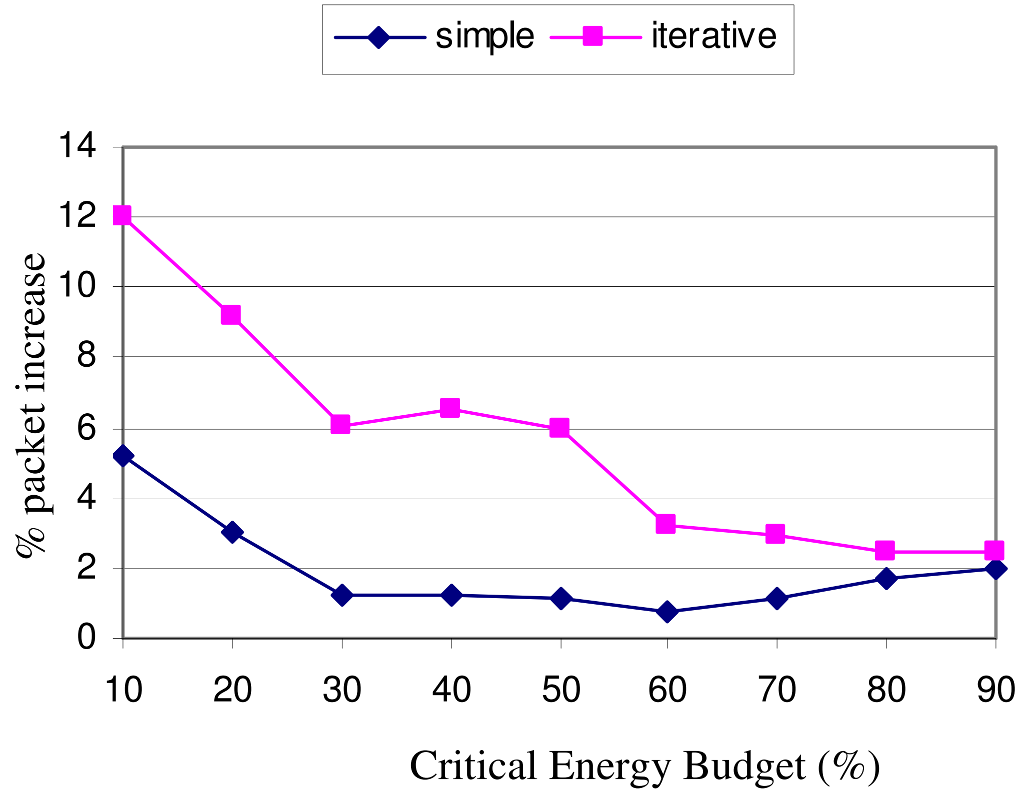


Large T_{tot} 7.5X improvement in # of data packets

Effect of different Rate Discretization

Normalized to Static rate selection,

More savings for low energy budgets



Conclusions

- Dynamically varying the TX rate for each node increases the number of packets delivered
  - by 7.5x (over NPM and for high T_{tot})
  - By up to 12% over Static data rate
- DRS requires minimal modifications and has relatively low overheads

Future Work

- Apply DRS for multiple connection flows→ fair resource allocation
- Integrating DRS on top of power aware routing