An Energy Consumption Model for Performance Analysis of Routing Protocols for Mobile Ad Hoc Networks

Laura Marie Feeney
Swedish Institute of Computer Science
lmfeeney@sics.se

Overview

- energy consumption treated as synonymous with bandwidth
- need energy-consumption model compatible with packet-level, mobility-oriented simulations
- small modifications to CMU's ns-2, plus extensive post-processing
- performance analysis of DSR and AODV
- nothing earth-shattering, but a few interesting observations

Power

- synonymous with bandwidth -- NOT!
  - non-renewable
  - cost at both sender and receiver
  - cost to discard
  - cost to drop

- protocol issues
  - large vs small packets
  - broadcast vs point-to-point
  - distribution

Energy consumption model

- must be abstract enough to evaluate from a high-level perspective
  - realistic traffic and mobility scenarios
- must be detailed enough to allow meaningful comparison of energy consumption
- must provide insight into how protocol behavior affects energy consumption
- biased toward CSMA/CA and IEEE 802.11

Energy consumption model

- Basic model:
  - $Cost = m \times size + b$
  - fixed cost - acquire channel
  - incremental cost - proportional to size
  - define sender s and nodes $n \in S$ in range of s
  - define dest d and nodes $n \in D$ in range of d
- Assumes:
  - same operation always has same cost

Energy consumption - broadcast

- 802.11: no negotiation

- send
  - $Cost = m_{send} \times size + b_{send}$

- receive
  - $Cost = \sum_{n \in S} (m_{recv} \times size + b_{recv})$

Energy consumption - p2p send

- incremental cost same as broadcast
- fixed cost also accounts for MAC control negotiation (802.11 RTS/CTS/data/ACK)
- send
  - $Cost = m_{send} \times size + b_{send} + b_{ctl}$
  - $Cost = m_{send} \times size + b_{send} + 3 \times b_{send-ctl}$

Energy consumption - p2p recv

- receive - $Cost = m_{recv} \times size + b_{recv} + b_{ctl}$
  - destination $Cost = m_{recv} \times size + b_{recv} + 3 \times b_{recv-ctl}$
  - non-destination - recv data traffic

    $$\sum_{n_{promisc} \in S} (m_{recv} \times size + b_{recv})$$

  - non-destination - discard data traffic

    $$\sum_{n_{non-promisc} \in S} (m_{discard} \times size + b_{discard})$$

  - non-destination - discard control traffic

    $$\sum_{\in S} (1 \times b_{discard-ctl}) + \sum_{n \in D} (2 \times b_{discard-ctl})$$

Energy consumption - drop

- drop at IFQ is essentially free
- drop due to collision is hard to calculate precisely; assume cost to receive $Cost = m_{recv} \times size + b_{recv}$
- drop for device overflow is same as cost to receive $Cost = m_{recv} \times size + b_{recv}$

Values for *m* and *b*

- power consumption of network interfaces (Gauthier, Harada, Stemm - MoMuC '96)

WaveLAN I (2.4 GHz)

	send	**recv**
m	.000405	.000157
b	.067594	.037701
sleep (mW)	177.328	
idle (mW)	1318.86	

- use an oscilloscope to measure current to NI while packets are being sent and received, calculate *m, b* using linear model

Simulation

- minor modifications to tracing facility of CMU ns-2
- reproduced subset of CMU experiments
- extensive post-processing on logs to calculate energy consumption based on model
- assume
  - $Cost_{discard} = 0.02 \times Cost_{recv}$
  - $Cost_{ctl} = 0.5 \times b_{ctl}$

Observations

- receiving counts!
  - traffic received not proportional to traffic sent
- discarding counts!
  - it had better be cheap
- broadcast traffic associated with flooding is very expensive
- cost of MAC control negotiation is significant
- cost is not very dependent on mobility

Observations

- DSR
  - cost of source routing headers isn't too high
  - operating the network interface in promiscuous mode is extremely expensive

- AODV
  - sends more broadcast traffic than DSR
  - cost of broadcast traffic is very high
  - initiates route discovery more often