Power Control and Clustering in Ad Hoc Networks

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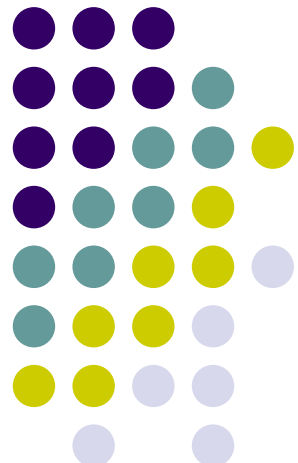
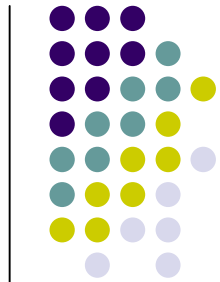
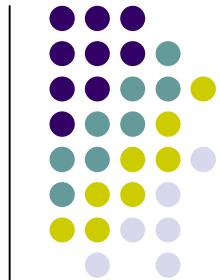


Introduction



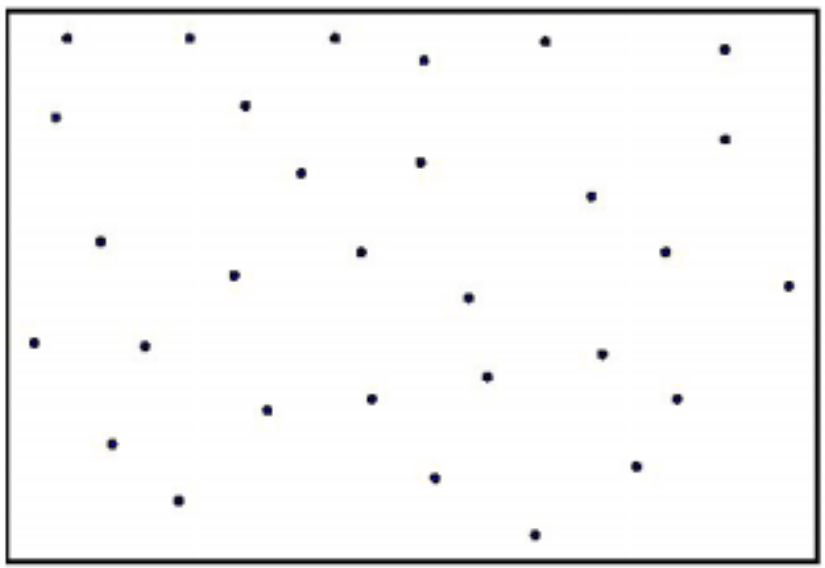
- Power control
  - How to choose the transmit power level for every packet
- Transmit power affects
  - Transmission range
  - Network topology and routing
  - Network capacity
  - Battery life
  - Packet end-to-end latency

Related Works

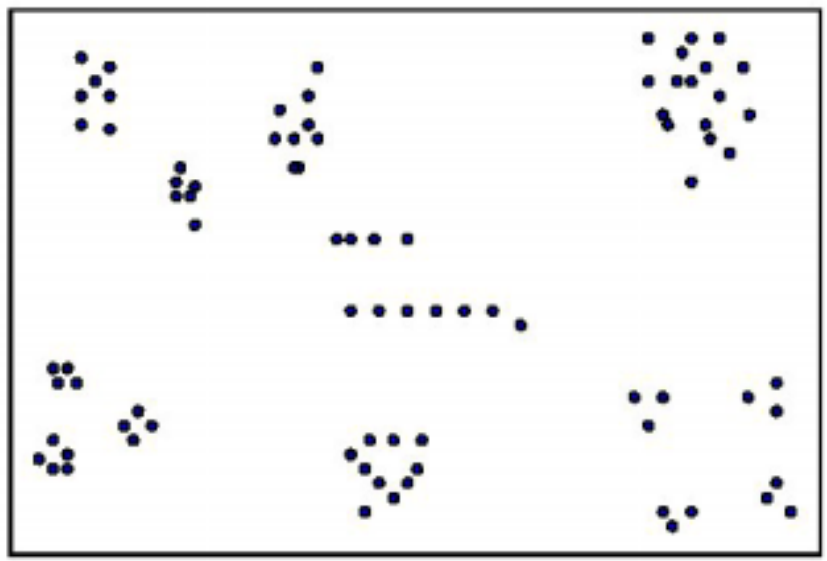


- Most work on power control can be classified into several categories:
  - Find an optimal transmit power
    - To control the connectivity of the network
    - COMPOW[2]
    - [3][4][5]
  - Power “aware” routing
    - Power based metric v.s. hop count based metric
    - [6][7][8][9]
  - Modifying the MAC layer
    - [10][11][12][13]

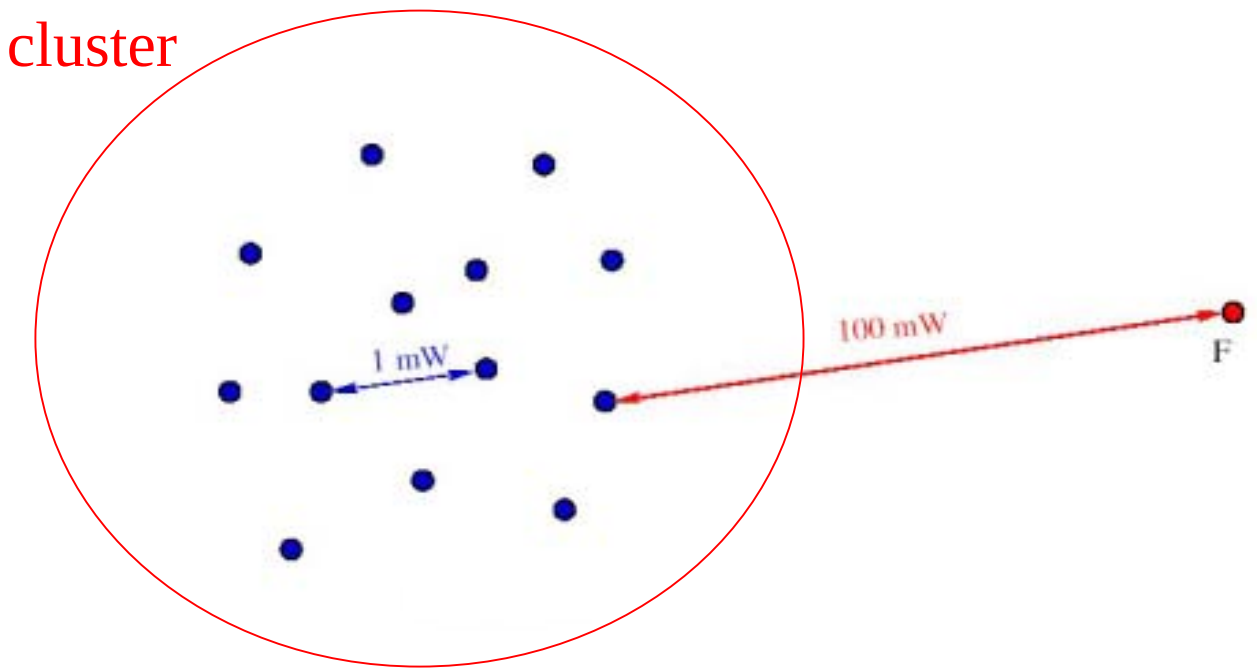
Homogeneous v.s. Non-homogeneous Networks



(a) Homogeneous spatial dispersion of nodes



(b) Nodes non-homogeneously dispersed



A common power level is not appropriate for non-homogeneous networks

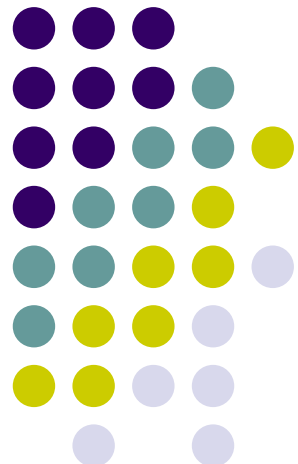
Clustering

- Can reduce route discovery overhead
- Usually need a cluster_head election
- Connections between different clusters must through these cluster_heads

Goals

- Power control in conjunction with routing
- Providing dynamic and implicit clustering of nodes
  - Without election of leader or gateway nodes
- Propose three solutions:
  - Maximize network capacity
    - CLUSTERPOW
    - Tunnelled CLUSTERPOW
  - Minimize energy consumption
    - MINPOW

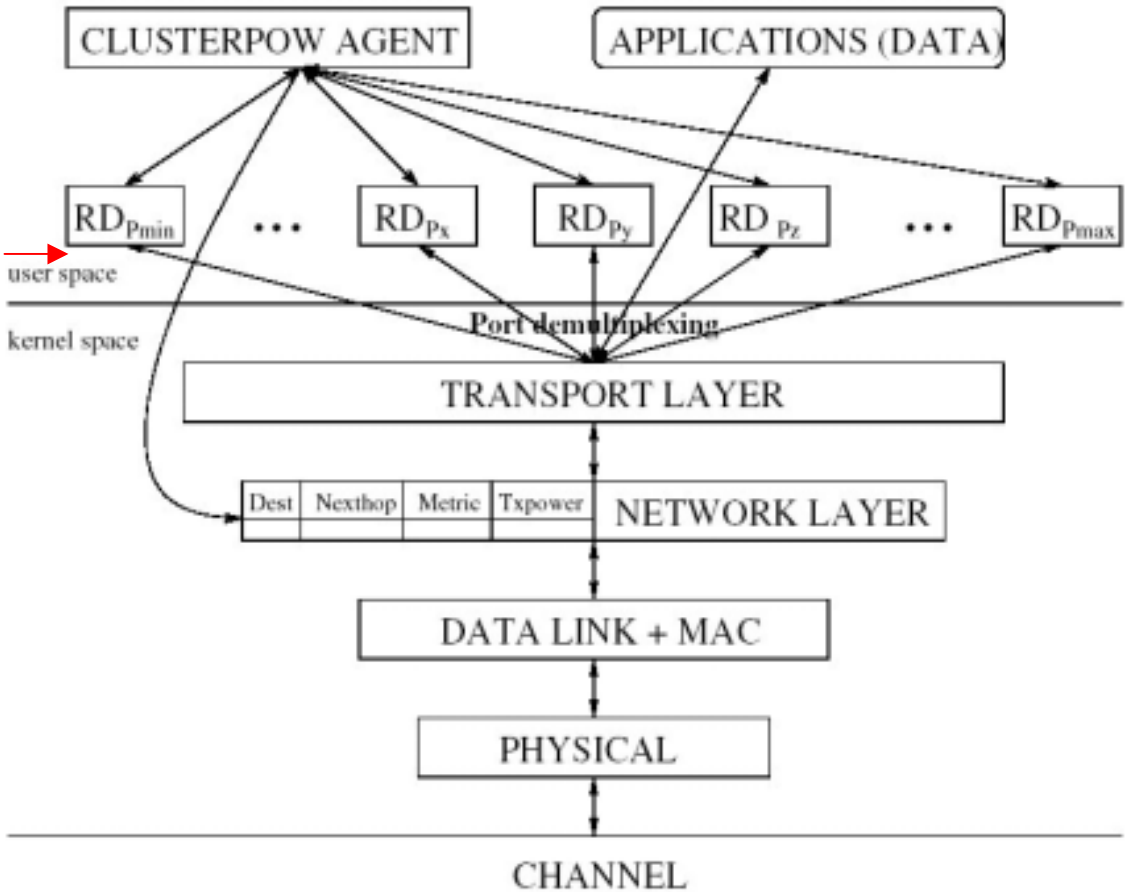
The CLUSTERPOW Power Control Protocol



- A route in CLUSTERPOW
  - Consists of hops of different transmit power
  - The clustered structure of network is respected

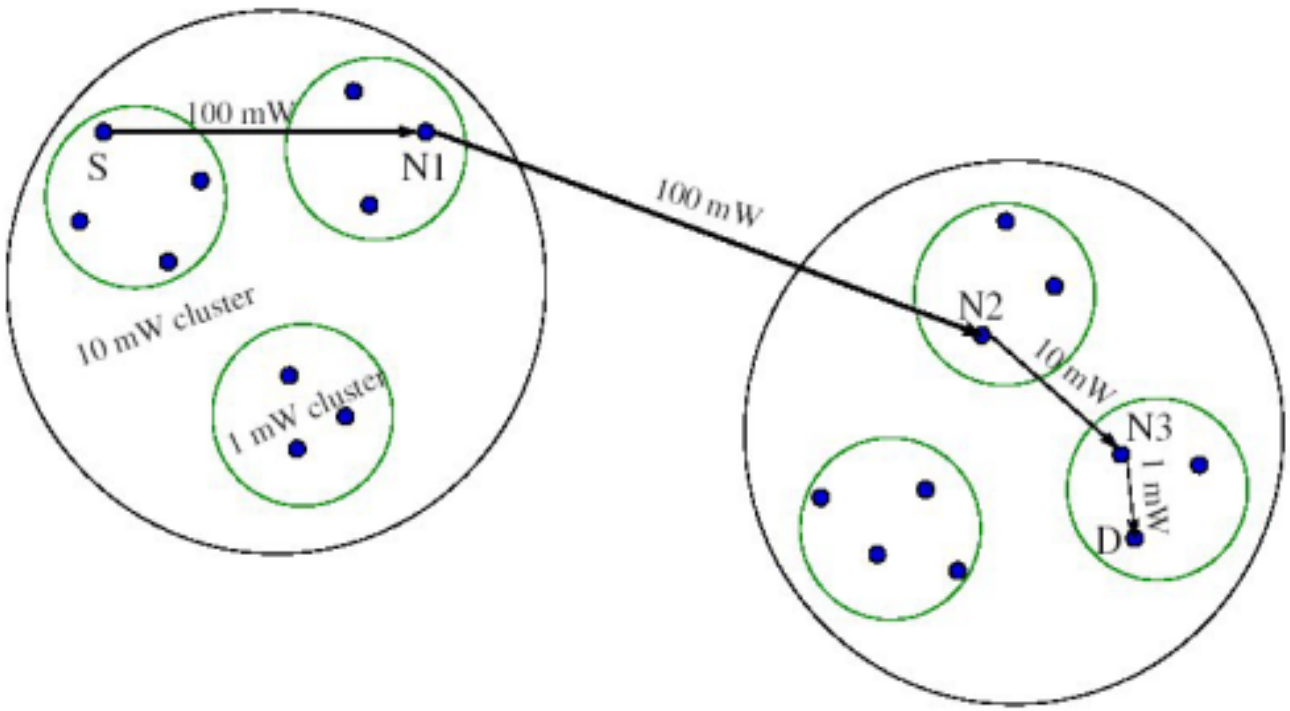
Architecture Design of CLUSTERPOW

Routing Daemons
(corresponding to each power level P_i)



Routing by CLUSTERPOW in A Typical Non-homogeneous Network

- First, using the maximum power *p* to find the route
- Then, using the power which is *not larger than p* revise the route



Routing Tables for All Power Levels

Node S

1 mW Routing Table

Dest	NextHop	Metric
D		Inf

10 mW Routing Table

Dest	NextHop	Metric
D		Inf

100 mW Routing Table

Dest	NextHop	Metric
D	N1	3

Kernel IP Routing Table

Dest	NextHop	Metric	TxPower
D	N1	3	100 mW

Node N2

1 mW Routing Table

Dest	NextHop	Metric
D		Inf

10 mW Routing Table

Dest	NextHop	Metric
D	N3	2

100 mW Routing Table

Dest	NextHop	Metric
D	D	1

Kernel IP Routing Table

Dest	NextHop	Metric	TxPower
D	N3	2	10 mW

Node N1

1 mW Routing Table

Dest	NextHop	Metric
D		Inf

10 mW Routing Table

Dest	NextHop	Metric
D		Inf

100 mW Routing Table

Dest	NextHop	Metric
D	N2	3

Kernel IP Routing Table

Dest	NextHop	Metric	TxPower
D	N2	3	100 mW

Node N3

1 mW Routing Table

Dest	NextHop	Metric
D	D	1

10 mW Routing Table

Dest	NextHop	Metric
D	D	1

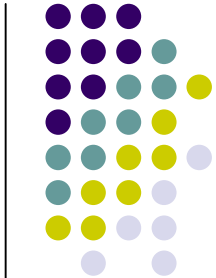
100 mW Routing Table

Dest	NextHop	Metric
D	D	1

Kernel IP Routing Table

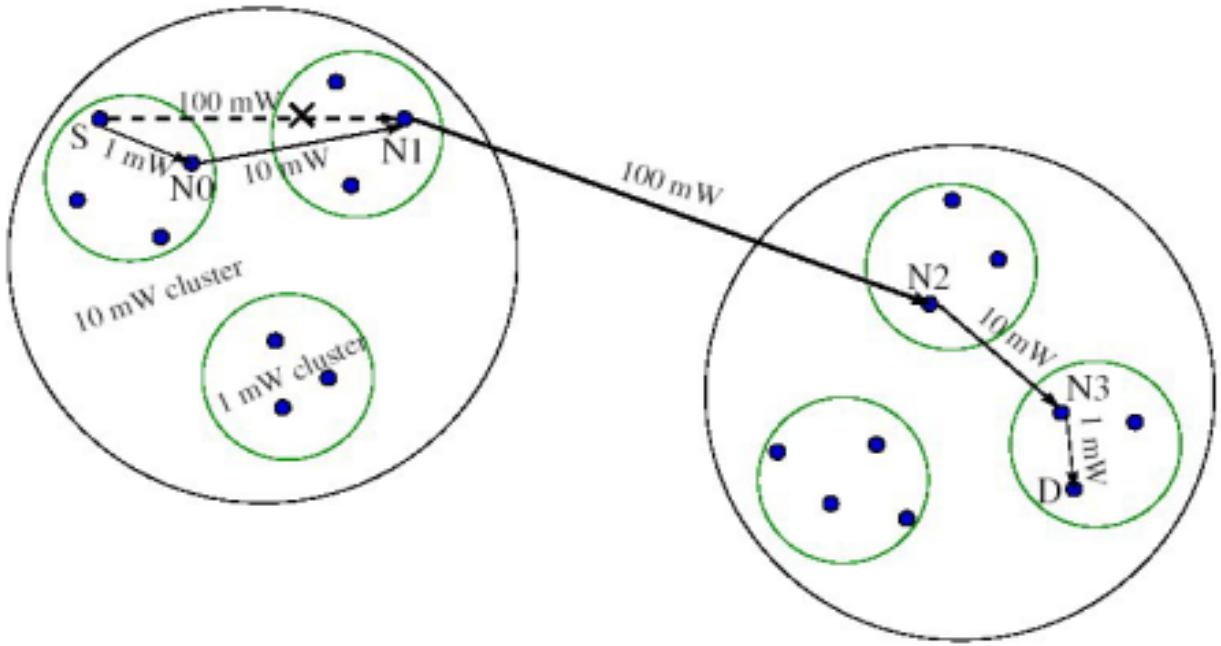
Dest	NextHop	Metric	TxPower
D	D	1	1 mW

Properties of CLUSTERPOW



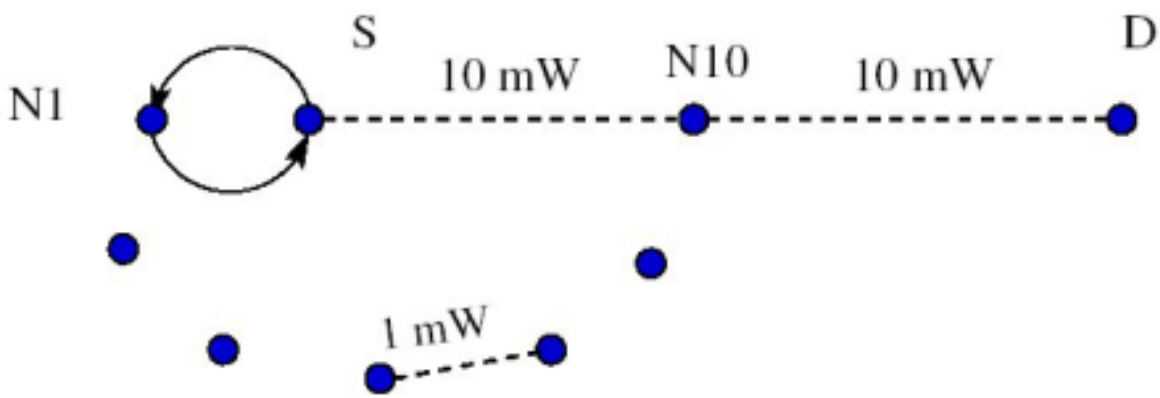
- The routes discovered consist of a non-increasing sequence of transmit power levels
- COMPOW[2] is a special case of CLUSTERPOW
- CLUSTERPOW can be used with any routing protocol, reactive or proactive.
- CLUSTERPOW is loop free.

Modifying the CLUSTERPOW protocol

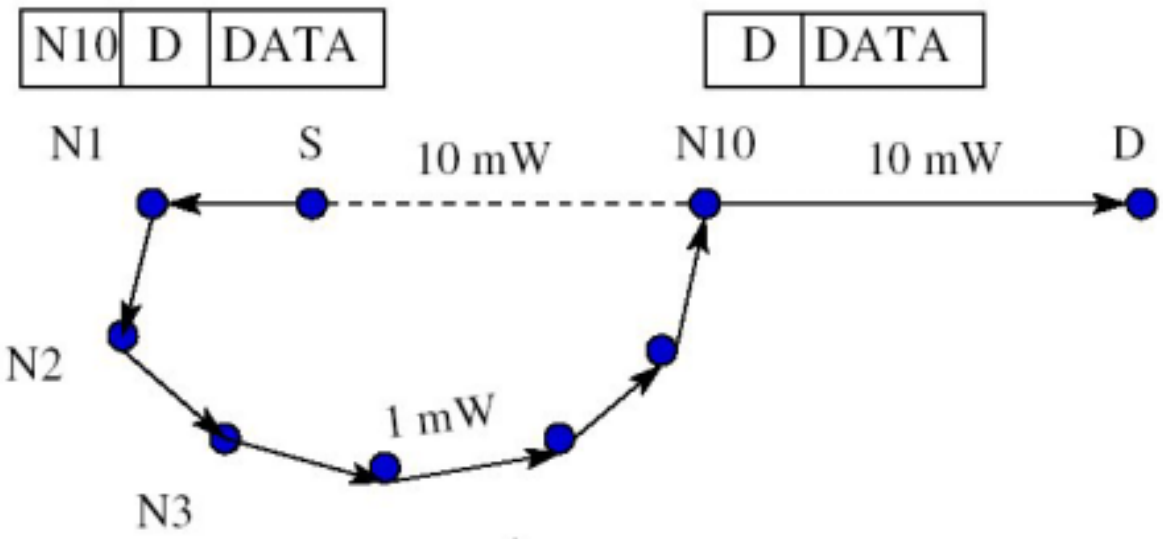


- To increase network capacity
- Using Recursive Lookup
  - May be lead to packets getting into infinite loops

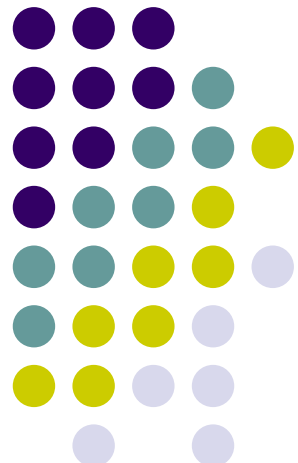
An Counterexample : infinite loops



Using Tunnelled CLUSTERPOW



The MINPOW Routing and Power Control Protocol



MINPOW

- To minimize the total power consumption
- Total power consumption as the cost
  - Instead of the hop count metric
- Any shortest path algorithm can be used
- Using “hello” packet
  - without requiring any support form the physical layer

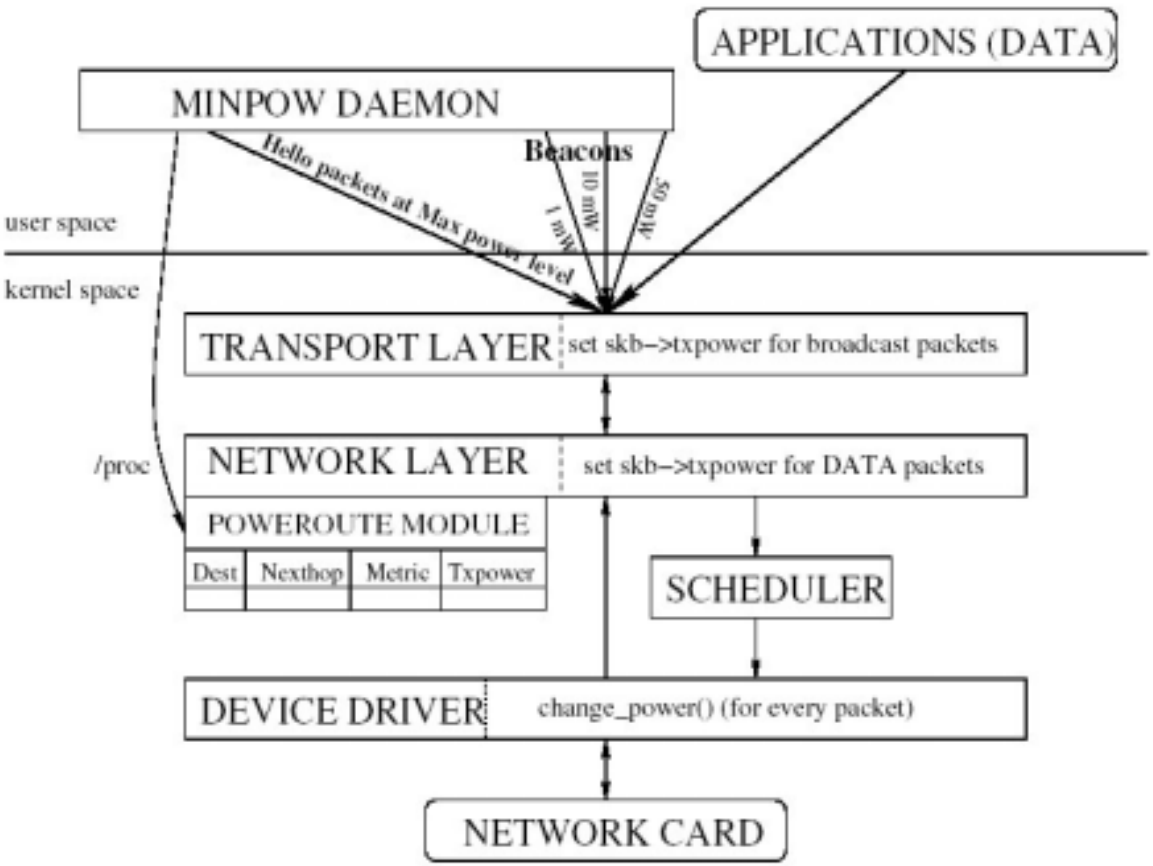
Link Cost

- $P_{RX_{elec}}$: the power consumed in receiver electronics
- $P_{TX_{elec}}$: the power consumed by the transmitter electronics
- $P_{TX_{Rad}}(p)$: the power consumed by the power amplifier to transmit a packet at power level p

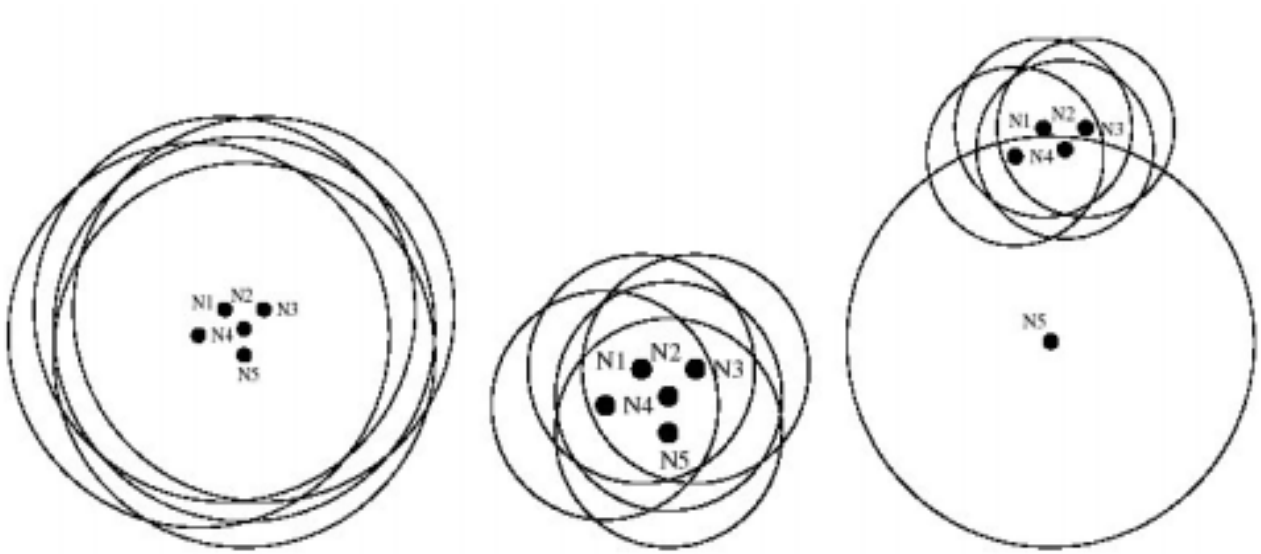
$$P_{Tx_{total}} = P_{Tx_{elec}} + P_{Tx_{Rad}}(p)$$

$$linkcost = \min_{beacons}(P_{Tx_{total}}) + P_{Rx_{elec}}$$

The software architecture of MINPOW



Some topologies for experimentation



(a) Co-located nodes at 100 mW.

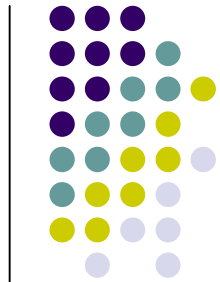
(b) 1 mW is enough.

(c) A clustered network.

Summary

- CLUSTERPOW
  - Provides adaptive and distributed clustering based on transmit power.
- Tunnelled CLUSTERPOW
  - To increase network capacity
- MINPOW
  - To minimize the total power consumption

Discussion



- The throughput problem
  - using high power level
- The latency problem
  - using low power level
- Load adaptive power control?
- Sleeping
  - Important for current hardware
  - The decision to sleep cannot be relegated entirely to the MAC layer