Energy Management in Ad Hoc Wireless Networks

Raj Jain
Washington University in Saint Louis
Saint Louis, MO 63130
Jain@cse.wustl.edu

These slides are available on-line at:

http://www.cse.wustl.edu/~jain/cse574-06/

- Battery Management:
  - Datalink and Network layers
- Transmit Power Management:
  - Datalink and Network layers
- System Power Management

Battery Management Schemes

- Key Fact: *Batteries recover their charge when idle*
  ⇒ Use some batteries and leave others to idle/recover
- Task scheduling:
  1. Round-robin batteries
  2. Divide batteries in High-charge and low-charge class. Select one from high-charge using round-robin

Datalink Layer Battery Management

- Lazy Packet Scheduling:
  Reduce the power ⇒ Increase the transmission time
- Battery-Aware MAC Protocol:
  Packets carry remaining charge.
  Lower back off interval for nodes with higher charge

Network Layer Battery Management

Goal: Increase the lifetime of the network

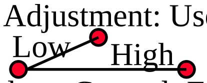
- Shaping: If battery charge becomes below threshold, stop next transmission allowing battery to recover
- Battery Energy Efficient (BEE) Routing Protocol: Minimize energy and use max battery charge

Transmission Power Management

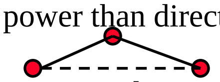
More transmit power ⇒ Longer reach but lower battery life

Datalink:

1. Dynamic Power Adjustment: Use the min power required for the next hop



2. Distributed Topology Control: Find power required and direction of neighbors. Remove neighbors that have two-hop paths with less power than direct transmission

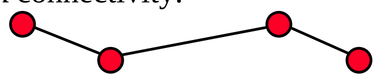


3. Distributed Power Control Loop: Find the minimum power required for successful RTS/CTS, Data/Ack
4. Centralized Topology Control: The power of each node is reduced until it has single connectivity, i.e., there is one path between each pair of nodes or bi-connectivity, i.e, there are 2 disjoint paths between each pair of nodes

Transmission Power Management (Cont)

Network Layer: Minimize computation (compression, idle listening, routing table)+transmission

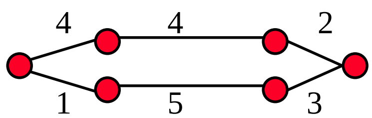
1. **Common Power Control**: Given reachability of each node as a function of power, find the min power level that provides network connectivity.



2. **Min Power Consumption Routing**: Bellman Ford using Power as the cost metric
3. **Min Variance in Node Power Levels**: Every node should relay the same amount of traffic. Select next hop with the shortest Q.

Transmission Power Management (Cont)

4. **Min Battery Cost Routing**: Minimize sum of battery cost (based on charge) along a path ⇒ Does not ensure that lower charge nodes are not used



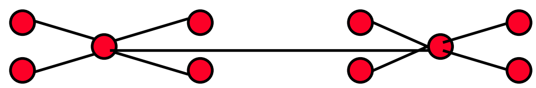
5. **Min-Max Battery Cost Routing**: Select the path which minimizes the max power required at *any* node
   - ⇒ Does not give min total power
   - ⇒ Reduced lifetime for the network
6. **Conditional Min-Max Battery Cost Routing**: Using only nodes that have battery charge over a threshold, Find the min total power path.

Transmission Power Management (Cont)

7. **Localized Power-Aware Routing**: Power $=ad^{\alpha}+c$, $\alpha > 2$
   $\Rightarrow$ Two one mile hops are better than one two mile hop

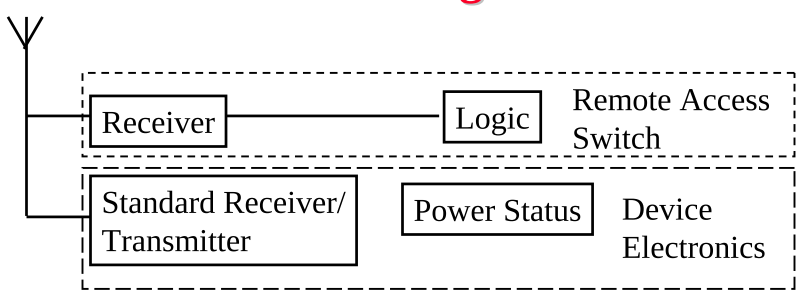
   $\Rightarrow$ n-hops are best, $n = \text{round}\{d a(\alpha-1)/c^{1/\alpha}\}$

   Find the neighbor with the minimum expected power
8. **Charge Based Clustering**: Select cluster head that has the highest charge. Reconfigure when the cluster head is not the one with highest charge.



Higher layers can also be made energy conscious
   $\Rightarrow$ shut down when inactive

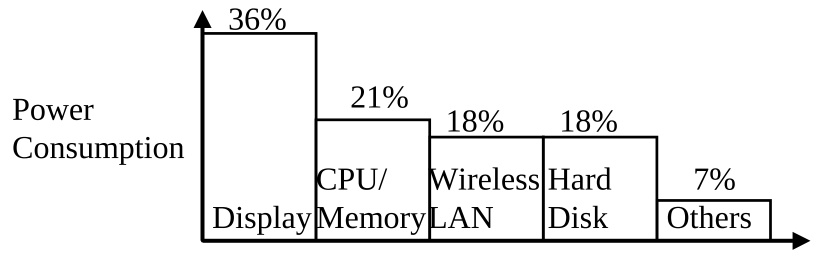
Processor Power Management Schemes



1. **Remote Access Switch**: System sleeps. Only PHY receiver is on. On receipt of a particular signal, wakes up the system.
2. **Power Aware Multi-Access Signaling** (PAMAS): Power-off if you hear RTS/CTS for another node or if you have nothing to send.

Device Power Management Schemes

- Turn off individual components: LCD display, DRAM, CDROM, CPU, Drive
- Run CPU at lower clock rate, lower voltages
- Spin down disks when unused



Summary

- **Battery Management**: idling increases the capacity of the battery
- **Transmission Power Management**: Distance vs. Power tradeoff
- **System Power Management**: Put system/components to sleep whenever possible

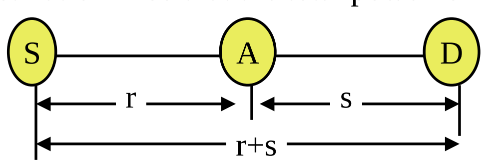
Reading Assignment

- Read Chapter 11 of Murthy and Manoj

Homework

Transmit power = $ad^{\alpha}+c$

1. Where should intermediate node A be located between source S and destination D so that the total power is minimized.



2. If the path between source S and destination D consists of n equal size hops. What should n be so that the total power is minimized?