

Energy Management in Ad Hoc Wireless Networks

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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 \Rightarrow 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

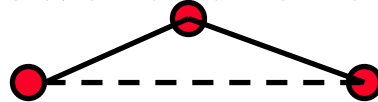
More transmit power \Rightarrow Longer reach but lower battery life

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

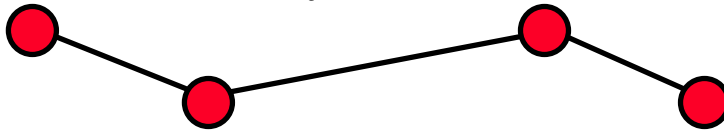


3. Distributed Power Control Loop: Find the minimum power required for successful RTS/CTS, Data/Ack
4. Centralized Topology Control: The power of each node is reduced until it has single connectivity, i.e., there is one path between each pair of nodes or bi-connectivity, i.e, there are 2 disjoint paths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

Transmission Power Management (Cont)

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

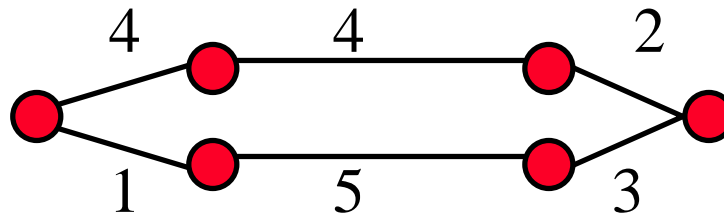
1. **Common Power Control:** Given reachability of each node as a function of power, find the min power level that provides network connectivity.



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 \Rightarrow 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
 \Rightarrow Does not give min total power
 \Rightarrow 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 = $ad^{\alpha} + c$, $\alpha > 2$

⇒ Two one mile hops are better than one two mile hop

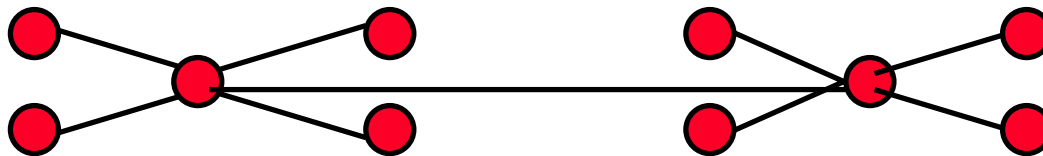


⇒ n-hops are best, $n = \text{round}\{da(\alpha-1)/c^{1/\alpha}\}$



Find the neighbor with the minimum expected power

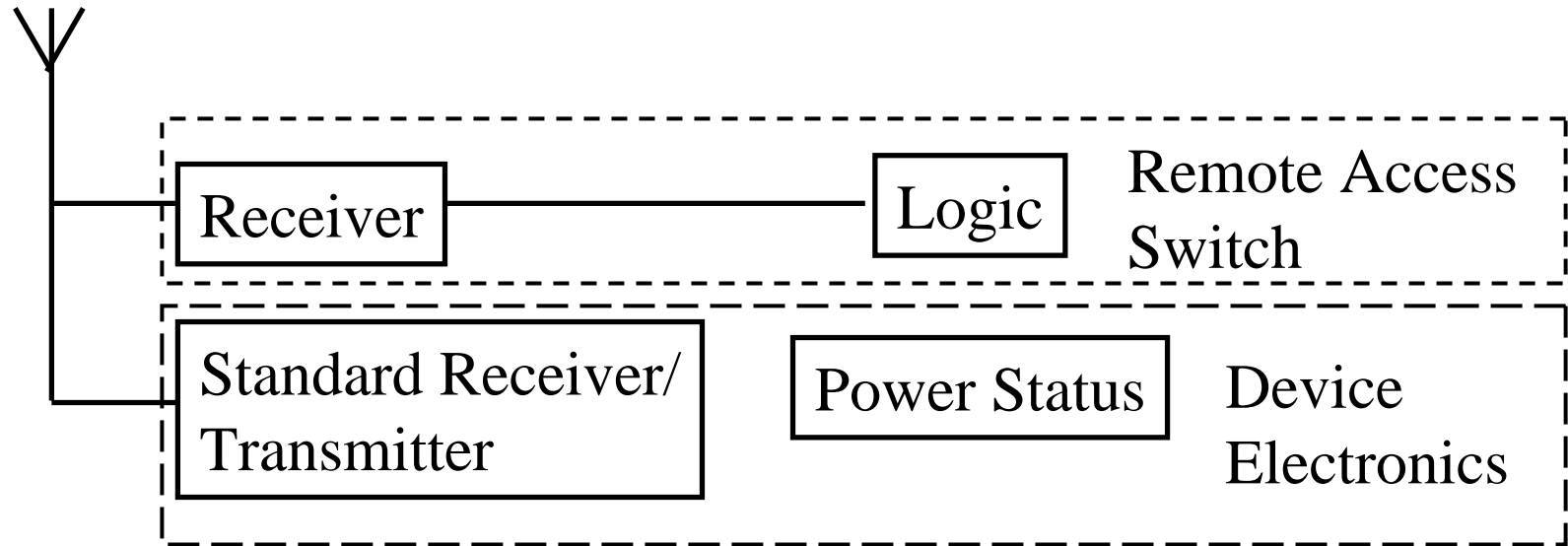
8. **Charge Based Clustering:** Select cluster head that has the highest charge. Reconfigure when the cluster head is not the one with highest charge.



Higher layers can also be made energy conscious

⇒ shut down when inactive

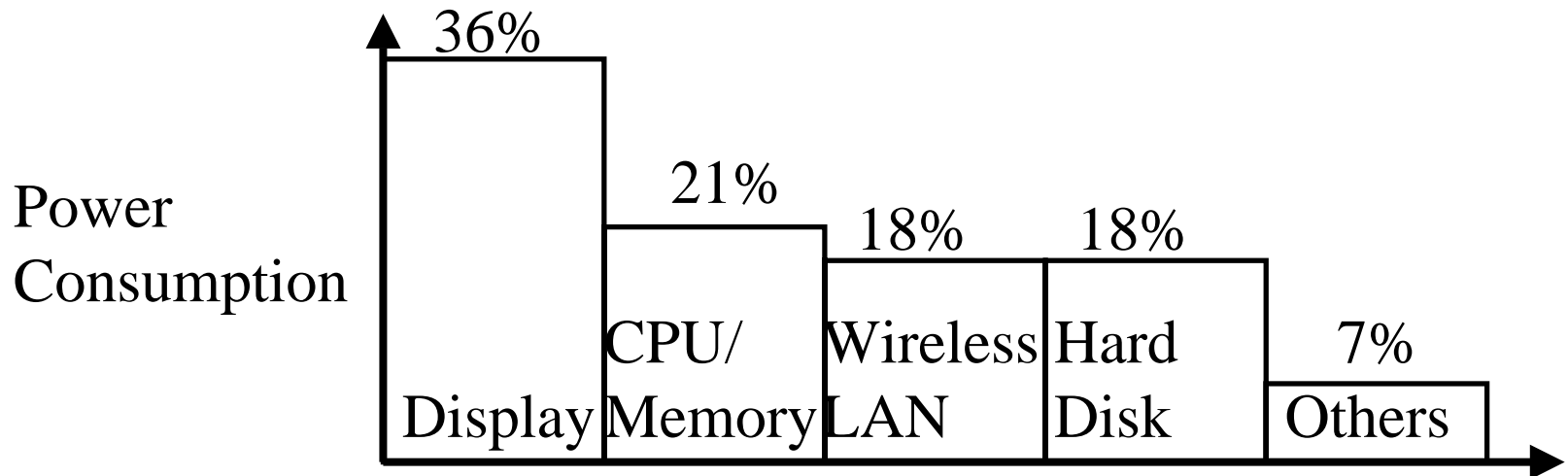
Processor Power Management Schemes



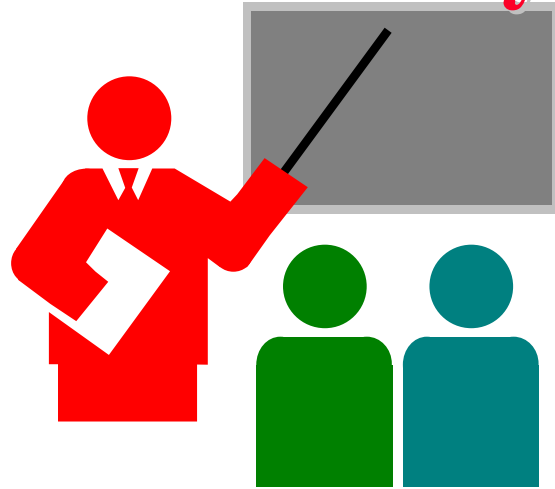
1. **Remote Access Switch**: System sleeps. Only PHY receiver is on. On receipt of a particular signal, wakes up the system.
2. **Power Aware Multi-Access Signaling** (PAMAS): Power-off if you hear RTS/CTS for another node or if you have nothing to send.

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

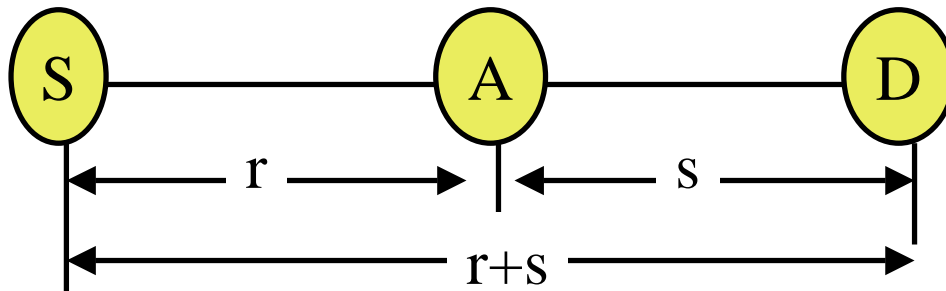
Reading Assignment

- Read Chapter 11 of Murthy and Manoj

Homework

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

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?

