Outline

- Energy Management Issue in ad hoc networks
- Main Reasons for Energy Management in ad hoc networks
- Classification of Energy Management Schemes
- Summary

Energy Management Issue in Ad Hoc Networks

- In ad hoc networks the devices are battery powered
- So the computation and communication capacity of each device is constrained
- Devices that expend their whole energy can be recharged when they leave the network
- Energy resources and computation workloads have different distributions within the network
- Therefore it is beneficial to redistribute spare energy resources to satisfy varying workloads in the network
Main Reasons for Energy Management in Ad Hoc Networks (1/2)

- Limited Energy Reserve: The improvement in battery technologies is very slow
- Difficulties in replacing the batteries: E.g. in battlefields or emergency applications
- Lack of central coordination: In ad hoc networks as distributed networks some nodes may work as relay nodes; when relay traffic is heavy the power consumption is high

Main Reasons for Energy Management in Ad Hoc Networks (2/2)

- Constraints on the battery source: The batteries should be small and not heavy; So low power is available at each node
- Selection of optimal transmission power: Higher transmission power results in higher energy consumption and higher interference between nodes

In General

- Energy management deals with the process of managing energy resources by means of:
  - Controlling the battery discharge
  - Adjusting the transmission power
  - Scheduling of power sources

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1. Battery Management Schemes

- The lifetime of a node is determined by the capacity of its energy source and the energy required by the node.
- There are some device dependent approaches that increase the battery lifetime by exploiting its internal characteristics.
- Key Fact: Batteries recover their charge when idle
  ⇒ Use some batteries and leave others to idle/recover

A) Device depending schemes:

I. Battery scheduling techniques:
   - In a battery package of L cells, a subset of batteries can be scheduled for transmitting a given packet leaving other cells to recover their charge. There are some approaches to select the subset of cells, e.g.
Battery Management Schemes

1. Joint technique: The same amount of current is drawn equally from all the cells which are connected in parallel.
2. Round robin technique: The current is drawn from the batteries in turn by switching from one to the next one.
3. Random technique: any one of the cells is chosen at random with a uniform probability.

B) Data link Layer Battery Management

I. Lazy Packet Scheduling:
   - Reduce the power ⇒ Increase the transmission time (lower bit rate)
   - But this may not suit practical wireless environment packets ⇒ a transmission schedule is designed taking into account the delay constraints of the packets

C) Network Layer Battery Management

I. Goal: Increase the lifetime of the network
   - Shaping algorithm:
     • introducing delay slots in the battery discharge process
     • If battery charge becomes below threshold, stop next transmission allowing battery to recover through idling
     • The remaining requests arriving at the system are queued up at a buffer
     • As soon as the battery recovers its charge and enters state higher than the threshold, it starts servicing the queued-up requests

Classification of Energy Management Schemes

2. Transmission Power Management Schemes

A) Link layer solutions:

I. Power Save in IEEE 802.11 Ad Hoc Mode
   - Time is divided into beacon intervals
   - Each beacon interval begins with an ATIM (ad hoc traffic indication message) window
Transmission Power Management Schemes

- If host A has a packet to transmit to B, A must send an ATIM Request to B during an ATIM Window.
- On receipt of ATIM Request from A, B will send an ATIM Ack, and stay up during the rest of the beacon interval.
- If a host does not receive an ATIM Request during an ATIM window, and has no pending packets to transmit, it may sleep during rest of the beacon interval.
- Size of ATIM window and beacon interval affects performance:
  - If ATIM window is too large, energy saving is reduced and may not have enough time to transmit buffered data.
  - If ATIM window is too small, not enough time to send ATIM request.

Transmission Power Management Schemes

II. Power Control in IEEE 802.11 Ad Hoc Mode

- A power control MAC protocol allows nodes to vary transmit power level on a per-packet basis.
- When C transmits to D at a high power level, B cannot receive A’s transmission due to interference from C.
- If C reduces transmit power, it can still communicate to D:
  - Reduces energy consumption at node C.
  - Allows B to receive A’s transmission (spatial reuse).

Transmission Power Management Schemes

- E.g. A has some data packets to send to B; C is idle.
- If C reduces transmit power, it can still communicate to D:
  - Reduces energy consumption at node C.
  - Allows B to receive A’s transmission (spatial reuse).
- But difference in transmit power can lead to increased collisions.
- In following example suppose nodes A and B use lower power level than nodes C and D.
- When A is transmitting to B, C and D may not sense the transmission.
- When C and D transmit to each other using higher power, their transmission may collide with the on-going transmission from A to B.
Transmission Power Management Schemes

- As a solution to this problem, RTS-CTS are transmitted at the highest possible power level but DATA and ACK at the minimum power level necessary to communicate.
- In figure nodes A and B send RTS and CTS respectively with highest power level such that node C receives the CTS and defers its transmission.
- By using a lower power level for DATA and ACK packets, nodes can save energy.

Transmission Power Management Schemes

- In the previous scheme, RTS-CTS handshake is used to decide the transmission power for subsequent DATA and ACK which can be achieved in two different ways:
  1. Suppose node A wants to send a packet to node B. Node A transmits RTS at power level $p_{\text{max}}$ (maximum possible). When B receives the RTS from A with signal level $p_r$, B calculates the minimum necessary transmission power level, $p_{\text{desired}}$. For the DATA packet based on received power level, $p_r$, transmitted power level, $p_{\text{max}}$, and noise level at the receiver B. Node B specifies $p_{\text{desired}}$ in its CTS to node A. After receiving CTS, node A sends DATA using power level $p_{\text{desired}}$.

III. 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.
Transmission Power Management Schemes

II. Min Variance in Node Power Levels:
– The motivation is to ensure that all the nodes are given equal importance and no node is drained at a faster rate compared to other nodes in the network.
– For transmitting a packet, a node selects the next-hop node so that it has the least amount of traffic among all neighbours of the node.

III. Min Battery Cost Routing:
– Minimize sum of battery cost along a path
⇒ Does not ensure that lower charge nodes are not used

⇒ The lower path is used.

Classification of Energy Management Schemes

3. System Power Management Schemes

• Efficient design of the hardware brings about significant reduction in the power consumed.
• This can be effected by operating some of the peripheral devices in power-saving mode by turning them off under idle conditions.
• System power consists of the power used by all hardware units of the node. This power can be conserved significantly by applying the following schemes:

– Processor power management schemes
– Device power management schemes
System Power Management Schemes

A) Processor Power Management Schemes:
- Deals with techniques that try to reduce the power consumed by the processor, e.g. reducing the number of calculations performed.

I. Power-Saving Modes:
- The nodes consume a substantial amount of power even when they are in an idle state since they keep listening to the channel, awaiting request packets from the neighbours.
- As a solution, the nodes are switched off during idle conditions and switched on only when there is an arrival of a request packet.
- Since the arrival of request packets is not known a priori, it becomes difficult to calculate the time duration for which the node has to be switched off.
- One solution to this problem calculates the node’s switch-off time based on the quality of service (QoS) requirements. Hard QoS requirements make the node stay active most of the time.

II. Power-Aware Multi-Access Signaling (PAMAS):
- Power-Aware Multi-Access Signaling is another approach for determining the time duration for which the node should be turned off.
- Conditions under which the node enters the power-off mode:
  - Condition 1: The node has no packets for transmission.
  - Condition 2: A neighbour node is transmitting or receiving packets, that is, the channel is busy.

B) Device Power Management Schemes:
- Some of the major consumers of power in ad hoc wireless networks are the hardware devices present in the nodes. Device power management schemes minimize the power consumption.
System Power Management Schemes

I. Low-Power Design of Hardware: varying clock speed CPUs, disk spin down, and flash memory
II. CPU Power Consumption: by changing the clock frequency, etc.
III. Power-Aware CPU Scheduling: a small reduction in the value of the voltage produces a quadratic in the power consumed, so clock rate has to be also reduced.
IV. Hard Disk Drive (HDD) Power Consumption: by bring down the speed of spinning on the disc drives

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Summary

- Three major divisions in energy management
  - Battery Management: When idling increases the capacity of the battery
  - Transmission Power Management: Distance vs. Power tradeoff
  - System Power Management: Put system/components to sleep whenever possible