Power Management

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Outline

- CPU Power Consumption
- Power Management

CPU Power Consumption

- Most modern CPUs are designed with power consumption in mind to some degree

- Power vs. energy
  - heat depends on power consumption
  - battery life depends on energy consumption

CMOS Power Consumption

Voltage drops

Power consumption proportional to V^2

Toggling

More activity means more power

Leakage

Basic circuit characteristics; can be eliminated by disconnecting power

CPU Power-Saving Strategies

- Reduce power supply voltage
- Run at lower clock frequency
- Disable function units with control signals when not in use
- Disconnect parts from power supply when not in use

Power Management Styles

TÉCNICO LISBOA

Static power management

- Does not depend on CPU activity
- Example: user-activated power-down mode

Dynamic power management

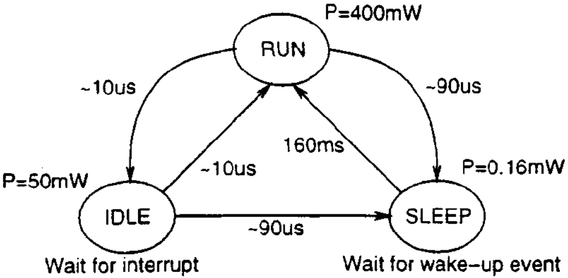
- Based on CPU activity
- Example: disabling off function units

Power-Down Costs

- Going into a power-down mode costs:
  - time
  - energy
- Must determine if going into mode is worthwhile
- Can model CPU power states with power state machine
  - states represent different modes

Power-Down Costs

StrongARM SA-1100



Source: Ben and al., 2000

Power Optimization

Power management

Determining how system resources are scheduled/used to control power consumption

- OS can manage for power just as it manages for time
- OS reduces power by shutting down units
  - may have partial shutdown modes

Power Management and Performance

- Power management and performance are often at odds

- Entering power-down mode consumes:
  - energy
  - time

- Leaving power-down mode consumes:
  - energy
  - time

Simple Power Management Policies

- Request-driven: power up once request is received
  - adds delay to response
  - works if delay is acceptable

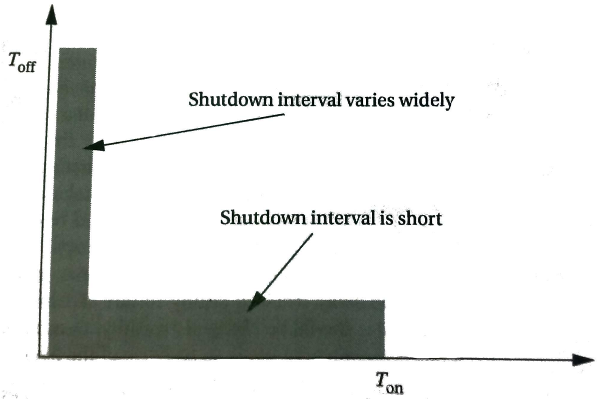
- Predictive shutdown: try to predict how long you have before next request
  - may start up in advance of request in anticipation of a new request
  - if you predict wrong, you will incur additional delay while starting up
  - may start itself when there's no imminent activity

Probabilistic Shutdown

- Assume service requests are probabilistic
- Optimize expected values:
  - power consumption
  - response time
- Simple probabilistic works best
  - shut down after time T_{on}
  - turn back on after waiting for T_{off}

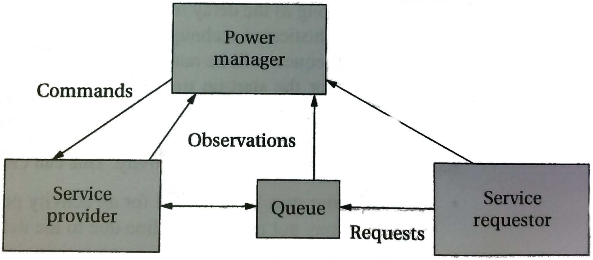
Probabilistic Shutdown

L-shaped usage distribution



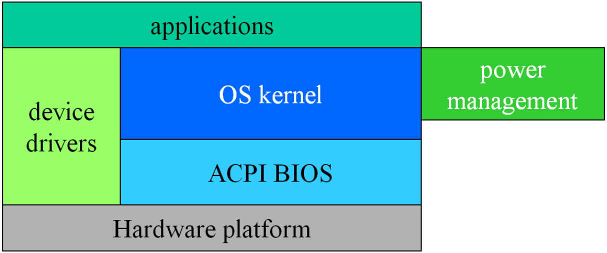
Probabilistic Shutdown

Power managed system



Advanced Configuration and Power Interface

- ACPI - open standard for power management services
- Designed to be compatible with a wide variety of OSs
- Provides basic power management facilities
- OS uses ACPI to send required controls to the hardware and to observe hardware state



ACPI Global Power States

- G0: working state
- G1: sleeping state
  - S1: low wake-up latency with no loss of context
  - S2: low latency with loss of CPU/cache state
  - S3: low latency with loss of all state except memory
  - S4: lowest-power state with all devices off
- G2: soft off
- G3: mechanical off

Monitoring Station

An environmental monitoring equipment installed in remote locations, periodically collects meteorological data and concentration of certain substances in the atmosphere and soil, transmitting these information by radio to a main server.

The equipment collects data from 16 sensors every half hour.

They should have the ability to retain the information collected during two weeks for the case of a long time failure of the communications system.

Most appropriate configuration for the controler?

- 8-bit CPU with interrupts, 16 MB non-volatile memory, 2 MB RAM, DMA controller, A/D converter with multiplexer channels, communication controller and timer
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- 8-bit CPU with interrupts, 16 MB non-volatile memory, 2 MB RAM, DMA controller, A/D converter with multiplexer channel D/A converter, timer and communication controller
- 8-bit CPU with interrupts, l6 MB non-volatile memory, 2 MB RAM, A/D converter with multiplexer channels, the three timers (real time clock, sampling clock and communications clock) and communication controller
- 8-bit CPU, 16 MB non-volatile memory, 2 MB RAM, A/D converter with multiplexer channels, D/A converter, timer and communication controller

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Power Consumption per Transmission Cycle

Power comsumption of the different modules

Operation	Relative duration	Consumption
Standby	97%	0.1 U
Sensor measurements	1%	10 U
Preparing transmission	1%	10 U
Data transmission	1%	100 U

Power consumption of the system (per transmission cycle) =
$.97*.1 + .01*10 + .01*10 + .01*100 = 1.297$ U

Algorithm To Minimize Power Consumption

Operation	Relative duration	Consumption
Standby	97%	0.1 U
Sensor measurements	1%	10 U
Preparing transmission	1%	10 U
Data transmission	1%	100 U

Data compression algorithms

Algorithm	Compression rate	Overhead in execution time
Z1	90%	1.1
Z2	75%	1.3
Z3	60%	1.5
Z4	57%	1.9

Transmission time is proportional to the amount of data to transmit.

Compute power consumption for the different algorithms.

Z1 => 1*10 + 1.1*10 + 0.9*100 + 97*0.1 => 1.207 U

Z2 => 1*10 + 1.3*10 + 0.75*100 + 96.95*0.1 => 1.07695 U

Z3 => 1*10 + 1.5*10 + 0.6*100 + 96.9*0.1 => 0.9469 U

Z4 => 1*10 + 1.9*10 + 0.57 * 100 + 96.53*0.1 => 0.95653 U

Sensor Network

To monitor the soil humidity in a large field, for agricultural purposes, a wireless sensor network was deployed. In this sensor network each node is responsible for collecting values from a moisture sensor and sending them to a server. The nodes are not all within wireless server range so data must be routed through different nodes until it reaches the server.

The nodes are always receiving data. Every 10 minutes each node measures the humidity and sends its data along with the values received from the other sensor nodes. Every node only sends the data once (received messages that were already sent are disregarded).

One sensor node was deployed in the field and the power consumption (in units of power) for each operation and how much time was spent in it were measured.

Power consumption with one node

What is the power consumption of the node (in units of power)?

One node	Percentage in each task	Power consumption
Standby	98%	10 U
Sensor measure and processing	1%	100 U
Data Transmission	1%	100000 U
Data Reception		200 U

P = .98*10 + .01*100 + .01*100000 + 200 = 1210.8 U

Power consumption with 20 nodes

What would be the power consumption in each node if the number of nodes in the field was 20 (assuming the worst case)?

One node	Percentage in each task	Power consumption
Standby	98%	10 U
Sensor measure and processing	1%	100 U
Data Transmission	1%	100000 U
Data Reception		200 U

What changes?

- In the worst case a node may have to send 20 times more data

P = (1-.01-.2)*10+.01*100+20*.01*100000+200 = 20208.9 U

Period of the measurements

If we have 100 nodes, what should be the time period of the measurements, in order to have a power consumption of 1000 U per node (assuming the worst case)?

One node	Percentage in each task	Power consumption
Standby	98%	10 U
Sensor measure and processing	1%	100 U
Data Transmission	1%	100000 U
Data Reception		200 U

P = 1000

P = (time in standby)*10 + 0.01/x *100 + 0.01/x *100*100000 + 200

time in standby = 1 - 0.01/x - 0.01/x * 100

x = 126.57

period = 126.57 * 10 min = 1265.7 min = 21 hours

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References

Computers as Components: Principles of Embedded Computing System Design , Marylin Wolf. Morgan Kaufman. Ch. 3.7 and 6.9

Next Class

- Program Design and Analysis