Title
Stargate: Energy Management Techniques

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Stargate: Energy Management Techniques

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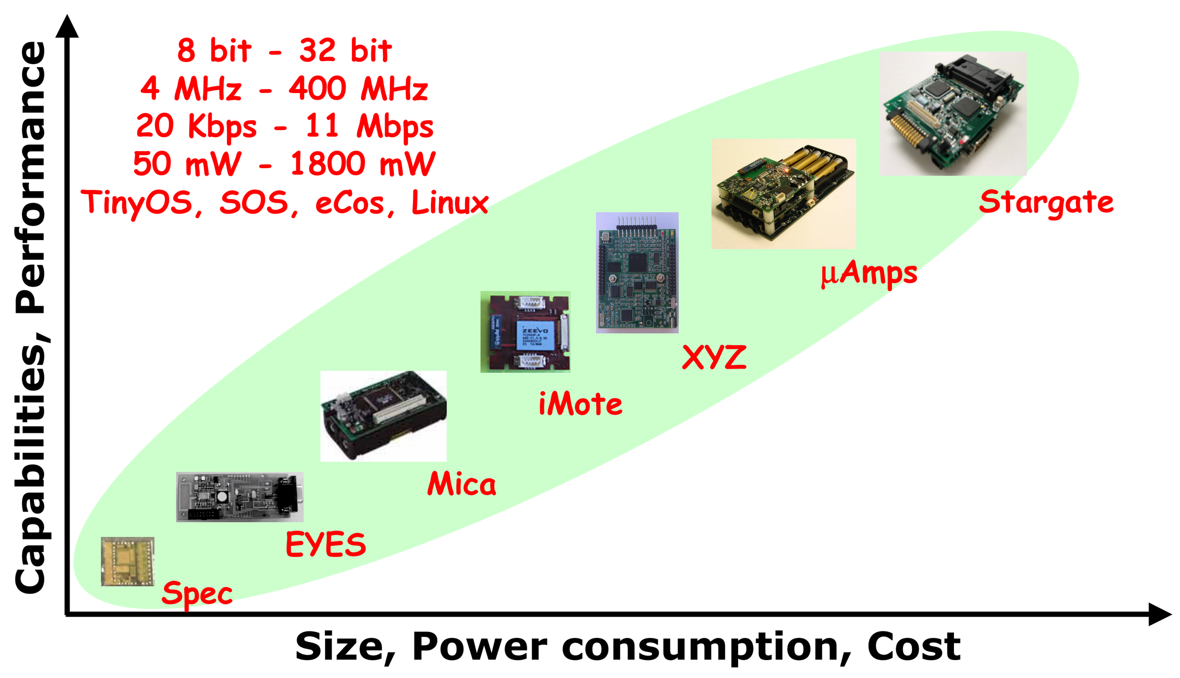
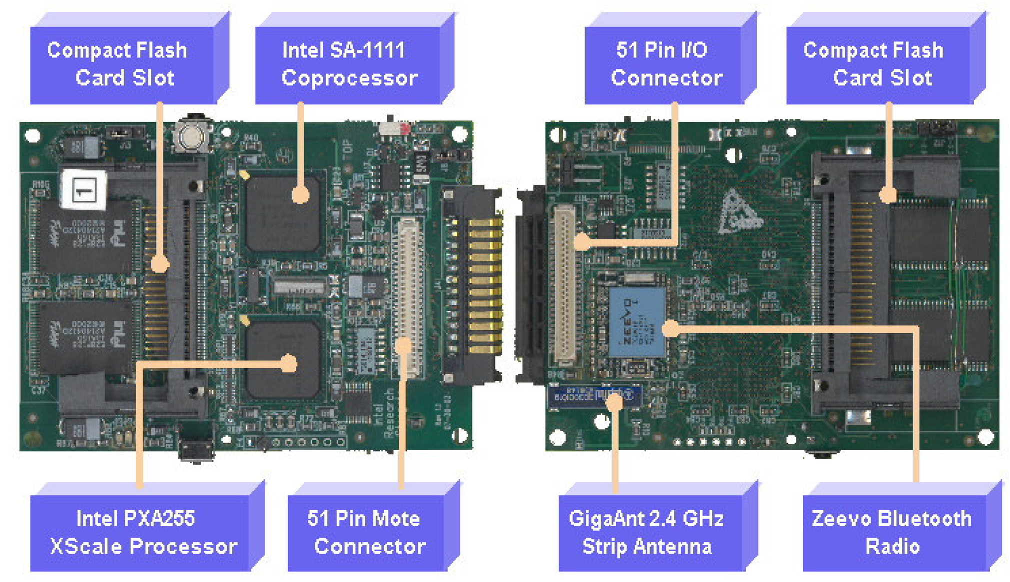
Introduction: Emergence of numerous rapidly evolving sensor node platforms

Diversity in sensor node platforms



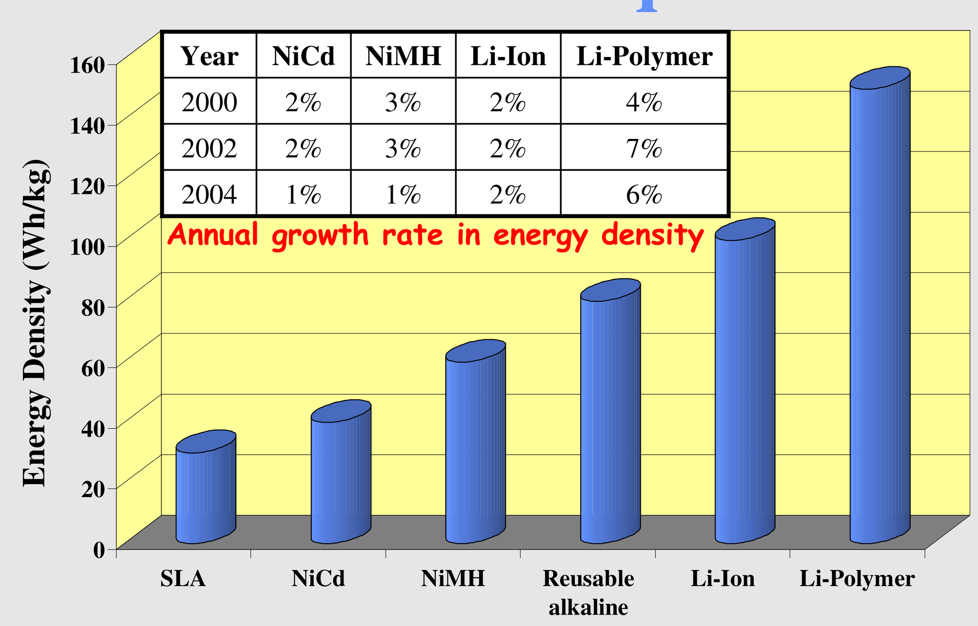
The Stargate embedded computing platform



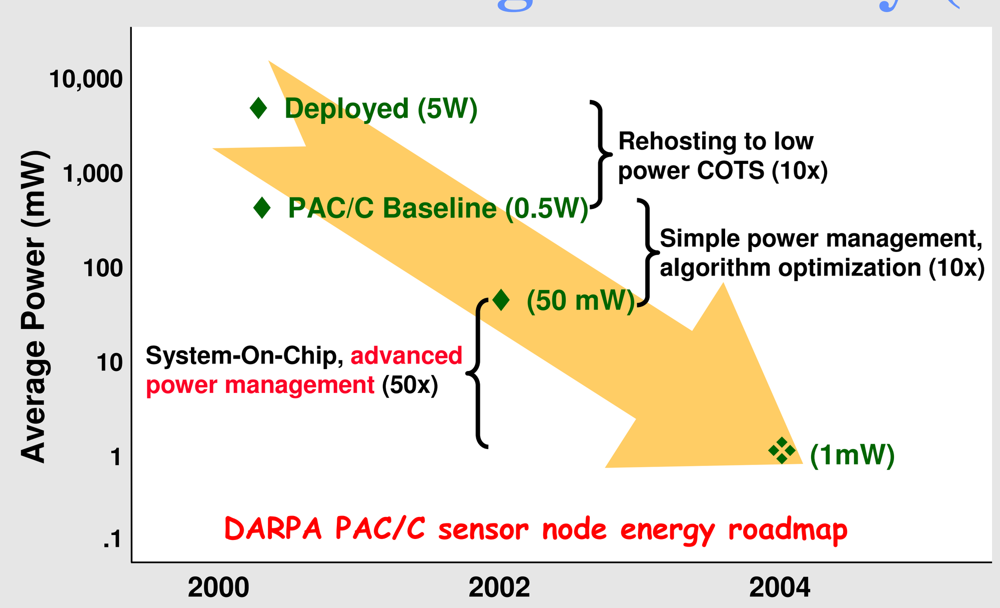
- PXA255 (XScale), 64 MB SDRAM, 32 MB Flash, Bluetooth, PCMCIA, CF, Mote connector, USB, Ethernet
- ARM Linux, TCP/IP networking, Java VM, Apache and SSH servers
- Potential use in several application domains, including sensor networks, mobile and ubiquitous computing

Problem Description: Platform specific energy management is crucial for long battery lifetime

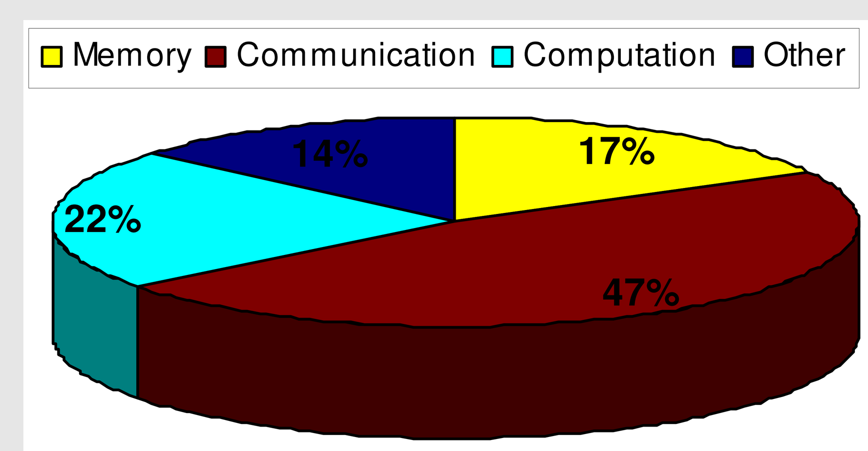
Concerted effort required at all levels of the design hierarchy (circuit, architecture, system, network)



Slowly improving battery capacities lag power requirements



Aggressive energy roadmap for the future



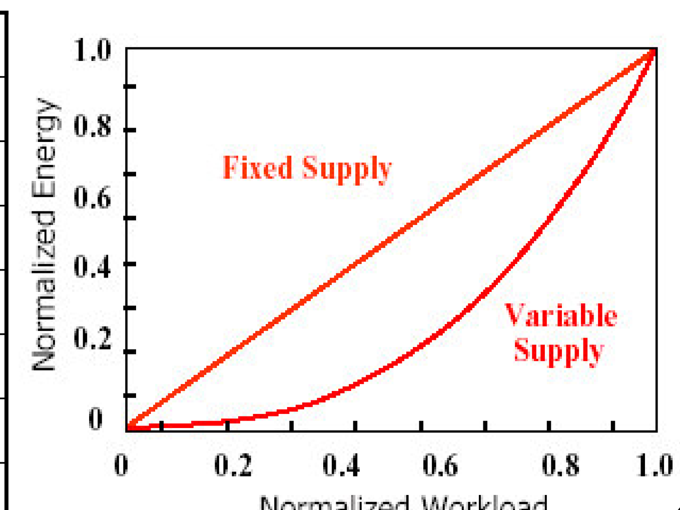
Communication subsystem often dominates total power consumption

Proposed Solution: System level energy management techniques and support for the Stargate

Computation Subsystem

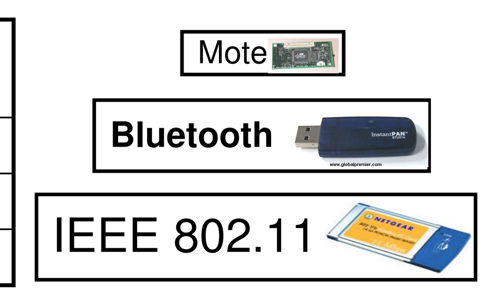
- PXA255 provides two shutdown modes (Idle, Sleep)
  - Core consumes 45mW in 33MHz Idle mode, 0.15mW in Sleep mode
- Dynamic voltage and frequency scaling supported
  - Results in a super-linear decrease in power consumption
  - 411 mW at 400 MHz, 178 mW at 200 MHz

Mode	Processor	System Bus	Voltage
1	100 MHz	50 MHz	0.85 V
2	200 MHz	50 MHz	1.00 V
3	200 MHz	100 MHz	1.00 V
4	300 MHz	50 MHz	1.10 V
5	300 MHz	100 MHz	1.10 V
6	400 MHz	100 MHz	1.30 V
7	400 MHz	200 MHz	1.30 V



Communication Subsystem

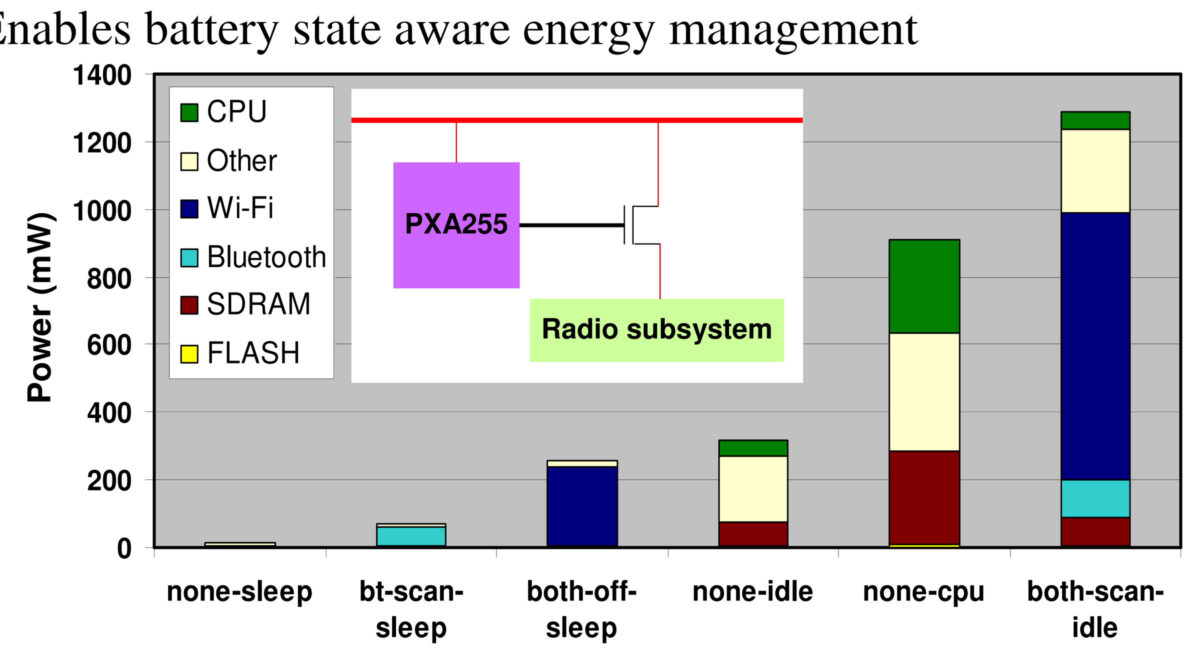
Radio	Data Rate	Tx Current	Energy per bit	Idle Current	Startup time
CC1000	76.8 Kbps	10 mA	430 nJ/bit	7 mA	Low
Bluetooth	1 Mbps	45 mA	149 nJ/bit	22 mA	Medium
802.11	11 Mbps	300 mA	90 nJ/bit	160 mA	High



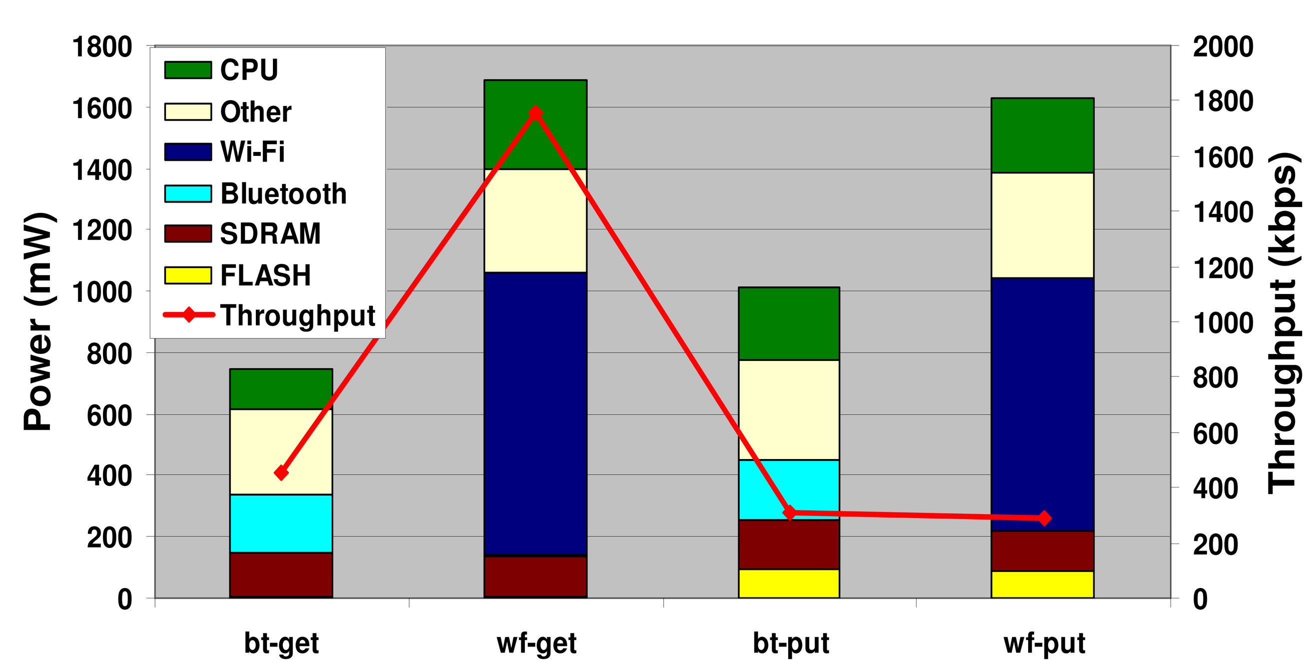
- Communication subsystem supports Mote, Bluetooth, 802.11
  - Each has vastly different performance / power characteristics
  - Mote is efficient for sending very little data, 802.11 for bulk data transfer
  - Radio hierarchy offers 10x power reduction potential in various scenarios
- Supports remote wakeup over Bluetooth channel
  - Enables on-demand, event driven power management
- Mote based wakeup mechanism
  - Provides energy scaleable computation/communication capability

Support for Energy Management

- Power gating provided for the Bluetooth and 802.11 radios
  - Overcomes inefficiencies in shutdown modes of the radios
  - Decreases shutdown mode power of 802.11 card from 250mW to 1mW
  - Increases wakeup latency since radio needs to be powered up first
- Gas gauge permits measurement of battery voltage and current
  - Enables battery state aware energy management



Power Breakdown and Observations



- Power consumption ranges from 15mW to 1700 mW
- Flash writes are a bottleneck causing power inefficient operation
- 802.11 often an overkill → Power penalty for unused bandwidth