Introduction

- Because rapid progress in microelectronics technology, a new, nomadic lifestyle has become widespread these days. People, regardless of location, enjoy greater connectivity through communication networks and intelligent electronic terminals. This nomadic lifestyle will become even more common as technology frees people from the constraints of time and location.
Introduction (cont)

- The cool chip, characterized by high performance and low power consumption, will play a key role in inaugurating the nomadic age.

- The nomadic tools basic requirements
  - intelligence
  - small size
  - low cost
  - long battery life
Figure of merit for the nomadic age

Figure of Merit = \frac{(Intelligence)}{(Size) \times (Cost) \times (Power)}
Various factors affect the figure of merit

\[
FM = \frac{(Intelligence)}{(Size) \times (Cost) \times (Power)}
\]

- Chip counts
- Package size
- Chip size
  - Process complexity
  - Assembly and test
  - Production quality
- Supply voltage
  - Plastic capacitance
  - Operating frequency
  - Architecture and algorithm

Influenced by finer geometry
Smaller, Faster, Cooler

- Semiconductor technology progress has led to smaller and lighter electronic devices
Example 1

Sharp (electronic calculator)

First model: 1964
area: 70,000 cubic centimeters
cost: $5,000
power dissipation: more than 100 watts

Second model: 1980
area: 3 cubic centimeters
cost: $10
power dissipation: only a few milliwatts

figure of merit: merit improved by roughly 11 orders of magnitude within a span of 20 years (the same function)
Example 2

- Use million instructions per second (MIPS) to represent the PC’s intelligence factor.

**Desktop PC**

- **First model**: 1980
  - Area: 60,000 cubic centimeters
  - Cost: several thousand dollars
  - Power dissipation: a few hundred watts
  - Intelligence: 1 MIPS

- **Second model**: 2001
  - Area: 20,000 cubic centimeters
  - Cost: $2000
  - Power dissipation: less than 100 watts
  - Intelligence: 1,000 MIPS
  - Figure of merit: improved by four orders of magnitude
Historical Review (power)

1960s 24 volts
mid-1970s ~ early 1990s 5 volts
deep-submicron 1.5~1.8 volts
2005 0.9~1.2 volts
2008 0.6~0.9 volts

(1999 International Technology Roadmap for Semiconductors issued by the Semiconductor Industry Association)
Historical Review

( CMOS convergence )

1963  RCA developed (lower power dissipation, slower and more expensive)

1970  Hitachi (CMOS 6147 SRAM) VS Intel (NMOS 2147 SRAM)
   » the same speed, area, power win
   » Flash memory and DRAM shifted from NMOS to CMOS

1981  Hitachi 8-bit microprocessor
   CMOS 6147 speed fast 2-fold
   » microprocessors and logic devices

1990  Servers and mainframes shifted from bipolar ECL/Bi-CMOS to CMOS

CMOS will remain in the mainstream
A processor consists of several distributed functional units, each fairly simple and with a very high frequency clock. A significant part of the microarchitecture design effort will involve partitioning the processor to accommodate delays.
Architecture Innovations (cont)

- New-generation RISC microprocessors
  - The power dissipation one or two watts or less
  - less-expensive plastic packages
  - vast improvement in MIPS cost-effectiveness
  - so popular for emerging digital consumer products
Circuitry Innovations

(a) Random modulation using multithreshold voltage
(b) Minimizing leakage and maximizing speed
Conclusion

Trends in power consumption for PCs and network infrastructures based on their analysis of the total PC installations in households and businesses.

Their estimates show that Internet usage accounted for 8 percent of US electricity consumption in 1998—hence, the warning implicit in their article’s title, “Dig More Coal—The PCs Are Coming.” Energy conservation highlights the importance of reducing power dissipation in semiconductor devices and ensures that “the cooler the better” will become one of the new century’s most important catch phrases.