Computer Science Perspectives on Green Computing

CSC 5930
Computing & The Environment

Based on slides from Coastal Carolina University

Energy

• Energy is measured in Joules.
  – 1 Newton (N) is the amount of force required to accelerate a mass of one kilogram at a rate of one meter per second per second.
  – 1 Joule = 1 Newton Meter (amount of ENERGY to push an object 1 meter using the force of 1 Newton)
• In everyday life, 1 J is approximately
  – the energy required to lift a small apple one meter straight up
• The kinetic energy of a tennis ball moving at 14 mph

Power

• Power is measured in Watts
  • 1 watt (1W) = 1 Joule/second
  • Energy = Power x Time
• How we purchase power: 1 kWh = 1,000 watt hours
Power to run a small data center

- A practical example
  - One server might use 400 W
  - In 24 hours it would use 9.6 kWh
  - $0.10/kWh = $1/day (approx)
  - 500 servers = $500 per day
  - $500 for cooling = $30K/month!
- Benefits of saving energy
  - Saving energy is GREEN
  - Saving energy is cost efficient

Green Computing

Traditional Single-Processor Systems
Algorithms are a well-defined procedure to solve a problem. Some are efficient and some are inefficient

Algorithm Speed

- We measure the relative efficiency by the ORDER OF AN ALGORITHM.
- It quantifies the maximum number of steps (worst-case scenario) number of steps for that algorithm to solve a problem
- Faster, bigger computer will increase speed
Green Computer Science

- As you might imagine, less efficient algorithms take more processor time.
- Processors require system resources to run
- Efficient (faster) algorithms require the less energy to solve a problem
- We can say a green philosophy is to improve the efficiency of algorithms
- Much work in this area was done in 70s-80s

Green Computer Science

- Scanning the river bottom of the Savannah River might generate 100 GB of data.

Green Computer Science

- To process this data and find interesting things, such as certain rock formations, requires a lot of time if you only use one processor
- One thing we can do to work on huge data sets is to break a problem into pieces and parallelize the algorithm.
- OPEN RESEARCH QUESTION: If we do this, then we can hopefully solve the problem quicker and use less energy.
Using Multiple Processors

- Distributed Computing: The Internet

Parallel Computing

- Parallel Computing: Decomposing a problem to run on multiple processors

- How do we go green in this scenario?
  - Slower processors
  - Lower cost
  - End-of-life-cycle use (SLEP)

How the Internet Works - TCP/IP

- APPLICATIONS are programs we use such as email
- TRANSPORT LAYER that prepares information to be sent over the network in packets, and on the other end, reassembles the packets
- INTERNET LAYER handles the addressing to make sure packets get to their correct destination
- CLIENT/SERVER model – a SERVER stores and sends information to requesting browsers (CLIENTS)
Environmentally Friendly Web Hosting

• Business Policies
  – Donating part of the revenues to green causes
  – Use solar power or wind-power to keep the operation running
  – REDUCE-REUSE-RECYCLE philosophy

• Who are some of these companies?
  – www.solarenergyhost.com
  – www.thinkhost.com
  – www.ipage.com (wind-powered web hosting)

3R’s - Reduce

• Virtualization: Duplicating hardware with software
• Important in Cloud Computing

3R’s - Reuse

• TCP Multiplexing
• Create a number of fixed open TCP channels and allow them to remain open to be reused (so we do not have the overhead of frequent creation and destruction to handle many TCP short requests)
3R’s - Recycle

- Application Accelerator
- Handle SSL encryption with a dedicated piece of hardware to specialize in one task and do it very well

Data Centers

- Large collections of servers that generate heat
- Frequently, the cost of cooling a data center is more than the cost of heating it, because heat is naturally generated
- Google and Amazon are looking into putting large data centers in northern Canada and Greenland (Northern hemisphere)

Virtualization

- Realizing a piece of hardware such as a web server or file server in software rather than hardware
- Writing a program that does the same exact thing as a piece of hardware
- Savings
  - Manufacturing
  - Servicing
  - Disposal
  - Power
Types of Virtualization

- **Operating System**
  - EX: Running Linux inside of VMware
  - EX: Running Windows on a Mac
  - EX: Running VM images in a cloud
- **Application Server (Load Balancing)**
  - Dividing a high volume of requests to different servers
- **Applications**
  - Thin Client concept (Google Apps)
- **Management**
  - Managers see a different view/permissions than others

Types of Virtualization

- **Network**
  - VLANS, or secure virtual networks partitioned on public networks
- **Hardware**
  - Allocating percents of a system to different tasks (such as encryption or searching such as Google Search Appliance) to gain efficiency
- **Storage**
  - Seeing a file system but not knowing (or caring) where the files are physically stored (perhaps in many locations)

Green Effects of Virtualization

- VMware publishes numbers that say between 50-70% can be saved from virtualization
- The Gartner group says that the energy savings of jobs running VMware alone will power all of New England! (they give no actual rates or metrics but this is an interesting claim)

- Who is doing this?
  - The USDA used virtualization to reduce/consolidate 255 servers into 22!
  - 4 Years ago, Los Alamos National Laboratories undertook a virtualization project that decommissioned 100 servers, resulting in the use of only 13. This has resulted in a savings of almost $1.5 Million dollars
Cloud Computing Architecture
Virtualization technologies combined in practical use
- Image repository
- Servers (application servers and storage)
- SAN (storage area network) switch
- Cloud manager
- Portal server

Cloud Computing Philosophies
- Microsoft
  - 3 screens (PCs, Mobile devices and consumer services) and the cloud
- Google
  - Everything is to be published and interconnected so it can all be
    - Indexed
    - Searched
    - AdWord-ized

Web Science
- Tim Berners-Lee
- Study of decentralized information systems
  - Semantic web
  - Web services
  - Web-scale computing
- A shift from "traditional" computing topics
CS – vs – WS: Metrics

- CS Metrics
  - Moore's Law
  - Order of algorithms
  - Capacity (MB, GB, TB, etc.)
- WS Metrics
  - Page Views
  - Unique visitors over a time period
  - Number of files/downloads

CS – vs – WS: Topics

- CS Topics
  - Computer networks
  - Packet switching
  - Relationships
  - Programming Languages
  - Databases, operating systems, compilers
- WS Topics
  - Social networks
  - VOIP, file sharing
  - Relationships
  - Wikis, blogs and tagging
  - Ecommerce, Elearning, Egovernment, medical informatics

CS – vs – WS: Applications

- CS Applications
  - Technology
  - Computers
  - Supercomputers
  - Programming
- WS Applications
  - Applications and their use
  - Users
  - Mobile devices
  - Usability
Green Web Science

- Measuring energy management
- More efficient server use and metrics (Example: virtualization has INCREASED the number of servers without increasing the manufacture of hardware
- Better design of data centers, measuring efficiency and cost savings
- Providing and measuring flexible resource allocation with cloud computing
- Monitoring and tracking energy usage (XML)
- Bandwidth conservation and measurement

Green Web Science Metric Focus

- Measuring energy savings
- Measuring cost savings
- Measuring increased productivity
- More access to technology through virtualization and mobile devices
- Measuring increased popularity of the Eworld
- Increased communication through blogs, wikis, etc

Example: Measuring Energy

- AMEE (Avoiding Mass Extinctions Engine): amee.com

  - Users create a front end web page which takes data from a user
  - Data is sent (XML format) to AMEE API
  - Calculations are performed to determine the amount of carbon dioxide emitted
  - This can be displayed on a webpage
Measuring Energy (2)

- **HOW TO:** Simply visit www.amee.com, sign up and get an API key
- **EXAMPLE:**
  - Usage information: a user might tell you that they drive 1000 km in a large, diesel car every month.
  - Emission factor: AMEE has stored the data item 2.6391 kg CO2/litre - the emission factor
  - Calculation: using the API, AMEE will return a value telling you that this emits 264.5 kg CO2 per month.
- **PRACTICAL EXAMPLE**
  - Current Cost energy meter (ENVI)
  - Generates data in the AMEE XML format

Measuring Energy (3)

- **FOR MORE INFORMATION**
  - Introduction to AMEE: Embed environmental intelligence into your applications by James Smith of AMEE, found at http://www.ibm.com/developerworks/xml/library/x-ameeintro/
  - The WIKI found at explorer.amee.com