VLSI Design Through Open-Source / Free Tools

Elias Kougianos[1], Saraju P. Mohanty[2], Priyadarsan Patra[3]

NanoSystem Design Laboratory (NSDL), University of North Texas, USA.[1,2]

Intel Corporation, USA.[3]

Email: priyadarsan.patra@intel.com[3], saraju.mohanty@unt.edu[2] , elias.kougianos@unt.edu[1]

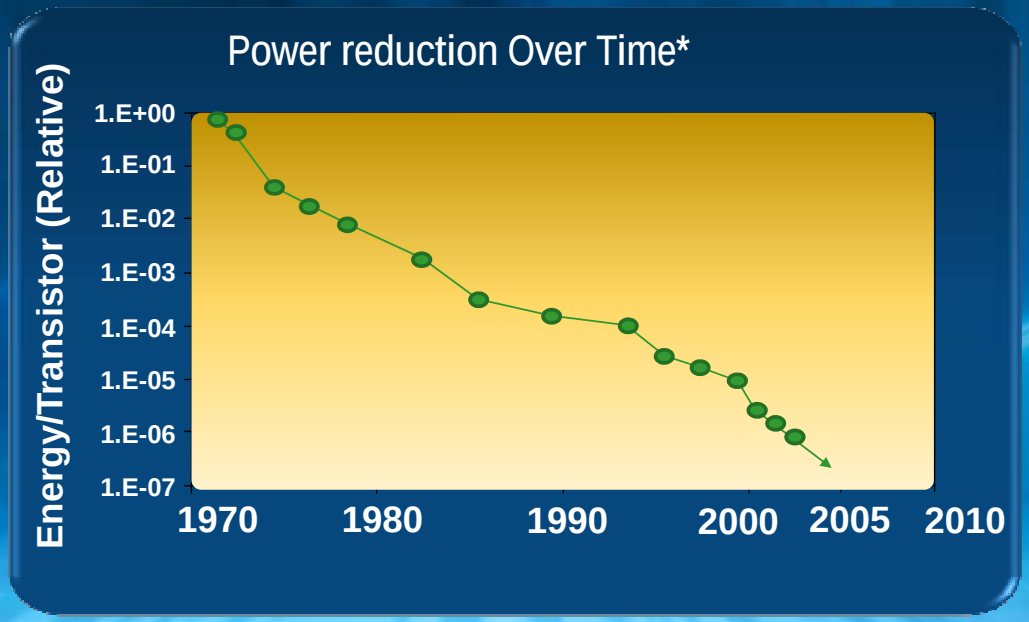
Acknowledgment: This research is supported in part by NSF awards CCF- 1054975 and DUE-0942629.

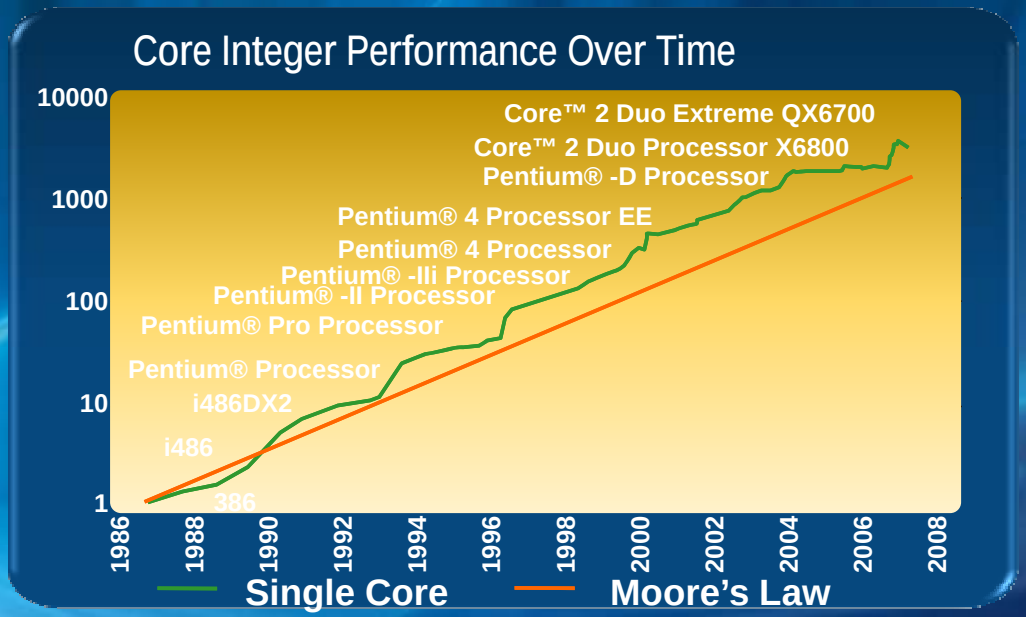
Outline of The Talk

- State-of-the-Art in Computing
- Open Source Softwares
- Open Source or Free VLSI Softwares
- Hardware/Software Platform Alternatives
- VLSI Design and Simulation Flow
- Individual CAD tools and Web Resources
- Summary and Conclusions

Computing -- State of the Art

(1) Continuum of Transistor Performance and Power





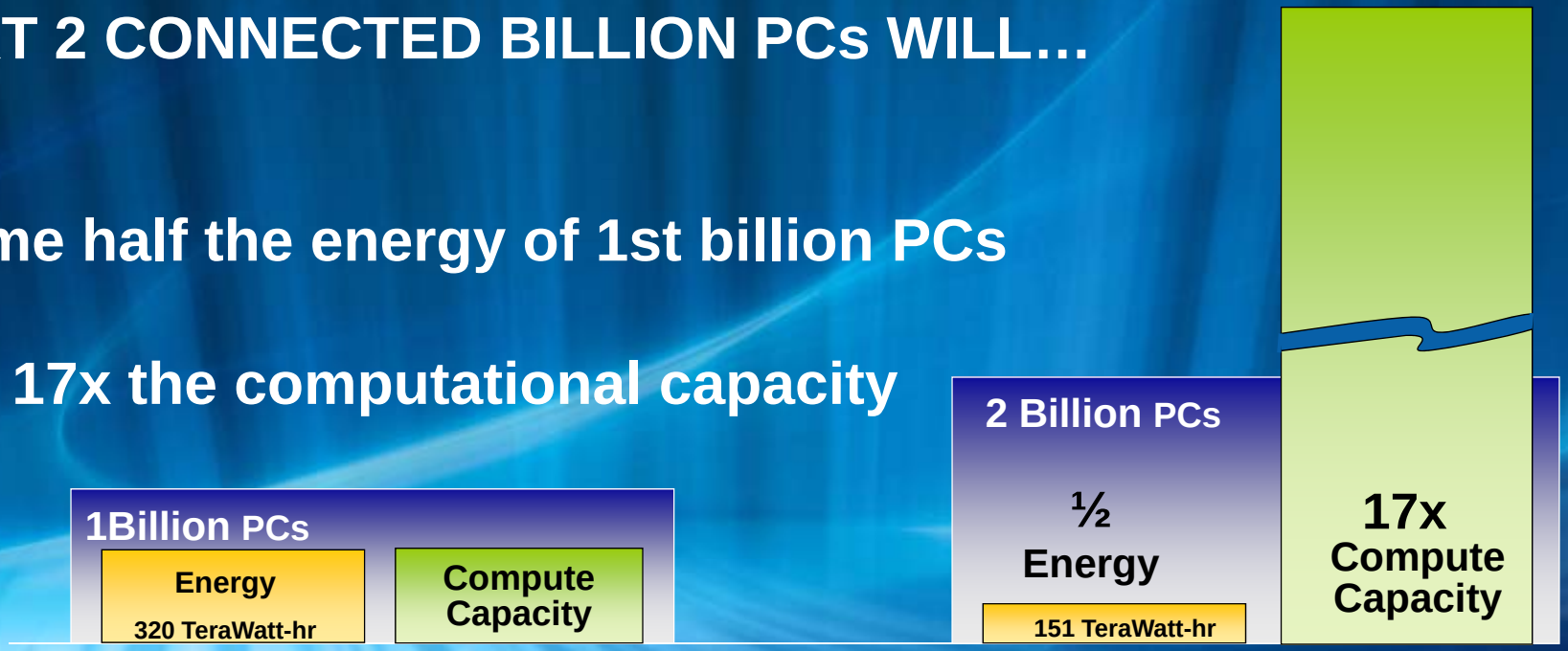
~ 1 Million Factor Reduction In Energy/Transistor Over 30+ Years Delivering Great Performance Within Power Envelope

Compute Energy Efficiency ➔ Positive Impact On Environment

COMPARED TO THE FIRST BILLION PCs INSTALLED THE NEXT 2 CONNECTED BILLION PCs WILL…

…consume half the energy of 1st billion PCs

…deliver 17x the computational capacity



Source: Intel Microprocessor Marketing and Business Planning

(2) Computing Device Continuum

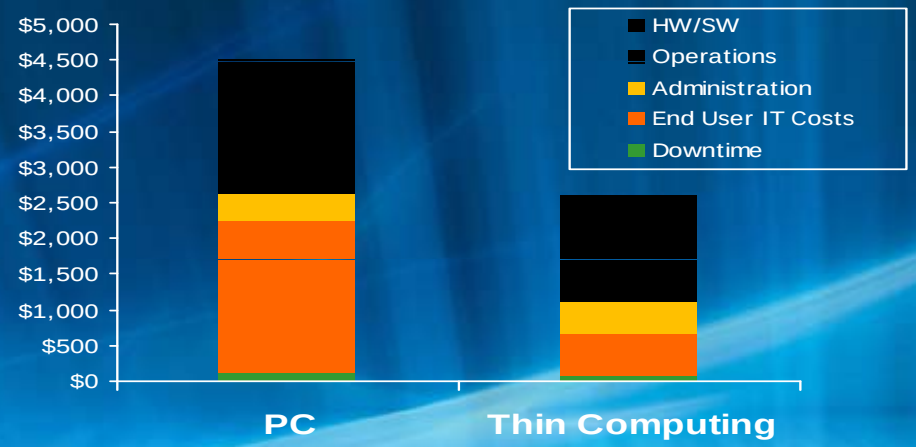
Explosion of Internet Growth & Services

	Today		2015
More Users	Only 25% of the world is Internet connected today[1]		New technologies will connect over 1 billion additional users to the cloud[2]
More Devices	~80% of Internet connected devices are computers & phones[3]		Cars, TVs, households, etc. to increase connected devices up to 2.5x to >10 billion globally[3]
More Content	2.5B photos on Facebook[4] 30B videos viewed/mos[5] Google indexes >1T pages[6]		Up to 8X network, 16X storage & 20x compute capacity needed[7]

What addresses the "bottom of the pyramid" billions?

Thin Computing Potential

Cost Benefits



40 % Reduction HW and SW costs

29 % Reduction IT operations costs

88 % Reduction worker downtime

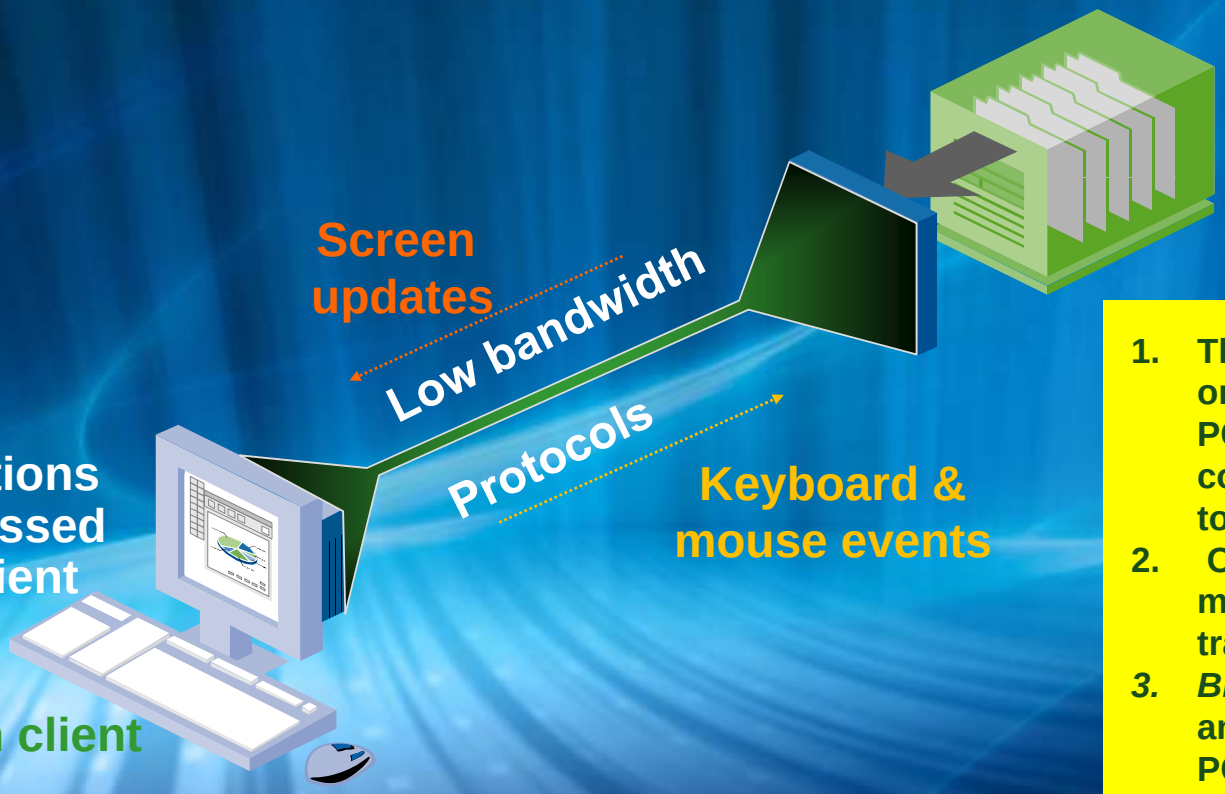
78 % Increase IT staff productivity

Business Benefits

- Security / Privacy
- Compliance
- Manageability
- Reliability
- Rapid Deployment
- Power / Noise / Cooling

Source: Gartner Inc (8/05), IDC (11/05), and Wyse Estimates

Thin Clients in a Virtualization Environment



Servers: Applications & data reside on
- Server (server-based computing)
- Virtual PC
- Blade PC

1. The application running remotely on server, virtual PC, or blade PC, the graphic is captured, compressed, encrypted and sent to the thin client.
2. On thin client, the keyboard and mouse events are captured and transmitted to the server.
3. *Brokers* (HP) are used to allocate an available virtual PC or a blade PC to a thin client.

IT Challenges Faced by Business, Government and Organizations

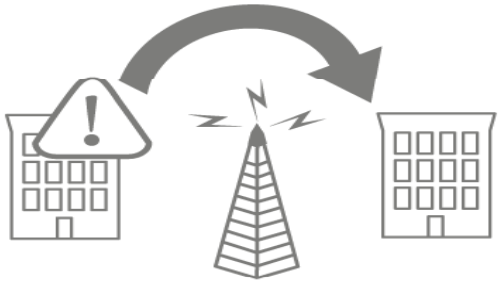
Compliance and Security

Need for preventative/proactive measures

- Data theft
- Virus/malware
- Phishing
- Hacking

Outsourced and offshore teams

Business continuity and disaster recovery



Diverse Workforce

- Office
- Corporate office
- Working from home
- Mobile employee

Heterogeneous hardware

- Desktops
- Laptops
- Multiple vendors
- Different refresh cycles

Go green

Characteristics of Clouds

Characteristic: Enterprises incur no infrastructure capital costs, just operational costs incurred on a pay-per-use basis, with no contractual obligations

Characteristic: Architecture specifics are abstracted. Run in multi-tenancy mode with multiple users accessing simultaneously

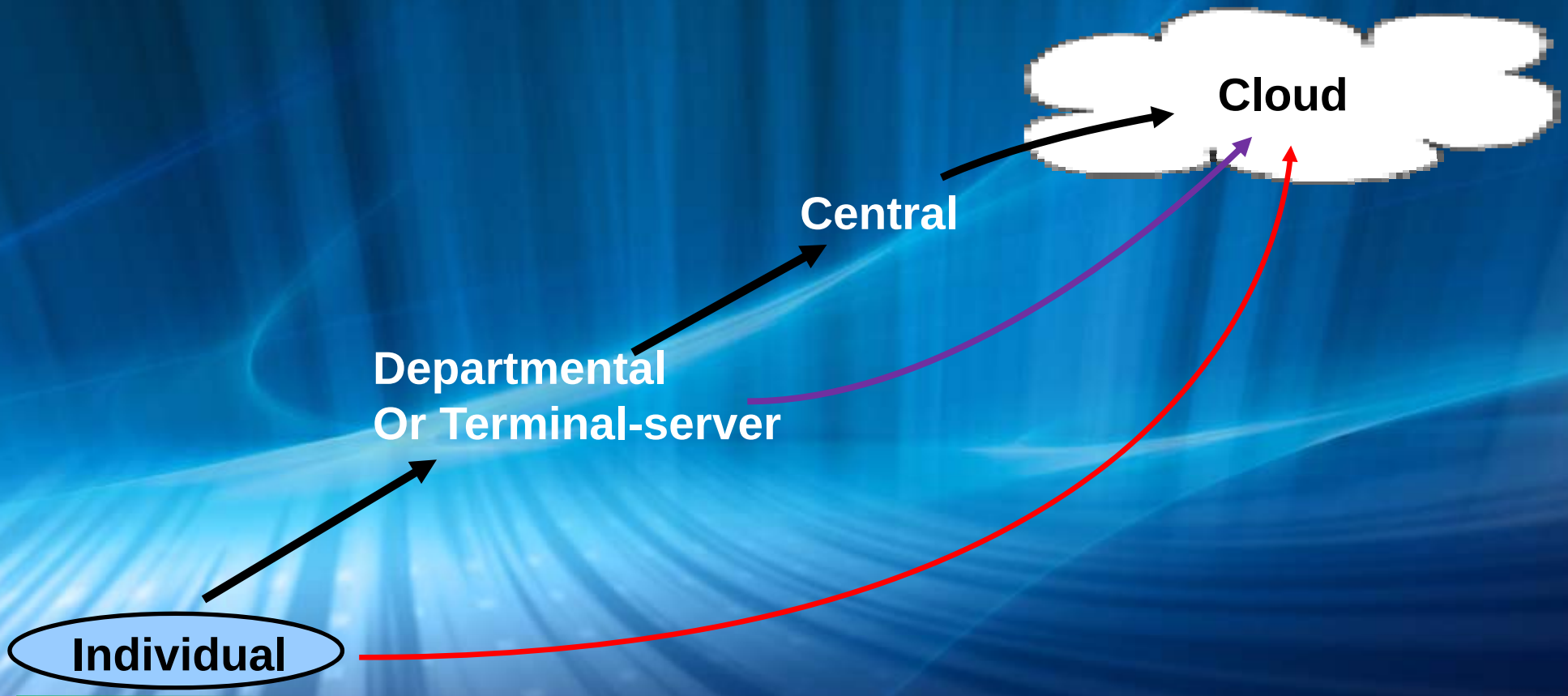
Definition: Clouds are hardware-based services offering compute, network and storage capacity where:

1. **Hardware management is highly abstracted from the buyer**
2. **Buyers incur infrastructure costs as variable OPEX**
3. **Infrastructure capacity is highly elastic (up or down)**

Characteristic: Capacity can be scaled up or down dynamically, and immediately,

Characteristic: The underlying hardware can be anywhere geographically

(3) Infrastructure Continuum: IT priesthood to Consumer Computing



Cloud Computing – Benefits

- Reduce capital expenditures
- Low barrier to entry
- Scalable infrastructure
- Cost-effective – Pay for what you use
- Acquire resources on demand
- Release resources when not needed
- Virtually infinite compute and storage resources
- Turn organization's fixed cost into variable cost
- *May* improve security
- Professional Patch management and managed services

Intel Cloud 2015 Vision

Federated
Data and services seamlessly and securely span clouds

Automated
Dynamically allocates resources to manage service level and optimize power

Client Aware
Secure access and optimal experience across the client continuum





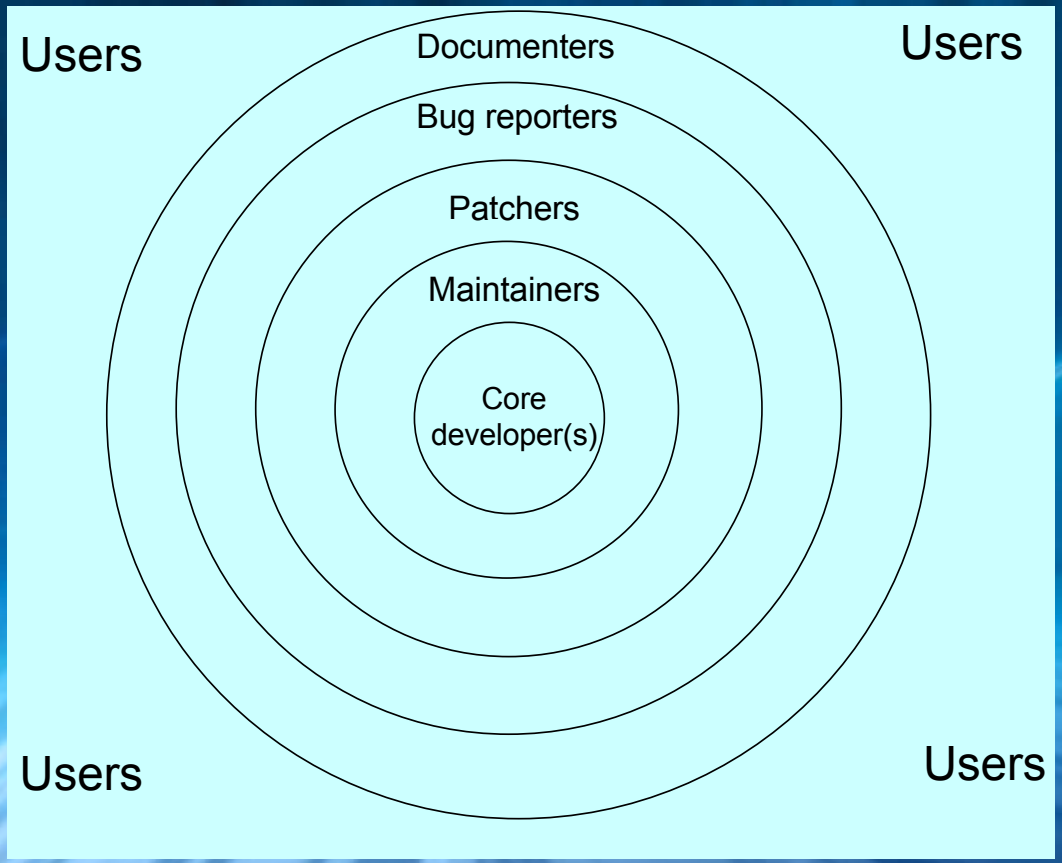




Desktops Laptops Netbooks Personal Devices Smartphones Smart TVs Embedded

Open Source Softwares

Open Source Software Development



Open Source! -- Some Milestones

- 1970s: UNIX operating system developed at Bell Labs with contributors outside of the Labs; later AT&T enforces intellectual property rights and “closes” the code
- 1983: Richard Stallman founds the Free Software Foundation
- 1993: Linus Torvalds releases first version of Linux built
- 1997: Debian Free Software Guidelines released
- 1998: Netscape releases Navigator with source
- 2000: OpenOffice by Sun

Examples of Open Source Software

- Internet
  - Apache, which runs over 50% of the world's web servers.
  - BIND, the software that provides the DNS (domain name service) for the entire Internet.
  - Sendmail, the most important and widely used email transport software on the Internet.
  - Mozilla, the open source redesign of the Netscape Browser
  - OpenSSL is the standard for secure communication
- Tools, Languages
  - Perl, Python, Tcl/Tk; GCC, Make, Autoconf; Zope, PHP; etc.

Open Source Software Sites

- Free Software Foundation www.fsf.org
- Open Source Initiative www.opensource.org
- Freshmeat.net
- SourceForge.net
- OSDir.com
- developer.BerliOS.de
- Bioinformatics.org
- www.apache.org or www.cpan.org
- http://www.gpleda.org/

A Few Open-Source Project Ideas

- EduTainment Software
- Windows Terminal Services Clone
- New Desktop / Microcontent Client / Web Services Browser
- Social Software: Blogs, Wikis, People Networks
- Local Language Software and Applications
- RSS-based Information Marketplace
- Outsourced Linux Support / Development Centre
- Open Office Call / Support Centre
- Tool for Business Applications and Process Management
- **Open Source VLSI (We will focus next)**

Open Source VLSI

Why Open Source or Free CAD / EDA

- Integrated circuit EDA tools are prohibitively expensive.
- A complete set of tools (through one license) for front and back end IC design costs hundreds of thousands of dollars.
- In addition, the computing and licensing servers (or platforms) in which they are parked are expensive.
- The skilled man power as a CAD engineer and IT support needed to maintain such facility is quite expensive.
- This cost is prohibitive and creates a serious discrepancy between the education of students from schools that can afford the software and those that cannot.

Open Source / Free EDA Tools

- **Electronic Design Automation (EDA) tools are used for**
  - logical design, schematic design, layout generation, design check and to **simulate circuits and systems**
- **Open Source EDA**:
  - Source code is free. Early examples : Electric, Magic
  - gEDA www.gpleda.org
  - Alliance www-asim.lip6.fr/recherche/alliance
  - Free Electronic Lab (Fedora based)
- **Free EDA**:
  - Free to use, but only executables available
  - LTspice is one example

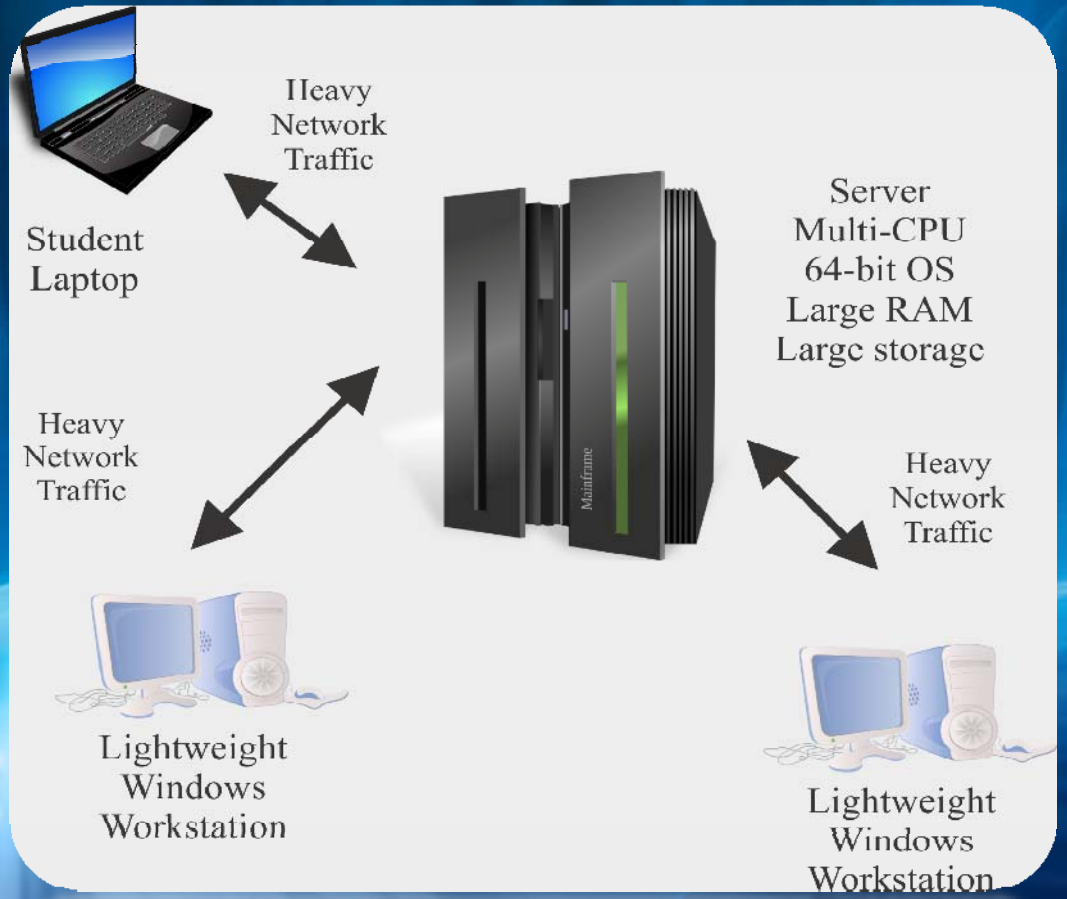
Selection of Hardware Platform

- The selection of platform is simple: x86-based personal computers are used. Their ubiquitous presence, ready availability and low-price make them the obvious choice.
- Two options for computational model:
  - Client-Server Model
  - Workstation-Only Model
  - Mixed-Mode Model

Selection of Software Platform

- Several factors affect the choice of operating system including the following:
  - Whether the environment will be client-server or workstation only.
  - Whether there is a dedicated lab available or general access labs are used.
  - Whether the software running on the server and the workstations will be 32 bit or 64 bit.

Client-Server Model of Lab Setup



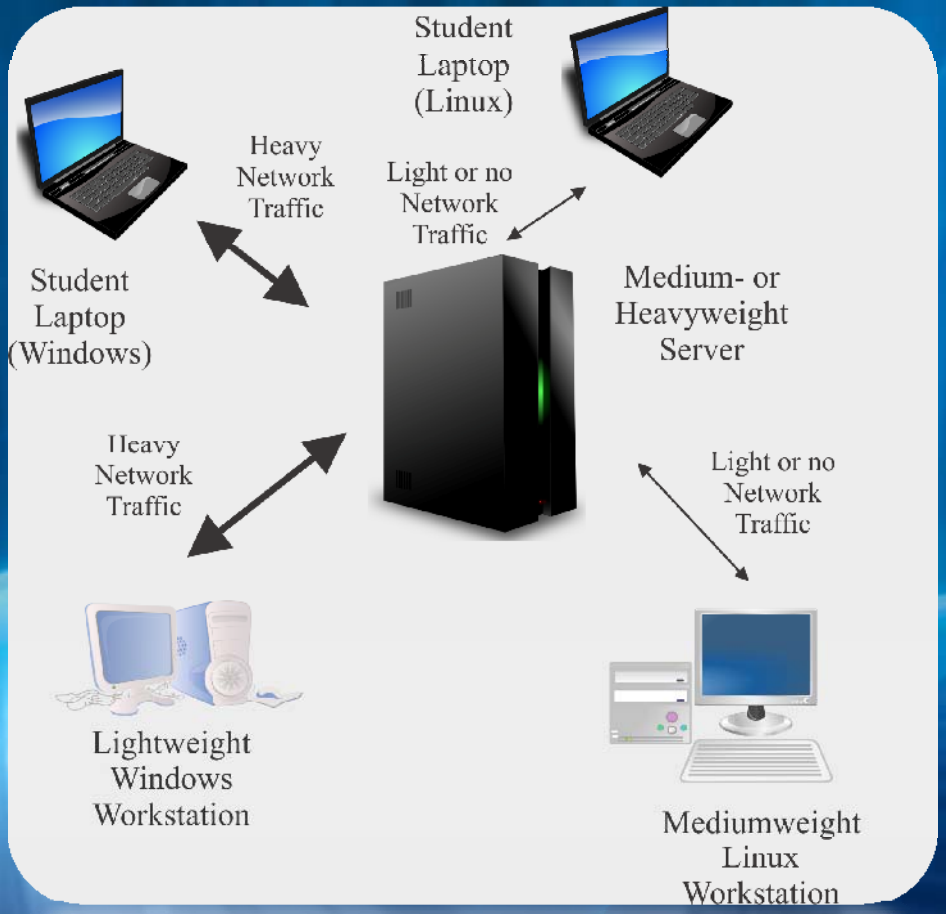
Client-Server Model of Lab Setup

- The vast majority of open source/free EDA/CAD tools have their roots in older, Unix-based projects, the operating system (OS) on the server side should be a variant of Unix.
- Due to the popularity of Linux, it is chosen as the server OS.
- A problem with Linux is the bewildering array of available distributions. The Community Enterprise Operating System (CentOS) version 5.5 was chosen due to its robustness, extremely wide support, frequent updating, and open source.
- The client side OS choice is more critical. There are two realistic alternatives: Microsoft Windows or Linux.

Workstation-Only Model of Lab Setup

- If a GAL is not available or if a lab is dedicated to the course projects but cost and maintenance associated with a server cannot be justified, a workstation-only model can be used.
- Each individual workstation must be responsible for user authentication, local working storage and tool execution.
- Since the tools will be running locally, a 32 or 64 bit (depending on available memory) version of Linux is installed.
- The workstation can be running CentOS or an EDA-specific version of Linux, the Fedora Electronic Lab.

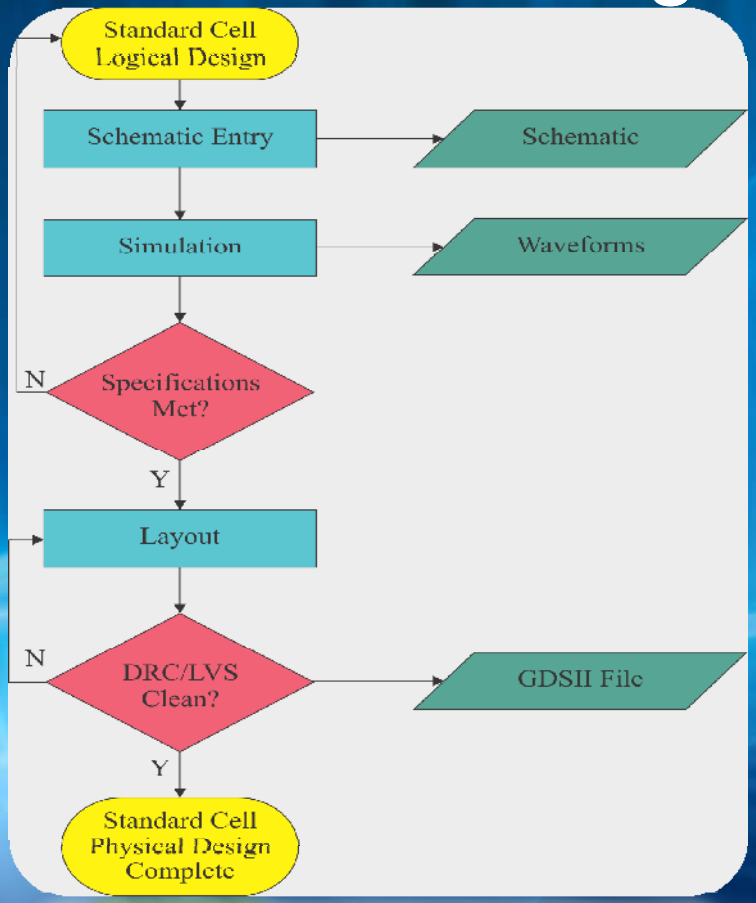
Mixed-Mode Model of Lab Setup



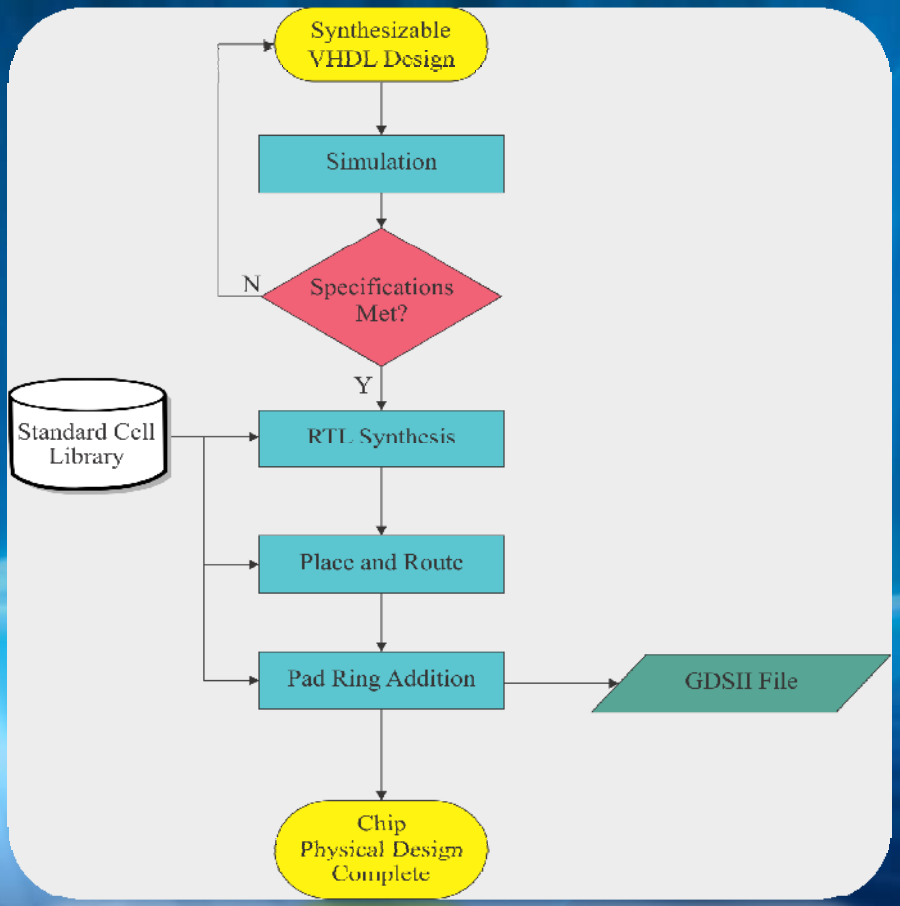
Mixed-Mode Model of Lab Setup

- In this usage model the server handles authentication and storage but the execution of the tools can take place locally, on the workstation, or remotely, on the server.
- The home directories of the students are also mounted, upon login, to the local workstation via NFS, or, if the workstation functions in “dumb terminal” mode, they can be on the server.
- Similarly to workstation-only model, the local machines run a Linux as the OS, but Windows PCs with Xming can be used.
- Laptops with right softwares can be part of the system.

Front-End of the Design Flow



Back-End of the Design Flow



Open Source or Free Tools: Schematic Entry

- An effective and programmable schematic entry tools is XCircuit.
- It allows schematic entry and automatic hierarchical SPICE netlist generation.
- The schematics can be exported in publication-quality postscript code which is useful when the students compose their project report.
- XCircuit is actively being developed with frequent releases and is part of most Linux distributions.

Open Source or Free Tools: Analog Simulation

- From the numerous variants available, ngspice is chosen due to its active development, improved stability and support of the BSIM 4.6.5 model which is necessary for effective nano-CMOS transistor level simulation (including gate leakage).
- Equally important is the availability of SPICE models that reflect current nano-CMOS technology capabilities.
- We use the Predictive Technology Model (PTM) which can be tailored to various technology nodes and processes.
- Postprocessing of the SPICE simulation results is done through the graphical waveform viewer GTKWave.

Open Source or Free Tools: Layout

- There are four major open source projects addressing the needs of IC layout: the venerable Magic, Toped, LayoutEditor and graal, which is part of the Alliance VLSI toolset.
- The choice is left on the individual instructor as long as the tool can export GDSII streams.
- We use Magic and graal since they support LVS (Layout vs. Schematic) and DRC (Design Rule Checking).

Open Source or Free Tools: Back-End

- Microwind is supported by two textbooks, but does not cover the back-end, is not open source and is Windows only.
- The back-end is the weakest link in open source EDA.
- Essentially there are two solutions but only in the form of integrated frameworks: Electric or Alliance VLSI system.
- Electric is fully integrated which means that establishing a flow with individual tools is difficult or impossible.
- Alliance VLSI system consists of a large number individual tools that cover complete front-to-back standard cell design.

Tools of Alliance VLSI System

- Hierarchical layout with DRC and LVS.
- Graphical Finite State Machine (FSM) entry, minimization and synthesis.
- VHDL simulation (including customized C modules) with waveform viewer.
- VHDL to Register Transfer Level (RTL) synthesis and optimization.
- Standard cell placement and routing.
- Routing for pads.

Summary and Conclusions

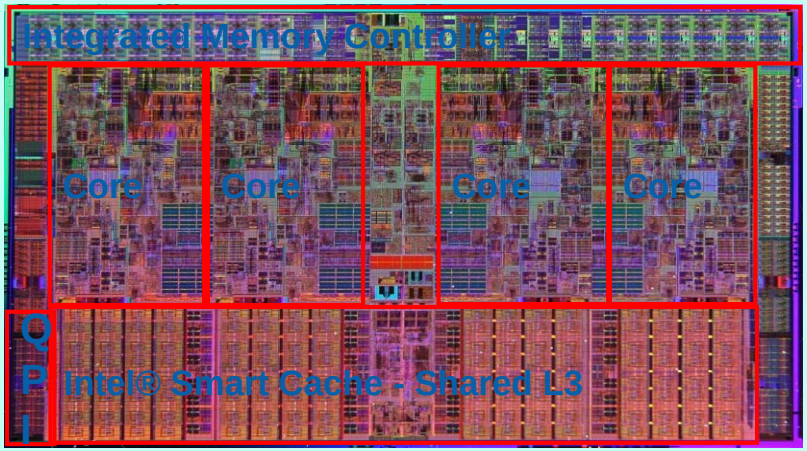
- Computing infrastructure is moving in the direction of cloud computing with the help of virtualization.
- Open source softwares have come a long way since their inception in 1970s and available in many areas including VLSI.
- We presented a conceptual organization of a digital, standard-cell based VLSI design flow using open source or free tools.
- The flow can be adapted to be part or the core of a one to two semester VLSI design course.
- The front-end uses traditional open source simulation and layout EDA tools while the backend is part of the open source Alliance VLSI system and allows for full customization.

References

- S. P. Mohanty, N. Ranganathan, E. Kougianos, and P. Patra, *Low-Power High-Level Synthesis for Nanoscale CMOS Circuits. Springer, 2008.*
- E. Sicard and S. D. Bendhia, *Basics of CMOS Cell Design. McGraw*-Hill, 2007.
- Magic VLSI layout tool, http://opencircuitdesign.com/magic/.
- Toped IC layout editor, http://www.toped.org.uk/.
- Alliance VLSI CAD, http://www-asim.lip6.fr/recherche/alliance/.
- Electric VLSI system, http://www.staticfreesoft.com/.
- OpenCores, http://opencores.org/projects.


Thank You

Example : Industry's First Dynamically Scalable Microarchitecture



Nehalem-EP

Performance/Features:

- Up to 4 cores with On-chip Shared Cache
- **Intel® QuickPath Interconnect**
- **Intel® Turbo Boost Technology**
- **Integrated Memory Controller**
- Intel Hyper-Threading Technology
- New multi-media and RMS Instructions
- Fully Unlocks Intel 45 nm High-k Silicon Benefits

Delivering the Next Generation of Energy Efficient Performance