CSE 333

Lecture 1 - Systems programming

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Welcome!

Today's goals:

- **introductions**
- *big picture*
- *course syllabus*
- *setting some expectations*

Us

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James Athappilly

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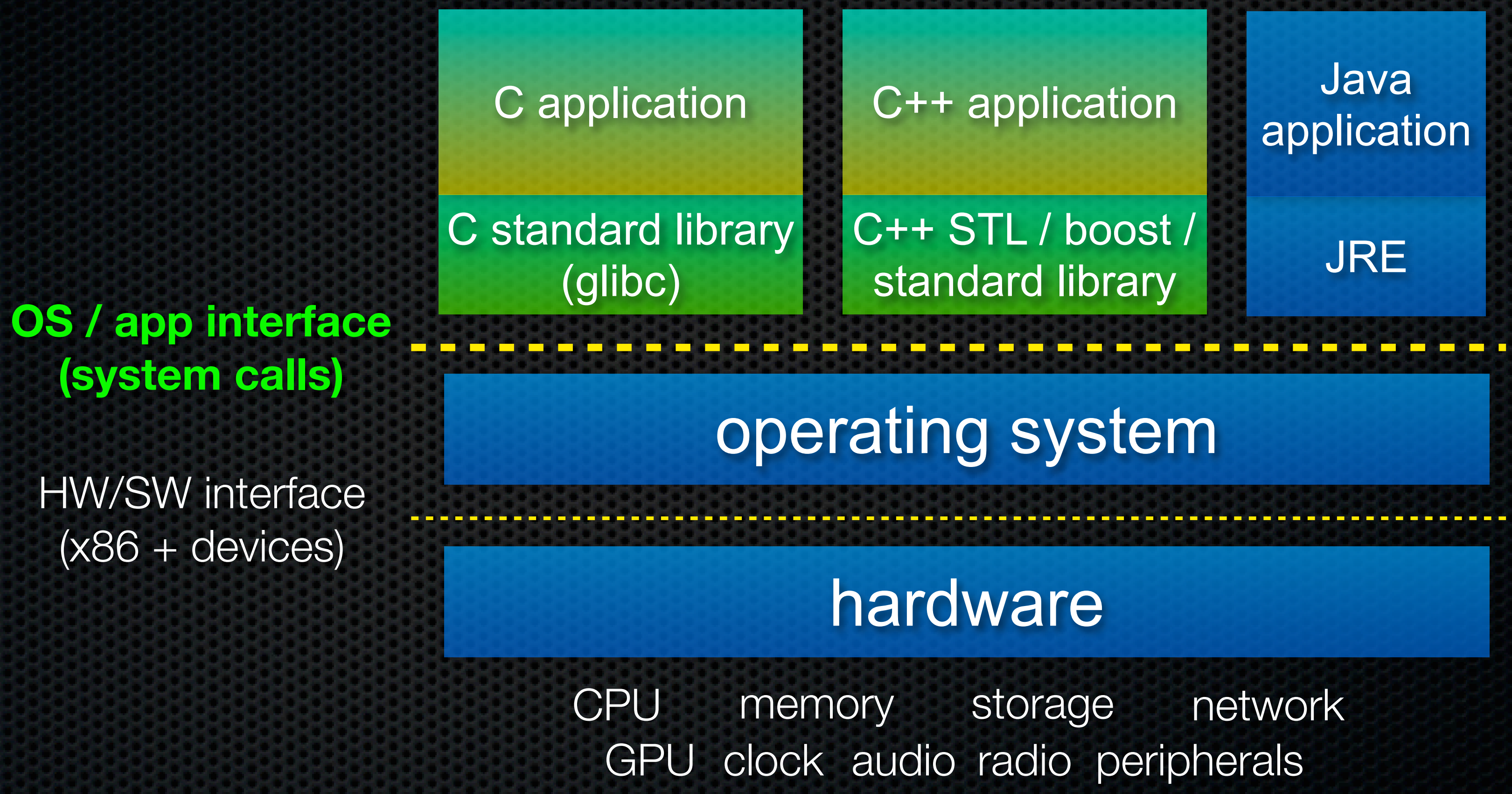
Course map: 100,000 foot view



C application

C standard library (glibc)

C++ application

C++ STL / boost / standard library

Java application

JRE

OS / app interface (system calls)

operating system

HW/SW interface (x86 + devices)

hardware

CPU memory storage network

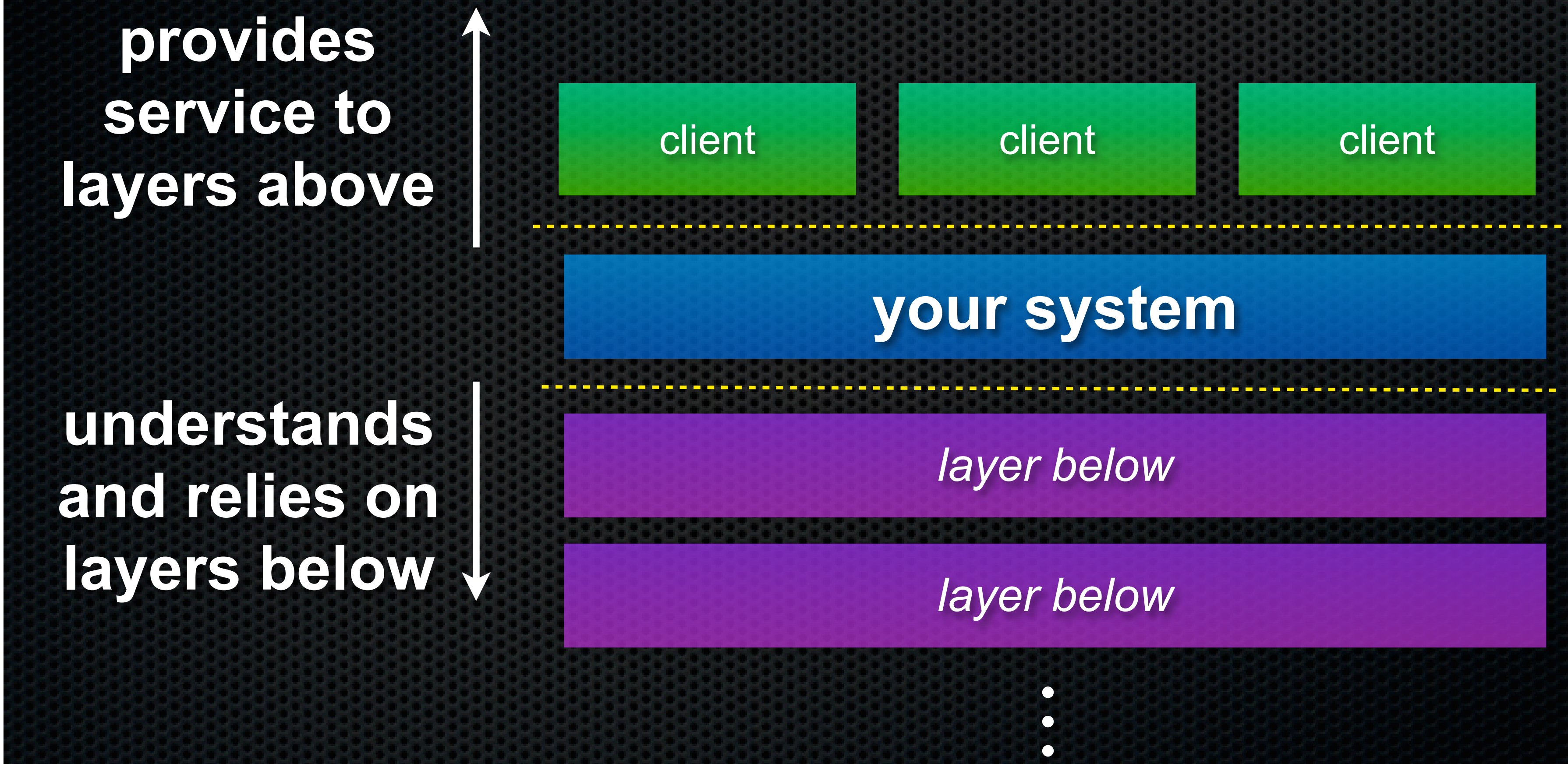
GPU clock audio radio peripherals

Software "System"

A platform, application, or other structure that:

- is composed of multiple modules
  - the system's **architecture** defines the *interfaces of* and *relationships between* the modules
- often is complex
  - in terms of its implementation, performance, management
- hopefully has requirements
  - performance, security, fault tolerance, data consistency

A layered view



provides service to layers above

client

client

client

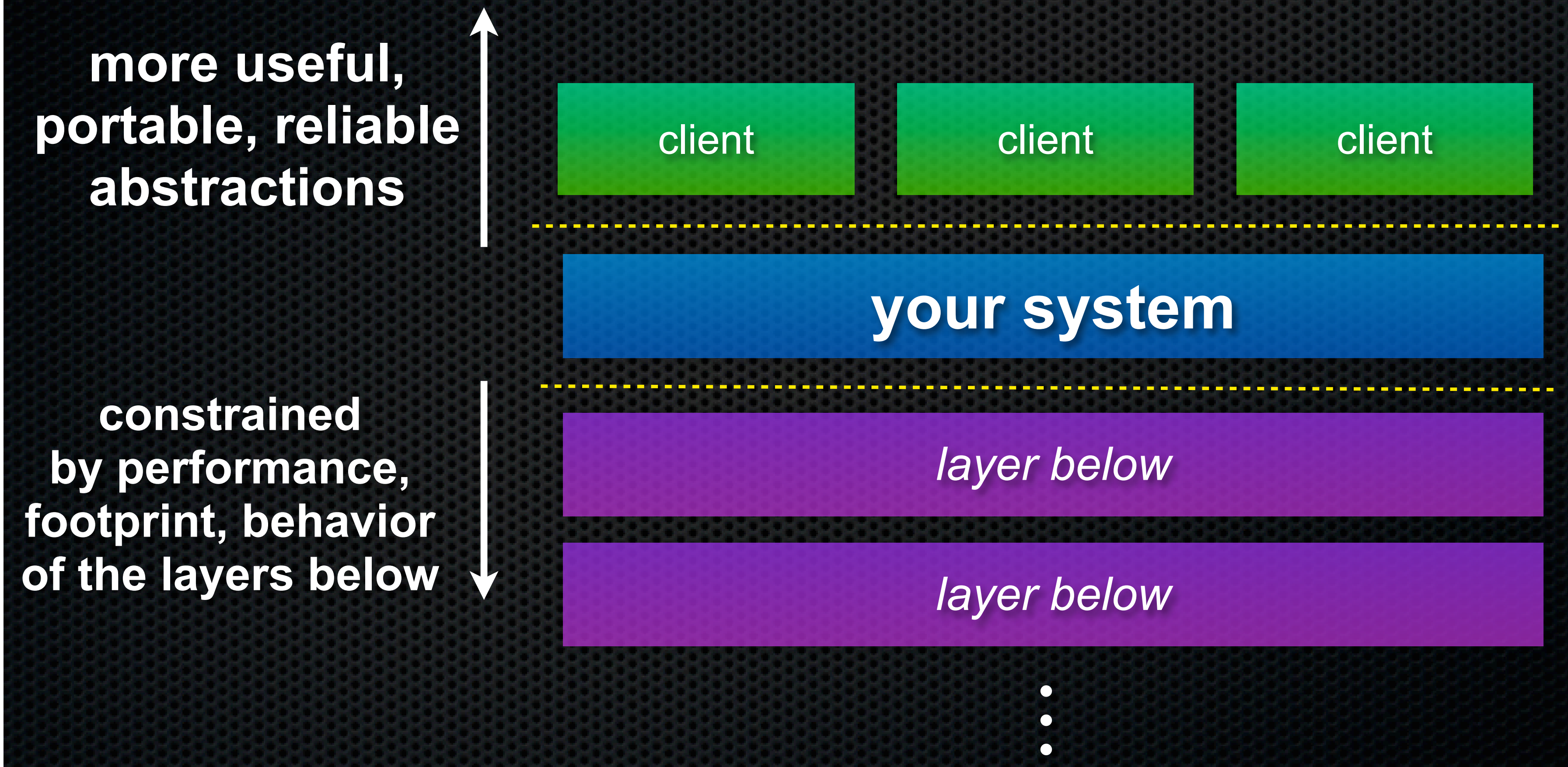
your system

understands and relies on layers below

layer below

layer below

A layered view


more useful, portable, reliable abstractions
client
client
client
your system
constrained by performance, footprint, behavior of the layers below
layer below
layer below

Example system

Operating system

- a software layer that abstracts away the messy details of hardware into a useful, portable, powerful interface
- modules:
    - file system, virtual memory system, network stack, protection system, scheduling subsystem, ...
    - each of these is a major system of its own!
- design and implementation has tons of engineering tradeoffs
    - e.g., speed vs. (portability, maintainability, simplicity)

Another example system

Web server framework

- a software layer that abstracts away the messy details of OSs, HTTP protocols, and storage systems to simplify building powerful, scalable Web services
- modules:
  - HTTP server, HTML template system, database storage, user authentication system, ...
- also has many, many tradeoffs
  - programmer convenience vs. performance
  - simplicity vs. extensibility

Systems programming

The programming skills, engineering discipline, and knowledge you need to build a system

- ***programming***: C / C++
- ***discipline***: testing, debugging, performance analysis
- ***knowledge***: long list of interesting topics
  - concurrency, OS interfaces and semantics, techniques for consistent data management, algorithms, distributed systems, ...
  - most important: deep understanding of the “layer below”
    - *quiz: how many copies of your data are made when you use the read( ) system call to read from a file?*

Programming languages

Assembly language / machine code

- *(approximately)* directly executed by hardware
- tied to a specific machine architecture, not portable
- no notion of structure, few programmer conveniences
- possible to write really, really fast code
- necessary for a few critical parts of the operating system
- extraordinarily painful and fragile

Programming languages

Structured but low-level languages (C, C++)

- hides some architectural details, is mostly portable, has a few useful abstractions like types, arrays, procedures, objects
- permits (forces?) programmer to handle low-level details like memory management, locks, threads
- low-level enough to be **fast** and to give the programmer **control** over resources
  - double-edged sword: low-level enough to be complex, error-prone
  - a useful shield: engineering discipline

Programming languages

High-level languages (Python, Ruby, JavaScript, ...)

- focus on productivity and usability over performance
- powerful abstractions shield you from low-level gritty details (bounded arrays, garbage collection, rich libraries, ...)
- usually interpreted, translated, or compiled via an intermediate representation
- slower (by 1.2x-10x), less control

Discipline

Cultivate good habits, encourage clean code

- coding style conventions
- unit testing, code coverage testing, regression testing
- documentation (code comments, design docs)
- code reviews

Will take you a lifetime to learn

- but oh-so-important, especially for systems code
  - avoid write-once, read-never code

Knowledge

Tools

- gcc, gdb, g++, objdump, nm, gcov/lcov, valgrind, IDEs, race detectors, model checkers, ...

Lower-level systems

- UNIX system call API, relational databases, map/reduce, Django, jQuery, ...

Systems foundations

- transactions, two-phase commit, consensus, RPC, virtualization, cache coherence, applied crypto, ...

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C / C++ programming

Major focus of this course

- ~2 weeks of diving deeper into C
    - review some material from 351 and go deeper
- ~4 weeks of a (sane subset) of C++
- exposure to programming tools
    - unit testing frameworks, performance profiling and analysis, revision control systems

Interacting with UNIX and standard libraries

The "layers below" we will be relying on

- learn C's standard library and some of C++'s STL
  - including memory management (malloc/new, free/delete)
  - we'll look at some of C++11 and boost
- learn aspects of the UNIX system call API
  - I/O: storage, networking
  - process management, signals

Potential additional topics

Concurrency

- threads
- perhaps asynchronous I/O and event-driven programming

Security

- will be mindful of security topics as they come up
- e.g., how to avoid buffer overflow issues in C/C++

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What you will be doing

Attending lectures and sections

- lecture: ~29 of them, MWF in this room
- sections: ~10 of then, Thu (8:30, 9:30, or 12:30) in MGH

Doing programming projects

- ~4 of them, successively building on each other
- includes C, C++; files, networking

Doing programming exercises

- one per lecture, due before the next lecture begins
- coarse-grained grading (0 or 1)

Requirements

CSE351 is a prerequisite

- I assume you have just a little exposure to C
- I assume you know what a linked list, tree, hash table is

You need access to a CSE linux environment

- undergraduate labs, ssh into `attu.cs`, use CSE home VMs

Textbooks

Required:

- Computer Systems, A Programmer's Perspective ("**CSAAP**")
    - [2nd Ed]. CSE351 textbook; do you already have it?

Recommended (strongly):

- C: A Reference Manual ("**CARM**") [5th Ed]
- C++ Primer ("**C++P**") [5th Ed]

Optional (but cool):

- Effective C++ [3rd Ed]

Collaboration

Some of the projects will be individual, some in teams

- assume individual unless explicitly stated otherwise

Cross-team collaboration is useful and expected

- help other teams with programming fundamentals, concepts

Plagiarism and cheating is verboten

- helping other teams with assignments, debugging their code
- relying on help without attributing in your writeups

For Wednesday

Homework #0 is due (a short survey):

- https://catalyst.uw.edu/webq/survey/gribble/162610

Exercise 0 is due

- http://www.cs.washington.edu/education/courses/cse333/exercises/ex0.html

See you on Wednesday!