CS 3204
Operating Systems

Lecture 40
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Announcements

• Project 4 due Wed, May 3, 11:59pm
• Read chapter 13 (networking)

Networking

(Most slides from Kurose/Ross: Computer Networking – A Top Approach Featuring The Internet)

traceroute

Provides delay measurement from source to router along end-end Internet path towards destination

• Problem:
  – Don’t know which route is taken

• How:
  – Send probes to destination
  – Tell probes to die off after \( i \) hops, \( i = 1..30 \)
  – Ask router to send echo packets if packets dies
  – Measure RTT

Layered Protocol Architecture

• What is a layered architecture?
• Motivation
• Terminology
• Reference Models
• Implementation Issues

Advantages of Layering

• Decomposition
  – Masters complexity

• Encapsulation
  – Hiding of implementation details

• Evolution
  – Layers can change/be replaced
  – Alternative implementations can be added, possibly coexist

• Robustness
  – Testing layers independently increases confidence
**Services vs Protocols**

Layer $k + 1$ Service provided by layer $k$

Layer $k$

Layer $k - 1$

(horizontal component)

- Layer $k$ may interact with peer layer $k$ only via protocols

**Interfaces vs Protocols**

- **Duality**
  - Both describe rules regarding order and format of "communication" between entities
- **Difference**:
  - Interface – vertical: between layers
  - Protocol – horizontal: between peers
- **NB:** Term "protocol" is sometimes used to describe module implementing a layer

**TCP/IP Reference Model**

**TCP/IP Hourglass View**

Application

Transport

Internet

Host-To-Network

TCP

IP

UDP

TCP

DNS

NFS

HTTP

FTP

Ethernet

ATM

... Wireless

**Encapsulation**

**Typical Implementation**

User App

Kernel: "top-half"

Kernel: "sw interrupt"

Kernel: "hw interrupt"
Queuing

Layer k+1

send queues

Layer k

recv queues

Layer k-1

General Implementation Issues

• Who schedules a layer’s processing:
  – On send: application thread
    • What if queues are full? Blocking vs. nonblocking
    • Who does retransmit if necessary?
  – On receive: interrupt-driven
    • Not all processing done right away; some delayed processing
    • Sometimes interrupts can be too slow; polling based approach used instead

• Memory management/Protection Issues:
  – How to prepend headers?
  – How do you strip headers?
  – When are copies needed?
  – Who allocates and frees packet buffers?