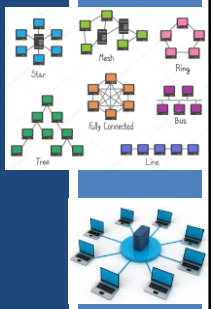
TCSS 558: APPLIED DISTRIBUTED COMPUTING

Processes: Virtualization, Clients & Servers

Wes J. Lloyd
School of Engineering & Technology (SET)
University of Washington - Tacoma



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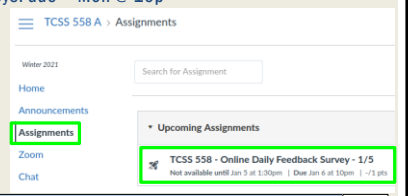
OBJECTIVES – 2/1

- **Questions from 2/1**
- Assignment 2: Key/Value Store
  - Coming Soon
- Midterm Thursday February 8
  - 2nd hour - Tuesday February 6 – practice midterm class activity
- Chapter 3: Processes
  - Chapter 3.1: Threads
    - Threading Models
    - Multithreaded clients/servers
  - Chapter 3.2: Virtualization
  - Chapter 3.3: Clients
  - Chapter 3.4: Servers

2

ONLINE DAILY FEEDBACK SURVEY

- Daily Feedback Quiz in Canvas – Available After Each Class
- Extra credit available for completing surveys ***ON TIME***
- Tuesday surveys: due by ~ Wed @ 10p
- Thursday surveys: due ~ Mon @ 10p



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TCSS 558 - Online Daily Feedback Survey - 1/5

Due Jan 6 at 10pm Points 1 Questions 4
Available Jan 5 at 1:30pm - Jan 6 at 11:59pm 1 day Time Limit None

Question 1 0.5 pts

On a scale of 1 to 10, please classify your perspective on material covered in today's class:

1 2 3 4 5 6 7 8 9 10

Mostly Review To Me | Equal New and Review | Mostly New to Me

Question 2 0.5 pts

Please rate the pace of today's class:

1 2 3 4 5 6 7 8 9 10

Slow | Just Right | Fast

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MATERIAL / PACE

- Please classify your perspective on material covered in today's class (25 respondents):
- 1-mostly review, 5-equal new/review, 10-mostly new
- **Average – 6.6 (↓ - *previous 6.77*)**

- Please rate the pace of today's class:
- 1-slow, 5-just right, 10-fast
- **Average – 5.8 (↑ - *previous 5.73*)**

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FEEDBACK FROM 1/30

- ***I asked about the 'one-to-one' model in class:***
- ***Regarding the one-to-one threading model, what is the ratio of user threads to kernel threads ?***
- ***Looking online it seems like an application can have multiple threads, and each thread has its own kernel threads. So 'one-to-one' refers to 'one-user-thread-to-one-kernel-thread'***
- The "kworker" is a placeholder process for kernel worker threads under which the timer, interrupt processing, and other internal kernel (system) calls run.
- Looking more closely at kworker processes, it appears that kworkers are created for each physical CPU core
- And there are different types of kworkers: events, kdmflush, mm_percpu_wq, dio/dm-0
- I counted about 47 distinct kworker processes
- kworker processes appear to be shared. They are on stand-by to run system calls. If there is no system call, they remain idle.

```
ps ax | grep kworker
```


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FEEDBACK - 2

- **Helpful links on Linux processes and threads:**
- https://www.baeldung.com/linux/process-vs-thread
- https://www.baeldung.com/linux/monitor-process-thread-count

- **kworkers in Linux:**
- https://medium.com/@boutnaru/the-linux-process-journey-kworker-f947634da73
- https://askubuntu.com/questions/33640/kworker-what-is-it-and-why-is-it-hogging-so-much-cpu

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AWS CLOUD CREDITS UPDATE

- We have been approved to receive AWS CLOUD CREDITS for TCSS 558 – Winter 2024
- Credits will be provided by email request
  - Please include: 12-digit AWS account ID, and AWS account email
- Credits will first be provided for students not in F'23 TCSS562
- Request codes by sending an email with the subject: "**AWS CREDIT REQUEST**" to **wlloyd@uw.edu**
- Codes can also be obtained in person (or zoom), in the class, during the breaks, after class, during office hours, by appt
- Credit codes are carefully exchanged, and not shared by IM
- For students ***unable*** to create a standard AWS account: Please contact instructor by email - *Instructor will work to create hosted IAM user account*

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ASSIGNMENT 1

- ***Preparing for Assignment 1: Intro to Cloud Computing Infrastructure and Load Balancing***
  - Establish AWS Account - Standard account
- Now posted:
  - Task 0 - Establish local Linux/Ubuntu environment
  - Task 1 –AWS account setup, obtain user credentials
  - Task 2 – Intro to: Amazon EC2 & Docker: create Dockerfile for Apache Tomcat
  - Task 3 – Create Dockerfile for haproxy (software load balancer)
  - Task 4 – Working with Docker-Machine
  - Task 5 – Submit Results of testing alternate server configs

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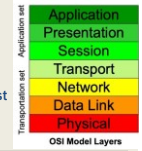
TESTING CONNECTIVITY TO SERVER (PG 16-18)

- **testFibPar.sh** script is a parallel test script
- Orchestrates multiple threads on client to invoke server multiple times in parallel
- To simplify coordination of parallel service calls in BASH, **testFibPar.sh** script ignores errors !!!
- To help test client-to-server connectivity, there is also a **testFibService.sh** script that supports 3 tests
- TEST 1: **Network layer** test
  - Ping (ICMP)
- TEST 2: **Transport layer** test
  - TCP: telnet (TCP Port 8080) – security group (fw) test
- TEST 3: **Application layer** test
  - HTTP REST – web service test



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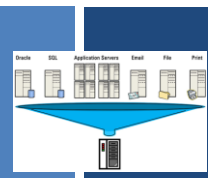

CH. 3.2: VIRTUALIZATION

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VIRTUALIZATION

- Initially introduced in the 1970s on IBM mainframe computers
- Legacy operating systems run in mainframe-based VMs
- Legacy software could be sustained by virtualizing legacy OSes
- 1970s virtualization went away as desktop/rack-based hardware became inexpensive
- Virtualization reappears in 2000s to leverage multi-core, multi-CPU processor systems
- VM-Ware virtual machines enable companies to host many virtual servers with mixed OSes on private clusters
- Cloud computing: Amazon offers VMs as-a-service (IaaS)

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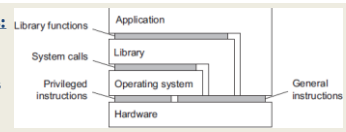
TYPES OF VIRTUALIZATION

- **Levels of Instructions:**
- **Hardware**: CPU
  - Privileged instructions KERNEL MODE
  - General instructions USER MODE



- **Operating system**: system calls
- **Library**: programming APIs: e.g. C/C++,C#, Java libraries
- **Application**:
- **Goal of virtualization:** mimic these interface to provide a virtual computer

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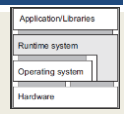
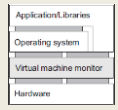
TYPES OF VIRTUALIZATION - 2

- **Process virtual machine**
  - Interpret instructions: (interpreters) (JavaVM) byte code → HW instructions
  - Emulate instructions: (emulators) (Wine) windows code → Linux code



- **Native virtual machine monitor (VMM)**
  - Hypervisor (XEN): small OS with its own kernel
  - Provides an interface for multiple guest OSes
  - Facilitates sharing/scheduling of CPU, device I/O among many guests
  - Guest OSes require special kernel to interface w/ VMM
  - Supports **Paravirtualization** for performance boost to run code directly on the CPU
  - Type 1 hypervisor



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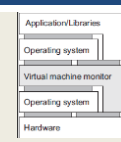
TYPES OF VIRTUALIZATION - 3

- **Hosted virtual machine monitor (VMM)**
  - Runs atop of hosted operating system
  - Uses host OS facilities for CPU scheduling, I/O
  - Full virtualization
  - Type 2 hypervisor
  - **Virtualbox**



- *Textbook: note 3.5–good explanation of full vs. paravirtualization*
- **GOAL**: run all user mode instructions directly on the CPU
- x86 instruction set has ~17 privileged user mode instructions
- **Full virtualization**: scan the EXE, insert code around privileged instructions to divert control to the VMM
- **Paravirtualization**: special OS kernel eliminates side effects of privileged instructions

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EVOLUTION OF AWS VIRTUALIZATION

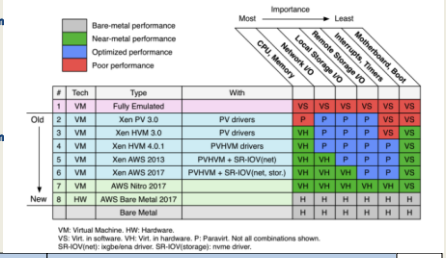
From http://www.brendangregg.com/blog/2017-11-29/aws-ec2-virtualization-2017.html

VS: Virtualization in software

P: Paravirtual

VH: Virtualization in Hardware

H: Hardware



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AWS VIRTUALIZATION - 2

- **Full Virtualization - Fully Emulated**
  - Never used on EC2, before CPU extensions for virtualization
  - Can boot any unmodified OS
  - Support via slow emulation, performance 2x-10x slower
- **Paravirtualization: Xen PV 3.0**
  - Software: Interrupts, timers
  - Paravirtual: CPU, Network I/O, Local+Network Storage
  - Requires special OS kernels, interfaces with hypervisor for I/O
  - Performance 1.1x – 1.5x slower than "bare metal"
  - Instance store instances: 1ST & 2nd generation- m1.large, m2.xlarge
- **Xen HVM 3.0**
  - Hardware virtualization: **CPU**, **memory** **(CPU VT-x required)**
  - Paravirtual: network, storage
  - Software: interrupts, timers
  - EBS backed instances
  - m1, c1 instances

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AWS VIRTUALIZATION - 3

- **XEN HVM 4.0.1**
  - Hardware virtualization: CPU, memory **(CPU VT-x required)**
  - Paravirtual: network, storage, **interrupts**, **timers**
- **XEN AWS 2013** *(diverges from opensource XEN)*
  - Provides hardware virtualization for CPU, memory, **network**
  - Paravirtual: storage, **interrupts**, **timers**
  - Called Single root I/O Virtualization (SR-IOV)
  - Allows sharing single physical PCI Express device (i.e. network adapter) with multiple VMs
  - Improves VM network performance
  - 3rd & 4th generation instances (c3 family)
  - Network speeds up to 10 Gbps and 25 Gbps
- **XEN AWS 2017**
  - Provides hardware virtualization for CPU, memory, network, **local disk**
  - Paravirtual: remote storage, **interrupts**, **timers**
  - Introduces hardware virtualization for EBS volumes (c4 instances)
  - Instance storage hardware virtualization (x1.32xlarge, i3 family)

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AWS VIRTUALIZATION - 4

- **AWS Nitro 2017**
  - Provides hardware virtualization for CPU, memory, network, **local disk, remote disk, interrupts, timers**
  - All aspects of virtualization enhanced with HW-level support
  - November 2017
  - Goal: provide performance indistinguishable from "bare metal"
  - 5th generation instances – c5 instances (also c5d, c5n)
  - Based on KVM hypervisor
  - Overhead around ~1%

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CH. 3.3: CLIENTS

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TYPES OF CLIENTS

- Thick clients
  - Web browsers
    - Client-side scripting
  - Mobile apps
  - Multi-tier MVC apps
- Thin clients
  - Remote desktops/GUIs (very thin)

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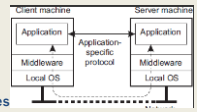
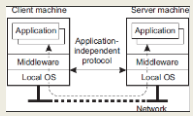
CLIENTS

- Application specific protocol
  - Thick clients
  - Clients maintain local data
  - Middleware (APIs)
  - Clients synchronize data with remote nodes
  - Example: shared calendar application



- Application independent
  - Thin clients
  - Client acts as a remote terminal
  - Provides interface to user (GUI / UI)
  - Server houses entire application stack



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X WINDOWS

- Layered architecture to transport UI over network
- Remote desktop functionality for Linux/Unix systems
- X kernel acts as a server
  - Provides the **X protocol**: application level protocol
  - Xlib instances (client applications) exchange data and events with X kernels (servers)
  - Clients and servers on single machine → Linux GUI
  - Client and server communication transported over the network → remote Linux GUI

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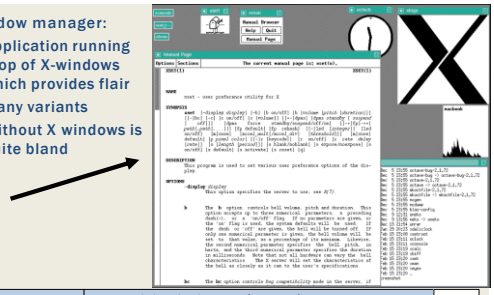
X WINDOWS - 2

- Window manager:
  - Application running atop of X-windows which provides flair
  - Many variants
  - Without X windows is quite bland



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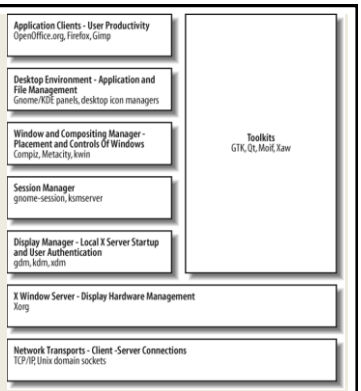
- **Layered architecture**
- X-kernel: low level interface/APIs for controlling screen, capturing keyboard and mouse events (X window Server)
- Provided on Linux as Xlib
- Provides network enabled GUI
- Layering allows for use for custom window managers



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EXAMPLE: VNC SERVER

- **How to Install VNC server on Ubuntu EC2 Instance VM:**
- `sudo apt-get update`
- `# ubuntu 16.04`
- `sudo apt-get install ubuntu-desktop`
- `sudo apt-get install gnome-panel gnome-settings-daemon metacity nautilus gnome-terminal`
- `# on ubuntu 18.04`
- `sudo apt install xfce4 xfce4-goodies`
- `sudo apt-get install tightvncserver  # both`
- Start VNC server to create initial config file
- `vncserver :1`

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EXAMPLE: VNC SERVER – UBUNTU 16.04

- On the VM: edit config file: `nano ~/.vnc/xstartup`
- Replace contents as below (Ubuntu 16.04):

```
#!/bin/sh

export XKL_XMODMAP_DISABLE=1
unset SESSION_MANAGER
unset DBUS_SESSION_BUS_ADDRESS

[ -x /etc/vnc/xstartup ] && exec /etc/vnc/xstartup
[ -r $HOME/.Xresources ] && xrdb $HOME/.Xresources
xsetroot -solid grey

vncconfig -iconic &
gnome-panel &
gnome-settings-daemon &
metacity &
nautilus &
gnome-terminal &
```


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EXAMPLE: VNC SERVER – UBUNTU 18.04

- On the VM:
- Edit config file: `nano ~/.vnc/xstartup`
- Replace contents as below (Ubuntu 18.04):

```
#!/bin/bash
xrdb $HOME/.Xresources
startxfce4 &
```


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VNC SERVER - UBUNTU 20.04 - GNOME

```
# install vnc server
sudo apt install tigervnc-standalone-server
sudo apt install ubuntu-gnome-desktop
vncserver :1              # creates a config file
vncserver -kill :1        # stop server
vi ~/.vnc/xstartup        # edit config file

#!/bin/sh
# Start Gnome 3 Desktop
[ -x /etc/vnc/xstartup ] && exec /etc/vnc/xstartup
[ -r $HOME/.Xresources ] && xrdb $HOME/.Xresources
vncconfig -iconic &
dbus-launch --exit-with-session gnome-session &

sudo systemctl start gdm       # start gnome desktop
sudo systemctl enable gdm
vncserver :1                   # restart vnc server
```


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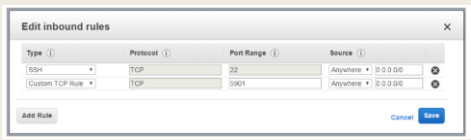
EXAMPLE: VNC SERVER - 3

- On the VM: reload config by restarting server
- `vncserver -kill :1`
- `vncserver :1`

- Open port 22 & 5901 in EC2 security group:



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EXAMPLE: VNC CLIENT

- On the client (e.g. laptop):
- Create SSH connection to securely forward port 5901 on the EC2 instance to your localhost port 5901
- This way your VNC client doesn't need an SSH key

```
ssh -i <ssh-keyfile> -L 5901:127.0.0.1:5901 -N
-f -l <username> <EC2-instance ip_address>
```

- For example:

```
ssh -i mykey.pem -L 5901:127.0.0.1:5901 -N -f -
l ubuntu 52.111.202.44
```


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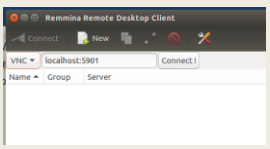
EXAMPLE: VNC CLIENT - 2

- On the client (e.g. laptop):
- Use a VNC Client to connect
- Remmina is provided by default on Ubuntu 16.04
- Can "google" for many others
- Remmina login:
- Chose "VNC" protocol
- Log into "localhost:5901"



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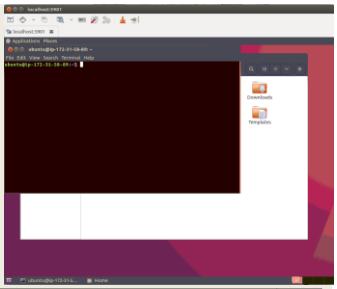
REMOTE COMPUTER IN THE CLOUD

- EC2 instance with a GUI. . .!!!



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THIN CLIENTS

- Thin clients
  - Besides VNC, there are a variety of other remote desktop protocols:

Remote desktop protocols include the following:

- Apple Remote Desktop Protocol (ARD) – Original protocol for Apple Remote Desktop on macOS machines.
- Appliance Link Protocol (ALP) – a Sun Microsystems-specific protocol featuring audio (play and record), remote printing, remote USB, accelerated video
- HP Remote Graphics Software (RGS) – a proprietary protocol designed by Hewlett-Packard specifically for high end workstation remoting and collaboration.
- Independent Computing Architecture (ICA) – a proprietary protocol designed by Citrix Systems
- NX technology (NoMachine NX) – Cross platform protocol featuring audio, video, remote printing, remote USB, H264-enabled.
- PC-over-IP (PCoIP) – a proprietary protocol used by VMware (licensed from Teradici)[2]
- Remote Desktop Protocol (RDP) – a Windows-specific protocol featuring audio and remote printing
- Remote Frame Buffer Protocol (RFB) – A framebuffer level cross-platform protocol that VNC is based on.
- SPICE (Simple Protocol for Independent Computing Environments) – remote-display system built for virtual environments by Qumranet, now Red Hat
- Splashtop – a high performance remote desktop protocol developed by Splashtop, fully optimized for hardware (H.264) including Intel / AMD chipsets, NVIDIA of media codecs, Splashtop can deliver high frame rates with low latency, and also low power consumption.
- X Window System (X11) – a well-established cross-platform protocol mainly used for displaying local applications; X11 is network transparent

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THIN CLIENTS - 2

- Applications should separate application logic from UI
- When application logic and UI interaction are tightly coupled many requests get sent to X kernel
- Client must wait for response
- Synchronous behavior and app-to-UI coupling adversely affects performance of WAN / Internet

- **Protocol optimizations**: reduce bandwidth by shrinking size of X protocol messages
- Send only differences between messages with same identifier
- Optimizations enable connections with 9600 kbps

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THIN CLIENTS - 3

- Virtual network computing (VNC)
- Send display over the network at the pixel level (instead of X lib events)
- Reduce pixel encodings to save bandwidth – fewer colors
- Pixel-based approaches loose application semantics
- Can transport any GUI this way

- **THINC**- hybrid approach
- Send video device driver commands over network
- More powerful than pixel based operations
- Less powerful compared to protocols such as X

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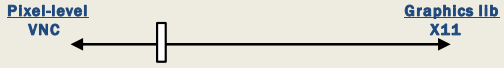
TRADEOFFS: ABSTRACTION OF REMOTE DISPLAY PROTOCOLS

- Tradeoff space: abstraction level of remote display protocols



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TRADEOFFS: ABSTRACTION OF REMOTE DISPLAY PROTOCOLS

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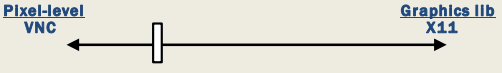

- Generic – no app context
- Graphics data
- Higher network bandwidth
- Fewer colors
- Utilize graphics compression
- More network traffic

- Application context is available
- UI data/operations
- Lower network bandwidth
- More colors

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WE WILL RETURN AT 5:05PM

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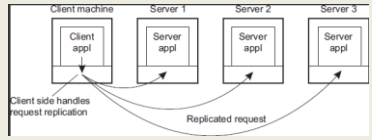
CLIENT ROLES IN PROVIDING DISTRIBUTION TRANSPARENCY

- Clients help enable distribution transparency of servers
- Replication transparency
  - Client aggregates responses from multiple servers
  - Only the client knows of replicas



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CLIENT ROLES IN PROVIDING DISTRIBUTION TRANSPARENCY - 2

- Location/relocation/migration transparency
  - Harness convenient naming system to allow client to infer new locations
  - Server inform client of moves / Client reconnects to new endpoint
  - Client hides network address of server, and reconnects as needed
  - May involve temporary loss in performance
- Replication transparency
  - Client aggregates responses from multiple servers
- Failure transparency
  - Client retries, or maps to another server, or uses cached data
- Concurrency transparency
  - Transaction servers abstract coordination of multithreading

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OBJECTIVES – 2/1

- Questions from 2/1
- Assignment 2: Key/Value Store
  - Coming Soon
- Midterm Thursday February 8
  - 2nd hour - Tuesday February 6 – practice midterm class activity
- Chapter 3: Processes
  - Chapter 3.1: Threads
    - Threading Models
    - Multithreaded clients/servers
  - Chapter 3.2: Virtualization
  - Chapter 3.3: Clients
  - **Chapter 3.4: Servers**

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CH. 3.4: SERVERS

L9.47

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SERVERS

- Cloud & Distributed Systems – rely on **Linux**
- http://www.zdnet.com/article/it-runs-on-the-cloud-and-the-cloud-runs-on-linux-any-questions/
- IT is moving to the cloud. And, what powers the cloud?
  - **Linux**
- Uptime Institute survey - 1,000 IT executives (2016)
  - 50% of IT executives – plan to migrate majority of IT workloads to off-premise to cloud or colocation sites
  - 23% expect the shift in 2017, 70% by 2020…
- Docker on Windows / Mac OS X
  - Based on **Linux**
  - Mac: Hyperkit Linux VM
  - Windows: Hyper-V Linux VM

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SERVERS - 2

- Servers implement a specific service for a collection of clients
- Servers wait for incoming requests, and respond accordingly

- **Server types**
- **Iterative**: immediately handle client requests
- **Concurrent**: Pass client request to separate thread

- Multithreaded servers are concurrent servers
  - E.g. Apache Tomcat

- *Alternative*: fork a new process for each incoming request
- *Hybrid*: mix the use of multiple processes with thread pools

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END POINTS

- Clients connect to servers via:
  IP Address and **Port Number**
- How do ports get assigned?
  - Many protocols support "default" port numbers
  - Client must find IP address(es) of servers
  - A single server often hosts multiple end points (servers/services)
  - When designing new TCP client/servers must be careful not to repurpose ports already commonly used by others

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COMMON PORTS

packetlife.net

TCP/UDP Port Numbers

7 Echo	554 RTSP	2745 Bagle.H	6891-6901 Windows Live
19 Chargen	546-547 DHCPv6	2967 Symantec AV	6970 Quicktime
20-21 FTP	560 rmonitor	3050 Interbase DB	7212 GhostSurf
22 SSH/SCP	563 NNTP over SSL	3074 XBOX Live	7648-7649 CU-SeeMe
23 Telnet	587 SMTP	3124 HTTP Proxy	8000 Internet Radio
25 SMTP	591 FileMaker	3127 MyDoom	8080 HTTP Proxy
42 WINS Replication	593 Microsoft DCOM	3128 HTTP Proxy	8086-8087 Kaspersky AV
43 WHOIS	631 Internet Printing	3222 GLBP	8118 Privoxy
49 TACACS	636 LDAP over SSL	3260 iSCSI Target	8200 VMware Server
53 DNS	639 MSDP (PIM)	3306 MySQL	8500 Adobe ColdFusion
67-68 DHCP/BOOTP	646 LDP (MPLS)	3389 Terminal Server	8767 TeamSpeak
69 TFTP	691 MS Exchange	3689 iTunes	8866 Bagle.B
70 Gopher	860 iSCSI	3690 Subversion	9100 HP JetDirect
79 Finger	873 rsync	3724 World of Warcraft	9101-9103 Bacula
80 HTTP	902 VMware Server	3784-3785 Ventrilo	9119 MXit
88 Kerberos	989-990 FTP over SSL	4333 mSQL	9800 WebDAV
102 MS Exchange	993 IMAP4 over SSL	4444 Blaster	9898 Dabber
110 POP3	995 POP3 over SSL	4664 Google Desktop	9988 RbotSpybot
113 Ident	1025 Microsoft RPC	4672 eMule	9999 Urchin
119 NNTP (Usenet)	1026-1029 Windows Messenger	4899 Radmin	10000 Webmin
123 NTP	1080 SOCKS Proxy	5000 UPnP	10000 BackupExec
135 Microsoft RPC	1080 MyDoom	5001 Slingbox	10113-10116 NetIQ
137-139 NetBIOS	1194 OpenVPN	5001 iperf	11371 OpenPGP
143 IMAP4	1214 Kazaa	5004-5005 RTP	12035-12036 Second Life
161-162 SNMP	1241 Nessus	5050 Yahoo! Messenger	12345 NetBus
177 XDMCP	1311 Dell OpenManage	5060 SIP	13720-13721 NetBackup
179 BGP	1337 WASTE	5190 AIM/ICQ	14567 Battlefield

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TYPES OF SERVERS

- Daemon server
  - Example: NTP server
- Superserver
- Stateless server
  - Example: Apache server
- Stateful server
- Object servers
- EJB servers

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NTP EXAMPLE

- Daemon servers
  - Run locally on Linux
  - Track current server end points (outside servers)
  - Example: network time protocol (ntp) daemon
    - Listen locally on specific port (ntp is 123)
    - Daemons routes local client traffic to the configured endpoint servers
    - University of Washington: time.u.washington.edu
    - Example "`ntpq -p`"
      - Queries local ntp daemon, routes traffic to configured server(s)

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SUPERSERVER

- Linux inetd / xinetd
  - Single superserver
  - Extended internet service daemon
  - Not installed by default on Ubuntu
  - Intended for use on server machines
  - Used to configure box as a server for multiple internet services
    - E.g. ftp, pop, telnet
  - inetd daemon responds to multiple endpoints for multiple services
  - Requests fork a process to run required executable program
- Check what ports you're listening on:
  - `sudo netstat -tap | grep LISTEN`

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INTERRUPTING A SERVER

- Server design issue:
  - Active client/server communication is taking place over a port
  - How can the server / data transfer protocol support interruption?
- Consider transferring a 1 GB image, how do you pass a unrelated message in this stream?
  1. **Out-of-band** data: special messages sent in-stream to support interrupting the server (*TCP urgent data*)
  2. Use a separate connection (different port) for admin control info
- Example: sftp secure file transfer protocol
  - Once a file transfer is started, can't be stopped easily
  - Must kill the client and/or server

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STATELESS SERVERS

- Data about state of clients is not stored
- Example: web application servers are typically stateless
  - Also function-as-a-service (FaaS) platforms
- Many servers maintain information on clients (e.g. log files)
- Loss of stateless data doesn't disrupt server availability
  - Loosing log files typically has minimal consequences
- **Soft state**: server maintains state on the client for a limited time (*to support sessions*)
- Soft state information expires and is deleted

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STATEFUL SERVERS

- Maintain persistent information about clients
- Information must be explicitly deleted by the server
- Example:
  File server - allows clients to keep local file copies for RW
- Server tracks client file permissions and most recent versions
  - Table of (client, file) entries
- If server crashes data must be recovered
- Entire state before a crash must be restored
- Fault tolerance - *Ch. 8*

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STATEFUL SERVERS - 2

- Session state
  - Tracks series of operations by a single user
  - Maintained temporarily, not indefinitely
  - Often retained for multi-tier client server applications
  - Minimal consequence if session state is lost
  - Clients must start over, reinitialize sessions
- Permanent state
  - Customer information, software keys
- Client-side cookies
  - When servers don't maintain client state, clients can store state locally in "cookies"
  - Cookies are not executable, simply client-side data

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OBJECT SERVERS

- **OBJECTIVE:** Host objects and enable remote client access
- Do not provide a specific service
  - Do nothing if there are no objects to host
- Support adding/removing hosted objects
- Provide a home where objects live
- Objects, *themselves*, provide "services"
- Object parts
  - State data
  - Code (methods, etc.)
- **Transient object(s)**
  - Objects with limited lifetime (< server)
  - Created at first invocation, destroyed when no longer used (i.e. no clients remain "bound").
  - Disadvantage: initialization may be expensive
  - Alternative: preinitialize and retain objects on server start-up

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OBJECT SERVERS - 2

- **Should object servers isolate memory for object instances?**
  - Share neither code nor data
  - May be necessary if objects couple data and implementation
- Object server threading designs:
  - Single thread of control for object server
  - One thread for each object
  - Servers use separate thread for client requests
- Threads created on demand **vs.**
  Server maintains pool of threads
- **What are the tradeoffs for creating server threads on demand vs. using a thread pool?**

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EJB – ENTERPRISE JAVA BEANS

- EJB- specialized Java object hosted by a EJB web container
- 4 types: stateless, stateful, entity, and message-driven beans
- Provides "middleware" standard (framework) for implementing back-ends of enterprise applications
- EJB web application containers integrate support for:
  - Transaction processing
  - Persistence
  - Concurrency
  - Event-driven programming
  - Asynchronous method invocation
  - Job scheduling
  - Naming and discovery services (JNDI)
  - Interprocess communication
  - Security
  - Software component deployment to an application server

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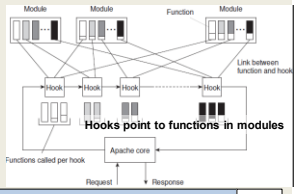
APACHE WEB SERVER

- Highly configurable, extensible, platform independent
- Supports TCP HTTP protocol communication
- Uses hooks – placeholders for group of functions
- Requests processed in phases by hooks
- Many hooks:
  - Translate a URL
  - Write info to log
  - Check client ID
  - Check access rights
- Hooks processed in order enforcing flow-of-control
- Functions in replaceable modules



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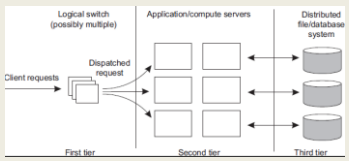
SERVER CLUSTERS

- Hosted across an LAN or WAN
- Collection of interconnected machines
- Can be organized in tiers:
  - Web server → app server → DB server
  - App and DB server sometimes integrated



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LAN REQUEST DISPATCHING

- Front end of three tier architecture (logical switch) provides distribution transparency – hides multiple servers
- Transport-layer switches: switch accepts TCP connection requests, hands off to a server
  - Example: hardware load balancer (F5 networks – Seattle)
  - HW Load balancer - OSI layers 4-7
- Network-address-translation (NAT) approach:
  - All requests pass through switch
  - Switch sits in the middle of the client/server TCP connection
  - Maps (rewrites) source and destination addresses
- Connection hand-off approach:
  - **TCP Handoff**: switch hands of connection to a selected server

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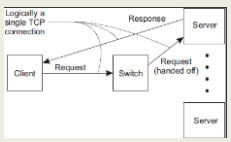
LAN REQUEST DISPATCHING - 2

- Who is the best server to handle the request?
- Switch plays important role in distributing requests
- Implements load balancing
- **Round-robin** – routes client requests to servers in a looping fashion
- **Transport-level** – route client requests based on TCP port number
- **Content-aware request distribution** – route requests based on inspecting data payload and determining which server node should process the request



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WIDE AREA CLUSTERS

- Deployed across the internet
- Leverage resource/infrastructure from Internet Service Providers (ISPs)
- Cloud computing simplifies building WAN clusters
- Resource from a single cloud provider can be combined to form a cluster
- **For deploying a cloud-based cluster (WAN), what are the implications of deploying nodes to:**
- (1) a single availability zone (e.g. us-east-1e)?
- (2) across multiple availability zones?

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WAN REQUEST DISPATCHING

- Goal: minimize network latency using WANs (e.g. Internet)
- Send requests to nearby servers
- Request dispatcher: routes requests to nearby server
- **Example**: Domain Name System
  - Hierarchical decentralized naming system
- Linux: find your DNS servers:

```
# Find you device name of interest
nmcli dev
# Show device configuration
nmcli device show <device name>
```


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DNS LOOKUP

- First query local server(s) for address
- Typically there are (2) local DNS servers
  - One is backup
- Hostname may be cached at local DNS server
  - E.g. www.google.com
- If not found, local DNS server routes to other servers
- Routing based on components of the hostname
- DNS servers down the chain mask the client IP, and use the originating DNS server IP to identify a local host
- ***Weakness:*** *client may be far from DNS server used. Resolved hostname is close to DNS server, but not necessarily close to the client*

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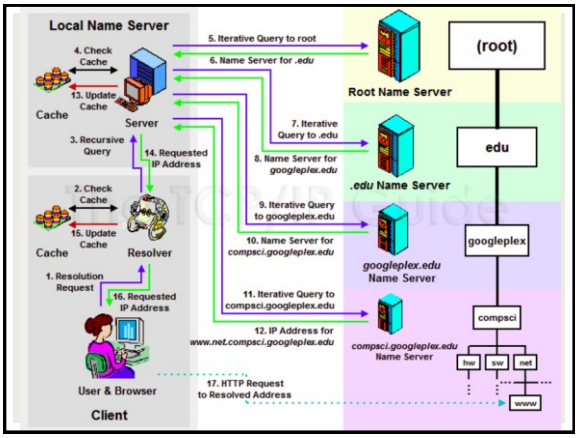

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DNS: LINUX COMMANDS

- `nslookup <ip addr / hostname>`
- Name server lookup – translates hostname or IP to the inverse
- `traceroute <ip addr / hostname>`
- Traces network path to destination
- By default, output is limited to 30 hops, can be increased

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DNS EXAMPLE – WAN DISPATCHING

- Ping www.google.com in WA from wireless network:
  - nslookup: 6 alternate addresses returned, choose (74.125.28.147)
  - Ping 74.125.28.147: Average RTT = **22.458 ms (11 attempts, 22 hops)**
- Ping www.google.com in VA (us-east-1) from EC2 instance:
  - nslookup: 1 address returned, choose 172.217.9.196
  - Ping 172.217.9.196: Average RTT = 1.278 ms (11 attempts, 13 hops)
- From VA EC2 instance, ping WA *www.google* server
- Ping 74.125.28.147: Average RTT 62.349ms (11 attempts, 27 hops)
- Pinging the WA-local server is ~60x slower from VA
- From local wireless network, ping VA us-east-1 google :
- Ping 172.217.9.196: Average RTT=81.637ms (11 attempts, 15 hops)

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DNS EXAMPLE – WAN DISPATCHING

- Ping www.google.com in WA from wireless network:
  - nslookup: 6 alternate addresses returned, choose (74.125.28.147)

Latency to ping VA server in WA: ~3.63x
WA client: local-google 22.458ms to VA-google 81.637ms

Latency to ping WA server in VA: ~48.7x
VA client: local-google 1.278ms to WA-google 62.349!

- From local wireless network, ping VA us-east-1 google :
- Ping 172.217.9.196: Average RTT=81.637ms (11 attempts, 15 hops)

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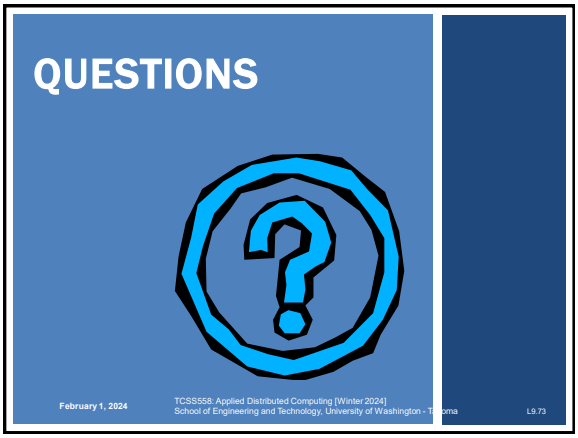
QUESTIONS
February 1, 2024
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