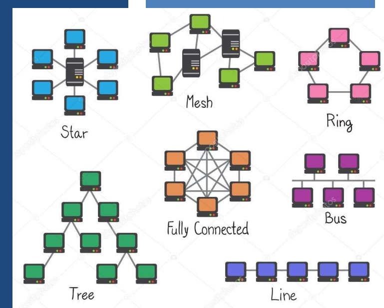
TCSS 558:
APPLIED DISTRIBUTED COMPUTING

Chapter 3 - Processes



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OBJECTIVES

- Homework 1 – 2/19
- Homework 2 Posted
- Midterm – Postponed until 2/20
- Feedback 2/11
- Practice midterm

- Chapter 3 Processes
  - 3.4 Servers
  - 3.5 Code Migration

FEEDBACK – 2/11

- How DNS System is related to WAN?
  - DNS is an example of WAN request dispatching
  - DNS servers operate collaboratively as a "WAN" over the internet
  - Continue to forward queries closer to a host's domain server to resolve the IP if not cached at a closer server
- Iterative vs concurrent servers: iterative server directly handles request, concurrent server passes off request to separate thread/process and continues to listen for requests
- LAN request dispatching methods:
  When would you use each dispatching method (round-robin, transport-level, content-aware request distribution)?
  - Round-robin – requests have equal work/resource requirements
  - Transports-level – route based on port / protocol
  - Content-aware – incorporate application knowledge into routing

FEEDBACK - 2

- When does the local DNS server cache update?
  - Presumably when new hosts are resolved – difficult to know details on cache management here
- What should we do if DNS server doesn't respond?
  - Clients usually specify at least 2 as a backup
- When we create a thread pool and add threads into it, should we allocate memories to the threads in advance?
- If we do so, how much memory should be allocated in advance? And if we don't allocate in advance, I think the memory usage would not be much greater than that of creating threads on demand.
  - What is included in the "context" of each thread?
  - For example, does it initialize and sustain a dedicated RDBMS connection? (*requires memory*)
  - 800 empty threads still consumes memory

FEEDBACK - 3

- When installing a VNC server, why we should use port 5901?
  - VNC by default uses TCP port 5900+N, where N is the display number (usually :0 for a physical display).
- DNS Linux commands and DNS lookup
  - Identify devices: Ifconfig / nmcli dev
  - Show details: nmcli device show wlp4s0
  - Resolve IP addr: nslookup www.google.com
- How does out-of-band data support interrupt?
  - An out of band data mechanism provides a conceptually separate channel for data exchange separate from the in-band (primary) channel
- I was not clear about the hooks , so is there a specific hook for a function or any hook can take any function ?

APACHE WEBSERVER HOOKS

- Hook: placeholder for a specific group of functions
- Apache provides standard hooks:
  - Hook to translate URL to local file name
  - Hook to write information to log
  - Hook for checking access rights
- Apache server core assumes client requests are processed in phases, where each phase consists of a few hooks
- Hooks represent actions that must execute to process a request
- Functions associated with hooks are provided by separate modules
- Developers may write custom modules containing functions to be called to process the standard hooks provided unmodified by apache
- Modules are mutually independent – functions in the same hook can be executed in arbitrary order
- Apache allows developer to specify an ordering
- **Take home: Apache is an extremely versatile web server**

CH. 3.4: SERVERS

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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 EXAMPLE

- 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: ~64x

Massive slowdown because WA is a wireless network

Latency to ping WA server in VA: ~2.8x

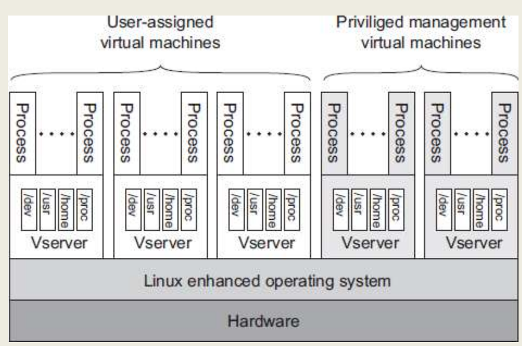
Less of a slowdown because VA is a cloud VM

- Local wireless network, ping us-east-1 google (172.217.9.196):
- Ping 74.125.28.147: Average RTT=81.637ms (11 attempts, 15 hops)

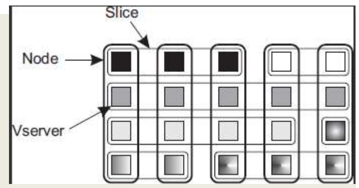
EXAMPLE: PLANETLAB

- Unstructured heterogeneous cluster of servers
- Similar to grid but organized as cluster (no grid middleware)
- Testbed established in 2002 for computer networking and distributed systems research
- Organizations share nodes in the cluster

Leverages Linux Vservers Early "containers" similar to Docker



PLANETLAB - 2



- **Slices**: set of Vservers running across PlanetLab
- Acts as a virtual server cluster (similar to Amazon VPC)
- **Node manager**: manages Vservers running on a host
- **Slice creation service (SCS)**: To create virtual server clusters
- Clients must be **slice authorities** to create cluster
- **Rspec**: resource specification
  - Specifies resource requirements for a slice
- **Rcap**: resource capability
  - Specifies resource capabilities of nodes

VSERVERS

- Early container based approach
- Vservers share a single operating system kernel
- Primary task is to support a group of processes
- Provides separation of name spaces
- Linux kernel maps process IDs: host OS → Vservers
- Each Vserver has its own set of libraries and file system
- Similar name separation as the "`chroot`" command
- Additional isolation provided to prevent unauthorized access among Vservers directory trees

VSERVERS - 2

- **Advantages of Vservers (containers) vs. VMs:**
- Simpler resource allocation
- Possible to overbook resources by leveraging dynamic resource allocation - **Example: CPU or RAM** *(assignment 0, config 1)*
- VMs reserve a block of memory
- Containers can oversubscribe memory
  - Memory not formally reserved
  - Linux kernel shares memory among processes
  - Swap filesystem can use disk as extended RAM
- Memory sharing important for PlanetLab
  - Early nodes had limited memory (e.g. 4 GB)
- Vserver hogging most memory reset when out of swap space

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CH. 3.5: CODE MIGRATION

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CODE MIGRATION

- Distributed systems can support more than **passing data**
- Some situations call for **passing programs** (e.g. *code*)
- **Live migration** – moving code while it is executing
- **Portability** – transferring code (running or not) across heterogeneous systems:

  Mac OS X → Windows 10 → Linux
- Code migration enables ***flexibility*** of distributed systems
  - Topologies can be dynamically reconfigured on-the-fly

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PROCESS MIGRATION

- Move an entire process from one node to another
- Motivation is always to address performance
- Process migration is slow, costly, and intricate
  - Need to pause, save intermediate state, move, resume
  - Consider application ***specific*** vs. ***agnostic*** approaches
- What would be:
  an **application agnostic** approach to migration?
  an **application specific** approach?
- What are advantages and disadvantages of each?

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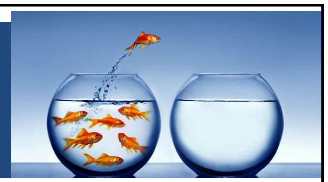
PROCESS MIGRATION - 2

- Move processes: from heavily loaded → lightly loaded nodes
- When do we consider a node as heavily loaded?
  - Load average
  - CPU utilization
  - CPU queue length
- Which process(es) should be moved?
  - Must consider ***resource requirements*** for the task
- Where should process(es) be moved to?

MOTIVATIONS FOR MIGRATION



- Can migrate processes or entire virtual machines
- Goals:
  - Off-loading machines: reduce load on oversubscribed servers
  - Loading machine: ensure machine has enough work to do
  - Minimize total hosts/servers in use to save energy/cost
- VM migration:
- Migrate complete VMs with apps to lightly loaded hosts
- Generally, VM migration is easier than process migration
- **Is VM migration application specific or agnostic?**

LOAD DISTRIBUTION ALGORITHMS

- Make decisions concerning allocation and redistribution of tasks across machines
- Provide resource management for compute intensive systems
- Often CPU centric
  - Algorithms should also account for other resources
  - Network capacity may be larger bottleneck that CPU capacity

WHEN TO MIGRATE?

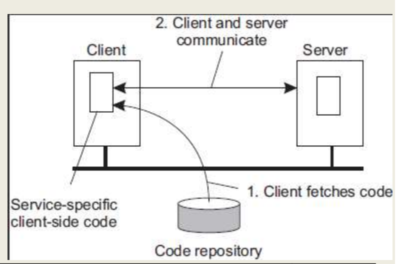
- Decisions to migrate code often based on qualitative reasoning or adhoc decisions vs. formal mathematical models
  - Difficult to formalize solutions due to heterogeneous composition and state of systems and networks
- Is it better to migrate code or data?
- <u>What factors should be considered?</u>
  - Size of code
  - Size of data
  - Available network transfer speed
  - Cost of data transfer
  - Processing power of nodes
  - Cost of processing
  - Are there security requirements for the data?

APPROACHES TO CODE MIGRATION

- Traditional clients
  - Client interacts with server using specific protocol
  - Tight coupling of client->server limits system flexibility
  - Difficult to change protocol when there are ***many*** clients
- Dynamic web clients
  - Web browser downloads client code immediately before use
  - New versions can readily be distributed

DYNAMIC WEB CLIENTS

- Advantages
  - Client code loaded in as necessary
  - Discarded when no longer needed
  - Can easily change the client/server protocol
- Disadvantages
  - Security: we have to trust the code
  - Downloading client requires network bandwidth & time



CODE MIGRATION

- Sender-initiated: (upload the code)… e.g. Github
- Receiver-initiated: (download the code)… e.g. web broswer
- **Remote cloning**
  - Produce a copy of the process on another machine while parent runs

CODE MIGRATION - 2

- What is migrated?
  - ***Code*** segment
  - ***Resource*** segment (device info)
  - ***Execution*** segment (process info: data, statem stack, PC)
- **Weak mobility**
  - Only ***code*** segment, no state
  - Code always restarts
- **Strong mobility**
  - ***Code*** + ***execution*** segment
  - Process stopped, state saved, moved, resumed
  - Represents true ***process migration***

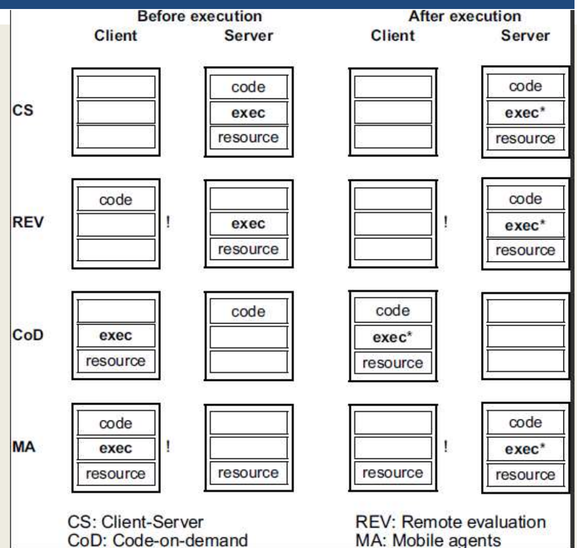
CODE MOBILITY TYPES

- CS: Client-Server
- REV: Remote Evaluation
- CoD: Code-on-demand
- MA: Mobile agents

- Where does state get modified?

- State is stored in exec

** shows what is modified*



MIGRATION OF HETEROGENEOUS SYSTEMS

- Assumption: code will always work at new node
- Invalid if node architecture is different (*heterogeneous*)

- What approaches are available to migrate code across heterogeneous systems?

- Intermediate code
  - 1970s Pascal: generate machine-independent intermediate code
  - Programs could then run anywhere
  - Today: web languages: Javascript, Java

- VM Migration

VIRTUAL MACHINE MIGRATION

- Four approaches:

1. **PRECOPY**: Push all memory pages to new machine (*slow*), resend modified pages later, transfer control
2. **STOP-AND-COPY**: Stop the VM, migrate memory pages, start new VM
3. **ON DEMAND**: Start new VM, copy memory as needed
4. **HYBRID**: PRECOPY followed by brief STOP-AND-COPY

- **What are some advantages and disadvantages of 1-4?**

1. **PRECOPY**: Push all memory pages to new machine (*slow*), resend modified pages later, transfer control
2. **STOP-AND-COPY**: Stop the VM, migrate memory pages, start new VM
3. **ON DEMAND**: Start new VM, copy memory pages as needed
4. **HYBRID**: PRECOPY and followed by brief STOP-AND-COPY

- **What are some advantages and disadvantages of 1-4?**
  - 1/3: no loss of service
  - 4: fast transfer, minimal loss of service
  - 2: fastest data transfer
  - 3: new VM immediately available

  - 1: must track modified pages during full page copy
  - 2: longest downtime - unacceptable for live services
  - 3: prolonged, slow, migration
  - 3: original VM must stay online for quite a while
  - 1/3: network load while original VM still in service

QUESTIONS

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EXTRA SLIDES

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