Best Practices for Sun Solaris Containers and VMware Infrastructure

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Agenda

- What is OS Virtualization ?
- What are Solaris Containers and how do they work ?
- Is it “VMware ESX or Containers” or “VMware ESX and Containers” ?
- Examination of common use cases

Background

- Assumptions:
  - You already understand VMware Infrastructure components
  - You have heard of Solaris Containers or Zones
- Observations:
  - Solaris Containers and VMware Infrastructure (ESX) technologies are complementary
  - Each provides a unique set of capabilities and efficiencies that can be leveraged together
- The key to success is knowing when to use each technology

Solaris Containers and OS Virtualization

- Multiple isolated execution environments within one Solaris instance
- Includes resource management, security, failure isolation
- Lightweight, flexible, efficient
    - More than 8,000 zones per system (or dynamic system domain)
- One operating system to manage
    - Device configuration details hidden
- Components:
    - Workload identification & accounting, process aggregation
    - Resource management (CPU, memory, ...)
    - Security/namespace isolation (zones)
- Features can be used separately or in combination

Evolution of Solaris Containers

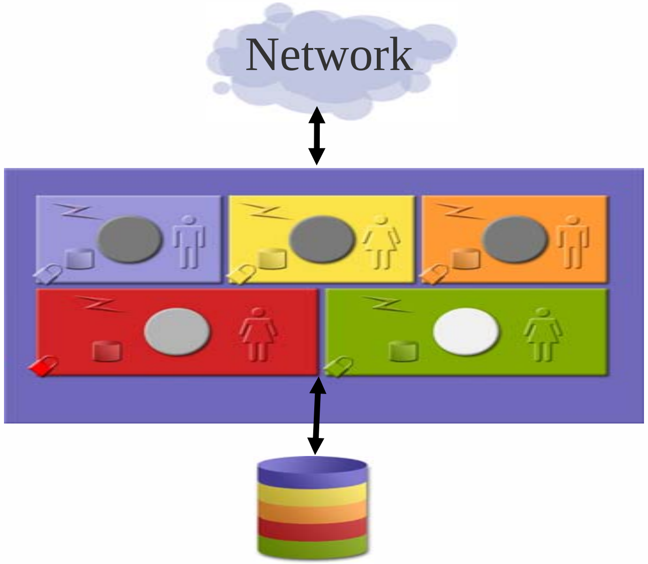
- **Solaris Containers prior to Solaris 10**
  - Introduced in Solaris 2.6 as SRM 1.0 [aka “Share II” scheduler]
  - Integrated into Solaris 9; new commands
  - Redesigned Fair Share Scheduler
  - Resource Capping Daemon
  - Introduced Extended Accounting
  - Better integration with Processor Pools/Sets
- **New In Solaris 10:**
  - Partitioning and Isolation with Zones
  - Dynamic Control of Pools
  - More Dynamic Resource Controls
    - Trend is to move away from /etc/system

Solaris Containers Components

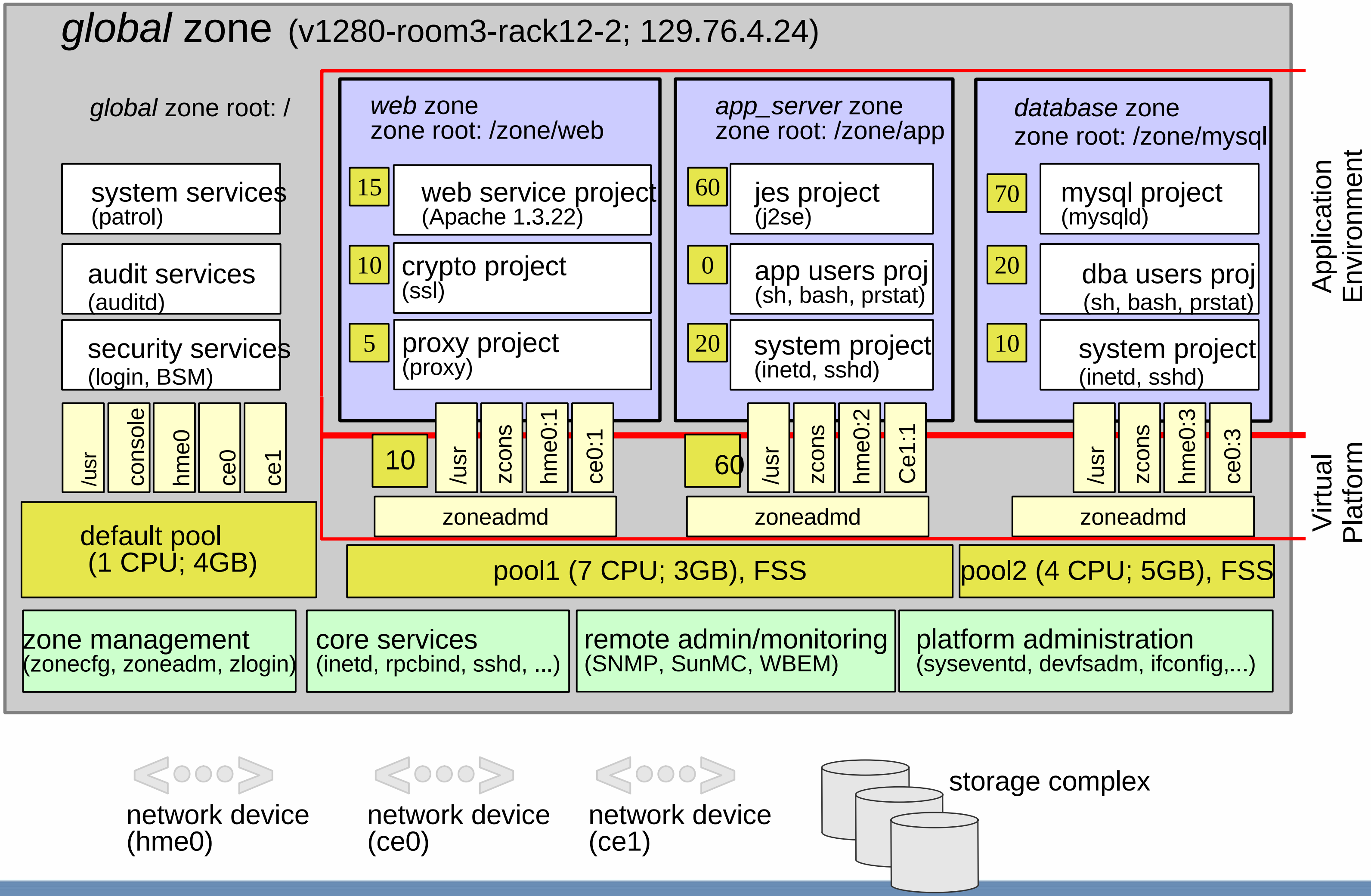
- Workload identification
  - Process aggregation via tasks, projects
  - Resource usage log with extended accounting
- Resource Management Tools
  - Guarantee minimum CPU use (FSS)
  - Limit maximum CPU use (pools, processor sets)
  - Limit physical memory use (resource capping daemon)
  - Limit virtual memory use (projects)
  - Limit network bandwidth use (ipqos)
- Workload isolation features
  - Privileges
  - Zones

OS Virtualization through Solaris Zones

- Virtualizes OS layer: file system, devices, network, processes
- Provides:
  - Privacy: can't see outside zone
  - Security: can't affect activity outside zone
  - Failure isolation: application or service failure in one zone doesn't affect others
- Lightweight, granular, efficient
- Complements resource management
- No porting; ABI/APIs are the same
- Requires no special hardware assist



Example



global zone (v1280-room3-rack12-2; 129.76.4.24)

global zone root: /

system services (patrol)

audit services (auditd)

security services (login, BSM)

/usr | console | hme0 | ce0 | ce1

default pool (1 CPU; 4GB)

web zone
zone root: /zone/web

15 web service project (Apache 1.3.22)

10 crypto project (ssl)

5 proxy project (proxy)

10 /usr | zcons | hme0:1 | ce0:1

zoneadmd

app_server zone
zone root: /zone/app

60 jes project (j2se)

0 app users proj (sh, bash, prstat)

20 system project (inetd, sshd)

60 /usr | zcons | hme0:2 | Ce1:1

zoneadmd

database zone
zone root: /zone/mysql

70 mysql project (mysqld)

20 dba users proj (sh, bash, prstat)

10 system project (inetd, sshd)

/usr | zcons | hme0:3 | ce0:3

zoneadmd

Application Environment

Virtual Platform

pool1 (7 CPU; 3GB), FSS

pool2 (4 CPU; 5GB), FSS

zone management (zonecfg, zoneadm, zlogin)

core services (inetd, rpcbind, sshd, ...)

remote admin/monitoring (SNMP, SunMC, WBEM)

platform administration (syseventd, devfsadm, ifconfig,...)

network device (hme0)

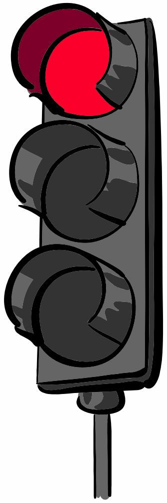
network device (ce0)

network device (ce1)

storage complex

Solaris Security

- User Rights Management
  - Limit access to privileged commands and operations
  - Manage “who can do what” centrally
  - Audit and report privileged command use
- Process Rights Management
  - Grant or revoke fine-grained privileges to individual processes and applications
  - Implement “Least Privilege”
    - Applications can only do exactly what they require to operate
  - Usually removes the need to run as root



Solaris Security (cont)

- More than 40 specific rights historically associated with UID 0 (root)
- For legacy compatibility, UID 0 has all rights by default
- Basic users have very few default rights
- Selectable privilege inheritance
- Role-based access control framework enables:
  - Privileges to be assigned to a role
  - Specific users to temporarily take on a role, gaining its privileges
- Kernel enforces rules based on uid and current privileges
  - No more “if (uid==0)”

Solaris Zones and Security

- Each zone has a security boundary
- Runs with subset of privileges(5)
- A compromised zone cannot escalate its privileges
- Important name spaces are isolated
- Processes running in a zone are unable to affect activity in other zones
- Zone-aware audit:
  - Global zone administrator can specify whether auditing should be global or per-zone
  - If per-zone, each zone administrator can configure and process their audit trails independently
- Solaris 10 11/06 introduces configurable privileges

Solaris Zones Security Limits

contract_event	Request reliable delivery of events	proc_lock_memory	Lock pages in physical memory
contract_observer	Observe contract events for other users	proc_owner	See/modify other process states
cpc_cpu	Access to per-CPU perf counters	proc_priocntl	Increase priority/sched class
dtrace_kernel	DTrace kernel tracing	proc_session	Signal/trace other session process
dtrace_proc	DTrace process-level tracing	proc_setid	Set process UID
dtrace_user	DTrace user-level tracing	proc_taskid	Assign new task ID
file_chown	Change file's owner/group IDs	proc_zone	Signal/trace processes in other zones
file_chown_self	Give away (chown) files	sys_acct	Manage accounting system (acct)
file_dac_execute	Override file's execute perms	sys_admin	System admin tasks (e.g. domain name)
file_dac_read	Override file's read perms	sys_audit	Control audit system
file_dac_search	Override dir's search perms	sys_config	Manage swap
file_dac_write	Override (non-root) file's write perms	sys_devices	Override device restricts (exclusive)
file_link_any	Create hard links to diff uid files	sys_ipc_config	Increase IPC queue
file_owner	Non-owner can do misc owner ops	sys_linkdir	Link/unlink directories
file_setid	Set uid/gid (non-root) to diff id	sys_mount	Filesystem admin (mount,quota)
ipc_dac_read	Override read on IPC, Shared Mem perms	sys_net_config	Config net interfaces,routes,stack
ipc_dac_write	Override write on IPC, Shared Mem perms	sys_nfs	Bind NFS ports and use syscalls
ipc_owner	Override set perms/owner on IPC	sys_res_config	Admin processor sets, res pools
net_icmpaccess	Send/Receive ICMP packets	sys_resource	Modify res limits (rlimit)
net_privaddr	Bind to privilege port (<1023+extras)	"ys_suser_compat	3rd party modules use of suser
net_rawaccess	Raw access to IP	sys_time	Change system time
proc_audit	Generate audit records		
proc_chroot	Change root (chroot)		
proc_clock_highres	Allow use of hi-res timers		
proc_exec	Allow use of execve()	Interesting	Some interesting privileges
proc_fork	Allow use of fork*() calls	Basic	Non-root privileges
proc_info	Examine /proc of other processes	Removed	Not available in Zones

Processes

- Certain system calls are not permitted or have restricted scope inside a zone
- From the global zone, all processes can be seen but control is privileged
- From within a zone, only processes in the same zone can be seen or affected
- `proc(4)` has been virtualized to only show processes in the same zone

```
# prstat -Z
   PID USERNAME  SIZE   RSS STATE  PRI NICE      TIME  CPU PROCESS/NLWP
  1344 root     8956K 8108K sleep   59    0   0:00:04 2.0% svc.configd/14
  1342 root     7312K 6456K sleep   59    0   0:00:01 0.4% svc.startd/12
  1460 root     3824K 2932K sleep   59    0   0:00:00 0.1% inetd/4


ZONEID    NPROC  SIZE   RSS MEMORY      TIME  CPU ZONE
     1       23   78M   46M   4.5%   0:00:05 2.8% zone1
```

Networking and Interprocess Communication

- Single TCP/IP stack for the system (today) so that zones can be shielded from configuration details for devices, routing and IPMP
- Each zone can be assigned IPv4/IPv6 addresses and has its own port space
- Applications can bind to `INADDR_ANY` and will only get traffic for that zone
- Zones cannot see the traffic of others
- Global zone can snoop traffic of all zones
- Expected IPC mechanisms such as System V IPC, STREAMS, sockets, `libdoor(3LIB)` and loopback transports are available inside a zone
- Key name spaces virtualized per zone
- Inter-zone communication is available using standard network interfaces over a private memory channel.
- Global zone can setup rendezvous too, although this is not commonly needed

Devices and Filesystems

- Unlike `chroot(2)`, processes cannot escape out of a zone's filesystems
- Additional directories can be mounted read-write
  - **Example `/usr/local`**
- Filesystems mounted by zoneadmd at zone boot time.
- Global zone managed filesystems also supported
  - Third party filesystems also work (ex: VxFS)
- Zones see a subset of “safe” pseudo devices in their **`/dev`** directory
  - Devices like **`/dev/random`** are safe but others like **`/dev/ip`** are not
- Zones can modify the permissions of their devices but cannot `mknod(2)`
- Physical device files like those for raw disks can be put in a zone with caution
  - Often unnecessary due to on-disk filesystem support in zonecfg

Zones and Solaris Dynamic Tracing (DTrace)

- Zonename variable available
- Example: Count syscalls by zone:

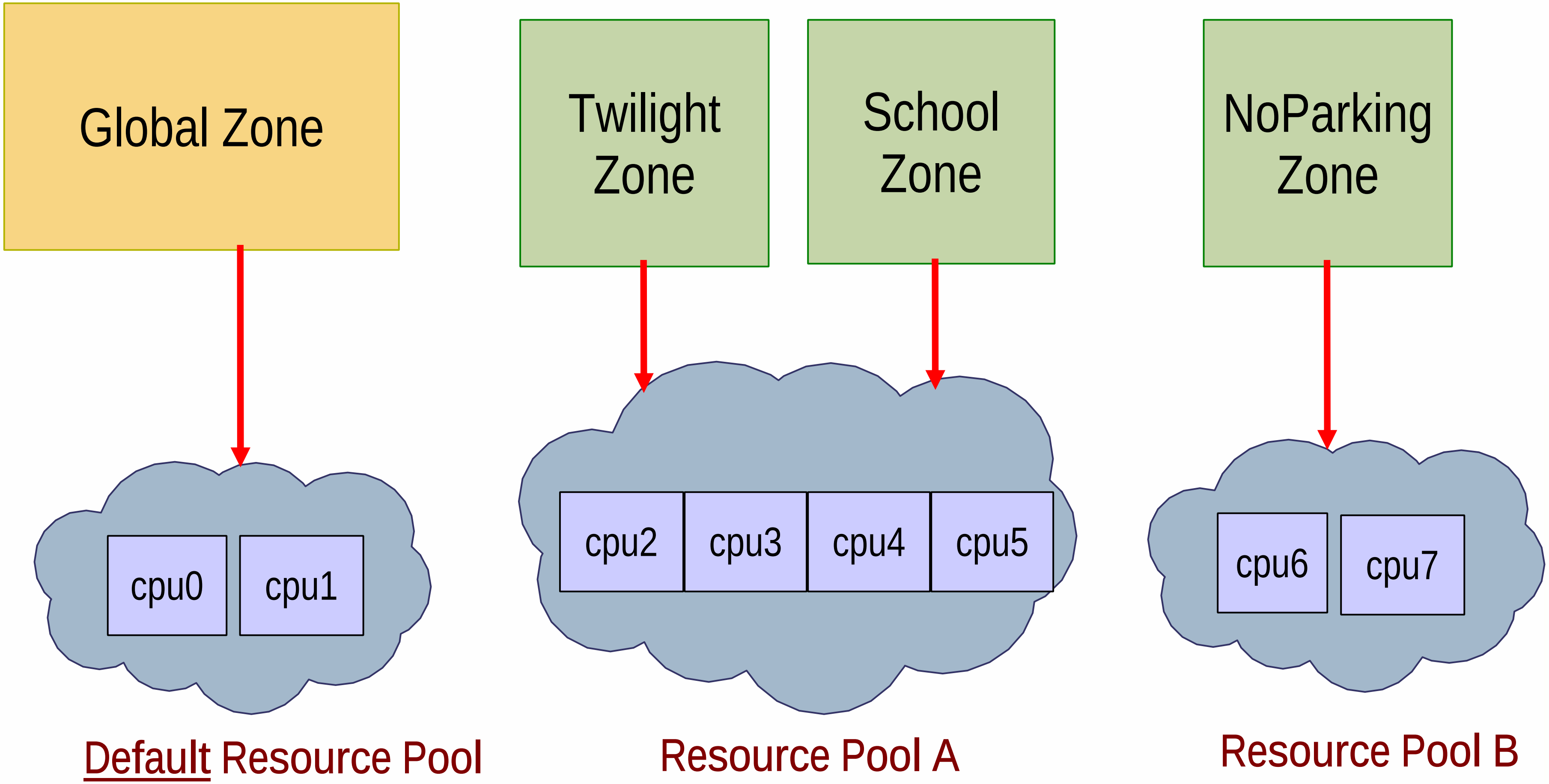
```
# dtrace -n 'syscall:::/zonename==”red”/
   {@[probefunc=count()}'
```

- Also available: `curpsinfo->pr_zoneid`
- DTrace can be useful for tracing multiple application tiers in conjunction with zones
  - Eliminates complexities such as clock skew
- Solaris 10 11/06 configurable privileges will allow dtrace_user and dtrace_proc to be granted to a zone
  - Allows tracing of processes (pid) and system calls (syscall)

Zones, Resources and Limits

- By default, all zones use all CPUs
  - Also, tools like prstat base %'s on all CPUs
- Restricted view is enabled automatically when resource pools are enabled
  - virtualized view based on the pool (pset) binding
  - Affects `iostat(1M)`, `mpstat(1M)`, `prstat(1M)`, `psrinfo(1M)`, `sar(1)`, etc.
  - `sysconf(3C)` (when detecting number of processors) and `getloadavg(3C)`
  - numerous `kstat(3KSTAT)` values from the `cpu`, `cpu_info` and `cpu_stat` publishers
- Oracle licensing to pool size

Resource Pools



Global Zone

Twilight Zone

School Zone

NoParking Zone

cpu0

cpu1

cpu2

cpu3

cpu4

cpu5

cpu6

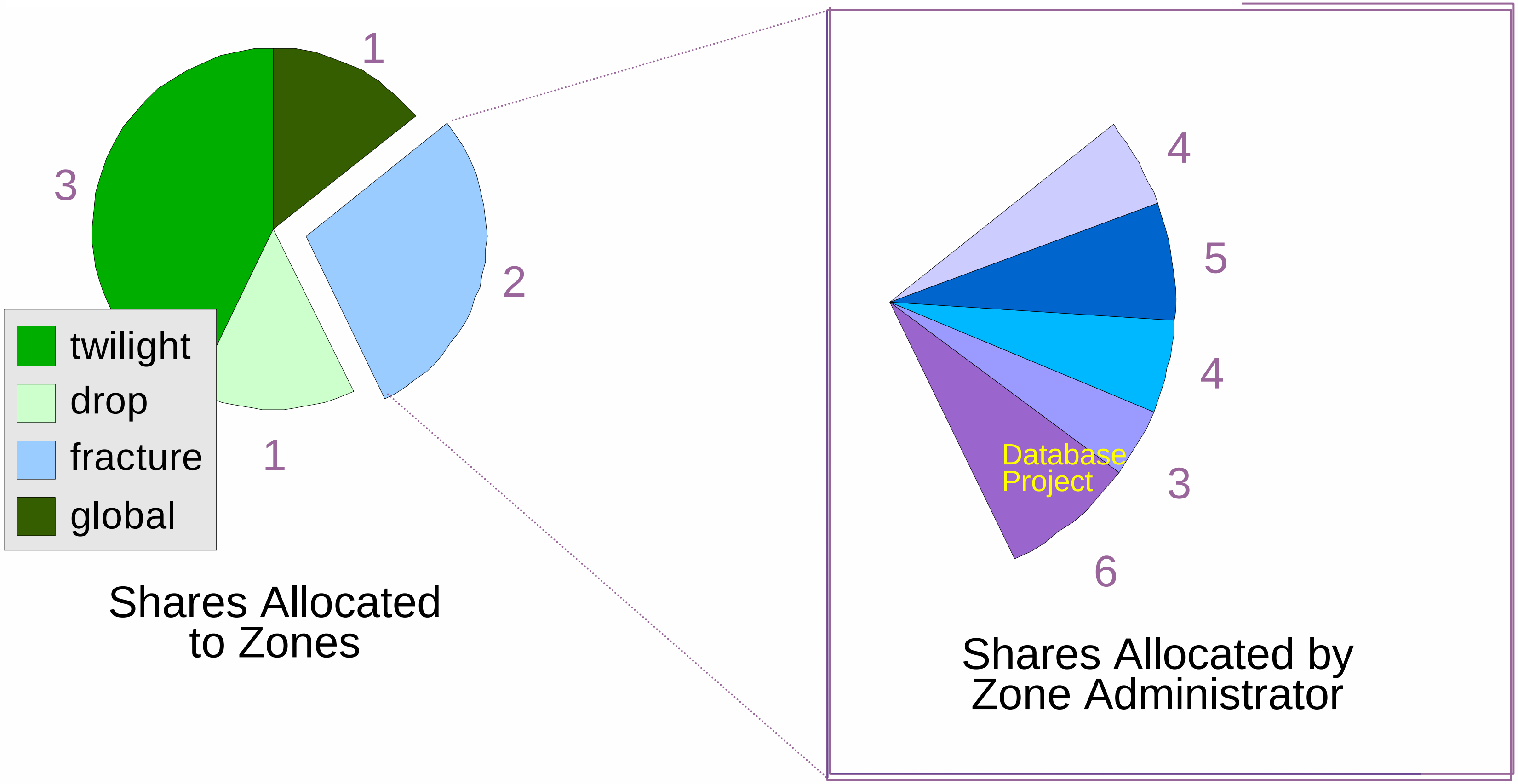
cpu7

Default Resource Pool

Resource Pool A

Resource Pool B

Zones and the Fair Share Scheduler (FSS)



Shares Allocated to Zones

Shares Allocated by Zone Administrator

$$\frac{2}{(3+1+2+1)} \times \frac{6}{(4+5+4+3+6)} = \frac{2}{7} \times \frac{6}{22} = \frac{6}{77} \sim 7.8\%$$

Sparse vs Whole Root Zones

- Each zone is assigned its own root file system and cannot see that of others
- The default file system configuration is called a “sparse-root” zone
  - The zone contains its own writable /etc, /var, /proc, /dev
  - Inherited file systems (/usr, /lib, /platform, /sbin) are read-only mounted via a loopback file system (LOFS)
  - /opt is a good candidate for inheriting
- A zone can be created as a “whole-root” zone
  - The zone gets its own writable copy of all Solaris file systems
- Advantages of a sparse root zone
  - Faster patching and installation due to inheritance of /usr and /lib
  - Read-only access prevents trojan horse attacks against other zones
  - Libraries shared across all zones reducing VM footprint

Packages and Patches

- Zones can add and remove own packages and patches (i.e. database)
  - Assuming packages don't conflict with global zone packages (or allzone packages)
- System Patches
  - Applied in global zone
  - Then in each non-global zones (zone will automatically boot -s to apply patch)
- Package types
  - `SUNW_PKG_HOLLOW:` Package info exists (to satisfy dependencies) but its contents are not present.
  - `SUNW_PKG_ALLZONES:` Package will be kept consistent between the global zone and all non-global zones (e.g. kernel drivers).
  - `SUNW_PKG_THISZONE:` If true, package installs only in the current zone (like pkgadd -G). If installed in the global zone, it will not be made available to future zones.

Zone Administration

- `zonecfg(1M)` is used to specify resources (e.g. IP interfaces) and properties (e.g. resource pool binding)
- `zoneadm(1M)` is used to perform administrative steps for a zone such as list, install, (re)boot, halt
- Installation creates a root file system with factory-default editable files
- A zone can be cloned very quickly using ZFS
- A zone can be moved to another system with detach/attach
- `zlogin(1)` is used to access a zone
  - `zlogin -C` to access the zone console

Zone Installation Process

- By default, all of the files that are packaged in the global zone are stored in the new zone
- Packaged files are copied directly out of the global zone's root file system except for those that are editable or volatile (see pkgmap(4))
- Editable and volatile files are copied from the sparse-root package archive
  - holds factory default copies of files
- A properly configured sparse-root zone is typically about 70-100MB; a whole-root zone is 3-5GB depending on installed packages

When to Use a Whole Root Zone

- Use full root zones when writes into /usr or /lib cannot be contained
  - Writable loopback mounts for individual directories (such as /usr/java) can be used for sparse root zones
  - Sometimes this is not practical (example: /usr/bin)
  - Use of writable loopback mounts makes /opt a good candidate for inheritance
- Requirement to patch Solaris user components individually
  - Third party software typically installed in /opt
- Use a sparse root zone for all other situations

Single or Multiple Applications Zones

- Single application zones
  - Low overhead (administrative and performance) makes this a recommended practice
  - All configuration files are in the default location
  - Virtualized IP space allows applications to reside on well known ports
  - Patching is simplified due to applications being where they are expected
- Multiple application zones
  - When applications require or can benefit from shared memory

VMware and Solaris Containers General Approach

- Use VMware when
  - Using heterogeneous or multiple (incompatible) versions of operating systems
  - Consolidated privileged applications are unstable
  - Operating system maintenance windows become unmanageable
  - Requiring live migration
  - Running obsolete operating systems on current hardware
- Use Solaris Containers when
  - Fine grained control of resource limits
  - Leveraging advanced Solaris features such as DTrace, Fault Management (FMA), ZFS
  - Resource sharing between environments can reduce platform costs
  - Deploying extremely heavy or very light services
    - Applications require high I/O throughput (databases)
- Combine generously as real world conditions are never sim

Solaris Containers Best Practices

- Use sparse root zones where possible
  - Maximize sharing of components
  - Minimize memory footprint (shared libs, binaries)
- Use full root zones only where needed
  - Extensive writing into /usr
  - Core component patch testing
  - Use of ZFS clones will make this much more attractive
- Group applications into zones
  - By shared memory requirements
  - By user credential domain
- Use loopback file system mounts to share data
- Use NFS to share data for zones that will be migrated

Solaris Containers Best Practices (cont)

- File system backup can be run in the global zone
  - Non-global zones have no private file system data that is not visible to the global zone
- Run backup clients in the non-global zone when there is some application state that needs to be captured or modified
- Run a minimum number of services in the global zone
  - ssh
  - Intrusion detection and auditing
  - Hardware monitoring
  - Accounting
  - Backup

Use Case 1: You are in a maze of web servers, all alike

- Considerations
  - Web servers prefer to live on well known ports
  - Server utilization can be very low
  - Many configurations are basic
  - Consolidating in a single operating system can become very complex
  - Classic partitioning problem in disguise
- Recommendation
  - One web server instance per Solaris zone
  - Very few operating system dependencies
  - Configuration files are all in their well known location
  - Patch automation is simplified
  - Separate content creation for a more secure solution
  - Can leverage Solaris least privilege

Use Case 2: Web 2.0

- Considerations
  - Operating system dependencies more complicated
  - Avoid unintended application linkages that make future updates or redeployment difficult
  - Leverage operating system hardening and privilege minimization
  - Require fine grain control over resource utilization
- Recommendation
  - Use Solaris zones with one application instance per zone
  - Deploy only the OS components necessary to support the service
  - Use configurable privileges to limit access to memory, network interfaces and kernel modules.
- Exceptions
  - Services that have dependencies on kernel modules
  - Heterogeneous operating system requirements

Use Case 3: ERP in a box

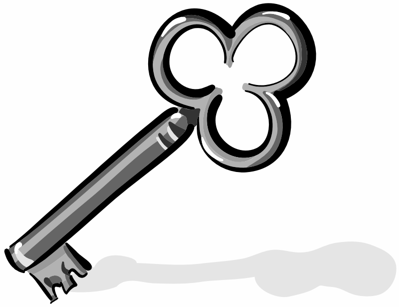
- Considerations
  - Different than typical ERP landscape
    - Trade off database performance considerations for reduced footprint
  - Not all features or applications run on all operating systems
  - Will require a combination of virtualization and partitioning
  - Desire fine grain control of resources
  - Observability and security are desired features, especially in development
- Recommendation
  - Use VMware ESX server to host multiple operating systems
  - Run database in one zone and application logic in separate zones based on software scalability features
    - Solaris Dynamic Tracing can be used across tiers
  - Host additional guest virtual machines for interfaces and application features not available on Solaris

Use Case 4: Enterprise Java Application Development

- Considerations
  - Leverage advanced development tools such as DTrace
    - Java Virtual Machine DTrace provider is very handy
  - Isolate to minimize impact on other developers
  - Develop in same environment as deployment
  - Rapidly provision complete software stacks
- Recommendation
  - Create development zones that mirror production and test environments
  - Use zone privilege limits to safely delegate administrative roles to developers
- Exceptions
  - Heterogeneous platform development
  - Develop on multiple operating system versions

Conclusion

- Solaris Containers and VMware Infrastructure (ESX) technologies are complementary
    - Each provides a unique set of capabilities and efficiencies that can be leveraged together
- The key to success is knowing when to use each technology



References and Additional Reading

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