Qumranet

KVM Live Migration

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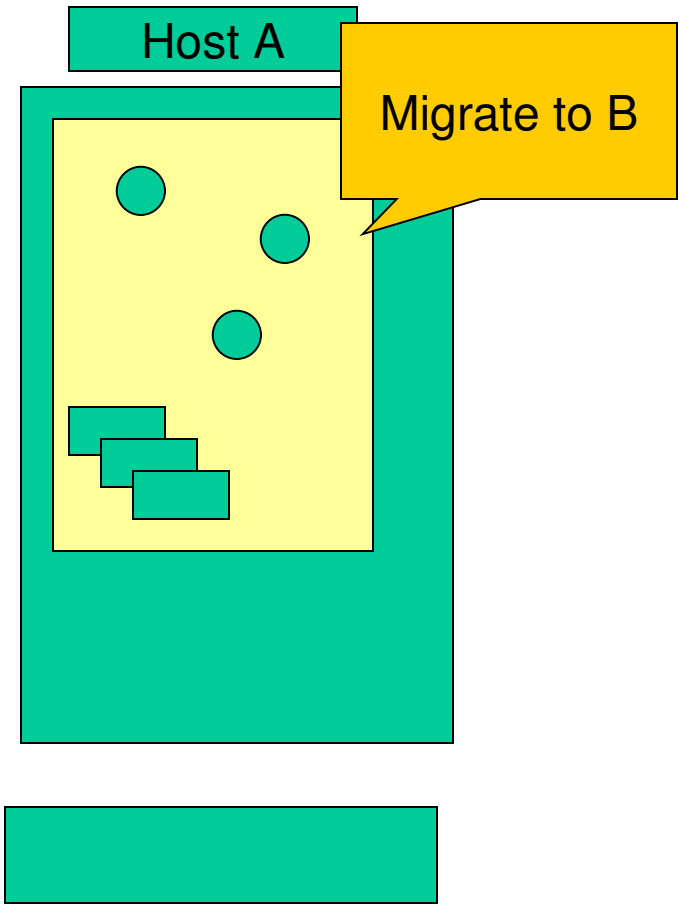
Agenda

- Introduction
- Algorithm
- Migration Protocols
- How to add migration support for new devices
- Using it
- Summary/Merits compared to other hypervisors
- Future Work

Introduction

- Live Migration, A valuable feature of any hypervisor
  - Almost unnoticeable guest downtime
  - Load Balancing, Maintenance, Hardware Upgrades Software Upgrades
- Guest is not involved
- Capable of tunneling VM State through an external program
- Short and Simple
- Easy to Enhance
- Hardware (almost) independence

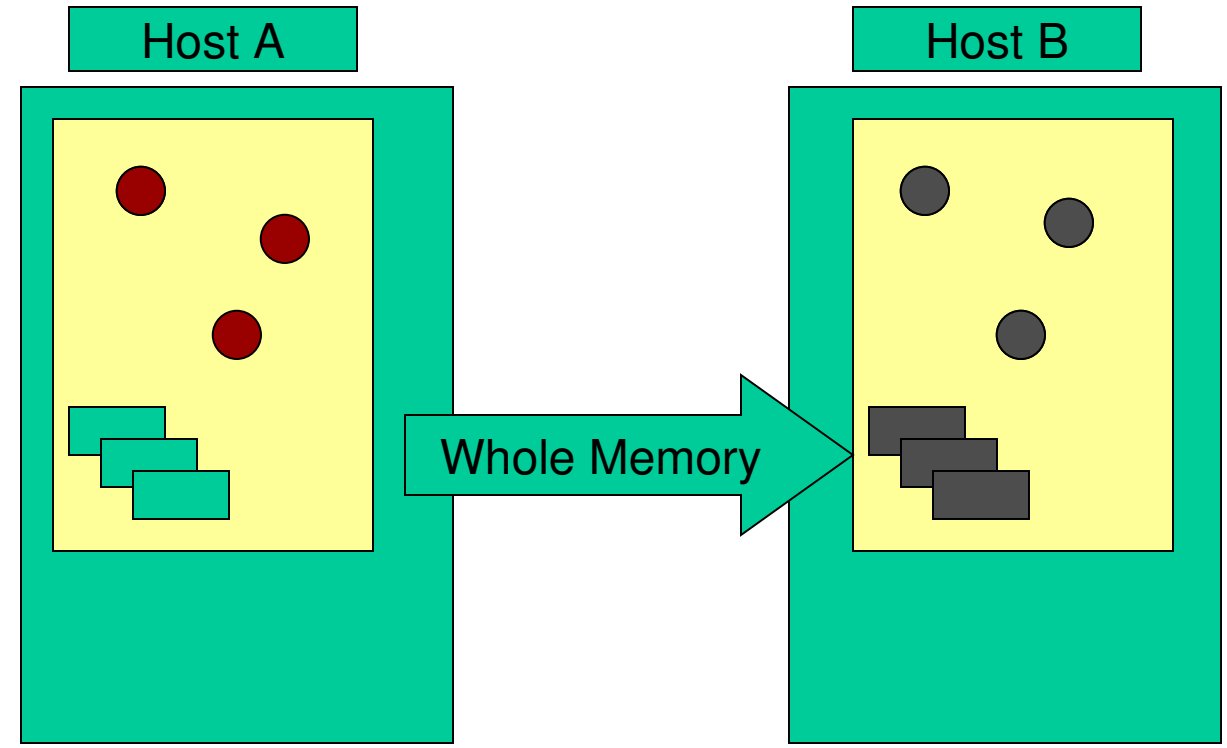
Algorithm



1. Setup

2. Transfer Memory

Algorithm

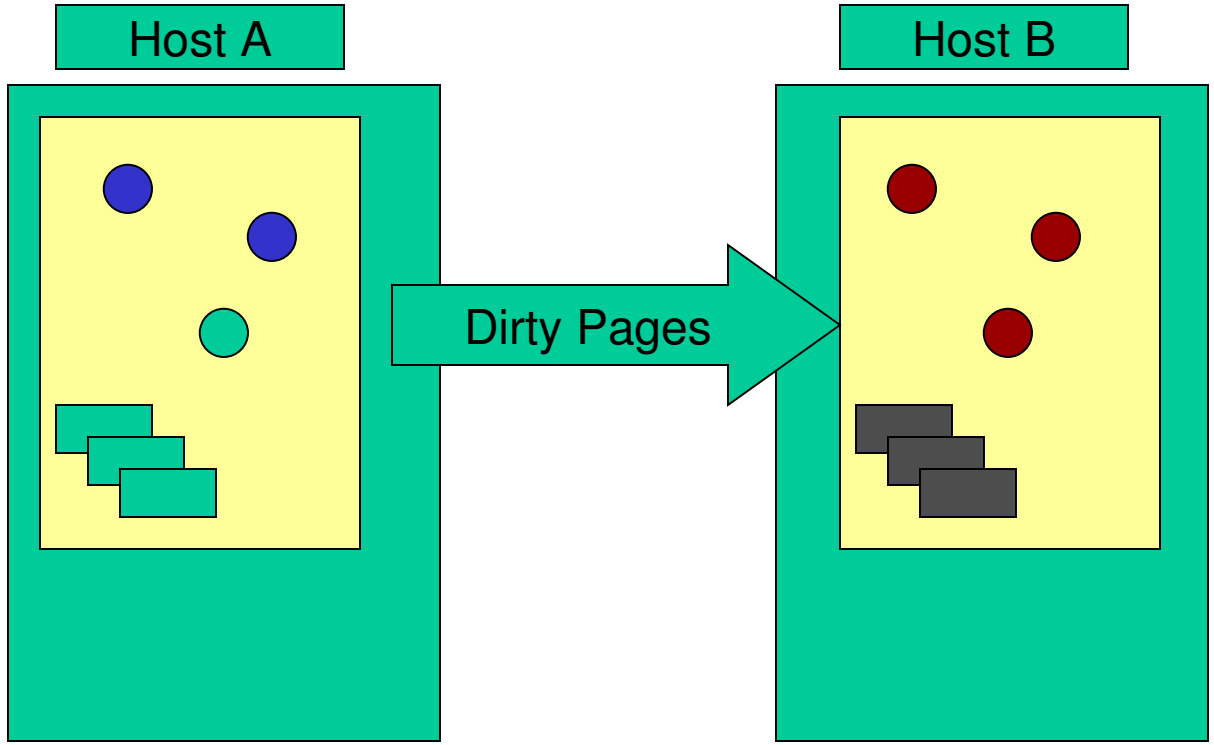


1. Setup

2. Transfer Memory

1 -- 133000

Algorithm

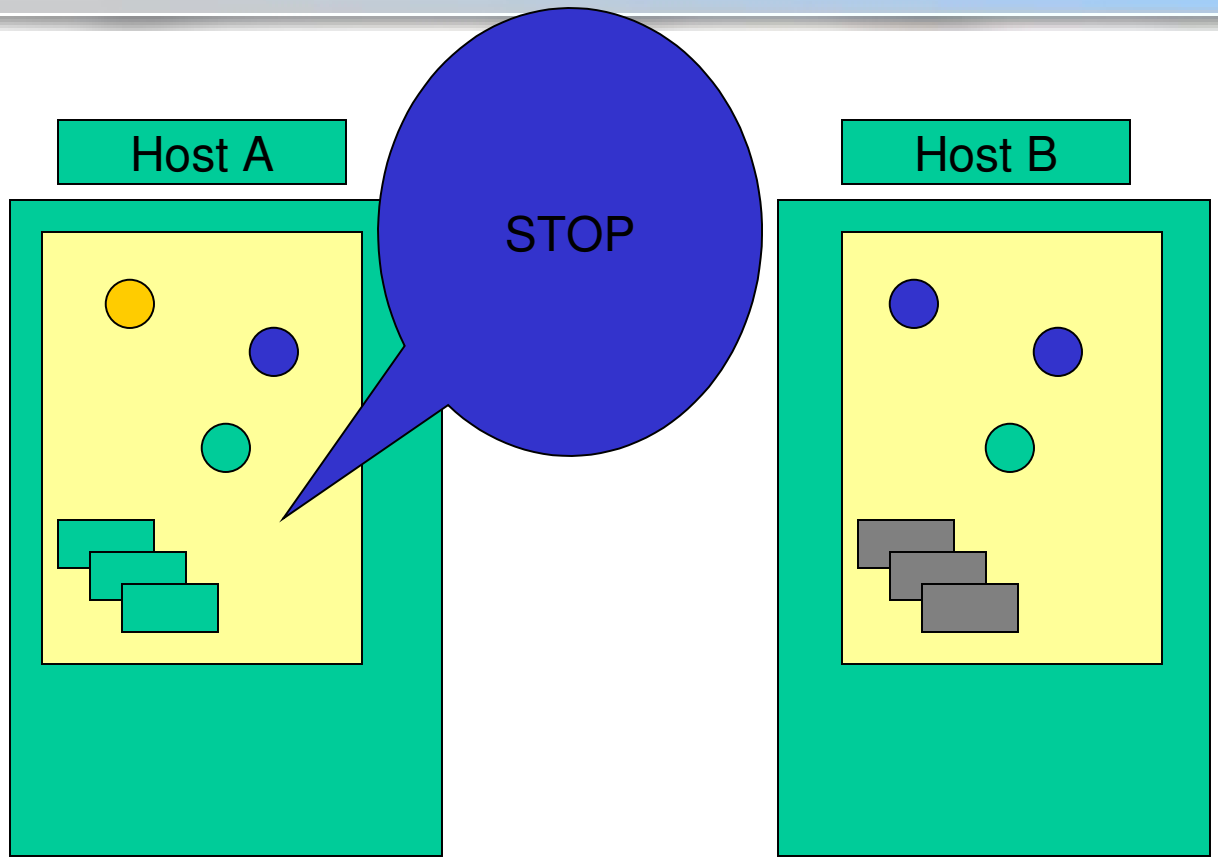


1. Setup

2. Transfer Memory

2 -- 5800

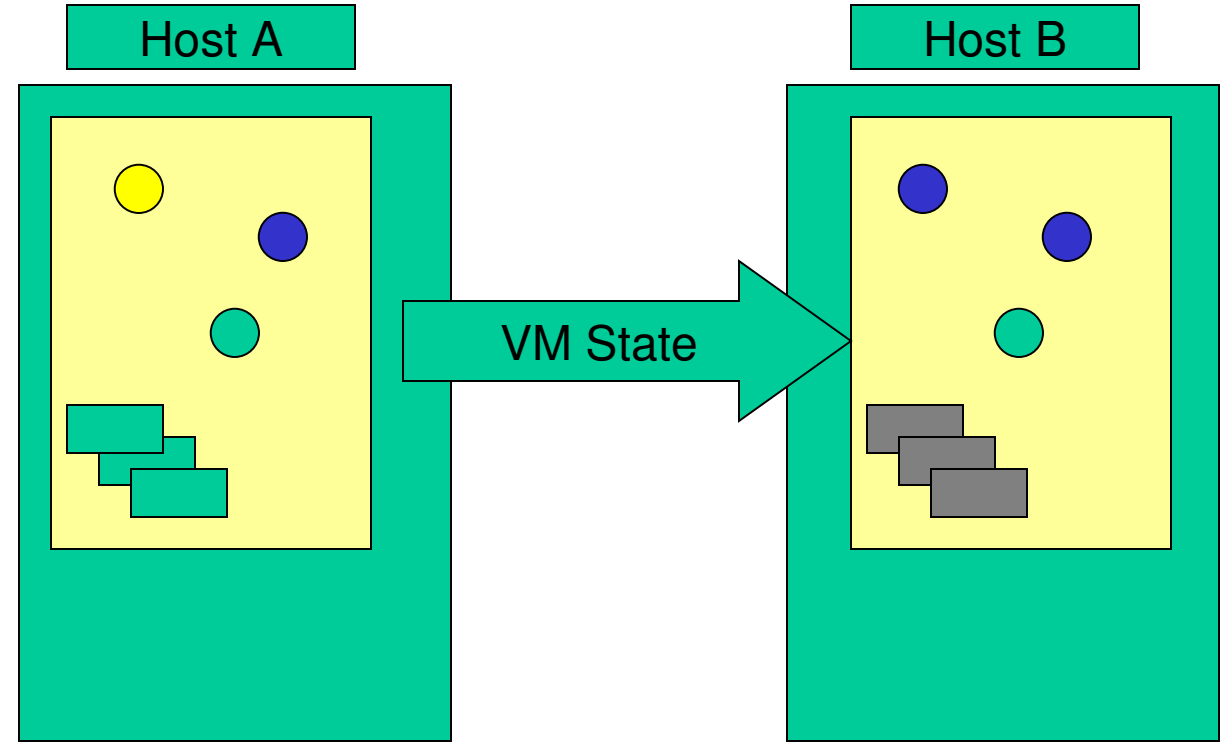
Algorithm



1. Setup
2. Transfer Memory
3. Stop the VM

3 -- 50

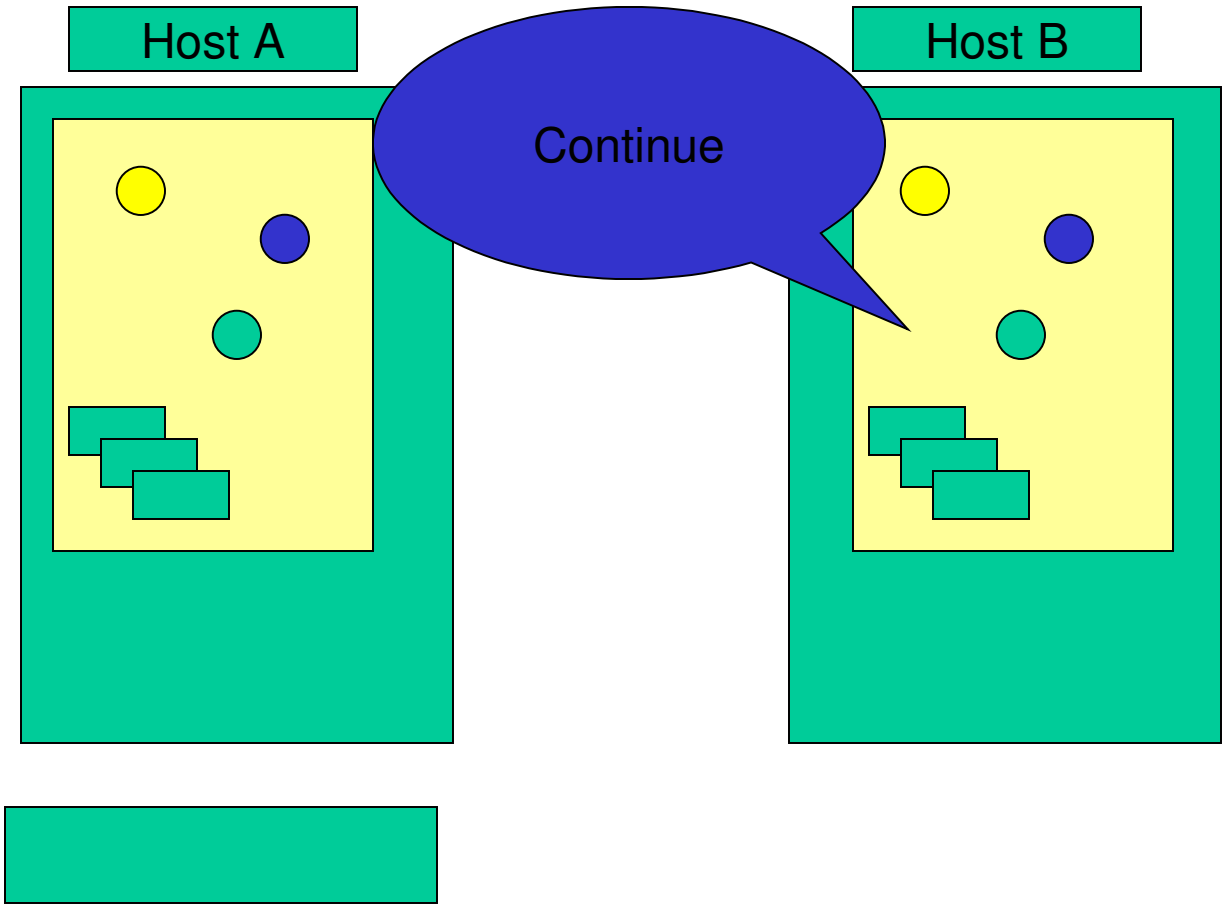
Algorithm



1. Setup
2. Transfer Memory
3. Stop the VM
4. Transfer State

1 -- 50

Algorithm



1. Setup
2. Transfer Memory
3. Stop the VM
4. Transfer State
5. Continue VM

Algorithm

1. Migration Request arrives (migrate VM from A to B)
   - Spawn external command (If applicable)
   - Connect (if applicable) and send header
   - Allocate resources + Setup

Algorithm

1. Migration Request arrives
2. Transfer Memory
   - First transfer all memory pages (first iteration)
   - For every next iteration I transfer all dirty pages of iteration i-1
   - Until convergence

Algorithm

1. Migration Request arrives
2. Transfer Memory
3. Stop the VM

Algorithm

1. Migration Request arrives
2. Transfer Memory
3. Stop the VM
4. Transfer VM State
   - Each device “transfer” its own state
   - Dirty pages (from the last iteration) included

Algorithm

1. Migration Request arrives
2. Transfer Memory
3. Stop the VM
4. Transfer VM State
5. Continue the VM
   - On remote (B) if migration was successful
     - Send (broadcast) an Ethernet packet to announce the new location
   - On local host (A) if migration failed

Memory Transfer

- Requires support for dirty memory page logging
- Homogeneous page optimization
- Rapidly written pages / Writeable Working Set
- Dynamic Bandwidth Limitation

Dirty Page Logging

- Qemu
  - One byte per page – supports up to 8 different dirty types
  - Devices that write directly into guest memory must update the dirty-byte-map
- KVM
  - One bit per page
  - Pages are mapped RO to intercept first-write
  - Enabled/Disabled when migration begins/ends
  - Merged with Qemu's dirty log before every memory transfer iteration

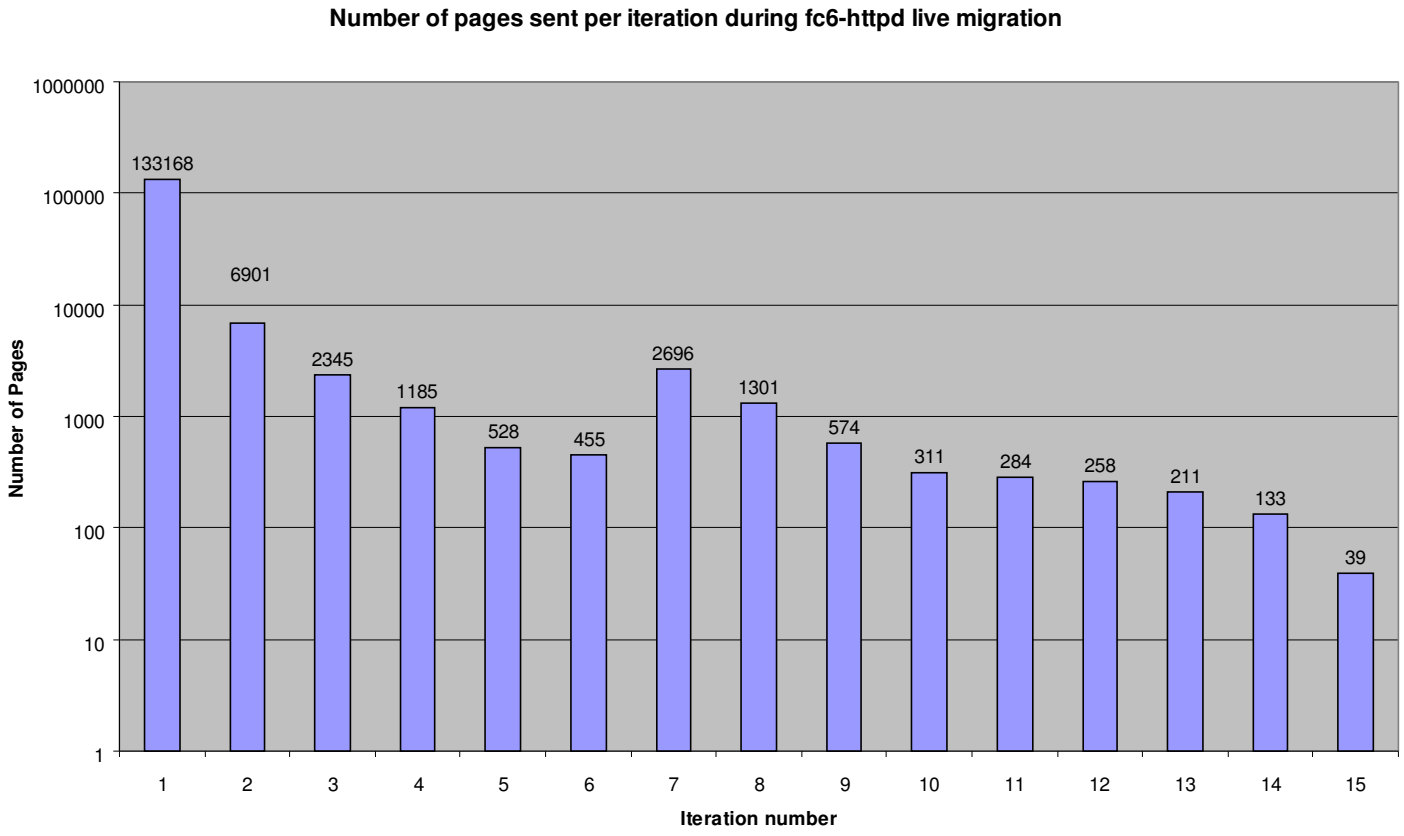
State Save/Load

- Qemu devices register save/load functions
- Functions are called upon VM save/load/migrate
- Versioning/Backwards-Compatibility
- KVM State (register values) is synchronized with qemu as part of cpu and other devices' state-functions

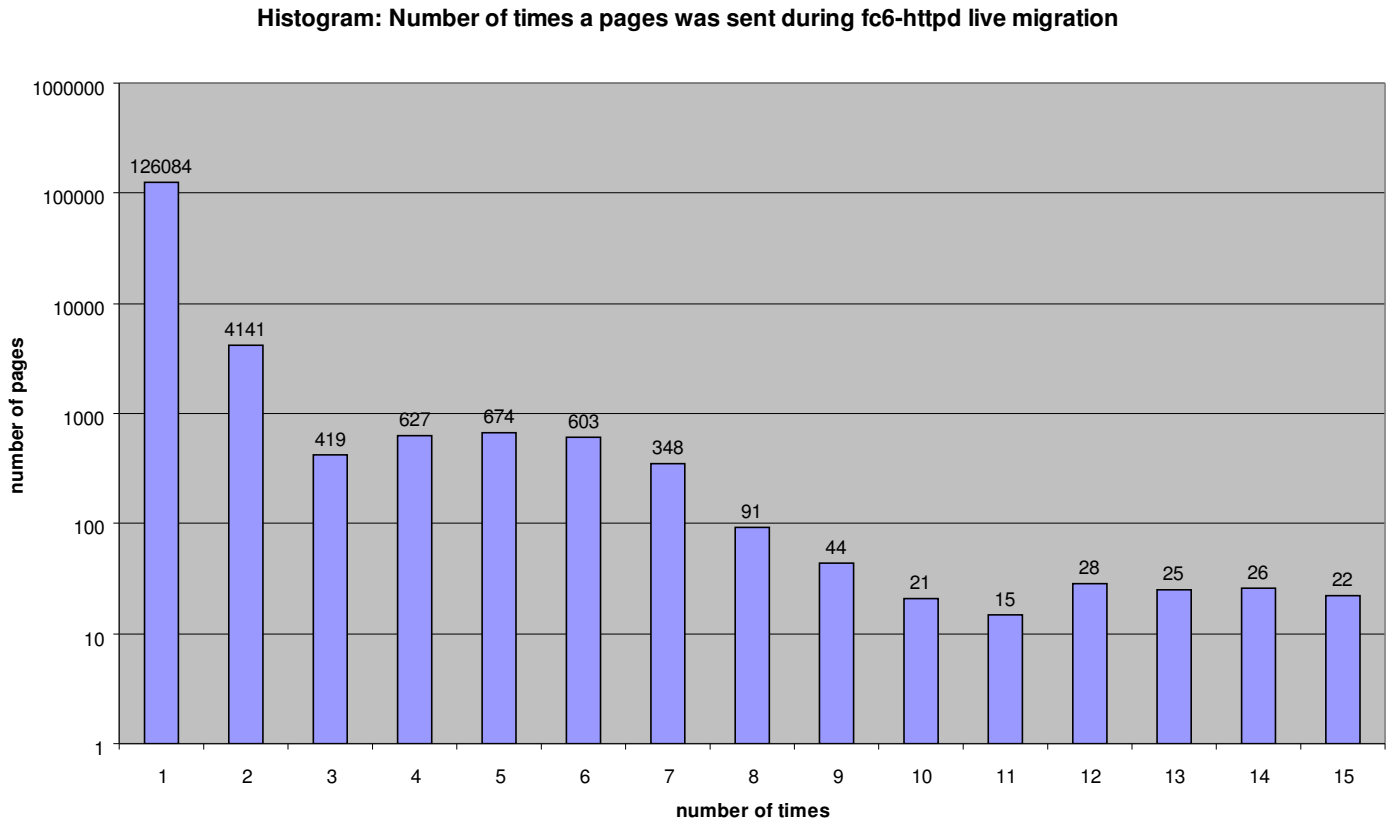
Memory Transfer Convergence Rules

- Transitions the algorithm from live phase to offline phase, according to the following rules:
- Convergence: N1=50 dirty pages (or less) left
- No Progress: N2=2 iterations where the number of transferred memory pages is smaller than the number of pages that got dirty.
- Hard limit: N3 = 30 iterations passed

Convergence example: fc6 running httpd

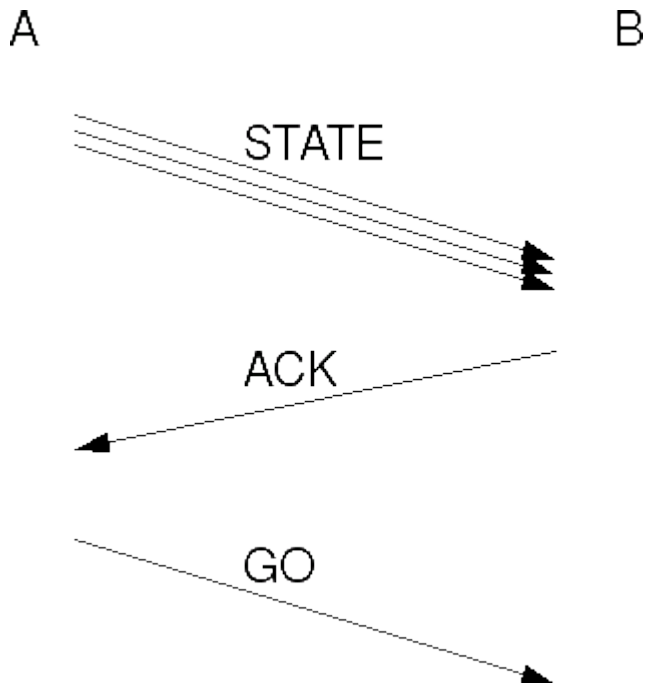


WWS example: fc6 running httpd



End Of Migration Protocol (for tcp://)

- Goal: prevent a case where a guest continues to run on both hosts
- Algorithm:
  - A Transfers state to B and waits for ACK
  - B receives state, sends ACK and waits for GO
  - A receives ACK, and sends GO
  - B receives GO and continues
  - Upon any timeout (lost messages), migration fails
- Worst Case: Go was lost
  - VM does not run (on any host)
  - A stops, B exits
  - Third party (management) intervention required



Migration Support for new devices

- If the new device writes directly to guest memory – update byte-map-log
- If some syncing needs to be done before/after state transfer, register to get VM stop/cont events
- Register save/load state function
- Don’t forget versioning (support for backwards compatibility)

Migration Support for PV drivers

- PV host-side must
  - Save/Load its state
  - Make sure guest state is valid on remote host
- Use Non-Locking guest-host synchronization mechanism.
  - Such as rings.
  - Guest must never be stopped while holding a guest-host shared lock.
- Keep hypercall-calling a single command

Qemu monitor commands and cmd line

- (qemu) migrate [–d] <migration_protocol:params>
  - On remote <kvm-cmd-line> –incoming <protocol:params>
  - /usr/bin/kvm –m 512 –hda /images/a.img –incoming stdio
- (qemu) migrate_set_speed <bytes_per_second>
- (qemu) migrate_cancel
- (qemu) info migration

Migration Protocols – Use Cases

- Using TCP sockets
  - Migrate tcp://remote:port
  - -incoming tcp://0:port
- Built In ssh support
  - Migrate ssh://remote
- Save image to file
  - Migrate “exec: dd of=STATEFILE”
  - -incoming file://STATEFILE
- Compress using gzip (bzip2)
  - Migrate “exec: gzip –c > FILE.gz”
- Encrypt using gpg into a file or to remote
  - Migrate “exec: gpg –q –e –r KEY –o FILE.gpg”
  - Migrate “exec: gpg –q –e –r KEY | nc remote port”
    - Nc –l port | gpg –q –d –r KEY | <kvm-cmd>

Merits compared to other hypervisors

- Short and Simple
- Built in security using ssh
- Guest is not involved
- Hardware independence
- Migration of stopped guests
- Tunneling/Flexibility/Extensibility
- Compression/Encryption
- Backwards Compatibility
- Upon Failure, guest continues to run on source host.
- Open

Future Work

- Support for more migration protocols
  - Live Checkpoints, compression, encryption, file
  - Partial support for unknown migration protocols
- WWS optimization
- Fine tune parameters
- Deal with device assignment/direct access.
- Migrate to a remote location
- Migrate disk as together with state.
- Support for new features of kvm (e.g. pass through)

Thank You ☺