Czech Technical University in Prague

Clustering & Scalability

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Agenda

- Clusters
  - HA
  - Load-balancing
  - Scalability
- JGroups
- Infinispan
- Clustering in AS7
- mod_cluster

Cluster in General

- “A computer cluster consists of a set of loosely connected computers that work together so that in many respects they can be viewed as a single system.”

  Wikipedia

Motivation

- Interconnected
- But independent
- Made possible with
  - high-speed networking
  - and cheap commodity hardware
- Improve performance and/or availability
- Scale to handle higher load

Lets Define “Our” Cluster for Today

- A cluster is a collection of JBoss AS 7 servers that communicate with each other so as to improve the availability of services by providing the following capabilities:
  - High Availability
  - Scalability
  - Failover
  - Fault Tolerance

High Availability / HA

- Capability to support server applications that can be reliably utilized with a minimum down-time.

Scalability

- Capability to handle a large number of requests by without service response time degradation.

Failover

- Capability for a cluster node to take over the tasks or requests processed by a failing node.

Fault Tolerance

- Guarantee of correct behaviour in the event of a failure.

What does Java EE say about clustering?

AS7 Clustering Areas

- Web session replication
- Stateful Session Bean replication
- Entity bean replication (2nd level caching)
- mod_cluster auto-configuration
- HornetQ (JMS) clustering
  - not covered here today

Making Deployments Clustered

- Distributed web sessions
  - Add `<distributable/>` tag to web.xml
  - Uses “web” cache container, by default
- Clustered Stateful Session Beans
  - Annotate `@Clustered @Stateful`
  - Uses “ejb” cache container, by default

Distributable Sessions

- All session attributes must be serializable
  - Must implement `java.io.Serializable`
  - Most native Java objects implement this functionality
- After changing any objects which are stored in the session
  - `HttpSession.setAttribute()` must be called to inform the session replication that the session has changed
- Ideally, sessions should be kept relatively small
  - less network traffic between the each clustered VM.

Application Must be Cluster-Aware

- Don't spawn custom services that should be singleton in the cluster.
  - Mailer threads, whatnot.
  - Locking becomes complex
- Don't store data as flat files
  - Store over NAS/SAN (NFS)
  - Use DB
  - Use data grid

SingletonService

```
MyService service = new MyService();

SingletonService<Environment> singleton =
new SingletonService<Environment>(service, MyService.SERVICE_NAME);

singleton.setElectionPolicy(new PreferredSingletonElectionPolicy(new
NamePreference(SingletonService.DEFAULT_CONTAINER), new
SimpleSingletonElectionPolicy()));

ServiceController<Environment> controller =
singleton.build(CurrentServiceContainer.getServiceContainer())
.addDependency(ServerEnvironmentService.SERVICE_NAME,
ServerEnvironment.class, service.getEnvInjector()).install();

controller.setMode(ServiceController.Mode.ACTIVE);
```

EE6 @Singleton

- Not cluster-wide singleton!
- @Singleton per JVM as spec dictates
- @Clustered @Singleton could be cluster-wide singleton (not yet)
- How to implement over SingletonService?

Clustered 2LC

- JPA/Hibernate 2nd level cache
  - – Infinispan is default 2nd level cache provider
- persistence.xml no longer needs to define hibernate.cache.region.factory_class
  - – Uses “hibernate” cache container, by default
  - – Non-clustering profiles use local-cache
- Provides eviction & expiration support
  - – “ha” profiles use clustered caches
- invalidation-cache for entities/collections

Operational Modes

- Clustering is orthogonal to
  - Standalone mode or
  - Domain mode
- Clustering in domain set to be easier to manage

Changes from AS 4/5/~6

- All clustering services start on demand and stop when no longer needed
- Lifecycle example
  - Deploy app1, starts channel and cache
  - Deploy app2
  - Undeploy app1
  - Undeploy app2, stops cache and channel
- Starting a server with no deployments will not start any channels/caches

Changes from AS 4/5/~6

- Infinispan replaced JBoss Cache as clustering toolkit and session cache
- Configuration is now centralized.
- No more farm deployment.
- Domains and server groups provide this functionality.
- No out-of-box HA Singleton deployer.
- No HA JNDI (replaced with client JNDI).

Extensions for Clustering in AS7

- `org.jboss.as.clustering.jgroups`

  the JGroups extension, which provides the communication between between cluster nodes

- `org.jboss.as.clustering.infinispan`

  the Infinispan extension, which provides the replicated caching functionality

- `org.jboss.as.modcluster`

  extension to provide integrations and configuration with mod_cluster software load balancer

Predefined Profiles

- Standalone mode
  - *standalone-ha.xml*
  - *standalone-full-ha.xml*
- `$ ./bin/standalone.sh -server-config standalone/configuration/standalone-ha.xml`

Predefined Profiles

- Domain mode
  - *ha profile*
  - *`full-ha` profile*
- Use “ha” profile from domain.xml

```
<server-group name="clustered-group" profile="ha">
     <socket-binding-group ref="ha-sockets"/>
</server-group>
```

- `$ ./bin/domain.sh`

JGroups

“Toolkit for reliable cluster communication”

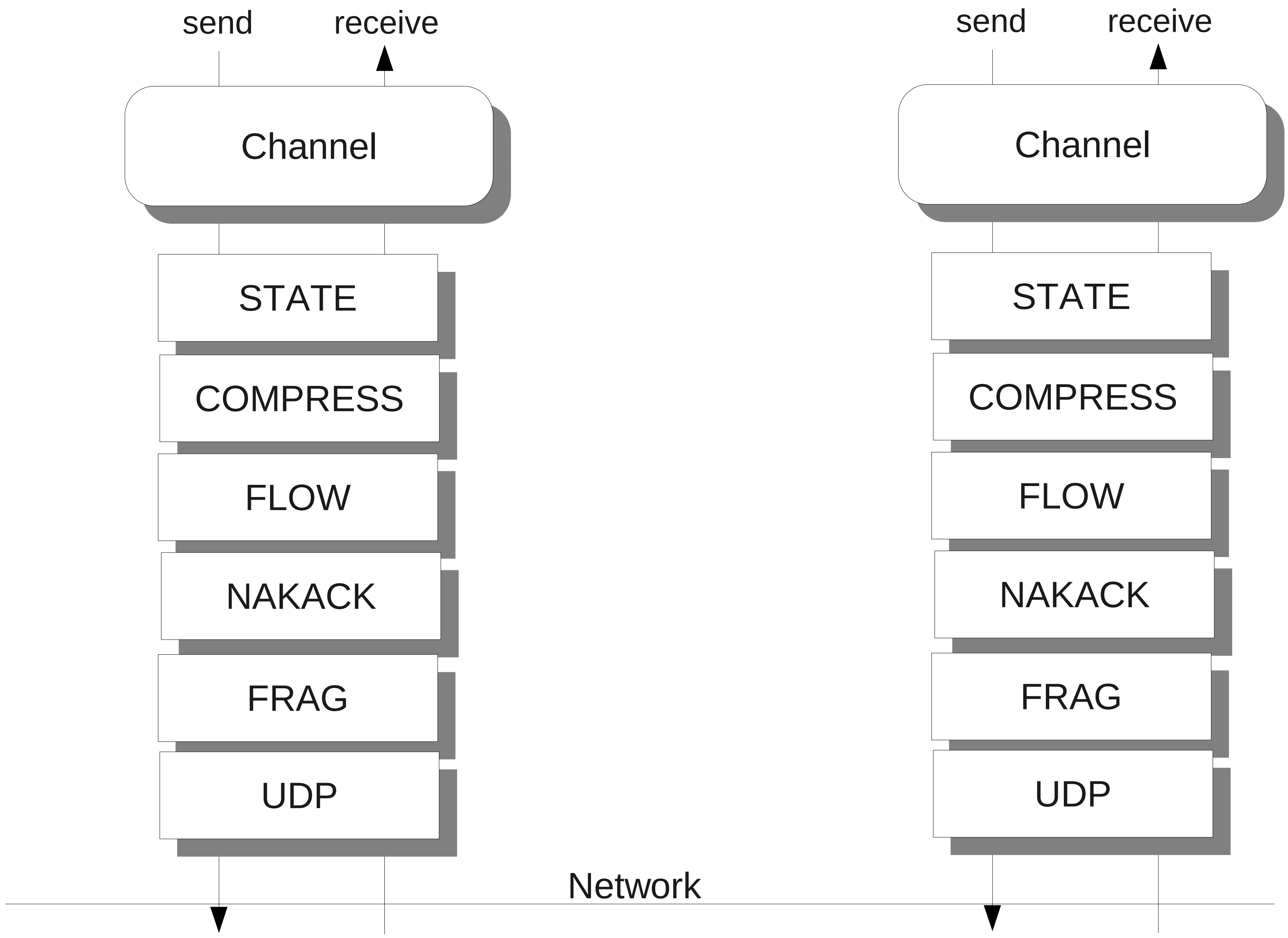
What is not reliable?

- Messages get
  - Lost and dropped
    - Too big (UDP has a size limit), no fragmentation
    - Buffer overflow at the receiver, switch
      - NIC, IP network buffer
  - Delivered in different order
- We don't know the members of the cluster (multicast)
  - No notification when new node joins, leaves, or crashes
- Faster sender might overload slower receiver
  - Flow control absence

So what Is JGroups ?

- Toolkit for reliable cluster communication
- Provides
  - Fragmentation
  - Message retransmission
  - Flow control
  - Ordering
  - Group membership, membership change notification
- LAN or WAN based
  - IP multicasting transport default for LAN
  - TCP transport default for WAN

Architecture of JGroups



A Message

- src, dest: Address
  - Address: identity of a member (of the cluster)
  - src: filled in when sending (by JGroups)
  - dest: null == send to all members of the group
- buffer: byte[]
- headers: hashmap of headers
  - each protocol can add/remove its own headers
  - example: sequence number for reliable retransmission
- Message travels across the network

Address

- A cluster consists of members
- Each member has its own address
- The address uniquely identifies one member
- Address is an abstract class
  - Implemented as a UUID
  - UUID is mapped to a physical address
- An address can have a logical name
  - For instance “a”
  - If not set, JGroups picks the name, e.g. „host-16524”

View

- List of members (Addresses)
- Is the **same** in all members:
    - A: {A,B,C}
    - B: {A,B,C}
    - C: {A,B,C}
- Updated when members join or leave
- All members receive all views in the same order
- `Channel.getView()` returns the current view

API

- Channel: similar to `java.net.MulticastSocket`
  - But with built-in group membership, reliability
- Operations:
  - Create a channel with a configuration (program. or xml)
  - Connect to a group named "x". Everyone that connects to "x" will see each other
  - Send a message to all members of “x“
  - Send a message to a single member
  - Receive a message
  - Be notified when members join, leave (including crashes)
  - Disconnect from the group
  - Close the channel

API (Code)

```
JChannel ch = new JChannel("udp.xml");
ch.setReceiver(new ReceiverAdapter() {

  @Override
  public void receive(Message msg) {
    System.out.println("msg from " + msg.getSrc() + ": " + msg.getObject());
  }

  @Override
  public void viewAccepted(View new_view) {
    System.out.println("new view: " + new_view);
  }
});
ch.connect("demo-group");
System.out.println("members are: " + ch.getView().getMembers());
Message msg = new Message(null, null, "Hello world");
ch.send(msg);
ch.close();
```

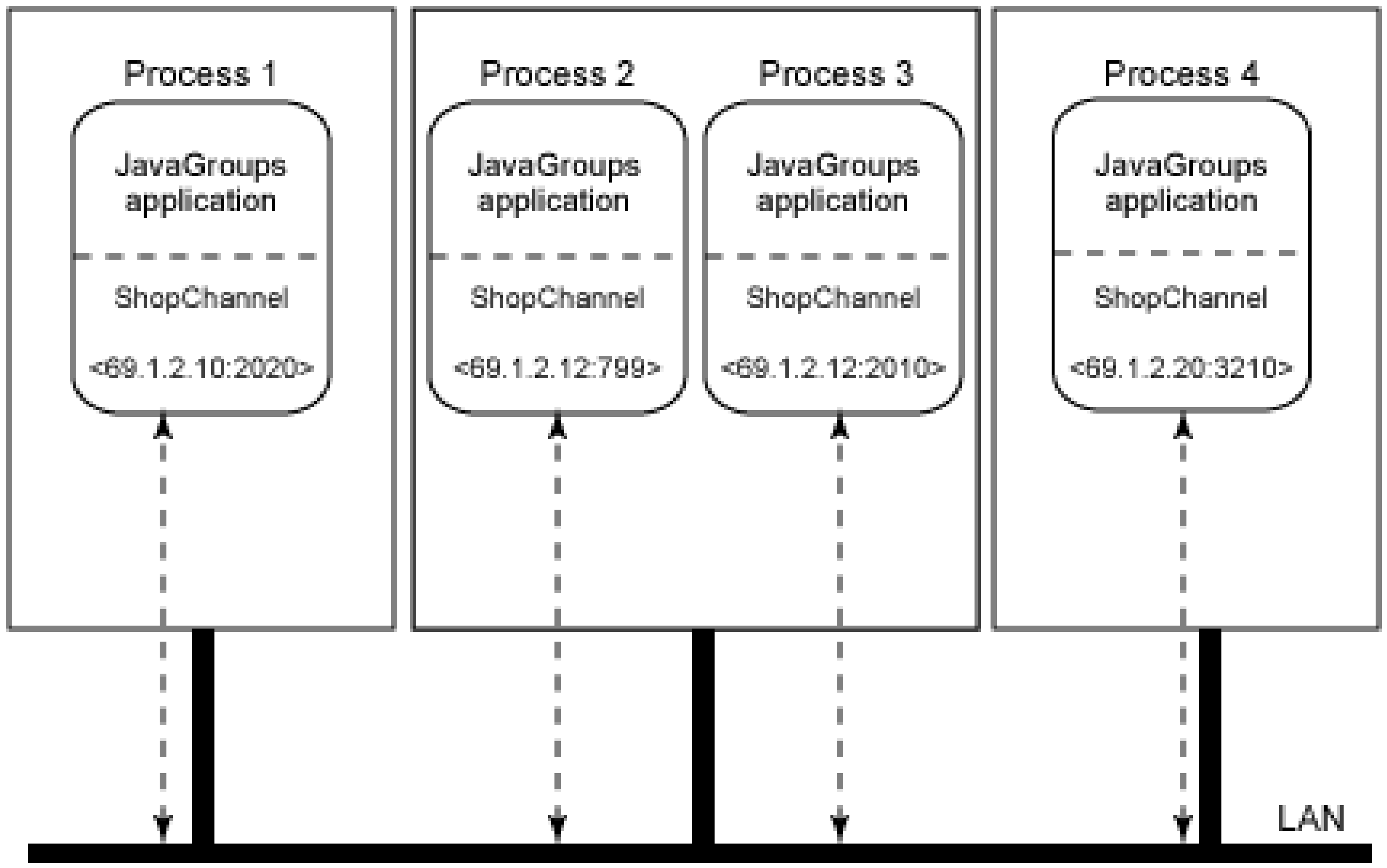
State transfer

- State is data shared by all nodes in a cluster
  - Stock quotes
  - HTTP web sessions
- Messages received in the same order will update the state consistently across a cluster
- To add state transfer to an application, it has to
  - Add STATE_TRANSFER to the config
  - Implement the state transfer callbacks
- A new joiner needs to acquire state

State transfer API

- `JChannel.getState()` called by state requester
- ReceiverAdapter:
  - byte[] getState()
    - Called on state provider
    - Needs to return serialized state
  - void setState(byte[] state)
    - Called on state requester
    - Needs to set state

Group Topology



Protocols (1)

- Transport
  - UPD (IP Multicast), TCP, TCP_NIE, LOOPBACK
- Member discovery
  - PING, TCPPING, TCPGOSSIP, MPING
- Failure detection (freeze up, crash)
  - FD, FD_SOCK, VERIFY_SUSPECT, MERGE
- Reliable transmission and Ordering
  - Sequence numbers, lost messages are retrasmitted
- Distributed Garbage Collection
  - Agreement on all received messages

Protocols (2)

- Group Membership
  - GMS
  - New view on memberhip change
- Flow control
  - FC
  - Fast sender does not owerhelm slow ones
- Fragmentation
  - FRAG, FRAG2
  - Big messages are trasmitted as smaller ones

Protocols (3)

- State Transder
    - STATE_TRANSFER
    - New member receives the state of the group
- Security
    - ENCRYPT, AUTH
- Debugging
    - PERF, TRACE, STATS
- Simulation and testing
    - DELAY, SHUFFLE, LOSS, PARTITIONER

JGroups Ergonomics

- Idea: observe the environment and adjust stack configuration dynamically
  - One configuration doesn't rule them all
  - Scale from small to large clusters
  - Shift from private to public cloud providers
  - Account for traffic patterns
- WIP
- You can contribute if you like networks.

Infinispan

Infinispan

- Open source data grid platform
- Distributed key/value store
- Transactional (JTA & XA)
- Low-latency (in-memory)
- Java-based (with Scala sprinkles)
- Remote access not only from JVM
- Optionally persisted to disk
- Feature-rich
- Very actively developed

Let's look at API first though...

- Map-like key/value store
- JSR-107 Java Temporary Caching API
  - javax.cache.Cache interface
- Asynchronous API

- CDI API
- Upcoming JPA-like layer
- Hibernate OGM

TRANSACTIONS

- Transactions are optional, designed for from beginning
  - TRANSACTIONAL
  - NON_TRANSACTIONAL
- Transactional possible locking modes
  - OPTIMISTIC
  - PESSIMISTIC
- And 2 isolation modes available
  - REPEATABLE_READ
  - READ_COMMITTED

TRANSACTIONS

```
Cache cache = cacheManager.getCache();

TransactionManager tm =
cache.getAdvancedCache().getTransactionManager();

tm.begin();
cache.put(k1, v1);
cache.remove(k2);
tm.commit();
```

QUERYING

- Based on Hibernate Search

```
@Indexed
@ProvidedId
public class JBugEvent {
    @Field String title;
    @Field String annotation;
    @Field @DateBridge(resolution=Resolution.DAY) Date day;
    ....
```

```
org.apache.lucene.search.Query luceneQuery = queryBuilder.phrase()
                                    .onField( "title" )
                                    .andField( "annotation" )
                                    .sentence( "session about Infinispan" )
                                    .createQuery();

CacheQuery query = searchManager.getQuery( luceneQuery,
JBugEvent.class );

List<JBugEvent> objectList = query.list();
```

DISTRIBUTED EXECUTORS

- Leverage familiar ExecutorService, Callable abstractions
- Expand it to distributed, parallel computing paradigm
- Looks like a regular ExecutorService
- Feels like a regular ExecutorService
- The “magic“ that goes on Infinispan grid is completely transparent to users

MAP REDUCE...

EXPIRATION

- Specify maximum time entries
  - stay in cache (lifespan)
  - stay in cache untouched (maxIdle)
- Can set default expiration in cache config
- Can explicitly set lifespan or maxIdle with every PUT

```
cache.put("Bad smell", "I'll begone in 30 seconds", 30,
TimeUnit.SECONDS);
cache.put("Annoying Girlfriend", "If you don't tell me you
love me every 5 minutes I 'll be gone!", -1,
TimeUnit.SECONDS, 5, TimeUnit.MINUTES);
```

EXPIRATION in AS

- HTTP Sessions expire
  - Timeout in web.xml
- SFSB Sessions expire
  - @CacheConfig annotation
- Sessions expire so that
  - Don't consume resources
  - They don't get abused if they are not invalidated

EVICTION

- Set maximum # of entries to keep in cache
- Multiple out-of-box eviction strategies
  - UNORDERED
  - FIFO
  - LRU – Least recently used
  - LIRS – Low Inter-Reference Recency Set

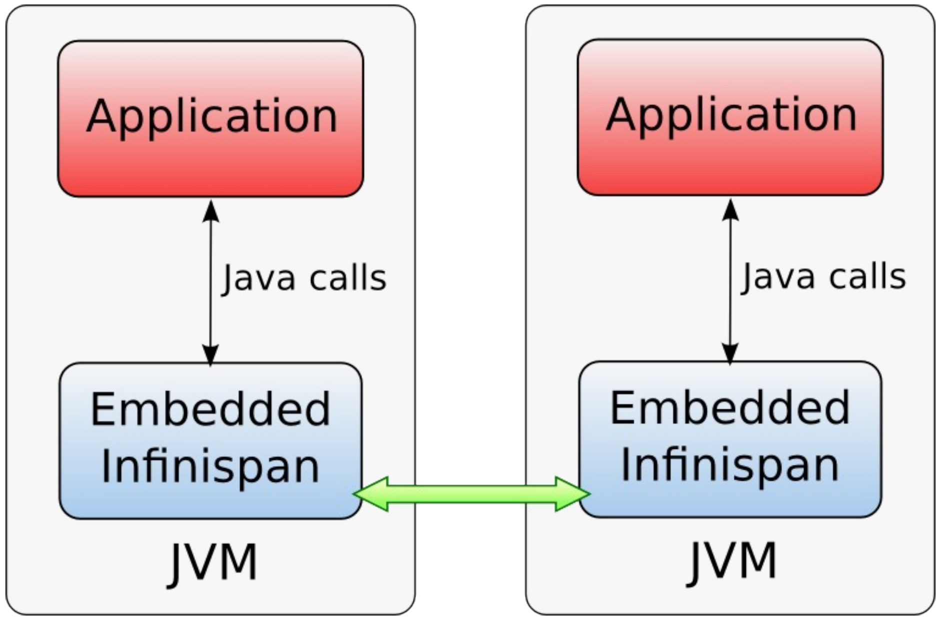
CACHE STORE / PERSISTENCE

- Store data from memory to other kind of storage
  - File System (FileCacheStore)
  - Relational Database (JdbcBinaryCacheStore, JdbcStringBasedCacheStore)
  - Other NoSQL stores (Cassandra, JClouds BlobStore, RemoteCacheStore)
- Not only in-memory
  - Write-through caching
  - Write-behind caching
- Passivation support (spillover to disk)
- Preloading & warm start support

EVICTION and PERSISTENCE in AS

- Handle too many active sessions
- Passivation - eviction from memory to disk
- A way to be nice to users (keep sessions for long time) and not crash the AS (with OOMs)
- Possibly handle restarts

Embedded Access Mode



Cache Modes

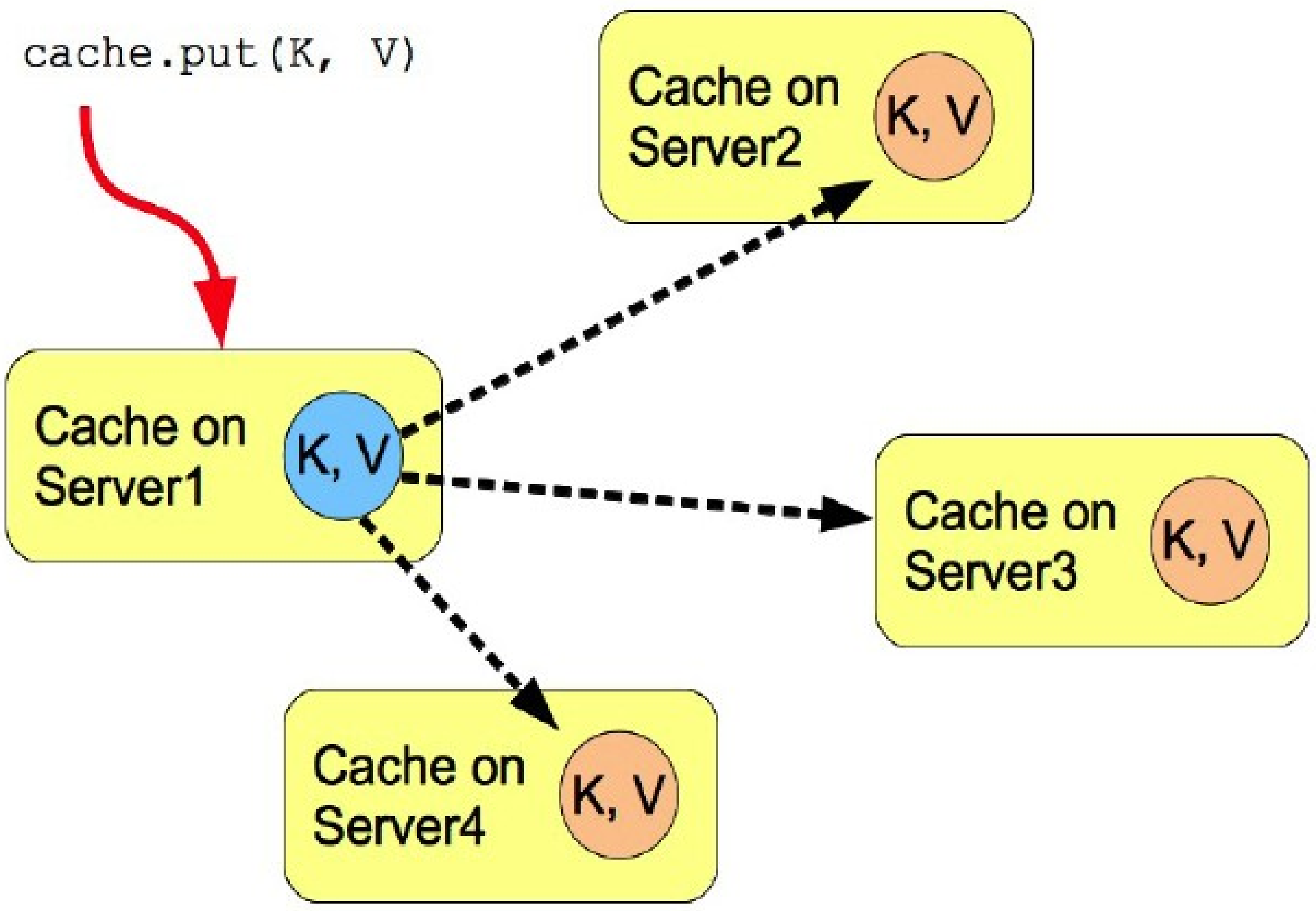
LOCAL

- Single node
- Non-clustered environment
  - Unaware of other instances on network
- Why use LOCAL cache in AS?

Replication mode

- Each node contains all the entries
- Advantages
  - N node cluster tolerates N-1 failures
  - Read friendly – we don't need to fetch data from owner node
    - Do we need read-friendly in session clustering?
  - Instant scale-in, no state transfer on leave
- Disadvantages
  - Write unfriendly, put must be to every node
  - Doesn't scale
  - Upon join all state has to be transfered to new node
  - Heap size stays the same when we add nodes

REPLICATION

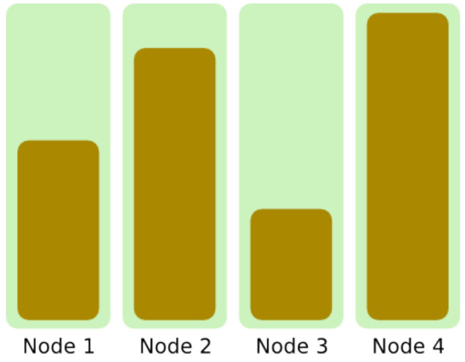


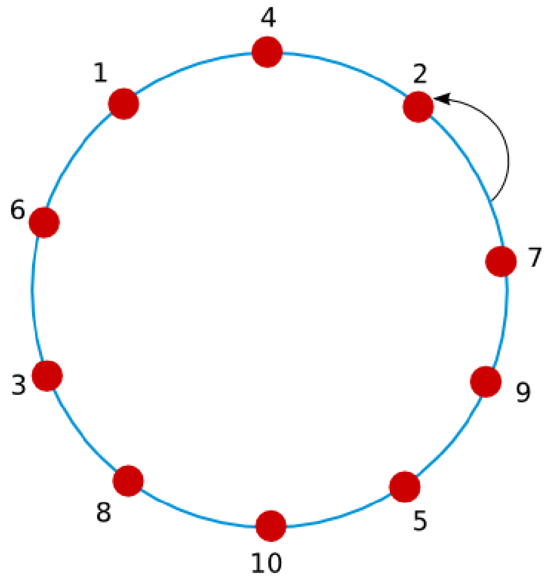
DISTRIBUTION

- Advantages
  - Scales – number of replications is independent of cluster size, depends only on number of owners
  - Number of ownsers set to compromise between failure tolerance and performance
  - *Virtual heap size = numNodes * heapSize / numOwners*
- Disadvantages
  - Not every node is an owner of the key, GET may require network hops
  - Node join and leave requires state transfer (rehash)

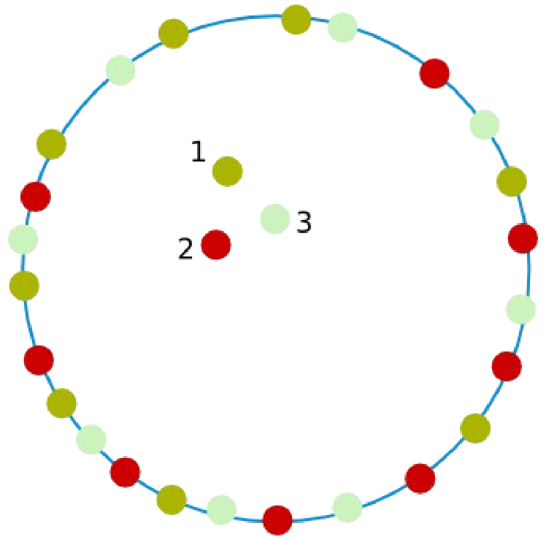
Consistent Hash function

- Even distribution of entries – balanced load
- Less expected rehash on node leave / join
- How usable in clustering?
- Who decides where the session will be stored?



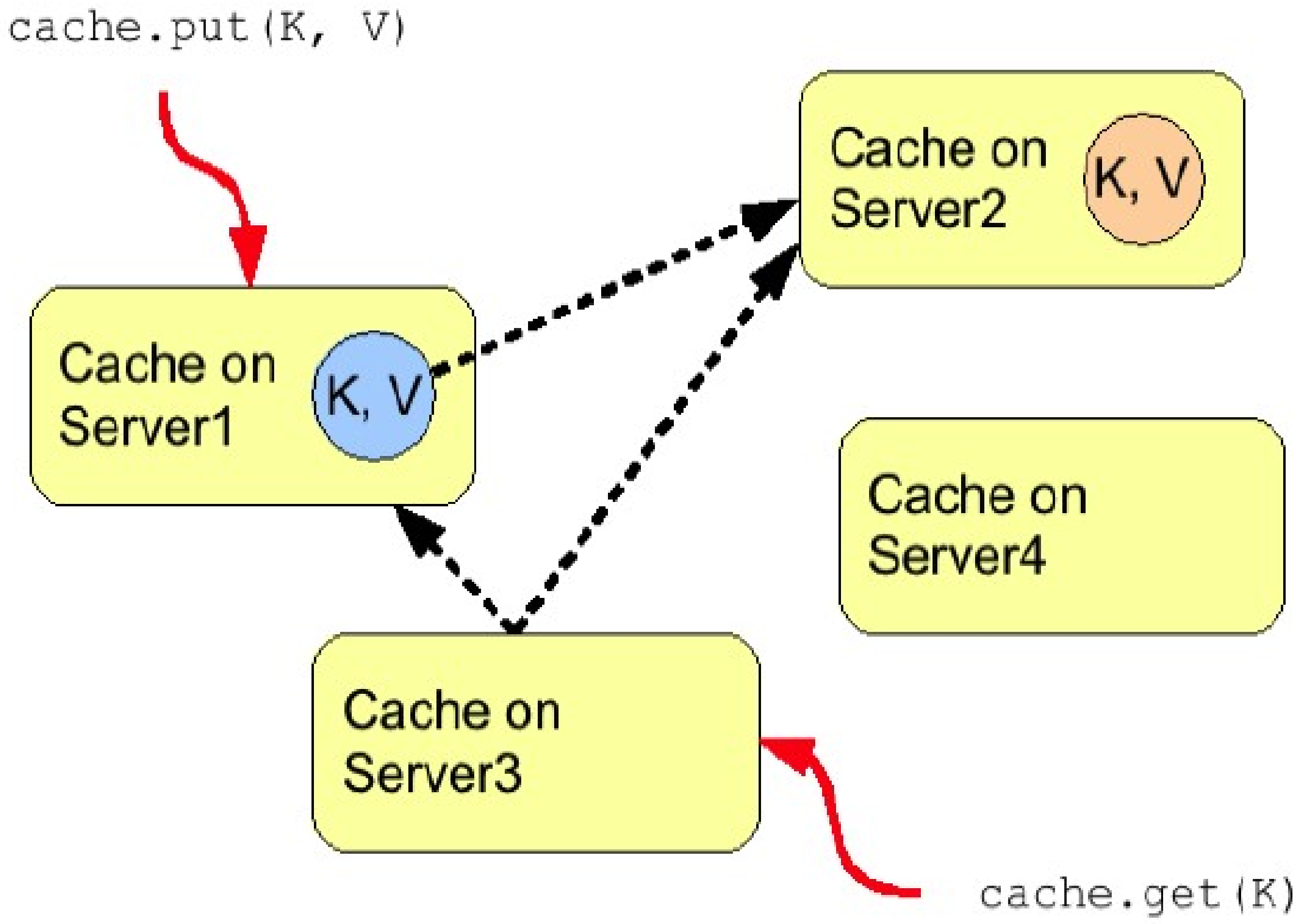


Hash wheel



Virtual nodes

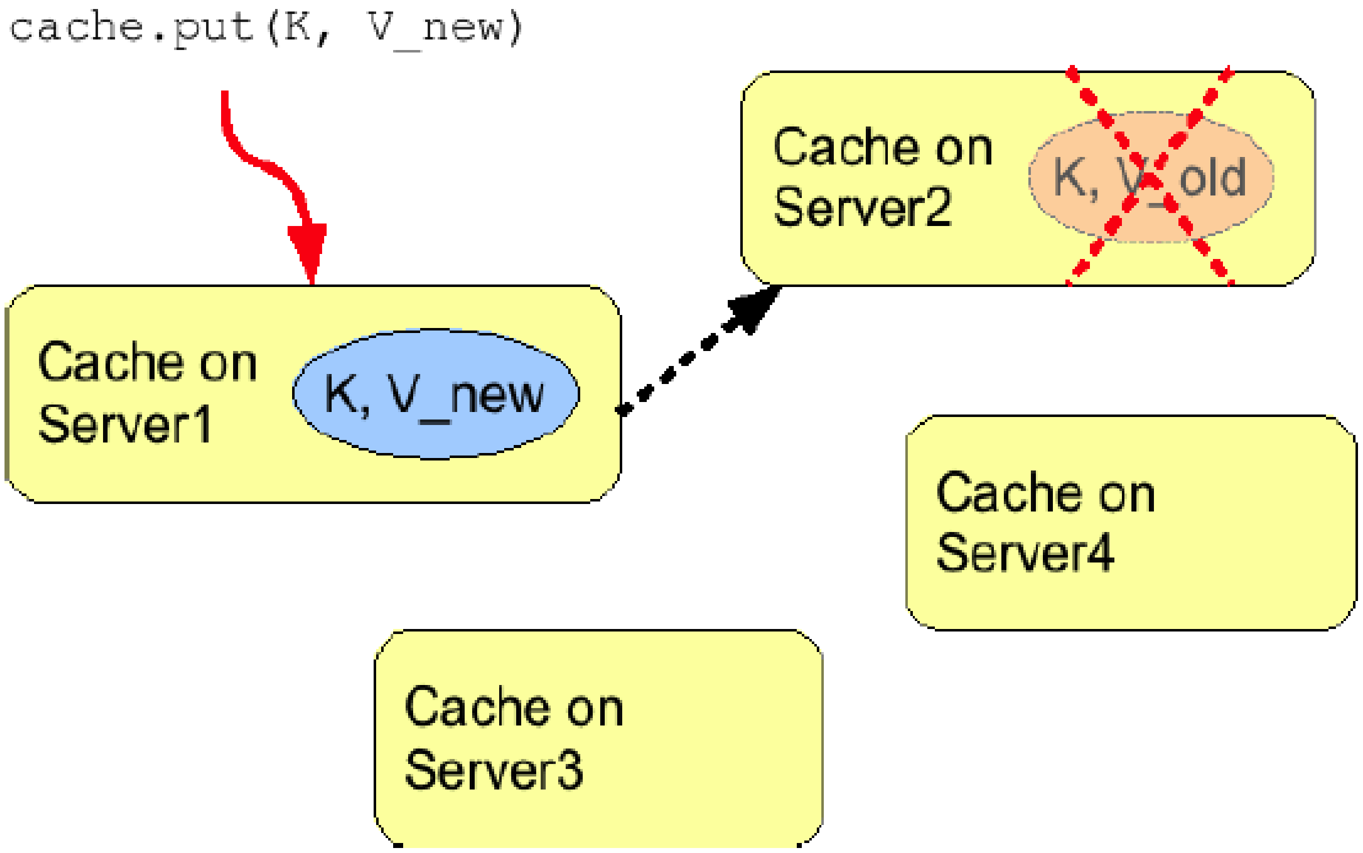
DISTRIBUTION



INVALIDATION

- Usable when often read, but rarely written (change entries)
- If entry exists in node's local cache
  - it's valid and can be returned to requestor
- If entry doesn't exist in node's local cache
  - it's retrieved from the persistent store
- If a node modifies/removes entry it's invalidated in other nodes
- Low cluster traffic, each PUT issues small invalidation message
- When use in clustering?
  - Suitable for RDBMS off-loading, used with shared cache store

INVALIDATION



SYNC and ASYNC

- Synchronous
  - All operations get confirmation that the other relevant cluster nodes reached the desired state
  - Implications to response times
  - 2PC
- Asynchronous
  - All operations block only until they perform local changes, we don't wait for JGroups responses.
  - Better throughput but no guarantees on data integrity in cluster.
- When use which?

Data Grids as Clustering Toolkits

- To introduce high availability and failover
  - Commercial and open source frameworks
  - In-house frameworks and reusable architectures
- Delegate all state management to the data grid
- Framework itself becomes stateless and hence as elastic as Infinispan is
- Important for cloud

Still Cooking

Interesting from clustering view:

- Cross-datacentre/WAN replication
  - Geographic failover
- Eventual consistency
  - Handling split brains
- Non-blocking state transfer
  - Less disruption on crash
- Heap-load based eviction
  - Better eviction/passivation
- Higher-level APIs

Using Infinispan from AS

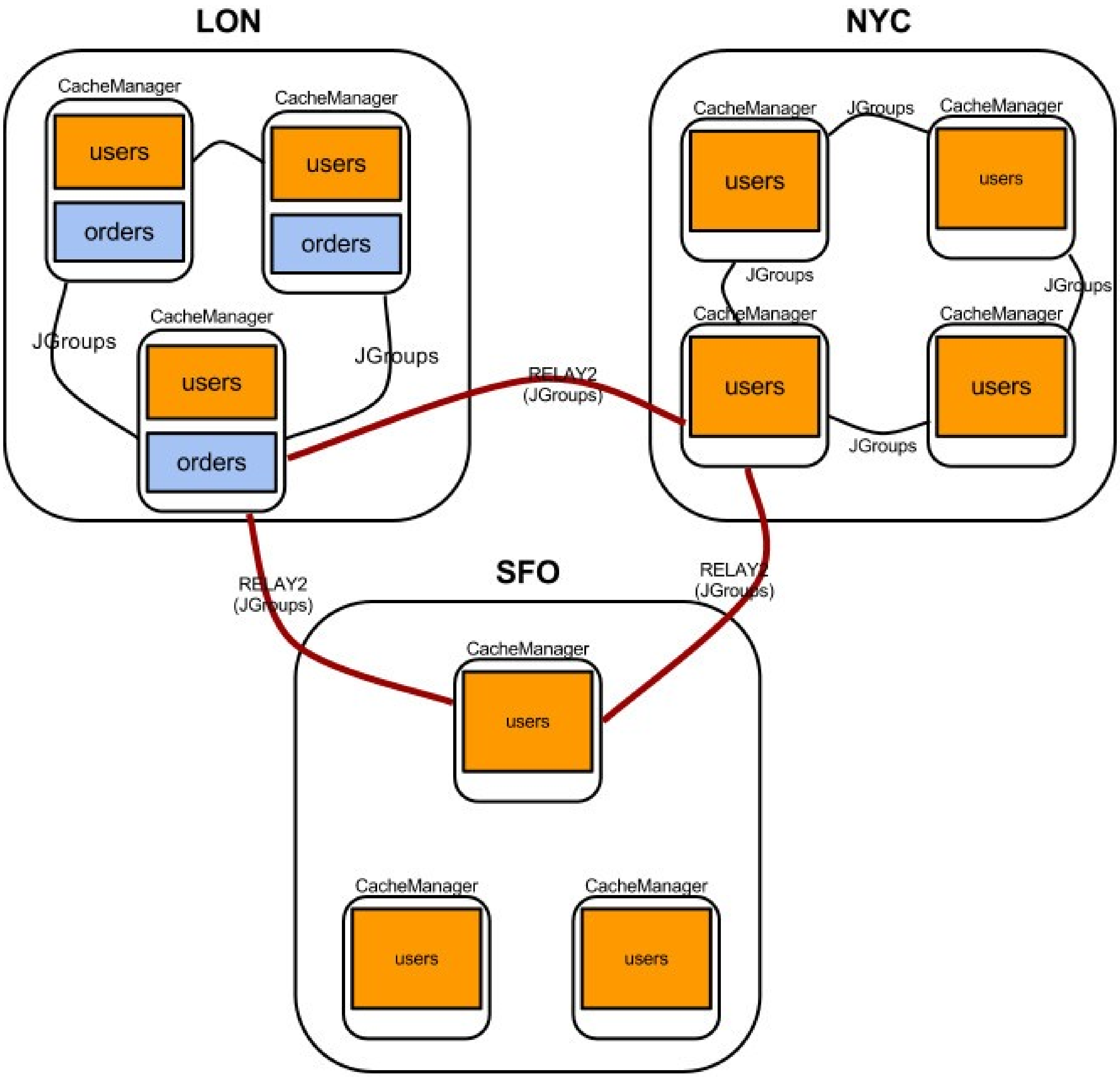
- Customizing Infinispan Caches
- Eager vs. lazy startup mode
  – <replicated-cache ... start=”LAZY|EAGER”>
- JNDI binding
  – <cache-container ... jndi-name=”...”>
  – Assumes java:global namespace if unqualified

Using Directly

- On demand injection of cache container

```
@ManagedBean
public class CustomBean<K, V> {
    @Resource(lookup = “java:jboss/infinispan/customcontainer”)
    private org.infinispan.manager.CacheContainer container;
    private org.infinispan.Cache<K, V> cache;

    @PostConstruct
    public void start() {
        this.cache = this.container.getCache();
    }
}
```


LON
NYC
SFO
CacheManager
users
orders
JGroups
RELAY2
(JGroups)

Load-balancers & mod_cluster

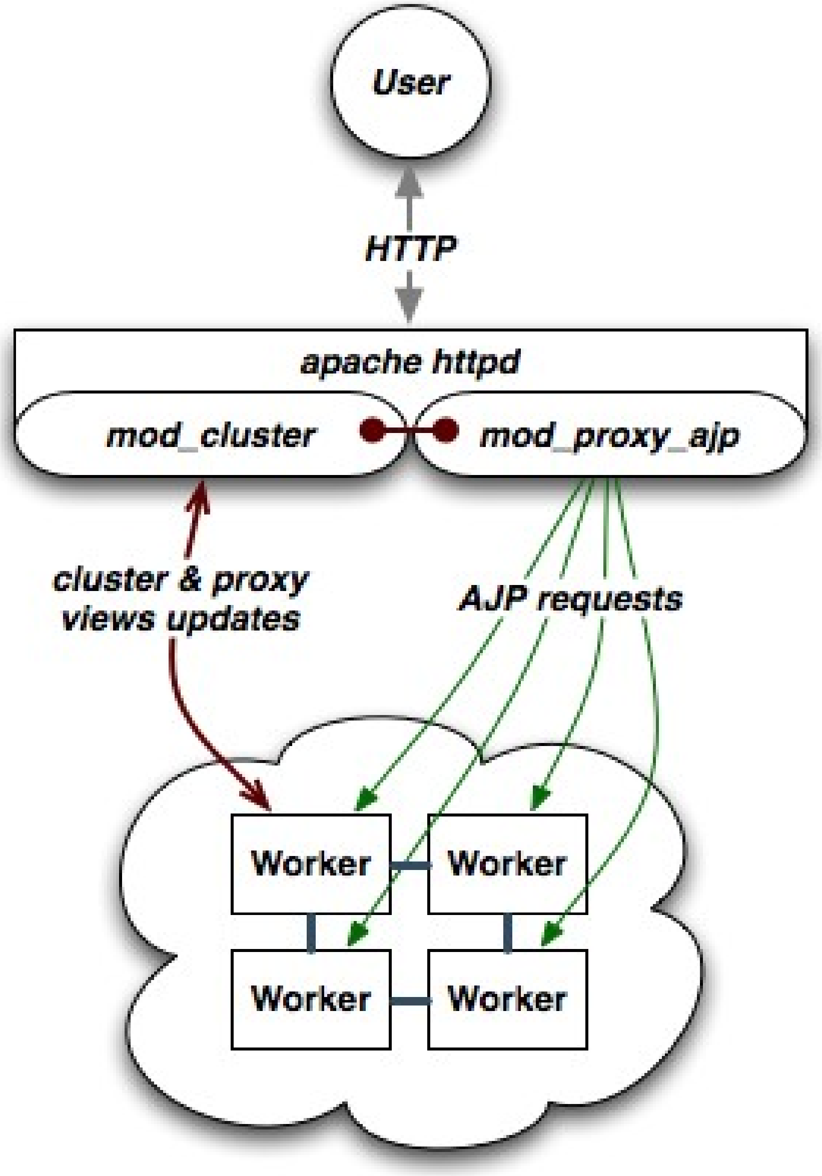
What is mod_cluster?

- Set of modules for Apache HTTPd and Tomcat-based web servers
  - requires Apache HTTPd 2.2.8+
  - requires JBoss AS 5.0+ or Tomcat 6+
- Similar to mod_jk and mod_proxy enables HTTPd to be a load-balancer in front of Java web servers
- JBoss.org LGPL project

Architecture

- Client requests proxied to back-end server
  - AJP, HTTP, HTTPS protocols
  - transparent to request handling on Java side
- **Key difference**: back channel from back-end to the front end
  - Life-cycle information
  - Load-balancing information
  - Uses HTTP/HTTPS

Architecture (2)



Overview of Key Benefits

- Simplified configuration
  - Dynamic configuration instead of static
  - HTTPd need not be preconfigured with cluster topology
  - Little configuration on the HTTPd and web server side
- Improved load-balancing
  - Load calculation done on the server side where more information is available
- Fine grained life-cycle control
  - Undeploy a running web app without 404s

Dynamic Configuration

- Backend web servers register with HTTPd at startup
- Backend web server register applications' as they are available
- No more static topology configuration on the HTTPd
  - No `workers.properties`
  - No `uriworkermap.properties`
- Auto-discovery
  - HTTPd servers advertize themselves for web servers to register with them using UDP multicast
  - No topology information

No more `worker.properties` & `uriworkermap.properties`

```
worker.list=lb
worker.lb.type=lb
worker.lb.balance_workers=node1,node2

worker.node1.type=ajp13
worker.node1.host=192.168.2.1
worker.node1.port=8009
worker.node1.lbfactor=1

worker.node2.type=ajp13
worker.node2.host=192.168.2.2
worker.node2.port=8009
worker.node2.lbfactor=1
```

```
/webapp/*=loadbalancer
/newwebapp/*=loadbalancer
```

Better Load-balancing

- **Problem**: load-balancer lacks information needed to make optimal load-balancing decision
  - Knows of: number of requests, sessions, sent/received bytes, response times
  - Ignores: backend server metrics, i.e. CPU usage, available memory, DB connection pool
  - Ignores: activity of other load-balancers
- **Solution**: backend web servers inform balancer how much load they can handle
  - Factor is a number between 1 to 100
  - Relative factors are used to make decisions
  - Backend servers have configured set of metrics

Load Metrics

- Metric tracked by the backend server to help make decision
  - e.g. available memory, CPU usage
- Multiple readings are combined to overall load factor
  - Older readings decline in importance/weight
- Highly configurable
  - Weights can be assigned to metrics, e.g. 50% CPU usage and 50% connection pool usage
  - Pluggable custom classes for metrics

List of Load Metrics

- Web tier usage:
  - active sessions, busy connections, bytes send and received, request count
- System utilization
  - CPU utilization, system memory usage, JVM heap usage, number of threads
- JCA connection pool usage

- Custom – build your own

Rolling Upgrades

- Problem: How to roll an upgrade without downtime?
  - Most downtime caused by upgrades, not crashes.
  - New release might be binary incompatible and cannot re-join the cluster.
    - Application and session incompatibilities
    - Major JBoss AS version upgrades (6.0 to 7.1)
    - Component upgrades (Infinispan)
    - DB Schema upgrades
  - General problem with large flat clusters.
    - State transfers, merges, scalability

Rolling Upgrades

- Solution: mod_cluster load balancing groups (mod_jk's domains)
  - 20 node cluster == 2 load balancing groups of 10 nodes, each LB group is a cluster
  - Session is replicated to all nodes within the LB group
  - In case of crash, failover happens within the LB group only
  - If there are no alive servers in LB group the session is lost forever and ever

Rolling Upgrades

- Upgrade entire domain at once.
  - Disable all contexts in the domain (mod_cluster manager)
  - No new sessions are created on disabled nodes.
  - Existing sessions are still directed to its' nodes.
  - Drain all sessions – all sessions expired in the domain.
  - Shutdown and perform an upgrade.
  - Start the group (enabled).

Installation HTTPd

- HTTPd modules and Java side:

  http://www.jboss.org/mod_cluster/downloads/
- Supported platforms
  - Linux x86, x64, ia64
  - Solaris x86, SPARC
  - Windows x86, x64, ia64
  - HP-UX PA-RISC, ia64
  - build your own from sources
- Distributes will full distribution or just use the modules
- Straightforward migration

HTTPd Configuration

```
LoadModule proxy_module modules/mod_proxy.so
LoadModule proxy_ajp_module modules/mod_proxy_ajp.so
LoadModule slotmem_module modules/mod_slotmem.so
LoadModule manager_module modules/mod_manager.so
LoadModule proxy_cluster_module modules/mod_proxy_cluster.so
LoadModule advertise_module modules/mod_advertise.so

Listen 192.168.1.1:8000

<VirtualHost 192.168.1.1:8000>
    <Directory />
        Order deny,allow
        Deny from all
        Allow from 192.168.2.
    </Directory>

    KeepAliveTimeout 60
    MaxKeepAliveRequests 0
    AdvertiseGroup 224.0.1.105:23364
</VirtualHost>
```

AS 7 Configuration

- Comes out-of-box in `standalone-ha.xml` profile.

```
./bin/standalone.sh –c standalone-
ha.xml
```

- Or add to your existing profile:

```
    <extensions>
        ...
        <extension module="org.jboss.as.modcluster"/>
        ...
    </extensions>
...
    <subsystem xmlns="urn:jboss:domain:modcluster:1.0">
        <mod-cluster-config advertise-socket="modcluster"/>
    </subsystem>
...
    <socket-binding-group name="standard-sockets" ...>
        <socket-binding name="modcluster" port="0" multicast-
address="224.0.1.105" multicast-port="23364"/>
...
```

AS 7 modcluster Subsystem Operations

- add
- add-custom-metric
- add-metric
- add-proxy
- disable
- disable-context
- enable
- enable-context
- list-proxies
- stop-context
- read-proxies-configuration
- read-proxies-info
- refresh
- remove
- remove-custom-metric
- remove-metric
- remove-proxy
- reset
- stop

Demo: Try This At Home

- Deployment
  - One HTTPd with mod_cluster
  - Two JBoss AS 7 instances
  - No static configuration – dynamic auto-discovery
- Scenario
  - WAR demo application
  - Client GUI to generate load and track load-balancing

- Part of distribution so you can try yourself!

Community

- http://www.jgroups.org/
- http://www.infinispan.org/
- http://www.jboss.org/