
# A4M36JEE

# Clustering & Scalability

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# Agenda

- Clusters
  - HA
  - Load-balancing
  - Scalability
- JGroups
- Infinispan
- Clustering in WildFly 8
- 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
  - 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 WildFly 8 servers that communicate with each other so as to improve the availability of services by providing the following capabilities:

- High Availability
- Scalability
- Fail-over
- 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 without service response time degradation.



# Fail-over

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



# Fault Tolerance

Guarantee of correct behavior in the event of a failure.



# So, why do we need Cluster?

Potential problems with deploying critical applications on a single node:

- ?
- ?



# What does Java EE say about clustering?

- Err, not much.



# WildFly Clustering Areas

- Web session replication — FO
- Stateful Session Bean (SFSB) replication — FO
- Entity bean replication (2nd level caching) — FO
- SingletonService
- mod_cluster auto-configuration — LB
- 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 `@Stateful` (`WildFly 8.0.0.Final`)
  - Automatically clustered unless: `passivationCapable=false`
  - Uses '**ejb**' cache container, by default



# Notice about EJBs clustering

`@Clustered` annotation needed previously

- **No more needed for WildFly**
- EJBs clustered automatically
- You can disable clustering of SFSB by: `@Stateful(passivationCapable=false)`
  - From EJB 3.2



# Distributable Sessions

- All session attributes must be serializable:
  - Must implement `java.io.Serializable`
  - Most native Java objects implement this functionality

- After updating any immutable objects stored in 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



# Distributable Sessions – Immutable objects

- Known immutable values:
  - Null, java.util.Collections.EMPTY_LIST/EMPTY_MAP/ EMPTY_SET
- The value type is or implements immutable type:
  - Boolean, Byte, Character, Double, Float, Integer, Long, Short
  - java.lang.Enum, StackTraceElement, String
  - ...
- The value type is annotated with:
  - `@org.wildfly.clustering.web.annotation.Immutable`



# Application Must be Cluster-Aware

- Don't spawn custom services that should be singleton in the cluster:
  - Timers, whatnot
  - Locking becomes complex

- Don't store data as flat files
  - Store over NAS/SAN (NFS)
  - Use DB
  - Use data grid



# EE @Singleton

**Not cluster-wide singleton!**

- `@Singleton` per JVM as spec dictates
- `@Clustered @Singleton` could be cluster-wide singleton (not yet)



# SingletonService (HA Singleton)

Create singleton service in ServiceActivator (**MSC**)

- SingletonService is started only on one node
  - start(StartContext) : `org.jboss.msc.service.Service`

**Example**:

https://github.com/wildfly/quickstart/tree/master/cluster-ha-singleton



# 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 “easier” to manage
- **More on next lecture on management!**



# 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.
  - Deploy application backend to only one node
- No HA JNDI (replaced with client JNDI).



# Extensions for Clustering in WildFly 8

**`org.jboss.as.clustering.jgroups`**

- Provides the communication between cluster nodes

**`org.jboss.as.clustering.infinispan`**

- Provides the replicated caching functionality

**`org.jboss.as.mod_cluster`**

- Provides integration and configuration with mod_cluster software load balancer



# Predefined Profiles

- Standalone mode
  - **standalone-ha.xml**
  - **standalone-full-ha.xml**

```
$ bin/standalone.sh -c 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

# 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 ?

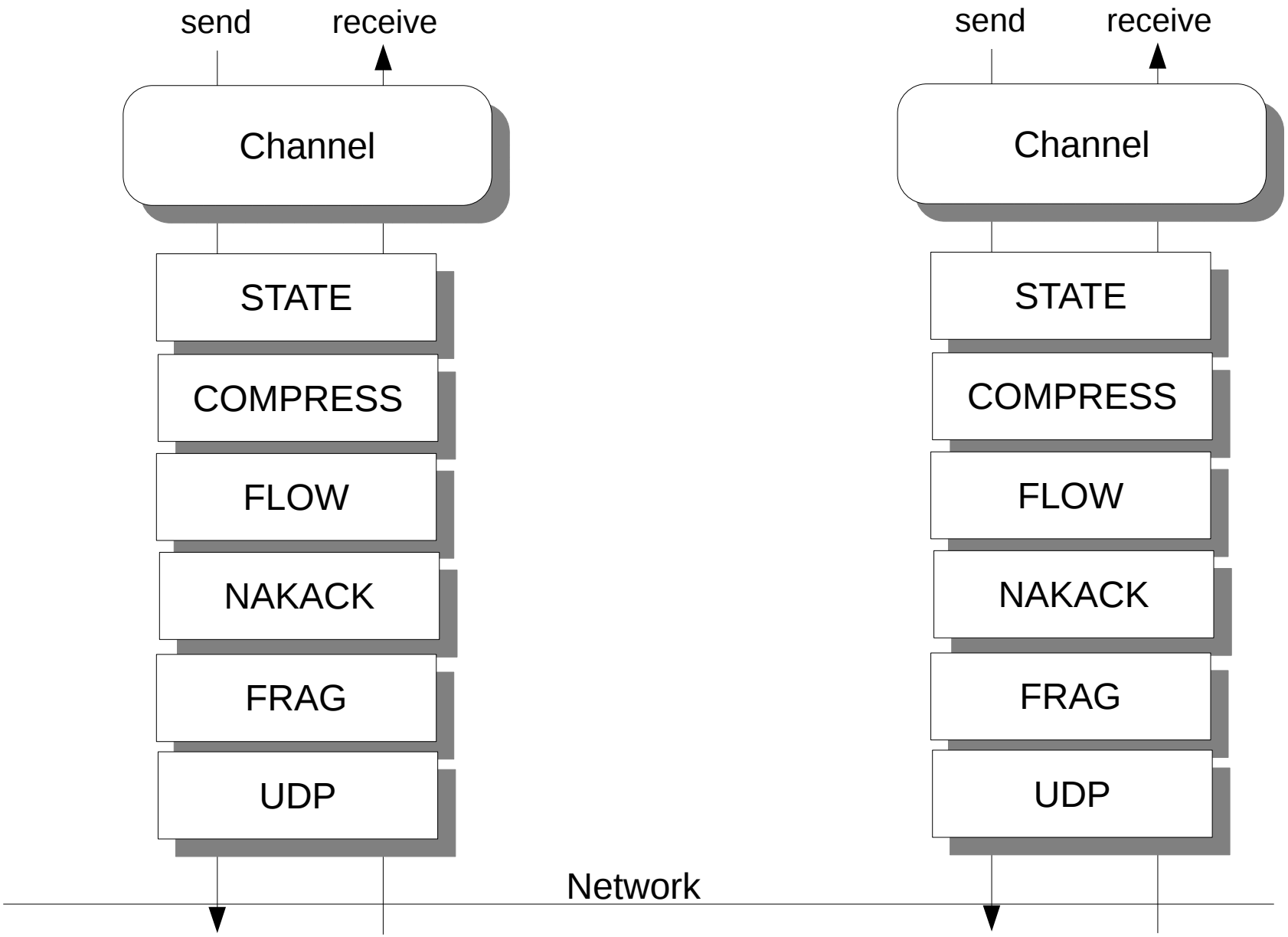
**Toolkit for reliable cluster communication**

- 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 (crashes included)
  - 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

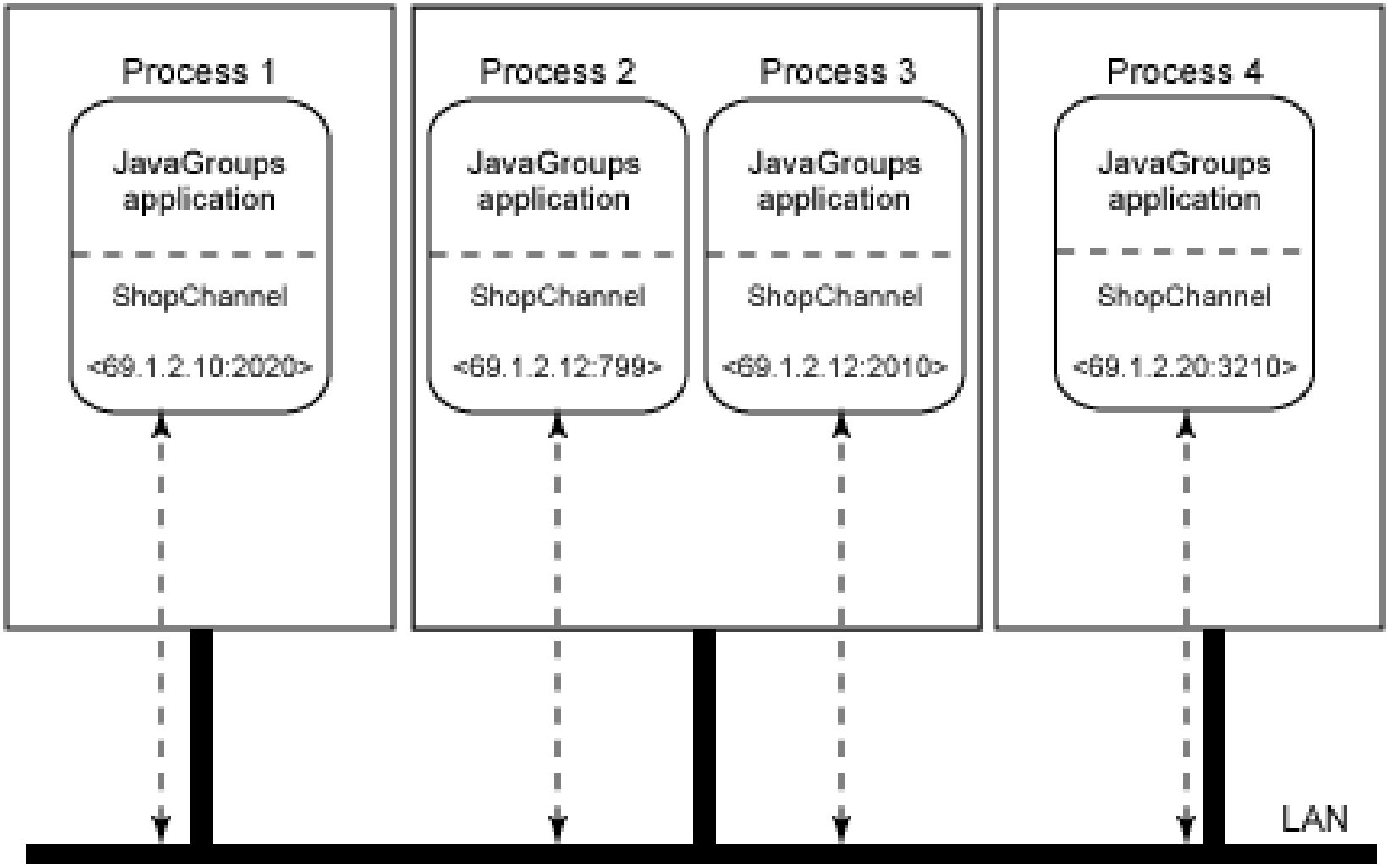
**State is data shared by all nodes in a cluster**

- 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



# 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 membership change
- Flow control
  - FC
  - Fast sender does not overwhelm slow ones
- Fragmentation
  - FRAG, FRAG2
  - Big messages are transmitted as smaller ones



# Protocols (3)

- State Transfer
  - 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

# CACHE STORE / PERSISTENCE

- Store data from memory to other kind of storage
  - File System, Relational Database, Other NoSQL stores

- Passivation support (spillover to disk)



# PASSIVATION IN WILDFLY

```
<max-active-sessions>
   1000
</max-active-sessions>
```

- Disabled by default
- Controls maximum number of sessions to keep in memory, rest will be passivated.



# 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 longer time) and not crash the AS (with OOMs)
- Possibly handle restarts/upgrades



# Cache Modes



# Local mode

- Single node
- Non-clustered environment
  - Unaware of other instances on network

- Why use LOCAL cache in AS?

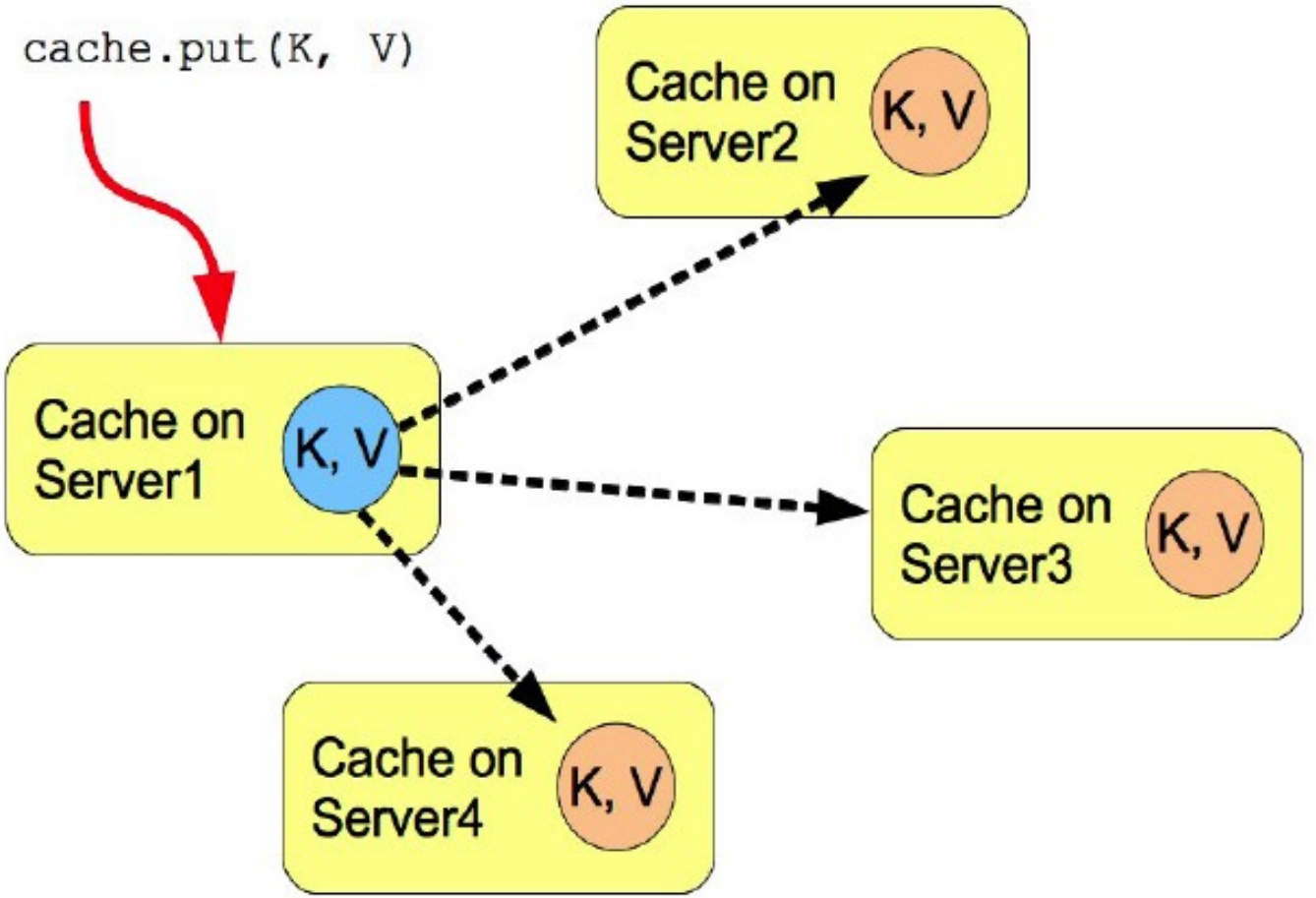


# Replication mode

- 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
  - Instant scale-in, no state transfer on leave
- Disadvantages
  - Write unfriendly, put broadcast to every node
  - Doesn't scale well
  - When node joins all state has to be transfered to new node
  - Heap size stays the same when we add nodes



# Replication mode



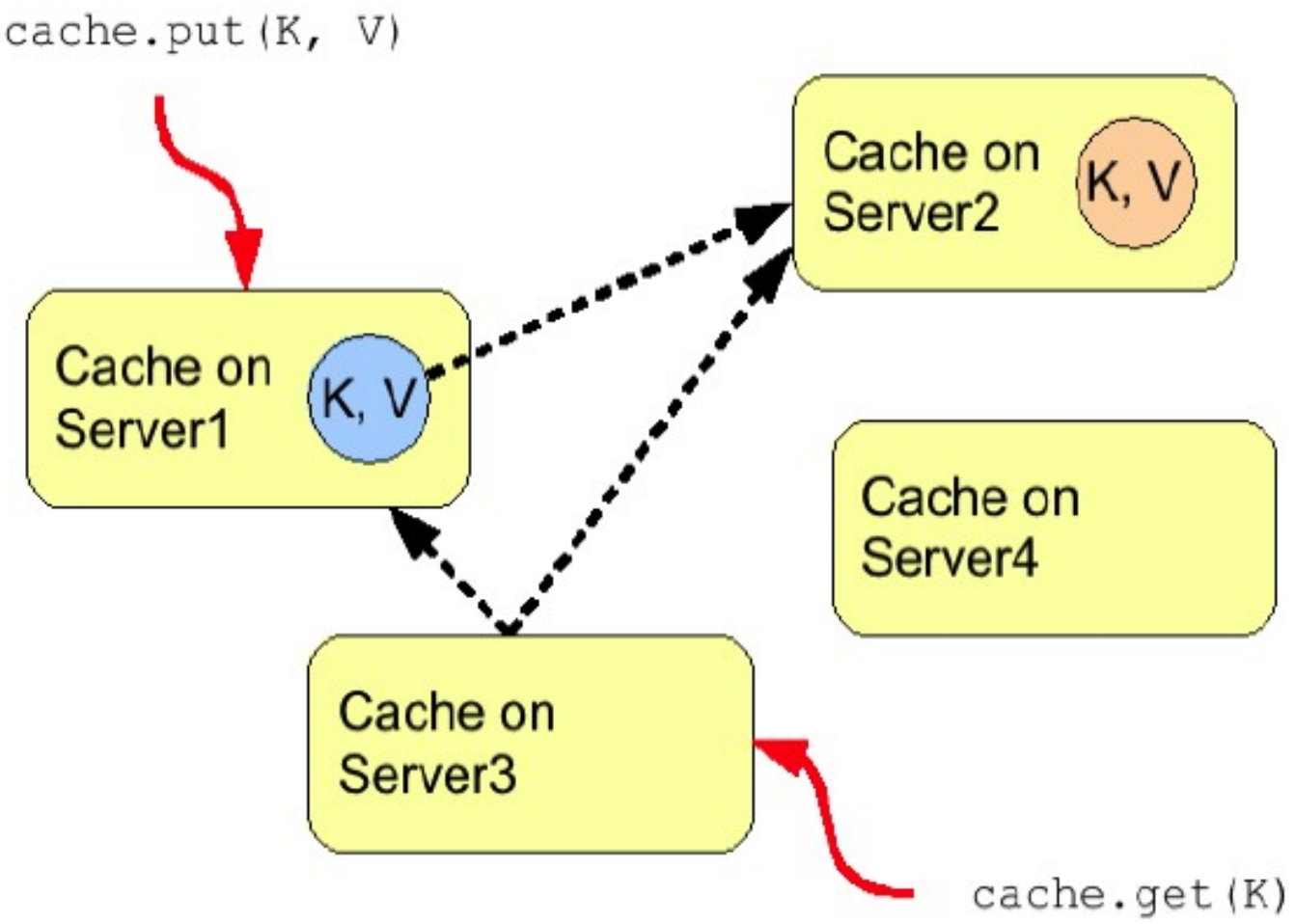



# Distribution mode

- Advantages
  - Scales – number of replications is independent of cluster size, depends only on number of owners
  - Number of owners 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)



# DISTRIBUTION



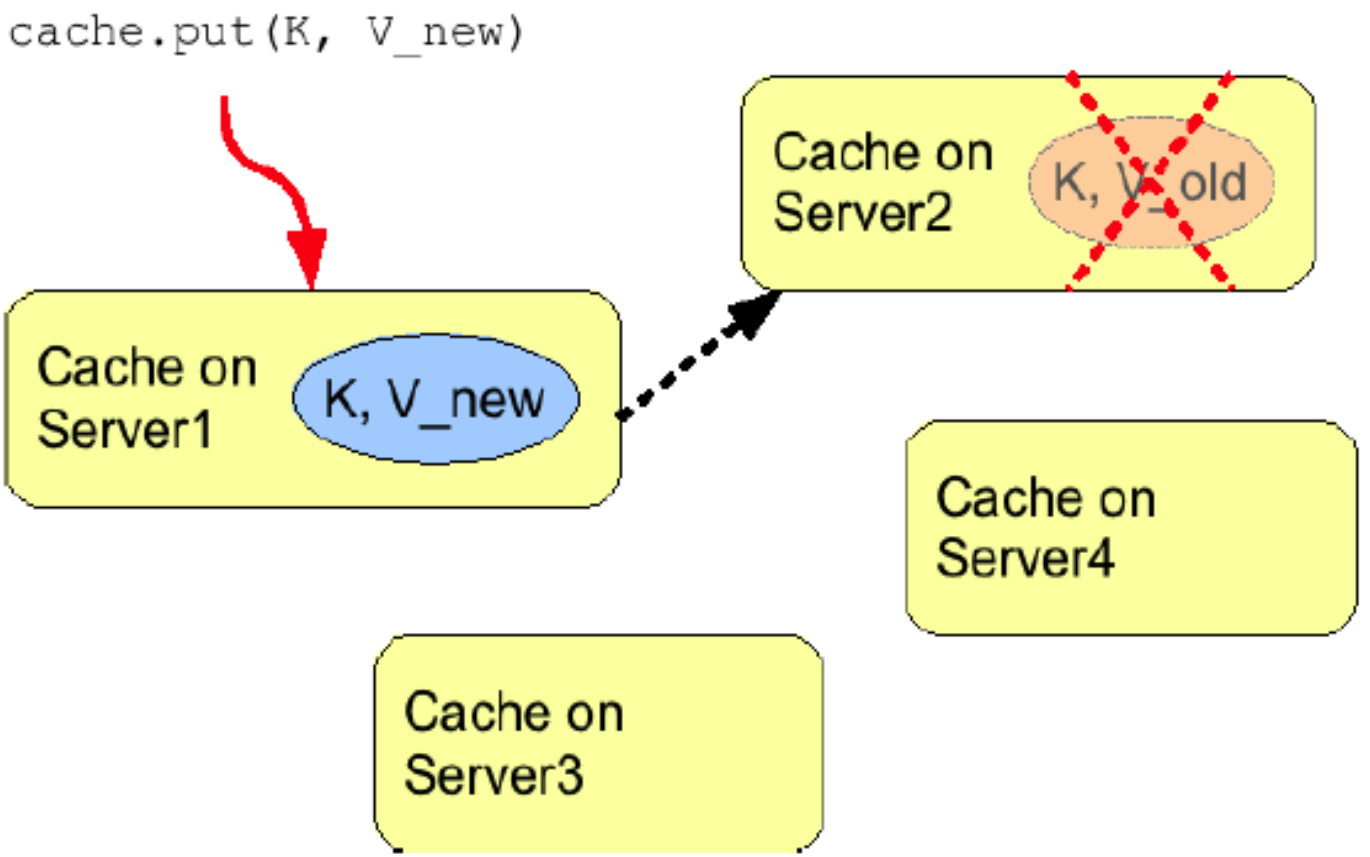



# Invalidation mode

- Suitable for RDBMS off-loading, used with shared cache store
- Entry exists in node's local cache => it's valid and can be
- returned to requestor
- 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 internode message traffic, PUT sends only invalidation
- messages and they are small.



# INVALIDATION






# Sync vs Async mode

- Synchronous
  - All operations get confirmation that the other relevant cluster nodes reached the desired state

- 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.



# 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();
    }
}
```




# 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



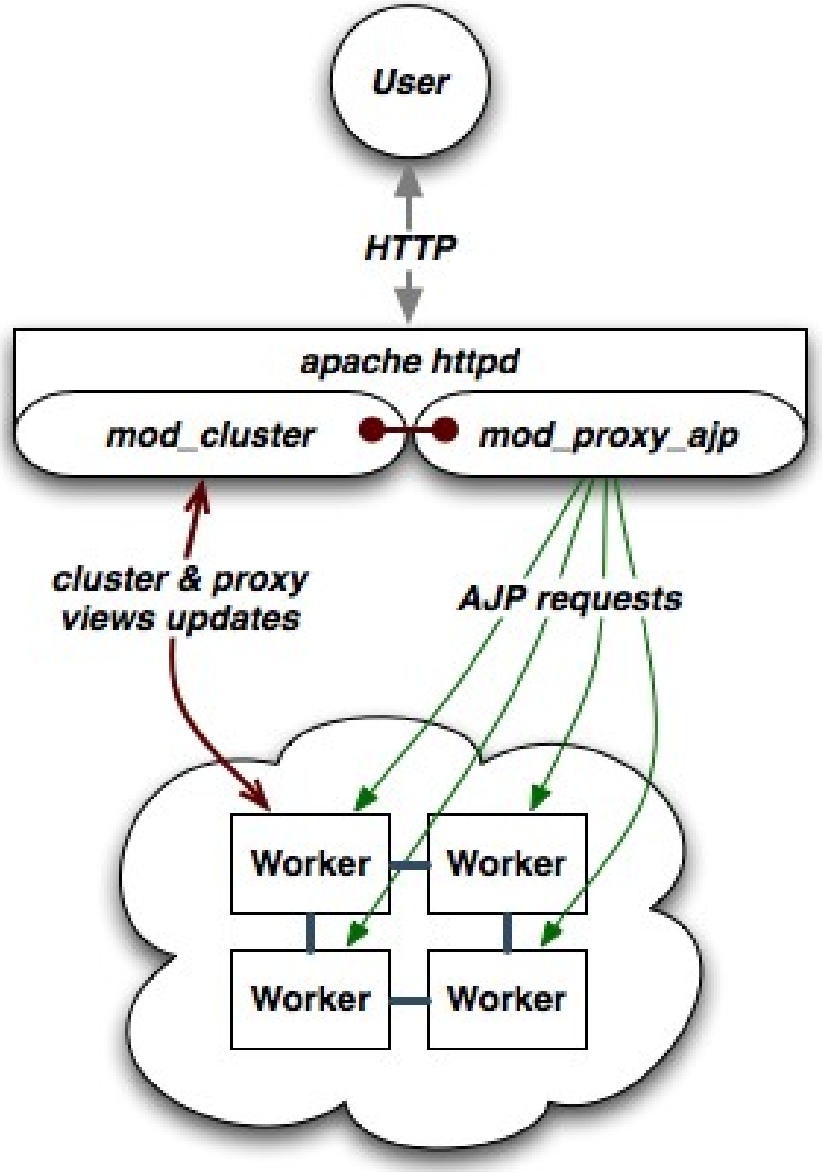
# Architecture #1

- 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 advertise themselves for web servers to register with them using UDP multicast
  - No topology information



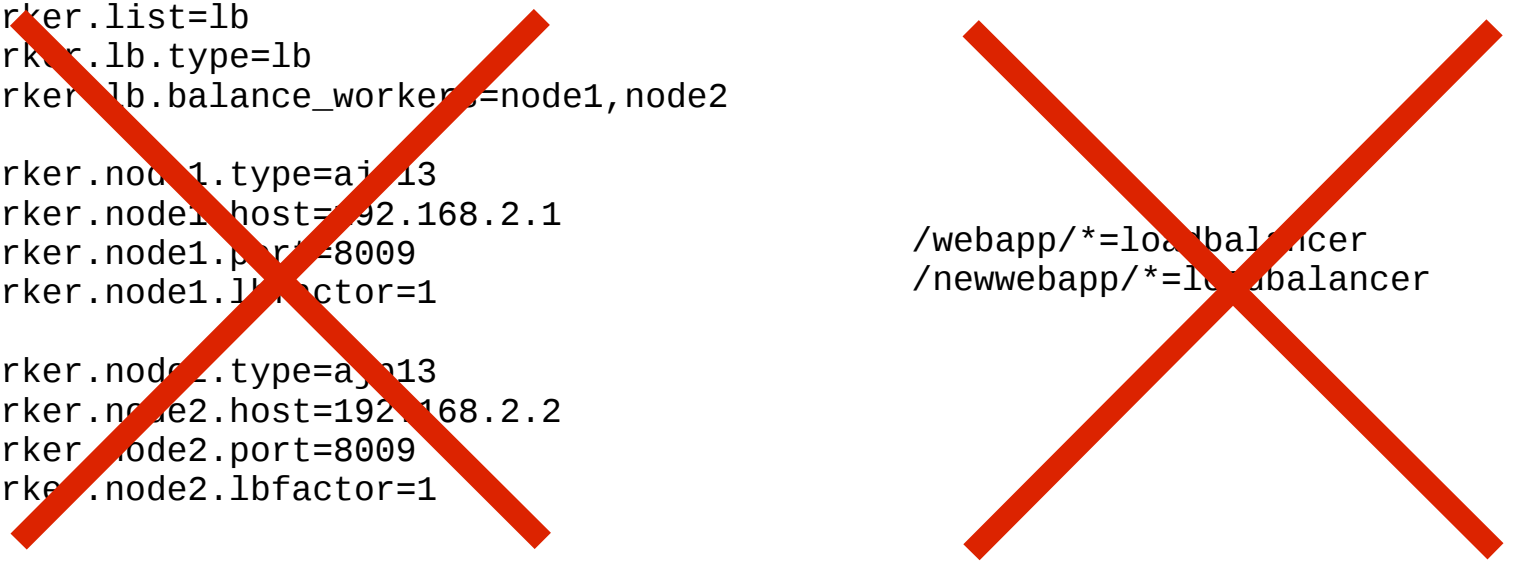
# No more `worker.properties` & `uriworkermap.properties`

```
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, fail-over 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 cluster_slotmem_module modules/mod_cluster_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

<IfModule manager_module>
    #Listen 127.0.1.1:6666
    Listen *:6666
    ManagerBalancerName mycluster

    <VirtualHost *:6666>
        KeepAliveTimeout 300
        MaxKeepAliveRequests 0
        AdvertiseFrequency 5
        ServerAdvertise On
        EnableMCPMReceive On
        AllowDisplay On
        <Location />
            Order deny,allow
            Allow from 127.0.1
        </Location>
        <Location /mod_cluster_manager>
            SetHandler mod_cluster-manager
            Order deny,allow
            #Deny from all
            #Allow from 127.0.1
            Allow from all
        </Location>
     </VirtualHost>
</IfModule>
```



# WildFly Configuration

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

- Or add to your existing profile:

```
    <extensions>
        ...
        <extension module="org.jboss.as.mod_cluster"/>
        ...
    </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"/>
...
```



# Demo: Try This At Home (Demo in LAB)

- Deployment
  - One HTTPd with mod_cluster
  - Two WildFly 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!



# Questions?



# Thank you!



# Community

- http://www.wildfly.org/
- http://www.jgroups.org/
- http://www.infinispan.org/
- https://www.jboss.org/mod_cluster
- http://www.jboss.org/