Challenging the world to change

heartbeat deployment tutorial

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Introduction

- Overview and concepts of High Availability
  - Introduction
  - Concepts
- heartbeat itself
  - Overview
  - Capabilities
  - drbd et al
  - Example configuration
- Other rants and topics
- Questions

Who is in the audience?

- Jobs:
  - System administrators
  - Developers
  - Users
  - Business people
- Experience
  - First timers
  - Experienced
  - Gurus
    - Go leave now ;-)

High Availability debuzzed

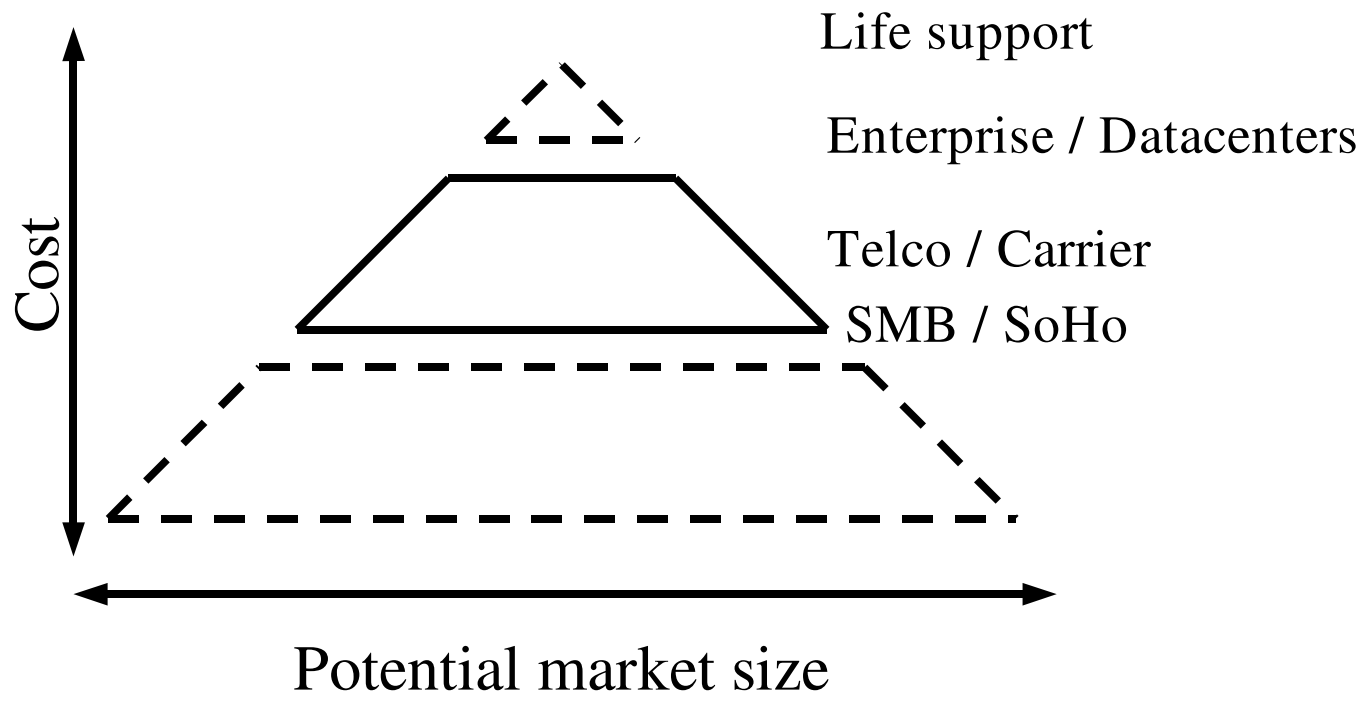
- Faults **will** occur – Murphy cannot be tricked.
- Unmasked faults show through to the users and cause downtime (and eventually loss of money)
- Some faults can be effectively masked completely („*fault tolerant*“, „*continuous availability*“) and some only can be recovered from quickly („*high availability*“)
- Redundancy is important.
- Redundancy is important.
- HA is **not** perfect and **not** the same as Continuous Availability.

Some numbers

- Most people only take into account unscheduled downtime
  - ... scheduled downtime would also include the time needed for any updates or other system maintenance!
- Systems can „tolerate“ a certain number *k* of independent failures (*k*-reliable) before total system failure.
- It's all about lies, damned lies and statistics

Availability percentage	Yearly downtime
100%	0
99,99999%	3s
99,9999%	30s
99,999%	5m
99,99%	52m
99,9%	9h

The pyramid


Life support
Enterprise / Datacenters
Telco / Carrier
SMB / SoHo
Cost
Potential market size

Increase reliability

- Use a stable operating system
  - Write bugfree code!
- Reduce complexity - **KISS!**
  - Increase testing coverage
  - QA-aware processes for development and release
- Contain faults
  - „*Failfast*“: suicide on uncorrectable faults turn **hard** byzantine faults into simple full failurs
    - Deadman, hangcheck, panic on IO errors etc
- Find faults before they occur (Orb of Detection anyone?)
  - Soft- and hardware monitoring

Reduce MTTR

- Introduce redundancy and eliminate SPoFs!
  - RAID redirects requests to healthy disks
  - Failover quickly reallocates service on healthy server
  - Load balancing redirects requests to healthy servers
  - Site failover eventually abandons site, backup data center goes live
- Needs to have redundant setups to have somewhere to move to.
  - States without redundancy are called „degraded modes“
  - Failed systems thus need to be repaired quickly still.
- Introduce redundancy and eliminate SPoFs!
- Also:
  - Service-level agreements, quick hardware replacement, good documentation

Single Points of Failure

- Infrastructure
  - Power
  - Air conditioning
  - Cabling in general
  - A single data center site
- Networking
  - Connection to the Internet
  - Intranet links
  - Firewalls
- Servers
  - Fans
  - Disks
  - Network cards
- Software
  - Applications
  - The cluster manager ;)
- Meatware
  - One administrator
  - No documentation

Clusters

- A cluster groups resources to form a system beyond the capabilities of a single node.
- Availability
  - Combined reliability of all nodes
  - Services remain up and running even if a single node fails
  - Remaining nodes take over
- Performance
  - Combined power of all nodes operating in parallel.
  - Distribute load among cluster members
  - Scalable systems

Cluster styles

- Failover
  - ... is like a good magicians trick:
  - **The hand moves faster than the eye**
  - Failover within a cupboard, rack or datacenter
  - Site-failover to protect against disasters
    - Different building or different continent...
- Load-balanced server farms
  - Provide load distribution, as well as protection against failed servers by shifting load away from them
  - Linux Virtual Server

Distributed Systems

- A number of nodes interconnected via some network
  - „Partially synchronous“
- Nodes:
  - Will fail, should try to contain faults locally
  - Assumed to have local stable storage
  - Randomly freeze, continue, do not run in step lock
- Certain assumptions about network reliability, performance
  - Links fail, packets get lost, the network gets partitioned
  - Packets get reordered, delayed, corrupted or messed with

Cluster Membership

- Cluster needs to have a consistent view of which nodes are valid members
- Nodes usually heartbeat actively or are otherwise monitored
- Lack of heartbeats received will lead to assumption of a node failure
- Difficult to distinguish between link failures, node failures if all links are cut – leads to *split-brain scenarios*
- Because failures can only be detected asynchronously, the cluster state is **never** certain.

Messaging in clusters

- Messages are transported via the network...
- *k*-reliable: At any phase of the protocol, *k* failures are tolerated and recovered, thus masked for the higher levels
- Ordered: Global ordering is enforced.
  - Total order: All nodes see all messages in the same order.
  - Causal order: A message is only seen if all messages it might depend on are received.
- Cryptography protects against (malicious) corruption.
- Fun: Network partitioning and byzantine failures

Time in clusters

- With unsynchronized clocks, events could have totally random timestamps.
- Partially synchronized clocks (NTP) allow the assumption that any two clocks do not differ by more than Δt
- To simulate strictly monotonous time, systems would never be allowed to produce a timestamp higher than that of an event received from another node. („causal“ time)
- Foundation on this theory done by Leslie Lamport

Resource Management

- Resource: Encapsulation of physical/logical entity providing a given service
  - *Resource type:* IP address, mounted partition, httpd, Oracle...
  - *Resource Instance* identified by type, name and other instance parameters
  - A *Resource Agent* script handles resources of a given type, providing a common API to the *Resource Manager*
  - Typically only one node can run a given resource instance at any given time, allocating it on multiple nodes will lead to data corruption and **must be avoided.**
- Typically grouped into *resource groups*
  - Stack of resources needed to provide a given service

Crown jewels

- **The data must be protected.**
- Without data, there is no service.
- Without data, there was no service.
- Without data, there will be no service.
- Data corruption must be prevented at all costs.
  - Rather have **no** running service than potentially corrupt data.
    - Exceptions exist, but this is the safe default.
  - Disconnect failed nodes from access to storage: *Fencing*

Accessing the data

- Shared storage via
  - Fibre Channel
  - Shared SCSI
  - iSCSI / HyperSCSI
  - Software replication
- Increasing hw reliability
  - Replication
  - Multi-path
  - RAID
- Increasing sw reliability
  - Software RAID
  - Replication
  - Journaled filesystems
  - Logical Volume Management
- Concurrent access
  - SAN-aware filesystems
    - GFS, PolyServe, IBM GPFS
  - Distributed filesystems
    - NFS, **Lustre**, AFS

IO fencing and STONITH

- Node-level fencing
  - Shot the other node/machine in the head (aka „**STONITH**“)
  - Crude, but simply effective.
  - A powered down node does not modify data.
- Resource-level fencing
  - Resources get to fence themselves by excluding non-members
  - Disabling the Fibre-Channel switchport
  - Self-fencing RAID controllers
  - SCSI reservations
    - Caveat, emperor: Dangerous in multipath environments, not always reliable

Kinds of failover systems

- Cold
  - Hardware ready, but not running
  - Services are manually started on the new system
  - Downtime very noticeable
- Warm
  - System up and running, data kept in sync
  - Services are started automatically
  - Short outage is usually noticeable („fast reboot“)
- Hot
  - Up and running
  - All systems active
  - Client talks to multiple systems at once („transaction monitor“)
  - No noticeable outage
- Why isn't everything Hot then?
  - Expensive
  - Software has to be adapted.

Failover summarized

- Servers constantly heartbeat eachother.
- A node fails to send heartbeats for a given period of time.
- Other node(s) detect this, assume node has failed.
- Node is prevented from corrupting the data by being fenced off.
- Membership computed anew.
- New node is chosen, services are reallocated there.
- Called „switchover“ if not triggered by a failure, for example for taking a node out of the cluster for maintenance.
- „Failback“ is either done automatically or manually initiated.

heartbeat overview I

- Started by Alan Robertson in 1999
  - Stable branch 1.2.0 (*1.0.4 still supported*)
  - Development branch 1.3.0
- 2 node warm failover for „resource groups“
  - Either automatic failback or controlled.
- Simple to setup
- Security focus, compact code base
- Redundant links for heartbeating and communication
  - Serial + IPv4 based unicast, broadcast, multicast
  - „ping“ nodes can be added as pseudo-cluster members

heartbeat overview II

- Locked into memory and soft realtime for minimal latency
- Sub-second node death detection possible with version ≥1.2
- Contains many interesting components:
  - Ipfail can monitor external conncectivity
  - Concensus Cluster Membership layer for upto *N*-nodes
  - STONITH modules, IPC library, PILS library
  - Simple, mostly reliable cluster communication
  - Cluster Test System (CTS) included
  - Application heartbeating, data checkpointing etc

heartbeat limitations

- Resource management limitted to two nodes
- Resources themselves not monitored for failure
- Configuration not automatically synchronized.
- Little real support for replicated resource types.

heartbeat future

- Multi-node functionality
- Dependency based resource model with constraint solver.
  - Internal model, users will probably need a helpful GUI
- Automatically replicated configuration (Cluster Information Base)
- *k*-reliable, causal/total ordered messaging service.
- Resource Agents conforming to OCF RA API
  - Resource monitoring will be extended
- Ready when it is ready, but work is underway.

Resource Agents

- Allow heartbeat to manage a given resource type
- heartbeat also supports using init.d scripts as Resource Agents
- Typically written as shell scripts
- Take simple list of options plus a requested action
- Key points to keep in mind:
- Resource agents need to be able to recover from an unclean shutdown
- Be extra careful.
- For more details, refer to Open Clustering Framework Resource Agent API

Currently available RAs

- IPaddr, IPaddr2
- IPsrcaddr
- Filesystem
- LVM
- RAID1
- ServeRAID
- ICP
- LinuxSCSI
- portblock
- xinetd
- db2
- WAS
- Mostly all init.d scripts
- It is **easy** to add your own.

STONITH modules

- Network power switches:
  - APC MasterSwitch
  - WTI NPS/TPS
  - BayTech RPC-xxx
  - Night/Ware RPC100S
- Serial power switches:
  - WTI RPS
  - APC Smart UPS
- IPMI over ethernet
- For testing only:
  - ssh
- meatware
  - (Manual operation)

ipfail

- heartbeat can monitor external nodes as pseudo cluster members by pinging them
- ipfail uses that information to determine where to place resources, namely on the node with the better external connectivity
- Dead simple configuration:
  - Configure ping nodes
  - Tell heartbeat to start ipfail

Cluster Test System

- CTS is the heartbeat test harness, stable releases are required to pass a few thousand iterations before release
- Can be extended with your own tests! (send patches!)
- Requires a test-controller which orchestrates the tests on the two victim nodes
- syslog may lose packets
- BasicSanityCheck as a single node, straight forward sanity check of the compiled system.
- No hardware? No problem:
  - User-Mode-Linux
  - VMware

Top 7 rules

1. Keep it simple, silly!
2. Redundancy.
3. Read documentation.
4. Write documentation.
5. Security.
6. Test.
7. Redundancy.

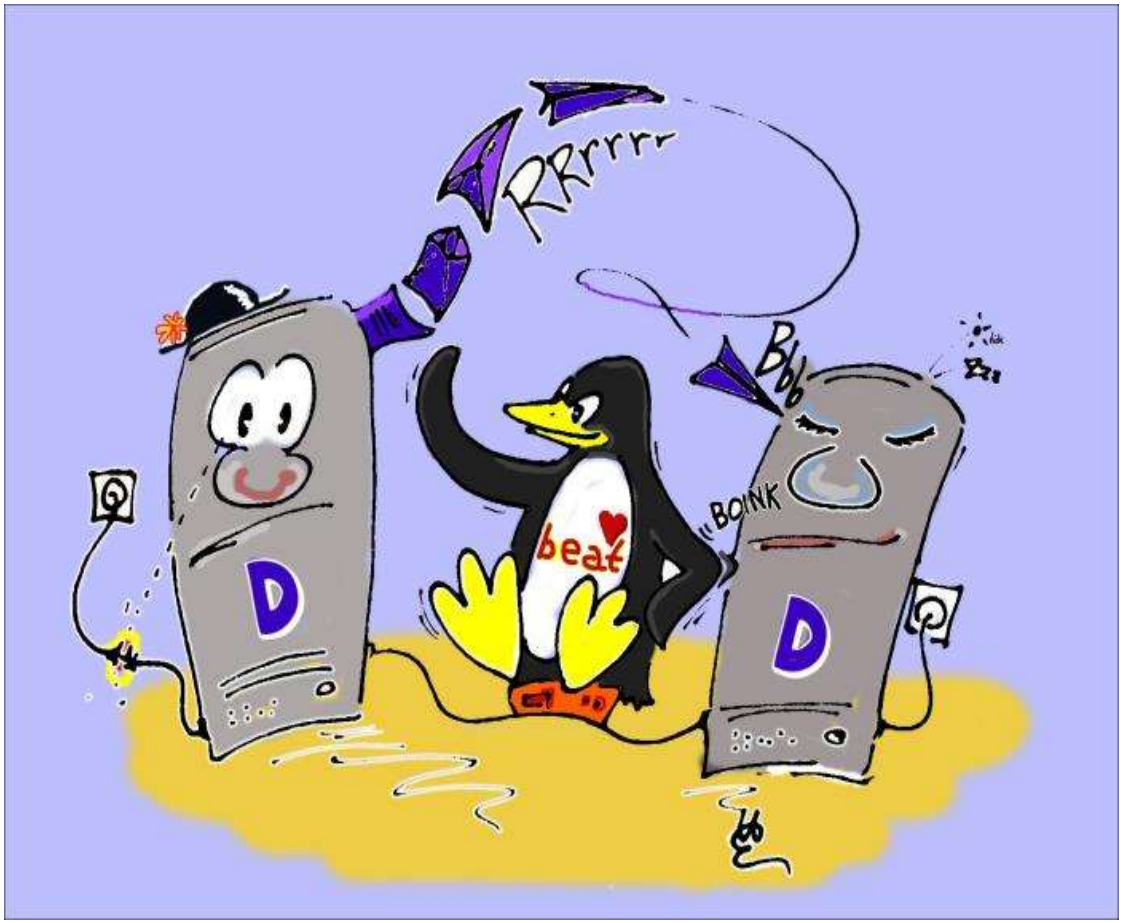
Common mistakes

- Not having the configuration files synchronized between all nodes.
- Controlling resources in the system init scripts and not under heartbeat's control
- Not using STONITH when recquired.
- Nodenames are case-sensitive.
- Cheap serial cables.
- Non-redundant heartbeat media.
- Resource Agents which do not report to „status“ correctly.

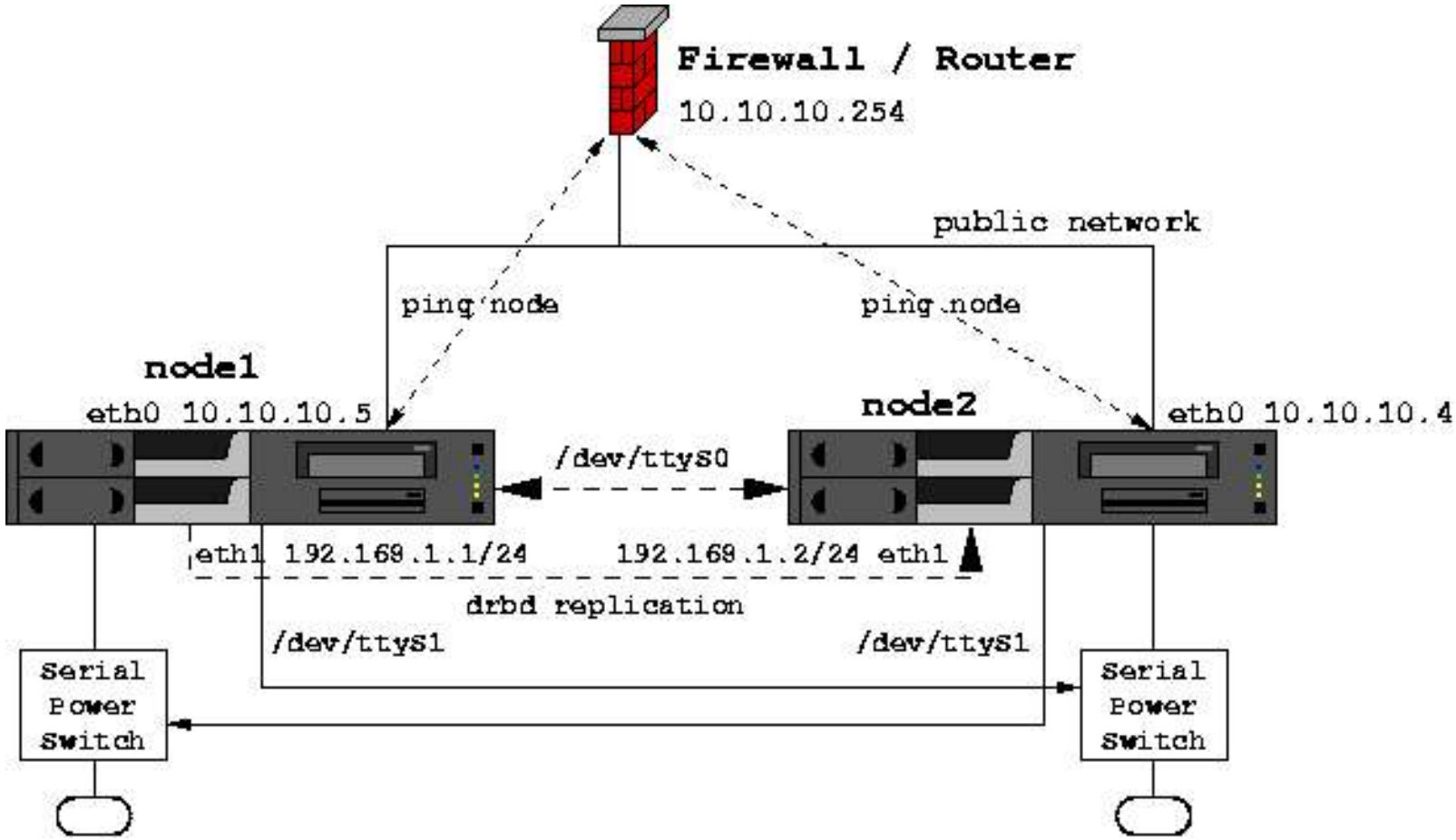
drbd present

- Distributed Replicated Block Device by Philipp Reisner
- Storage replication over the network (like RAID1) between two nodes over an „arbitary“ distance
- „*Smart resync*“ for all failure scenarios now, reducing MTTR
- Three protocols with different data integrity/performance trade-offs
- Benchmarks show that with GigE, performance is limitted by spindle and wire speed, drbd overhead neglible

drbd illustrated



heartbeat diagram



ha.cf example

```
keepalive 200ms
warntime 500ms
deadtime 1s
initdeadtime 30
auto_failback off
baud 19200
serial /dev/ttyS0
mcast eth0 225.0.0.1 694 1 0
bcast eth1
stonith_host node1 rps10 /dev/ttyS1 node2 0
stonith_host node2 rps10 /dev/ttyS1 node1 0
node node1 node2
ping 10.10.10.254
respawn hacluster /usr/lib/heartbeat/ipfail
```

haresources + authkeys

- haresources

```
node1 10.10.10.11 datadisk::drbd0 \
   Filesystem::/dev/nb0::/ha/apache::reiserfs apache

node2 10.10.10.12 datadisk::drbd1 \
   Filesystem::/dev/nb1::/ha/mysql::ext3 mysql
```

- authkeys **must** be root:root, mode 0600!

```
auth 1
1 sha1 MySeCrritPassword
```

drbd.conf

```
resource drbd0 {
 protocol = C
  fsckcmd  = /bin/true
  inittimeout=0
  disk {
    do-panic
    disk-size = 4194304k
  }
  net {
    sync-min    = 40M
    sync-max    = 90M
    tl-size     = 5000
    timeout     = 60
    connect-int = 10
    ping-int    = 1
  }
  on node1 {
    device  = /dev/nb0
    disk    = /dev/hdc1
    address = 192.168.1.1
    port    = 7788
  }
  on node2 {
    device  = /dev/nb0
    disk    = /dev/hdc1
    address = 192.168.1.2
    port    = 7788
  }
}

resource drbd1 {
...
```

Standards ... and so many!

- Interoperability does not exist.
- Open Clustering Framework as a community-driven approach
  - Very slow going.
  - Resource Agent API done, though
  - Working group of the FSG.
- Service Availability Forum as an „Industry driven“ initiative
  - Telco focus
  - Closed group, expensive membership
- CGL / DCL OSDL wishlists keep listing clustering

Other projects

- Other failover software:
  - RH ClusterManager
  - WitchDoctor WDX
  - IBM Tivoli System Automation for Linux
  - PolyServe
- Related topics:
  - Stateful firewall failover
  - Security
    - Denial of Service, data corruption, etc affect reliability
    - A cluster is basically a single administrative entity
  - „RAS“ of all sorts
    - Hotplug of memory, CPUs, you name it

Single System Image

- Implementation by HP / Bruce Walker, ported from Tru64 and older.
- All nodes form a virtual single system, moving the cluster boundary even below the administrator.
- Cluster-wide devices, cluster-wide memory (NC-NUMA) etc
- Mostly complete cluster infrastructure
- Fairly invasive, but still interesting.

Cluster Volume Manager

- LVM2:
- Proprietary Cluster-extensions by Sistina
- EVMS2:
- Cluster-extensions based on top of heartbeat, all Open Source
  - Actually EVMS project contributed the CCM to heartbeat for this useage
- **Significantly** higher priority than CFS
  - Few apps can take real advantage of concurrent access to the same filesystem still, but CVM is a real pre-requisite to sensibly managing storage in a cluster

Linux Virtual Server

- Started by Wensong Zhang, very stable
- Load balances working on TCP/UDP layer
- Dedicated node acts as load balancer / firewall
  - Need two of them, too.
- Virtual IP mapped via a scheduler to a set of real servers and then forwarded via NAT, „Direct Routing“ or tunneling
- Various scheduling methods
- Can replicate state table from a master LB to a secondary
- Layer 7 load balancing (*ktcpvs*) in alpha quality

Cluster Alias

- Load balancing without a load balancer
- All nodes bring up the same IP address – how can this work?
- Nodes all reply to ARP requests with a multicast MAC
- Only *one* node replies to an incoming new connection; other packets are silently ignored.
  - (src ip, port; dst ip, port) can be used as a hash key, Cluster Manager reallocates hash buckets in case of failures
- IP address can be used for outgoing connections too
- Implementation being done right now

Software RAID issues

- Bootloader integration for RAID1 / multipath
- DM/MD/LVM2/EVMS2/hotplug integration still not fully designed
- 2.6 code base is mostly a rewrite, experience from 2.4 suggests substantial testing and debugging efforts

Software RAID

- md codebase in 2.4 sucks
- MD codebase in 2.6 doesn't suck as badly
- Used for local replication & redundancy
- Up to one fault per RAID group can be masked for RAID>0
- MTTR can be reduced by added hotspares
- Multipathing can protect against certain media failures
- RAID1 on top of multipathing can provide „fault tolerance“
- RAID6 can mask 2 failures per array and increases space-efficiency for bigger arrays

drbd vs nbd/md

- drbd is more tightly integrated with the version vector; failures like split-brain, one node rebooting etc do not occur in md scenarios
- Close integration with the network layer makes the protocol A and B possible, which would be rather difficult to add to nbd
- md+nbd is more complex to setup
- Possibility would be to add appropriate scripting around md+nbd to ease this, but nobody steps forward to do that ;-)

Further reading

- *In search of clusters* by Gregory F. Pfister
- *Blueprints in High Availability* by Evan Marcus, Hal Stern
- *Fault tolerance in Distributed Systems* by Pankaj Jalote
- *Distributed Algorithms* by Nancy Lynch
- *Transaction Processing* by Jim Gray
- *http://www.lcic.org/* for more links to projects
- http://linuxha.trick.ca/ Linux HA Wiki
- http://linux-ha.org/

No questions!^H?