PERCONA LIVE

How to evaluate which MySQL High Availability solution best suits you

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NOKIA
Connecting People

Senior Performance Architect, Nokia

- SOA:
  - Each team does their own thing
- Nokia and web?
  - App store, music store, Maps, SSO...
  - Store: 13M apps/day, 100M registered users
- Architect
  - reviews, "internal consultant"
- MySQL improvements:
  - Recommend backup, HA, version etc... best practices

Ben Mildren

MySQL DBA, Pythian

- Over 10 years experience as a Production DBA
- Experience of MySQL (4.1+), SQL Server, Oracle
- Ex-Nokia Services, worked with Henrik on Music, Maps, Messaging, etc

Pythian

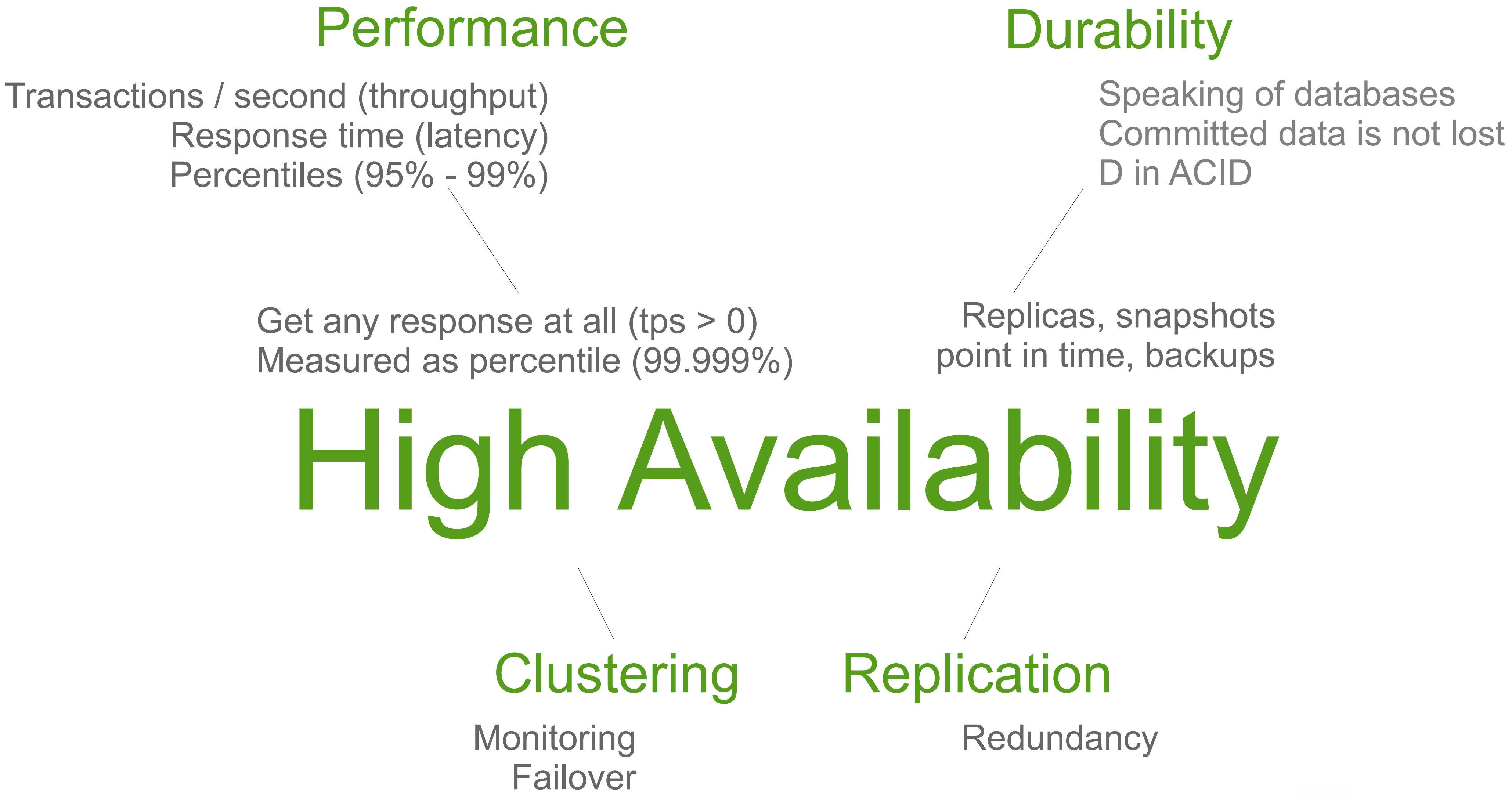
love your data

About Pythian

- Global industry-leader in remote database administration services and consulting for Oracle, Oracle Applications, MySQL and SQL Server
- Work with over 150 multinational companies such as Toyota, Fox Sports, and MDS Inc. to help manage their complex IT deployments
- Employ 7 Oracle Aces, including 2 Ace Directors
- 24/7/365 global remote support for DBA and consulting, systems administration, special projects or emergency response

What is High Availability?

What is high availability?



Performance

Transactions / second (throughput)
Response time (latency)
Percentiles (95% - 99%)

Get any response at all (tps > 0)
Measured as percentile (99.999%)

Durability

Speaking of databases
Committed data is not lost
D in ACID

Replicas, snapshots
point in time, backups

High Availability

Clustering

Monitoring
Failover

Replication

Redundancy

Uptime

Percentile target	Max downtime per year
90%	36 days
99%	3.65 days
99.5%	1.83 days
99.9%	8.76 hours
99.99%	52.56 minutes
99.999%	5.26 minutes
99.9999%	31.5 seconds

Beyond system availability: Average downtime per user.

High Availability HOWTO

- HA is achieved via redundancy:
  - RAID: If one disk crashes, other one still works
  - Clustering: If one server crashes, other one still works / can take over
  - Power: In case a fuse blows, have another power input
  - Network: If a switch/NIC crashes, have a second network route
  - Geographical: If a datacenter is destroyed (or just disconnected), move all computation to another data center.
  - Biological: If you lose a kidney, you have another one left.

Redundancy

Making data available

Durability

- Data is stored on physical disks
  - Is it really written to the disk?
  - Also: Written in transactional way, to guarantee
    - atomicity
    - integrity
    - crash safety
- *"Durability is an interesting concept. If I sync a commit to disk, the transaction is said to be durable. But if I now take a backup, then it is even more durable.*

  - Heikki Tuuri, MySQL Conference 2009

High Availability for databases

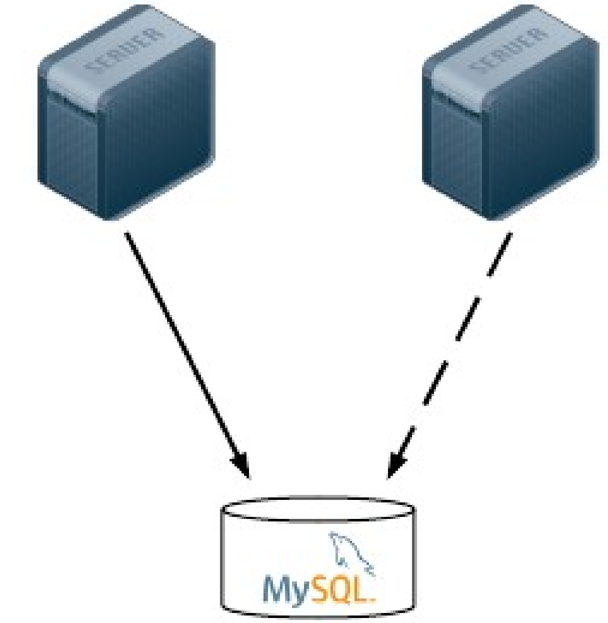
- HA is harder for databases
  - Must make both **HW resources and data redundant**
  - Not just data, but constantly changing data
  - HA means operation can continue "uninterrupted", i.e. not by restoring a backup to a new server
- Can be achieved in several ways:
  - Shared disks
  - Disk based replication
  - MySQL based replication
  - Client side XA transactions

Redundancy through shared storage

- Requires specialist hardware
  - e.g. DAS or SAN
  - Complex to operate?

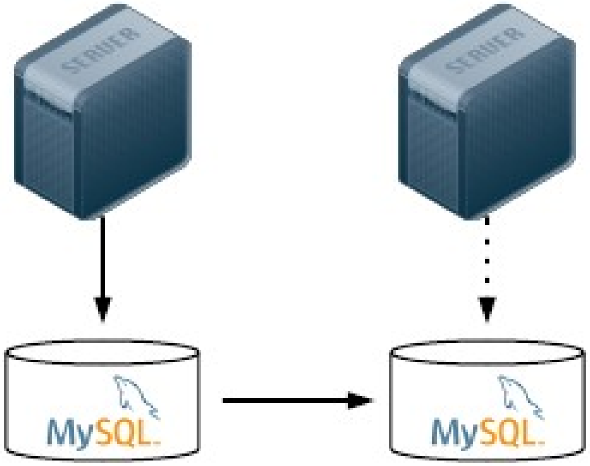
    http://www.percona.com/about-us/mysql-white-paper /causes-of-downtime-in-production-mysql-servers/
- One set of data
  - Single Point of Failure
- Active / Passive

  (or bad things will happen)
- Active / Active: Oracle RAC, ScaleDB



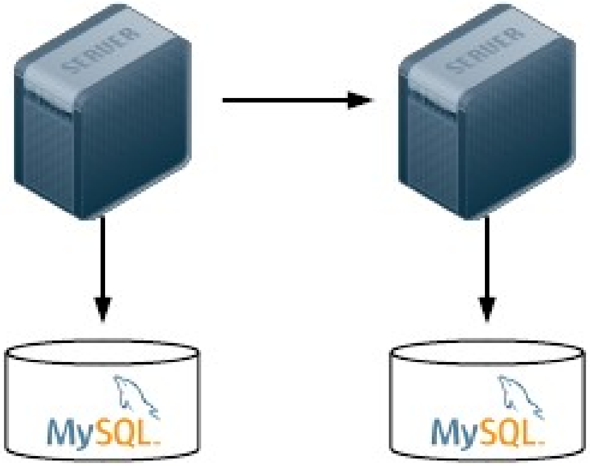
Redundancy through disk replication

- Requires specialist software
  - DRBD
  - SAN based software
- Storage requirement multipliec
- Second set of data inaccessibl
- Again active / passive



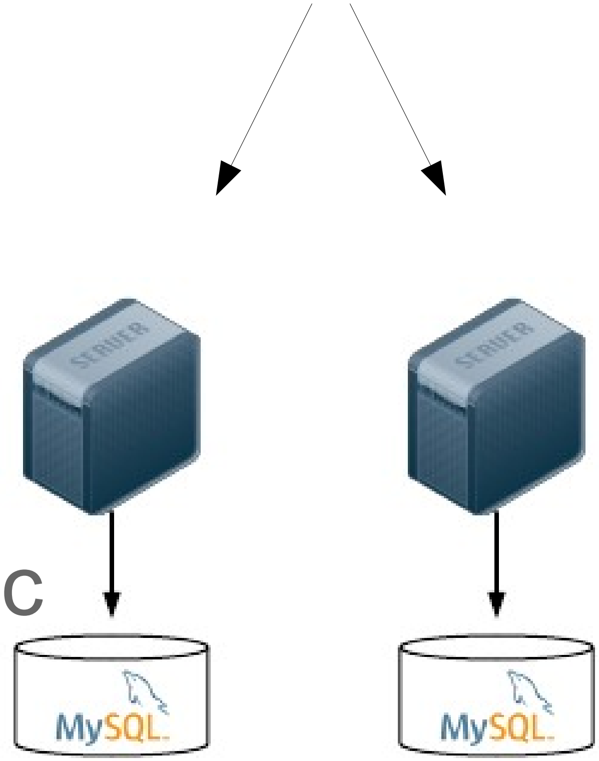
Redundancy through MySQL replication

- Replication at the RDBMS layer
  - MySQL
  - Tungsten Replicator
  - Galera
  - MySQL NDB Cluster
- Storage requirement multiplied
- Includes potential for scaling out



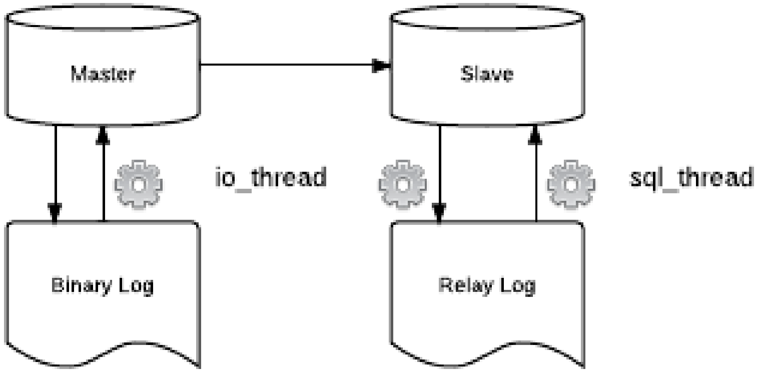
Redundancy through Client side XA transactions

- Client writes to 2 independent but identical databases
- Example: HA-JDBC
- No replication anywhere
- Sounds simple
- Got many databases out of sync
- Not covered in this tutorial



So what is MySQL Replication?

- Replication copies transactions from the master and replays them to the slave:



Inside the binary log (SBR)

```
> mysqlbinlog mysql-bin.*
[...]
/*!40019 SET @@session.max_insert_delayed_threads=0*/;
/*!50003 SET @OLD_COMPLETION_TYPE=@@COMPLETION_TYPE,COMPLETION_TYPE=0*/;
DELIMITER /*!*/;
# at 240
#120331  0:54:56 server id 1  end_log_pos 339   Query   thread_id=6     exec_time=0     error_code=0
use test/*!*/;
SET TIMESTAMP=1333144496/*!*/;
SET @@session.pseudo_thread_id=6/*!*/;
SET @@session.foreign_key_checks=1, @@session.sql_auto_is_null=1, @@session.unique_checks=1,
@@session.autocommit=1/*!*/;
SET @@session.sql_mode=1574961152/*!*/;
SET @@session.auto_increment_increment=1, @@session.auto_increment_offset=1/*!*/;
/*!\C latin1 *//*!*/;
SET @@session.character_set_client=8,@@session.collation_connection=8,@@session.collation_server=8/*!*/;
SET @@session.lc_time_names=0/*!*/;
SET @@session.collation_database=DEFAULT/*!*/;
INSERT INTO testnumber VALUES (1334)
/*!*/;
DELIMITER ;
DELIMITER /*!*/;
ERROR: File is not a binary log file.
DELIMITER ;
# End of log file
ROLLBACK /* added by mysqlbinlog */;
/*!50003 SET COMPLETION_TYPE=@OLD_COMPLETION_TYPE*/;
```

Row based replication event

```
> mysqlbinlog mysql-bin.*
DELIMITER /*!*/;
# at 4
#120331  0:52:23 server id 1  end_log_pos 240   Start: binlog v 4, server v 5.2.4-MariaDB-rpl-mariadb98~maverick-log
created 120331  0:52:23 at startup
# Warning: this binlog is either in use or was not closed properly.
ROLLBACK/*!*/;
BINLOG '
Fyt2Tw8BAAAA7AAAAPAAAAABAAQANS4yLjQtTWFyaWFEQi1ycGwtbWFyaWFkYjk4fm1hdmVyaWNr
LWxvZwAAAAAAAAAAAAAAXK3ZPEzgNAAgAEgAEBAQEEgAA2QAEGggAAAAICAgCAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAA=
'/*!*/;
```

- Yes, you can execute that statement against MySQL!
- MariaDB has SQL annotation of row based events.

SHOW SLAVE STATUS

```
mysql> show slave status\G
*************************** 1. row ***************************
Slave_IO_State: Waiting for master to send event
Master_Host: server1
Master_User: repluser
Master_Port: 3306
...
Master_Log_File: server1-binlog.000008         <- io_thread (read)
Read_Master_Log_Pos: 436614719                     <- io_thread (read)
Relay_Log_File: server2-relaylog.000007            <- io_thread (write)
Relay_Log_Pos: 236                             <- io_thread (write)
Relay_Master_Log_File: server1-binlog.000008   <- sql_thread
Slave_IO_Running: Yes
Slave_SQL_Running: Yes
...
Exec_Master_Log_Pos: 436614719                 <- sql_thread
...

Seconds_Behind_Master: 0
```

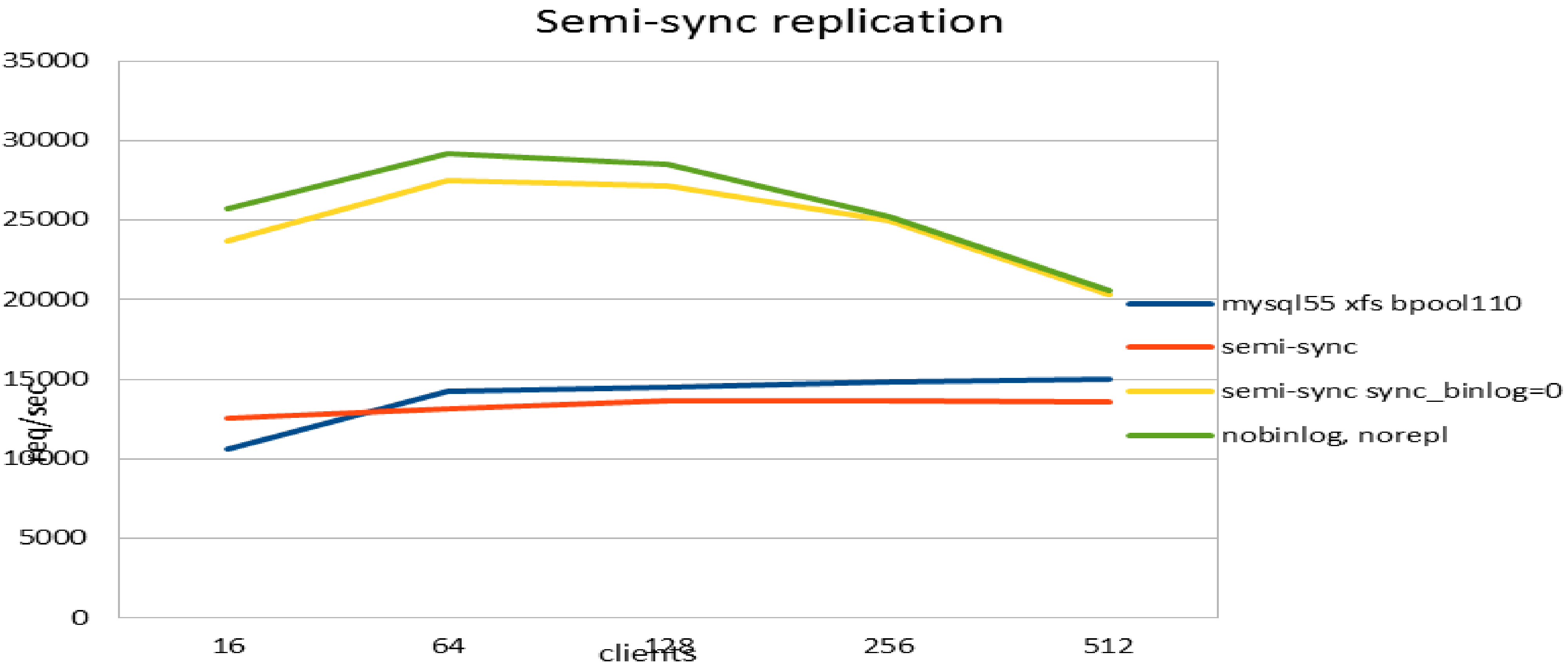
So what is MySQL Replication?

- Statement based, or Row based (5.1+)
- Asynchronous
- Semi Synchronous plugin in 5.5+
- MySQL 5.6
  - Global Transaction ID
  - Server UUID
  - Ignore (master) server-ids
  - Per-schema multi-threaded slave
    - Watch out for relay-log position with multiple slaves!
  - Checksums
  - Crash safe binlog and relay-log
  - Delayed replication
  - http://dev.mysql.com/doc/refman/5.6/en/mysql-nutshell.html
- Due to the nature of replication, tools like pt-table-checksum and pt-table-sync are important part of the picture!

MySQL 5.6 binary log

```
$ mysqlbinlog mysql-bin.000001
...
# at 207
#120331 22:38:30 server id 1  end_log_pos 282   Query     thread_id=1   exec_time=0
error_code=0
SET TIMESTAMP=1333222710/*!*/;
BEGIN
/*!*/;
# at 282
#120331 22:38:30 server id 1  end_log_pos 377   Query     thread_id=1   exec_time=0
error_code=0
SET TIMESTAMP=1333222710/*!*/;
insert into t1 values (1)
/*!*/;
# at 377
#120331 22:38:30 server id 1  end_log_pos 404  Xid = 10
COMMIT/*!*/;
```

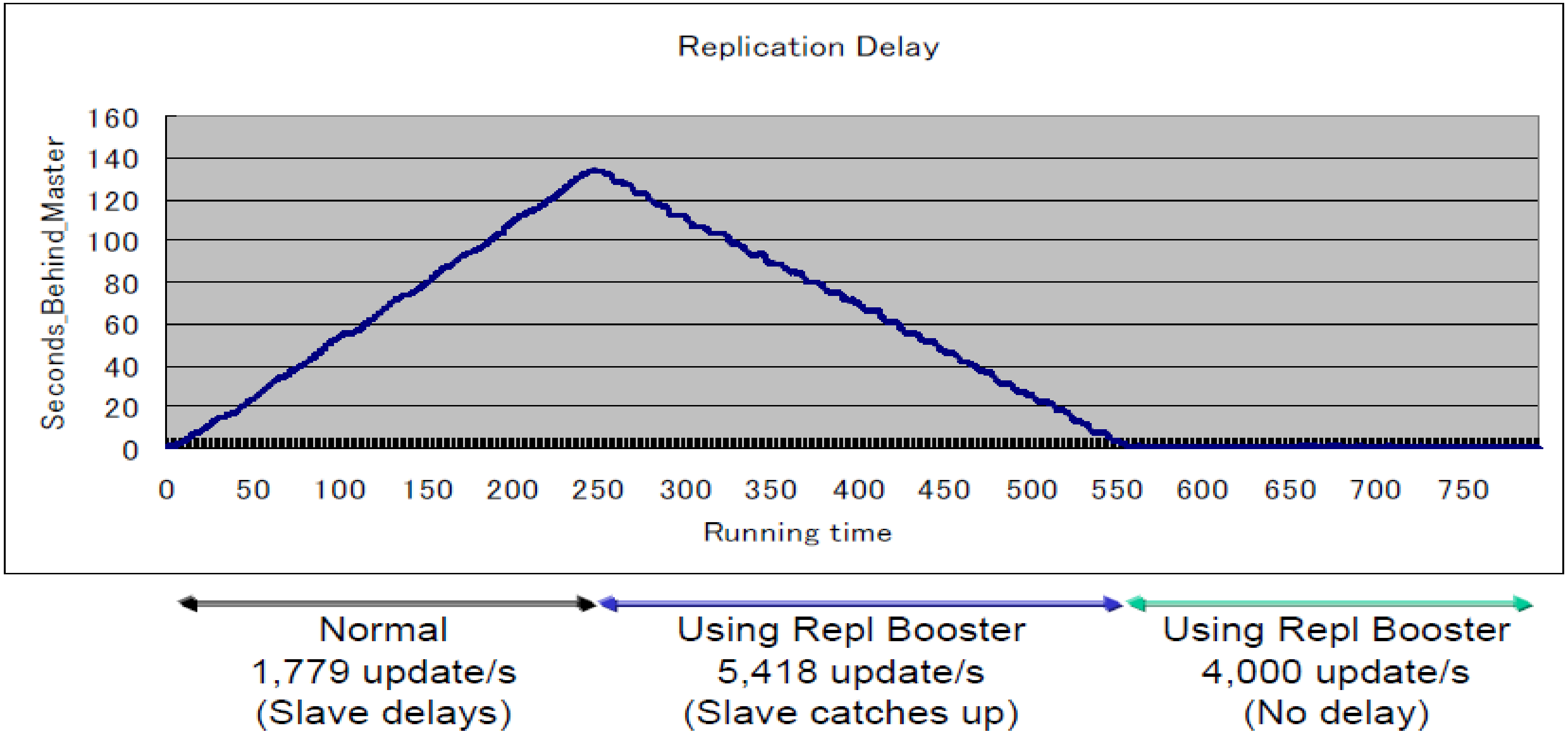
Semi sync vs Single node (memory bound)



Practically no performance overhead
Opportunity to relax sync_binlog setting (green - yellow)

Slave lag (disk bound)

Executing 4,000 update/s on master



Normal
1,779 update/s
(Slave delays)

Using Repl Booster
5,418 update/s
(Slave catches up)

Using Repl Booster
4,000 update/s
(No delay)

Graph and benchmark (C) Yoshinory Matsunobu, Percona Live UK 2011
http://www.percona.com/files/presentations/percona-live/london-2011/PLUK2011-linux-and-hw-optimizations-for-mysql.pdf

With disk bound workload (data set > RAM), slave lag is common
In practice limits master throughput 50-90%
Slave-prefetch tools combat this well. See:
Yoshinori Matsunobu, Anders Karlsson, Percona Toolkit

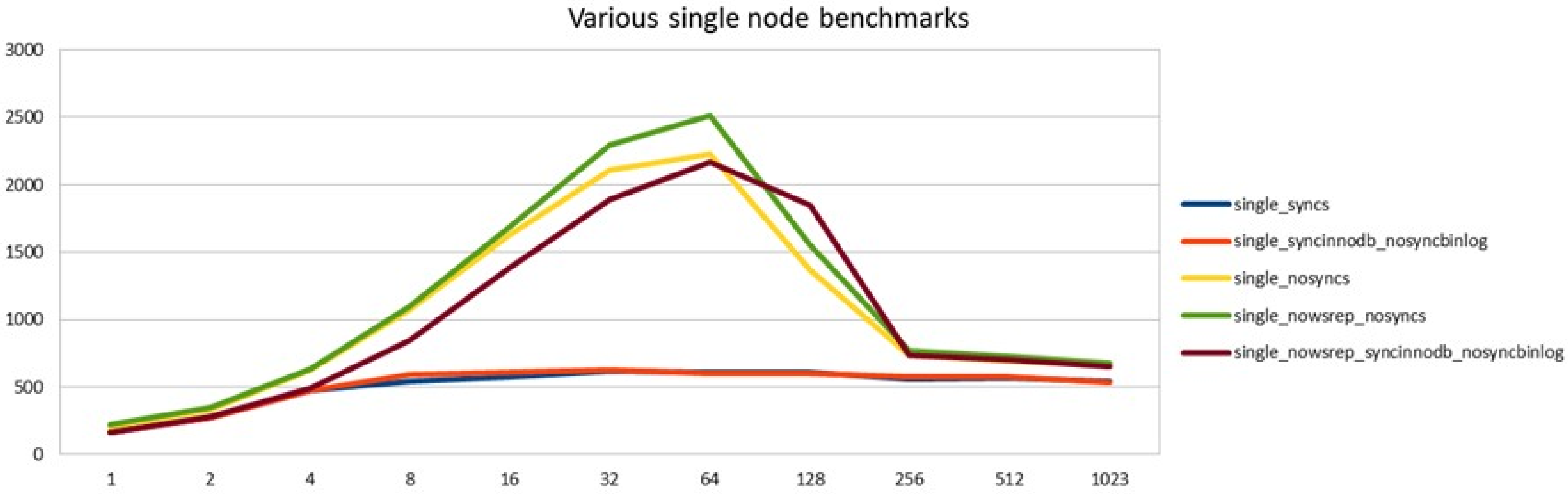
So what is Tungsten Replicator?

- Replaces MySQL Replication
  - MySQL writes binary log, Tungsten reads it and uses its own replication protocol
- Global Transaction ID
- Per-schema multi-threaded slave
- Heterogeneous replication: MySQL <-> MongoDB <-> Pg
- Multi-master
  - Including multiple masters to single slave
  - Complex topologies
- Tungsten Enterprise

So what is Galera?

- Inside MySQL: a replication plugin (kind of)
  - Supports InnoDB only
- Replaces MySQL replication (or you could use both)
- True multi-master, active-active
- Synchronous
  - Still pretty good over WAN: 100 - 300 ms / commit
- Multi-threaded slaves, no limitation on use case
- No slave lag or integrity issues
- Automatic node provisioning
- Percona XtraDB Cluster is based on Galera

Single node



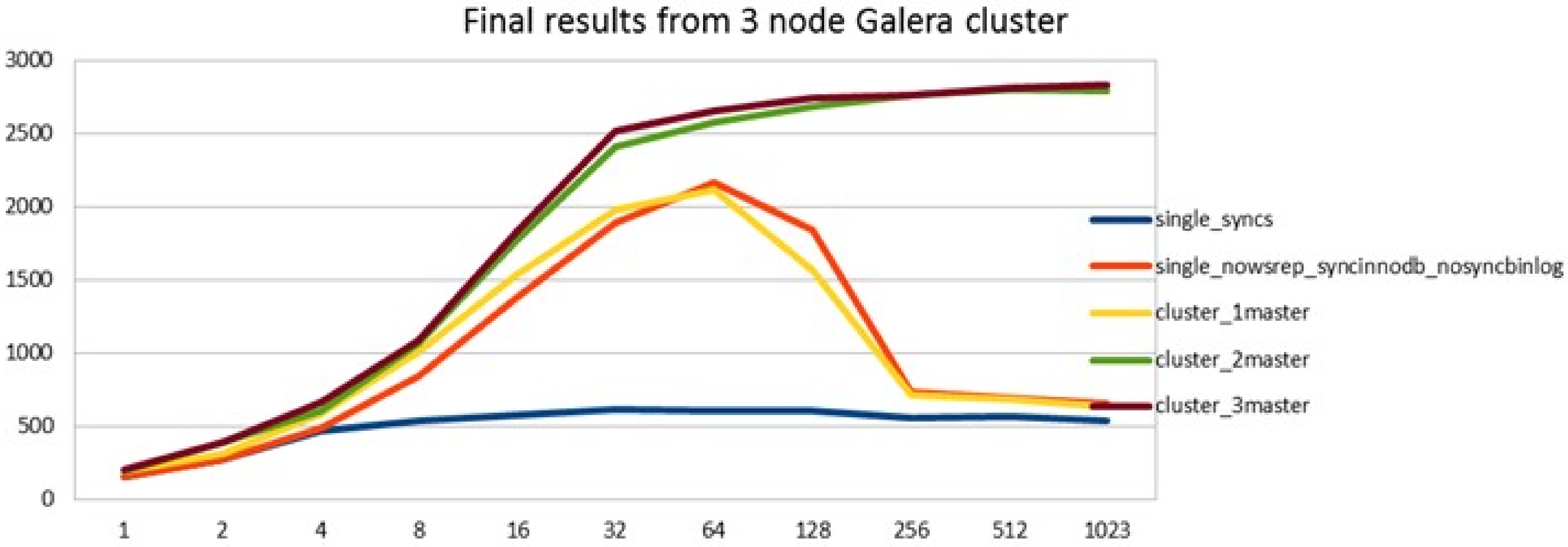
Baseline single node performance

"Group commit bug" when sync_binlog=1 & innodb_flush_log_at_trx_commit=1

- Fixed in Percona Server 5.5, MariaDB 5.3 and MySQL 5.6

Wsrep api (Galera module, no replication) adds minimal overhead

3 node Galera cluster



Blue & Red: Baseline single node performance

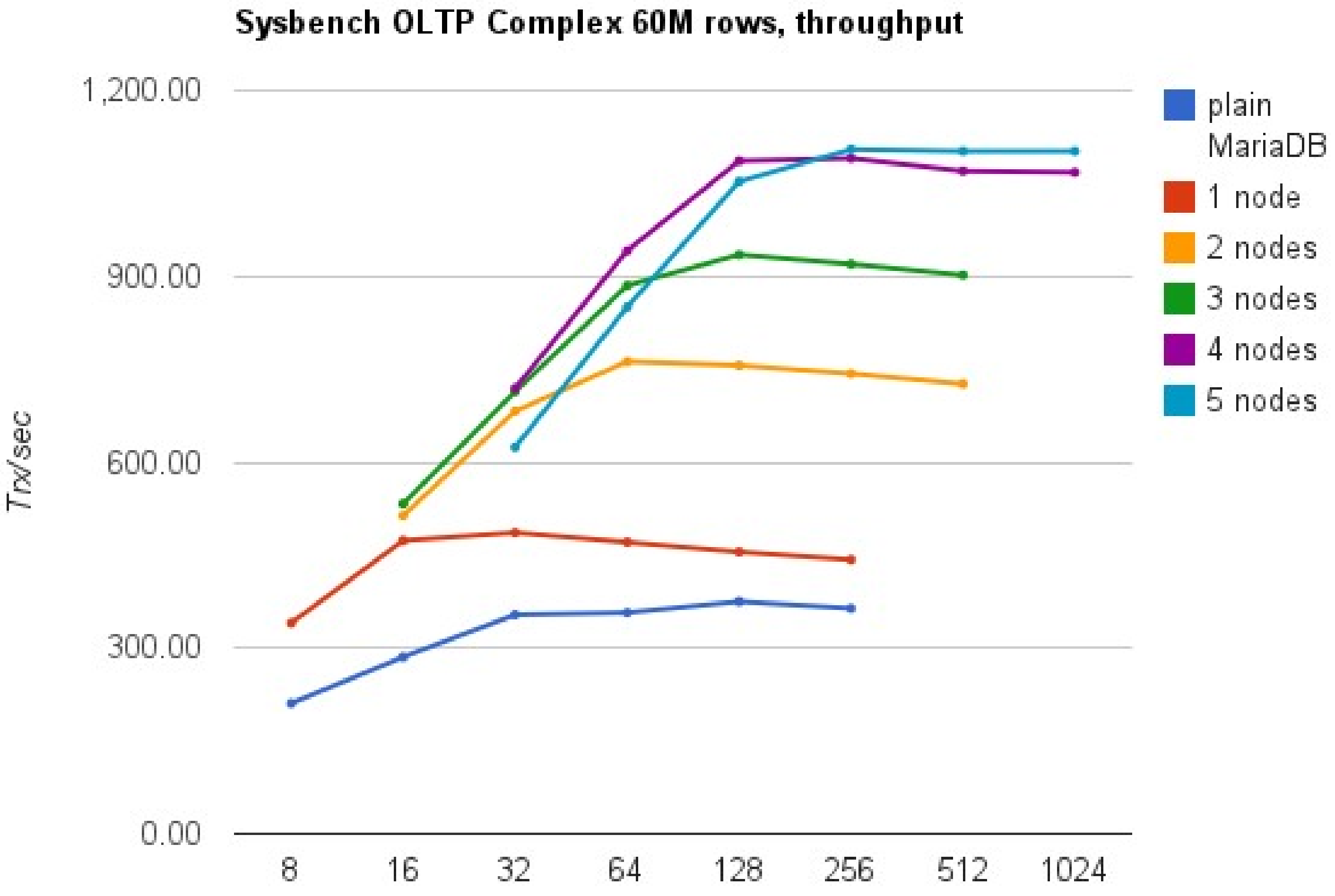
Blue: "Group commit bug" when sync_binlog=1 & innodb_flush_log_at_trx_commit=1

- Fixed in Percona Server 5.5, MariaDB 5.3 and MySQL 5.6

No overhead in master-slave mode (red vs yellow)

Small **benefit!** in multi-master mode

Galera w disk bound workload (EC2)



20 GB data / 6 GB buffer pool
Significant read-write scale-out up to 4 nodes!

Graph and benchmark courtesy of and copyright Codership Oy
http://codership.com/content/scaling-out-oltp-load-amazon-ec2-revisited

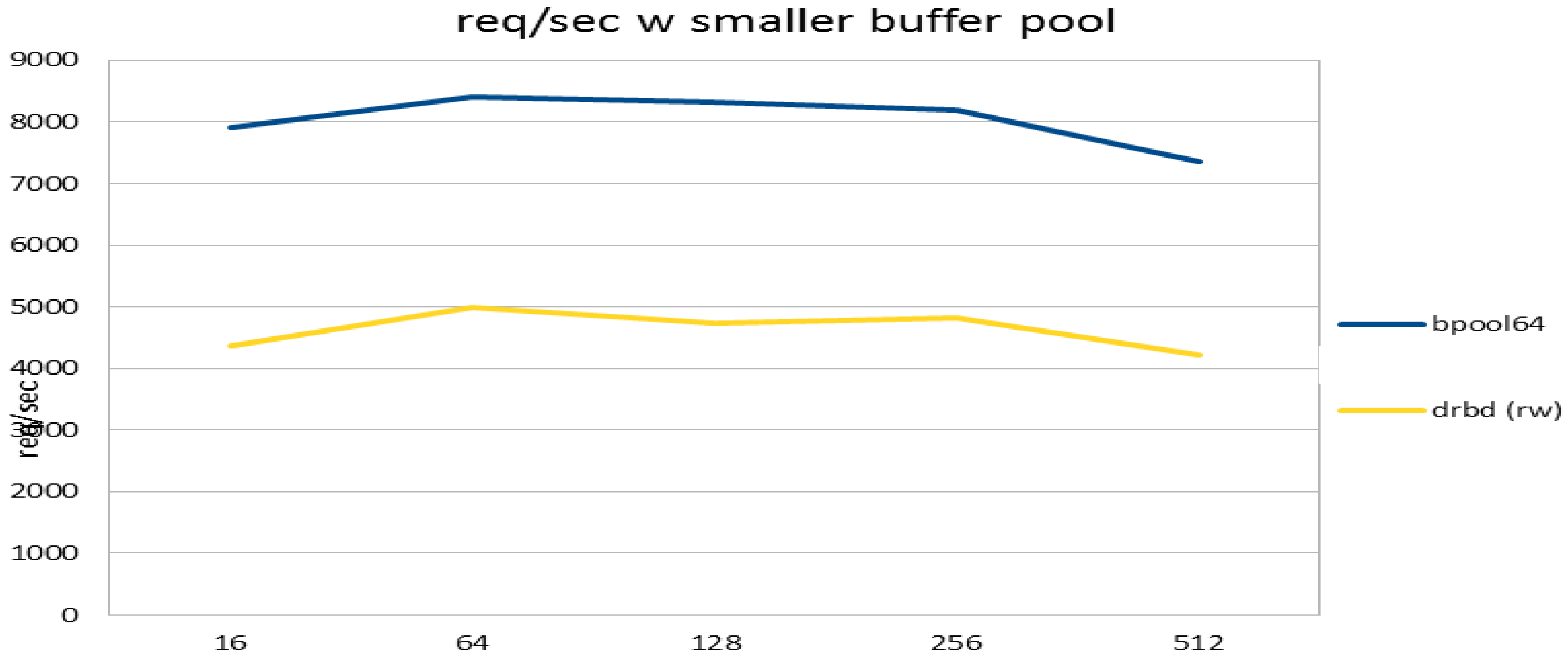
So what is MySQL NDB Cluster?

- 3 node types: sql, data, and management.
  - MySQL node provides an interface to the data, alternate API is available: LDAP, Memcache, native NDB API
  - Data nodes aka NDB storage engine.
    - Note: Different features and performance compared to InnoDB! (Consider training.)
    - Transactions are synchronously written to 2 nodes (or more) aka replicas.
    - Transparent sharding:
      Partitions = data nodes / replicas
    - Automatic node provisioning, online re-partitioning
- Management node manages the cluster, used to start and stop nodes, and take backups, etc.

So what is DRBD?

- Linux disk driver: "RAID over network"
- Pros:
  - Transparent to application: Replicate anything
  - Synchronous
  - Cold-standby: Not possible to write to slave
- Cons:
  - Performance overhead (see next slide)
  - Single server, no scale-out
    - But can be coupled with MySQL read-only slaves
  - Failover time 1 minute or more
  - Linux sysadmin skills vs MySQL DBA skills

DRBD vs Single node



60% of single node performance
Minimum latency 10x higher but average is not so bad (not shown)

Note: This is different HW than the Galera test, and different metric

Summary of Replication Performance

- SAN has "some" latency overhead compared to local disk. Can be great for throughput.
- DRBD = 50% performance penalty
- Replication, when implemented correctly, has 0 performance penalty
  - But MySQL replication w disk bound data set has single-threadedness issues!
- Galera & NDB = r/w scale-out = **more** performance

Other

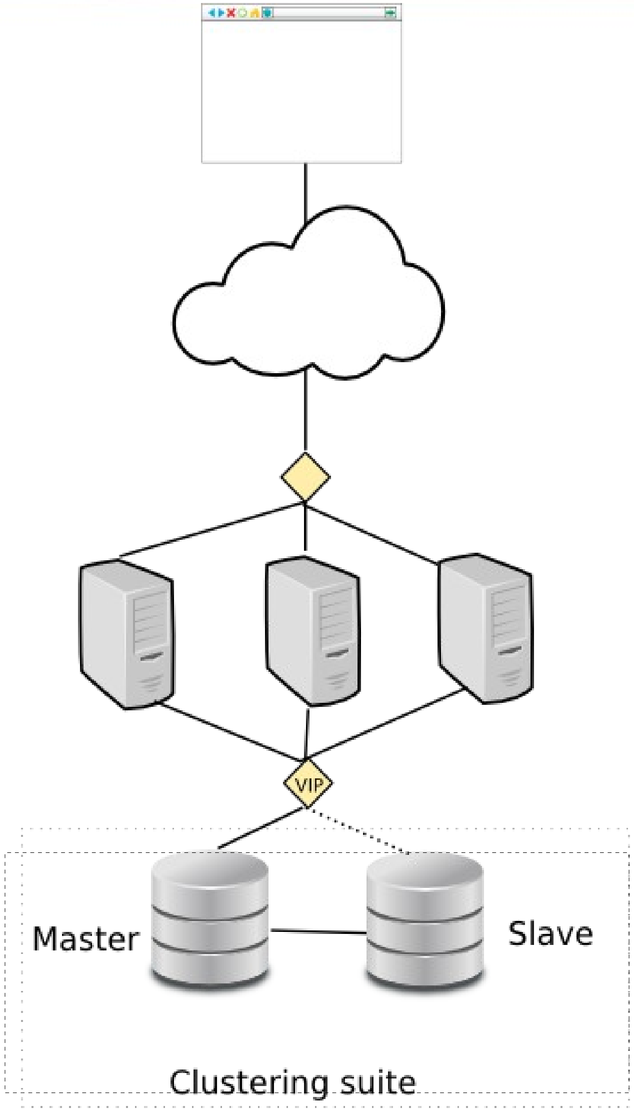
- Read-only, read-mostly databases
- Database sharding
  - > Database partially unavailable
- Does it need to be in the database?
  - Flat files
- Kind of replicas:
  Caching, message queues, full-text engines

Dealing with failures
aka
Clustering Frameworks

Dealing with failure

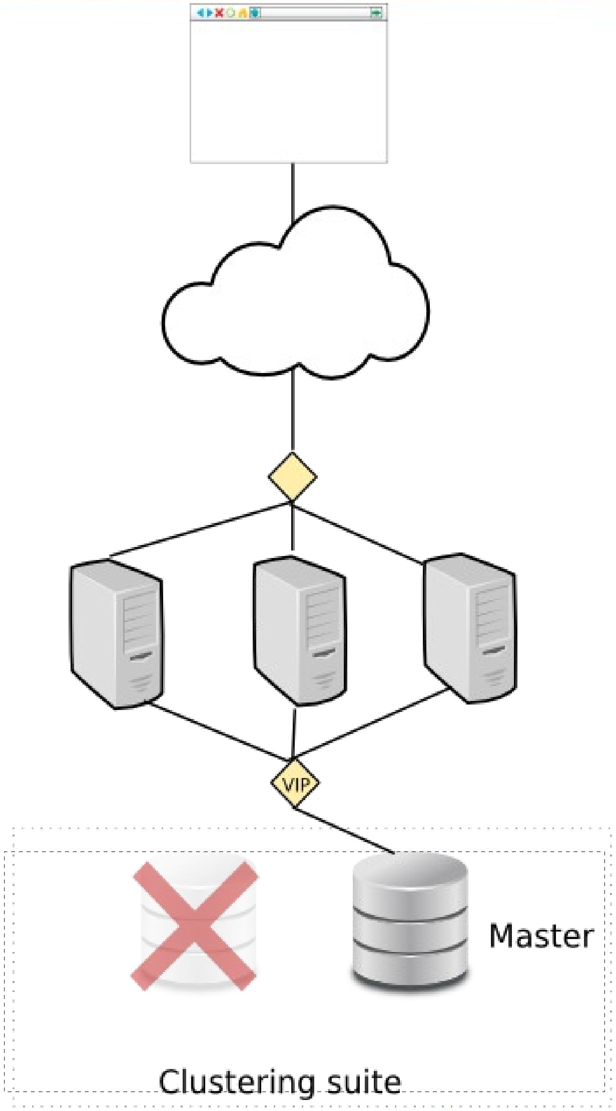
- Problem #1: How do we find out about failure?
  - Polling, monitoring, alerts...
  - Error returned to and handled in client side
- Problem #2: What should we do about it?
  - Direct requests to the spare nodes (or datacenters)
- Problem #3: Not as easy as you'd think, remember to protect data integrity:
  - Master-slave is unidirectional: Must ensure there is only one master at all times.
  - DRBD and SAN have cold-standby: Must mount disks and start mysqld.
  - In all cases must ensure that 2 disconnected replicas cannot both commit independently.

Clustering frameworks



- VIP points to Master
- External clustering suite polls all nodes for health
- In case of Master error, move VIP to Slave
- + other management tasks
- Solutions:
  - Automated Replication Failover
  - Cluster Suites
  - VM based

Failover



Automated Replication Failover

- When using MySQL replication
  - MySQL-MMM, MySQL-MHA, Severalnines
  - Tungsten Enterprise to manage Tungsten Replicator
- Specialized solutions
  - Understand MySQL and MySQL replication

So what is MySQL-MMM?

- You have to setup all nodes and replication manually
- MMM gives Monitoring + Automated and manual failover on top
- Architecture consists of Monitor and Agents
- Typical topology:
  2 master nodes
  Read slaves replicate from each master
  If a master dies, all slaves connected to it are stale
- Support from Open Query and Percona
- Is there still a place for MMM?
- http://mysql-mmm.org/

MMM example

```
# mmm_control show
  db1(192.168.0.31) master/ONLINE. Roles: writer(192.168.0.50), reader(192.168.0.51)
  db2(192.168.0.32) master/ONLINE. Roles: reader(192.168.0.52)
  db3(192.168.0.33) slave/ONLINE. Roles: reader(192.168.0.53)

# mmm_control set_offline db1
OK: State of 'db1' changed to ADMIN_OFFLINE. Now you can wait some time and check all roles!

mon:~# mmm_control show
  db1(192.168.0.31) master/ADMIN_OFFLINE. Roles:
  db2(192.168.0.32) master/ONLINE. Roles: writer(192.168.0.50), reader(192.168.0.52)
  db3(192.168.0.33) slave/ONLINE. Roles: reader(192.168.0.51), reader(192.168.0.53)
```

Courtesy and copyright of http://mysql-mmm.org/mysql-mmm.html

So what is Severalnines ClusterControl?

- Origin as automated deployment of MySQL NDB Cluster
  - 4 node cluster up and running in 5 min!
- Now also supports
  - MySQL replication and Galera
  - Semi-sync replication
  - Automated failover
  - Manual failovers, status check, start & stop of node, replication, full cluster... from single command line.
  - Monitoring
- Topology: Pair of semi-sync masters, additional read-only slaves
  - Can move slaves to new master
- Commercial closed source features: backup, online add node, rolling restart
- http://severalnines.com/

So what is MySQL-MHA?

- Like MMM, specialized solution for MySQL replication
  - Developed by Yoshinori Matsunobu at DeNA
  - Support from SkySQL
- Automated failover and manual failover
- Topology: 1 master, many slaves
  - Choose new master by comparing slave binlog positions
- Can be used in conjunction with other solutions
- http://code.google.com/p/mysql-master-ha/

So what is Tungsten Enterprise?

- Use with Tungsten Replicator
- Like "all of the above"
- Includes proxy / load balancer that can further protect slaves from accidental writes, etc...
- Closed source, commercial
- http://continuent.com/

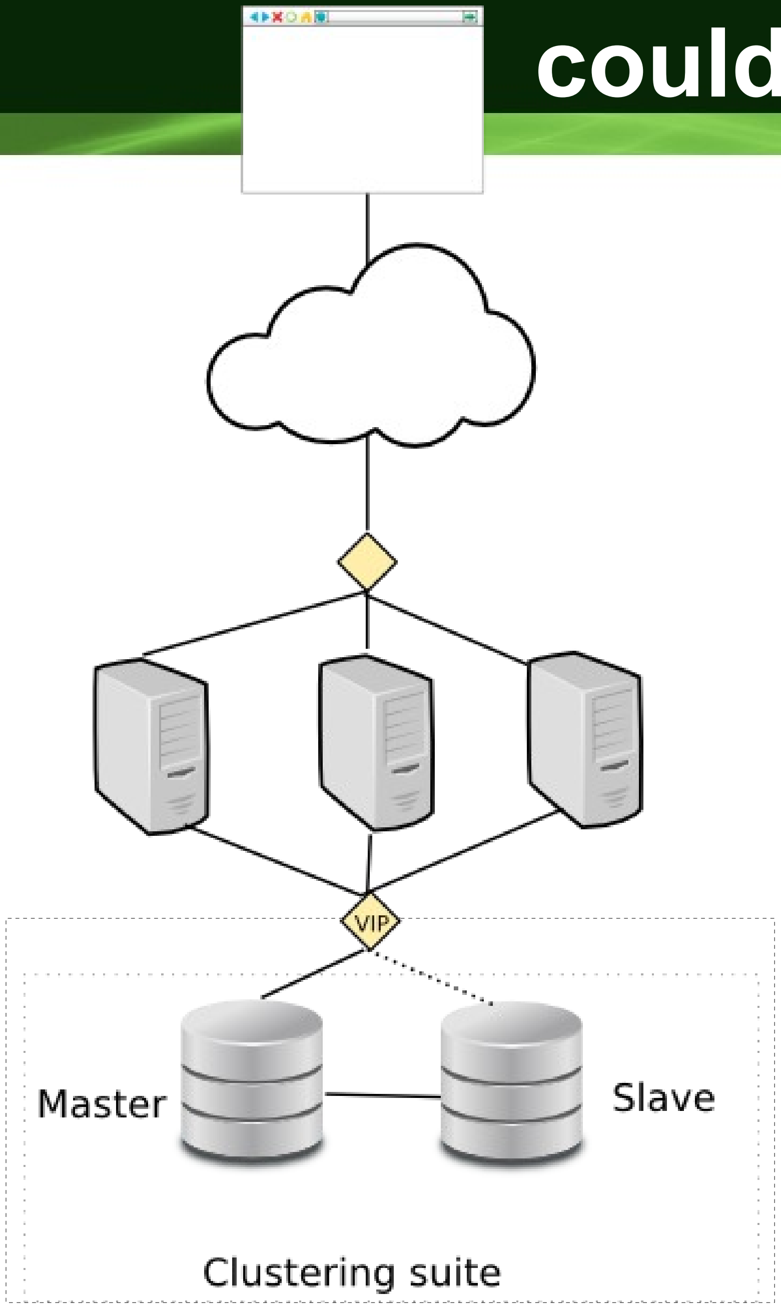
Cluster suites

- Heartbeat, Pacemaker, Red Hat Cluster Suite
- Generic, can be used to cluster any server daemon
- Usually used in conjunction with Shared Disk or Replicated Disk solutions
  - Preferred choice
- Can be used with Replication.
- Robust, Node Fencing / STONITH

So what is Pacemaker?

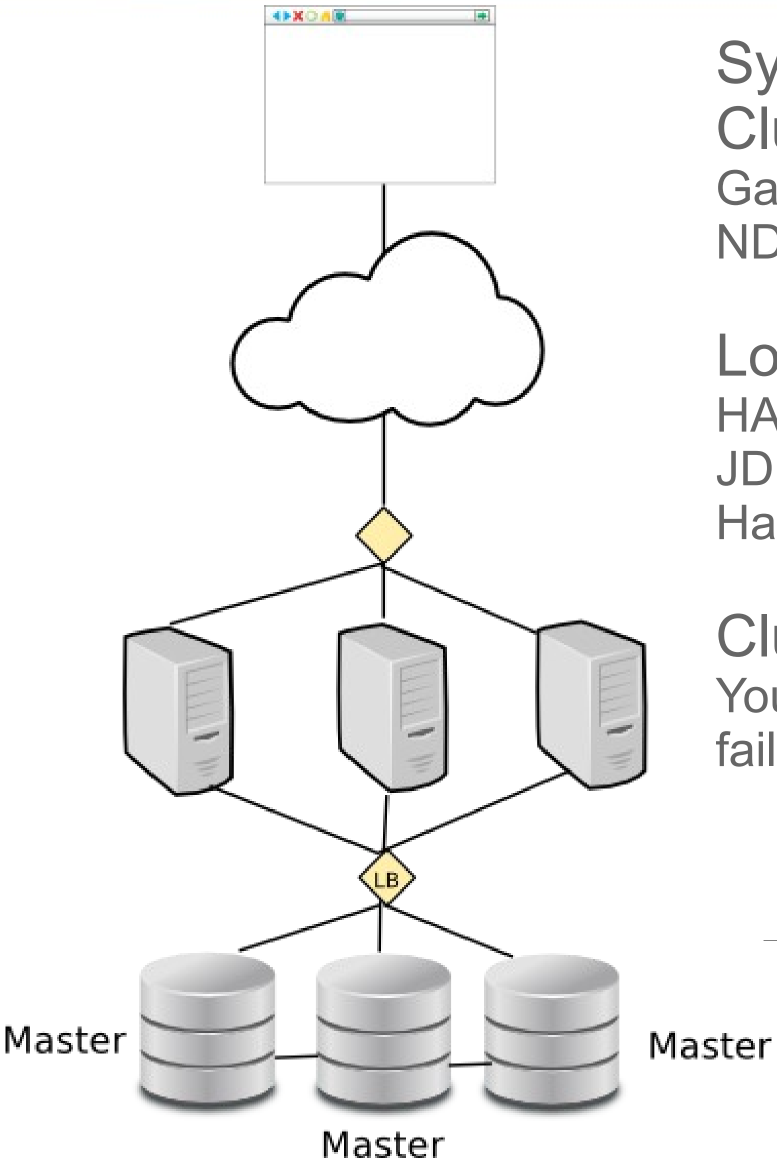
- Heartbeat v1, Heartbeart v2, Pacemaker
- Heartbeat and Corosync
- Resource Agents, Percona-PRM
- http://www.clusterlabs.org/
- Percona Replication Manager
  - Pacemaker agent specialized on MySQL replication
  - "Done right" (but not yet there?)
  - https://launchpad.net/percona-prm

Sounds simple. What could possibly go wrong?



- Old Master must stop service (VIP, os, DB). But it is not responding, so how do you make it stop?
- Polling from the outside. Interval = 1 sec, 10 sec, 60 sec!
- What if replication fails first and client transactions don't?
- Polling connectivity of DB nodes but not client p.o.v.
- Failover can be expensive (SAN, DRBD) -> false positives costly

Load Balancers for Multi-Master clusters



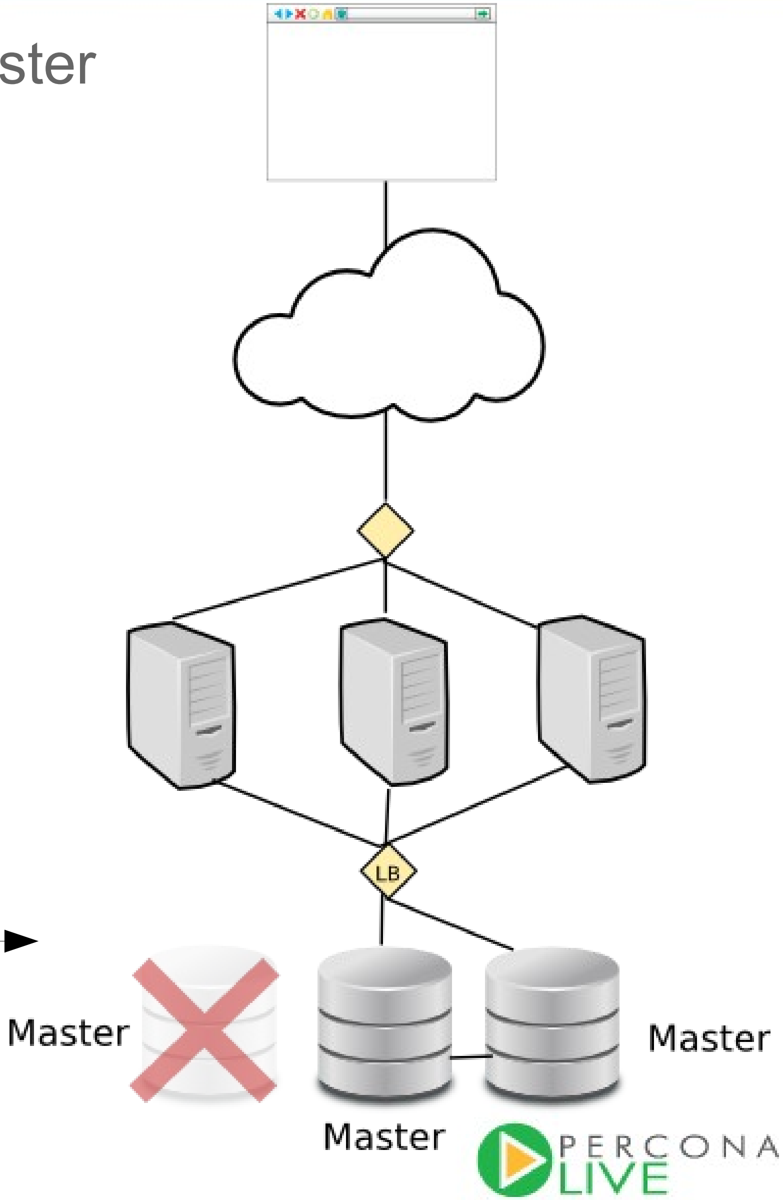
Synchronous Multi-Master Clusters:
Galera
NDB

Load balancers:
HAProxy
JDBC/PHP Driver
Hardware (e.g. F5, Cisco)

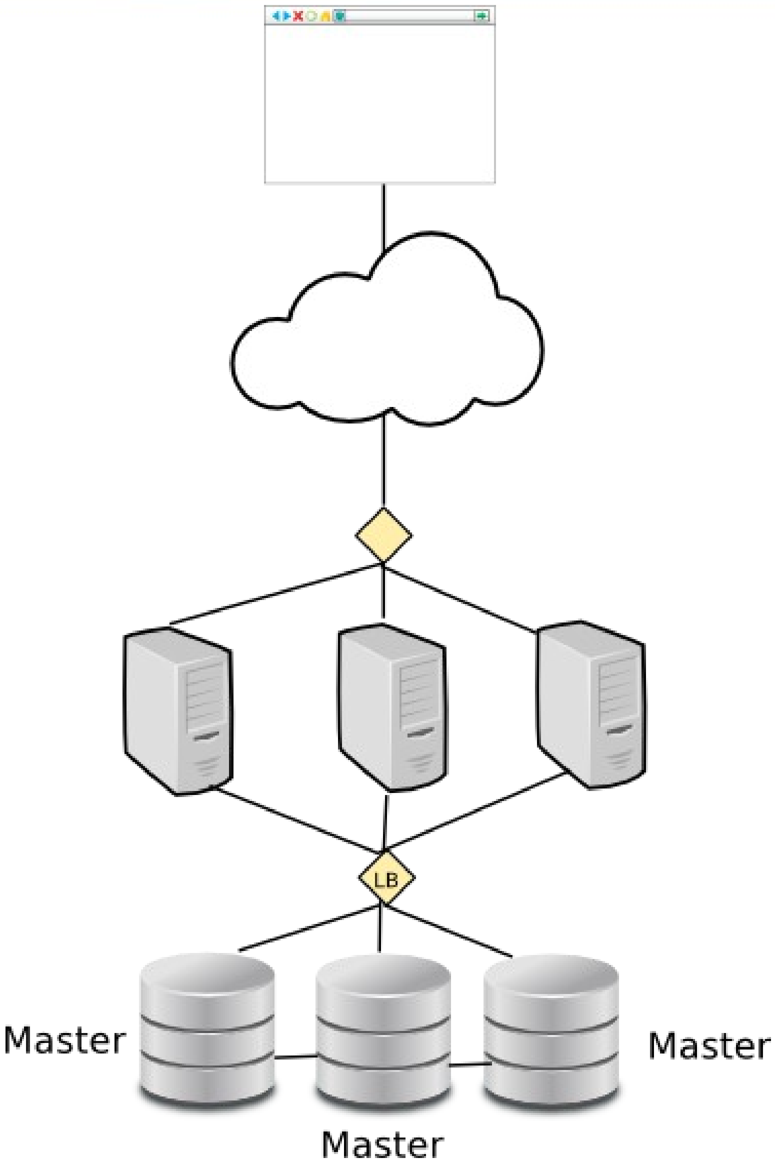
Clustering Suites:
You could use VIP based failover too, but why?

Node failure →

No "failover"

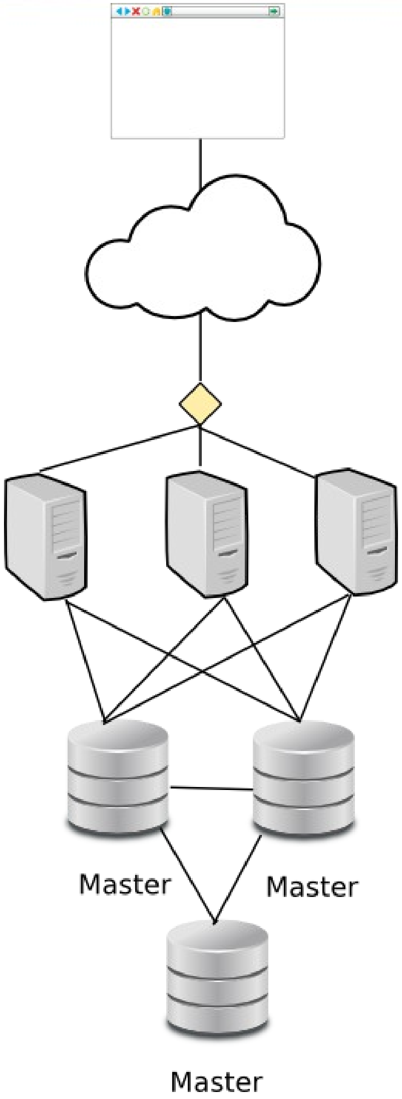


No failover needed

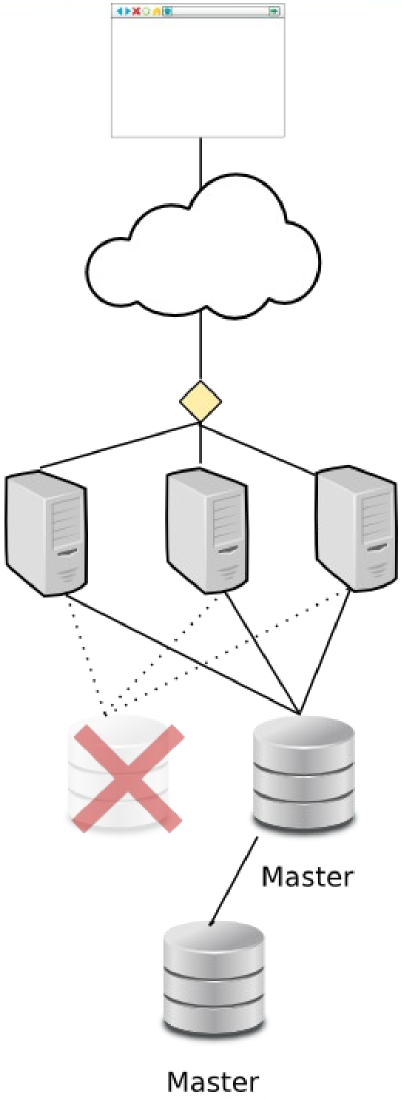


- What do you mean no failover???
  - Use a load balancer
  - Application sees just one IP
  - Write to any available node, round-robin
  - If node fails, just write to another one
  - What if load balancer fails? -> Turtles all the way down

Load Balancer in JDBC/PHP client



- No Single Point of Failure
- One less layer of network components
- Is aware of MySQL transaction states and errors
- Variant: Load balancer (like HA proxy) installed on each app node
  > For other languages than Java & PHP



Key takeaway: Is a clustering solution part of the solution or part of the problem?

- "Causes of Downtime in Production MySQL Servers" by Baron Schwartz:
  - #1: Human error
  - #2: SAN
- Complex clustering framework + SAN =
  - More problems, not less!
- Galera and NDB =
  - Replication based, no SAN or DRBD
  - No "failover moment", no false positives
  - No clustering framework needed (JDBC loadbalance)
  - Simple and elegant!

Choosing a solution that best suits you

So we pick a HA solution and are done!

	MySQL 5.0	MySQL 5.1	MySQL 5.5	MySQL 5.6	Tungsten	Galera	DRBD	SAN	NDB
InnoDB									
Usability									
Performance									
Asynchronous									
Statement based									
Row based									
Semi-sync									
Synchronous									
Global trx id									
Multi threaded									
HA Options									

?

InnoDB based?

	MySQL 5.0	MySQL 5.1	MySQL 5.5	MySQL 5.6	Tungsten	Galera	DRBD	SAN	NDB
InnoDB	+	+	+	+	+	+	+	+	

InnoDB

We use InnoDB. We want to continue using InnoDB.

Which solutions support InnoDB?

NDB is it's own storage engine.

It's great. It can blow away all others in a benchmark.

But it's not InnoDB and is not considered here.

Replication type?

	MySQL 5.0	MySQL 5.1	MySQL 5.5	MySQL 5.6	Tungsten	Galera	DRBD	SAN	NDB
InnoDB	+	+	+	+	+	+	+	+	
Usability	+	+	+	+	++	++		-	+
Performance				(1)	(1)	+	-	-	+

<------------ MySQL server level replication ----------> <- disk level-> <engine>

Higher level replication is better

Competence:
Replication = MySQL DBA can manage
DRBD = Linux sysadmin can manage
SAN = Nobody can manage

Operations:
Disk level = cold standby = long failover time
Replication = hot standby = short failover time
++ for global trx id, easy provisioning

Performance:
SAN has higher latency than local disk
DRBD has higher latency than local disk
Replication has surprisingly little overhead

Redundancy:
Shared disk = Single Point of Failure
Shared nothing = redundant = good

Statement vs Row based?
Asynchronous vs Synchronous?

	MySQL 5.0	MySQL 5.1	MySQL 5.5	MySQL 5.6	Tungsten	Galera	DRBD	SAN	NDB
InnoDB	+	+	+	+	+	+	+	+	
Usability	+	+	+	+	++	++		-	+
Performance				(1)	(1)	+	-	-	+
Asynchronous	+	+	+	+	+	(2)			
Statement based	+	+	+	+	+				+
Row based		+	+	+	+	+	(3)	(3)	
Semi-sync			+	+					
Synchronous						+	+	+	+
Global trx id				+	+	+			+
Multi threaded				(1)	(1)	+			+

Row based = deterministic = good
Statement based = dangerous

Global trx id = easier setup & failover for complex topologies

Asynchronous = data loss on failover
Synchronous = good

Multi-threaded = scalability

Clustering framework vs load balancing?

	MySQL 5.0	MySQL 5.1	MySQL 5.5	MySQL 5.6	Tungsten	Galera	DRBD	SAN	NDB
InnoDB	+	+	+	+	+	+	+	+	
Usability	+	+	+	+	+	++		-	+
Performance				(1)	(1)	+	-	-	+
Asynchronous	+	+	+	+	+	(2)			
Statement based	+	+	+	+	+				+
Row based		+	+	+	+	+	(3)	(3)	
Semi-sync			+	+					
Synchronous						+	+	+	+
Global trx id				+	+	+			+
Multi threaded				(1)	(1)	+			+
Failover suite / LB						+			+

1) Multi-threaded slave, 1 per schema
2) No, but can be combined with MySQL replication
3) Reliability comparable to row based replication

Conclusions

- Simpler is better
- MySQL level replication is better than DRBD which is better than SAN
- Synchronous replication = no data loss
- Asynchronous replication = no latency (WAN replication)
- Synchronous Multi-Master = no failover = no clustering frameworks
- Multi-threaded slave increases performance in disk bound workload
- Global trx id, autoprovisioning increases operations usability
- Galera (and NDB) provides all these with good performance and stability

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