PA152: Efficient Use of DB

# 12. Replication and High Availability

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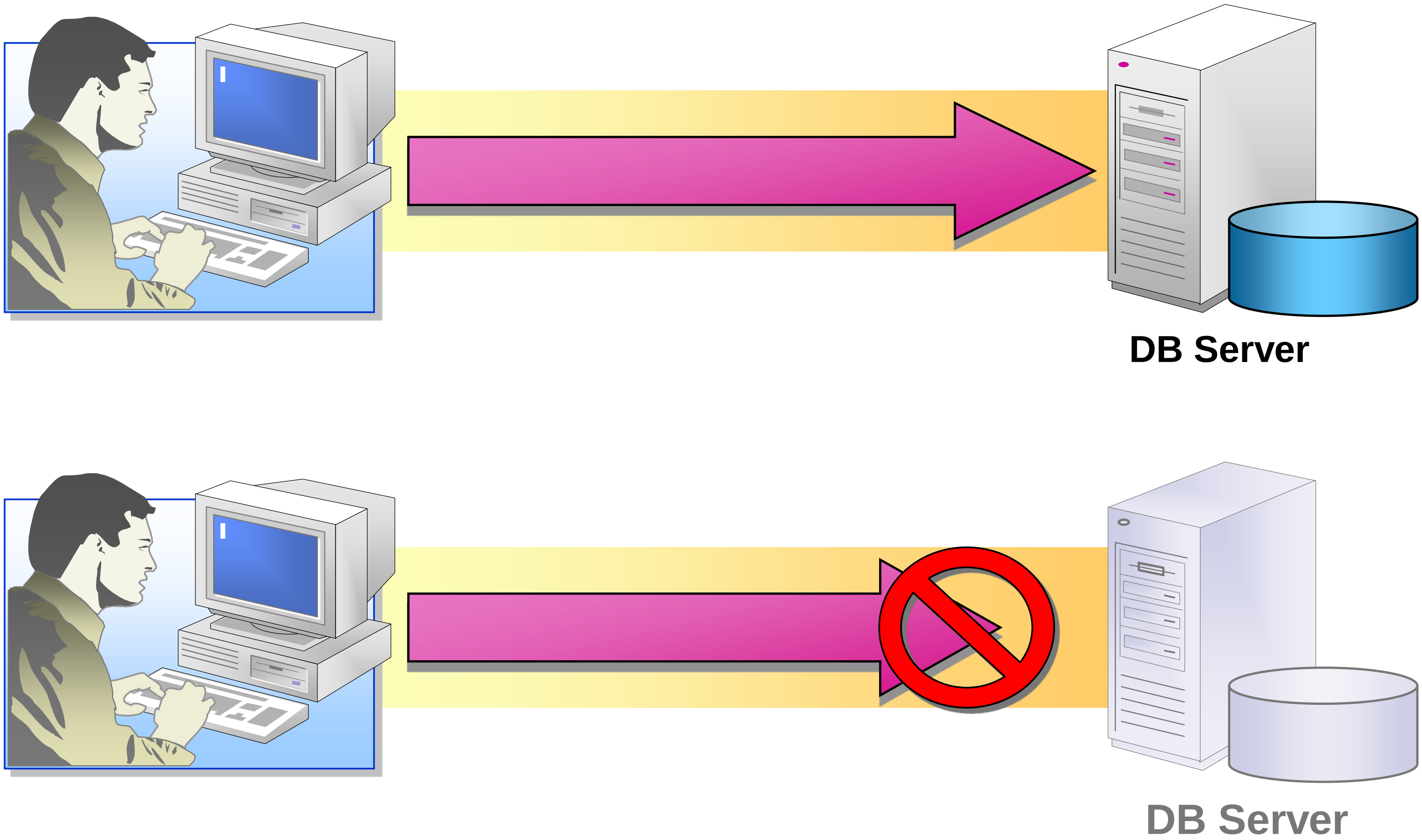
# Credits

- This presentation is based on:
  - Microsoft MSDN library
  - Course *NoSQL databases and Big Data management*
    - Irena Holubová
    - Charles University, Prague
    - http://www.ksi.mff.cuni.cz/~holubova/NDBI040/
  - PostgreSQL documentation
    - http://www.postgresql.org/docs/9.3/static/high-availability.html

# Contents

- Availability
- Data distribution & Replication
- High availability
- Failover
- Recommendations

# Availability




Source: Microsoft

# Determining Availability Requirements

- Hours of Operation
  - Business hours vs. all of the time
    - intranet service vs. web services
    - shift workers vs. all-around the world customers
- Connectivity Requirements
  - Online vs. offline applications
- Tight/Loose coupling of app and DBMS
  - Synchronous vs. asynchronous data updates

# Availability

- Definition in operation hours
  - Av = “up time” / “total time” = MTTF / (MTTF+MTTR)
    - “up time” = the system is up and operating
  - More practical def.
    - Av = (total time - down time) / total time
- Down time
  - Scheduled – reboot, SW/HW upgrade, …
  - Unscheduled – HW/SW failure, security breaches, network unavailability, power outage, disasters, …
- For “true” high-availability, down time is not distinguished

# Nines

- Availability as percentage of uptime
  - Class of nines: $c = \lfloor -\log_{10}(1 - Av) \rfloor$

- Assuming 24/7 operation:

| Nine class | Availability | Downtime per year | Downtime per month | Downtime per week |
|---|---|---|---|---|
| 1 | 90% | 36.5 days | 72 hours | 16.8 hours |
| 2 | 99% | 3.65 days | 7.20 hours | 1.68 hours |
| 3 | 99.9% | 8.76 hours | 43.8 minutes | 10.1 minutes |
| 4 | 99.99% | 52.56 minutes | 4.32 minutes | 1.01 minutes |
| 5 | 99.999% | 5.26 minutes | 25.9 seconds | 6.05 seconds |
| 6 | 99.9999% | 31.5 seconds | 2.59 seconds | 0.605 seconds |
| 7 | 99.99999% | 3.15 seconds | 0.259 seconds | 0.0605 seconds |

Source: Wikipedia.org

# Scalability

- Providing access to a number of concurrent users
- Handling growing amounts of data without losing performance
- With acceptable latency!

# Need for Distributing Data

- Brings data closer to its user
- Allows site independence
- Separates
  - Online transaction processing
  - Read-intensive applications
- Can reduce conflicts during user requests
- Process big data

# Scalability: Solutions

- Scaling Up – vertical scaling → vendor dependence
  - Increasing RAM
  - Multiprocessing
- Scaling Out – horizontal scaling
  - Replication
  - Read-only standby servers
  - Server federations / clusters / data distribution

# Horizontal Scaling

- Systems are distributed across multiple machines or nodes
  - Commodity machines → cost effective
  - Often surpasses scalability of vertical approach
- Fallacies of distributed computing by Peter Deutsch
  - Network
    - Is reliable, secure, homogeneous
    - Topology does not change
    - Latency and transport cost is zero
    - Bandwidth is infinite
  - One administrator

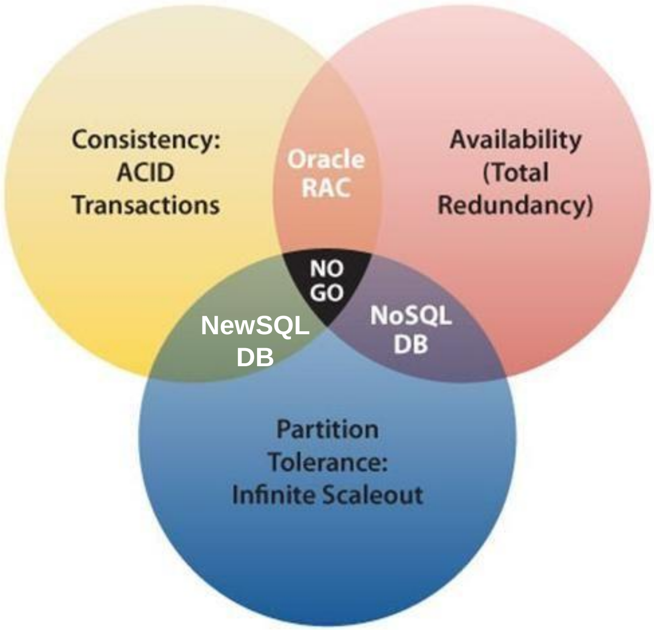
Source: https://blogs.oracle.com/jag/resource/Fallacies.html

# Brewer's CAP Theorem

- Consistency
  - After an update, all readers in a distributed system see the same data
  - All nodes are supposed to contain the same data at all times
  - E.g. in multiple instances, all writes must be duplicated before write operation is completed.
- Availability
  - Every request receives a response
    - about whether it was successful or failed
- Partition Tolerance
  - System continues to operate despite arbitrary message loss or failure of part of the system.

# Brewer's CAP Theorem

- Only 2 of 3 guarantees can be given in a "shared-data" system.
  - Proved by Nancy Lynch in 2002
- ACID
  - provides Availability and Consistency
  - E.g. database on a single machine
- BASE
  - provides Availability and Partition tolerance
  - Reality: you can trade a little consistency for some availability
  - E.g. distributed database




Source: http://bigdatanerd.wordpress.com

# NewSQL

- Distributed database system that scales out
- CP system
  - trades availability for consistency when partition happens
- MySQL cluster, Google Spanner, VoltDB, …
  - In fact, master-master replication with data sharding

# BASE Properties

- Basically Available
  - Partial failures can occur, but without total system failure
- Soft state
  - System is in flux / non-deterministic
    - Changes occur all the time
- Eventual consistency (replica convergence)
  - is a liveness guarantee
    - reads eventually return the same value
  - is not safety guarantee
    - can return any value before it converges

# Consistency

- Strong (ACID) vs. Eventual (BASE) consistency
- Example:

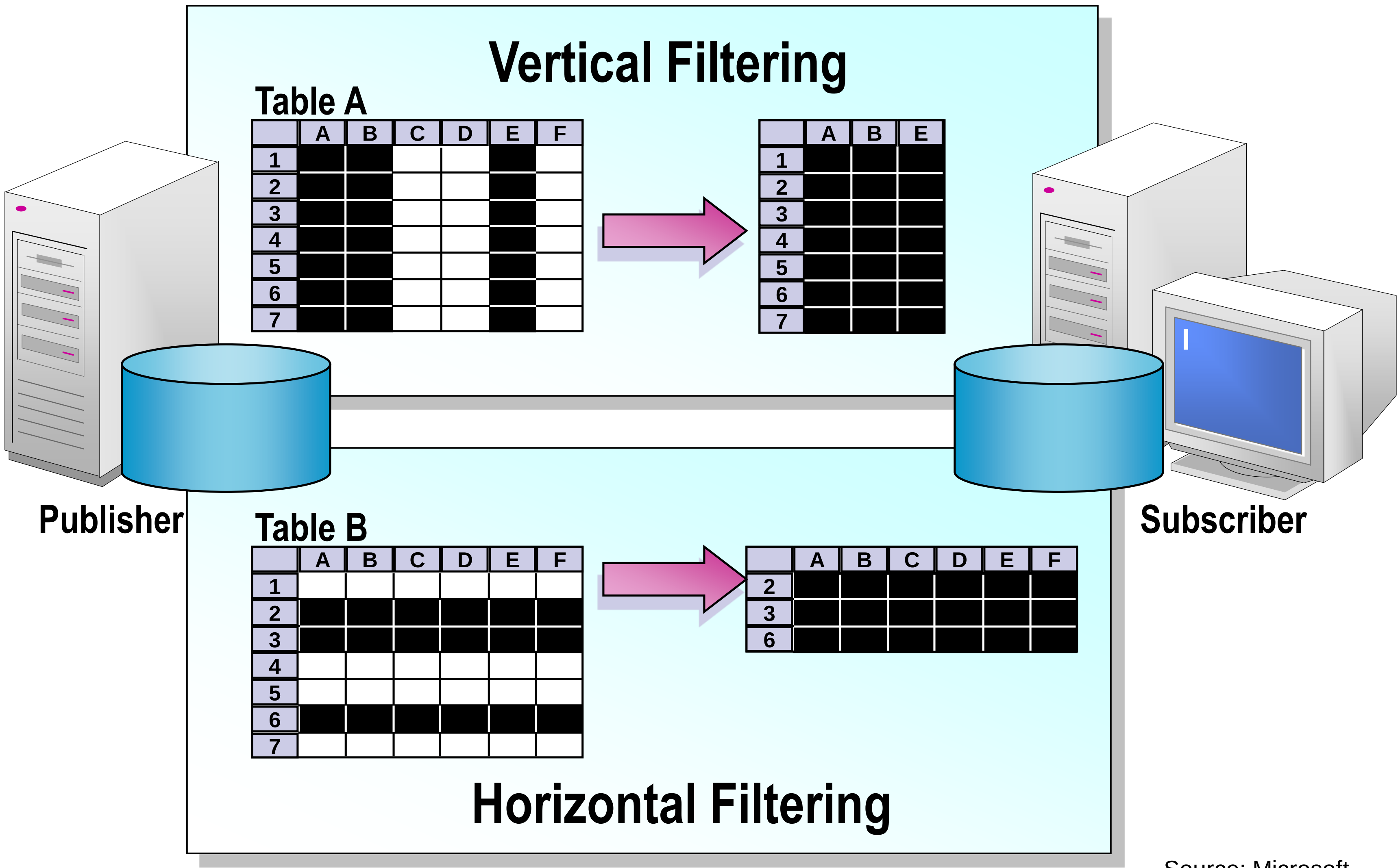
time →

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Eventual | Server A: | read(A)=1 | | write(A,2) | | read(A)=2 | |
| | Server B: | read(A)= 1 | | | read(A)=1 | | read(A)=2 |
| | Server C: | | read(A)= 1 | | read(A)=2 | | |
| | | | | Inconsistent state | | | |
| Strong | Server A: | read(A)=1 | | write(A,2) | | read(A)=2 | |
| | Server B: | read(A)= 1 | | | read(A)=2 | | read(A)=2 |
| | Server C: | | read(A)= 1 | | read(A)=2 | | |

# Replication / Distribution Model

- Model of distributing data
  - Replication
    - The same data stored in more nodes.
  - Filtering data (sharding)
    - The data is partitioned and stored separately
    - Helps avoid replication conflicts when multiple sites are allowed to update data.

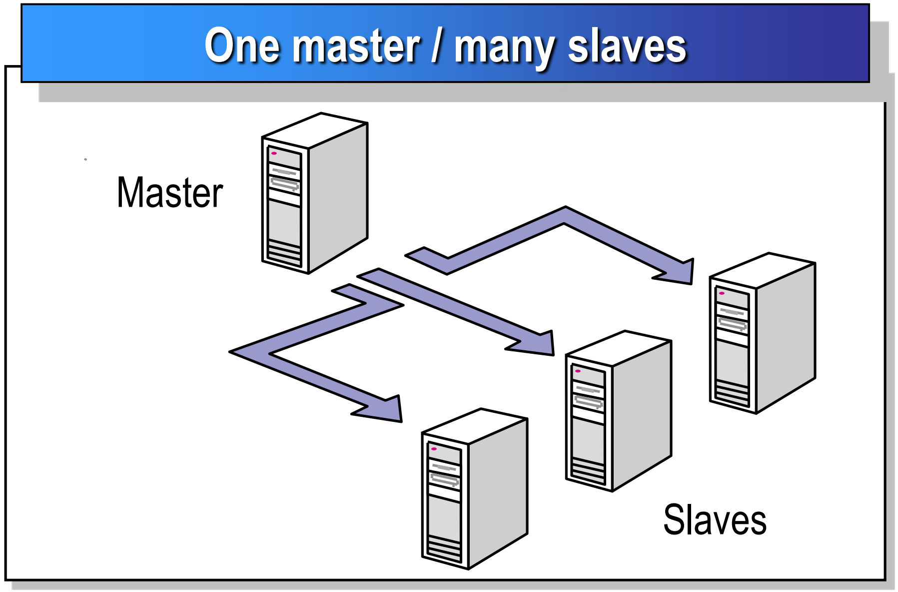
# Filtering Data




Source: Microsoft

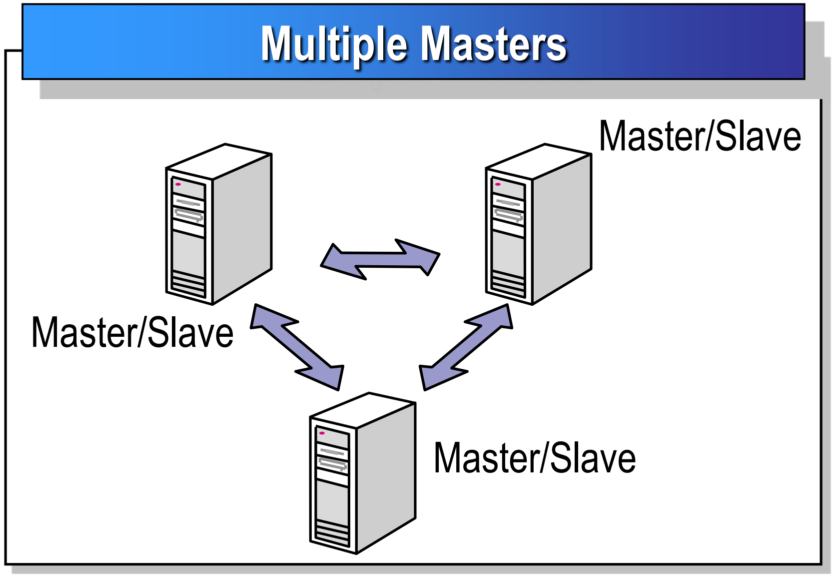
# Distribution Model: Replication

- Master-slave model
  - Load-balancing of read-intensive queries
- Master node
  - manages data
  - distributes changes to slaves
- Slave node
  - stores data
  - queries data
  - no modifications to data



# Distribution Model: Replication

- Master-master model
  - Typically with filtering data
    - Master for a subset of data
    - Slave for the rest
  - Consistency needs resolving of update conflicts



# Master-master Model

**Orders (Master A)**

| Primary Key | | | |
|---|---|---|---|
| *Area* | *Id* | *Order_no* | *Qty* |
| 1 | 1000 | ~ | 15 |
| 1 | 3100 | ~ | 22 |
| 2 | 1000 | ~ | 32 |
| 2 | 2380 | ~ | 8 |
| 3 | 1000 | ~ | 7 |
| 3 | 1070 | ~ | 19 |

Master/Slave

Master/Slave

**Orders (Master B)**

| Primary Key | | | |
|---|---|---|---|
| *Area* | *Id* | *Order_no* | *Qty* |
| 1 | 1000 | ~ | 15 |
| 1 | 3100 | ~ | 22 |
| 2 | 1000 | ~ | 32 |
| 2 | 2380 | ~ | 8 |
| 3 | 1000 | ~ | 7 |
| 3 | 1070 | ~ | 19 |

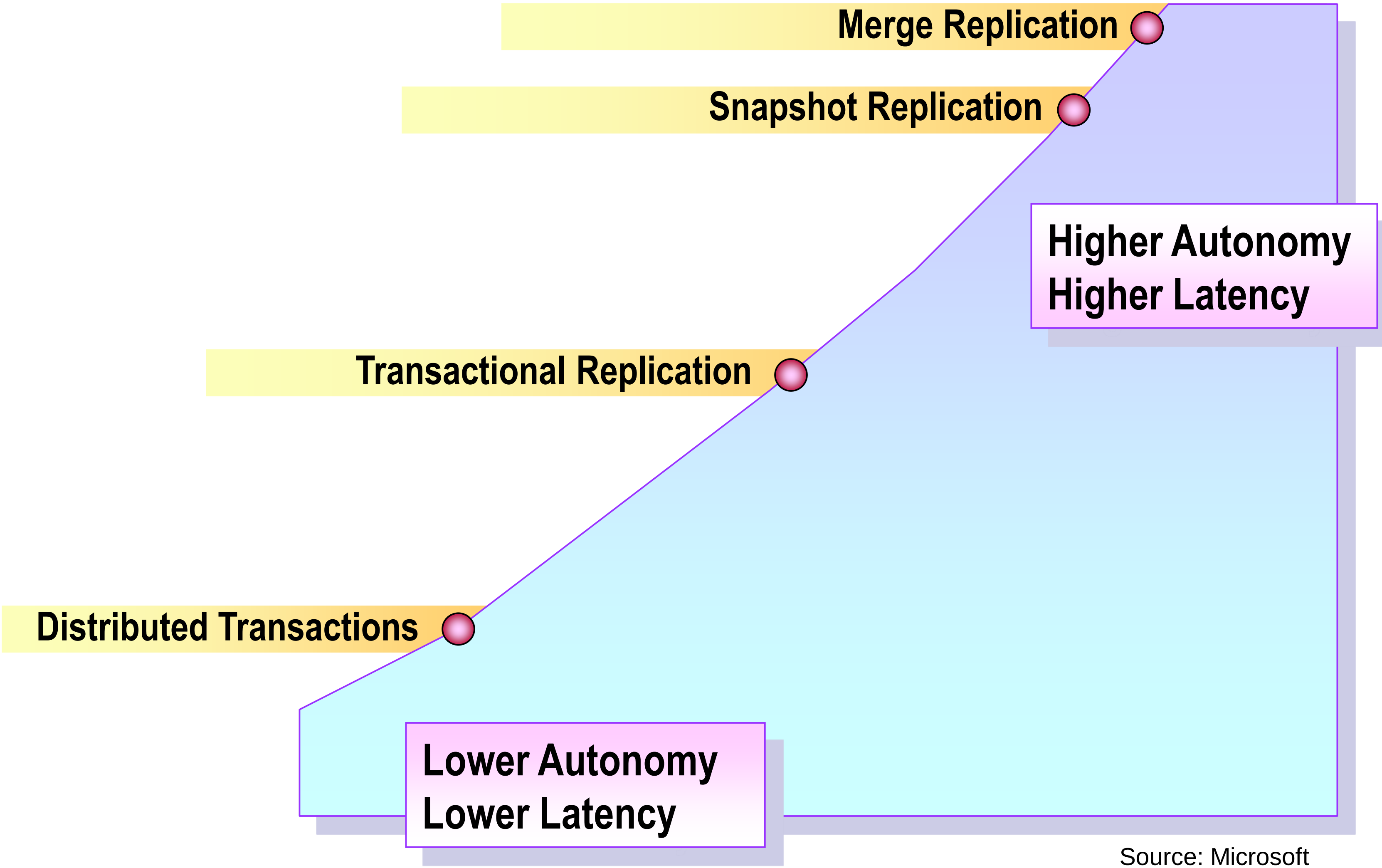
Master/Slave

**Orders (Master C)**

| Primary Key | | | |
|---|---|---|---|
| *Area* | *Id* | *Order_no* | *Qty* |
| 1 | 1000 | ~ | 15 |
| 1 | 3100 | ~ | 22 |
| 2 | 1000 | ~ | 32 |
| 2 | 2380 | ~ | 8 |
| 3 | 1000 | ~ | 7 |
| 3 | 1070 | ~ | 19 |

Source: Microsoft

# Replication Types




Source: Microsoft

# Replication Types

- Distributed Transactions
  - For “real” master-master model, ensures consistency
  - Low latency, high consistency
- Transactional Replication
  - Replication of incremental changes
  - Minimal latency

# Replication Types

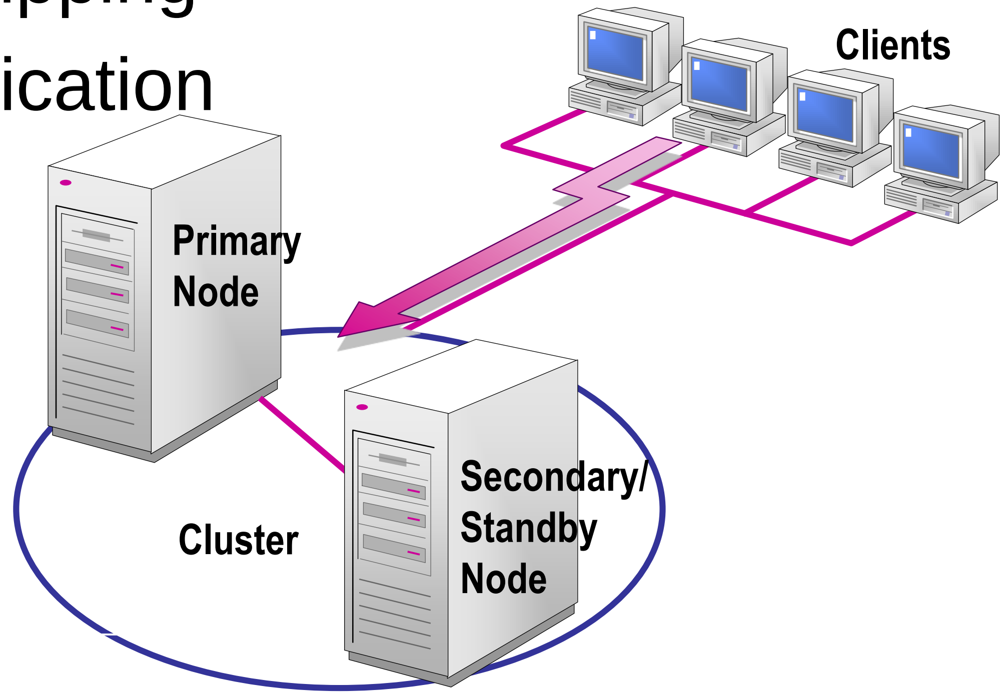
- Snapshot Replication
  - Periodic bulk transfer of new snapshots of data
  - Data changes – substantial but infrequent
  - Slaves are read-only
  - High latency is acceptable

# Replication Types

- Merge Replication
  - Autonomous changes to replicated data are later merged
  - Does not guarantee transactional consistency, but converges
  - Default and custom conflict resolution rules
  - Adv: Nodes can update data offline, sync later
  - Disadv: Changes to schema needed.

# Maintaining High-Availability

- Standby server
  - Shared disk failover (NAS)
  - File system replication (DRBD)
  - Transaction log shipping
  - Trigger-based replication
  - Statement-Based Replication Middleware



# Log-shipping Standby Server

- Also called warm standby
- Primary node
  - serves all queries
  - in permanent archiving mode
    - Continuous sending of WAL records to standby servers
- Standby server
  - serves no queries
  - in permanent recovery mode
    - Continuous processing of WAL records arriving from primary node
- Log shipping can be synchronous/asynchronous
- Disadvantage: all tables are replicated typically
- Advantage: no schema changes, no trigger definitions

# Failover

- If primary fails, standby server begins failover.
  - Standby applies all WAL records pending,
  - marks itself as primary,
  - starts to serve all queries.
- If standby fails, no action taken.
  - After becoming online, catch-up procedure is started.
- Heartbeat mechanism
  - to continually verify the connectivity between the two and the viability of the primary server

# Failover

- Failover by standby succeeded
  - New standby should be configured

  - Original primary node becomes available
  - → inform it that it is no longer the primary
    - do so-called STONITH (Shoot The Other Node In The Head),
    - otherwise serious data corruption/loss may occur

  - Typically old primary becomes new standby

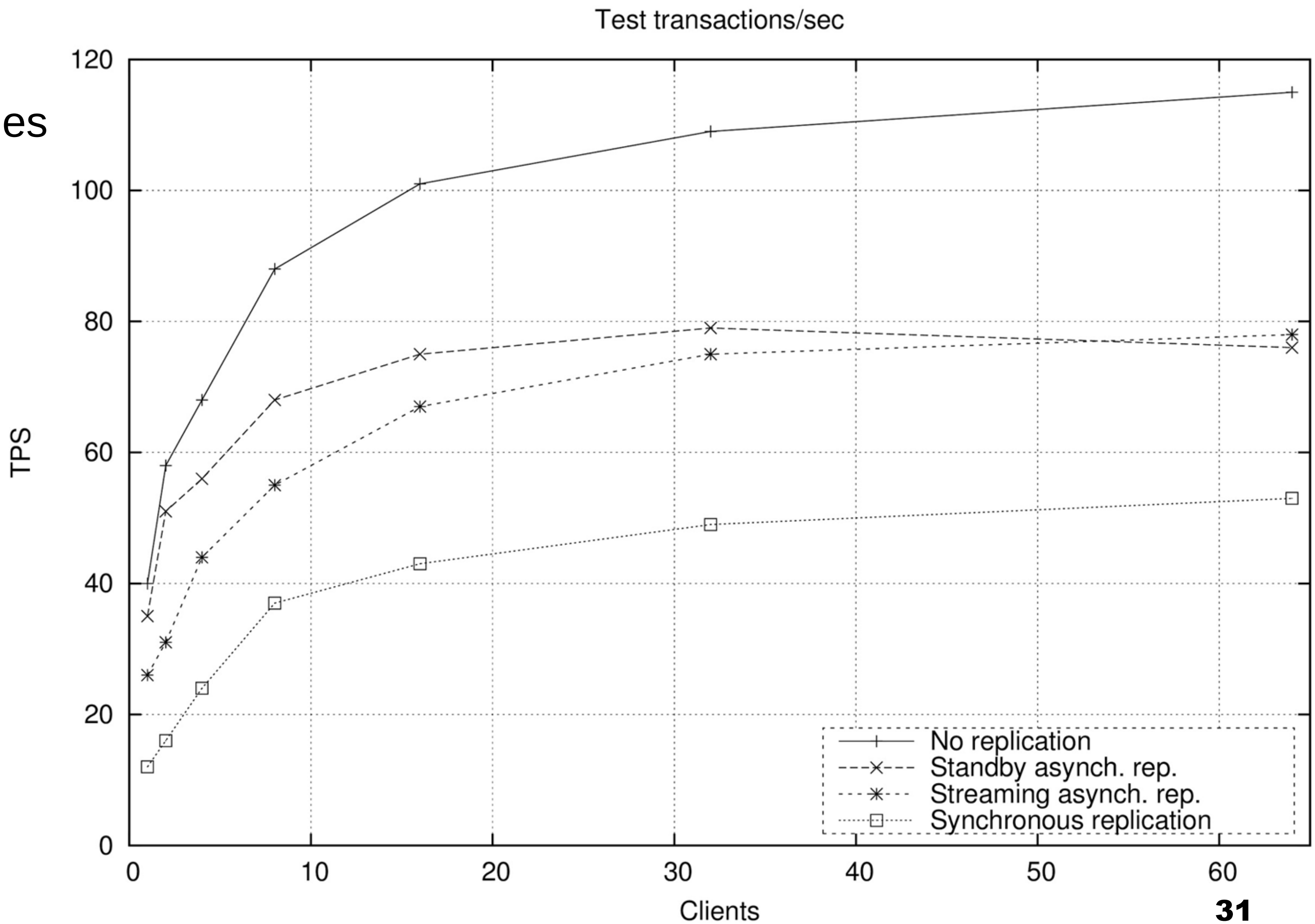
# Primary and Standby Servers

- Swap primary and standby regularly
  - To verify recovery steps
  - To do necessary maintenance on standby server
    - SW/HW upgrades, …

# PostgreSQL: Replication

- TPC Benchmark B

scale factor 1
1 trans. = 5 queries



# Recommended Practices

- Maximize availability at each tier of the application
- Keep standby servers on a different subnet
- Different power supply to the primary server
- Test whether your availability solution works