SQL Azure: Database-as-a-Service
What, how and why Cloud is different

Nigel Ellis <nigele@microsoft.com>

July 2010

Talk Outline

- Database-as-a-Service
- SQL Azure
  - Overview
  - Deployment and Monitoring
  - High availability
  - Scalability
- Lessons and insight

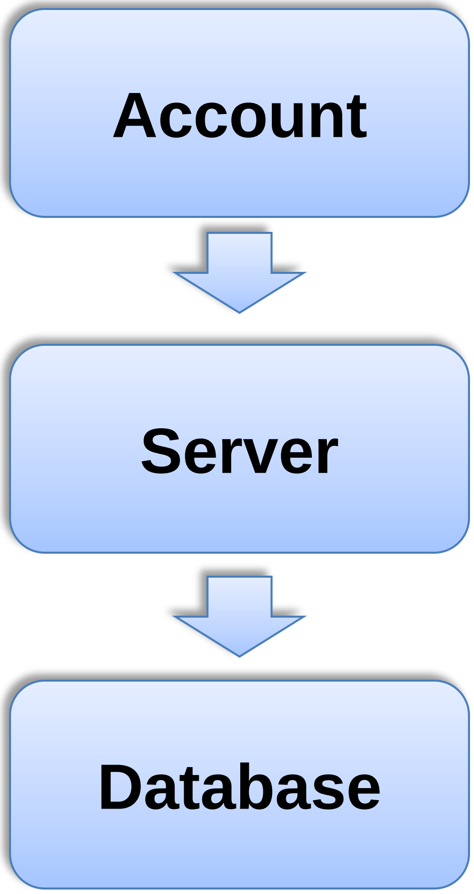
SQL Azure Database as a Service

- On-demand provisioning of SQL databases
- Familiar relational programming model
  - Leverage existing skills and tools
- SLA for availability and performance
- Pay-as-you-go pricing model
- Full control over logical database administration
  - No physical database administration headaches
- Large geo-presence
  - 3 regions (US, Europe, Asia), each with 2 sub-regions

Challenges And Our Approach

- Challenges
  - Scale – storage, processing, and delivery
  - Consistency – transactions, replication, failures, HA
  - Manageability – deployment and self-management
- Our approach
  - SQL Server technology as node storage
  - Distributed fabric for self-healing and scale
  - Automated deployment and provisioning (low OpEx)
  - Commodity hardware for reduced CapEx
  - Software to achieve required reliability

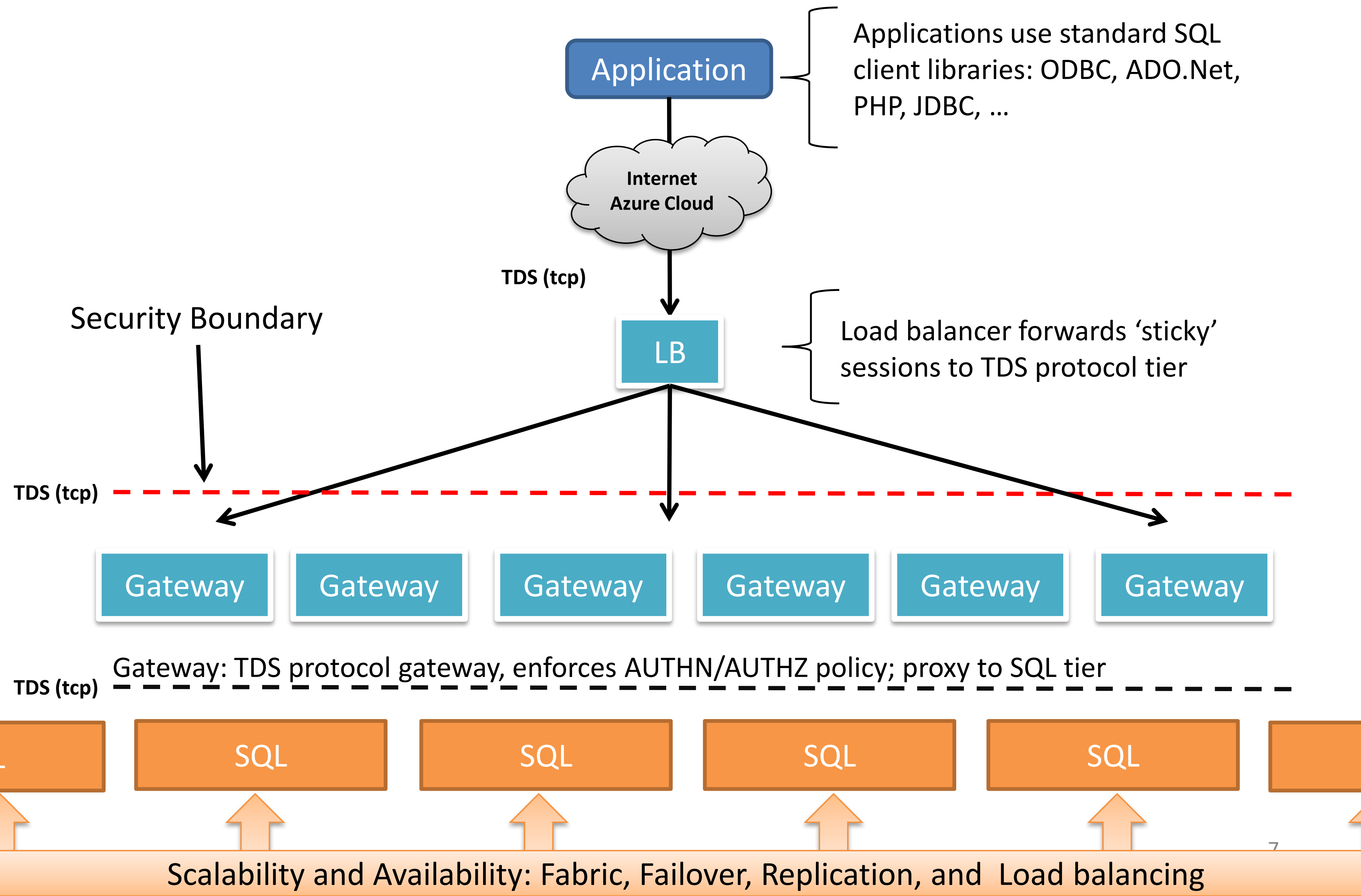
SQL Azure model



- Each **account** has zero or more **servers**
  - Azure wide, provisioned in a common portal
  - Billing instrument
- Each **server** has one or more **databases**
  - Zone for authentication: userId+password
  - Zone for administration and billing
    - Metadata about the databases and usage
  - Network access control based on client IP
  - Has unique DNS name and unit of geo-location
- Each **database** has standard SQL objects
  - Unit of consistency and high availability (autonomous replication)
  - Contains Users, Tables, Views, Indices, etc…
  - Most granular unit of usage reports
  - Three SKUs available (1GB, 10GB and 50GB)

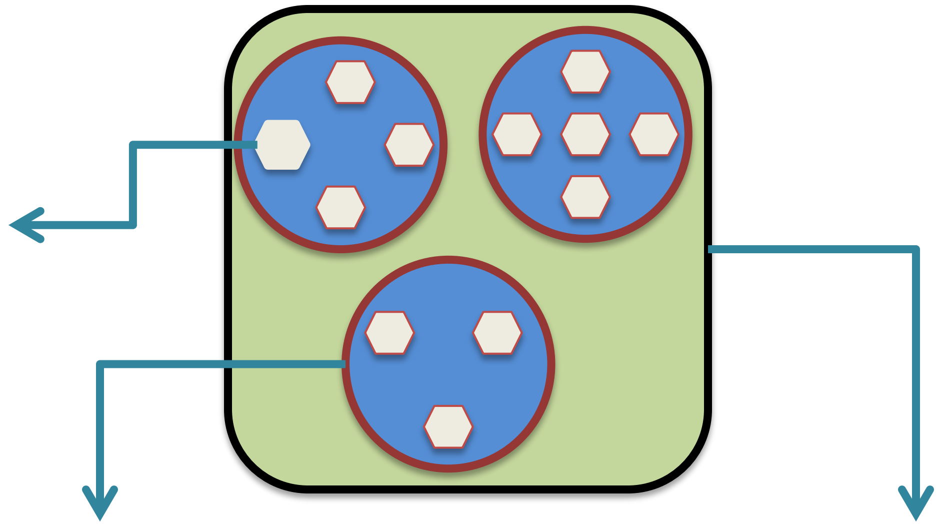
ARCHITECTURE

Network Topology



HIGH AVAILABILITY

Concepts



Storage Unit
- Supports CRUD operations

e.g. DB row

Consistency Unit (aka Rowgroup)
- Set of storage units
- Specified by “application”
- Range partitioned or entire DB
- SQL Azure uses entire DB only
  - Infra supports both

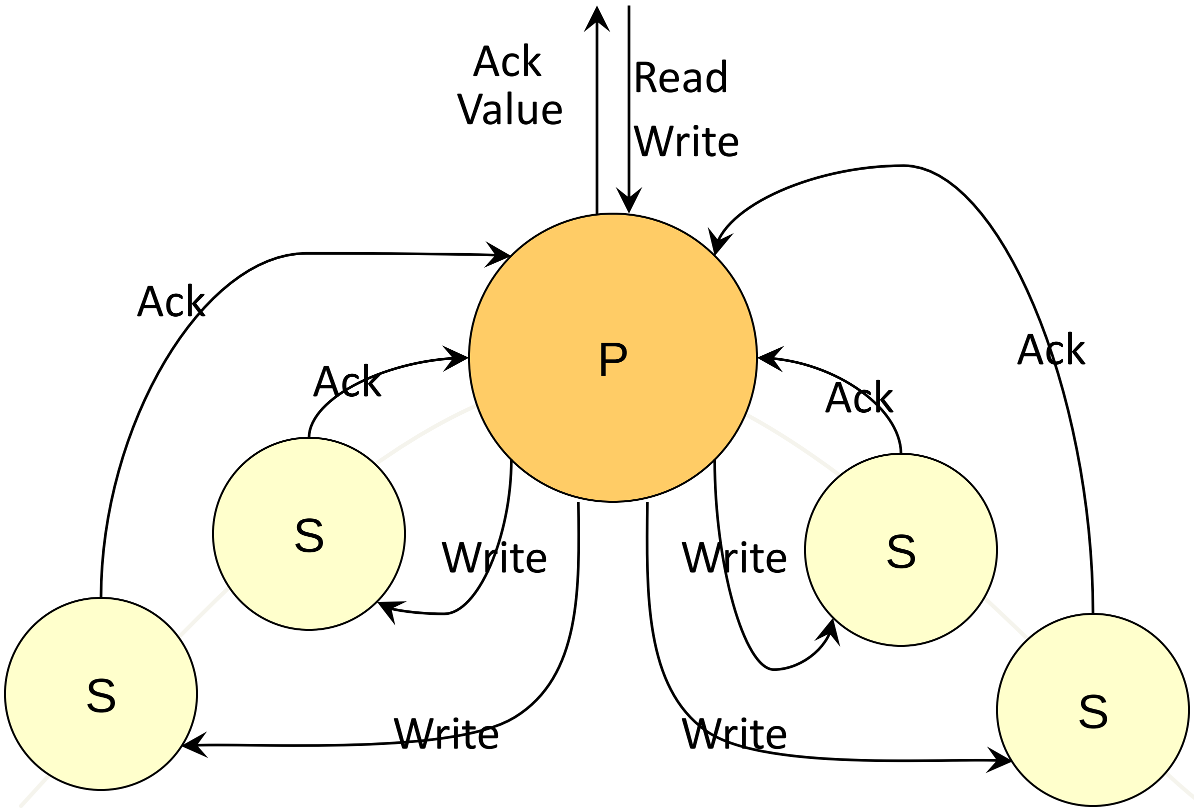
Failover Unit (aka Partition)
- Unit of management
- Group of consistency units
- Determined by the system
- Can be split or merged at consistency unit boundaries

Data Consistency

- Each Failover Unit is replicated for HA
  - Desired replica count is configurable and actual count is dynamic at runtime
- Clients must see the same linearized order of read and write operations
- Replica set is dynamically reconfigured to account for member arrivals and departures
  - Read-Write quorums are supported and are dynamically adjusted

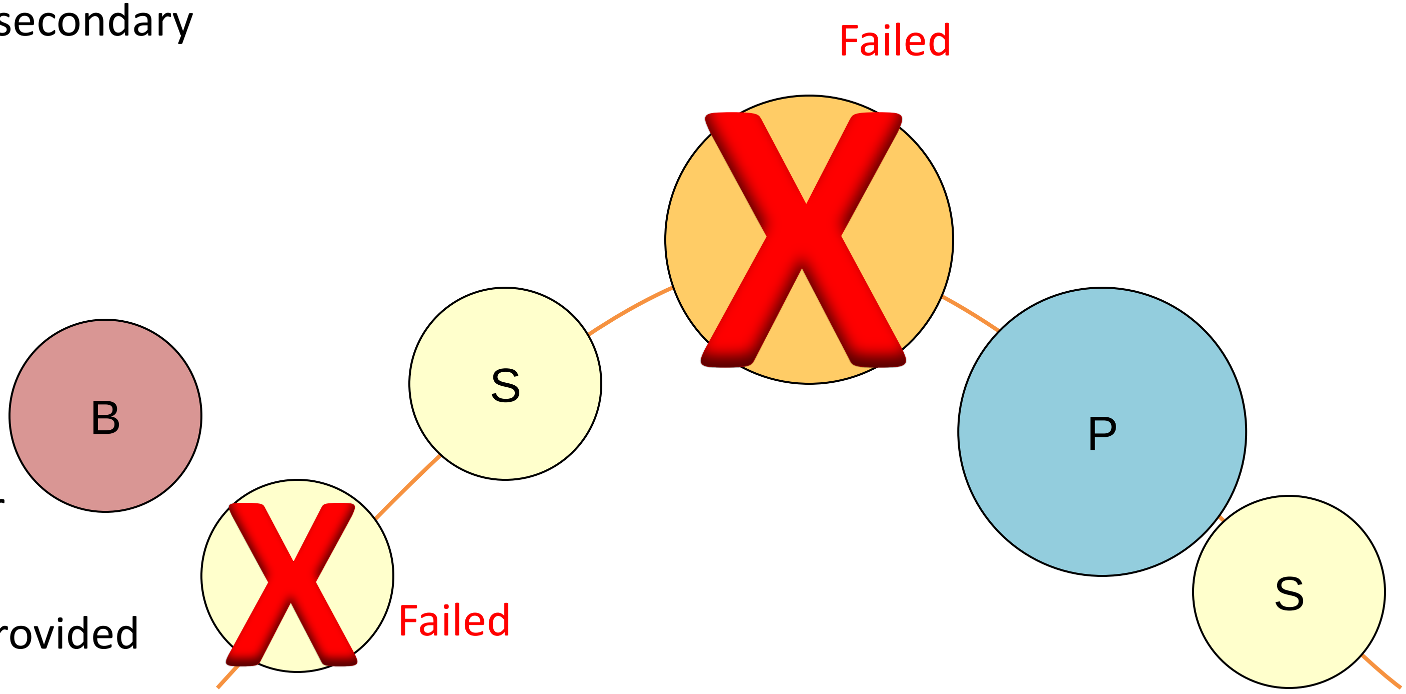
Replication

- All reads are completed at the primary
- Writes replicated to write quorum of replicas
- Commit on secondaries first then primary
- Each transaction has a commit sequence number (epoch, num)



Reconfiguration

- Types of reconfiguration
  - Primary failover
  - Removing a failed secondary
  - Adding recovered replica
  - Building a new secondary



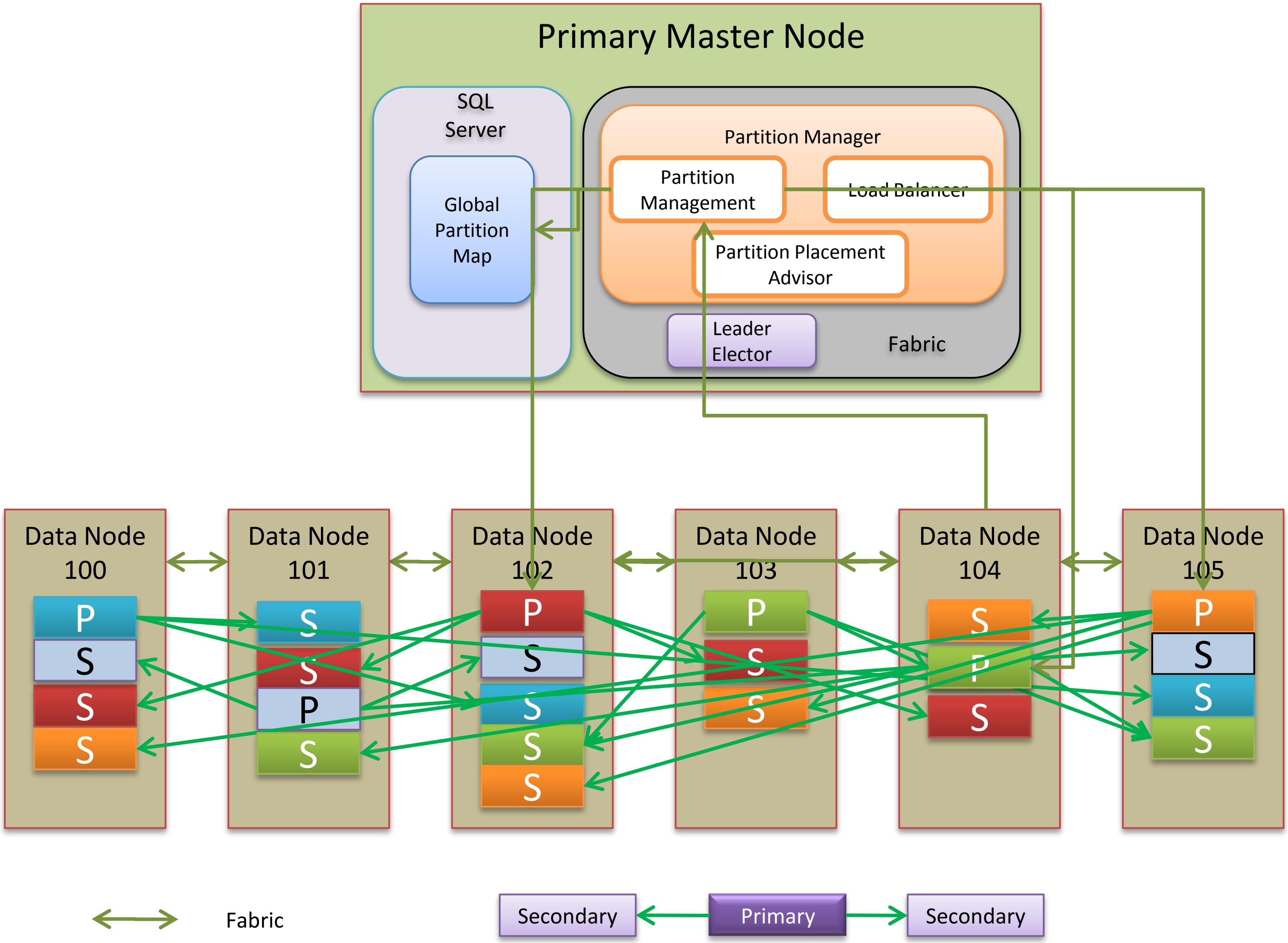
- Assumes
  - Failure detector
  - Leader election
  - Both services provided by Fabric layer

Safe in the presence of cascading failures

Partition Management

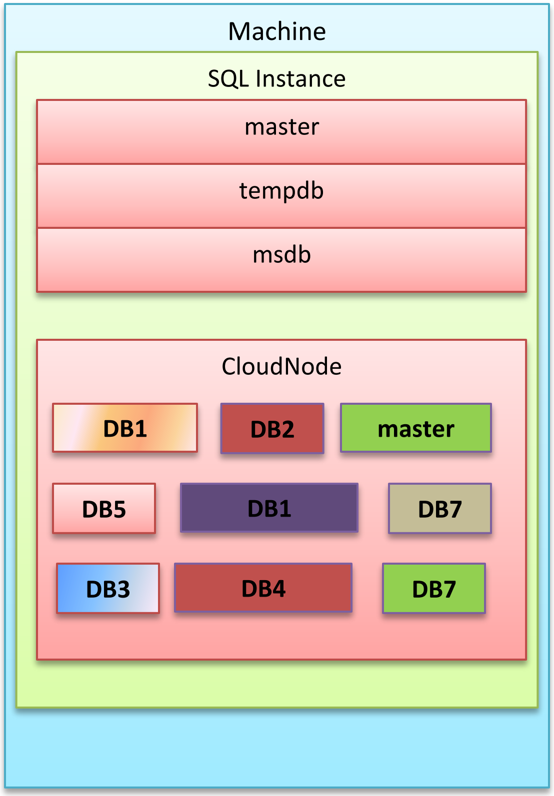
- Partition Manager (PM) is a highly available service running in the Master cluster
  - Ensures all partitions are operational
  - Places replicas across failure domains (rack/switch/server)
  - Ensures all partitions have target replica count
  - Balances the load across all the nodes
- Each node manages multiple partitions
- Global state maintained by the PM can be recreated from the local node state in event of disaster (GPM rebuild)

System in Operation



SQL node Architecture

- Single physical DB for entire node
- DB files and log shared across every logical database/partition
  - Allows better logging throughput with sequential IO/group commits
  - No auto-growth on demand stalls
  - Uniform manageability and backup
- Each partition is a "silo" with its own independent schema
- Local SQL backup guards against software bugs

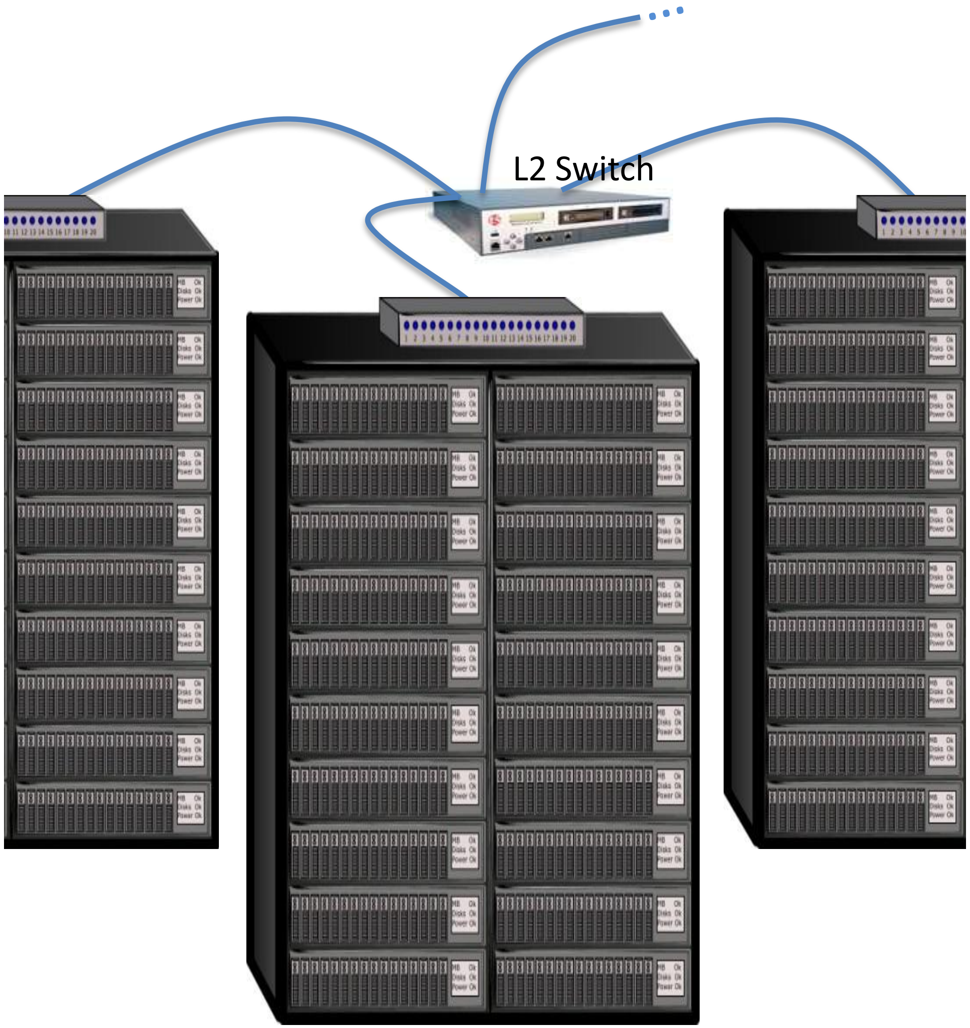


Recap

- Two kinds of nodes:
  - Data nodes store application data
  - Master nodes store cluster metadata
- Node failures are reliably detected
  - On every node, SQL and Fabric processes monitor each other
  - Fabric processes monitor each other across nodes
- Local failures cause nodes to fail-fast
- Failures cause reconfiguration and placement changes

DEPLOYMENT

Hardware Architecture



- Each rack hosts 2 pods of 20 machines each
- Each pod has a TOR mini-switch
  - 10GB uplink to L2 switch
- Each SQL Azure machine runs on commodity box
- Example:
  - 8 cores
  - 32 GB RAM
  - 1TB+ SATA drives
  - Programmable power
  - 1Gb NIC
- Machine spec changes as hardware (pricing) evolves

Hardware Challenges

- SATA drives
  - On-disk cache and lack of true "write through" results in Write Ahead Logging violations
    - DB requires in-order writes to be honored
    - Can force flush cache, but causes performance degradation
  - Disk failures happen daily (at scale), fail-fast on those
    - Bit-flips (enabled page checksums)
    - Drives just disappear
    - IOs are misdirected
- Faulty NIC
  - Encountered message corruption
    - Enabled message signing and checksums

Software Deployment

- OS is automatically imaged via deployment
- All the services are setup using file copy
  - Guarantees on which version is running
  - Provides fast switch to new version
  - Minimal global state allows running side by side
  - Yes, that includes the SQL Server DB engine
- Rollout is monitored to ensure high availability
  - Knowledge of replica state health ensure SLA is met
  - Two phase rollouts for data or protocol changes
- Leverages internal Autopilot technologies with SQL Azure extensions

Software Challenges

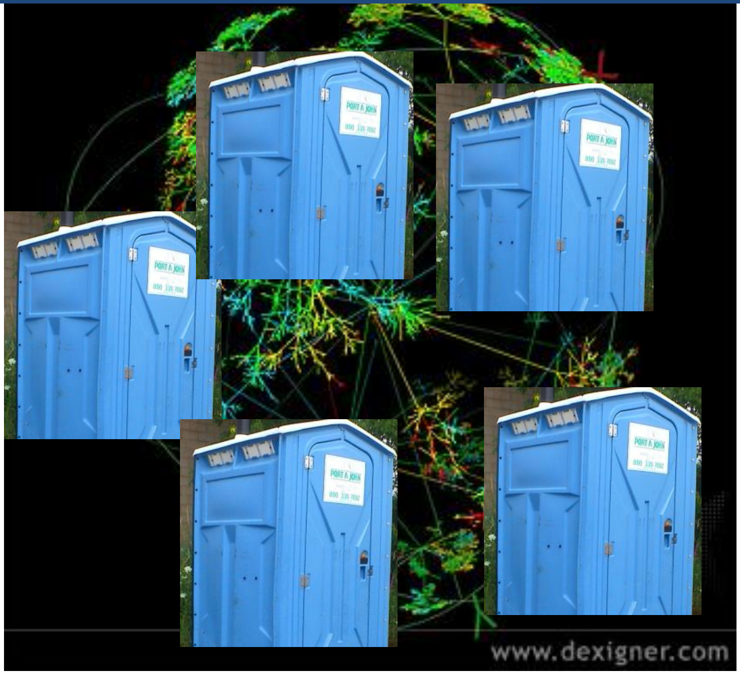
- Lack of real-time OS features
  - CPU priority
    - High priority for Fabric lease traffic
  - Page Faults/GC
    - Locked pages for SQL and Fabric (in managed code)
- Fail fast or not?
  - Yes, for corruption/AV
  - No, for other issues **unless** centrally controlled
- What is really considered failed?
  - Some failures are non-deterministic or hangs
  - Multiple protocols / channels means partial failures too

Monitoring

- Health model w/repair actions
  - Reboot → Re-deploy → Re-image (OS) → RMA cycle
- Additional monitoring for SQL tier
  - Connect / network probes
  - Memory leaks / hung worker processes
  - Database corruption detection
  - Trace and performance stats capture
    - Sourced from regular SQL trace and support mechanisms
    - Stored locally and pushed to a global cluster wide store
    - Global cluster used for service insight and problem tracking

LESSONS LEARNED

How is Cloud Different?



Minor differences:

- Cheap hardware
  - No SANs, no SCSI, no Infiniband
  - Iffy routers, network cards
  - Relatively homogeneous
  - *Hardware not selected for the purpose*
- Lots of it
  - Not one machine, not 10 machines – think 1000+
- Public internet
  - High latencies, sometimes
  - All over the world
  - Scary people (untrusted) lurking in the shadows

How is Cloud Different?

Real differences:

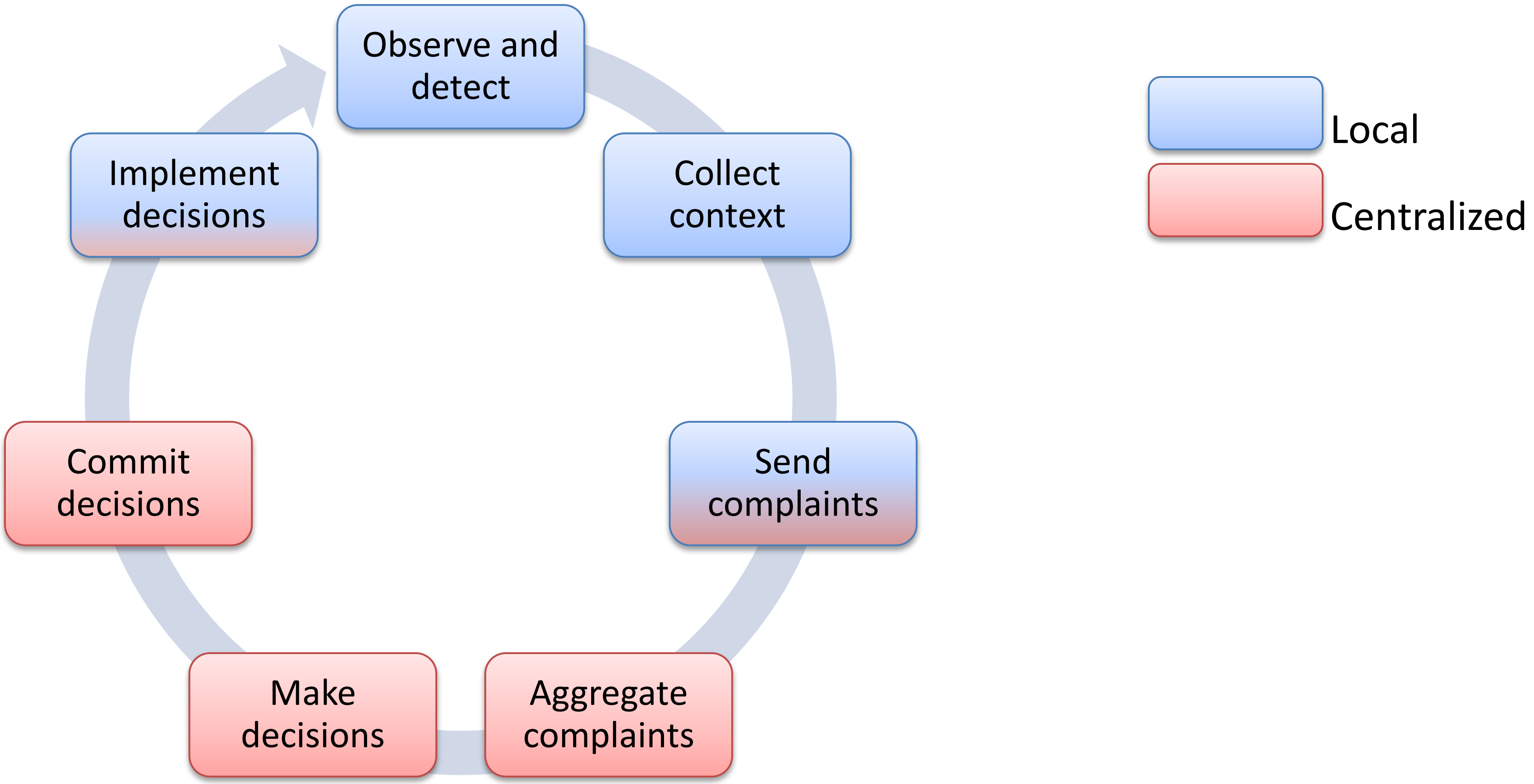
- You are responsible for the whole thing
  - No such thing as “can you send us a repro”
  - No such thing as “it’s a hardware problem” (it’s us)
  - No such thing as “it’s a network issue” (it’s us)
  - No such thing as “it’s a configuration issue” (it’s us)
  - No such thing as “It’s not us, it’s DNS” (it’s us)
  - No such thing as “It’s not us, it’s AD” (it’s us)
- User expectations: it’s a utility!
  - Utility of databases, not instances or servers
  - Highly available (means “it’s there” not “replication has been enabled”)
  - Elastic (you need more, you can have it right away)
  - Load-balanced (automatically)
  - And yet: symmetric (“give me cursors or give me death”)

Design for Failure

- Common mistake #1: Failures can be eliminated
  - Everybody fails! Hardware, software, universe

- Common mistake #2: All failures can be detected
  - No watchdog is fast enough or good enough
- Common mistake #3: Failures can be enumerated
  - Cannot deal with issues one at a time
  - Must take a holistic, statistical approach
  - Learn only as much as you need to take action
- Common mistake #4: Failures can be dealt with independently
  - Local observation generates insufficient insight, leads to global disasters

Design for Failure



Design for Mediocre

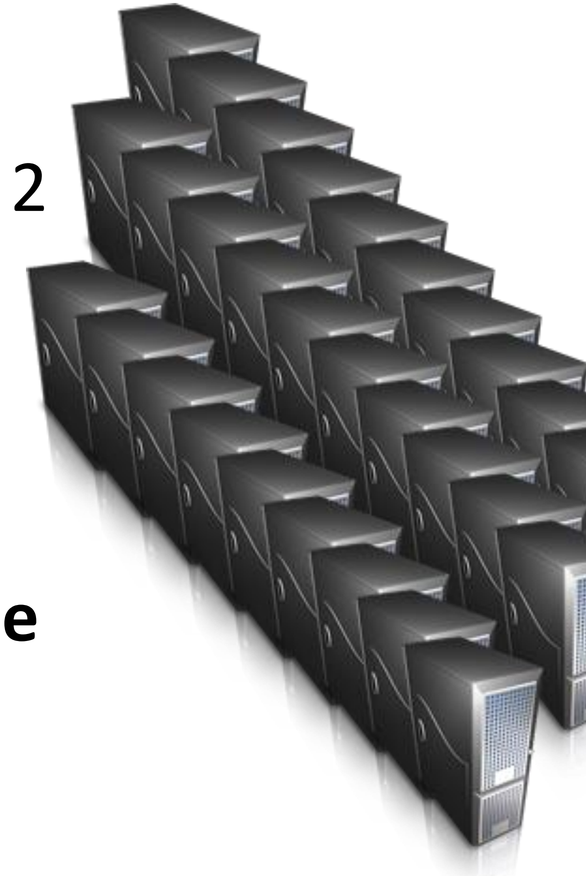
- **Network** is not fast or slow, it varies
  - Design for huge latency variance
  - Machine independence is key
- **Machines** are not up or down, they are kind of slow
  - Measure, it's never black-and-white
- **People** are not good or fired, they all make mistakes
  - Tools and processes to minimize risk
- **Environment** is often iffy
  - Integrated security? Not so fast…
- It's less important to succeed, than to **know the difference**

Design for (appropriate) Simplicity

- There's no such thing as a "repro"
  - Everything must be debuggable from logs (and dumps)
  - This is much harder than it sounds – takes time to log the right stuff
- System state must be externally examinable
  - Not locked in internal data structures
- Fail-fast
  - Is great! Very hard to reason about partial failures. We kill it fast.
  - Is awful! Cascading failures can kill entire system if you are not careful
  - Principle: If you are sure it's local, kill it. If not, not so fast
- 'No workflows' is best
  - Machine independence is a virtue
  - Things that can safely be local, should be
- Single-level workflows is next (reduce number of moving parts)
  - Resumable (not tied to a specific machine)
  - Design with failure as norm using distributed (persisted) state machines

Design for many

- Many machines is great!
  - Reduce focus on machine **reliability**
    - By the time RDBMS runs recovery, the world has moved on
  - Distribution enables **load-balancing**
    - Focus on elasticity and flexibility
  - **HA** with 100 machines is better than 2
    - Load distribution, parallelism of copy



- Many machines is hard!
  - Elasticity needs to be **built** in
  - All operations must be **multi-machine**
  - Correlated failures are a fact of life

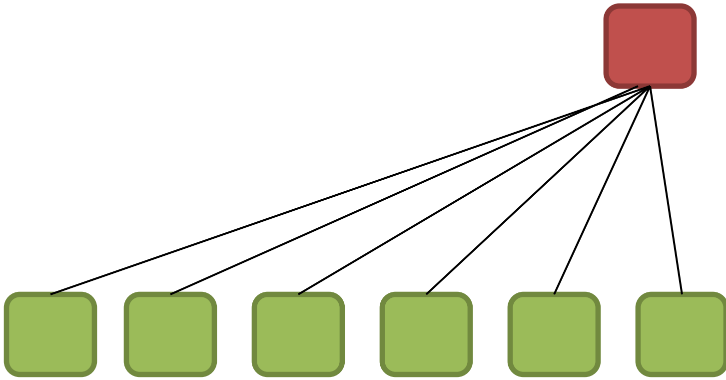
Design for multi-tenancy

- Customers like using many machines
  - Enables load-balancing and elasticity
  - But they don’t like paying for many machines
- Solution: multi-tenancy!
  - Everyone gets many slices
- Hard!
  - Isolation for security and performance
  - Many small databases? Costs….
  - Many relationships (replication)
  - Tradeoffs: isolation vs. elasticity?

Local vs. Global

Balance between local and global is key!

- “Normal case” decisions must be local
  - Any global state (e.g. routes) must be cached
  - The fewer parties are involved, the better
  - Otherwise: bottlenecks, single points of failure
- “Special case” decisions must be global
  - How to react to an error?
  - When to failover?
  - When and where to balance load?
  - When and how to upgrade software?
  - Otherwise: instability, chaos, low availability



- Data must be where it is needed
  - Global data needed for local operations must be cached locally
  - Local data needed for management must be aggregated globally

Real Symmetry is End-to-End

- Symmetry is **not** just about **surface** area
  - Too much focus on features
- It's **not** symmetric if:
  - If the **syntax** is the same, but it works in subtly different ways
  - If my connection **drops** too often
  - If the **latency** causes me to put everything in SPs
  - If operations unpredictably take **10x** as long sometimes
- Customers want clarity, **predictability**, and minimal **learning curve**

Summary

- Cloud is different
  - Not a different place to host code
- Opportunities are great
  - Customers want a utility approach to storage
  - New businesses and abilities in scale, availability, etc
- But the price must be paid
  - Which is a good thing, otherwise everyone would be doing it!

Future Work and Challenges

- Performance SLAs
  - Delivering on “guaranteed capacity” while consolidating diverse workloads is hard
- Privacy, Governance and Compliance
  - Perceptions and realities
  - Private Cloud appliances
- Programming Models
  - Support for loosely coupled scaleout patterns such as sharding
  - Transparent multi-node scaleout
- Data Redundancy
  - Point in time restore (backup knobs)
  - Geo-availability for multiple points of presence
- Health Model for Applications
  - Data tier is only part of the problem – support for hosting N-tier apps and providing insight into health and performance

QUESTIONS?

SQL Azure Links

- SQL Azure
  http://www.microsoft.com/windowsazure/sqlazure/
- SQL Azure "under the hood"
  http://www.microsoftpdc.com/sessions/tags/sqlazure
- SQL Azure Fabric
  http://channel9.msdn.com/pdc2008/BB03/