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Active-Active Geo-Distributed Apps with Redis CRDTs (conflict free replicated data-types)

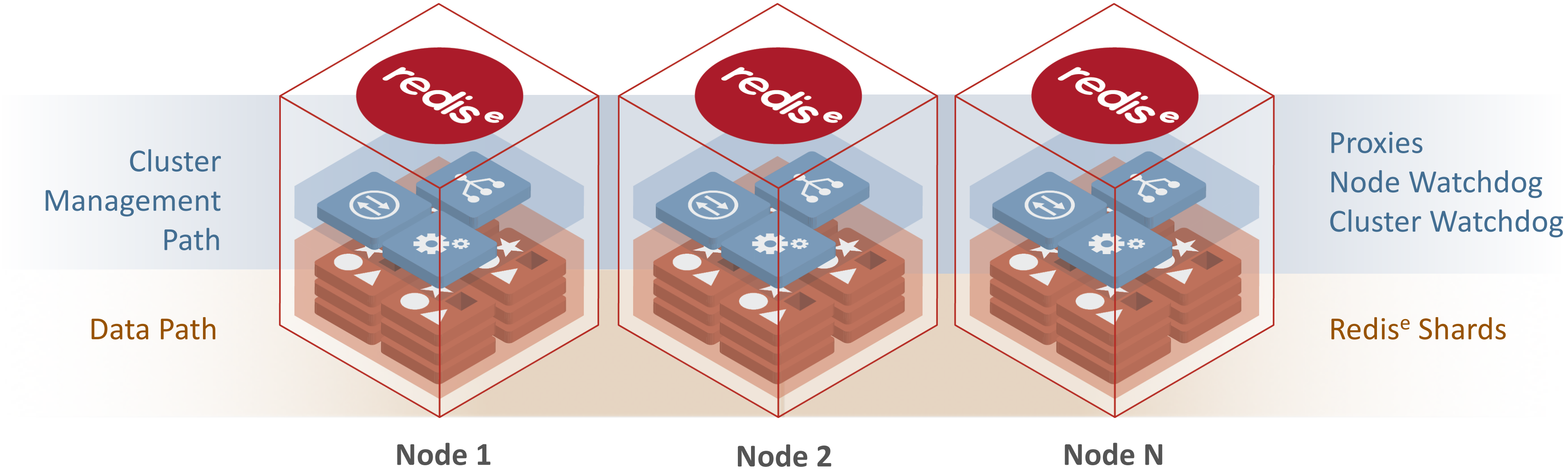
REDISCONF 2018

Agenda

- Quick Intro to Redis Enterprise
- Redis Enterprise Architecture
- Redis CRDTs
  - Introductions to Redis CRDTs
    - CAP Theorem and Redis CRDTs
  - How to develop apps with Redis CRDTs
    - Counters
    - Strings
    - Sets
    - Lists

Introduction to Redis Enterprise

Redis^e Cluster



Cluster Management Path

Data Path

Proxies
Node Watchdog
Cluster Watchdog

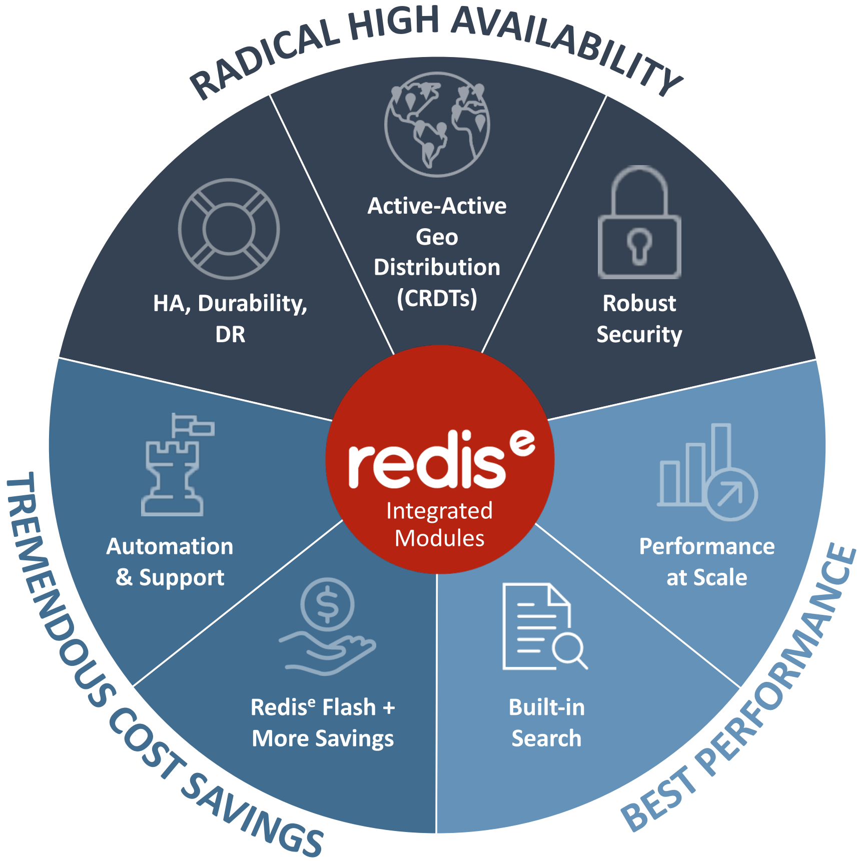
Redis^e Shards

Node 1

Node 2

Node N

Introduction to Redis Enterprise – cont.



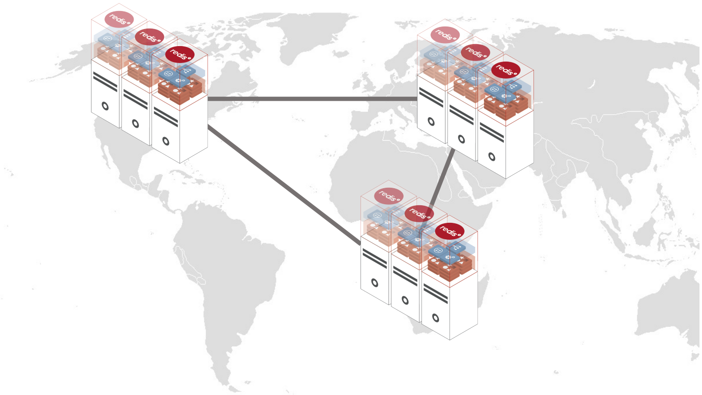
Replication Architecture

Replication Architecture with Redis Enterprise

Low Replication Lag & High Replication Throughput

- Local Replication: Built for LAN
  - Higher bandwidth
  - Lower latency
  - High quality links susceptible to fewer failures and retransmits

- Cross-Geo Replication: Built for WAN
  - Lower bandwidth
  - Higher latency
  - “Noisier” network quality susceptible to more failures and retransmits

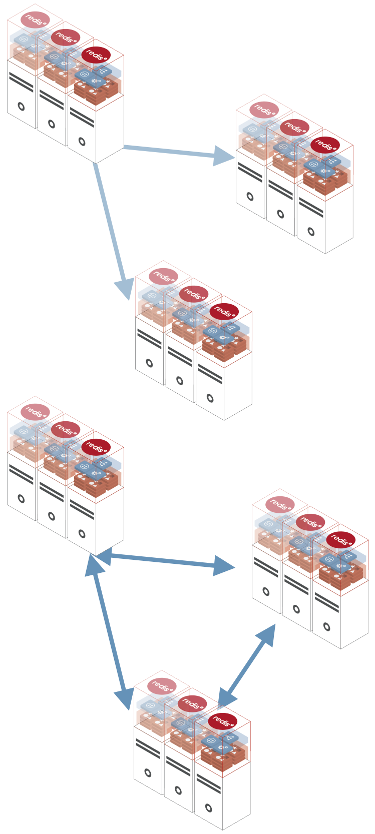


Cross-Geo Replication

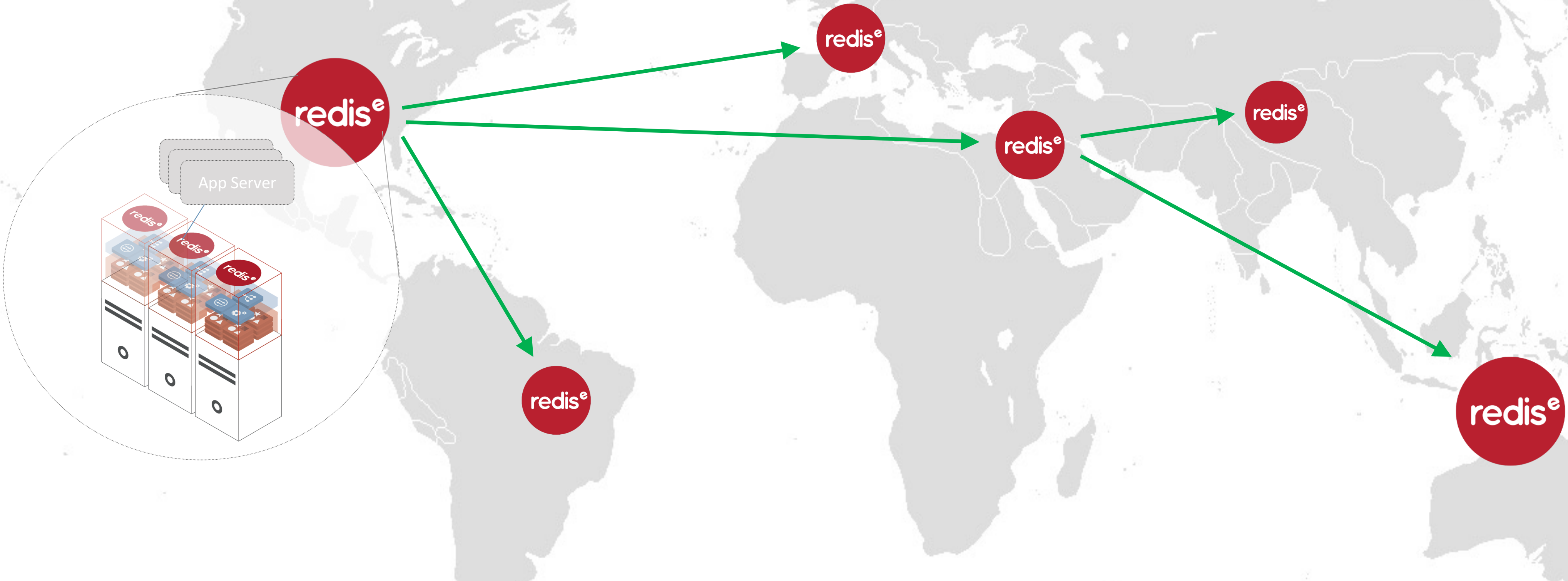
- Unidirectional Replication
  - *Replica Of* – Data Movement between Source to Destination DB
    - Content Distribution to Various Geographies for low latency, local reads
    - Continuous Data Transfer *to* and *from* Other Redis or Redis^{e} Databases

- Bi-Directional Replication
  - *Redis CRDTs* *(Conflict-free Replicated Data Tpes)* - Active-Active Writes & Reads
    - Advanced Protection against Regional Failures
    - Geo-Distributed Apps for Concurrent Active-Active Writes & Reads

Geo-Distributed Clusters



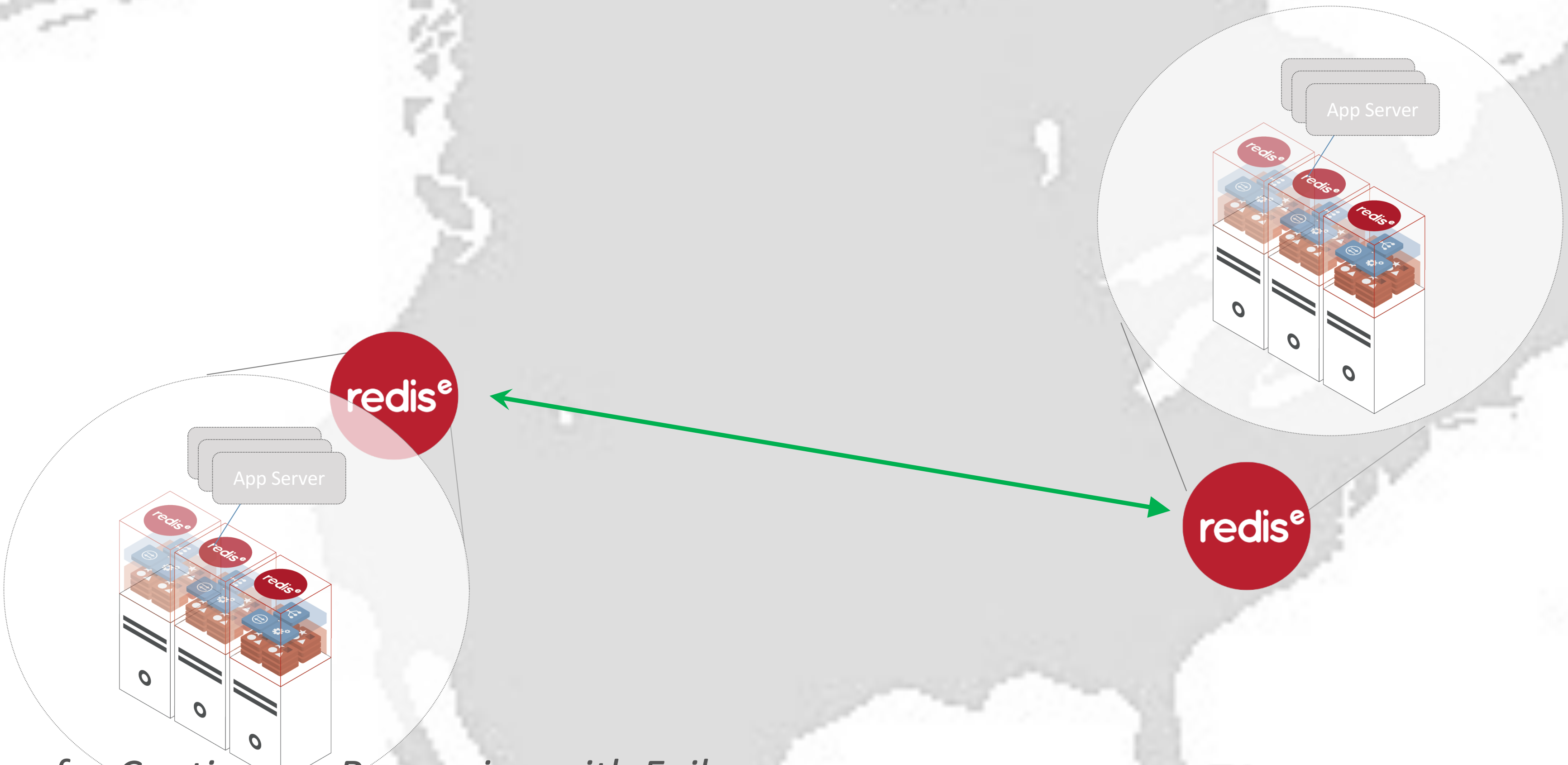
Replica Of: Geo Distribution for Fast Local Data Access



Geo Distribution for Local Data Access (CDN Like)

- Read local copy with low latency, instead of crossing borders
- Push updates to all regions with fast, memory based replication

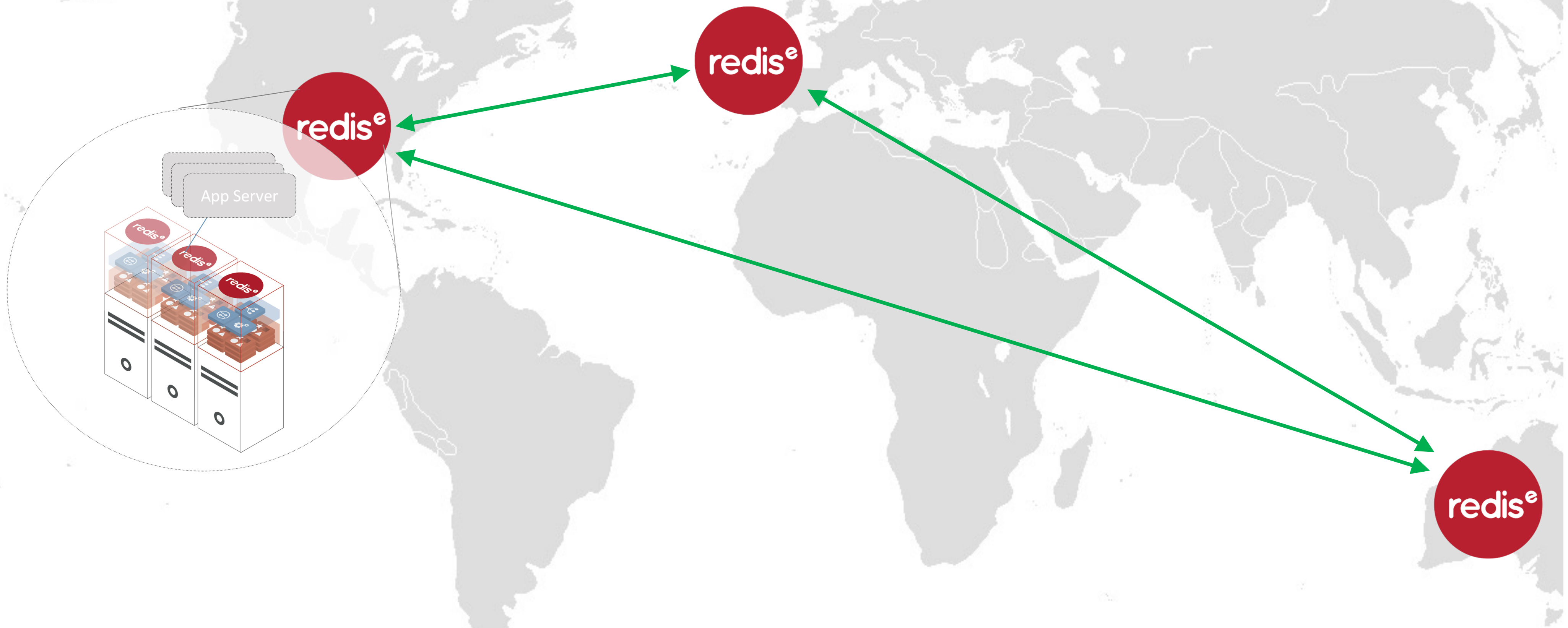
Redis CRDTs: Active-Active Geo Distribution for Geo-Failover



Geo Distribution for Continuous Processing with Failover

- Redis CRDTs for reliable handling of race conditions during geo-failover

Redis CRDTs: Active-Active Geo-Distribution



Active-Active Reads/Writes

Redis Conflict Free Replicated Data Types a.k.a CRDTs With Smart Conflict Resolution

Introducing Redis CRDTs

(Conflict-free Replicated Data Types)

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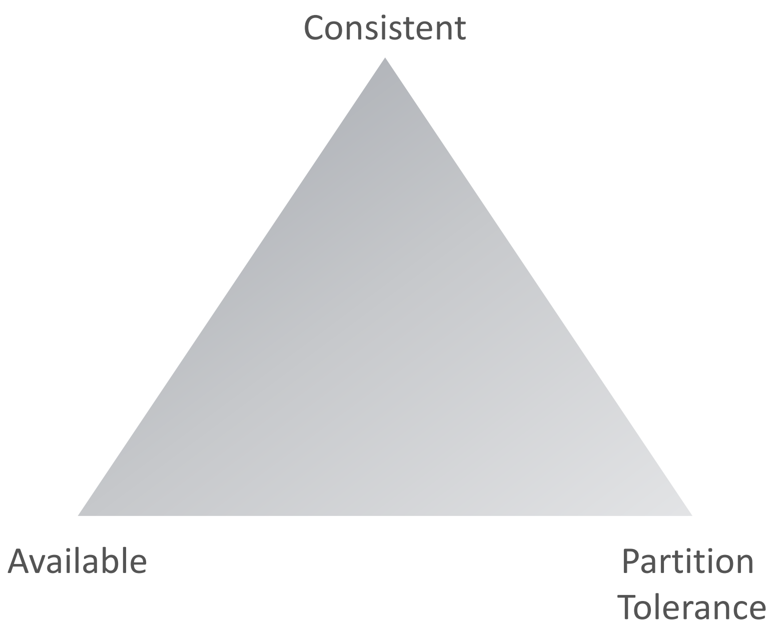
Active-Active Geo-Distributed Applications Are Hard!

- Consensus Driven Protocols – 2 Phase Commit
  - *Very chatty over LAN and WAN with very low throughput*
  - *Strictly “Consistent” thus not “Available” by nature*
  - *Products: Relational Databases*
- Quorum Based Writes and Reads
  - *Very chatty over LAN and WAN with very low throughput*
  - *Strictly “Consistent” thus not “Available” by nature*
  - *Products: DynamoDB, Cassandra*

Consistent but NOT Available



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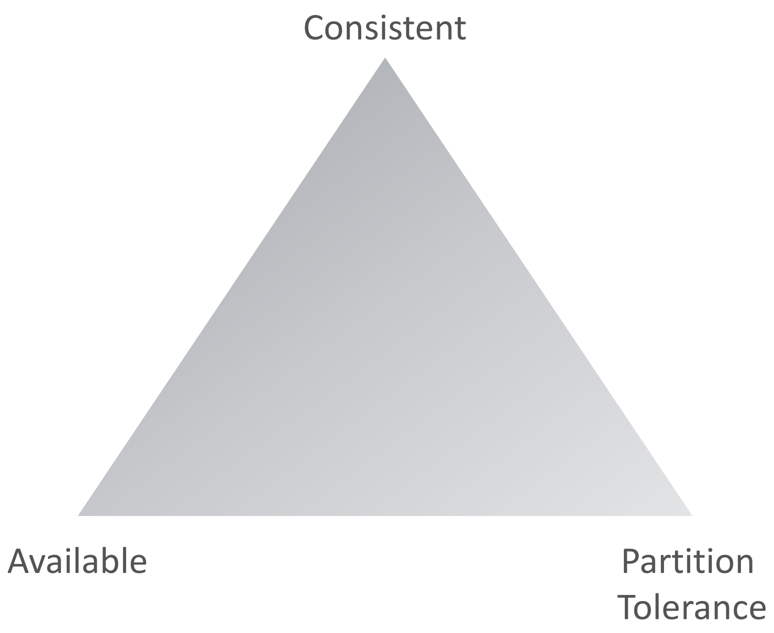
- Quorum Based Writes and Reads
  - *Very chatty over LAN and WAN with very low throughput*
  - *Strictly "Consistent" thus not "Available" by nature*
  - *Products: Cassandra*

Consistent but NOT Available

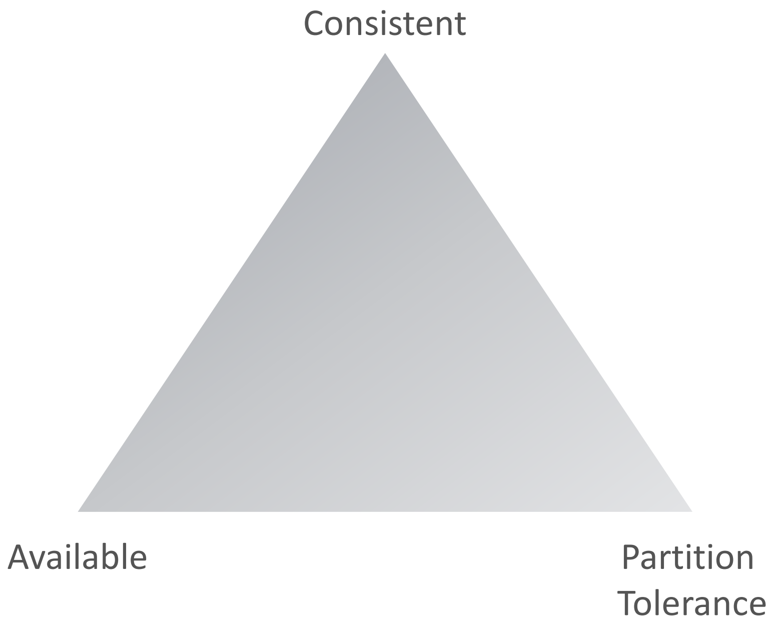
- LWW - Last Writer Wins Conflict Resolution
  - *Inaccurate and Insufficient for many apps (see next slide…)*
  - *Products: Couchbase*
- MVCC - Multi Version Concurrency Control
  - *High overhead and slow throughput due to large metadata*
  - *Complex to program against*
  - *Products: CouchDB*

Available but NOT Consistent



Introducing CRDTs (Conflict-Free Replicated Data Types)

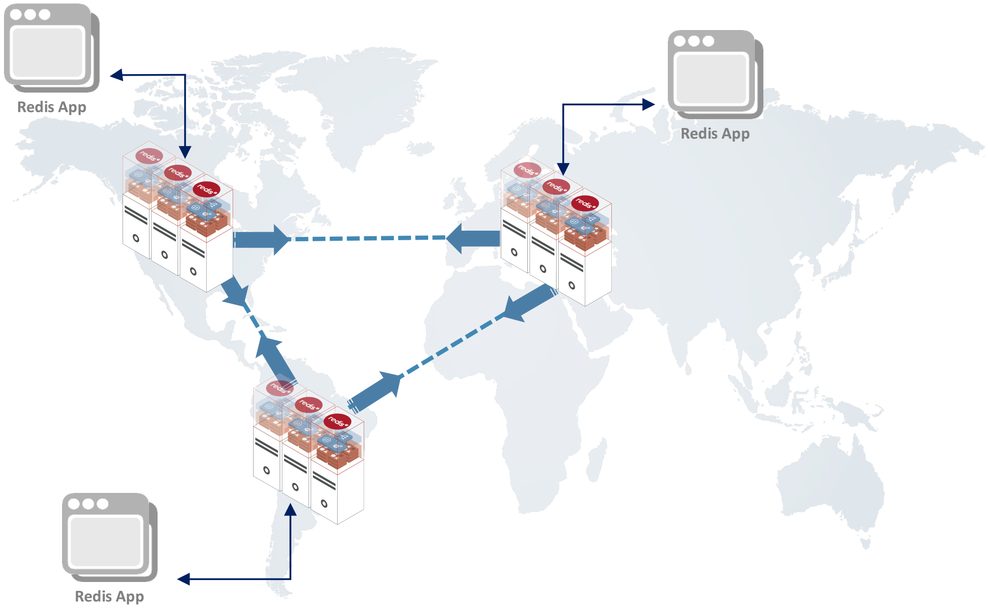
- **Consistency**: Strong eventual consistency + Causal Consistency
  - Eventually Consistent: Any two nodes that receive same but unordered updates will be in the same states
  - Causally Consistent: Events ordered across all participants
- **Availability**: Based on *consensus-free* protocol
  - Available: Local cluster availability is sufficient
  - No expensive multi-step consensus communication
- **Smart conflict resolution** with complex data types
  - Each Redis “type + method” expresses developer intent in resolving conflicts
- Based on proven **Mathematical Models**
  - Eric Brewer “*CAP Twelve Years Later: How the "Rules" Have Changed*”
  - Marc Shapiro “Strong Eventual Consistency and Conflict-free Replicated Data Types”



Active - Active Geo Distributed Apps with Redis CRDTs

Redis CRDTs

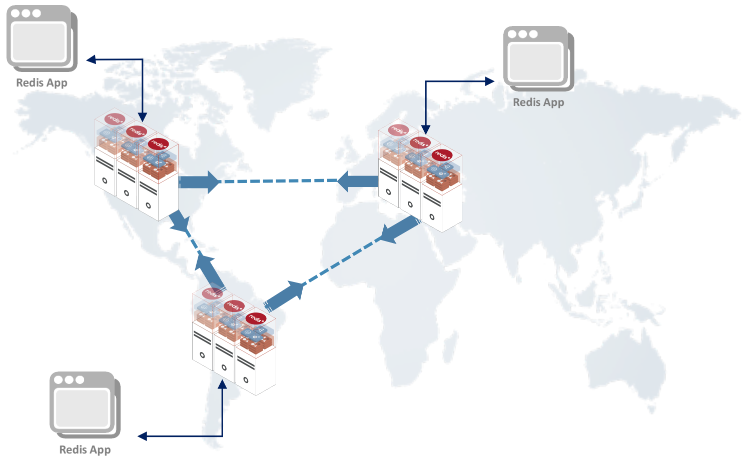
Active-Active Geo-Distributed Redis Apps with Smart Auto-Conflict Resolution and Simplified Development



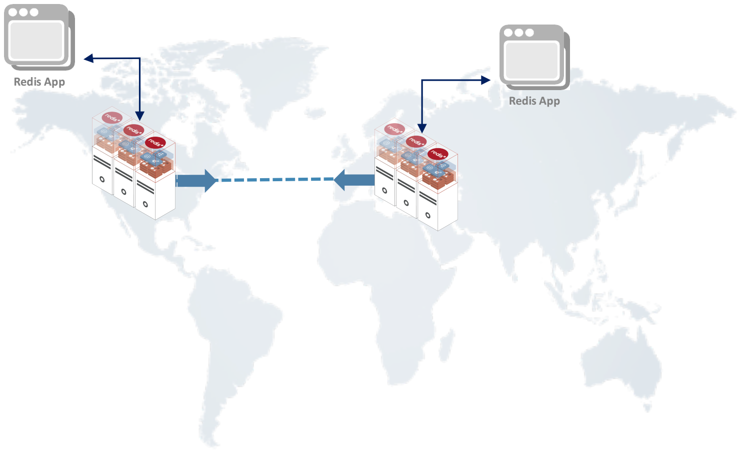
- Geo-Replicated Active-Active Deployments
- Smart & Transparent Conflict Resolution
- Based on CRDT Technology (*conflict free replicated data types*)

Redis CRDTs

- Geo-Replicated Active-Active Deployments
  - Global Database distributed across clusters in multiple regions
  - Fast bi-directional replication across data-centers
  - Low latency local reads & writes: *sub-millisecond latencies*



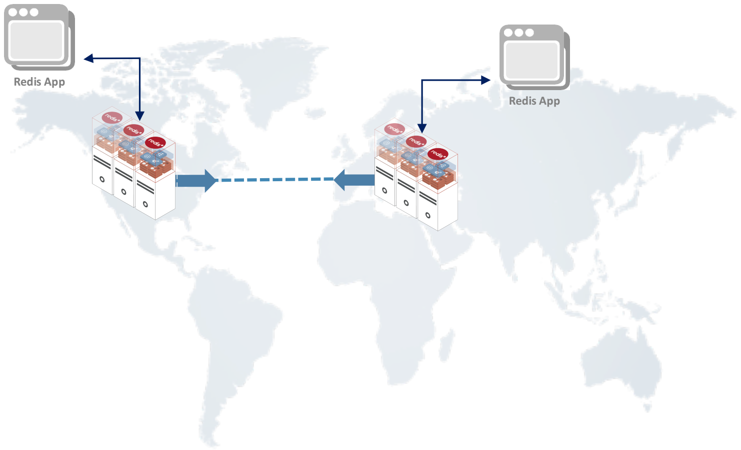
Redis CRDTs



- Smart & Transparent Conflict Resolution
  - CRDBs power concurrent writes across geographies
  - CRDBs handle failover conflicts safely!

time	US Data Center	EU Data Center
t1	SADD cart1 “costume”	

Redis CRDTs



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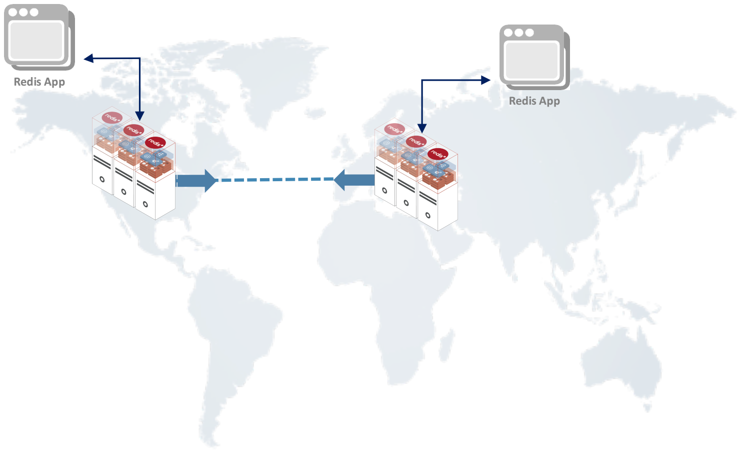
t2	US Data Center Fails – Sync Fails	

Redis CRDTs



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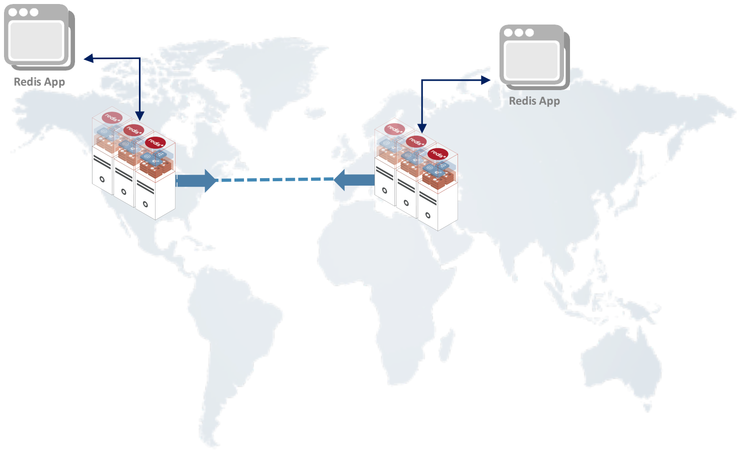
t2	US Data Center Fails – Sync Fails	
t3		SADD cart1 “mask”

Redis CRDTs



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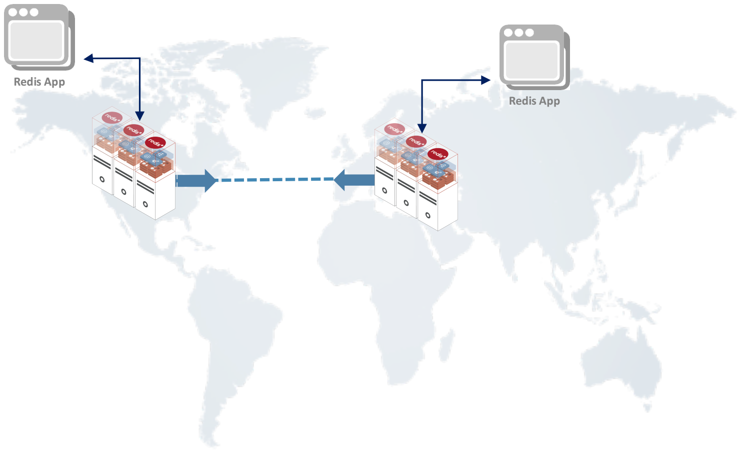
t3		SADD cart1 “mask”
t4	US Data Center Recovers – Resume Sync	

Redis CRDTs



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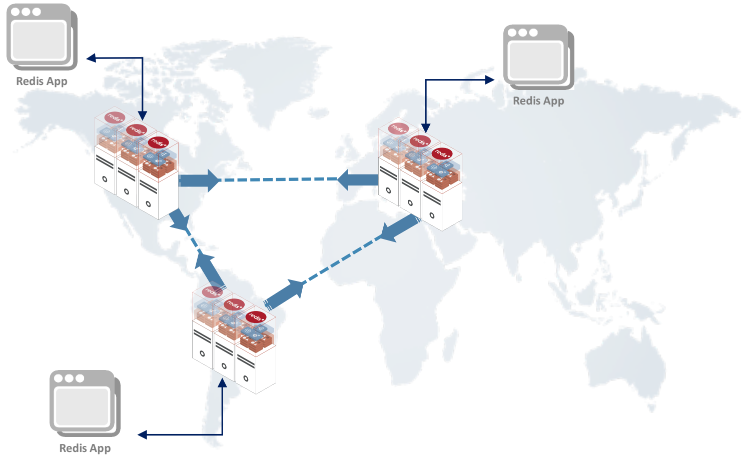
  - CRDBs handle failover conflicts safely!

time	US Data Center	EU Data Center
t1	SADD cart1 “costume”	
t2	US Data Center Fails – Sync Fails	
t3		SADD cart1 “mask”
t4	US Data Center Recovers – Resume Sync	
t5	SMEMBERS cart1 “costume” “mask”	SMEMBERS cart1 “costume” “mask”

Redis CRDTs

- Based on CRDT Technology
  - Simple to develop with Redis Commands
  - Smarter-conflict resolution based on "developers intent"

time	US Data Center	EU Data Center
t1	INCR TxCounter1	



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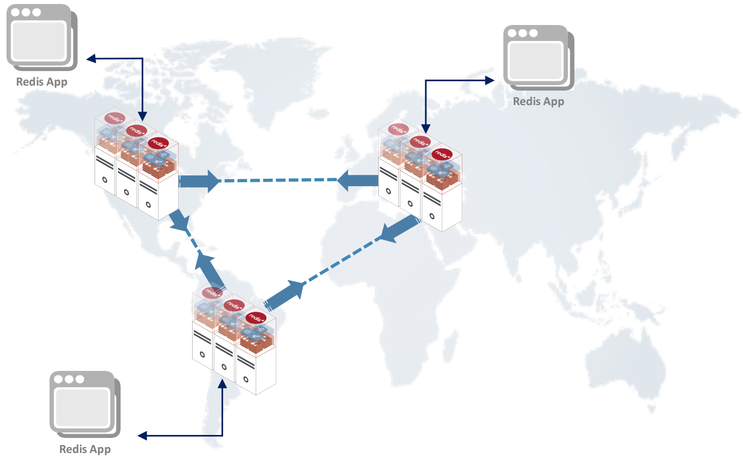
time	US Data Center	EU Data Center
t1	INCR TxCounter1	
t2		INCR TxCounter1



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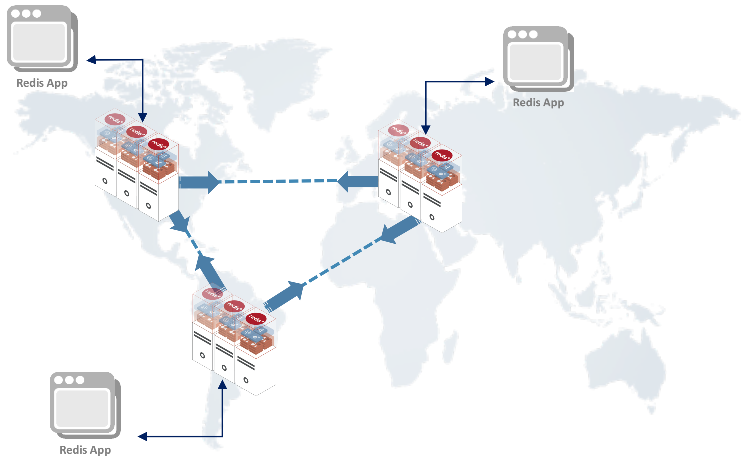
time	US Data Center	EU Data Center
t1	INCR TxCounter1	
t2		INCR TxCounter1
t3	INCR TxCounter1	



Redis CRDTs

- Based on CRDT Technology
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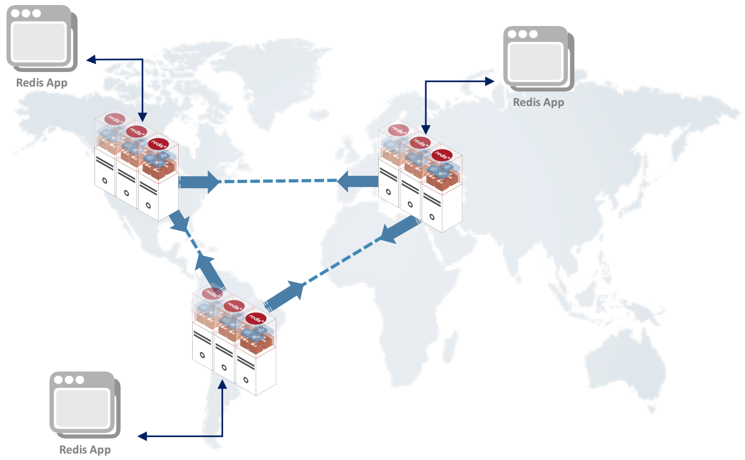
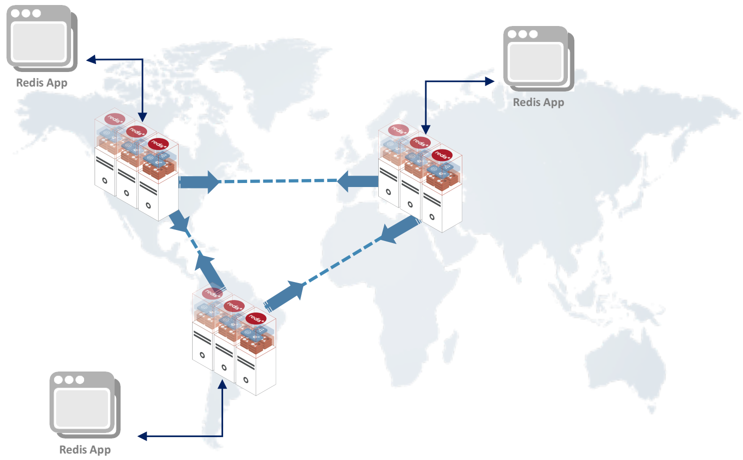
time	US Data Center	EU Data Center
t1	INCR TxCounter1	
t2		INCR TxCounter1
t3	INCR TxCounter1	
t4	Sync	



Redis CRDTs

- Based on CRDT Technology
  - Simple to develop with Redis Commands
  - Smarter-conflict resolution based on "developers intent"

time	US Data Center	EU Data Center
t1	INCR TxCounter1	
t2		INCR TxCounter1
t3	INCR TxCounter1	
t4	-- Sync --	
t5	GET TxCounter1 3	GET TxCounter1 3



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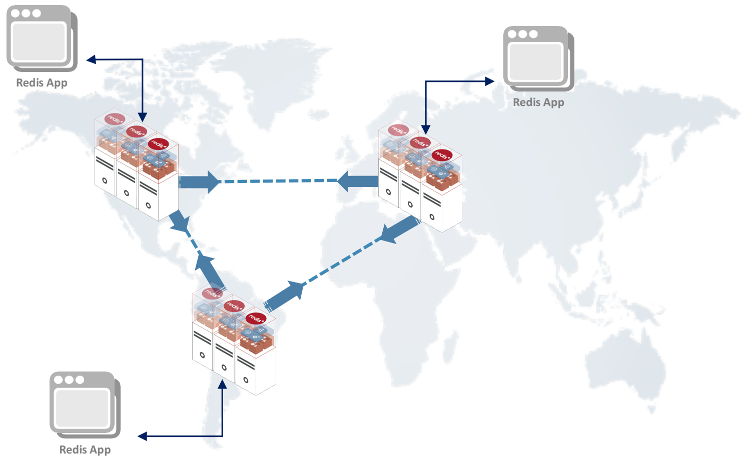
How Does Redis CRDTs Work?

Redis CRDTs == CRDBs (Conflict free replicated databases)

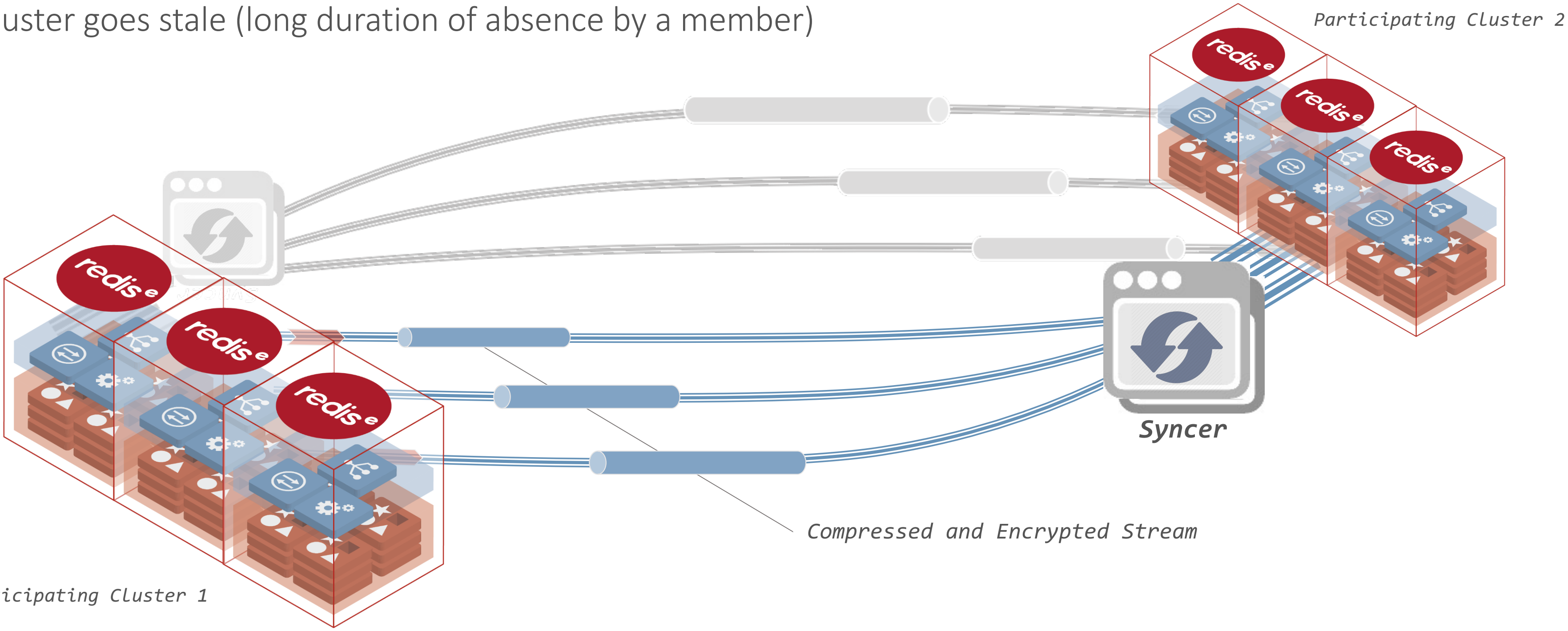
- CREATING a CRDB
  - Set global CRDB options
  - Initialize member CRDB on each participating cluster
    - In case of Error, Rollback
  - Establish bi-directional replication among all members



CRDB Architecture

Bi-directional Replication

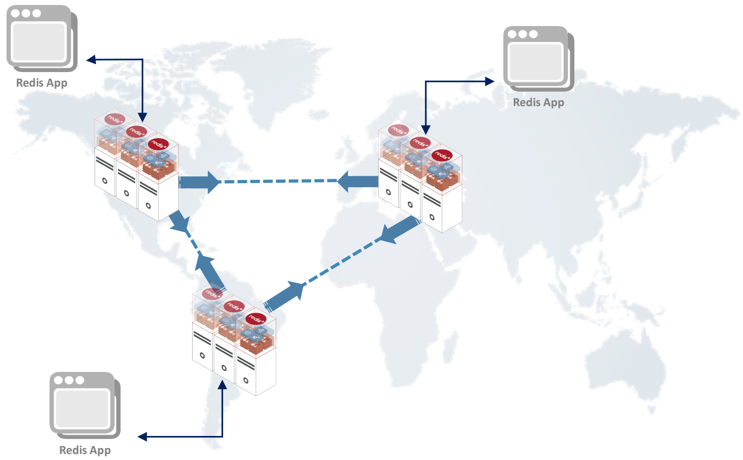
- *Syncer* uses replicas to replicate operations in a streaming fashion
- Resume-able replication under failures but may resync if a participating cluster goes stale (long duration of absence by a member)



How to Develop Applications with CRDBs?

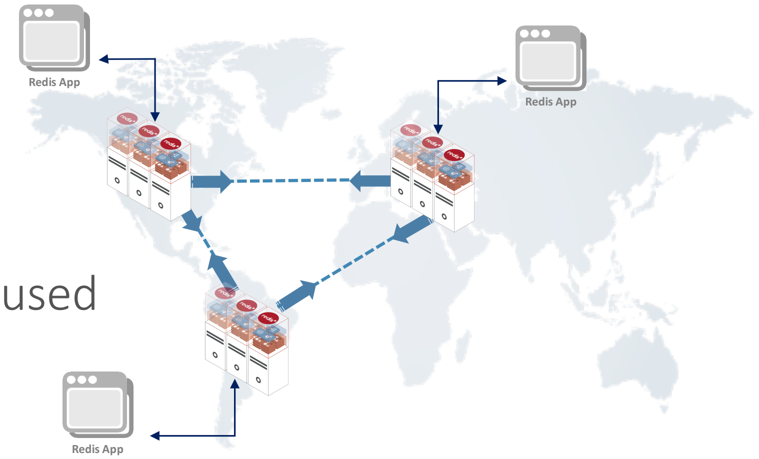
Developing Apps with a CRDB

- App Topology
  - All apps connect to the local member CRDB in the participating cluster
  - Reads/Writes occur on local member CRDB
    - Outcome of concurrent writes are predictable and based on a set of rules
  - Bi-directional replication automatically syncs changes
    - No application code required to resolve conflicts



Developing Applications with CRDBs

- Simply use Redis with Redis Client SDKs!
- Conflict Resolution is smart and automatic
  - Counters - using INCR or INCRBY, INCRBYFLOAT and so on
  - Sets & Sorted Sets – SADD/SREM and so on (new)
  - Hash – HSET/HDEL and so on
  - Strings - using SET/APPEND and so on
  - Lists – using LPUSH/POP and so on (new)
- Conflict Resolution is specific to data type + commands used
  - Total increments since last sync for Counters
  - Add wins with observed remove for Sets
  - Last writer wins for Strings
  - Counter or String semantics for Hash
  - Lists – using item IDs
  - And so on.



Conflicting Writes

- No conflicts here…

time	US Data Center	EU Data Center
t1	SET key1 “value1”	
t2	-- Sync --	
t3		SET key1 “value2”
t4	-- Sync --	
t5	SET key1 “value3”	GET key1 => value2
t6	-- Sync --	
t7	GET key1 => “value3”	GET key1 => “value3”

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Counters in CRDBs

REDIS CRDTS IN ACTION!

Counters

- Counter: New numeric type in CRDTs
  - #type returns Counter
- Value is 5 bit shorter, i.e.
  - Redis supports <= 9,223,372,036,854,775,807 (64 bit signed)
  - CRDB supports <= 288,230,376,151,711,743 (59 bit signed)

Conflicting Writes with Counters - Truly Conflict Free

- Counter value is the SUM() of all operations

time	**US Data Center**	**EU Data Center**
t1	INCRBY key1 10	INCRBY key1 50
t2	-- Sync --	
t3	GET key1 => 60	GET key1 => 60
t4	DECRBY key1 60	INCRBY key1 60
t5	-- Sync --	
t6	GET key1 => 60	GET key1 => 60

Delete vs Update Conflict - Observed Remove

- Conflicting Update vs Delete
  - DEL logically resets the counter.

time	US Data Center	EU Data Center
t1	INCRBY key1 100	
t2	-- Sync --	
t3	DEL key1	INCRBY key1 10
t4	-- Sync ---	
t5	GET key1 => 10	GET key1 => 10

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Strings in CRDBs

REDIS CRDTS IN ACTION!

String Add vs Delete - Add Wins

- Concurrent APPEND and DEL.
  - Add (including Update) Wins.

time	US Data Center	EU Data Center
t1	SET key1 “Hello”	
t2	-- Sync ---	
t3	APPEND key1 “There”	
t4		DEL key1
t5	-- Sync --	
t6	GET key1 => “HelloThere”	GET key1 => “HelloThere”

Key Concurrent Expiration – Longer TTL Wins

- Concurrent Expiration
  - Longer TTL wins (*Non volatile keys have infinite TTL*)

time	US Data Center	EU Data Center
t1	SET key1 “val1”	
t2	-- Sync ---	
t3	EXPIRE key1 10	EXPIRE key1 30
t4	-- Sync --	
t5	TTL key1 => 30	TTL key1 => 30

String APPEND vs. APPEND

- Concurrent APPEND operations
  - LWW (last writer wins)

Time	US Data Center	EU Data Center
t1	SET key1 “Hello”	
t2	-- Sync ---	
t3	APPEND key1 “There”	
t4		APPEND key1 “World”
t5	-- Sync --	
t6	GET key1 => “HelloWorld”	GET key1 => “HelloWorld”

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Sets in CRDBs

REDIS CRDTS IN ACTION!

Sets SADD vs SADD

- Concurrent SADD Operation
  - Preserve merged items

time	US Data Center	EU Data Center
t1	SADD cart1 “costume”	
t2	US Data Center Fails – Sync Fails	
t3		SADD cart1 “mask”
t4	US Data Center Recovers – Resume Sync	
t5	SMEMBERS cart1 “costume” “mask”	SMEMBERS cart1 “costume” “mask”

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Hashes in CRDBs

REDIS CRDTS IN ACTION!

Hashes HSET vs HSET

- Concurrent HSET Operation
  - Preserve merged items

time	US Data Center	EU Data Center
t1	HSET k1 f1 “a”	
t2	-- Sync --	
t3	HSET k1 f2 “b”	
		HSET k1 f3 “123”
t4	-- Sync --	
t5	HGETALL k1 “f1” “a” “f2” “b” “f3” “123”	HGETALL k1 “f1” “a” “f2” “b” “f3” “123”

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Lists in CRDBs

REDIS CRDTS IN ACTION!

Lists LPUSH vs LPOP

- Concurrent LPUSH vs LPOP Operation
  - Preserve merged items

time	US Data Center	EU Data Center
t1	LPUSH l1 “a” “b” “c”	
t2	-- Sync --	
t3	LPUSH l1 “d”	
		LPOP l1
t4	-- Sync --	
t5	LRANGE l1 -100 100 “b” “c” “d”	LRANGE l1 -100 100 “b” “c” “d”

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PUB/SUB in CRDBs

REDIS CRDTS IN ACTION!

PUB/SUB and Eventual Consistency

- Multiple Publishers and Subscribers
  - Message order received can be different per subscriber

time	US Data Center	EU Data Center	ASIA Data Center
t1	PUBLISH c1 “a”	SUBSCRIBE c1	SUBSCRIBE c1
t2	-- Sync --		-- X --
t3	SUBSCRIBE c1	”a”	
		PUBLISH c1 “b”	
t4	-- Sync --		
t5	“b”		“b” “a”

PUB/SUB with Causal Consistency

- Multiple Publishers and Subscribers
  - Causal Consistency Ensure Ordering of Messages

time	US Data Center	EU Data Center	ASIA Data Center
t1	PUBLISH c1 “a”	SUBSCRIBE c1	SUBSCRIBE c1
t2	-- Sync --		-- X --
t3	SUBSCRIBE c1	”a”	
		PUBLISH c1 “b”	
t4	-- Sync --		
t5	“b”		“a” “b”

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Demo!

REDIS CRDTS IN ACTION!

Recap

Active - Active Geo Distribution

Redis Enterprise with Redis CRDTs (Conflict Free Replicated Data-types)

Build Fast Active-Active Geo-Distributed Redis Apps

with Smart Auto-Conflict Resolution

- Geo-Replicated Active-Active Deployments
  - Fast bi-directional across data-centers
  - Low latency local reads & writes : sub-millisecond latencies
- Smart & Transparent Conflict Resolution
  - Build safe regional failover and geo-distributed apps
  - Each Redis Data Type have smart conflict resolution based on “developer intent”
- Based on CRDT Technology (conflict free replicated data types)
  - Simplifies development

Get Started with Redis CRDTs Today!

Redislabs.com

- Download Redis Enterprise 5.0

- Visit Docker Hub: *redislabs/redis:latest*