SCALARIS

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RoadMap

- Motivation
- Overview
- Architecture
- Features
- Implementation
- Benchmarks
- API
- Users
- Demo
- Conclusion

Motivation (NoSQL)

Stonebraker

"One size doesn't fit all"

Reinefeld

Design Goals

- Key/Value store
- Scalability: many concurrent write accesses
- Strong data consistency
- Evaluate on a real-world web app
    - Wikipedia
- Implemented in Erlang
- Java API

Motivation (Consistency)

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High Level Overview

Erlang implementation of a distributed key-value store that has majority based transactions on top of replication on top of a structured peer to peer overlay network

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Architecture - P2P Layer

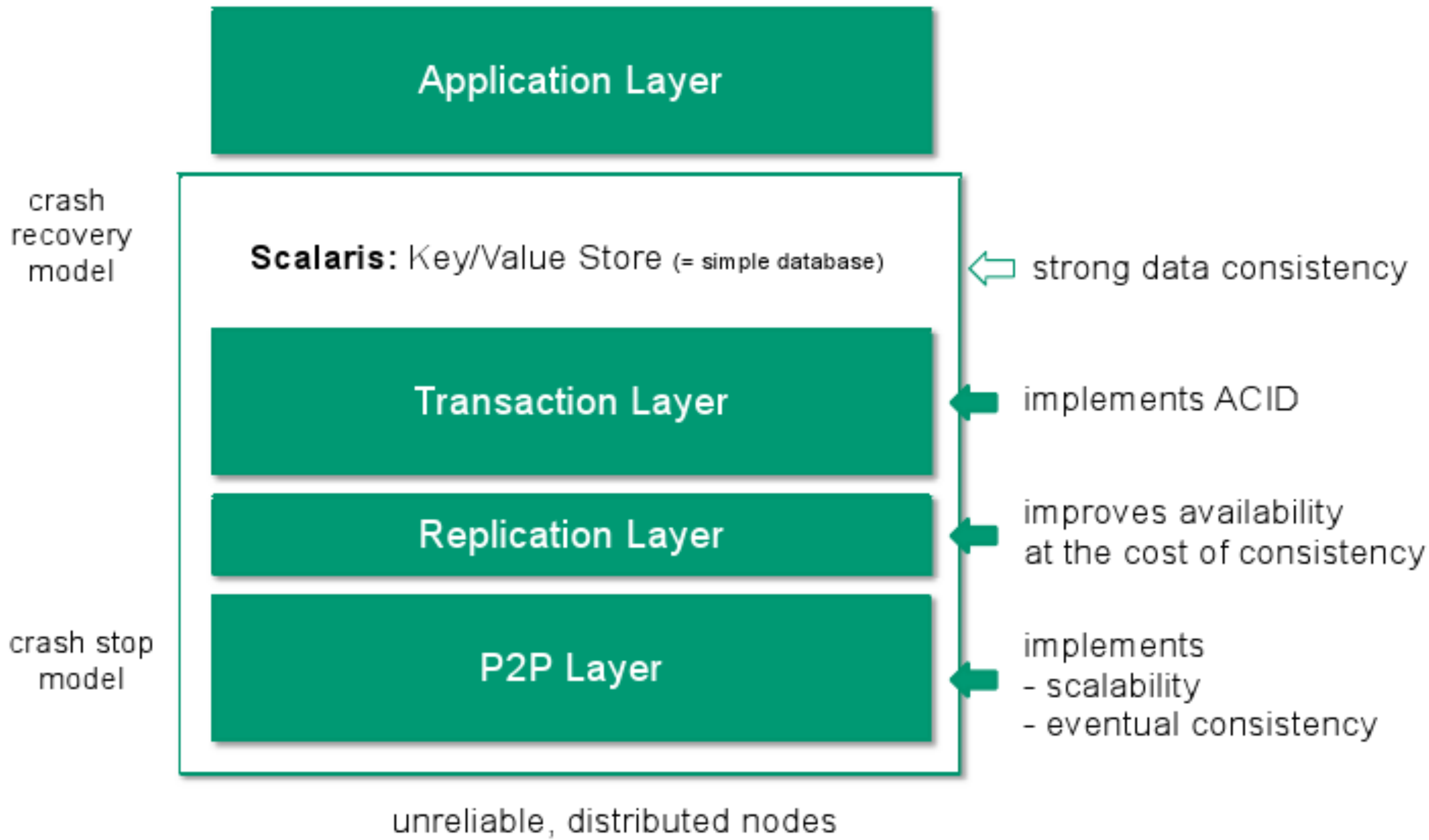


Figure 1. Scalaris system architecture.

Architecture - Chord

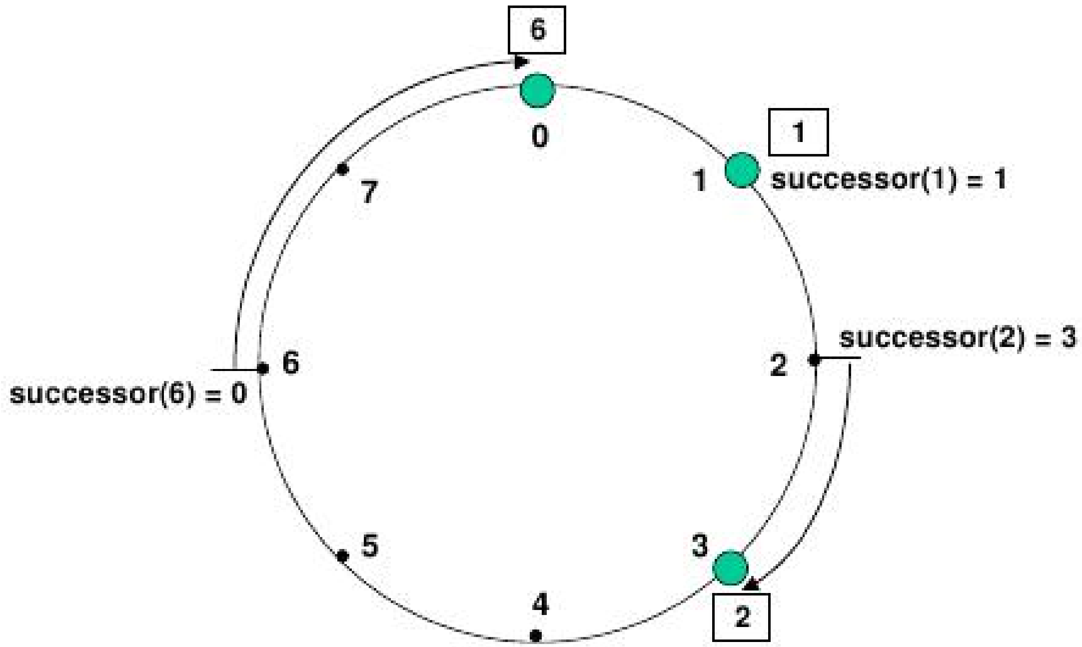


Figure 2: An identifier circle consisting of the three nodes 0, 1, and 3. In this example, key 1 is located at node 1, key 2 at node 3, and key 6 at node 0.

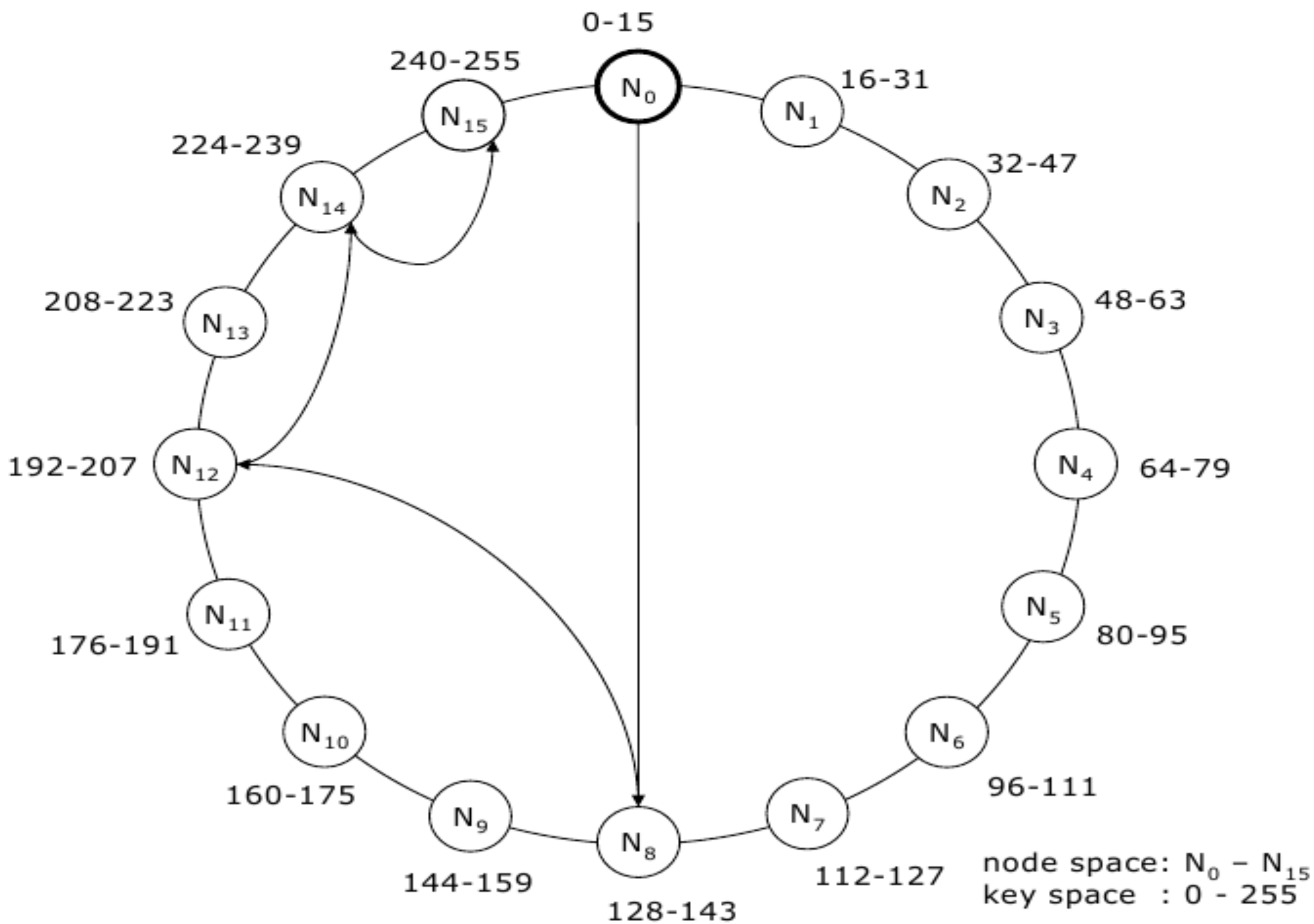
Architecture - Chord - Properties

- Load balancing
  - consistent hashing
- Logarithmic routing
  - finger tables
- Scalability
- Availability
- Elasticity

Architecture - Chord # - Properties

- No consistent hashing
- Keys are ordered lexicographically
- Efficient range queries
- Load balancing
  - must be done periodically if the keys are not randomly distributed

Chord



0-15
N0
16-31
N1
32-47
N2
48-63
N3
64-79
N4
80-95
N5
96-111
N6
112-127
N7
128-143
N8
144-159
N9
160-175
N10
176-191
N11
192-207
N12
208-223
N13
224-239
N14
240-255
N15
node space: N0 – N15
key space : 0 - 255

Architecture - Replication Layer

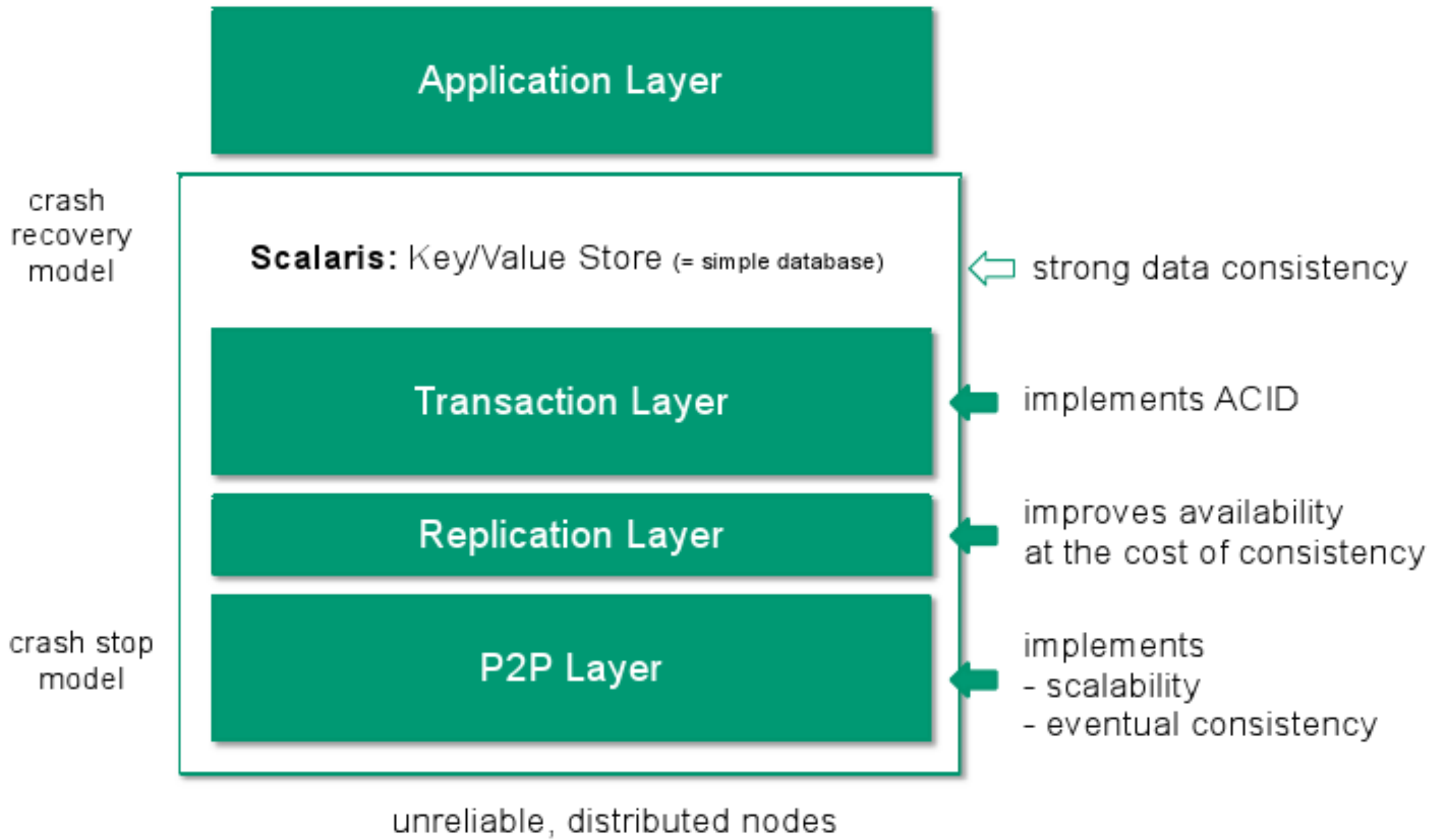


Figure 1. Scalaris system architecture.

Replication Layer

- Symmetric replication
- Replicated to *r* nodes
- Operations performed on a majority of replicas

Replication Layer

- Can tolerate at most (r - 1) / 2 failures
- Objects have version numbers
- Return the object with the highest version number from a majority of votes

Architecture - Transaction Layer

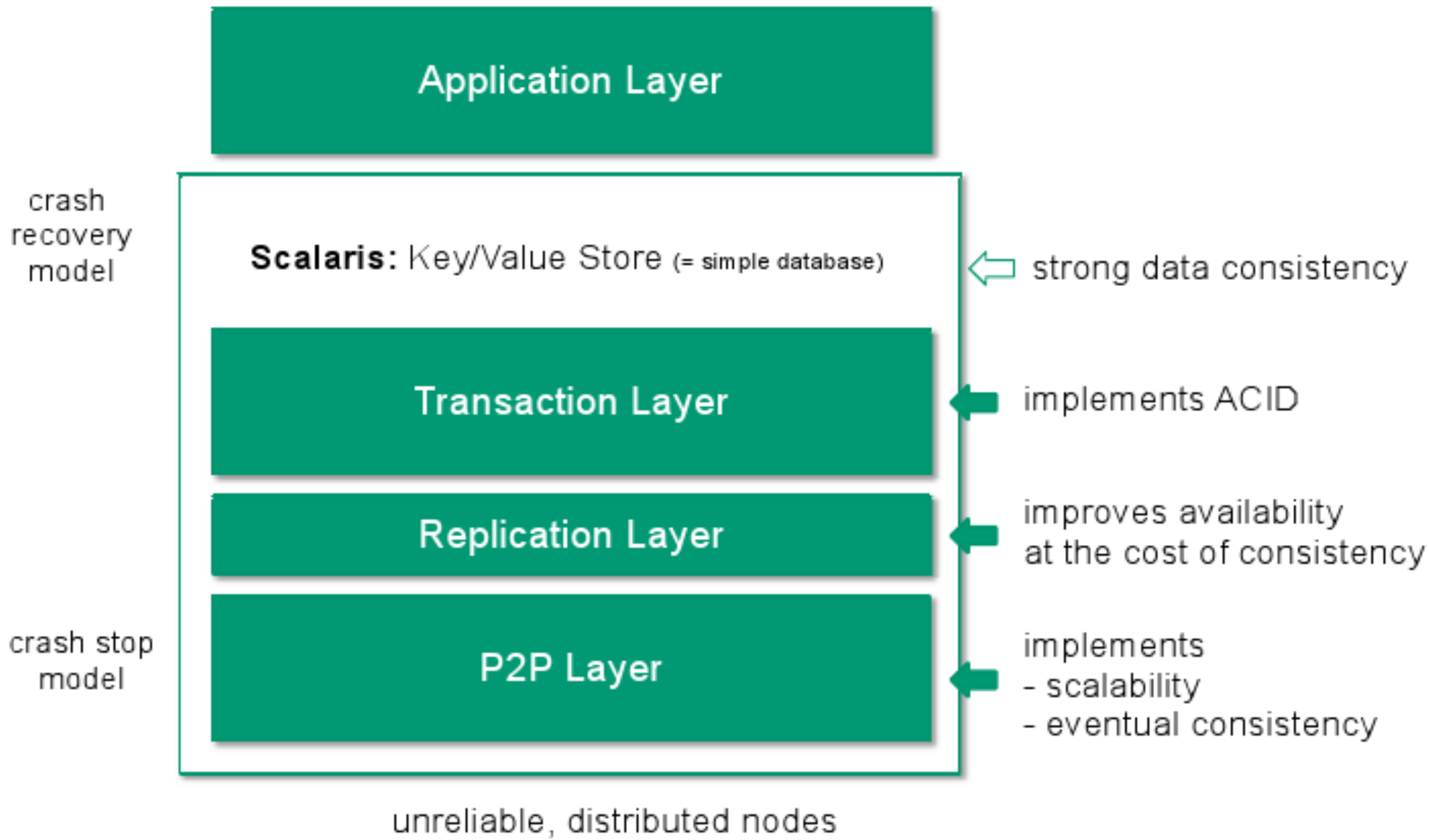


Figure 1. Scalaris system architecture.

Transaction Layer

- Writes use the adapted Paxos commit protocol
- Non-blocking protocol
- Strong consistency
  - Update all replicas of a key consistently
- Atomicity
  - Multiple keys transactions.

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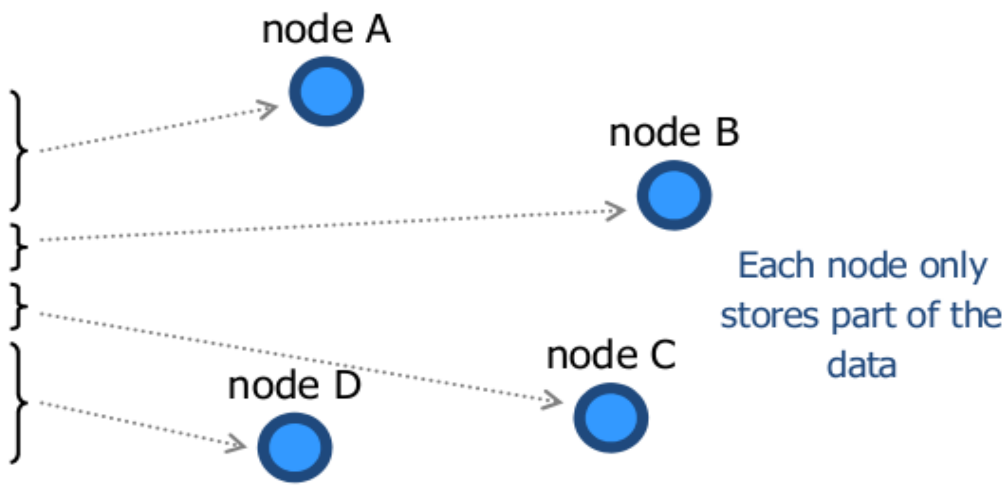
Data Model

- Key - Value Store
- Keys are represented as strings
- Values are represented as binary large objects
- In-memory
- Persistence is difficult with quorum algorithms
- Snapshot mechanism is best option for persistence
- Database back ends provide storage beyond RAM & Swap

Data Model

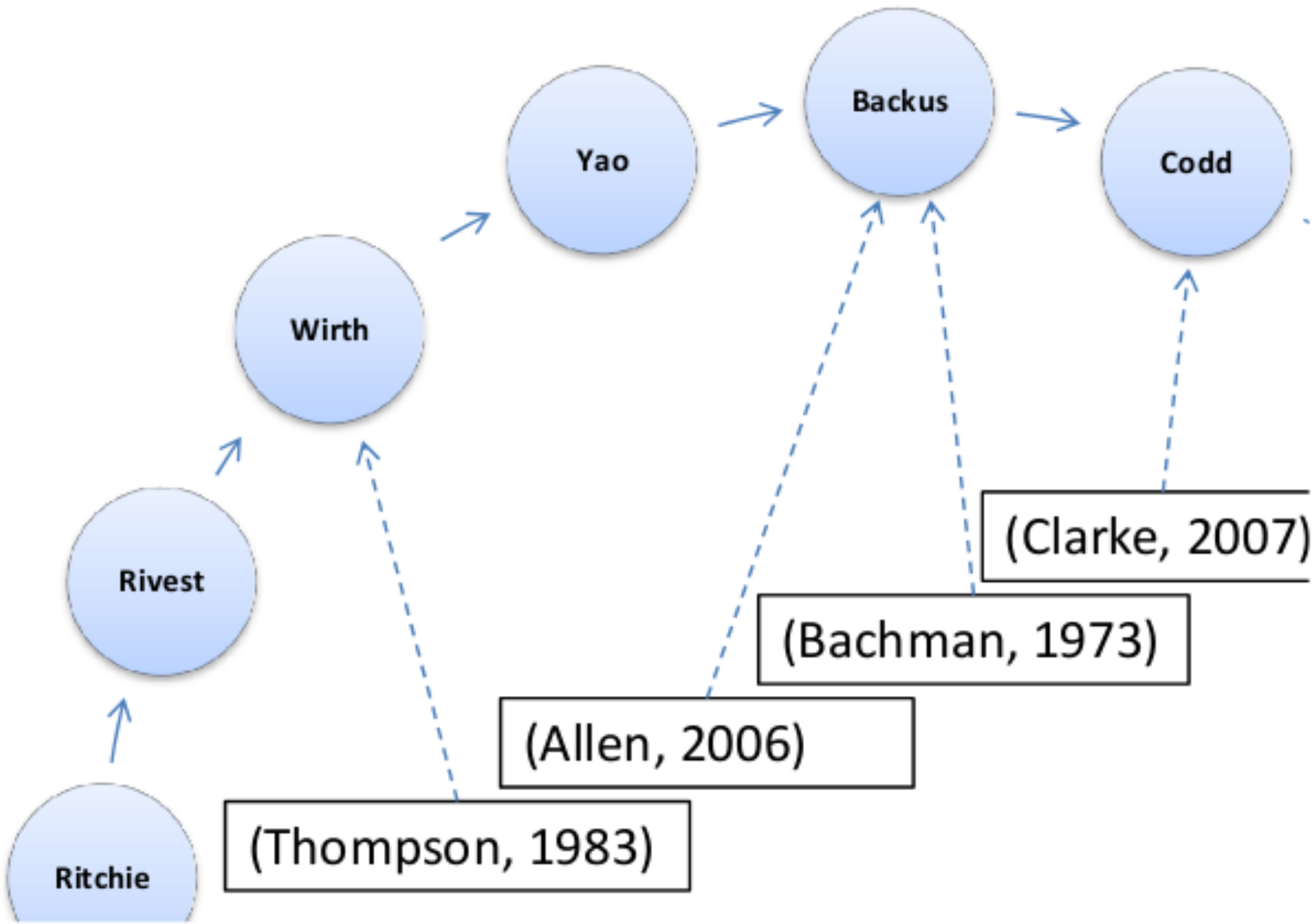
- The dictionary has three operators
  - `insert(key, value)`
  - `delete(key)`
  - `lookup(key)`
- Scalaris implements a distributed dictionary

Key	Value
Clarke	2007
Allen	2006
Bachman	1973
Thompson	1983
Knuth	1974
Codd	1981



Distributed Dictionary on Chord

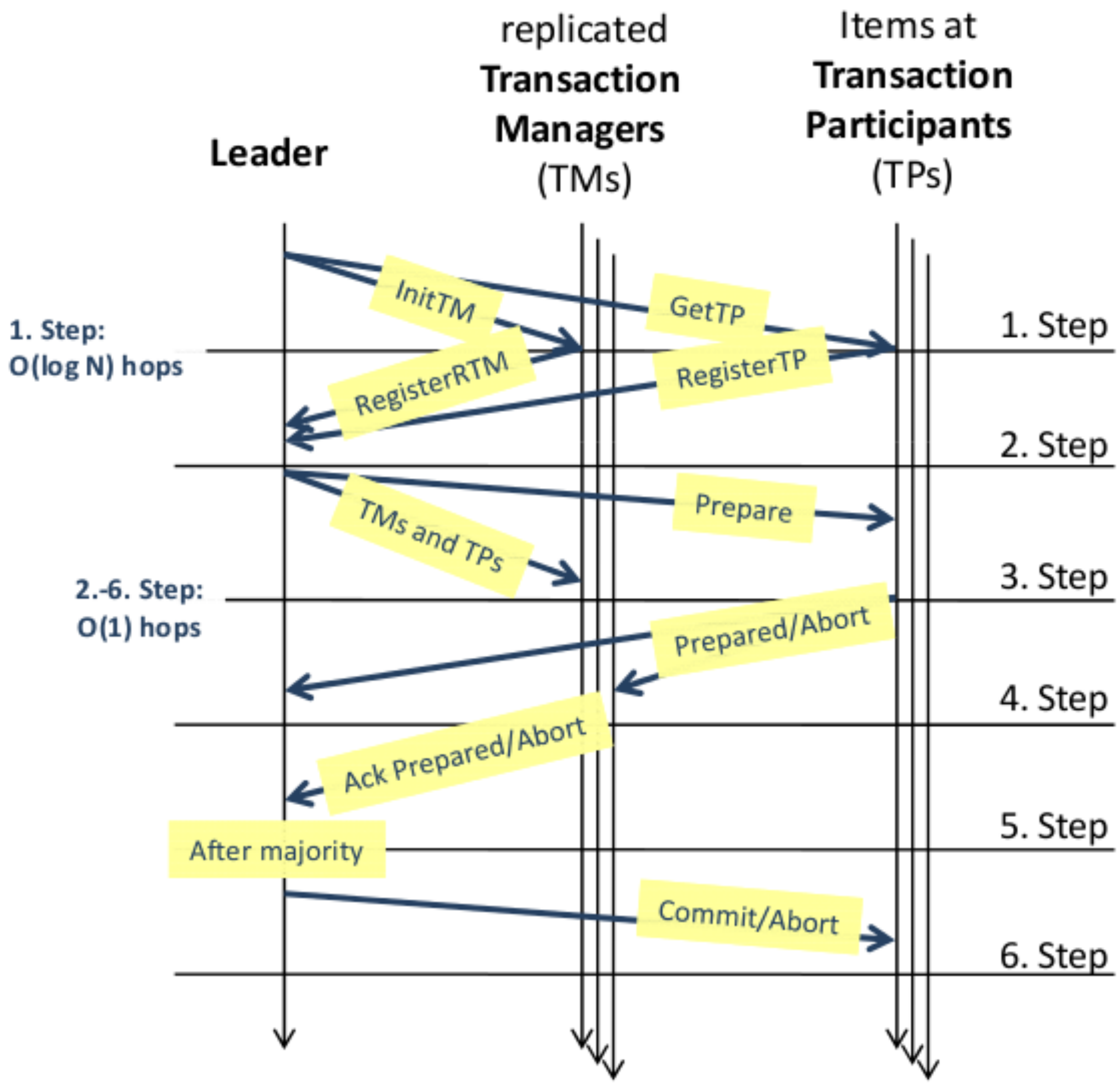
Items are stored on their clockwise successor



Adapted Paxos Commit

- Middle Layer of Scalaris
- Ensures that all replicas of a single key are updated consistently
- Used for implementing transactions over multiple keys
- Realizes ACID

Adapted Paxos Commit



Replica Management

- All key/value pairs over *r* nodes using symmetric replication
- Read and write operations are performed on a majority of the replicas, thereby tolerating the unavailability of up to $\lfloor (r - 1)/2 \rfloor$ nodes
- A single read operation accesses $\lceil (r + 1)/2 \rceil$ nodes, which is done in parallel.

Failure Management

- Self-Healing
  - Continuously monitors the system
  - Nodes can crash
    - If they announce the system handles gracefully
    - Unresponsive nodes lead to false positives
      - Failure detector reduces FP to .001
  - When a node crashes, the overlay network is immediately rebuilt

- Crash Stop
  - Assumption is that a majority of replicas are available
  - If a majority of replicas are not available, the data is lost

Consistency Model

- Strict consistency between replicas
    - adapted Paxos protocol
    - atomic transactions

ACID Properties

- Atomicity, Consistency and Isolation
  - majority based distributed transactions
  - Paxos protocol

- Durability
  - replication
  - no disk persistence
  - Scalaxis: branch version, adds disk persistence

Elasticity

- Implemented at the p2p layer level
- Transparent addition and removal of nodes in Chord #
  - failures
  - replication
  - automatic load distribution
- Self-organization
- Low maintenance

Load Balancing

- Based on p2p system properties
- Chord: consistent hashing
- Chord #: explicit load balancing
- efficient adaptation to heterogeneous hardware and item popularity

Optimizing for Latency

- Multiple datacenters
  - Only one overlay network
- Symmetric replication
  - Store replicas at consecutive nodes
  - i.e. same datacenter
- Chord # supports explicit load balancing
  - Place replicas to minimize latency to majority of clients
    - e.g. German pages of Wikipedia in European datacenters

Optimizing for Latency

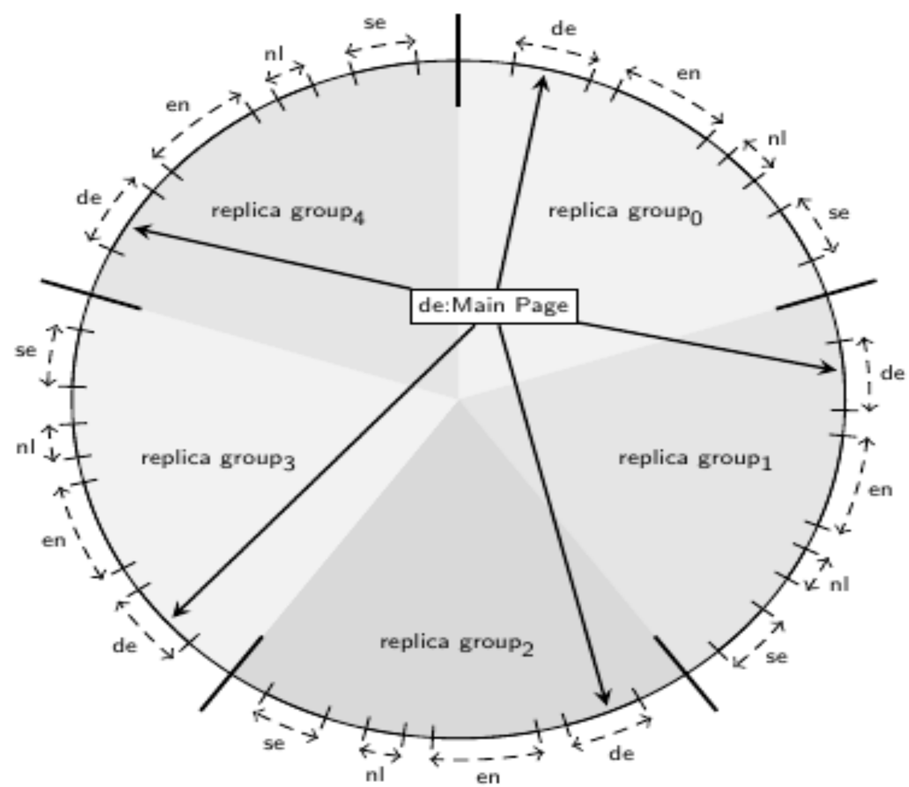


Figure 3. Symmetric replication and multi-datacenter scenario. By assigning the majority of the 'de'-, 'nl'-, and 'se'-replicas to nodes in Europe, latencies can be reduced.

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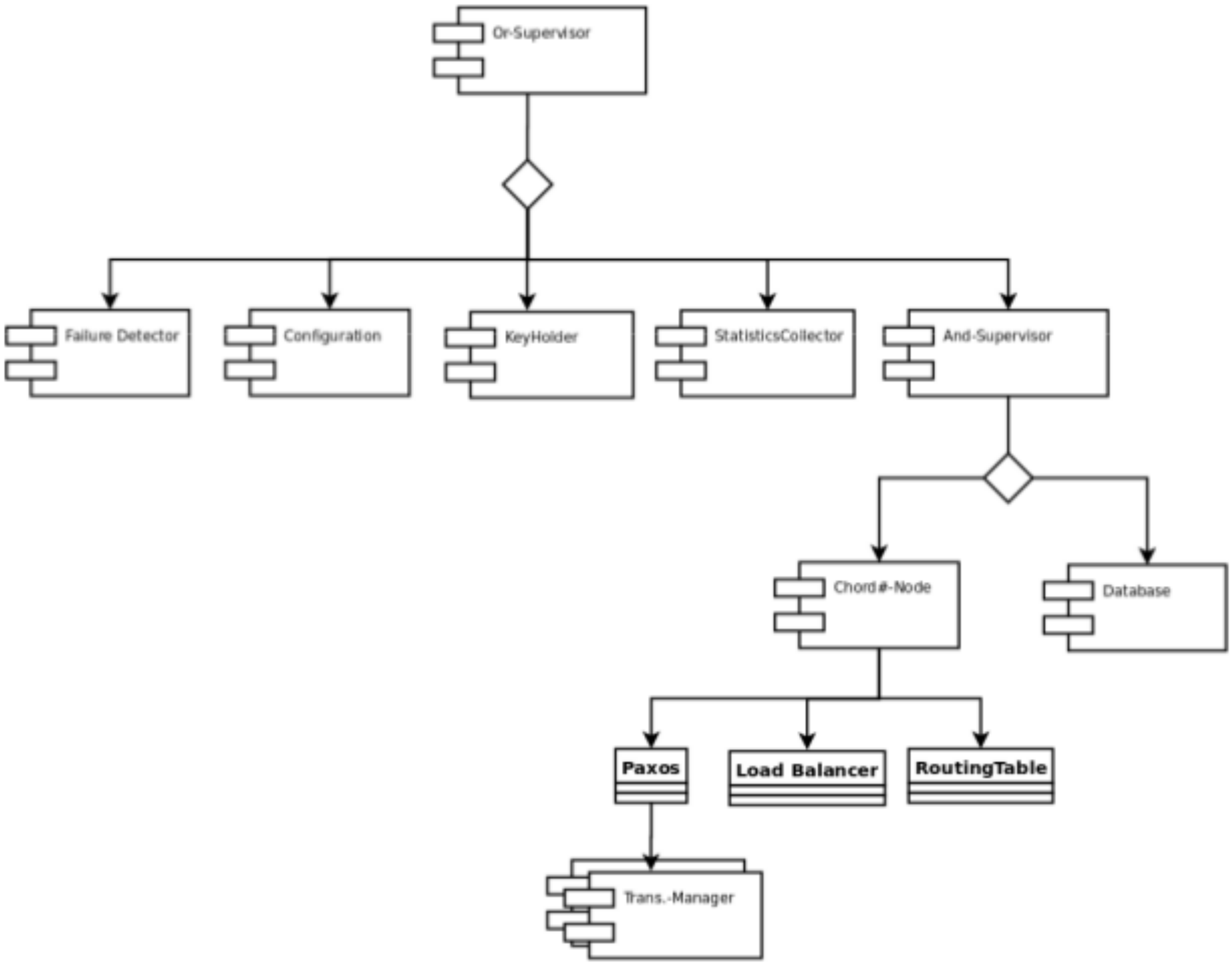
Implementation

- 19,000 lines of code of Erlang
  - 2,400 lines of code for the transactional layer
  - 16,500 for the rest of the system
- 8,000 lines of code of the Java API
- 1,700 lines of code for the Python API

Each Scalaris node runs the following processes:

- Failure Detector
- Configuration
- Key Holder
- Statistics Collector
- Chord # Node
- Database

Implementation



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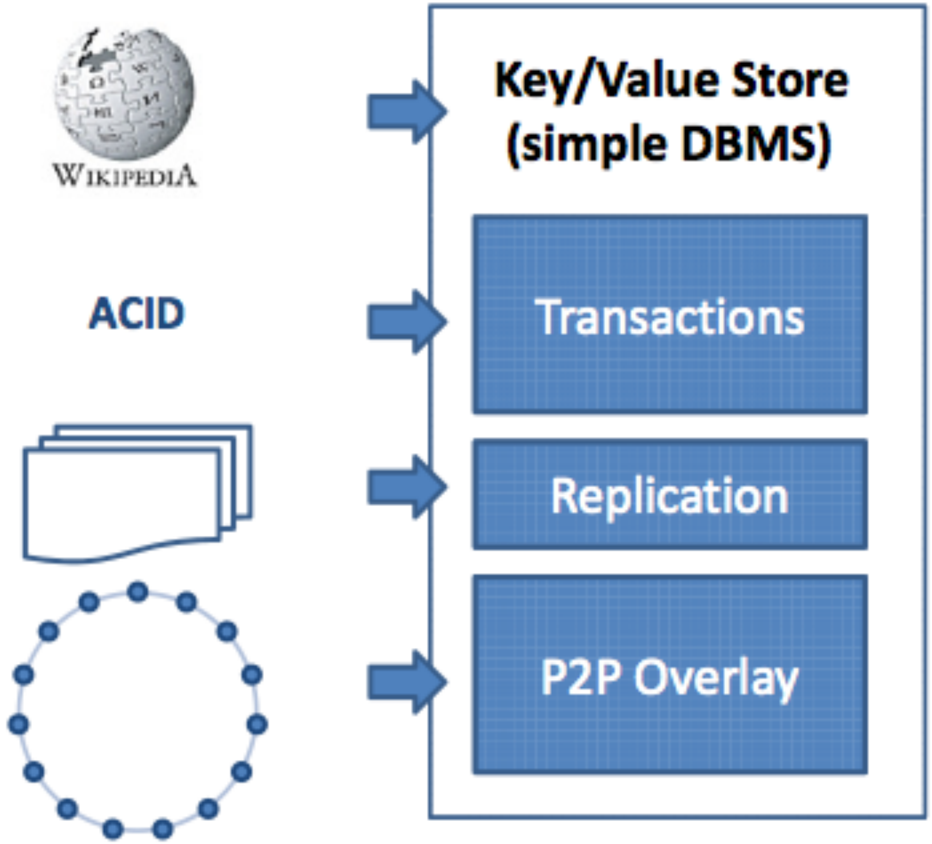
Performance: Wikipedia



50,000 requests per second
- 48,000 handled by proxy
- 2,000 hit the DB cluster

Proxies and web servers were "embarrassingly parallel and trivia to scale"

Focus therefore was implementing the data layer

Translating the Wikipedia Data Model

Wikipedia

– SQL DB

Chord#

– Key-Value Store

```
CREATE TABLE /*$wgDBprefix*/page (
page_id int unsigned NOT
        NULL auto_increment,
page_namespace int NOT NULL,
...
```

Map Relations to Key-Value Pairs

- (Title, List of Versions)
- (CategoryName, List of Titles)
- (Title, List of Titles) //Backlinks

Performance: Wikipedia

MySQL

- Master/Slave setup
  - 200 servers
  - 2,000 requests
  - Scaling is an issue

Scalaris□□

- Chord# setup
  - 16 servers
  - 2,500 requests per second
  - Scales almost linearly
  - All updates are handled in transactions
  - Replica synchronization is handled automatically

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API - Erlang interface

```
F = fun (TransLog) ->
     {X, TL1} = read(TransLog, "Account A"),
     {Y, TL2} = read(TL1, "Account B"),
      if
        X > 100 ->
            TL3 = write(TL2, "Account A", X - 100),
            TL4 = write(TL3, "Account B", Y + 100)
            {ok, TL4};
        true ->
            {ok, TL2};
      end
end,
transaction:do_transaction(F, ...).
```

API - Java Interface

```
// new Transaction object
Transaction transaction = new Transaction();

// start new transaction
transaction.start();
//read account A
int accountA =
   new Integer(transaction.read(”accountA”)).intValue();
//read account B
int accountB =
   new Integer(transaction.read(”accountB”)).intValue();

//remove 100$ from accountA
transaction.write(”accountA”, new Integer(accountA - 100).toString());
//add 100$ to account B
transaction.write(”accountB”, new Integer(accountB + 100).toString());

transaction.commit();
```

API - Erlang

```
TFun = fun(TransLog) ->
    Key = ”Increment”,
    {Result, TransLog1} = transaction_api:read(Key, TransLog),
    {Result2, TransLog2} =
        if Result == fail ->
            Value = 1, % new key
            transaction_api:write(Key, Value, TransLog);
        true ->
            {value, Val} = Result, % existing key
            Value = Val + 1,
            transaction_api:write(Key, Value, TransLog1)
        end,
    % error handling
    if Result2 == ok ->
        {{ok, Value}, TransLog2};
        true -> {{fail, abort}, TransLog2}
    end
end,
SuccessFun = fun(X) -> {success, X} end,
FailureFun =
    fun(Reason)-> {failure, ”test increment failed”, Reason} end,
% trigger transaction
transaction:do_transaction(State, TFun, SuccessFun, FailureFun, Source_PID).
```

Users

- Mostly an academic project
  - Actively developed by Zuse Institute
- onScale
  - Zuse spin-off
  - Scalarix
    - DB snapshotting
    - multi-datacenter optimization
- Eonblast
  - Scalaris fork
  - Scalaxis
    - Disk Persistence
    - Externel Interface, Atomic Operations, Query Extensions, more

Demo

Conclusions

- Scalable key/value store
- Strong data consistency
- Good performance
  - Wikipedia
- Implemented in Erlang
- Java API

Opinions

Joe Armstrong (Ericsson):

“So my take on this is that this is one of the sexiest applications I've seen in many a year. I've been waiting for this to happen for a long while. The work is backed by quadzillion Ph.D's and is really good believe me. “

Richard Jones (lastfm):

"Scalaris is probably the most face-meltingly awesome thing you could build in Erlang. CouchDB, Ejabberd and RabbitMQ are cool, but Scalaris packs by far the most impressive collection of sexy technologies."

Discussion

- Do we need strict consistency?

Discussion

- Does it affect performance?

Discussion

- Does it make implementation more complex?

Discussion

- Is Scalaris a practical system?