SCALING A STARTUP WITH A 21ST CENTURY PROGRAMMING LANGUAGE

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LIGHTKONE
Lightweight computation for networks at the edge

WHO AM I?

Industry (1998 – 2016)

- Software Development Manager for Berklee College of Music online learning platform
- Basho Technologies, developer of Riak database
- Worked on roughly 6 different NoSQL databases

Academia (2016+)

- Ph.D. candidate based in Portugal & Belgium
- Creator of the Lasp programming system for large-scale, asynchronous distributed computing
- Contributor to Microsoft Orleans distributed computing framework

NARRATIVE: WINE RECOMMENDER APP

1. **Implement version 1.0 features using a traditional architecture.**

   We demonstrate implementing features of our application using Martinelli with a traditional three-tier architecture.

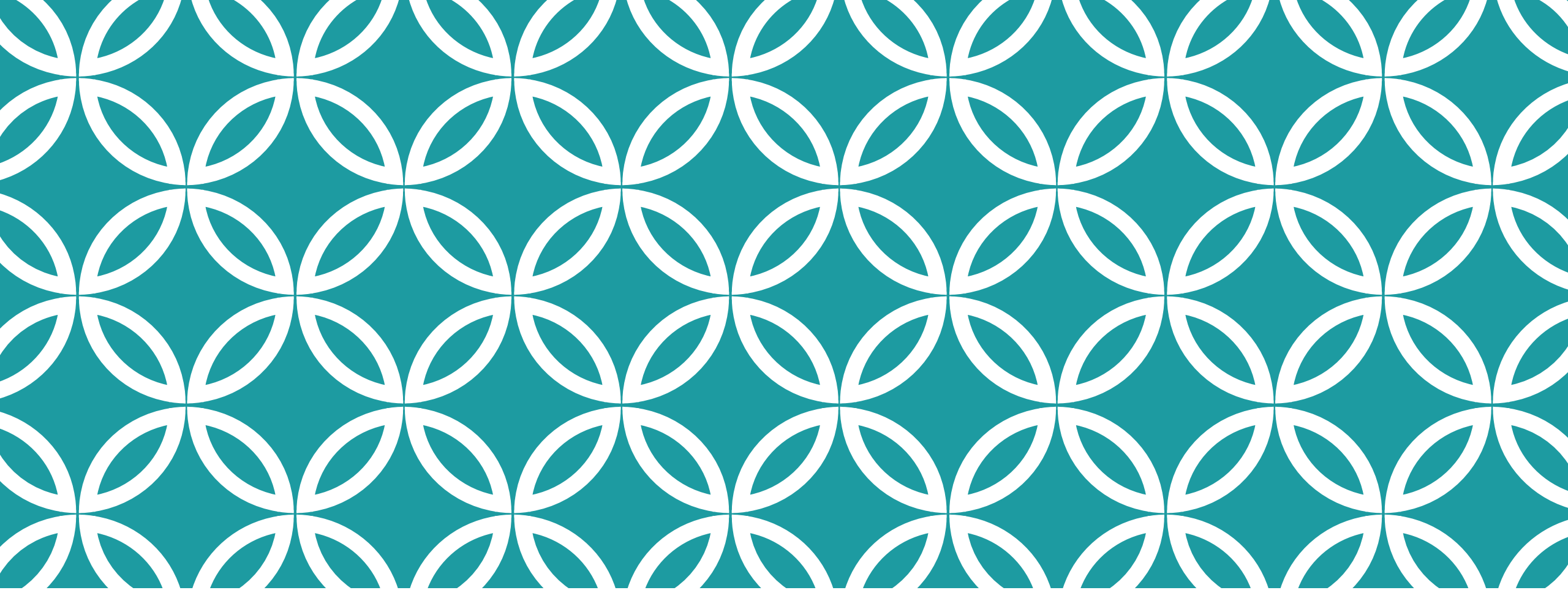
2. **Implement version 2.0 features using an ideal architecture.**

   We demonstrate implem lli with an ideal peer-to-peer highly-avc

3. **What is Martinelli?**

   We present the principles behind Martinelli and the techniques and tools that Martinelli uses to achieve this.

Martinelli is a **fictional** programming language demonstrating an "ideal" in distributed programming language design.



APPLICATION

What features should our application have and how do we build it?

V1.0 FEATURES

Our core feature set for our mobile application, designed using existing technologies and using a traditional data center focused design

Users upload photos of bottles of wine they enjoy through app

Data is processed with ML/AI algorithm to identify and classify

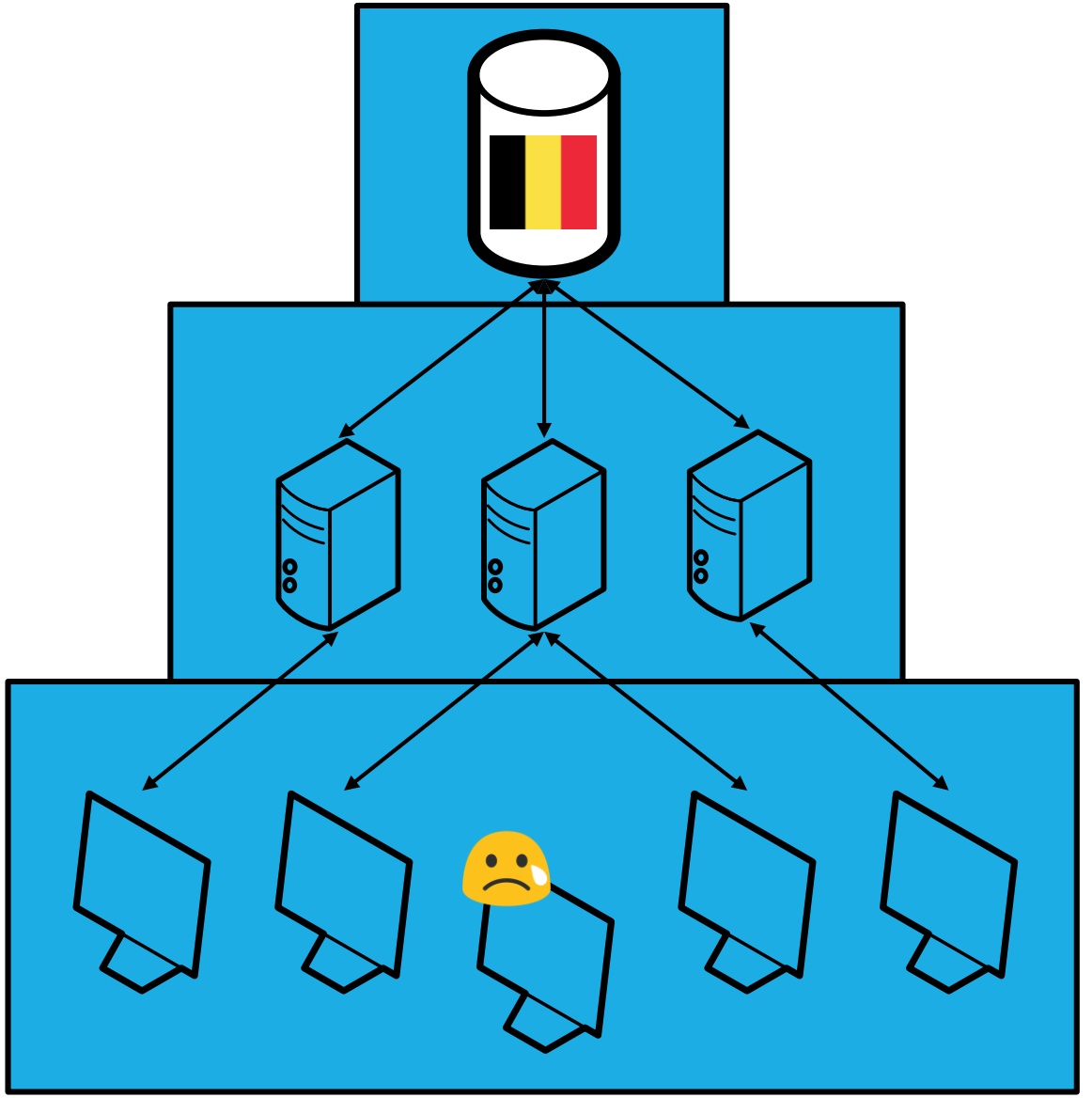
Recommendations are created using an iterative algorithm

TRADITIONAL ARCHITECTURE

- Communication through data center
- Application servers run business logic
- Clients must be online to operate

Analysis

- Application is easy to program
- Exhibits high latency (non-native)
- Exhibits low availability (DC-focused)



CODE: PHOTO UPLOAD

Server

```
database :photos

on_photo do |user_id, photo|
        photos[:user_id].add(photo)
end
```

Key-value store to store photos: in essence, a map.

Store each photo in a map indexed by user.

Client

```
database :photos

on_photo do |photo|
        upload(user_id, photo)
end
```

Every time a photo is taken, upload it to the server.

CODE: RECOMMENDATIONS

Serv

```
databas
databas

process do |user_id in users|
        classify(photos[:user_id], favorites[:user_id])
end

process do |user_id in users|
        recommend(favorites[:user_id], recs[:user_id])
end
```

One process per user to classify photos into favorites.

Client

```
database :recs
database :favorites

process do
        refresh(user_id)
end
```

Key-value stores for recommendations and favorites.

Process keyword defines a concurrent process that keeps executing.

One process per user to recommend based on favorites.

V2.0 FEATURES

Features we would like to add to our application in the near future to enable a better experience for our users

[Fully offline]
Recommendations while offline

- Use local information when offline
- Augment information and refine recommendation when online using available local information; augment recommendations when online

[Partially offline]
Share and modify both favorites and recommendations with friends when offline

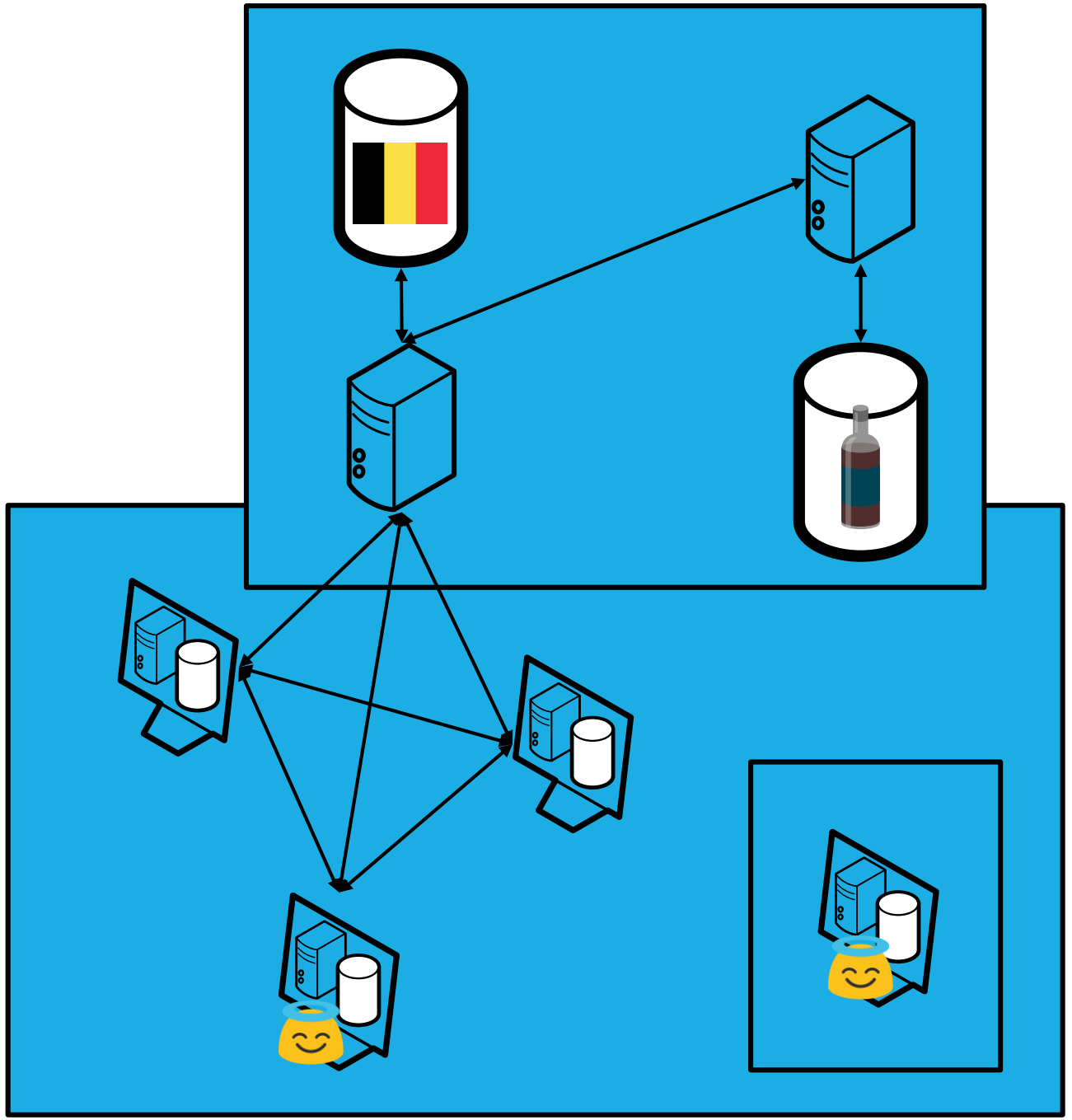
[Online]
Purchase wine off of your recommendation list with transactional guarantees

IDEAL ARCHITECTURE

- Application code at the edge
- Peer-to-peer communication redundancy
- Application is transactional

Analysis

- Application is hard to program
- Exhibits low latency
- Exhibits high availability



CODE: OFFLINE WITH REPLICATION

```
process do |user_id in users|
        refine(photos, favorites)
end

process do |user_id in users|
        refine(favorites, recs)
end
```

Clients run same code as server, operates with available data.

```
database :photos,
    :replicated => :user_id
database :favorites,
    :replicated => true
database :recs,
    :replicated => :user_id
```

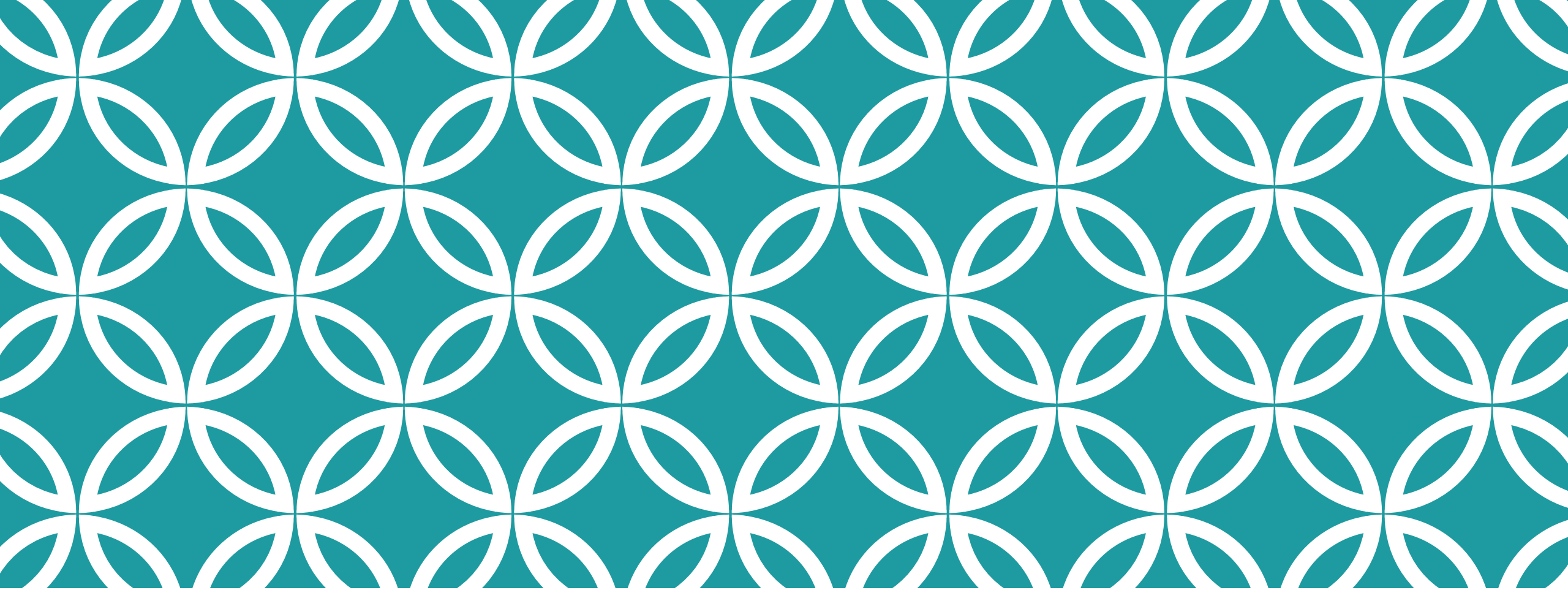
Fully replicated.

Partially replicated by user.

CODE: TRANSACTIONS

```
on_purchase do |user_id, wine|
        atomic do
                recs[:user_id].remove(wine)
                perform_purchase(user_id, wine)
        end
end
```

Wrap operations in an atomic block.



MARTINELLI

"While you're at it, why don't you try my Martinelli?"

– Tom Frost, Naked Lunch

WHY MARTINELLI?

Why do we need a language like Martinelli?

Techniques for v2.0 features exist only in isolation

- Systems, algorithms, etc.

Development largely addressed from a systems composition perspective

- Kafka, to Hadoop with Spark, etc.

Programmers responsible for "gluing" services together at boundaries

An ad-hoc programming model

- Weak semantics
- APIs define the "programming language"

HISTORICALLY

What can history tell us about distributed programming languages?

[Well designed, no adoption]

Pure approaches, new runtime and language

- Argus (Liskov et al. 1986)
  - Transactional support, fault-tolerant handling of RPCs
- Emerald (Black et al. 1986)
  - Objects with object migration; separation of typing/implementation

[Poorly designed, high adoption]

Retrofitting existing systems

- CORBA (OMG, 1991)
  - Leverage existing language semantics, make distribution transparent to the user
  - Cross-language, cross-system, cross-architecture

MARTINELLI

What exactly is Martinelli?

Language for building applications on top of composed systems

- Not possible to reimplement all existing systems into a new runtime
- Composition, “glue” can be independently verified via existing techniques (LDFI 2015, etc.)

Fault-tolerant, highly available infrastructure for application execution

- Peer-to-peer, client-side application execution and data replication

Programming model designed for distributed applications

- Restricted language semantics depending on the network topology and environment the application is being deployed in

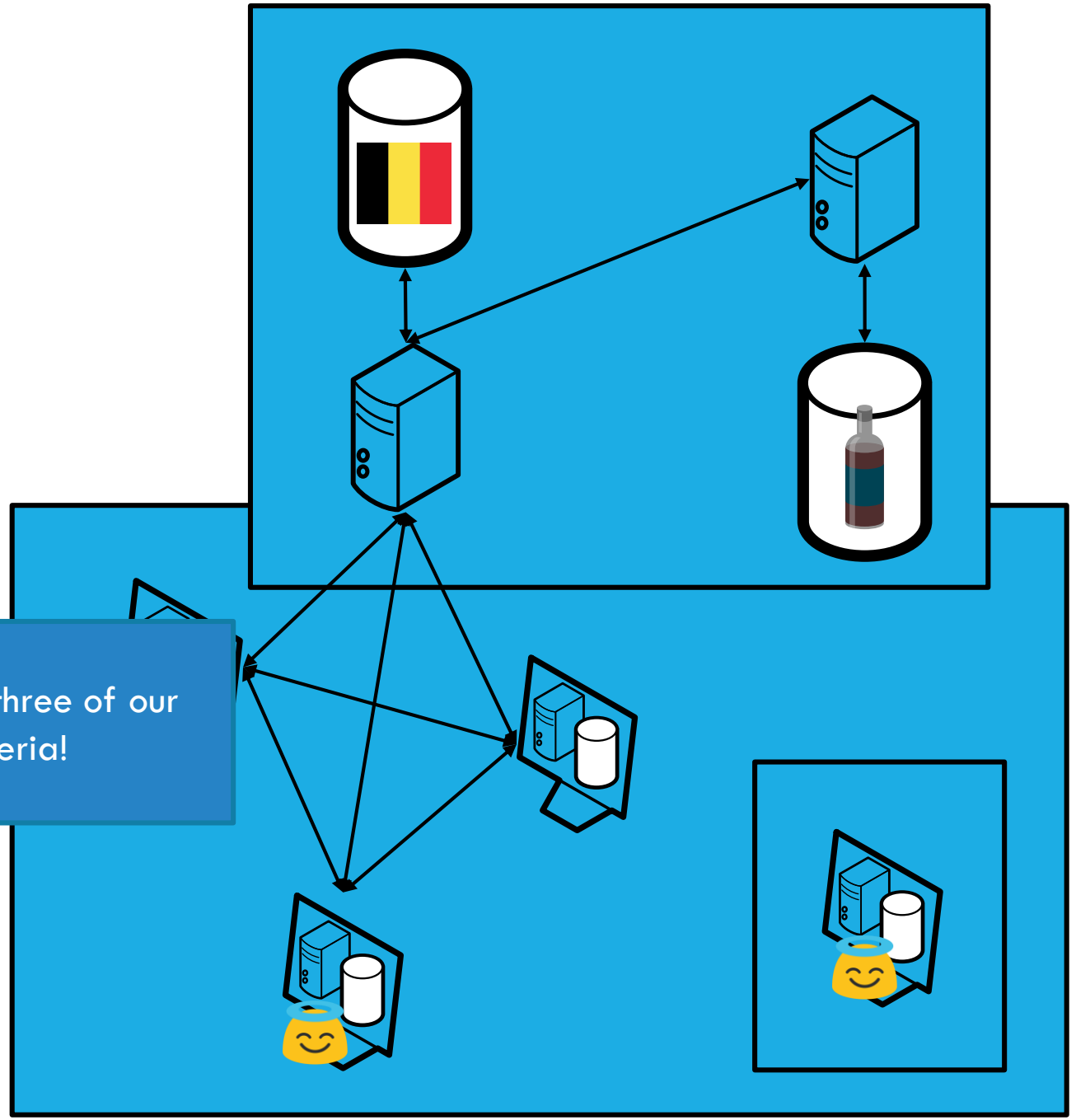
MARTINELLI ARCHITECTURE

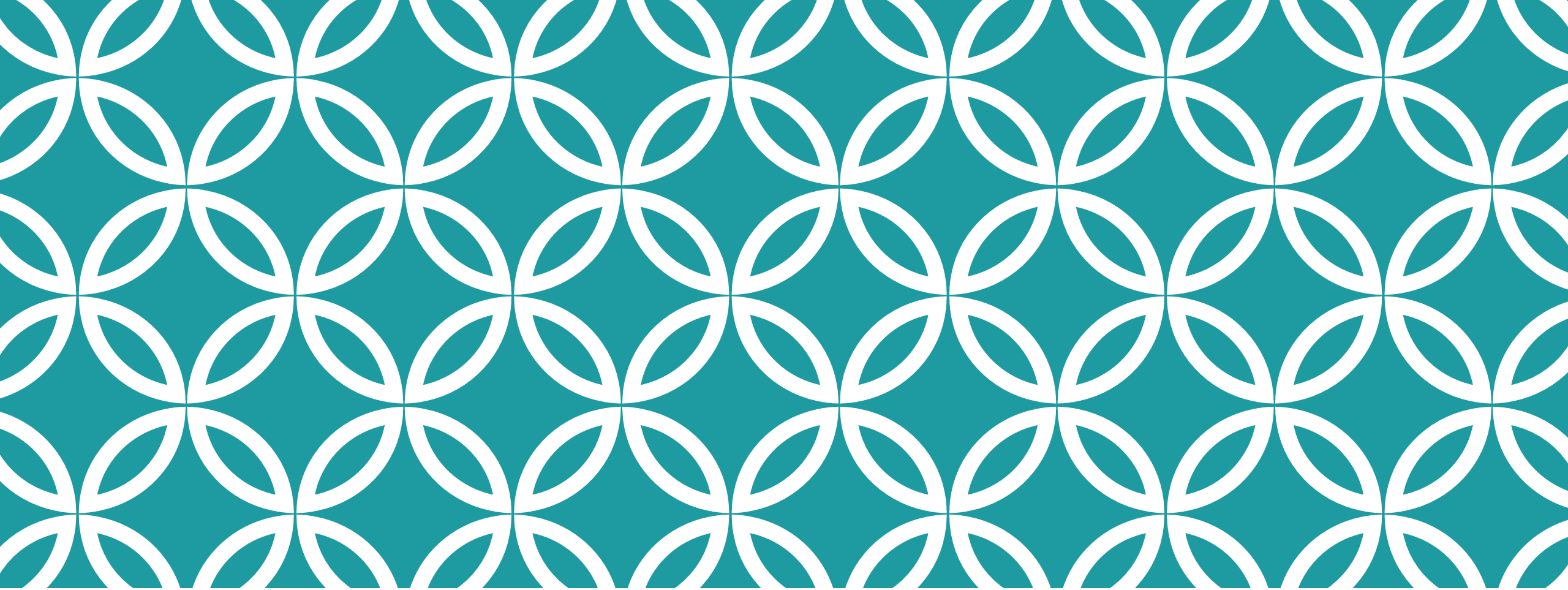
- Application code at the edge
- Peer-to-peer communication redundancy
- Application is transactional

Analysis

- Application is easy to program
- Exhibits low latency
- Exhibits high availability

Meets all three of our criteria!





TECHNIQUES AND METHODS

What are the techniques and methods Martinelli leverages?

PEER-TO-PEER INTERACTIONS

Peer-to-peer communication enables highly resilient communication when failures occur in large networks.

Peer-to-peer topologies widely studied and successful, examples:

- Kademlia (BitTorrent)
- Lasp, Cassandra (HyParView)

Provide greater redundancy and efficient management of state and communication links

Eliminate the need for a central coordination point

APPLICATION MIGRATION

Applications (and their data) must be migrated to the edge to exploit local operation and low latency interactions.

Edge computing moves app to the device

- Provides a better experience to user

Today, this implementation must be duplicated, implemented twice

Promising approaches:

- Portable VMs
- Architecture specific code targeting
- Program slicing

CONVERGENT COMPUTATION

Concurrency is problematic for large-scale distributed applications.

Concurrent operation may generate conflicts

- How to pick "winning" update?
- How to present conflicts to the end user?

Edge introduces additional concurrency

- False concurrency (efficient tracking, false positives)
- Modifying stale data (conflicts from staleness)

Specialized data structures:

- Conflict-free Replicated Data Types
- Operational Transformations
- Cloud Types
- Mergeable Data Structures

ATOMIC OPERATIONS

Transaction protocols typically provide both atomicity and isolation for groups of updates.

Transactions provide ACID

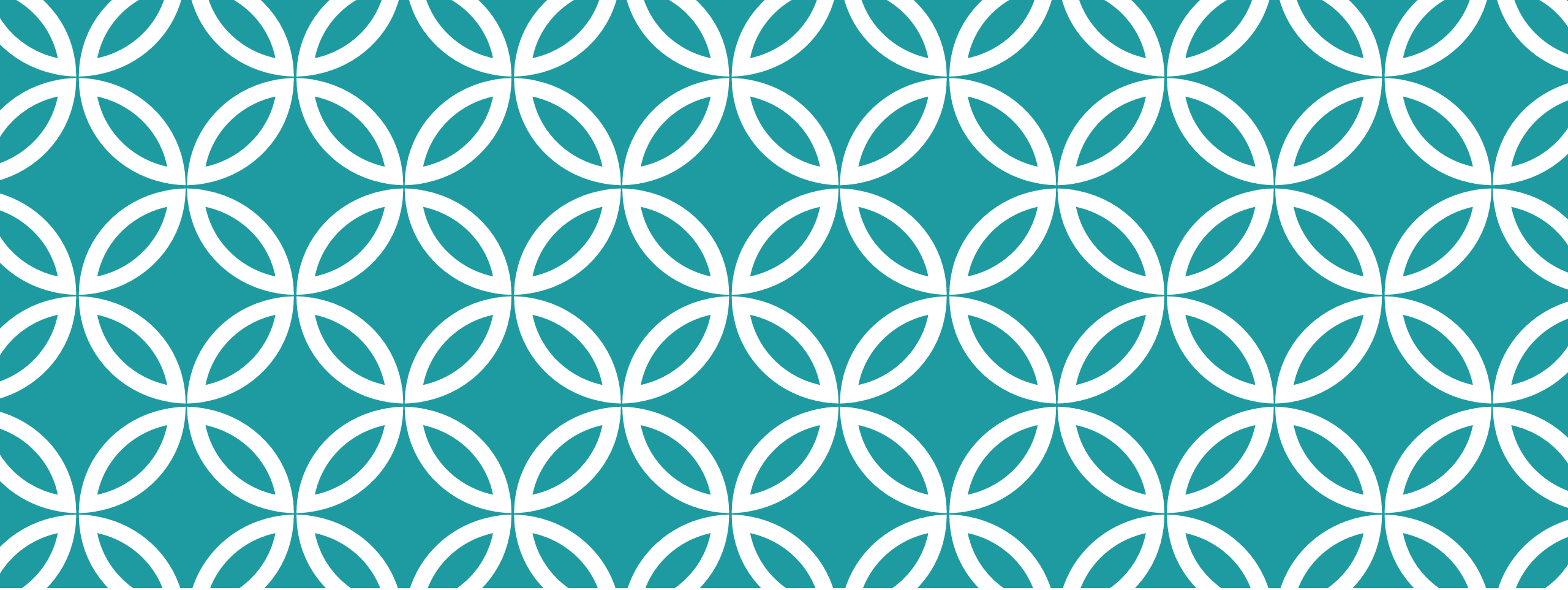
- Atomicity (A): indivisible groups
- Isolation (I): sequentiality of groups

Distribution makes it difficult

- 2PC: fault-tolerant atomic commitment
- 2PL: isolation (serializability), but locking problematic under partition

Promising approaches:

- Distributed Sagas: atomicity, no isolation
- MSFT Orleans: 2PL/2PC at single-DC scale
- Cure: causal, weak isolation, atomicity for geo-scale



THE FUTURE

Where are we and what's next in distributed language design?

EVOLVING LANDSCAPE

Research systems.

Independent solu
Martinelli-like languages with peer-to-peer interactions, application code at the edge, transactional guarantees and convergent-by-design programming models.

Production systems that evolved from research systems.

Lasp connects Erlang systems together using a safe distributed programming model on very large P2P clusters (1024+ nodes)

Legion provides P2P client interactions for vanilla JavaScript apps with CRDTs and Google AppEngine

SwiftCloud provides causally consistent transactions at the client

Erlang VM has been ported to extremely low-power computing devices enabling application migration to the edge

MSFT Orleans provides 2PL/2PC transactions at geo-scale

LDFI verifies fault-tolerance under composition; latter, for application invariants under weak ordering

MOVING FORWARD

We've seen new greenfield systems fail to gain adoption

- CORBA vs. Argus, Emerald, etc.

Therefore, we must strive to build research solutions that leverage existing tools

- Orleans with Microsoft CLR, CRDTs in Riak, Legion with Google AppEngine

Systems centric approach provides a weak foundation

- Weak semantics, hard to make guarantees about composition correctness

Strive for higher-level abstractions via programming languages and models

- Strong semantics, focus on writing applications and not gluing services together

THANKS!

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