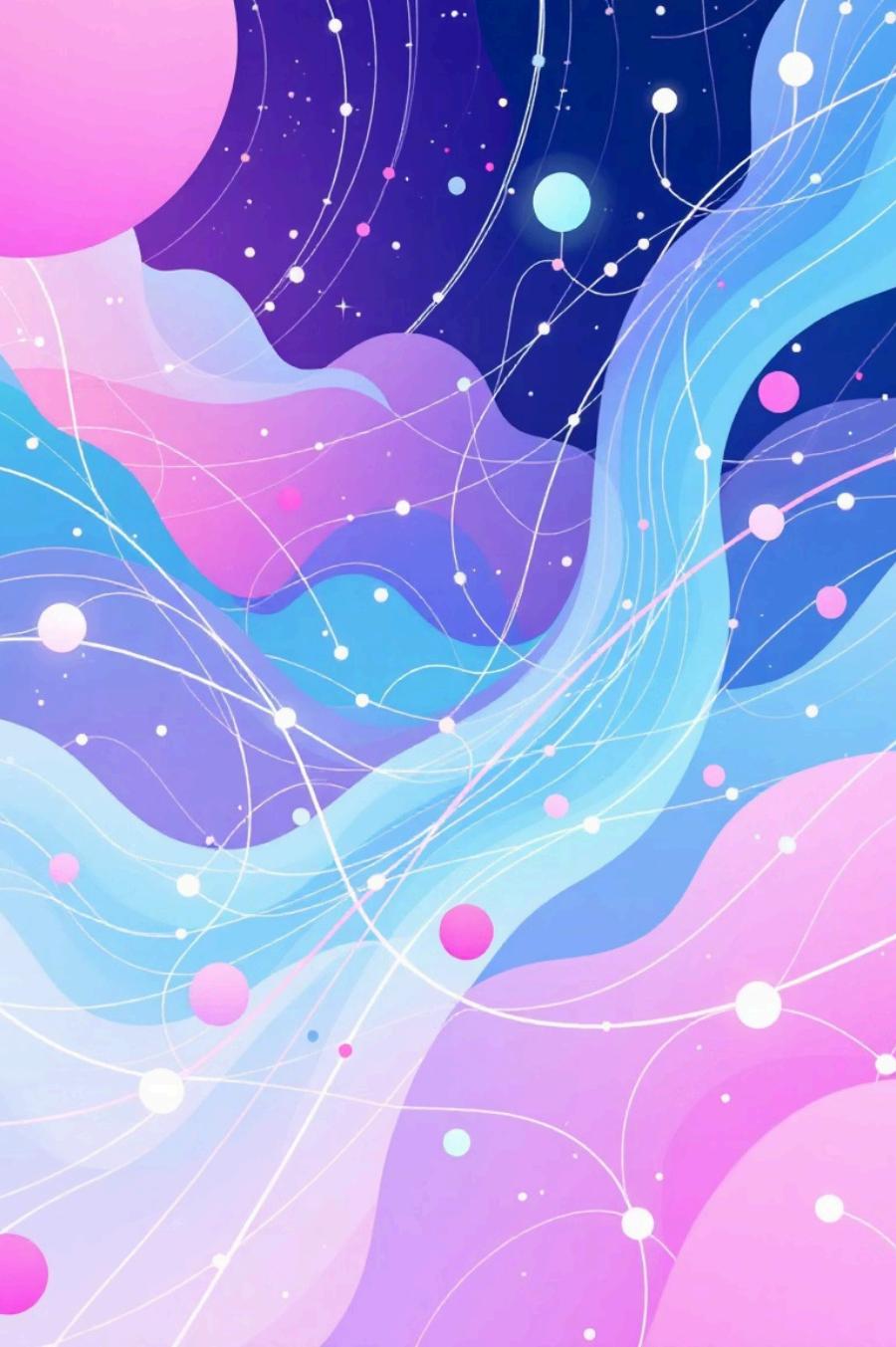


URL Shortener with Click Analytics

High-Performance Global Link Management System

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System Overview

What We're Building

A globally distributed URL shortening platform that combines lightning-fast redirects with comprehensive click analytics. This system transforms long, unwieldy URLs into memorable short links while capturing detailed engagement metrics in real-time.

Core Capabilities

- Sub-50ms redirect latency worldwide
- 99.99% uptime guarantee across all regions
- Real-time analytics with <60s freshness
- Handles billions of monthly redirections
- Custom domain support with SSL

Design Document Purpose



Target Audience

Product managers, software engineers, SREs, and security teams working with distributed systems



What's Covered

Complete system architecture, data models, scalability patterns, API specifications, and security posture



End Goal

A comprehensive blueprint for building, deploying, and operating a production-grade URL shortening service

Problem Statement & Market Context

The Long URL Problem

URLs are becoming increasingly complex with tracking parameters, deep paths, and encoded content. They're difficult to share, track, and manage across marketing campaigns and customer touchpoints.

Analytics Blind Spots

Existing solutions lack real-time visibility into click patterns, geographic distribution, device types, and referral sources. Marketing teams need actionable insights within seconds, not hours.

Business Impact

Without proper link management and analytics, organizations lose critical data for campaign optimization, compliance reporting, and strategic decision-making. Every unmeasured click is a missed opportunity.



System Vision & Objectives

<50ms

Redirect Latency

Sub-50 millisecond response time globally

99.99%

System Uptime

Four nines availability guarantee

<60s

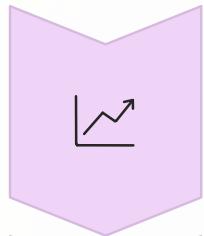
Analytics Freshness

Real-time data with minimal delay

Key Features

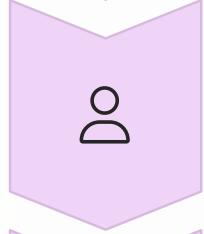
- Custom branded domains with SSL
- REST and GraphQL APIs
- Horizontal scalability
- Cost-optimized infrastructure
- Enterprise-grade security
- 99.999% data durability

High-Level Architecture



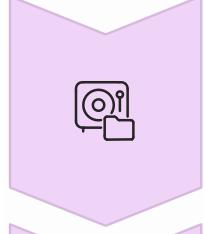
Global Edge CDN

Geographic distribution and caching layer



Microservices Layer

Link management and redirect services



Cache & KV Store

Redis cache with persistent key-value storage



Event Streams

Kafka pipeline for analytics ingestion



Analytics Warehouse

OLAP database for queries and reporting

Hot Path (Redirect)

Optimized for sub-50ms latency using edge caching and KV lookups

Cold Path (Analytics)

Asynchronous processing through streaming pipeline for enrichment and aggregation

Core System Components

01

Link Service

Handles link creation, updates, and management. Generates unique short codes using base62 encoding and manages custom domain mappings with validation.

02

Redirect Service

Ultra-fast lookup and HTTP 301/302 redirects. Deployed at edge locations with multi-layer caching (CDN → Redis → KV store) for optimal performance.

03

Analytics Ingest

Captures click events asynchronously without impacting redirect latency. Publishes to Kafka with guaranteed delivery and handles peak traffic spikes.

04

Stream Processor

Enriches raw events with geo-IP data, user-agent parsing, referrer analysis, and bot detection. Transforms data for downstream analytics.

05

Analytics API

GraphQL and REST endpoints for querying metrics, generating reports, and powering dashboards. Supports complex aggregations and time-series queries.

-  **Architecture Principle:** Complete separation of redirect and analytics planes ensures redirect performance remains unaffected by analytics workload.

Data Model Architecture



- 1 Raw Events
Timestamp, short code, IP, user agent, referrer captured at click time
- 2 Enriched Events
Geo data, device type, browser, OS, bot flags added via stream processing
- 3 Aggregates
Pre-computed rollups by time, geography, device for fast dashboard queries
- 4 Analytics API
Real-time and historical queries served from OLAP warehouse

Core Entities

- **User:** Authentication, permissions, API keys
- **Organization:** Team workspaces, billing
- **Link:** Short code → long URL mapping

Storage Strategy: KV store (DynamoDB) for sub-10ms lookups on redirect path. OLAP database (ClickHouse) for analytics queries with columnar storage and compression.

Non-Functional Requirements

Performance

- P99 redirect latency: <50ms
- 10M+ requests per second capacity
- Analytics queries: <500ms P95
- Cache hit ratio: >95%

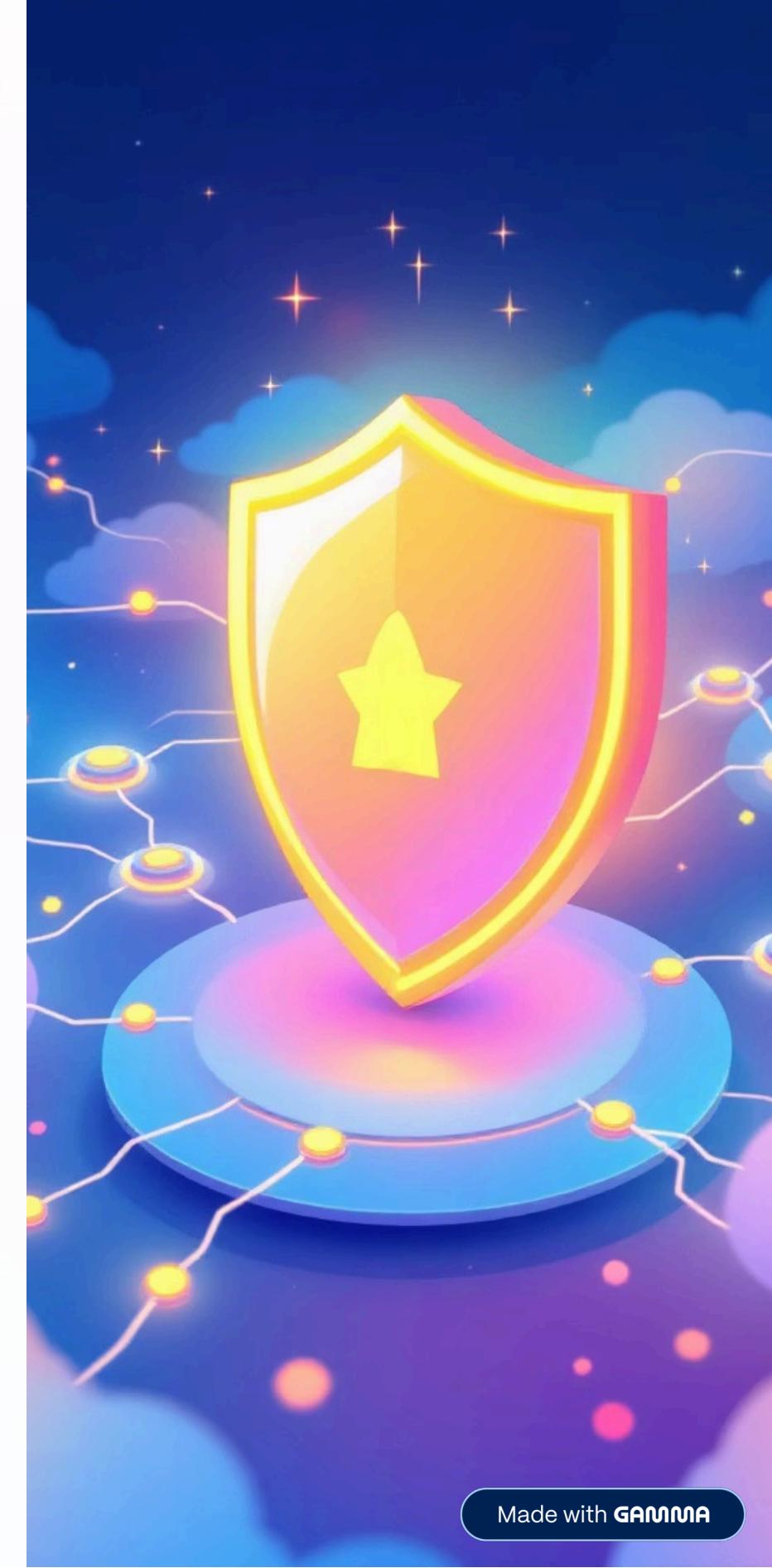
Reliability

- 99.99% uptime SLA for redirects
- Multi-AZ deployment with auto-failover
- Circuit breakers and graceful degradation
- Zero data loss for analytics events

Security

- TLS 1.3 for all connections
- Encryption at rest (AES-256)
- RBAC with fine-grained permissions
- GDPR/CCPA compliant data handling

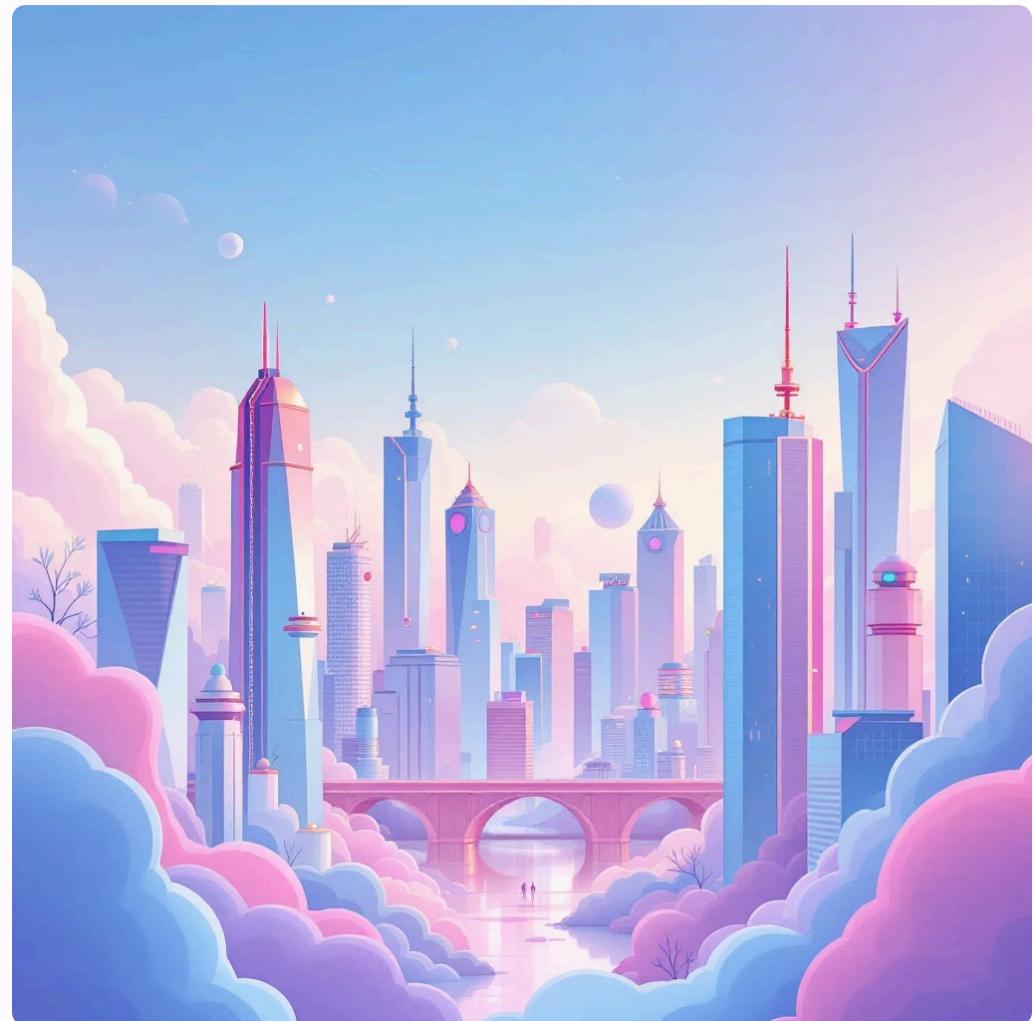
Resilience Strategies: Multi-region active-active deployment, cache fallback layers, rate limiting, DDoS protection, and automated health checks ensure continuous availability even during infrastructure failures or traffic surges.



Looking Forward

Why This Architecture Wins

This design delivers global scale, sub-50ms performance, and real-time analytics through careful separation of concerns, multi-layer caching, and event-driven architecture. The system is built for reliability with 99.99% uptime, comprehensive security, and GDPR compliance from day one.



Phase 1: Proof of Concept

Validate core redirect performance and basic analytics in single region



Phase 2: Full Analytics

Deploy complete streaming pipeline with enrichment and dashboard



Phase 3: Multi-Region

Expand to 3+ regions with active-active topology and SLO validation

- Future Enhancements: Machine learning for click prediction, anomaly detection for fraud prevention, advanced A/B testing capabilities, and expanded geographic coverage to 15+ edge locations.