

Event-driven architecture in payments:

Lessons from scaling Digital Twin

Building high-performance, resilient and scalable financial systems requires more than just robust infrastructure. It demands a deep understanding of the technical bottlenecks that stymie even the most well thought-out architectures.

With over 30 years of Core banking and transaction processing experience, Matera applied deep expertise to design Digital Twin, a real-time transaction ledger that:

- Authorizes transactions and updates balances 24X7
- Operates as a 'shadow ledger,' meaning it can mirror account balances without directly interfering with the main Core system
- Handles sub-millisecond reads and high-throughput writes - over 13,000 tps in cloud environments
- Eliminates bottlenecks of legacy batch processing by maintaining a write-back cache for real-time financial operations
- Ensures data integrity in distributed deployments through multi-datacenter replication with eventual consistency guarantees
- Runs on AWS-native infrastructure (Aurora, Kafka, Graviton, etc.) to maximize scalability and efficiency.

While Digital Twin is software that works alongside a financial institution's Core, its primary impact is on customer experience. Consumers, today, don't have patience for slow banking services or failed transactions. Digital Twin is modern software that enables financial institutions to meet the real-time expectations of their customers.

The following is a breakdown of how the above technical outcomes are achieved.

Design based on first principles

Core banking systems do many things well - maintaining accounts, generating reports, calculating fees, among many other complicated tasks.

What Cores do not provide is a good transaction ledger. They were designed for batch processing, and struggle with instant balance validation and atomic updates required by modern payments.

Instead of forcing Core banking systems to act in real-time, Digital Twin operates in parallel, processing transactions instantly and syncing back asynchronously.

Digital Twin is architected to hold minimal logic and perform few, but critical functions, to achieve extremely high throughput and response times while maintaining resiliency. It doesn't consume unnecessary resources, and it scales up or down as needed.

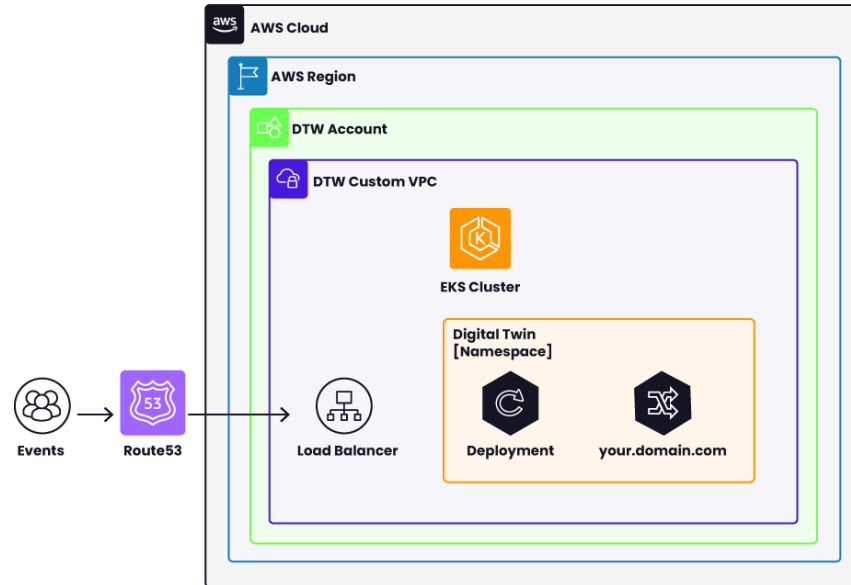
Key Features

- Tracks balances from any account type - DDAs, savings, cards, loyalty, crypto etc.
- Multi-currency, multi-decimal point, multi-time zone
- Event-driven architecture
- All financial operations are logged as immutable events
- Optimized for high-volume reads & writes: handles millions of balance updates per second without performance degradation
- Eventual consistency: distributed write-back cache ensures instant updates while maintaining near real-time reconciliation with Core systems, not stopping or slowing down in case of Core banking failures. Double spending solved!
- Supports multiple database types - MySQL, SQL Server, Oracle, at the same time, making it resilient even on database software bugs

With Digital Twin, financial institutions can de-couple transaction authorization from the Core.

Cloud-native scaling and AWS integration

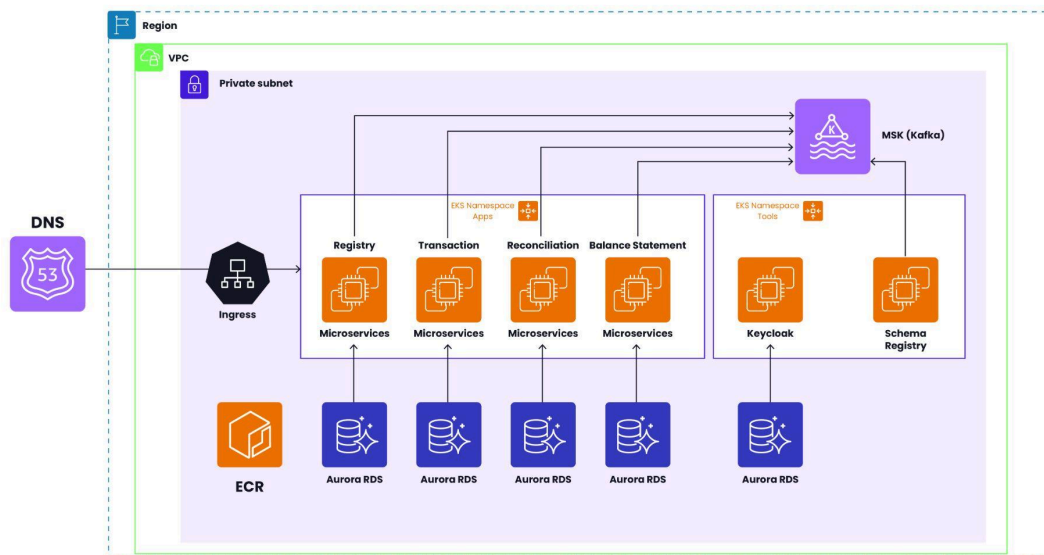
Digital Twin leverages AWS-native services like Aurora MySQL, Kafka, and ElastiCache to ensure high performance and scalability. It supports multi-region failover, enabling high availability and disaster recovery across AWS regions. With real-time event streaming powered by Kafka, transactions are replicated instantly for seamless processing. Additionally, Digital Twin can integrate with AI & ML pipelines, feeding transaction data into Amazon SageMaker for fraud detection, risk modeling, and advanced analytics. Below is an AWS deployment example.



How Digital Twin Delivers Unmatched Performance

➤ Multi-database architecture for maximum efficiency

Digital Twin does not rely on a single database. Instead, it optimizes workloads across multiple databases within its microservices architecture, ensuring that activity in one module doesn't impact the performance of another.



Here's how each microservice is designed for efficiency:

- Transaction Service: High-Speed Balance Validation
The Transaction Service is responsible for real-time transaction approvals and ensuring funds availability. It operates on Amazon Aurora MySQL and can be adapted to DynamoDB if ACID compliance is met. This service is dedicated solely to authorization, which prevents competing queries from slowing down performance. By isolating this function, Digital Twin achieves ultra-fast reads and writes, making it highly efficient for processing high-volume transactions with minimal latency.
- Balance & Statements Service: Queries & Statement Generation
The Balance & Statements Service handles on-demand balance lookups and statement generation, which occur less frequently than transaction authorizations and it's a readonly operation. It currently uses Aurora MySQL but may evolve to support Amazon Redshift to improve large-scale query performance. Designed with an append-only model, this service does not update records but instead logs every new transaction as a separate row, making it ideal for event journaling, regulatory compliance, and full historical auditing. Efforts are ongoing to explore leveraging Redshift to support analytics and large-scale balance queries more efficiently.
- Account Registry: Account Lifecycle Management
The Account Registry tracks the status of accounts, whether they are open, closed, or blocked. Unlike balance validation or transaction processing, these operations do not require frequent updates, making it essential to separate them from transactional databases. By isolating account lifecycle management, this service prevents unnecessary database load, reducing clutter in high-speed transaction systems while allowing independent scaling for account onboarding and lifecycle events.
- Reconciliation Database: Cross-System Data Validation
The Reconciliation Database ensures balance accuracy across systems by handling cross-system data validation. This service operates in the background, periodically comparing and validating transaction data without disrupting real-time operations. By keeping reconciliation separate, Digital Twin ensures that high-performance transactional workloads remain uninterrupted while maintaining data integrity across the entire ecosystem.

➤ **AWS Optimizations: Built for Graviton & Kafka Streaming**

Digital Twin runs on AWS Graviton CPUs, which provide higher performance per dollar compared to traditional x86 processors, while also consuming less power and improving scalability.

To handle real-time transaction processing efficiently, Digital Twin utilizes Kafka-based streaming, ensuring that all transactions are forwarded to Kafka before reaching the query database. This approach enables asynchronous batch processing, significantly reducing the load on transactional databases by offloading intensive read operations, resulting in faster performance and greater system reliability.

➤ **Unique Innovation: Solving High-Frequency Debit Bottlenecks**

Traditional ledgers struggle with high-frequency debit transactions, especially when a single account processes thousands of debits per second. This is because each debit requires sequential balance validation, creating a bottleneck that slows performance.

Digital Twin overcomes this challenge by leveraging intelligent batch processing with Kafka. Instead of processing each debit synchronously through an API, Digital Twin detects high-frequency debits, aggregates them in real-time, and updates the balance once with the total amount. This approach eliminates the need for thousands of individual balance checks, significantly reducing latency. Transactions are then bulk-inserted into the ledger, drastically improving efficiency. In real-world tests, this method has achieved 3,400 transactions per second (TPS) per account, with performance scaling even faster as volume increases.

Real world applications of Digital Twin

Instant Payments

Most Cores go offline nightly for batch processing and are unable to process instant payments during this time. With Digital Twin authorizing transactions 24 X 7, banks can offer instant payments to their customers without replacing their Core.

M&A or Core replacement

Instead of migrating from one Core to another at one time, banks can shadow account balances on Digital Twin from the legacy Core well in advance of the final transition. During

this period, Digital Twin can handle transaction authorization and support digital channels, allowing the bank to gradually migrate customer data, posting rules, and other critical elements in phases while ensuring seamless operations.

Banking-as-a-Service (Baas)

As a high performance ledger, Digital Twin can host both sponsor bank balances and fintech partner account balances so the bank has visibility into all accounts for reconciliation and overall fraud and AML monitoring.

Resiliency during unexpected outages

Digital Twin ensures continuity because it's authorizing transactions and updating balances whether the Core is up or down. Even during unexpected outages, customers can continue making payments, checking balances, and conducting business as usual.

How Cielo Used Digital Twin to Seamlessly Migrate to a New Core

In early 2024, Cielo, Brazil's largest merchant acquirer and payment processor, chose Madera as their new Pix provider and Core Banking Solution, with Digital Twin playing a key role in the transition.

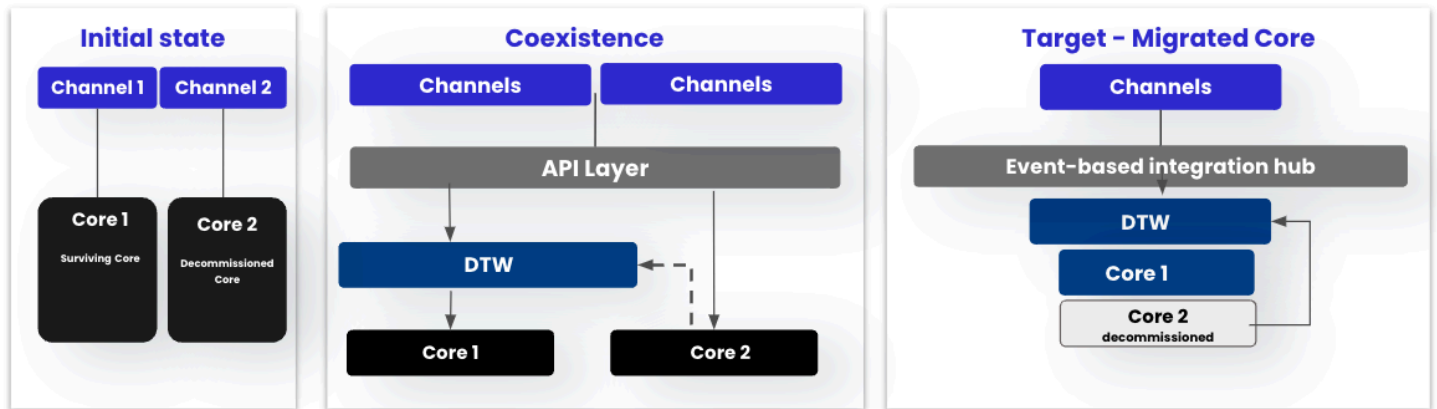
The key challenge was transitioning from a SaaS ledger to Digital Twin, running in their own AWS account without disrupting its massive payment operations.

The migration took a phased approach to minimize risk. Cielo first replaced its old Pix provider with Madera, completing that transition in just three months. Then, they began moving accounts from the Old Core to Madera's Core using Digital Twin. They started by replicating low-volume accounts to Digital Twin first before gradually replicating high-volume accounts until all 1.2 million merchant accounts had been migrated.

During this process, a transaction router determined whether an account was on Digital Twin or the Old Core, ensuring seamless processing. Notably, merchants whose accounts were migrated to Digital Twin first reported significantly faster transaction times, proving the efficiency of the new system.

The full Core migration took about four months, and the impact was immediate. Pix transaction volumes skyrocketed, going from zero to over 120 million transactions per month in just eight months. Even during Black Friday—when transaction volumes surged 30%—Cielo's system handled the load flawlessly. Today, with Digital Twin optimizing its Core operations, Cielo continues to

process over 120 million transactions per month, proving that a phased, well-executed migration strategy can deliver massive performance gains without disruption.



Bottom Line: A Ledger is More Than Just Two Tables

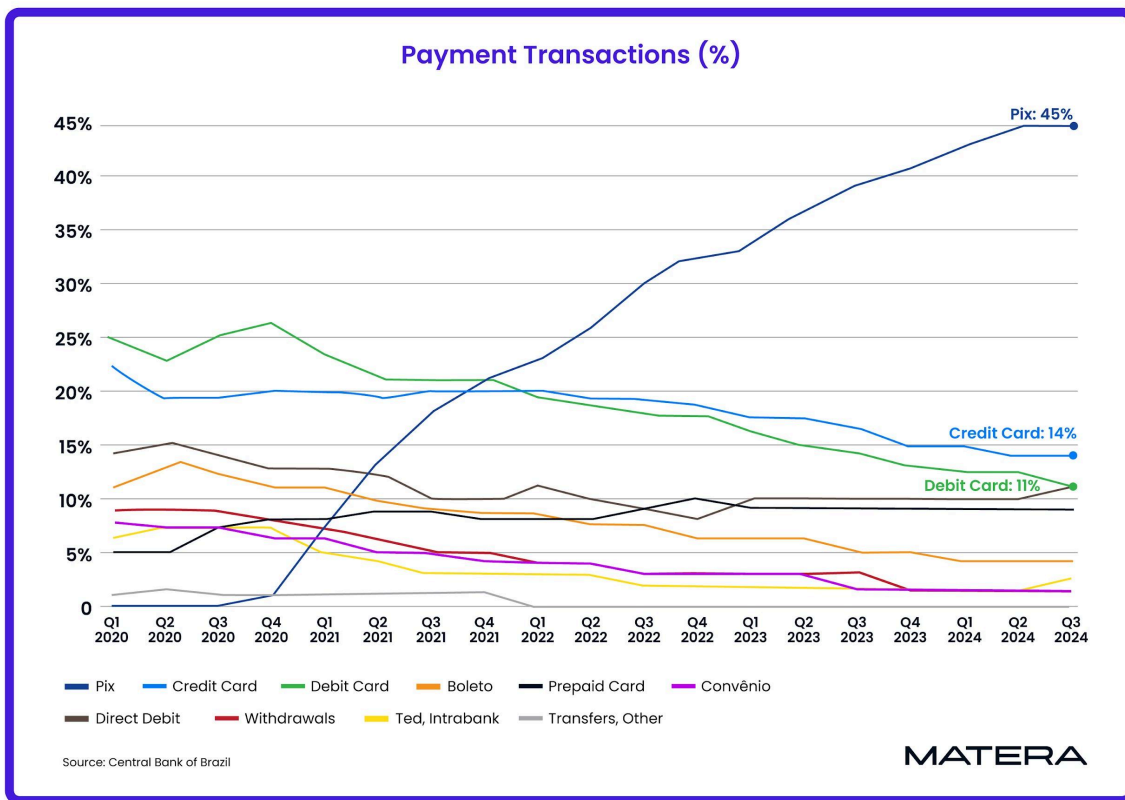
Most ledgers rely on a simple balance and transactions table, but Digital Twin proves that real-world performance demands specialized architecture. By separating workloads across multiple databases, leveraging real-time batch processing, and optimizing with AWS-native services like Graviton, Kafka, DynamoDB, and Redshift, Digital Twin removes contention and maximizes efficiency under high load.

Appendix

Genesis of Digital Twin

Matera is a tech company headquartered in Brazil with expertise in Core Banking and Instant Payments. Matera’s Core has over 50 modules that have been continuously improved over three decades. When Pix instant payments launched in Brazil in 2020, Matera built Pix software so clients could send and receive payments in under six seconds.

Pix is the most successful instant payments scheme in the world. Within one year after launch, the number of Pix transactions exceeded credit and debit transactions combined, and over 70% of Brazilians had used Pix. Today, there are over 6 billion Pix instant payments per month, 80% more than credit and debit combined. 45% of all payment transactions are now Pix compared to 14% credit card and 11% debit card.



Matera is now the largest 3rd party provider of Pix software facilitating over 350 million instant payments a month.

It was this meteoric rise in Pix that led to the creation of Digital Twin. Core banking systems struggled to keep up. Rather than build a new Core, Matera created Digital Twin to decouple transaction authorization from the Core.