QBurst | A High AI-Q™ Company

Real-Time Digital Twin Platform for Underground Mining Operations

Enabling live workforce visibility, asset telemetry, and operational intelligence through a scalable mining digital twin platform.

Overview

- Delivered a cloud-native digital twin platform combining real-time workforce tracking, equipment telemetry, and 3D mine visualization.
- Unified live location intelligence with asset health monitoring through event-driven microservices and streaming architecture.
- Enabled sub-second operational updates across dashboards for movement tracking, utilization, safety monitoring, and equipment diagnostics.
- Improved emergency response readiness, operational coordination, and data-driven decision-making across underground mining operations.

Client Profile

A large-scale mining operations organization, based in the Middle-East, managing complex underground environments across active mining zones. The company leverages advanced operational technologies and real-time monitoring systems to support workforce safety, asset visibility, equipment telemetry, and coordinated underground operations at scale.

Challenges

Underground mining operations presented significant challenges related to visibility, connectivity, coordination, and safety monitoring across active mining zones.

- Limited real-time situational awareness across underground tunnels, shafts, and operational zones.
- Dependence on manual check-ins and radio communications for personnel coordination and emergency response.

- Lack of unified visibility across asset movement, workforce tracking, and equipment health telemetry.
- Need for accurate tracking across multiple mine levels and complex underground pathways.
- Requirement for scalable monitoring capable of supporting thousands of tracked assets and workers.
- Environmental risks including signal interference, connectivity loss, and hardware resilience challenges underground.

QBurst Solution: Building a Real-Time Mining Digital Twin Platform

We designed and implemented a real-time asset and workforce monitoring platform that combined live location intelligence with asset health telemetry in a unified operational environment.

The solution leveraged an event-driven microservices architecture running on Kubernetes to support high-throughput streaming, distributed processing, and real-time responsiveness at scale.

At the core of the platform, digital twins were created for every tracked asset using a distributed virtual actor model, enabling continuous state management, telemetry processing, and live operational visualization.

The platform delivered:

- Real-time tracking of personnel, vehicles, mobile equipment, and fixed assets.
- Continuous monitoring across underground tunnels, shafts, access routes, and operational zones.
- Live 2D and 3D mine visualization with multi-level map support.
- Dynamic movement visualization with live location overlays and path tracing.
- Zone, geofence, and restricted-area monitoring for safety and operational control.
- Real-time dashboards displaying movement, utilization, idle time, safety zones, and equipment health.

- Dispatcher views for operational coordination and monitoring.
- Time usage, utilization, check-in/check-out, and operational analytics dashboards.

Asset Health Telemetry Integration

The telemetry module monitored engine diagnostics and operational metrics using CAN bus data captured from on-asset hardware devices installed on vehicles and mining equipment.

- High-frequency telemetry and diagnostic data collection from equipment.
- Raw telemetry file ingestion into distributed file storage.
- Connector services for telemetry extraction, decoding, and event publishing.
- Real-time stream processing and normalization using distributed backend services.
- Historical telemetry persistence within a time-series database.
- Conditional monitoring and real-time alarm generation.
- Live dashboard updates through sub-second streaming events.

Real-Time Location Tracking Integration

The location intelligence module provided precise indoor and outdoor tracking through a hybrid tracking infrastructure.

The solution incorporated:

- BLE and Wi-Fi-based tracking tags attached to assets for redundancy and precision.
- BLE anchor deployment across mining areas for consistent underground coverage.
- Gateway infrastructure for signal aggregation and transmission.
- Real-time signal triangulation and geolocation normalization.
- Coordinate mapping to nearest node graph points for accurate path alignment and visual movement representation.
- Smooth real-time movement updates across digital mine maps.

Safety, Visualization, and Operational Intelligence

The platform enabled multiple operational and safety-focused capabilities, including:

- Panic and SOS alert support.
- Man-down and inactivity detection.
- Automated emergency notifications and evacuation alerts.
- Dynamic route guidance to safe exits.
- Heatmaps, dwell-time analysis, and operational flow monitoring.
- Bottleneck identification and anomaly detection for unusual behavior or unauthorized movement.
- Equipment active/inactive monitoring and movement path visualization.
- Worker-to-equipment assignment visibility.
- Configurable zone management based on operational requirements.
- The system also supported clustered, section-wise, and individual worker views, enabling supervisors and control room operators to monitor live operational activity across multiple mining units simultaneously.

Scalable Cloud-Native Architecture

The platform was built using:

- .NET Core for backend microservices and worker services.
- Microsoft Orleans for distributed digital twin state management and stream processing.
- Apache Kafka for high-throughput event streaming.
- CrateDB for large-scale time-series telemetry storage.
- Kubernetes for orchestration and scalability.
- SignalR for sub-second real-time frontend updates.
- Distributed file storage for telemetry log management.

The architecture was designed to support enterprise-grade scalability, reliability, security, and usability across multiple mining sites and thousands of tracked devices.

Technical Highlights

- Event-driven microservices architecture running on Kubernetes.
- Digital twin implementation using distributed virtual actor models.
- High-throughput telemetry and location streaming using Apache Kafka.
- Real-time SignalR-based movement and telemetry updates.
- Hybrid RTLS infrastructure supporting BLE, Wi-Fi, RFID, GNSS/GPS, and related tracking technologies.
- CAD-integrated 2D and 3D multi-level mine visualization.
- Time-series telemetry processing and historical analytics.
- Node graph mapping for accurate underground movement visualization.
- Multi-user and multi-operation monitoring support.
- Configurable geofencing and safety zone management.

Impact

- Improved real-time operational visibility by **55%** across underground personnel, vehicles, and equipment.
- Enhanced emergency response readiness by **48%** through live tracking, SOS alerts, and evacuation intelligence.
- Increased worker safety by **52%** with continuous monitoring, inactivity detection, and hazard-aware visualization.
- Improved operational coordination through dispatcher views, live utilization metrics, and equipment monitoring.
- Enabled proactive, data-driven decision-making using movement history, telemetry insights, and operational analytics.
- Delivered a scalable digital foundation for intelligent underground mining operations.