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NGORONGORO CONSERVATION AREA AUTHORITY

Software Requirements Specification

NCAA Digital Transformation - Offline Operations & Sync Module

Version: 1.0

Date: 2025-11-06

Status: Draft

https://www.ncaa.go.tz

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1 Document Information

Field	Value
Project Name	NCAA Digital Transformation - Offline Operations & Sync Module
Version	1.0
Date	2025-11-06
Project Manager	TBD
Tech Lead	TBD
Qa Lead	TBD
Platforms	['Ubuntu Server 22.04', 'PostgreSQL 15+', 'NAS Linux']
Document Status	Draft
Module Code	OFFLINE_SYNC
Parent Project	NCAA Digital Transformation - Ngorongoro Gateway System

2 Project Overview

2.1 What Are We Building

2.1.1 System Function

Offline-first data management and synchronization system enabling 9 gates to operate independently without network connectivity while maintaining data consistency and integrity. System includes local PostgreSQL storage on Intel NUC, hourly backups to NAS RAID 1, gate-to-gate synchronization with 15-minute maximum delay, and UPS power backup for 2-4 hour runtime.

2.1.2 Users

- Gate Staff: Operate system during network outages
- System Administrators: Monitor sync status and resolve conflicts
- Technical Support: Troubleshoot sync issues
- Management: Monitor system health and uptime

2.1.3 Problem Solved

Safari portal system frequently down due to network failures, 30+ minute wait times for data synchronization at Old HQ, manual workarounds when system unavailable, data loss risk from paper records, no backup systems at remote locations (Lemala 2 has no computer), slow internet at Ndutu and Olduvai causing service delays, system misbehavior at Main Gate showing false overstay errors

2.1.4 Key Success Metric

99% system uptime regardless of network status, gate-to-gate sync within 15 minutes maximum, zero data loss, hourly backups completed successfully, 2-4 hour operation on UPS during power outages, automatic conflict resolution for 95% of sync conflicts

2.2 Scope

2.2.1 In Scope

- Local PostgreSQL database on Intel NUC at each gate
- Fast NVMe SSD storage for live operations

- Hourly automated backup to NAS RAID 1
- Daily NAS snapshots for point-in-time recovery
- Weekly encrypted USB backup to safe
- Gate-to-gate data synchronization over HTTP API
- Conflict detection and resolution
- Network failure detection and automatic offline mode
- Sync queue management for batch processing
- UPS integration for power backup (2-4 hours)
- Data integrity checks and validation
- Sync monitoring and alerting
- Manual sync trigger for urgent updates

2.2.2 Out Of Scope

- Real-time streaming replication (eventual consistency acceptable)
- Distributed database clustering
- Automatic failover to cloud systems
- Satellite internet connectivity
- Multi-master write conflicts (single master per gate for gate-specific data)

3 User Requirements

3.1 Offline Operation

Feature Code	I Want To	So That I Can	Priority	Notes
FT-SYNC-OFFLINE-MODE	Operate system fully offline when network unavailable	Continue processing visitors at gates with no/poor connectivity (Ndutu, Lemala, slow Olduvai)	Must	All core functions available offline: registration, permit verification, vehicle logging, capacity tracking. Network detection automatic.
FT-SYNC-OFFLINE-INDICATOR	See clear visual indicator of online/offline status	Know when system is operating offline and when sync will occur	Must	Status bar showing: Online (syncing), Offline (X hours since last sync), Syncing now. Color-coded: green/yellow/red.
FT-SYNC-OFFLINE-QUEUE	View pending changes waiting to sync	Monitor what data needs to be synchronized when network returns	Should	Queue shows: pending records count, oldest pending change time, estimated sync time.
FT-SYNC-OFFLINE-PERFORMANCE	Experience same performance whether online or offline	Maintain service quality regardless of network status	Must	Local NVMe SSD ensures fast query response. No performance

Feature Code	I Want To	So That I Can	Priority	Notes
				degradation offline.

3.2 Data Synchronization

Feature Code	I Want To	So That I Can	Priority	Notes
FT-SYNC-GATE-TO-GATE	Sync data between gates within 15 minutes maximum	Maintain near real-time capacity tracking and prevent duplicate entries	Must	Small payloads (10-50KB). HTTP API between NUCs. Works over 2G. Automatic retry on failure.
FT-SYNC-PRIORITY	Prioritize critical data for sync (permits, capacity) over lower priority (historical reports)	Ensure most important data syncs first on limited bandwidth	Must	Priority levels: Critical (permits, capacity - 5min target), High (vehicle logs - 15min), Normal (reports - 1hr), Low (archives - 24hr).
FT-SYNC-BATCH	Batch multiple changes for efficient sync	Minimize network overhead on slow connections (2G at remote gates)	Must	Batch size: 100 records or 50KB, whichever comes first. Compression enabled.
FT-SYNC-CONFLICT-DETECT	Automatically detect sync conflicts (same record modified at multiple gates)	Prevent data corruption and inconsistencies	Must	Timestamp-based conflict detection. Last-write-wins for most data. Manual resolution for critical conflicts.
			Must	

Feature Code	I Want To	So That I Can	Priority	Notes
FT-SYNC-CONFLICT-RESOLVE	Automatically resolve common sync conflicts	Minimize manual intervention (target 95% auto-resolution)		Rules: Vehicle logs append-only, capacity updates merge, permit updates from originating gate wins. Conflict log maintained.
FT-SYNC-MANUAL-TRIGGER	Manually trigger sync for urgent updates	Immediately sync critical changes (emergency permit extensions)	Must	Manual sync button. Confirmation dialog showing sync scope. Progress indicator.
FT-SYNC-INTEGRITY	Validate data integrity during sync	Ensure no data corruption during transmission	Must	Checksums for each batch. Transaction rollback on failure. Retry mechanism.

3.3 Backup Recovery

Feature Code	I Want To	So That I Can	Priority	Notes
FT-SYNC-BACKUP-HOURLY	Automatically backup PostgreSQL to NAS every hour	Protect against NUC SSD failure with hourly granularity	Must	pg_dump + rsync to NAS. Backup time <10 minutes. Verification after backup. Retention: 7 days hourly.
FT-SYNC-BACKUP-DAILY	Create daily snapshots on NAS for point-in-time recovery	Recover from data corruption or accidental deletion	Must	Daily NAS snapshots at midnight. Retention: 30

Feature Code	I Want To	So That I Can	Priority	Notes
				days. Space-efficient incremental snapshots.
FT-SYNC-BACKUP-WEEKLY	Create weekly encrypted USB backups for disaster recovery	Maintain offline backup in safe for catastrophic failures	Must	Weekly USB backup. AES-256 encryption. Physical storage in safe. Retention: 12 weeks.
FT-SYNC-RESTORE-HOURLY	Restore from hourly NAS backup within 30 minutes	Quickly recover from NUC failure	Must	Documented restore procedure. Tested monthly. Restore script automated.
FT-SYNC-RESTORE-POINT	Restore to specific point in time from daily snapshots	Recover from data corruption or user errors	Must	Point-in-time recovery UI. Preview restore before commit. Backup current state before restore.

3.4 Power Management

Feature Code	I Want To	So That I Can	Priority	Notes
FT-SYNC-UPS-INTEGRATION	Integrate with UPS for 2-4 hour power backup	Continue operations during power outages	Must	UPS 1000VA powers NUC + NAS + Switch. Runtime: 2-4 hours. Low battery alerts.
FT-SYNC-UPS-SHUTDOWN	Gracefully shutdown systems when	Prevent data corruption from	Must	10% battery triggers graceful shutdown. Save

Feature Code	I Want To	So That I Can	Priority	Notes
	UPS battery critically low	sudden power loss		all pending changes. Close database connections. Shutdown sequence: PWA -> PostgreSQL -> OS.
FT-SYNC-UPS-ALERT	Receive alerts when on UPS power or battery low	Take action before system shutdown	Must	Visual alert on PWA. SMS to technical staff. Battery percentage displayed.
FT-SYNC-POWER-RECOVERY	Automatically restart and resume operations when power restored	Minimize downtime without manual intervention	Must	Auto-boot on power restore. Database integrity check. Resume pending syncs. Staff notification.

3.5 Local Storage

Feature Code	I Want To	So That I Can	Priority	Notes
FT-SYNC-STORAGE-NVME	Store live operational data on fast NVMe SSD	Ensure quick query response for gate operations	Must	512GB NVMe SSD on NUC. PostgreSQL optimized for SSD. Query response <100ms.
FT-SYNC-STORAGE-NAS	Archive historical data on NAS RAID 1	Protect against disk failure with redundancy	Must	2x 2TB drives in RAID 1. Survives single disk failure. Hot-swap capability.

Feature Code	I Want To	So That I Can	Priority	Notes
FT-SYNC-STORAGE-MONITORING	Monitor storage usage and receive alerts when space low	Prevent system failure due to full disk	Must	Alert at 80% full. Critical alert at 90%. Automatic archive to NAS when NUC SSD >80%.
FT-SYNC-STORAGE-CLEANUP	Automatically archive old data from NUC SSD to NAS	Manage limited SSD space efficiently	Must	Archive records >30 days old to NAS. Keep current month on NUC SSD for fast access.

3.6 Network Resilience

Feature Code	I Want To	So That I Can	Priority	Notes
FT-SYNC-NET-DETECT	Automatically detect network availability	Switch between online and offline modes seamlessly	Must	Ping test to Old HQ every 30 seconds. Exponential backoff on failures. Switch to offline mode after 3 failed pings.
FT-SYNC-NET-SLOW	Detect slow network and adjust sync strategy	Optimize for 2G connections at remote gates	Must	Bandwidth detection. Reduce batch size on slow connection. Increase priority threshold.
FT-SYNC-NET-RETRY	Automatically retry failed sync with exponential backoff	Handle intermittent network issues without manual intervention	Must	Retry: immediately, 30sec, 1min, 5min, 15min, then hourly. Max 10 retries

Feature Code	I Want To	So That I Can	Priority	Notes
				before manual intervention needed.
FT-SYNC-NET-CELLULAR	Support cellular data (2G/3G) for sync	Sync even with minimal connectivity	Must	Works over 2G. Small payloads optimized for slow connections. Compression enabled.

3.7 Monitoring Alerting

Feature Code	I Want To	So That I Can	Priority	Notes
FT-SYNC-MONITOR-STATUS	View sync status dashboard for all 9 gates	Monitor system health from Old HQ	Must	Dashboard shows: last sync time, pending records, online/offline status, errors. Per-gate view.
FT-SYNC-MONITOR-ALERTS	Receive alerts for sync failures or delays	Proactively address issues before they impact operations	Must	Alert conditions: Sync delay >1 hour, backup failure, storage >80%, UPS on battery, conflict requiring manual resolution.
FT-SYNC-MONITOR-LOGS	Access detailed sync logs for troubleshooting	Diagnose and resolve sync issues	Must	Logs: sync attempts, success/failure, duration, records synced, conflicts, errors. Searchable. 30-day retention.

Feature Code	I Want To	So That I Can	Priority	Notes
FT-SYNC-MONITOR-METRICS	View historical sync performance metrics	Identify trends and optimize sync strategy	Should	Metrics: avg sync time, success rate, network uptime, backup success rate. Charts and graphs.

4 Technical Requirements

4.1 Performance Standards

Requirement	Target	How To Test
Gate-to-gate sync delay	≤ 15 minutes maximum	Create record at one gate, verify receipt at others within 15 min
Hourly backup duration	< 10 minutes	Monitor pg_dump + rsync time for typical database size
Database query response	< 100ms for 95% of queries	Load testing with typical query patterns
System uptime	99% regardless of network status	Offline operation tests, uptime monitoring over 30 days
UPS runtime	2-4 hours for NUC + NAS + Switch	Full load test with UPS disconnected from mains
Conflict auto-resolution rate	≥ 95%	Synthetic conflict scenarios, measure manual intervention rate

4.2 Platform Requirements

Platform	Minimum Version	Target Version	Notes
Database	PostgreSQL 15	PostgreSQL 16+	Logical replication features, better performance
Operating System	Ubuntu Server 22.04 LTS	Ubuntu Server 24.04 LTS	Long-term support, security updates
Storage	512GB NVMe SSD, 2x 2TB HDD RAID 1	1TB NVMe SSD, 2x 4TB HDD RAID 1	Future-proofing for data growth

4.3 Security Privacy

Requirement	Must Have	Implementation
Data encryption at rest	True	AES-256 encryption for NAS backups and USB backups
Data encryption in transit	True	TLS 1.2+ for gate-to-gate sync over HTTP API
Backup integrity verification	True	Checksums verified after every backup, test restore monthly
Access control for backups	True	Role-based access to backup systems, audit trail for restore operations

5 External Dependencies

5.1 Third Party Services

Service	What It Does	Criticality	Backup Plan
SMS Gateway (optional)	Send alerts for critical sync failures	Nice to have	Email alerts only

5.2 Device Requirements

Feature	Required	Optional	Notes
UPS 1000VA	True	False	Powers NUC + NAS + Switch for 2-4 hours. USB or network management interface.
Network connectivity (intermittent OK)	True	False	Works with 2G minimum. Offline operation when unavailable.
NAS with RAID 1	True	False	4-bay Synology/ QNAP, 2x 2TB minimum, supports snapshots

6 Release Planning

6.1 Development Phases

Phase	Features Included	Timeline	Success Criteria
Phase 1 (Single Gate Testing)	['Local PostgreSQL setup', 'Offline operation', 'NAS backup', 'UPS integration', 'Basic monitoring']	6 weeks	Single gate operational offline for 7 days, hourly backups successful, restore tested
Phase 2 (Multi-Gate Sync - 3 Gates)	['Gate-to-gate sync', 'Conflict detection & resolution', 'Priority sync', 'Sync monitoring dashboard']	8 weeks	3 gates syncing within 15 minutes, 95% auto-conflict resolution, zero data loss
Phase 3 (Full Deployment - 9 Gates)	['All 9 gates operational', 'Full monitoring & alerting', 'Performance optimization', 'Network resilience features']	8 weeks	All gates syncing reliably, 99% uptime, comprehensive monitoring in place

6.2 Release Checklist

- PostgreSQL configured on all NUC units
- NAS backup systems operational at all gates
- UPS installed and tested (2-4hr runtime verified)
- Gate-to-gate sync tested and performing within 15min SLA
- Conflict resolution rules implemented and tested
- Offline operation tested at all gates for 24+ hours
- Backup and restore procedures documented and tested

- Monitoring dashboard operational at Old HQ
- Alert system configured and tested
- Weekly USB backups established
- Staff trained on sync monitoring and manual triggers

7 Risks Assumptions

7.1 Risks

Risk	Probability	Impact	Mitigation
Network outages longer than 4 hours causing significant sync delays	Medium	Medium	Offline-first design, large sync queues, manual sync triggers when network restored, acceptable delay up to 24 hours for non-critical data
Sync conflicts requiring manual resolution overwhelming staff	Low	Medium	95% auto-resolution target, conflict resolution training, clear escalation procedures
Storage capacity exhausted due to unexpected data growth	Low	High	Storage monitoring with 80% alerts, automatic archival, spare drives available, documented expansion procedure
UPS battery degradation reducing runtime below 2 hours	Medium	Medium	Annual UPS battery replacement, runtime testing quarterly, spare batteries stocked
Database corruption requiring restore	Low	High	Hourly backups with verification, daily snapshots, weekly offline backups, tested restore procedures

7.2 Assumptions

- Network connectivity available intermittently (even if slow/unreliable)
- Gate staff can operate system with clear offline/online indicators
- 15-minute sync delay acceptable for capacity management
- Power outages typically shorter than 4 hours (UPS capacity)
- NUC hardware reliable for 24/7 operation in remote conditions
- RAID 1 on NAS provides sufficient redundancy for backup data
- Sync conflicts infrequent due to gate-specific data partitioning

8 Market Specific Considerations

8.1 Primary Market

- Ngorongoro Conservation Area, Tanzania - 9 remote gates

8.2 Target Demographics

- Gate staff operating in offline conditions
- System administrators monitoring from Old HQ

8.3 Local Considerations

- Very limited network connectivity at remote locations (Ndutu no cellular, Lemala 1&2 low connectivity)
- Slow internet even when available (2G speeds common)
- Power reliability issues requiring UPS backup
- Remote locations making physical repairs challenging (spare NUC units at Old HQ)
- Staff may have limited technical skills for troubleshooting
- Harsh environment conditions (dust, heat) affecting hardware

9 Sign Off

9.1 Approval

Role	Name	Signature	Date

9.2 Document History

Version	Date	Changes Made	Changed By
1.0	2025-11-06	Initial draft based on gate nodes architecture and field report observations	Development Team

10 Detailed Feature Requirements

10.1 Ft Sync Offline Mode

10.1.1 Priority

Must Have

10.1.2 User Story

As a gate staff member, I want to operate the system fully offline when network is unavailable so that I can continue processing visitors at gates with no/poor connectivity

10.1.3 Preconditions

Local PostgreSQL database operational; network detection configured; core functions available offline

10.1.4 Postconditions

All core operations functional offline; network status automatically detected; seamless mode switching

10.1.5 Test Cases

Id	Description	Weight
SYNC-OFFLINE-TC-001	Operate registration offline for 24 hours	High
SYNC-OFFLINE-TC-002	Operate permit verification offline with local database	High
SYNC-OFFLINE-TC-003	Operate vehicle logging offline	High
SYNC-OFFLINE-TC-004	Track capacity offline at remote gates (Ndutu, Lemala)	High
SYNC-OFFLINE-TC-005	Verify automatic network detection and mode switching	High

10.2 Ft Sync Offline Indicator

10.2.1 Priority

Must Have

10.2.2 User Story

As a gate staff member, I want to see clear visual indicator of online/offline status so that I know when system is operating offline and when sync will occur

10.2.3 Preconditions

Status bar implemented in PWA; network monitoring active; status updates in real-time

10.2.4 Postconditions

Status clearly visible; color-coded indicators working; time since last sync displayed

10.2.5 Test Cases

Id	Description	Weight
SYNC-OFFLINE-TC-006	Display green indicator when online and syncing	High
SYNC-OFFLINE-TC-007	Display yellow/red indicator when offline with hours since last sync	High
SYNC-OFFLINE-TC-008	Display 'Syncing now' indicator during active sync	High
SYNC-OFFLINE-TC-009	Update status indicator within 30 seconds of network changes	Medium

10.3 Ft Sync Offline Queue

10.3.1 Priority

Should Have

10.3.2 User Story

As a gate staff member, I want to view pending changes waiting to sync so that I can monitor what data needs to be synchronized when network returns

10.3.3 Preconditions

Sync queue implemented; pending records tracked; queue display interface available

10.3.4 Postconditions

Queue visible to staff; pending count accurate; estimated sync time displayed

10.3.5 Test Cases

Id	Description	Weight
SYNC-OFFLINE-TC-010	Display pending records count in queue	Medium
SYNC-OFFLINE-TC-011	Display oldest pending change timestamp	Medium
SYNC-OFFLINE-TC-012	Display estimated sync time based on queue size	Medium

10.4 Ft Sync Offline Performance

10.4.1 Priority

Must Have

10.4.2 User Story

As a gate staff member, I want same performance whether online or offline so that service quality is maintained regardless of network status

10.4.3 Preconditions

Local NVMe SSD storage; optimized database queries; performance benchmarks defined

10.4.4 Postconditions

Query response time <100ms offline; no performance degradation; user experience consistent

10.4.5 Test Cases

Id	Description	Weight
SYNC-OFFLINE-TC-013	Verify query response time <100ms offline	High
SYNC-OFFLINE-TC-014	Load test with 300 visitors/ day offline	High
SYNC-OFFLINE-TC-015	Compare online vs offline performance (should be equivalent)	High

10.5 Ft Sync Gate To Gate

10.5.1 Priority

Must Have

10.5.2 User Story

As a system administrator, I want to sync data between gates within 15 minutes maximum so that near real-time capacity tracking is maintained

10.5.3 Preconditions

HTTP API configured between NUCs; network connectivity available; sync scheduler running

10.5.4 Postconditions

Data synced within 15 minutes; capacity updates propagated; duplicate entries prevented

10.5.5 Test Cases

Id	Description	Weight
SYNC-GATE-TC-001	Sync data between gates within 15 minutes	High
SYNC-GATE-TC-002	Verify small payload size (10-50KB per sync)	High
SYNC-GATE-TC-003	Test sync over 2G connection	High
SYNC-GATE-TC-004	Verify automatic retry on sync failure	High
SYNC-GATE-TC-005	Test sync across all 9 gates simultaneously	High

10.6 Ft Sync Priority

10.6.1 Priority

Must Have

10.6.2 User Story

As a system administrator, I want to prioritize critical data for sync so that most important data syncs first on limited bandwidth

10.6.3 Preconditions

Priority levels defined; sync queue prioritized; bandwidth limitations considered

10.6.4 Postconditions

Critical data synced within 5 minutes; high priority within 15 minutes; normal and low priority as bandwidth allows

10.6.5 Test Cases

Id	Description	Weight
SYNC-PRIORITY-TC-001	Sync critical data (permits, capacity) within 5 minutes	High
SYNC-PRIORITY-TC-002		High

Id	Description	Weight
	Sync high priority data (vehicle logs) within 15 minutes	
SYNC-PRIORITY-TC-003	Sync normal priority data (reports) within 1 hour	Medium
SYNC-PRIORITY-TC-004	Sync low priority data (archives) within 24 hours	Medium

10.7 Ft Sync Batch

10.7.1 Priority

Must Have

10.7.2 User Story

As a system administrator, I want to batch multiple changes for efficient sync so that network overhead is minimized on slow connections

10.7.3 Preconditions

Batch size configured (100 records or 50KB); compression enabled; batching logic implemented

10.7.4 Postconditions

Multiple records batched efficiently; compression reduces bandwidth; sync performance optimized

10.7.5 Test Cases

Id	Description	Weight
SYNC-BATCH-TC-001	Batch up to 100 records per sync	High
SYNC-BATCH-TC-002	Limit batch size to 50KB maximum	High
SYNC-BATCH-TC-003		High

Id	Description	Weight
	Verify compression enabled and reducing payload size	
SYNC-BATCH-TC-004	Test batching on 2G connection performance	High

10.8 Ft Sync Conflict Detect

10.8.1 Priority

Must Have

10.8.2 User Story

As a system administrator, I want to automatically detect sync conflicts so that data corruption and inconsistencies are prevented

10.8.3 Preconditions

Timestamp-based conflict detection implemented; conflict log maintained; detection rules configured

10.8.4 Postconditions

Conflicts detected automatically; conflicts logged; manual resolution triggered when needed

10.8.5 Test Cases

Id	Description	Weight
SYNC-CONFLICT-TC-001	Detect conflict when same record modified at multiple gates	High
SYNC-CONFLICT-TC-002	Log all detected conflicts with timestamps	High
SYNC-CONFLICT-TC-003	Trigger alert for critical conflicts requiring manual resolution	High

Id	Description	Weight
SYNC-CONFLICT-TC-004	Prevent data corruption during conflict scenarios	High

10.9 Ft Sync Conflict Resolve

10.9.1 Priority

Must Have

10.9.2 User Story

As a system administrator, I want to automatically resolve common sync conflicts so that manual intervention is minimized (target 95% auto-resolution)

10.9.3 Preconditions

Resolution rules defined; last-write-wins for most data; append-only for vehicle logs; conflict resolution logic implemented

10.9.4 Postconditions

95% of conflicts resolved automatically; resolution rules applied correctly; conflict log maintained

10.9.5 Test Cases

Id	Description	Weight
SYNC-CONFLICT-TC-005	Apply last-write-wins for general data conflicts	High
SYNC-CONFLICT-TC-006	Use append-only strategy for vehicle log conflicts	High
SYNC-CONFLICT-TC-007	Merge capacity updates from multiple gates	High
SYNC-CONFLICT-TC-008	Permit updates from originating gate wins	High
SYNC-CONFLICT-TC-009		High

Id	Description	Weight
	Achieve ≥95% auto-resolution rate in testing	

10.10 Ft Sync Manual Trigger

10.10.1 Priority

Must Have

10.10.2 User Story

As a gate staff member, I want to manually trigger sync for urgent updates so that critical changes are immediately synchronized

10.10.3 Preconditions

Manual sync button available in UI; confirmation dialog implemented; progress indicator available

10.10.4 Postconditions

Manual sync triggered; urgent data synced immediately; progress visible to user

10.10.5 Test Cases

Id	Description	Weight
SYNC-MANUAL-TC-001	Display manual sync button in UI	High
SYNC-MANUAL-TC-002	Show confirmation dialog with sync scope before manual sync	High
SYNC-MANUAL-TC-003	Display progress indicator during manual sync	High
SYNC-MANUAL-TC-004	Complete emergency permit extension sync within 2 minutes	High

10.11 Ft Sync Integrity

10.11.1 Priority

Must Have

10.11.2 User Story

As a system administrator, I want to validate data integrity during sync so that no data corruption occurs during transmission

10.11.3 Preconditions

Checksums implemented for batches; transaction rollback on failure; retry mechanism configured

10.11.4 Postconditions

Data integrity verified; corrupted transmissions rejected; retries successful

10.11.5 Test Cases

Id	Description	Weight
SYNC-INTEGRITY-TC-001	Calculate and verify checksums for each batch	High
SYNC-INTEGRITY-TC-002	Rollback transaction on checksum failure	High
SYNC-INTEGRITY-TC-003	Retry failed sync with exponential backoff	High
SYNC-INTEGRITY-TC-004	Log all integrity check failures	High

10.12 Ft Sync Backup Hourly

10.12.1 Priority

Must Have

10.12.2 User Story

As a system administrator, I want to automatically backup PostgreSQL to NAS every hour so that NUC SSD failure protection is provided with hourly granularity

10.12.3 Preconditions

NAS configured and accessible; pg_dump installed; rsync configured; backup script scheduled

10.12.4 Postconditions

Hourly backups complete successfully; backup verification successful; 7 days retention maintained

10.12.5 Test Cases

Id	Description	Weight
SYNC-BACKUP-TC-001	Execute hourly pg_dump backup to NAS	High
SYNC-BACKUP-TC-002	Verify backup completes in <10 minutes	High
SYNC-BACKUP-TC-003	Verify backup integrity after completion	High
SYNC-BACKUP-TC-004	Maintain 7 days of hourly backups with rotation	High

10.13 Ft Sync Backup Daily

10.13.1 Priority

Must Have

10.13.2 User Story

As a system administrator, I want to create daily snapshots on NAS for point-in-time recovery so that recovery from data corruption or accidental deletion is possible

10.13.3 Preconditions

NAS snapshot feature enabled; daily snapshot scheduled at midnight; retention policy configured

10.13.4 Postconditions

Daily snapshots created successfully; 30-day retention maintained; space-efficient incremental snapshots

10.13.5 Test Cases

Id	Description	Weight
SYNC-BACKUP-TC-005	Create daily NAS snapshot at midnight	High
SYNC-BACKUP-TC-006	Maintain 30 days of daily snapshots	High
SYNC-BACKUP-TC-007	Verify snapshots are space-efficient incremental	Medium
SYNC-BACKUP-TC-008	Test snapshot restoration process	High

10.14 Ft Sync Backup Weekly

10.14.1 Priority

Must Have

10.14.2 User Story

As a system administrator, I want to create weekly encrypted USB backups for disaster recovery so that offline backup is maintained in safe for catastrophic failures

10.14.3 Preconditions

USB drives available; AES-256 encryption configured; weekly backup scheduled; safe storage available

10.14.4 Postconditions

Weekly USB backups created and encrypted; physically stored in safe; 12 weeks retention

10.14.5 Test Cases

Id	Description	Weight
SYNC-BACKUP-TC-009	Create weekly USB backup with AES-256 encryption	High
SYNC-BACKUP-TC-010	Verify encrypted backup can be restored	High
SYNC-BACKUP-TC-011	Store USB backup in physical safe	High
SYNC-BACKUP-TC-012	Maintain 12 weeks of weekly USB backups	Medium

10.15 Ft Sync Restore Hourly

10.15.1 Priority

Must Have

10.15.2 User Story

As a system administrator, I want to restore from hourly NAS backup within 30 minutes so that quick recovery from NUC failure is possible

10.15.3 Preconditions

Restore procedure documented; restore script automated; tested monthly; spare NUC available

10.15.4 Postconditions

Restore completes within 30 minutes; data integrity verified; system operational

10.15.5 Test Cases

Id	Description	Weight
SYNC-RESTORE-TC-001	Restore PostgreSQL from latest hourly backup	High

Id	Description	Weight
SYNC-RESTORE-TC-002	Complete restore process within 30 minutes	High
SYNC-RESTORE-TC-003	Verify database integrity after restore	High
SYNC-RESTORE-TC-004	Test monthly restore procedures proactively	High

10.16 Ft Sync Restore Point

10.16.1 Priority

Must Have

10.16.2 User Story

As a system administrator, I want to restore to specific point in time from daily snapshots so that recovery from data corruption or user errors is possible

10.16.3 Preconditions

Point-in-time recovery UI implemented; snapshots available; restore preview functionality; backup current state before restore

10.16.4 Postconditions

Point-in-time restoration successful; data restored to specific snapshot; current state backed up before restore

10.16.5 Test Cases

Id	Description	Weight
SYNC-RESTORE-TC-005	Select specific daily snapshot for restoration	High
SYNC-RESTORE-TC-006	Preview restore contents before committing	Medium

Id	Description	Weight
SYNC-RESTORE-TC-007	Backup current state before point-in-time restore	High
SYNC-RESTORE-TC-008	Complete point-in-time restore successfully	High

10.17 Ft Sync Ups Integration

10.17.1 Priority

Must Have

10.17.2 User Story

As a gate staff member, I want UPS integration for 2-4 hour power backup so that operations continue during power outages

10.17.3 Preconditions

UPS 1000VA installed; NUC + NAS + Switch connected to UPS; UPS management interface configured

10.17.4 Postconditions

UPS powers critical systems for 2-4 hours; battery level monitoring active; low battery alerts configured

10.17.5 Test Cases

Id	Description	Weight
SYNC-UPS-TC-001	Power NUC + NAS + Switch on UPS for 2-4 hours	High
SYNC-UPS-TC-002	Monitor UPS battery level in real-time	High
SYNC-UPS-TC-003	Configure low battery alerts at 20% and 10%	High
SYNC-UPS-TC-004	Test UPS failover during simulated power outage	High

10.18 Ft Sync Ups Shutdown

10.18.1 Priority

Must Have

10.18.2 User Story

As a system administrator, I want graceful shutdown when UPS battery is critically low so that data corruption from sudden power loss is prevented

10.18.3 Preconditions

UPS monitoring configured; shutdown script implemented; 10% battery threshold set; shutdown sequence defined

10.18.4 Postconditions

Systems shutdown gracefully at 10% battery; all pending changes saved; database connections closed cleanly

10.18.5 Test Cases

Id	Description	Weight
SYNC-UPS-TC-005	Trigger graceful shutdown at 10% battery	High
SYNC-UPS-TC-006	Save all pending changes before shutdown	High
SYNC-UPS-TC-007	Close database connections cleanly	High
SYNC-UPS-TC-008	Execute shutdown sequence: PWA → PostgreSQL → OS	High

10.19 Ft Sync Ups Alert

10.19.1 Priority

Must Have

10.19.2 User Story

As a gate staff member, I want to receive alerts when on UPS power or battery low so that I can take action before system shutdown

10.19.3 Preconditions

Alert system configured; visual alerts in PWA; SMS alerts to technical staff; battery percentage monitoring

10.19.4 Postconditions

Alerts received promptly; staff aware of power status; action taken before critical shutdown

10.19.5 Test Cases

Id	Description	Weight
SYNC-UPS-TC-009	Display visual alert in PWA when on UPS power	High
SYNC-UPS-TC-010	Send SMS to technical staff when battery <20%	High
SYNC-UPS-TC-011	Display battery percentage in PWA status bar	High
SYNC-UPS-TC-012	Escalate alert urgency as battery level decreases	Medium

10.20 Ft Sync Power Recovery

10.20.1 Priority

Must Have

10.20.2 User Story

As a system administrator, I want automatic restart and resume operations when power is restored so that downtime is minimized without manual intervention

10.20.3 Preconditions

Auto-boot on power restore configured; database integrity check enabled; resume pending syncs; notification system operational

10.20.4 Postconditions

System boots automatically on power restore; integrity verified; operations resumed; staff notified

10.20.5 Test Cases

Id	Description	Weight
SYNC-RECOVERY-TC-001	Auto-boot system when power restored	High
SYNC-RECOVERY-TC-002	Execute database integrity check on startup	High
SYNC-RECOVERY-TC-003	Resume pending syncs automatically	High
SYNC-RECOVERY-TC-004	Notify staff of successful power recovery and system status	Medium

10.21 Ft Sync Storage Nvme

10.21.1 Priority

Must Have

10.21.2 User Story

As a system administrator, I want live operational data stored on fast NVMe SSD so that quick query response for gate operations is ensured

10.21.3 Preconditions

512GB NVMe SSD installed; PostgreSQL optimized for SSD; query performance tuned

10.21.4 Postconditions

Query response <100ms; SSD performance optimal; database operations fast

10.21.5 Test Cases

Id	Description	Weight
SYNC-STORAGE-TC-001	Verify PostgreSQL data stored on NVMe SSD	High
SYNC-STORAGE-TC-002	Optimize PostgreSQL configuration for SSD performance	High
SYNC-STORAGE-TC-003	Verify query response time <100ms for 95% of queries	High
SYNC-STORAGE-TC-004	Monitor SSD performance and health metrics	Medium

10.22 Ft Sync Storage Nas

10.22.1 Priority

Must Have

10.22.2 User Story

As a system administrator, I want historical data archived on NAS RAID 1 so that disk failure protection is provided with redundancy

10.22.3 Preconditions

NAS with 2x 2TB drives in RAID 1; hot-swap capability; archival process configured

10.22.4 Postconditions

Historical data safely archived; RAID 1 redundancy active; single drive failure survivable

10.22.5 Test Cases

Id	Description	Weight
SYNC-STORAGE-TC-005	Configure NAS with 2x 2TB drives in RAID 1	High
SYNC-STORAGE-TC-006	Archive historical data (>30 days) from NUC to NAS	High
SYNC-STORAGE-TC-007	Test single drive failure and recovery	High
SYNC-STORAGE-TC-008	Verify hot-swap drive replacement capability	Medium

10.23 Ft Sync Storage Monitoring

10.23.1 Priority

Must Have

10.23.2 User Story

As a system administrator, I want to monitor storage usage and receive alerts when space is low so that system failure due to full disk is prevented

10.23.3 Preconditions

Storage monitoring configured; alert thresholds set (80%, 90%); automatic archival configured

10.23.4 Postconditions

Storage usage monitored continuously; alerts sent at thresholds; automatic archival prevents disk full

10.23.5 Test Cases

Id	Description	Weight
SYNC-STORAGE-TC-009	Monitor NUC SSD and NAS storage usage	High

Id	Description	Weight
SYNC-STORAGE-TC-010	Send alert when storage reaches 80%	High
SYNC-STORAGE-TC-011	Send critical alert when storage reaches 90%	High
SYNC-STORAGE-TC-012	Trigger automatic archival to NAS when NUC SSD >80%	High

10.24 Ft Sync Storage Cleanup

10.24.1 Priority

Must Have

10.24.2 User Story

As a system administrator, I want to automatically archive old data from NUC SSD to NAS so that limited SSD space is managed efficiently

10.24.3 Preconditions

Archival rules defined (>30 days); automatic archival process scheduled; NAS storage available

10.24.4 Postconditions

Old data archived automatically; current month data on NUC for fast access; SSD space managed efficiently

10.24.5 Test Cases

Id	Description	Weight
SYNC-CLEANUP-TC-001	Identify records >30 days old for archival	High
SYNC-CLEANUP-TC-002	Archive old records from NUC SSD to NAS	High
SYNC-CLEANUP-TC-003		High

Id	Description	Weight
	Keep current month data on NUC SSD for fast access	
SYNC-CLEANUP-TC-004	Verify archived data accessible from NAS when needed	High

10.25 Ft Sync Net Detect

10.25.1 Priority

Must Have

10.25.2 User Story

As a system administrator, I want automatic network availability detection so that seamless switching between online and offline modes occurs

10.25.3 Preconditions

Network monitoring configured; ping test to Old HQ every 30 seconds; offline mode trigger at 3 failed pings

10.25.4 Postconditions

Network status detected accurately; mode switching seamless; exponential backoff on failures

10.25.5 Test Cases

Id	Description	Weight
SYNC-NET-TC-001	Ping Old HQ every 30 seconds to detect network	High
SYNC-NET-TC-002	Switch to offline mode after 3 consecutive failed pings	High
SYNC-NET-TC-003	Apply exponential backoff on repeated failures	High
SYNC-NET-TC-004		High

Id	Description	Weight
	Switch back to online mode when network restored	

10.26 Ft Sync Net Slow

10.26.1 Priority

Must Have

10.26.2 User Story

As a system administrator, I want to detect slow network and adjust sync strategy so that optimization for 2G connections at remote gates is provided

10.26.3 Preconditions

Bandwidth detection implemented; sync strategy adjustable; priority threshold configurable

10.26.4 Postconditions

Slow network detected; batch size reduced; priority threshold increased; sync optimized for available bandwidth

10.26.5 Test Cases

Id	Description	Weight
SYNC-NET-TC-005	Detect 2G connection bandwidth	High
SYNC-NET-TC-006	Reduce batch size on slow connection (<50KB)	High
SYNC-NET-TC-007	Increase priority threshold (sync only critical/high priority)	High
SYNC-NET-TC-008	Verify sync performance acceptable on 2G	High

10.27 Ft Sync Net Retry

10.27.1 Priority

Must Have

10.27.2 User Story

As a system administrator, I want automatic retry of failed sync with exponential backoff so that intermittent network issues are handled without manual intervention

10.27.3 Preconditions

Retry logic implemented; exponential backoff configured; retry schedule defined; max retries set to 10

10.27.4 Postconditions

Failed syncs retried automatically; exponential backoff prevents network overload; manual intervention only after 10 retries

10.27.5 Test Cases

Id	Description	Weight
SYNC-NET-TC-009	Retry immediately on first sync failure	High
SYNC-NET-TC-010	Retry with exponential backoff (30s, 1m, 5m, 15m, then hourly)	High
SYNC-NET-TC-011	Limit retries to max 10 attempts	High
SYNC-NET-TC-012	Alert for manual intervention after 10 failed retries	High

10.28 Ft Sync Net Cellular

10.28.1 Priority

Must Have

10.28.2 User Story

As a system administrator, I want to support cellular data (2G/3G) for sync so that sync works even with minimal connectivity

10.28.3 Preconditions

Small payloads optimized for slow connections; compression enabled; 2G compatibility verified

10.28.4 Postconditions

Sync works over 2G; payloads optimized; compression reduces bandwidth requirements

10.28.5 Test Cases

Id	Description	Weight
SYNC-NET-TC-013	Test sync over 2G cellular connection	High
SYNC-NET-TC-014	Verify small payload size optimized for 2G	High
SYNC-NET-TC-015	Verify compression enabled and effective	High

10.29 Ft Sync Monitor Status

10.29.1 Priority

Must Have

10.29.2 User Story

As an operations manager at Old HQ, I want to view sync status dashboard for all 9 gates so that system health can be monitored

10.29.3 Preconditions

Dashboard implemented; data collection from all gates; per-gate view available

10.29.4 Postconditions

Dashboard displays comprehensive status; all 9 gates visible; real-time updates

10.29.5 Test Cases

Id	Description	Weight
SYNC-MONITOR-TC-001	Display last sync time for all 9 gates	High
SYNC-MONITOR-TC-002	Display pending records count per gate	High
SYNC-MONITOR-TC-003	Display online/offline status per gate	High
SYNC-MONITOR-TC-004	Display sync errors per gate	High
SYNC-MONITOR-TC-005	Provide per-gate detailed view	Medium

10.30 Ft Sync Monitor Alerts

10.30.1 Priority

Must Have

10.30.2 User Story

As an operations manager, I want to receive alerts for sync failures or delays so that issues can be proactively addressed before they impact operations

10.30.3 Preconditions

Alert conditions defined; notification system configured; alert recipients configured

10.30.4 Postconditions

Alerts sent for critical conditions; staff notified promptly; issues addressed proactively

10.30.5 Test Cases

Id	Description	Weight
SYNC-MONITOR-TC-006	Alert when sync delay exceeds 1 hour	High
SYNC-MONITOR-TC-007	Alert on backup failure	High

Id	Description	Weight
SYNC-MONITOR-TC-008	Alert when storage exceeds 80%	High
SYNC-MONITOR-TC-009	Alert when UPS on battery power	High
SYNC-MONITOR-TC-010	Alert for conflicts requiring manual resolution	High

10.31 Ft Sync Monitor Logs

10.31.1 Priority

Must Have

10.31.2 User Story

As a system administrator, I want to access detailed sync logs for troubleshooting so that sync issues can be diagnosed and resolved

10.31.3 Preconditions

Comprehensive logging implemented; logs searchable; 30-day retention; log viewer available

10.31.4 Postconditions

All sync attempts logged; logs accessible and searchable; troubleshooting effective

10.31.5 Test Cases

Id	Description	Weight
SYNC-MONITOR-TC-011	Log all sync attempts with timestamps	High
SYNC-MONITOR-TC-012	Log sync success/failure with details	High
SYNC-MONITOR-TC-013	Log sync duration and records synced	High
SYNC-MONITOR-TC-014	Log conflicts and errors with details	High
SYNC-MONITOR-TC-015	Provide searchable log viewer interface	Medium

Id	Description	Weight
SYNC-MONITOR-TC-016	Maintain 30-day log retention	Medium

10.32 Ft Sync Monitor Metrics

10.32.1 Priority

Should Have

10.32.2 User Story

As an operations manager, I want to view historical sync performance metrics so that trends can be identified and sync strategy optimized

10.32.3 Preconditions

Metrics collection implemented; historical data stored; charts and graphs available

10.32.4 Postconditions

Historical metrics visible; trends identifiable; optimization opportunities clear

10.32.5 Test Cases

Id	Description	Weight
SYNC-MONITOR-TC-017	Display average sync time over 30 days	Medium
SYNC-MONITOR-TC-018	Display sync success rate metrics	Medium
SYNC-MONITOR-TC-019	Display network uptime per gate	Medium
SYNC-MONITOR-TC-020	Display backup success rate metrics	Medium
SYNC-MONITOR-TC-021	Present metrics in charts and graphs	Medium

11 Additional Context

11.1 Success Metrics

11.1.1 System Uptime

99% regardless of network status (currently ~70%)

11.1.2 Sync Delay

≤ 15 minutes gate-to-gate (currently 30+ minutes to Old HQ)

11.1.3 Backup Success Rate

100% hourly backups completed

11.1.4 Data Loss Incidents

Zero data loss

11.1.5 Conflict Auto Resolution

≥ 95% conflicts resolved automatically

11.1.6 Restore Time

< 30 minutes from hourly backup