Binlog/WAL Monitor - Complete Flow

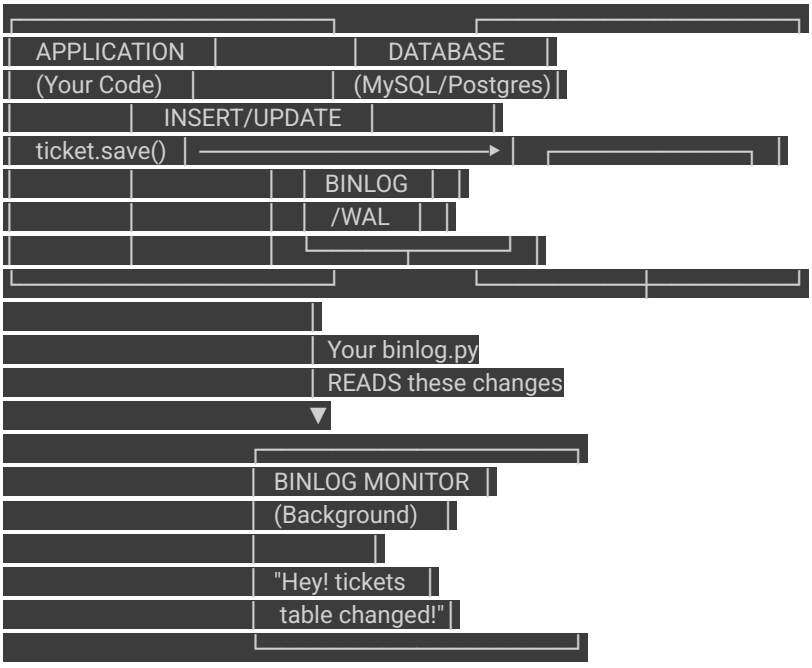
What is Binlog/WAL?

BINLOG (MySQL):

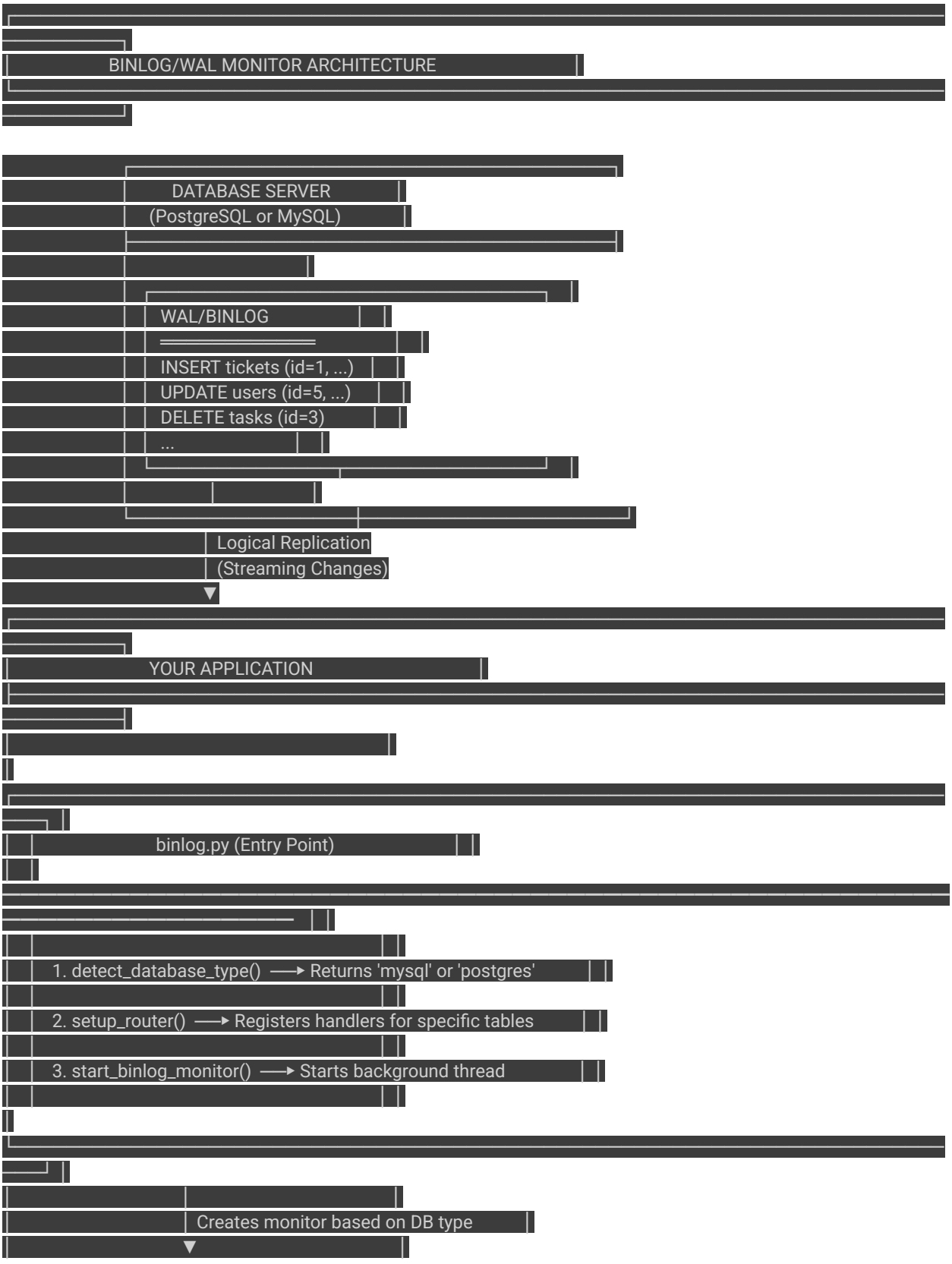
- Binary Log - records ALL changes to database
- Used for: replication, point-in-time recovery, change tracking
- Your app: reads binlog to detect INSERT/UPDATE/DELETE

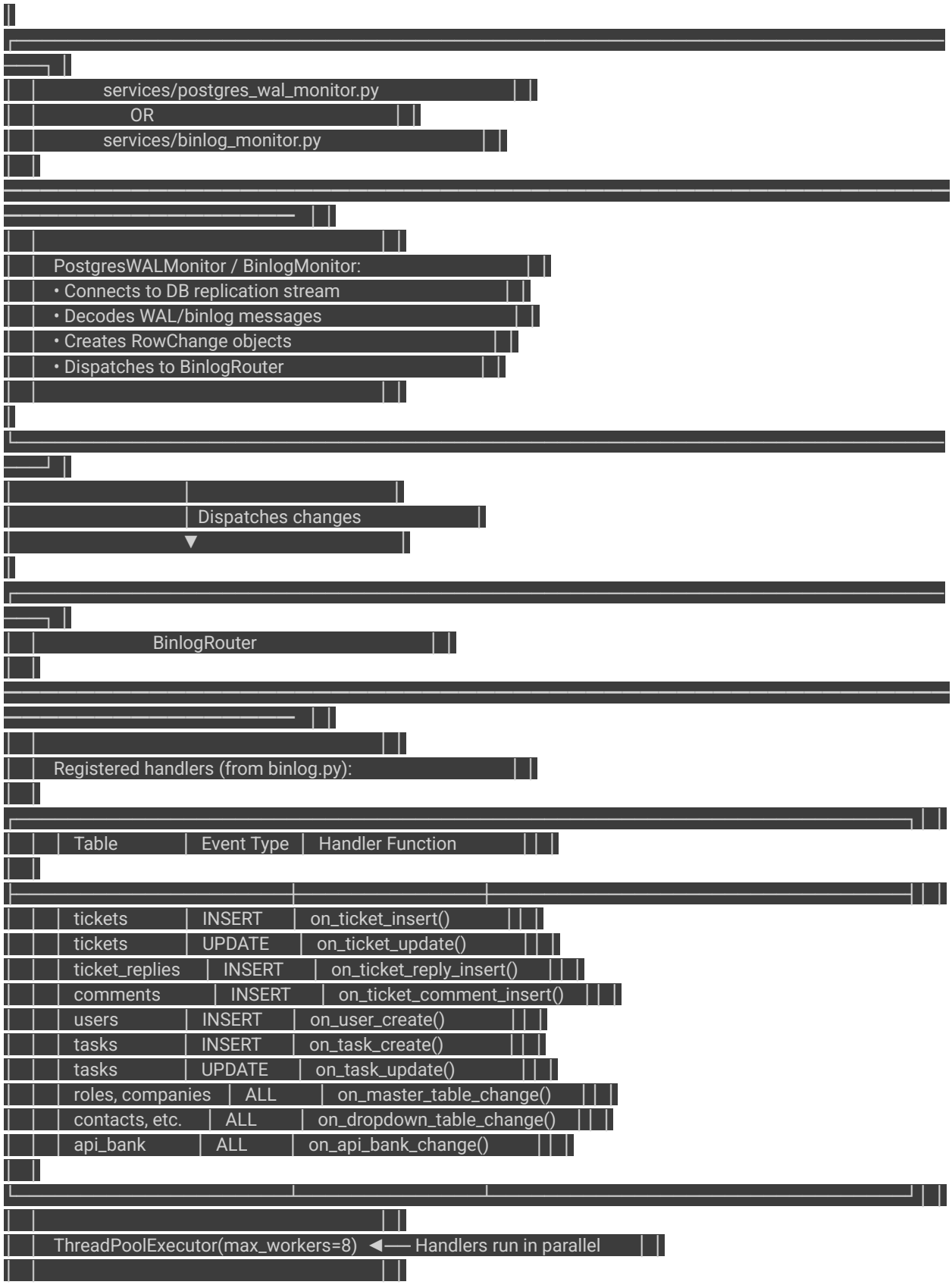
WAL (PostgreSQL):

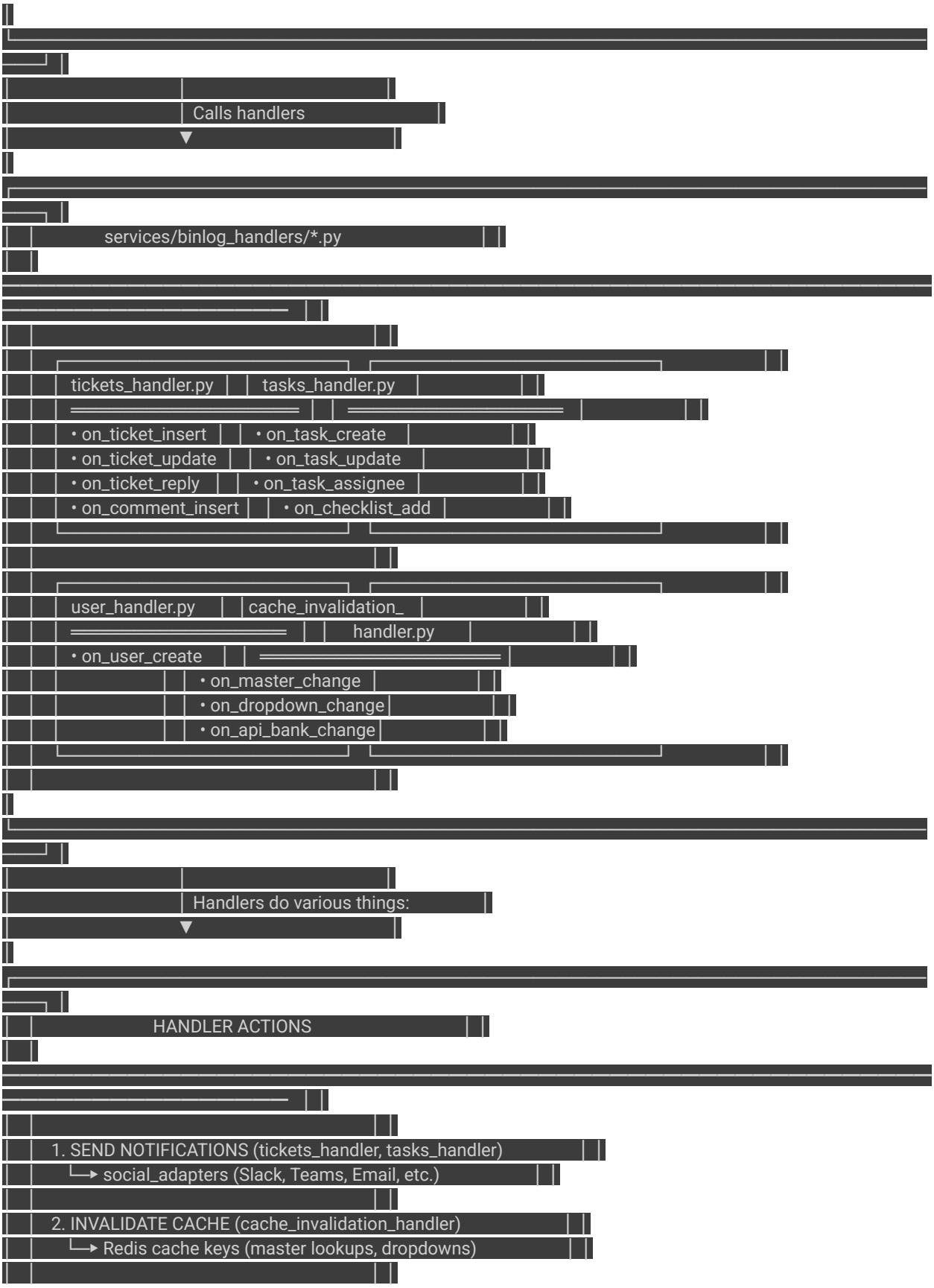
- Write-Ahead Log - records ALL changes before they're committed
- Used for: crash recovery, replication, change tracking
- Your app: uses "Logical Replication" to decode WAL into readable events

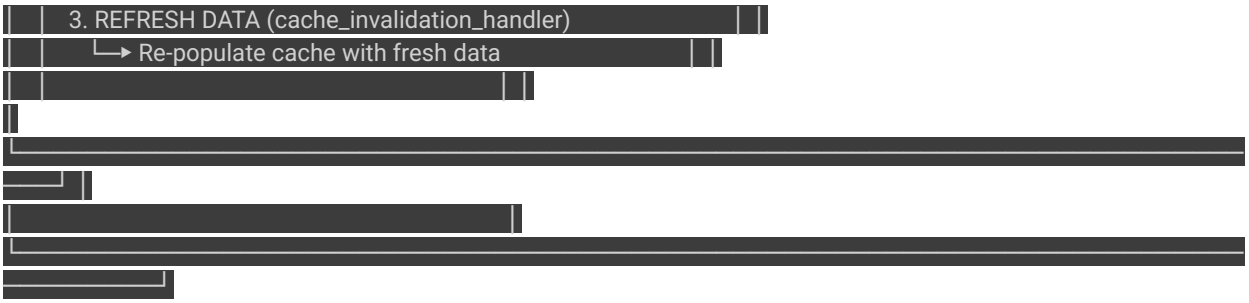


Complete Architecture

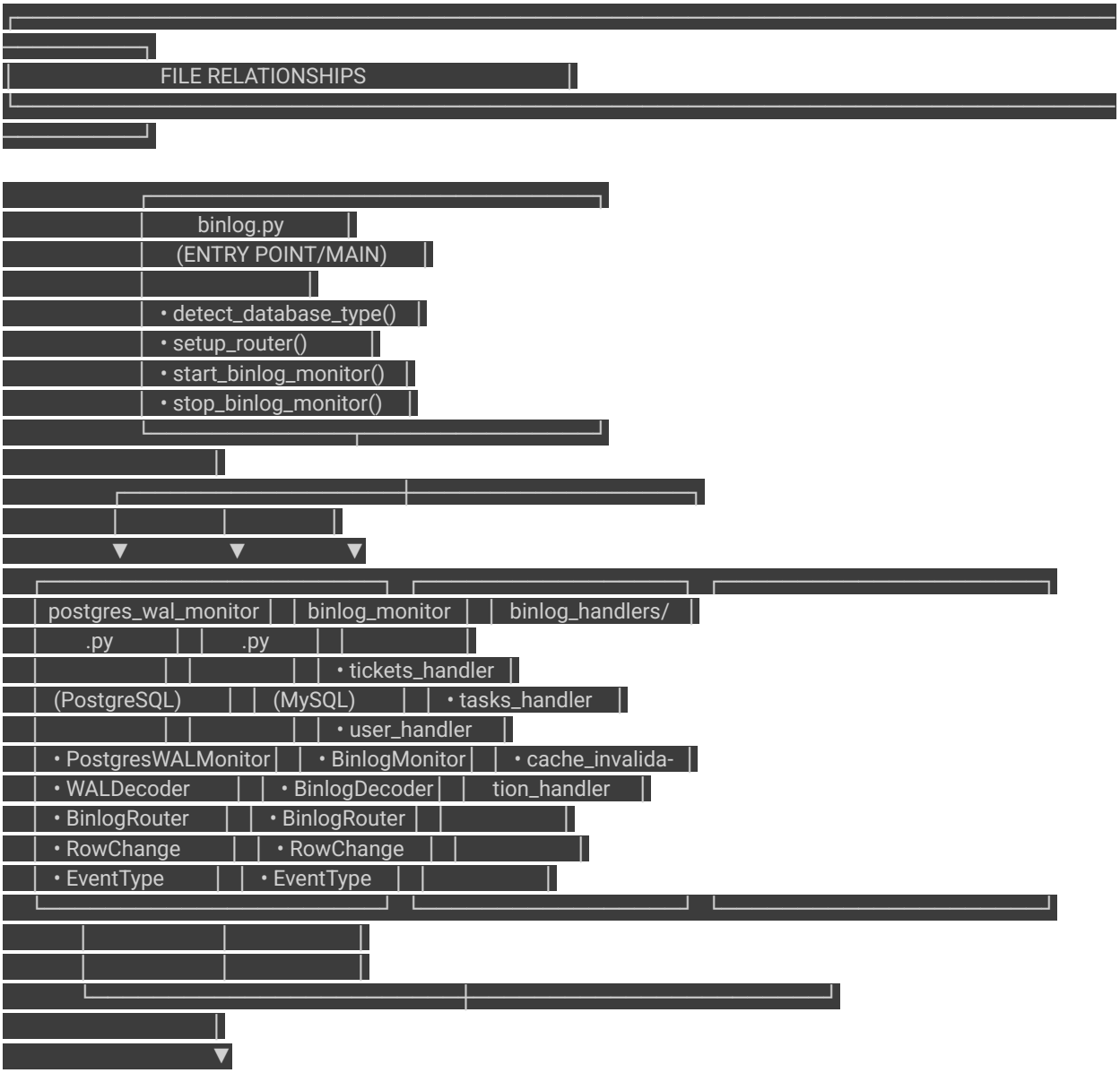

BINLOG/WAL MONITOR ARCHITECTURE
DATABASE SERVER
(PostgreSQL or MySQL)
WAL/BINLOG
INSERT tickets (id=1, ...)
UPDATE users (id=5, ...)
DELETE tasks (id=3)
...
Logical Replication
(Streaming Changes)
YOUR APPLICATION
binlog.py (Entry Point)
1. detect_database_type() ⟶ Returns 'mysql' or 'postgres'
2. setup_router() ⟶ Registers handlers for specific tables
3. start_binlog_monitor() ⟶ Starts background thread
Creates monitor based on DB type

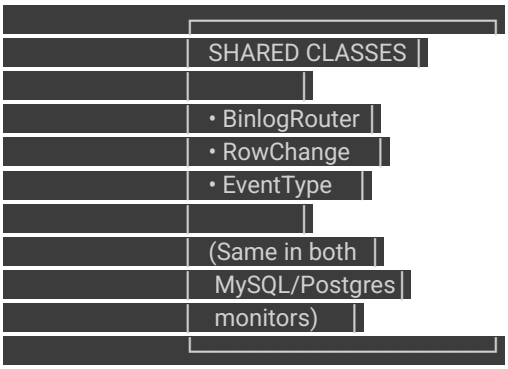

services/postgres_wal_monitor.py
OR
services/binlog_monitor.py
PostgresWALMonitor / BinlogMonitor:
• Connects to DB replication stream
• Decodes WAL/binlog messages
• Creates RowChange objects
• Dispatches to BinlogRouter
Dispatches changes
BinlogRouter
Registered handlers (from binlog.py):
Table
Event Type
Handler Function
tickets
INSERT
on_ticket_insert()
tickets
UPDATE
on_ticket_update()
ticket_replies
INSERT
on_ticket_reply_insert()
comments
INSERT
on_ticket_comment_insert()
users
INSERT
on_user_create()
tasks
INSERT
on_task_create()
tasks
UPDATE
on_task_update()
roles, companies
ALL
on_master_table_change()
contacts, etc.
ALL
on_dropdown_table_change()
api_bank
ALL
on_api_bank_change()
ThreadPoolExecutor(max_workers=8)
Handlers run in parallel


Calls handlers
services/binlog_handlers/*.py
tickets_handler.py
• on_ticket_insert
• on_ticket_update
• on_ticket_reply
• on_comment_insert
tasks_handler.py
• on_task_create
• on_task_update
• on_task_assignee
• on_checklist_add
user_handler.py
• on_user_create
cache_invalidation_handler.py
• on_master_change
• on_dropdown_change
• on_api_bank_change
Handlers do various things:
HANDLER ACTIONS
1. SEND NOTIFICATIONS (tickets_handler, tasks_handler)
social_adapters (Slack, Teams, Email, etc.)
2. INVALIDATE CACHE (cache_invalidation_handler)
Redis cache keys (master lookups, dropdowns)



File Relationships





Complete Flow - Step by Step


```
1️⃣ APP STARTS
   │
   │  main.py calls:
   │  start_binlog_monitor(max_workers=8)
   │
   ▼
2️⃣ binlog.py :: start_binlog_monitor()
   │
   │  a) detect_database_type()
   │     └─ Checks DATABASE_URL → Returns 'postgres' or 'mysql'
   │
   │  b) setup_router(max_workers=8)
   │     └─ Creates BinlogRouter
   │     └─ Registers handlers for each table:
   │
   │        router.register("public", "tickets", [INSERT], on_ticket_insert)
   │        router.register("public", "tickets", [UPDATE], on_ticket_update)
   │        router.register("public", "users",   [INSERT], on_user_create)
   │        router.register("public", "roles",   [ALL],    on_master_table_change)
   │        ... etc.
   │
   │  c) Create Monitor:
   │     └─ PostgresWALMonitor(database_url, slot_name, router=router)
   │        OR
   │     └─ BinlogMonitor(database_url, router=router)
   │
   │  d) Start Background Thread:
   │     └─ threading.Thread(target=_monitor.start, daemon=True)
```

```
│
▼
3️⃣ PostgresWALMonitor :: start()  (Background Thread)
│
│   a) _ensure_replication_slot()
│      └─ Creates replication slot if not exists
│
│   b) Connect with LogicalReplicationConnection
│
│   c) _cursor.start_replication(slot_name="nextgen_slot_...")
│
│   d) _cursor.consume_stream(_process_message)  ◄── BLOCKS HERE
│      └─ Continuously receives WAL changes
│
│   e) Start Keepalive Thread (prevents slot from going inactive)
│
▼
4️⃣ DATABASE CHANGE OCCURS
│
│   Example: User creates a new ticket via API
│   └─ INSERT INTO tickets (title, assigned_to_id, ...) VALUES (...)
│
│   PostgreSQL writes to WAL
│   WAL is streamed to your monitor
│
▼
5️⃣ _process_message(msg)
│
│   a) Decode WAL message (wal2json format):
│      {
│        "change": [{
│          "kind": "insert",
│          "schema": "public",
│          "table": "tickets",
│          "columnnames": ["id", "title", "assigned_to_id", ...],
│          "columnvalues": [123, "Fix bug", 5, ...]
│        }]
│      }
│
│   b) Create RowChange object:
│      RowChange(
│        schema="public",
│        table="tickets",
│        event=EventType.INSERT,
│        row={"id": 123, "title": "Fix bug", "assigned_to_id": 5, ...}
│      )
│
│   c) Call self._emit(change)
│
▼
6️⃣ BinlogRouter :: dispatch(change)
│
```

```
│   Checks all registered rules:
│
│
┌──────────────────────────────────────────────────────────────────────────────────────────────────────────────────────┐
│   Rule: ("public", "tickets", [INSERT], on_ticket_insert)                                                            │
│                                                                                                                      │
│   Does change match?                                                                                                 │
│   • change.schema == "public" ✓                                                                                      │
│   • change.table == "tickets" ✓                                                                                      │
│   • change.event == INSERT ✓                                                                                         │
│                                                                                                                      │
│   MATCH! Submit to thread pool:                                                                                      │
│   ThreadPoolExecutor.submit(on_ticket_insert, change)                                                                │
│                                                                                                                      │
└──────────────────────────────────────────────────────────────────────────────────────────────────────────────────────┘
    │
    ▼
7] tickets_handler.py :: on_ticket_insert(change, db_factory)
    │
    a) Extract data from change.row:
       ticket_id = 123
       assigned_to_id = 5
    │
    b) Fetch complete ticket from DB:
       ticket = db.query(Tickets).filter(Tickets.id == 123).first()
    │
    c) Build notification data:
       ticket_data = {
         "id": 123,
         "ticket_id": "TKT-00123",
         "title": "Fix bug",
         "assigned_to": "John Doe",
         "priority": "High",
         ...
       }
    │
    d) Send notification to assigned user:
       notify_users(db, [5], "New Ticket", ticket_data)
    │
    e) Notify managers:
       manager_ids = get_manager_ids(5, db)
       notify_users(db, manager_ids, "Manager: New Ticket", ticket_data)
    │
    ▼
8] NOTIFICATION SENT
    │
    social_adapters/slack_adapter.py
    └─ Sends Slack message to user's connected account
    │
    social_adapters/teams_adapter.py
```

```
│   └─ Sends Teams message
│
│  etc.
│
▼
9️⃣ ACK & SAVE POSITION
│
│  Back in _process_message():
│  • msg.cursor.send_feedback(flush_lsn=msg.data_start)
│  • _save_offset(msg.data_start)
│
│  This saves the position so if app restarts,
│  it continues from where it left off
│
▼
🔟 LOOP CONTINUES
│
│  _cursor.consume_stream() continues waiting for next change
│
└──▶ Go back to step 4️⃣
```

Cache Invalidation Flow

```
┌──────────────────────────────────────────────────────────────────────────
──────────┐
│                CACHE INVALIDATION FLOW                                   │
└──────────────────────────────────────────────────────────────────────────
──────────┘

SCENARIO: Admin updates a "Role" in the database

1️⃣ UPDATE roles SET name = 'Super Admin' WHERE id = 1

2️⃣ WAL captures the change

3️⃣ PostgresWALMonitor receives:
  RowChange(
    schema="public",
    table="roles",
    event=EventType.UPDATE,
    before={"id": 1, "name": "Admin"},
    after={"id": 1, "name": "Super Admin"}
  )

4️⃣ BinlogRouter matches rule:
  router.register("public", "roles", [UPDATE], on_master_table_change)

5️⃣ cache_invalidation_handler :: on_master_table_change()
```

```
│
│   a) Look up cache keys for "roles" table:
│      TABLE_TO_CACHE_KEYS["roles"] = ["master:roles"]
│
│   b) Call invalidate_cache_keys(["master:roles"], row_data, db)
│
│   c) For each key:
│      └─ refresh_master_cache_key("roles", db)
│         └─ Deletes old cache
│         └─ Fetches fresh data from DB
│         └─ Stores new data in Redis
│
▼
6️⃣ RESULT:
│
│   Redis cache is now updated with fresh "roles" data
│   Next API request will get "Super Admin" instead of "Admin"
│
│   ┌──────────────────────────────────────────────────┐
│   │ BEFORE:                                          │
│   │ Redis["master:roles"] = [{"id":1, "name":"Admin"}]  │
│   │                                                  │
│   │ AFTER:                                           │
│   │ Redis["master:roles"] = [{"id":1, "name":"Super Admin"}]  │
│   └──────────────────────────────────────────────────┘
```

Threading Architecture

```
┌──────────────────────────────────────────────────────────────────────────────────────────────────────────────┐
│                                    THREADING ARCHITECTURE                                                    │
└──────────────────────────────────────────────────────────────────────────────────────────────────────────────┘

┌──────────────────────────────────────────────────────────────────────────────────────────────────────────────┐
│                                         MAIN PROCESS                                                         │
├──────────────────────────────────────────────────────────────────────────────────────────────────────────────┤
│                                                                                                              │
│   ┌─────────────────────┐                                                                                    │
│   │    MAIN THREAD      │  FastAPI/Uvicorn handles HTTP requests                                             │
│   │                     │                                                                                    │
│   └─────────────────────┘                                                                                    │
│                                                                                                              │
│   ┌─────────────────────┐                                                                                    │
│   │  POSTGRES-WAL-      │  Consumes WAL stream from PostgreSQL                                               │
│   │  MONITOR THREAD     │  • _cursor.consume_stream()                                                        │
```

Summary Comparison: Calls Flow vs Binlog Flow

Aspect	Call System	Binlog/WAL System
Trigger	HTTP webhook from Grandstream	Database change (INSERT/UPDATE/DELETE)
Entry Point	grandstream_routes.py	binlog.py
Queue/Stream	RabbitMQ	PostgreSQL WAL / MySQL Binlog
Consumer	grandstream_consumer.py	postgres_wal_monitor.py
Handlers	Inside consumer file	services/binlog_handlers/*.py
State Storage	Redis (call_cache.py)	N/A (just triggers actions)
Output	WebSocket to agents	Notifications + Cache refresh
Threading	Consumer in background thread	Monitor + Thread pool for handlers

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Key Concepts You Should Remember

```
╔═══════════════════════════════════════════════════════════════════════════╗
║                          KEY CONCEPTS                                     ║
╚═══════════════════════════════════════════════════════════════════════════╝
```

1️⃣ WAL/BINLOG = Database transaction log that records ALL changes
   • Your app connects to this log and "streams" the changes in real-time

2️⃣ REPLICATION SLOT = PostgreSQL's way of tracking what you've consumed
   • Prevents data loss if your app disconnects
   • Resumes from last position on restart

3️⃣ BINLOG ROUTER = Pattern-matching dispatcher
   • You register: (table, event_type, handler_function)
   • When change matches, handler is called

4️⃣ HANDLERS = Functions that react to database changes
   • on_ticket_insert → Send notification to assignee
   • on_master_table_change → Refresh Redis cache

5️⃣ THREAD POOL = Parallel handler execution
   • max_workers=8 means 8 handlers can run simultaneously
   • Prevents slow handler from blocking others

6️⃣ WHY USE THIS?
   • Real-time reactions to database changes
   • Decoupled from application code (doesn't matter HOW data was changed)
   • Works even if change came from direct SQL, admin panel, etc.

Would you like me to explain any specific part in more detail?

i want to know that if someone has to do this mean binloger functionality then how and from where he will start as this was already implemented so there was no issue but if someone who dont know the binloger from where he will start or how he will structure the code?

Excellent question! Let me give you a complete guide on **how to implement a binlog/WAL monitor from scratch** - as if you were starting a new project.

Binlog/WAL Implementation Guide - From Zero to Hero

Part 1: Understanding the Problem First

```
┌──────────────────────────────────────────────────────────────────────────────┐
│                    WHY DO YOU NEED BINLOG/WAL MONITORING?                    │
└──────────────────────────────────────────────────────────────────────────────┘
```

PROBLEM:
You want to react to database changes in real-time, but:

• Changes can come from ANYWHERE (API, admin panel, direct SQL, cron jobs)
• You can't add code to every place that modifies data
• You want a SINGLE source of truth for "what changed"

SOLUTION:
Monitor the database's transaction log (WAL/Binlog) - it captures ALL changes
regardless of where they came from.

USE CASES:
✓ Send notifications when ticket is created/updated
✓ Invalidate cache when master data changes
✓ Sync data to external systems (Elasticsearch, analytics)
✓ Audit logging
✓ Real-time dashboards

Part 2: Prerequisites & Setup

```
┌──────────────────────────────────────────────────────────────────────────────┐
│                         STEP 1: DATABASE SETUP                               │
└──────────────────────────────────────────────────────────────────────────────┘
```

FOR POSTGRESQL:

1. Enable logical replication in postgresql.conf:

```
┌─────────────────────────┐
│ wal_level = logical     │
│ max_replication_slots = 4 │
│ max_wal_senders = 4     │
└─────────────────────────┘
```

2. Restart PostgreSQL

3. Install wal2json extension (for readable output):

```
  $ sudo apt install postgresql-15-wal2json

  Or compile from source:
  $ git clone https://github.com/eulerto/wal2json.git
  $ cd wal2json && make && make install

4. Create a user with replication privileges:
  CREATE ROLE replication_user WITH REPLICATION LOGIN PASSWORD 'secret';
  GRANT SELECT ON ALL TABLES IN SCHEMA public TO replication_user;


FOR MYSQL:
═══════════

1. Enable binlog in my.cnf:
  ┌──────────────────────────────────────────────────────┐
  │ [mysqld]                                             │
  │ log-bin = mysql-bin                                  │
  │ binlog-format = ROW                                  │
  │ binlog-row-image = FULL                              │
  │ server-id = 1                                        │
  └──────────────────────────────────────────────────────┘

2. Restart MySQL

3. Create user with replication privileges:
  CREATE USER 'replication_user'@'%' IDENTIFIED BY 'secret';
  GRANT REPLICATION SLAVE, REPLICATION CLIENT, SELECT ON *.* TO 'replication_user'@'%';
```

Part 3: Project Structure (Start Here!)

```
┌──────────────────────────────────────────────────────────────────────────────┐
│                    STEP 2: CREATE PROJECT STRUCTURE                          │
└──────────────────────────────────────────────────────────────────────────────┘

Start with this folder structure:

my_project/
│
├── main.py                    # App entry point
├── config/
│   └── settings.py            # Database URL, settings
│
├── database.py                # SQLAlchemy setup
│
├── binlog.py                  # ⭐ ENTRY POINT for binlog monitoring
```

```
│
├── services/
│   ├── __init__.py
│   ├── wal_monitor.py          # ⭐ Core WAL/Binlog monitor class
│   │
│   └── binlog_handlers/        # ⭐ Your event handlers
│       ├── __init__.py
│       ├── ticket_handler.py   # Handle ticket changes
│       ├── user_handler.py     # Handle user changes
│       └── cache_handler.py    # Handle cache invalidation
│
└── requirements.txt
```

Part 4: Step-by-Step Implementation

Step 1: Install Dependencies

```
┌─────────────────────────────────────────────────────────────────────────────┐
│                    STEP 3: INSTALL DEPENDENCIES                             │
└─────────────────────────────────────────────────────────────────────────────┘
```

requirements.txt:

```
# For PostgreSQL
psycopg2-binary>=2.9.0

# For MySQL (alternative)
mysql-replication>=0.31

# Common
sqlalchemy>=2.0.0
```

Step 2: Create Core Classes

```
┌─────────────────────────────────────────────────────────────────────────────┐
│                    STEP 4: CREATE CORE CLASSES                              │
│                    File: services/wal_monitor.py                            │
└─────────────────────────────────────────────────────────────────────────────┘
```

```
# services/wal_monitor.py
"""
```

```
Core WAL/Binlog monitoring classes.
This is the FOUNDATION - build this first!
"""

import json
import logging
import threading
from enum import Enum
from dataclasses import dataclass
from typing import Any, Callable, Dict, List, Optional
from concurrent.futures import ThreadPoolExecutor

logger = logging.getLogger(__name__)


# ═══════════════════════════════════════════════════════════════════════════
# STEP 4.1: Define Event Types
# ═══════════════════════════════════════════════════════════════════════════
class EventType(str, Enum):
    """Database operation types."""
    INSERT = "insert"
    UPDATE = "update"
    DELETE = "delete"


# ═══════════════════════════════════════════════════════════════════════════
# STEP 4.2: Define RowChange Data Class
# ═══════════════════════════════════════════════════════════════════════════
@dataclass
class RowChange:
    """
    Represents a single database row change.
    This is what your handlers will receive.
    """
    schema: str                         # Database schema (e.g., "public")
    table: str                          # Table name (e.g., "tickets")
    event: EventType                    # INSERT, UPDATE, or DELETE
    row: Optional[Dict[str, Any]] = None     # Row data for INSERT/DELETE
    before: Optional[Dict[str, Any]] = None  # Old values for UPDATE
    after: Optional[Dict[str, Any]] = None   # New values for UPDATE

    def get_id(self) -> Optional[int]:
        """Helper to get the row ID."""
        data = self.row or self.after or self.before
```

```
        return data.get("id") if data else None


# ═══════════════════════════════════════════════════════════════════════════
# STEP 4.3: Define Router (Dispatcher)
# ═══════════════════════════════════════════════════════════════════════════
class EventRouter:
    """
    Routes database change events to appropriate handlers.
    Think of it as a "switchboard" - directs events to the right handler.
    """

    def __init__(self, db_session_factory: Callable, max_workers: int = 4):
        """
        Args:
            db_session_factory: Function that creates a new DB session
            max_workers: Number of parallel handler threads
        """
        self._rules: List[tuple] = []
        self._pool = ThreadPoolExecutor(max_workers=max_workers)
        self._db_session_factory = db_session_factory

    def register(
        self,
        schema: str,
        table: str,
        events: List[EventType],
        handler: Callable[[RowChange, Callable], None]
    ) -> None:
        """
        Register a handler for specific table/event combinations.

        Example:
            router.register("public", "tickets", [EventType.INSERT], on_ticket_insert)
        """
        self._rules.append((schema, table, events, handler))
        logger.info(f"Registered handler for {schema}.{table} on {events}")

    def dispatch(self, change: RowChange) -> None:
        """
        Route a change event to all matching handlers.
        Runs handlers in thread pool for parallel execution.
        """
        for schema, table, events, handler in self._rules:
            # Check if this change matches the rule
            if (change.schema == schema and
                change.table == table and
                change.event in events):
```

```
                # Submit to thread pool (non-blocking)
                self._pool.submit(self._safe_call, handler, change)

    def _safe_call(self, handler: Callable, change: RowChange) -> None:
        """Execute handler with error isolation."""
        try:
            handler(change, self._db_session_factory)
        except Exception as e:
            logger.exception(f"Handler error for {change.table}: {e}")

    def shutdown(self) -> None:
        """Shutdown the thread pool."""
        self._pool.shutdown(wait=True)


#
================================================================================
=========
# STEP 4.4: Define WAL Monitor (PostgreSQL)
#
================================================================================
=========
class PostgresWALMonitor:
    """
    Connects to PostgreSQL logical replication and streams changes.
    This is the "engine" that reads the database changes.
    """

    def __init__(
        self,
        host: str,
        port: int,
        user: str,
        password: str,
        database: str,
        slot_name: str = "my_app_slot",
        router: Optional[EventRouter] = None
    ):
        self.conn_params = {
            "host": host,
            "port": port,
            "user": user,
            "password": password,
            "database": database
        }
        self.slot_name = slot_name
        self.router = router
        self.running = False
        self._conn = None
        self._cursor = None

    def _ensure_slot_exists(self) -> None:
```

```
        """Create replication slot if it doesn't exist."""
        import psycopg2

        conn = psycopg2.connect(**self.conn_params)
        conn.autocommit = True
        cur = conn.cursor()

        # Check if slot exists
        cur.execute(
            "SELECT slot_name FROM pg_replication_slots WHERE slot_name = %s",
            (self.slot_name,)
        )

        if cur.fetchone() is None:
            # Create slot with wal2json plugin
            cur.execute(
                f"SELECT pg_create_logical_replication_slot('{self.slot_name}', 'wal2json')"
            )
            logger.info(f"Created replication slot: {self.slot_name}")

        cur.close()
        conn.close()

    def start(self) -> None:
        """Start monitoring WAL stream. Call this in a background thread."""
        import psycopg2
        from psycopg2.extras import LogicalReplicationConnection

        self.running = True
        logger.info(f"Starting WAL monitor with slot: {self.slot_name}")

        # Ensure slot exists
        self._ensure_slot_exists()

        # Connect with replication protocol
        self._conn = psycopg2.connect(
            connection_factory=LogicalReplicationConnection,
            **self.conn_params
        )
        self._cursor = self._conn.cursor()

        # Start consuming the replication stream
        self._cursor.start_replication(
            slot_name=self.slot_name,
            decode=True,
            options={"format-version": "1"}
        )

        # This blocks and calls _process_message for each WAL entry
        self._cursor.consume_stream(self._process_message)

    def _process_message(self, msg) -> None:
```

```
        """Process a single WAL message."""
        if not self.running:
            raise StopIteration("Monitor stopped")

        try:
            # Parse wal2json message
            payload = json.loads(msg.payload)

            for change_data in payload.get("change", []):
                # Convert to RowChange object
                change = self._parse_change(change_data)
                if change and self.router:
                    self.router.dispatch(change)

            # Acknowledge the message
            msg.cursor.send_feedback(flush_lsn=msg.data_start)

        except Exception as e:
            logger.exception(f"Error processing WAL message: {e}")

    def _parse_change(self, data: Dict) -> Optional[RowChange]:
        """Convert wal2json data to RowChange object."""
        kind = data.get("kind")
        schema = data.get("schema")
        table = data.get("table")

        if not all([kind, schema, table]):
            return None

        # Build row data from columns
        columns = data.get("columnnames", [])
        values = data.get("columnvalues", [])
        row_data = dict(zip(columns, values))

        if kind == "insert":
            return RowChange(
                schema=schema,
                table=table,
                event=EventType.INSERT,
                row=row_data
            )
        elif kind == "delete":
            return RowChange(
                schema=schema,
                table=table,
                event=EventType.DELETE,
                row=row_data
            )
        elif kind == "update":
            # For UPDATE, get old values too
            old_cols = data.get("oldkeys", {}).get("keynames", [])
            old_vals = data.get("oldkeys", {}).get("keyvalues", [])
```

```
            before_data = dict(zip(old_cols, old_vals))

            return RowChange(
                schema=schema,
                table=table,
                event=EventType.UPDATE,
                before=before_data,
                after=row_data
            )

        return None

    def stop(self) -> None:
        """Stop the monitor."""
        self.running = False
        if self._cursor:
            self._cursor.close()
        if self._conn:
            self._conn.close()
        if self.router:
            self.router.shutdown()
        logger.info("WAL monitor stopped")
```

Step 3: Create Entry Point

```
┌─────────────────────────────────────────────────────────────┐
│                  STEP 5: CREATE ENTRY POINT                 │
│                  File: binlog.py                            │
└─────────────────────────────────────────────────────────────┘
```

```
# binlog.py
"""
Entry point for database change monitoring.
This file:
1. Creates the router
2. Registers all handlers
3. Starts the monitor in a background thread
"""

import threading
import logging
from typing import Optional

from config.settings import settings
from database import SessionLocal
from services.wal_monitor import PostgresWALMonitor, EventRouter, EventType
```

```
# Import your handlers
from services.binlog_handlers.ticket_handler import on_ticket_insert, on_ticket_update
from services.binlog_handlers.user_handler import on_user_create
from services.binlog_handlers.cache_handler import on_cache_table_change

logger = logging.getLogger(__name__)

# Global state (singleton pattern)
_monitor: Optional[PostgresWALMonitor] = None
_thread: Optional[threading.Thread] = None


def db_session_factory():
    """Creates a new database session for handlers."""
    return SessionLocal()


def setup_router() -> EventRouter:
    """
    Setup the event router with all handlers.

    THIS IS WHERE YOU REGISTER YOUR HANDLERS!
    Add new handlers here when you want to react to new tables.
    """
    router = EventRouter(db_session_factory, max_workers=4)

    #
═══════════════════════════════════════════════════════════════════════════
═══
    # TICKET HANDLERS
    #
═══════════════════════════════════════════════════════════════════════════
═══
    router.register("public", "tickets", [EventType.INSERT], on_ticket_insert)
    router.register("public", "tickets", [EventType.UPDATE], on_ticket_update)

    #
═══════════════════════════════════════════════════════════════════════════
═══
    # USER HANDLERS
    #
═══════════════════════════════════════════════════════════════════════════
═══
    router.register("public", "users", [EventType.INSERT], on_user_create)

    #
═══════════════════════════════════════════════════════════════════════════
═══
    # CACHE INVALIDATION HANDLERS
    # React to changes in "master" tables and refresh cache
```

```
    # ═══════════════════════════════════════════════════════════════════════
    cache_tables = ["roles", "companies", "departments", "priorities"]
    for table in cache_tables:
        router.register(
            "public",
            table,
            [EventType.INSERT, EventType.UPDATE, EventType.DELETE],
            on_cache_table_change
        )

    return router


def start_binlog_monitor() -> None:
    """
    Start the database change monitor in a background thread.
    Call this once when your app starts.
    """
    global _monitor, _thread

    if _monitor is not None:
        logger.info("Monitor already running, skipping...")
        return

    # Setup router with handlers
    router = setup_router()

    # Create monitor
    _monitor = PostgresWALMonitor(
        host=settings.DB_HOST,
        port=settings.DB_PORT,
        user=settings.DB_USER,
        password=settings.DB_PASSWORD,
        database=settings.DB_DATABASE,
        slot_name="my_app_slot",
        router=router
    )

    # Start in background thread (daemon=True so it dies with main app)
    _thread = threading.Thread(
        target=_monitor.start,
        daemon=True,
        name="wal-monitor"
    )
    _thread.start()

    logger.info("Database change monitor started in background")


def stop_binlog_monitor() -> None:
```

```
    """Stop the monitor (for graceful shutdown)."""
    global _monitor, _thread

    if _monitor:
        _monitor.stop()
        _monitor = None
        _thread = None
        logger.info("Database change monitor stopped")
```

Step 4: Create Handlers

```
┌─────────────────────────────────────────────────────────────────────────────┐
│                    STEP 6: CREATE HANDLERS                                  │
│                    File: services/binlog_handlers/ticket_handler.py         │
└─────────────────────────────────────────────────────────────────────────────┘
```

```
# services/binlog_handlers/ticket_handler.py
"""
Handlers for ticket table changes.
Each handler receives:
- change: RowChange object with the change data
- db_factory: Function to create a DB session
"""

import logging
from typing import Callable
from sqlalchemy.orm import Session

from services.wal_monitor import RowChange

logger = logging.getLogger(__name__)


def on_ticket_insert(change: RowChange, db_factory: Callable[[], Session]) -> None:
    """
    Handle new ticket creation.

    Example: Send notification to assigned user
    """
    db = db_factory()
    try:
        # Get data from the change
        row = change.row or {}
        ticket_id = row.get("id")
        assigned_to_id = row.get("assigned_to_id")
        title = row.get("title")
```

```
        if not ticket_id or not assigned_to_id:
            return

        logger.info(f"New ticket created: #{ticket_id} - {title}")

        # ═══════════════════════════════════════════════════════════
        # YOUR LOGIC HERE!
        # Examples:
        # - Send email notification
        # - Send Slack message
        # - Push to websocket
        # - Update analytics
        # ═══════════════════════════════════════════════════════════

        # Example: Send notification (pseudo-code)
        # send_notification(
        #     user_id=assigned_to_id,
        #     title="New Ticket Assigned",
        #     message=f"Ticket #{ticket_id}: {title}"
        # )

    except Exception as e:
        logger.error(f"Error in on_ticket_insert: {e}")
    finally:
        db.close()


def on_ticket_update(change: RowChange, db_factory: Callable[[], Session]) -> None:
    """
    Handle ticket updates.

    Example: Notify if status or assignee changed
    """
    db = db_factory()
    try:
        before = change.before or {}
        after = change.after or {}
        ticket_id = after.get("id")

        if not ticket_id:
            return

        # Check what changed
        old_status = before.get("status_id")
        new_status = after.get("status_id")

        old_assignee = before.get("assigned_to_id")
        new_assignee = after.get("assigned_to_id")

        # Status changed?
        if old_status != new_status:
            logger.info(f"Ticket #{ticket_id} status changed: {old_status} → {new_status}")
```

```
            # Send status change notification...

        # Assignee changed?
        if old_assignee != new_assignee:
            logger.info(f"Ticket #{ticket_id} reassigned: {old_assignee} → {new_assignee}")
            # Notify old and new assignee...

    except Exception as e:
        logger.error(f"Error in on_ticket_update: {e}")
    finally:
        db.close()


# services/binlog_handlers/cache_handler.py
"""
Handler for cache invalidation.
When master tables change, invalidate/refresh the cache.
"""

import logging
from typing import Callable
from sqlalchemy.orm import Session

from services.wal_monitor import RowChange

logger = logging.getLogger(__name__)


def on_cache_table_change(change: RowChange, db_factory: Callable[[], Session]) -> None:
    """
    Handle changes to tables that are cached.
    Invalidate/refresh the cache when these tables change.
    """
    db = db_factory()
    try:
        table = change.table
        event = change.event.value

        logger.info(f"Cache table changed: {table} ({event})")

        # ═══════════════════════════════════════════════════════════════
        # YOUR CACHE LOGIC HERE!
        # Examples:
        # - Delete Redis key
        # - Refresh cache with new data
        # ═══════════════════════════════════════════════════════════════

        # Example (pseudo-code):
        # cache_key = f"master:{table}"
        # redis_client.delete(cache_key)
        #
        # Or refresh:
```

```
        # fresh_data = db.query(Model).all()
        # redis_client.set(cache_key, serialize(fresh_data))

    except Exception as e:
        logger.error(f"Error in on_cache_table_change: {e}")
    finally:
        db.close()
```

Step 5: Start on App Launch

```
┌─────────────────────────────────────────────────────────────────────────────┐
│                    STEP 7: START ON APP LAUNCH                              │
│                    File: main.py                                            │
└─────────────────────────────────────────────────────────────────────────────┘


# main.py
from fastapi import FastAPI
from contextlib import asynccontextmanager

from binlog import start_binlog_monitor, stop_binlog_monitor


@asynccontextmanager
async def lifespan(app: FastAPI):
    """
    App lifespan - runs on startup and shutdown.
    """
    #
═══════════════════════════════════════════════════════════════════════════
    # STARTUP
    #
═══════════════════════════════════════════════════════════════════════════
    print("Starting binlog monitor...")
    start_binlog_monitor()

    yield  # App is running

    #
═══════════════════════════════════════════════════════════════════════════
    # SHUTDOWN
    #
═══════════════════════════════════════════════════════════════════════════
    print("Stopping binlog monitor...")
```

```
    stop_binlog_monitor()


app = FastAPI(lifespan=lifespan)


@app.get("/")
def root():
    return {"status": "ok"}
```

Part 5: Complete Roadmap Summary

```
┌─────────────────────────────────────────────────────────────────────────────┐
│                        IMPLEMENTATION ROADMAP                               │
└─────────────────────────────────────────────────────────────────────────────┘

PHASE 1: PREPARATION
═══════════════════
□ Step 1: Configure database for logical replication
□ Step 2: Install wal2json extension (PostgreSQL) or enable binlog (MySQL)
□ Step 3: Create replication user with proper privileges

PHASE 2: CORE INFRASTRUCTURE
═══════════════════════════
□ Step 4: Create project structure
□ Step 5: Define core classes:
        • EventType (enum)
        • RowChange (data class)
        • EventRouter (dispatcher)
        • PostgresWALMonitor (or MySQLBinlogMonitor)

PHASE 3: ENTRY POINT
═══════════════════
□ Step 6: Create binlog.py:
        • setup_router() - register all handlers
        • start_binlog_monitor() - start background thread
        • stop_binlog_monitor() - graceful shutdown

PHASE 4: HANDLERS
════════════════
□ Step 7: Create handler files for each domain:
        • ticket_handler.py
        • user_handler.py
```

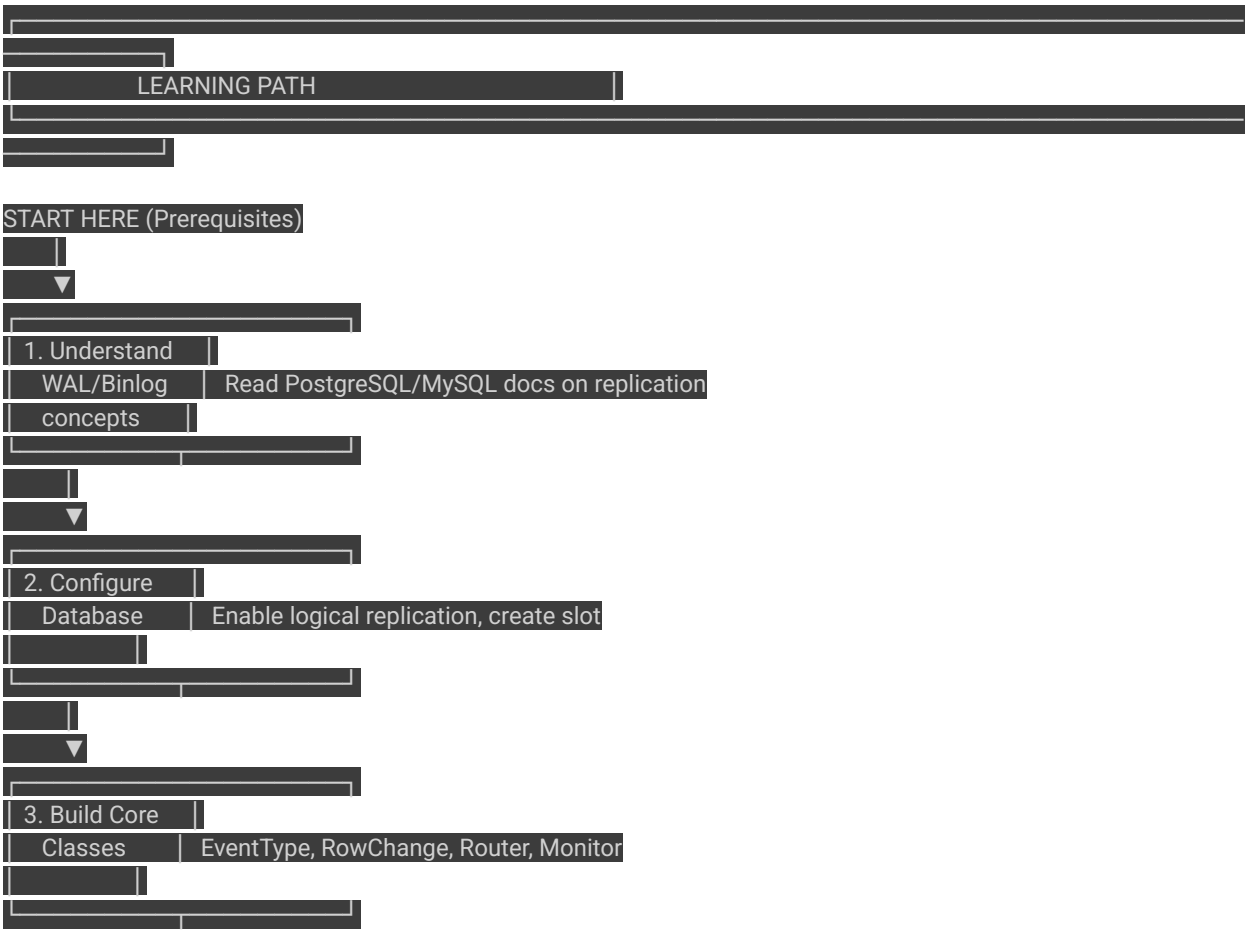
```
        • cache_handler.py
        • (add more as needed)


PHASE 5: INTEGRATION
═══════════════════
□ Step 8: Start monitor in main.py (app lifespan)
□ Step 9: Test with real database changes
□ Step 10: Add error handling, logging, monitoring


PHASE 6: PRODUCTION READINESS
════════════════════════════
□ Step 11: Add offset saving (resume from last position)
□ Step 12: Add reconnection logic (handle connection drops)
□ Step 13: Add keepalive thread (prevent slot timeout)
□ Step 14: Add metrics/monitoring
```

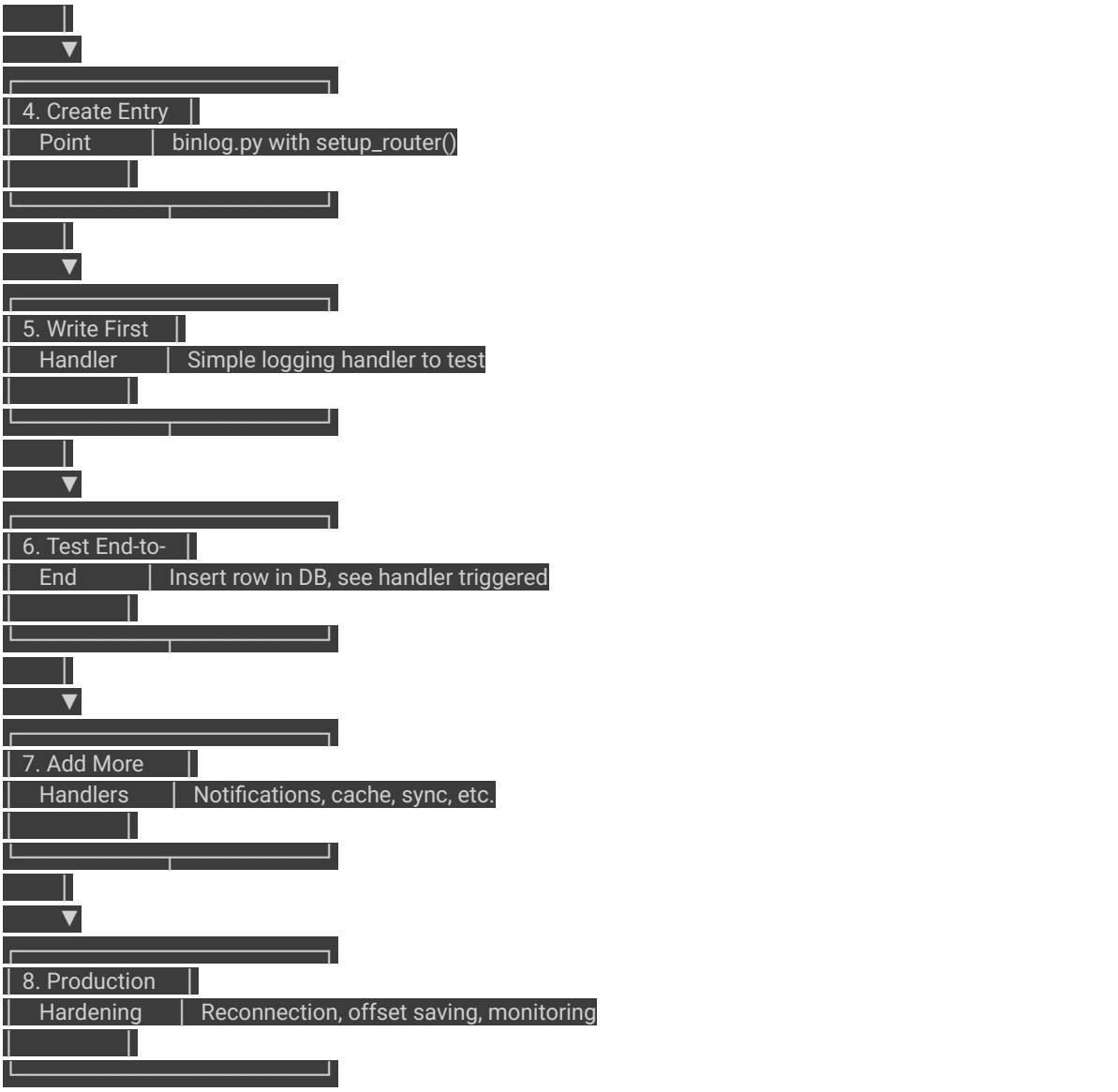
Part 6: How to Add a New Handler (Day-to-Day Usage)

```
┌──────────────────────────────────────────────────────────────────────────────┐
│                    HOW TO ADD A NEW HANDLER                                  │
│                    (After initial setup is done)                             │
└──────────────────────────────────────────────────────────────────────────────┘

SCENARIO: You want to send notifications when a new "Task" is created

STEP 1: Create handler function
═══════════════════════════════
File: services/binlog_handlers/task_handler.py

    def on_task_create(change: RowChange, db_factory: Callable) -> None:
        db = db_factory()
        try:
            task_id = change.row.get("id")
            assigned_to = change.row.get("assigned_to_id")

            # Your notification logic here
            send_notification(assigned_to, f"New task #{task_id}")
        finally:
            db.close()


STEP 2: Register handler in binlog.py
═════════════════════════════════════
File: binlog.py
```

```
    from services.binlog_handlers.task_handler import on_task_create

    def setup_router() -> EventRouter:
        router = EventRouter(...)

        # ... existing handlers ...

        # ADD THIS LINE:
        router.register("public", "tasks", [EventType.INSERT], on_task_create)

        return router


STEP 3: Done! Restart app and test
═══════════════════════════════════
Any INSERT to "tasks" table will now trigger your handler.
```

Part 7: Visual Learning Path





Quick Reference Card

```
┌─────────────────────────────────────────────────────────────────┐
│                    QUICK REFERENCE                              │
└─────────────────────────────────────────────────────────────────┘

FILE PURPOSES:
═══════════════
binlog.py                  → Entry point, registers handlers, starts monitor
services/wal_monitor.py    → Core classes (Monitor, Router, RowChange)
```

```
services/binlog_handlers/*   → Your business logic (handlers)

KEY CLASSES:
═══════════
EventType                    → INSERT, UPDATE, DELETE
RowChange                    → Contains change data (table, before, after)
EventRouter                  → Matches changes to handlers
PostgresWALMonitor           → Reads WAL stream from PostgreSQL

HANDLER SIGNATURE:
═════════════════
def my_handler(change: RowChange, db_factory: Callable[[], Session]) -> None:
    db = db_factory()
    try:
        # Your logic here
        # change.table - table name
        # change.event - INSERT/UPDATE/DELETE
        # change.row   - row data (INSERT/DELETE)
        # change.before/after - for UPDATE
    finally:
        db.close()

REGISTER HANDLER:
════════════════
router.register(
    "public",               # schema name
    "tickets",              # table name
    [EventType.INSERT],     # event types to listen for
    on_ticket_insert        # handler function
)
```

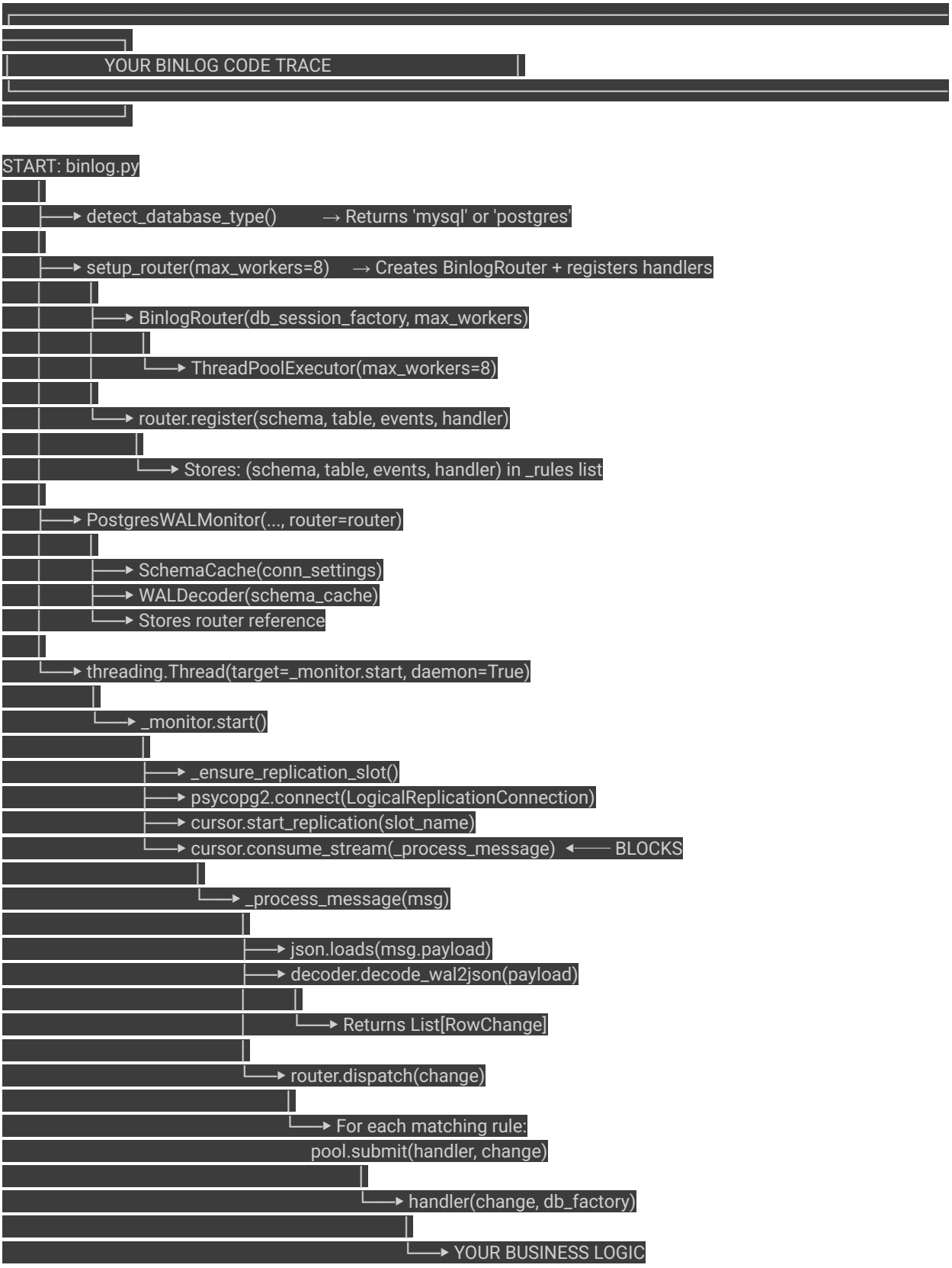
Would you like me to explain any specific part in more detail, or show you how to implement something specific like MySQL binlog monitoring or error handling?

i want to know the track of my binlog code as it is started from binlog.py file where our binlogrouter are set and handlers ,and these are defned in servces folder where those again calling other functions or classes or dtypes ,actually my still same issue is existing that i dont know fully or always confused that how i should defined a class or a function by keeping in mind what?

This is a **very important question** - you're asking about **software design thinking**. Let me break down your existing binlog code and teach you **HOW to think** when designing classes and functions.

Understanding Code Design Through Your Binlog Example

Part 1: Let's Trace Your Binlog Code First



Part 2: The Design Questions You Should Ask

When you're confused about whether to create a **class** or **function**, ask these questions:

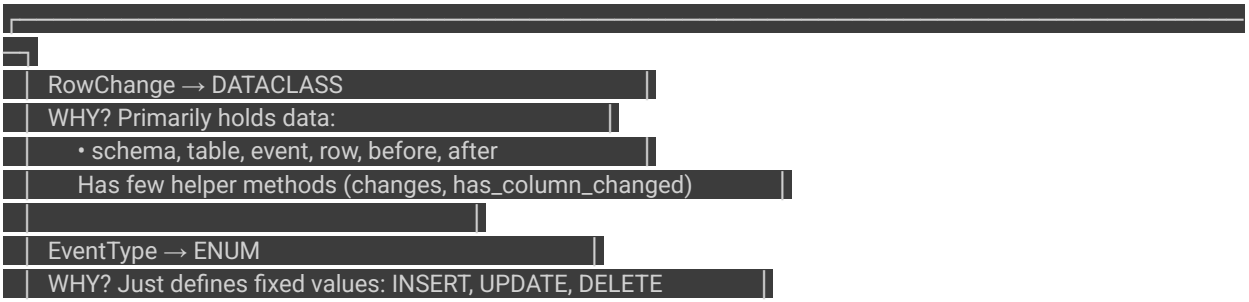
```
┌─────────────────────────────────────────────────────────────────────────────┐
│                          THE 5 KEY QUESTIONS                                │
└─────────────────────────────────────────────────────────────────────────────┘

❓ QUESTION 1: Does it need to REMEMBER something?
═══════════════════════════════════════════════════

  YES → Use a CLASS (has state/data to store)
  NO  → Use a FUNCTION (just does something and returns)

  EXAMPLES FROM YOUR CODE:

  ┌──────────────────────────────────────────────────────────────────────────┐
  │  PostgresWALMonitor → CLASS                                              │
  │  WHY? Needs to remember:                                                 │
  │      • self._conn (connection)                                           │
  │      • self._cursor (cursor)                                             │
  │      • self.running (state flag)                                         │
  │      • self.router (reference to router)                                 │
  │      • self.slot_name (configuration)                                    │
  │                                                                          │
  │  detect_database_type() → FUNCTION                                       │
  │  WHY? Just checks URL and returns 'mysql' or 'postgres'                  │
  │      Doesn't need to remember anything                                   │
  └──────────────────────────────────────────────────────────────────────────┘


❓ QUESTION 2: Does it have a LIFECYCLE (start/stop, open/close)?
═══════════════════════════════════════════════════════════════════

  YES → Use a CLASS
  NO  → Use a FUNCTION

  EXAMPLES:

  ┌──────────────────────────────────────────────────────────────────────────┐
  │  PostgresWALMonitor → CLASS                                              │
  │  WHY? Has lifecycle:                                                     │
```

```
│      • start() - begins monitoring                  │
│      • stop()  - ends monitoring                    │
│      • _cleanup() - releases resources              │
│                                                     │
│   on_ticket_insert() → FUNCTION                     │
│   WHY? Just runs once when called, no lifecycle     │
│                                                     │
└─────────────────────────────────────────────────────┘

❓ QUESTION 3: Will there be MULTIPLE INSTANCES with different data?
═══════════════════════════════════════════════════════════

  YES → Use a CLASS
  NO  → Could be either (depends on other factors)

  EXAMPLES:

┌─────────────────────────────────────────────────────┐
│   RowChange → CLASS (dataclass)                     │
│   WHY? Each database change creates a NEW RowChange with different: │
│      • table name                                   │
│      • event type                                   │
│      • row data                                     │
│                                                     │
│   You might have 100 RowChange objects at any time, each different │
│                                                     │
└─────────────────────────────────────────────────────┘

❓ QUESTION 4: Does it GROUP related operations together?
═══════════════════════════════════════════════════════════

  YES → Use a CLASS
  NO  → Use separate FUNCTIONS

  EXAMPLES:

┌─────────────────────────────────────────────────────┐
│   BinlogRouter → CLASS                              │
│   WHY? Groups related operations:                   │
│      • register() - add a handler                   │
│      • dispatch() - route to handlers               │
│      • shutdown() - cleanup                         │
│      All operate on same data (_rules, _pool)       │
│                                                     │
│   WALDecoder → CLASS                                │
│   WHY? Groups decoding operations:                  │
```

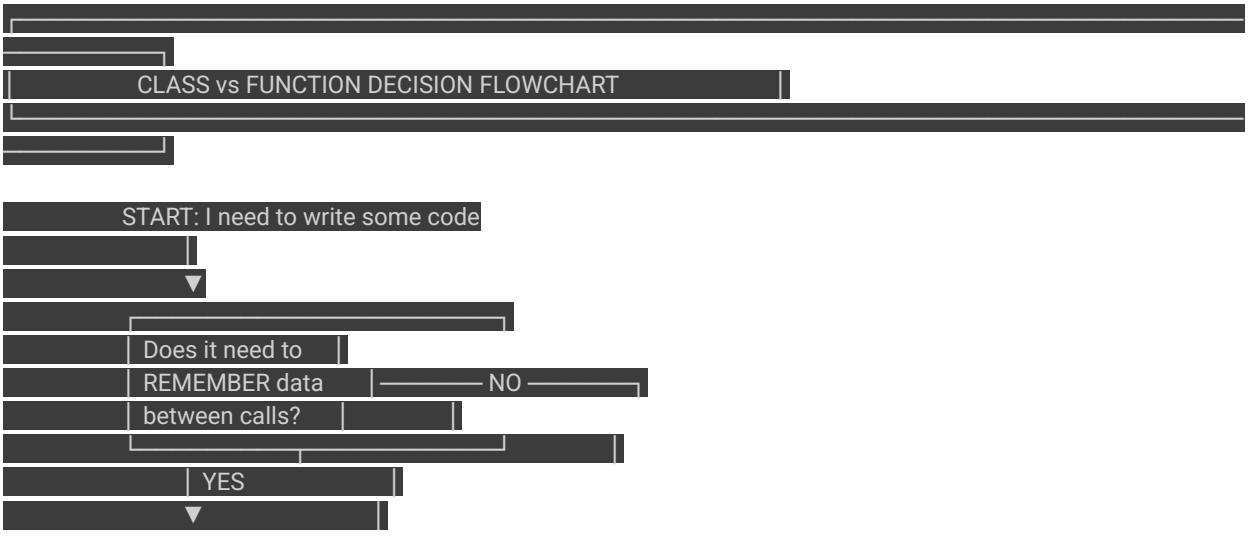
❓ QUESTION 5: Is it just DATA with no behavior?

YES → Use a DATACLASS or simple CLASS
NO → Use a regular CLASS with methods

EXAMPLES:



Part 3: Decision Flowchart



Part 4: Your Binlog Code - Why Each Thing Exists

Let me explain **WHY** each class/function in your binlog code was designed that way:

1️⃣ EventType (Enum)
═══════════════════

```
class EventType(str, Enum):
    INSERT = "insert"
    UPDATE = "update"
    DELETE = "delete"

WHY ENUM?
• Fixed set of values that never changes
• Provides type safety (can't accidentally use "insrt")
• Self-documenting code

ALTERNATIVE (BAD):
• Using strings directly: "insert", "update", "delete"
• Problem: Easy to make typos, no autocomplete
```

2️⃣ RowChange (Dataclass)
═══════════════════════

```
@dataclass
class RowChange:
    schema: str
    table: str
    event: EventType
    row: Optional[Dict] = None
    before: Optional[Dict] = None
    after: Optional[Dict] = None

WHY DATACLASS?
• Primarily holds DATA (schema, table, row data)
• Automatically gets __init__, __repr__, __eq__
• Clean, readable structure
• Has some helper methods (changes, has_column_changed)

WHY NOT DICT?
• Dict has no structure: data["schmea"] typo won't be caught
• No autocomplete in IDE
• Hard to understand what fields exist
```

3️⃣ BinlogRouter (Class)
═══════════════════════

```
class BinlogRouter:
    def __init__(self, db_session_factory, max_workers):
        self._rules = []                        # REMEMBERS rules
        self._pool = ThreadPoolExecutor(max_workers)  # REMEMBERS pool
        self._db_session_factory = db_session_factory # REMEMBERS factory
```

```
    def register(self, schema, table, events, handler): ...
    def dispatch(self, change): ...
    def shutdown(self): ...

  WHY CLASS?
  ✓ REMEMBERS data: _rules, _pool, _db_session_factory
  ✓ GROUPS related operations: register, dispatch, shutdown
  ✓ Has LIFECYCLE: created → used → shutdown

  ALTERNATIVE (BAD):
  • Global variables + functions
  • Problem: Hard to test, can't have multiple routers


4️⃣ WALDecoder (Class)
  ═══════════════════════

  class WALDecoder:
    def __init__(self, schema_cache):
        self.schema_cache = schema_cache  # REMEMBERS cache

    def decode_wal2json(self, payload): ...
    def _decode_v1(self, payload): ...
    def _decode_v2(self, payload): ...
    def decode_test_decoding(self, message): ...

  WHY CLASS?
  ✓ REMEMBERS: schema_cache (shared across all decode calls)
  ✓ GROUPS related operations: all decode methods

  WHY NOT FUNCTIONS?
  • All decode methods need access to schema_cache
  • Would have to pass schema_cache to every function call


5️⃣ PostgresWALMonitor (Class)
  ═══════════════════════════════

  class PostgresWALMonitor:
    def __init__(self, database_url, slot_name, router, ...):
        self.running = False          # REMEMBERS state
        self._conn = None             # REMEMBERS connection
        self._cursor = None           # REMEMBERS cursor
        self.router = router          # REMEMBERS router
        self.slot_name = slot_name    # REMEMBERS config
        self.decoder = WALDecoder(...) # REMEMBERS decoder

    def start(self): ...      # LIFECYCLE
    def stop(self): ...       # LIFECYCLE
    def _cleanup(self): ...   # LIFECYCLE
    def _process_message(self, msg): ...
```

WHY CLASS?
✓ REMEMBERS lots of state: connection, cursor, running flag
✓ Has LIFECYCLE: start → running → stop
✓ GROUPS related operations: start, stop, process, cleanup

THIS IS THE MOST COMPLEX CLASS because:
• Manages a long-running connection
• Has multiple states (stopped, running, reconnecting)
• Coordinates multiple components (decoder, router)

6️⃣ on_ticket_insert (Function)

```
def on_ticket_insert(change: RowChange, db_factory: Callable) -> None:
    db = db_factory()
    try:
        # Process the change
        ticket_id = change.row.get("id")
        # Send notification...
    finally:
        db.close()
```

WHY FUNCTION?
✗ Doesn't REMEMBER anything between calls
✗ No LIFECYCLE (just runs once)
✗ Single operation (not a group)
✓ One-time transformation: change → side effect (notification)

7️⃣ detect_database_type (Function)

```
def detect_database_type() -> str:
    db_url = DATABASE_URL.lower()
    if 'postgres' in db_url:
        return 'postgres'
    elif 'mysql' in db_url:
        return 'mysql'
    return 'postgres'
```

WHY FUNCTION?
✗ Doesn't REMEMBER anything
✗ No LIFECYCLE
✓ Simple input → output transformation
✓ Stateless operation

8️⃣ start_binlog_monitor (Function)

```
_monitor = None  # Global state
_thread = None   # Global state

def start_binlog_monitor():
    global _monitor, _thread
    router = setup_router()
    _monitor = PostgresWALMonitor(...)
    _thread = threading.Thread(target=_monitor.start, daemon=True)
    _thread.start()

WHY FUNCTION (not class)?
• This is an "orchestrator" function
• Uses global variables for singleton pattern
• COULD be a class, but function is simpler for this use case

WHEN WOULD IT BE A CLASS?
• If you needed multiple monitors running
• If you needed more complex lifecycle management
```

Part 5: Design Patterns Used in Your Code

```
┌─────────────────────────────────────────────────────────────────────────────┐
│                    DESIGN PATTERNS IN YOUR BINLOG CODE                      │
└─────────────────────────────────────────────────────────────────────────────┘

1️⃣ SINGLETON PATTERN (binlog.py)
   ═══════════════════════════════

_monitor = None
_thread = None

def start_binlog_monitor():
    global _monitor, _thread
    if _monitor is not None:
        return  # Already running
    _monitor = PostgresWALMonitor(...)

PURPOSE: Only ONE monitor should run at a time
HOW: Global variable + check before creating


2️⃣ FACTORY PATTERN (db_session_factory)
   ═══════════════════════════════════

def db_session_factory():
```

```
    return SessionLocal()

# Used by handlers:
def on_ticket_insert(change, db_factory):
    db = db_factory()  # Creates new session
    try:
        # Use db
    finally:
        db.close()

PURPOSE: Handlers create their own DB sessions
HOW: Pass a function that creates sessions


3️⃣ OBSERVER/PUBLISH-SUBSCRIBE PATTERN (Router)
═══════════════════════════════════════════════

# Register (subscribe)
router.register("public", "tickets", [INSERT], on_ticket_insert)

# Dispatch (publish)
router.dispatch(change)  # Notifies all matching handlers

PURPOSE: Decouple change detection from handling
HOW: Register handlers, dispatch calls all matching ones


4️⃣ STRATEGY PATTERN (Database Type)
═══════════════════════════════════

if db_type == 'mysql':
    from services.binlog_monitor import BinlogMonitor
    _monitor = BinlogMonitor(...)
else:
    from services.postgres_wal_monitor import PostgresWALMonitor
    _monitor = PostgresWALMonitor(...)

PURPOSE: Same interface, different implementations
HOW: Both monitors have start(), stop(), same behavior


5️⃣ TEMPLATE METHOD PATTERN (Handlers)
═══════════════════════════════════

# All handlers follow same template:
def on_something(change, db_factory):
    db = db_factory()
    try:
        # 1. Extract data from change
        # 2. Do business logic
        # 3. Side effects (notify, cache, etc.)
    except Exception as e:
```

```
            logger.error(...)
        finally:
            db.close()

    PURPOSE: Consistent structure across handlers
    HOW: Same signature, same try/finally pattern
```

Part 6: How to Think When Designing NEW Code

```
┌──────────────────────────────────────────────────────────────────────────────┐
│                    STEP-BY-STEP DESIGN THINKING                              │
└──────────────────────────────────────────────────────────────────────────────┘
```

Let's say you need to add: "Email notification system for database changes"

STEP 1: IDENTIFY THE RESPONSIBILITIES
═══════════════════════════════════════

What does this system need to do?
• Connect to email server (SMTP)
• Format email content
• Send emails
• Track sent emails (optional)
• Handle failures/retries

Write them down as a list!

STEP 2: GROUP RELATED RESPONSIBILITIES
═══════════════════════════════════════

Group 1: Email Server Connection
  • Connect to SMTP
  • Disconnect
  • Check connection status

Group 2: Email Formatting
  • Format ticket notification email
  • Format user notification email
  • Generate HTML body

Group 3: Email Sending
  • Send single email
  • Send batch emails

Group 4: Each group might become a CLASS

STEP 3: ASK THE 5 QUESTIONS FOR EACH GROUP
═══

Group 1: Email Server Connection
  Q1: Remember something? YES (connection, config)
  Q2: Lifecycle? YES (connect/disconnect)
  → DECISION: CLASS (EmailConnection or SMTPClient)

Group 2: Email Formatting
  Q1: Remember something? NO (just transforms data)
  Q2: Lifecycle? NO
  → DECISION: FUNCTIONS (format_ticket_email, format_user_email)
  → OR: CLASS if they share templates/config

Group 3: Email Sending
  Q1: Remember something? YES (connection, queue)
  Q2: Lifecycle? YES (start/stop for background sending)
  → DECISION: CLASS (EmailSender)

STEP 4: DESIGN THE INTERFACES
═════════════════════════════

Before writing code, define WHAT each class/function does:

```
  class EmailSender:
      def __init__(self, smtp_host, smtp_port, ...): ...
      def connect(self) -> None: ...
      def disconnect(self) -> None: ...
      def send(self, to: str, subject: str, body: str) -> bool: ...
      def send_async(self, to: str, subject: str, body: str) -> None: ...

  def format_ticket_email(ticket_data: dict) -> tuple[str, str]:
      """Returns (subject, body)"""
      ...

  def format_user_email(user_data: dict) -> tuple[str, str]:
      """Returns (subject, body)"""
      ...
```


STEP 5: IMPLEMENT
═════════════════

Now write the actual code!

Part 7: Practical Exercise

Let me show you how to think through a real example:

```
┌─────────────────────────────────────────────────────────────────────────────┐
│                    EXERCISE: Design a Cache System                          │
└─────────────────────────────────────────────────────────────────────────────┘

REQUIREMENT: Cache database query results in Redis

STEP 1: What does it need to do?
─────────────────────────────────
• Connect to Redis
• Store data with key
• Retrieve data by key
• Delete data by key
• Set expiration time
• Handle connection failures

STEP 2: Ask the questions
─────────────────────────

"Connect to Redis"
  Q1: Remember something? YES (connection)
  Q2: Lifecycle? YES (connect/disconnect)
  → CLASS: RedisClient

"Store/Retrieve/Delete data"
  Q1: Remember something? YES (uses RedisClient)
  Q2: Lifecycle? Not really
  Q3: Group related operations? YES
  → CLASS: CacheService (uses RedisClient)

"Set expiration"
  → Part of CacheService.set() method

STEP 3: Design interface
────────────────────────

  class RedisClient:
      def __init__(self, host, port, db): ...
      def connect(self) -> None: ...
      def disconnect(self) -> None: ...
      def get(self, key: str) -> Optional[str]: ...
      def set(self, key: str, value: str, ttl: int = None) -> None: ...
      def delete(self, key: str) -> None: ...

  class CacheService:
      def __init__(self, redis_client: RedisClient):
          self.redis = redis_client
```

```
    def get_cached(self, key: str) -> Optional[Any]:
        data = self.redis.get(key)
        return json.loads(data) if data else None

    def cache(self, key: str, data: Any, ttl: int = 3600) -> None:
        self.redis.set(key, json.dumps(data), ttl)

    def invalidate(self, key: str) -> None:
        self.redis.delete(key)

STEP 4: Usage
═══════════════

  # Setup
  redis = RedisClient(host="localhost", port=6379, db=0)
  redis.connect()
  cache = CacheService(redis)

  # Use
  data = cache.get_cached("users:all")
  if not data:
      data = db.query(User).all()
      cache.cache("users:all", data, ttl=3600)
```

Part 8: Quick Reference Card

```
┌──────────────────────────────────────────────────────────────────────────────┐
│                    QUICK REFERENCE: WHEN TO USE WHAT                         │
└──────────────────────────────────────────────────────────────────────────────┘

USE A CLASS WHEN:
═══════════════════
✓ It needs to remember data between method calls
✓ It has a lifecycle (start/stop, open/close, connect/disconnect)
✓ It groups related operations that share data
✓ You need multiple instances with different data
✓ It represents a "thing" (Monitor, Router, Connection, Service)

USE A FUNCTION WHEN:
══════════════════════
✓ It's a one-time operation
✓ It transforms input → output
✓ It doesn't need to remember anything
✓ It's stateless (same input always gives same output)
✓ It represents an "action" (validate, format, calculate, detect)
```

USE A DATACLASS WHEN:
═══════════════════════
✓ It's primarily data with little/no behavior
✓ It represents a "record" or "message" (RowChange, UserDTO, Config)
✓ You want automatic __init__, __repr__, __eq__

USE AN ENUM WHEN:
═══════════════════
✓ It's a fixed set of choices
✓ Values don't change at runtime
✓ You want type safety and autocomplete

NAMING CONVENTIONS:
═══════════════════
Classes: PascalCase → PostgresWALMonitor, BinlogRouter, RowChange
Functions: snake_case → detect_database_type, on_ticket_insert
Constants: UPPER_CASE → EVENT_TYPE, MAX_WORKERS
Variables: snake_case → db_session, router, change
Private: _prefix → _rules, _pool, _process_message

Summary

The key insight is: **Design is about asking the right questions**

1. **What does it need to DO?** (list responsibilities)
2. **Does it need to REMEMBER?** (state → class)
3. **Does it have a LIFECYCLE?** (start/stop → class)
4. **Does it GROUP related things?** (multiple methods → class)
5. **Is it just DATA?** (dataclass)
6. **Is it a one-time ACTION?** (function)

Would you like me to walk through designing any specific feature using this thinking process?

i thnk we should first understand the flow of the task and then Think about When Designing NEW Code,so now tell me this thing about my binloger code

You're absolutely right! Let me trace your binlog code flow **step by step** first, then explain the design thinking behind each part.

Binlog Code Flow - Complete Understanding

Step 1: The Entry Point (Where It All Starts)

Your app starts in main.py:

Complete Binlog Flow with Design Thinking

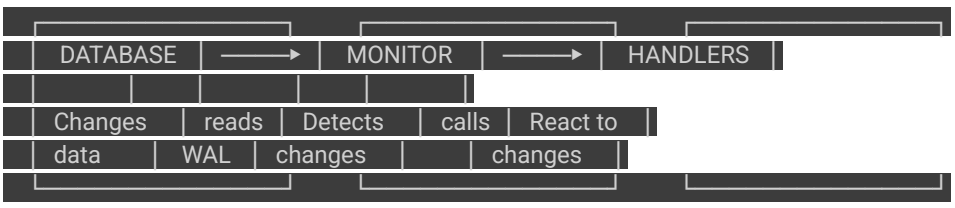
The Big Picture First

WHAT IS THE GOAL?

"When database changes, do something automatically"

Examples:
• Ticket created → Send notification to assignee
• User created → Send welcome email
• Role updated → Invalidate cache

HOW DOES IT WORK?



Step-by-Step Flow

FLOW STEP 1: App Starts → Calls start_binlog_monitor()

```
┌─────────────────────────────────────────────────────────────────────────────┐
│  FLOW STEP 1: APP STARTUP                                                   │
│  File: main.py → binlog.py                                                  │
└─────────────────────────────────────────────────────────────────────────────┘

  main.py (line 36)
  ─────────────────
  @asynccontextmanager
  async def app_lifespan(app: FastAPI):
      # Startup
      start_binlog_monitor()    ◄─── ENTRY POINT
      ...


  binlog.py :: start_binlog_monitor()
  ──────────────────────────────────

  def start_binlog_monitor(max_workers: int = 8) -> None:
      global _monitor, _thread

      # Step 1.1: Check if already running (Singleton)
      if _monitor is not None:
          return  # Already running, skip

      # Step 1.2: Detect database type
      db_type = detect_database_type()  # Returns 'postgres' or 'mysql'

      # Step 1.3: Setup router with handlers
      router, EventType = setup_router(max_workers)

      # Step 1.4: Create monitor
      if db_type == 'mysql':
          _monitor = BinlogMonitor(...)
      else:
          _monitor = PostgresWALMonitor(...)

      # Step 1.5: Start background thread
      _thread = threading.Thread(target=_monitor.start, daemon=True)
      _thread.start()
```

```
DESIGN THINKING:
═══════════════
Q: Why is start_binlog_monitor() a FUNCTION, not a class?
A: It's an "orchestrator" - it coordinates other components but doesn't
   need to remember much itself. Uses global variables for singleton pattern.

Q: Why global variables (_monitor, _thread)?
A: Singleton pattern - only ONE monitor should run at a time.
   If we call start_binlog_monitor() twice, second call does nothing.

Q: Why daemon=True for the thread?
A: Daemon thread dies when main app dies. Don't want orphan threads.
```

FLOW STEP 2: detect_database_type()

```
┌──────────────────────────────────────────────────────────────────────────────┐
│  FLOW STEP 2: DETECT DATABASE TYPE                                           │
│  File: binlog.py                                                             │
└──────────────────────────────────────────────────────────────────────────────┘
```

```
    def detect_database_type() -> str:
        db_url = DATABASE_URL.lower()
        if 'postgres' in db_url:
            return 'postgres'
        elif 'mysql' in db_url:
            return 'mysql'
        else:
            return 'postgres'  # Default
```

```
DESIGN THINKING:
═══════════════
Q: Why is this a FUNCTION?
A:
   ✗ Doesn't remember anything
   ✗ No lifecycle
   ✓ Simple input → output (URL → 'postgres' or 'mysql')
   ✓ Stateless (same input = same output)

Q: Why is it a SEPARATE function?
A: Single Responsibility - one function does one thing.
   Makes code readable and testable.
```

FLOW STEP 3: setup_router() - The Most Important Part

```
┌─────────────────────────────────────────────────────────────────────────────┐
│  FLOW STEP 3: SETUP ROUTER (Register Handlers)                              │
│  File: binlog.py                                                            │
└─────────────────────────────────────────────────────────────────────────────┘

  def setup_router(max_workers: int = 8):
      db_type = detect_database_type()

      # Step 3.1: Import correct classes based on DB type
      if db_type == 'mysql':
          from services.binlog_monitor import BinlogRouter, EventType
      else:
          from services.postgres_wal_monitor import BinlogRouter, EventType

      schema_name = "public"  # For PostgreSQL

      # Step 3.2: Create the router
      router = BinlogRouter(db_session_factory, max_workers=max_workers)

      # Step 3.3: Register handlers for each table
      #
      # FORMAT: router.register(schema, table, [events], handler_function)
      #
      # This says: "When THIS table has THESE events, call THIS function"

      # Ticket handlers
      router.register(schema_name, "tickets", [EventType.INSERT], on_ticket_insert)
      router.register(schema_name, "tickets", [EventType.UPDATE], on_ticket_update)
      router.register(schema_name, "ticket_replies", [EventType.INSERT], on_ticket_reply_insert)

      # Task handlers
      router.register(schema_name, "tasks", [EventType.INSERT], on_task_create)
      router.register(schema_name, "tasks", [EventType.UPDATE], on_task_update)

      # Cache invalidation handlers (for many tables)
      master_tables = ["roles", "companies", "departments", ...]
      for table in master_tables:
          router.register(
              schema_name,
              table,
              [EventType.INSERT, EventType.UPDATE, EventType.DELETE],
              on_master_table_change
          )

      return router, EventType


WHAT DOES THIS CREATE?
```

```
═══════════════════════════════

    router._rules = [
        ("public", "tickets",       [INSERT],              on_ticket_insert),
        ("public", "tickets",       [UPDATE],              on_ticket_update),
        ("public", "ticket_replies", [INSERT],             on_ticket_reply_insert),
        ("public", "tasks",         [INSERT],              on_task_create),
        ("public", "tasks",         [UPDATE],              on_task_update),
        ("public", "roles",         [INSERT, UPDATE, DELETE], on_master_table_change),
        ("public", "companies",     [INSERT, UPDATE, DELETE], on_master_table_change),
        ... more rules ...
    ]


DESIGN THINKING:
═══════════════
Q: Why is setup_router() a FUNCTION, not a class?
A: It just creates and configures a router, then returns it.
   No state to remember. One-time setup operation.

Q: Why is BinlogRouter a CLASS?
A:
   ✓ REMEMBERS: _rules (list of registered handlers)
   ✓ REMEMBERS: _pool (ThreadPoolExecutor)
   ✓ REMEMBERS: _db_session_factory
   ✓ GROUPS related operations: register(), dispatch(), shutdown()

Q: Why separate handlers into different files?
A: Organization by domain:
   • tickets_handler.py - all ticket-related handlers
   • tasks_handler.py - all task-related handlers
   • cache_invalidation_handler.py - all cache handlers
```

FLOW STEP 4: Create Monitor

```
┌──────────────────────────────────────────────────────────────────────────────┐
│  FLOW STEP 4: CREATE MONITOR                                                 │
│  File: binlog.py → services/postgres_wal_monitor.py                          │
└──────────────────────────────────────────────────────────────────────────────┘

    # In start_binlog_monitor():

    _monitor = PostgresWALMonitor(
        database_url=DATABASE_URL,
        slot_name="nextgen_slot_mydb",
        plugin="wal2json",
        only_schemas=["public"],
```

```
    router=router,          ◄─── Router passed here
    resume_stream=True
)

WHAT DOES THIS CREATE?
═══════════════════════

  PostgresWALMonitor instance with:
  ├── self.running = False
  ├── self.database_url = "postgresql://..."
  ├── self.slot_name = "nextgen_slot_mydb"
  ├── self.plugin = "wal2json"
  ├── self.only_schemas = ["public"]
  ├── self.router = router        ◄─── Reference to router
  ├── self.resume_stream = True
  ├── self._conn = None           (will be set later)
  ├── self._cursor = None         (will be set later)
  ├── self.schema_cache = SchemaCache(conn_settings)
  └── self.decoder = WALDecoder(schema_cache)

DESIGN THINKING:
═══════════════
Q: Why is PostgresWALMonitor a CLASS?
A:
  ✓ REMEMBERS lots of state: connection, cursor, running flag, config
  ✓ Has LIFECYCLE: start() → running → stop()
  ✓ GROUPS related operations: start(), stop(), _process_message(), _cleanup()
  ✓ Manages resources: database connection, replication slot
```

FLOW STEP 5: Start Background Thread

```
┌──────────────────────────────────────────────────────────────────────────────┐
│  FLOW STEP 5: START BACKGROUND THREAD                                        │
│  File: binlog.py                                                             │
└──────────────────────────────────────────────────────────────────────────────┘

  # In start_binlog_monitor():

  _thread = threading.Thread(
      target=_monitor.start,    ◄─── This function will run in thread
      daemon=True,              ◄─── Dies with main app
      name="postgres-wal-monitor"
  )
  _thread.start()               ◄─── Thread starts running
```

```
WHAT HAPPENS?
═══════════════

  MAIN THREAD                    BACKGROUND THREAD
  ═══════════                    ═════════════════

  start_binlog_monitor()
      │
      ├──► _thread.start() ──────────► _monitor.start() begins
      │                                        │
      └──► Returns immediately                 │
           (doesn't wait)                      ▼
                                    Connects to PostgreSQL
                                               │
      Main thread continues                    ▼
      handling HTTP requests        Starts reading WAL
                                               │
                                               ▼
                                    BLOCKS here, waiting
                                    for database changes
                                               │
                                               ▼
                                    When change detected:
                                    _process_message(msg)


DESIGN THINKING:
═══════════════
Q: Why a separate thread?
A: WAL monitoring BLOCKS - it waits for changes.
   Can't block the main thread (would freeze HTTP server).

Q: Why daemon=True?
A: Daemon threads are automatically killed when main app exits.
   Don't want orphan threads running after app stops.
```

FLOW STEP 6: Monitor Starts Running

```
┌─────────────────────────────────────────────────────────────────────────────┐
│  FLOW STEP 6: MONITOR RUNS (Background Thread)                              │
│  File: services/postgres_wal_monitor.py                                     │
└─────────────────────────────────────────────────────────────────────────────┘


  class PostgresWALMonitor:

      def start(self):
```

```
        self.running = True

        # Step 6.1: Create replication slot if needed
        self._ensure_replication_slot()

        # Step 6.2: Connect to PostgreSQL with replication protocol
        self._conn = psycopg2.connect(
            connection_factory=LogicalReplicationConnection,
            **self.conn_settings
        )
        self._cursor = self._conn.cursor()

        # Step 6.3: Start consuming the WAL stream
        self._cursor.start_replication(
            slot_name=self.slot_name,
            decode=True,
            options={"format-version": "1"}
        )

        # Step 6.4: Start keepalive thread
        self._start_keepalive_thread()

        # Step 6.5: BLOCK and process messages
        #           This line BLOCKS forever until stop() is called
        self._cursor.consume_stream(self._process_message)
        #                   ▲
        #                   |
        #           For each WAL message, call _process_message()


DESIGN THINKING:
═══════════════════════
Q: Why _ensure_replication_slot() separate method?
A: Single responsibility - one method does one thing.
  Also might fail, want clear error messages.

Q: Why consume_stream() with callback?
A: PostgreSQL library design - it calls your function for each message.
  Alternative would be polling loop (less efficient).

Q: Why keepalive thread?
A: PostgreSQL closes inactive connections. Need to periodically
  say "I'm still here" to keep connection alive.
```

FLOW STEP 7: Database Change Detected

```
┌──────────────────────────────────────────────────────────────────────────────────────────────────────────────┐
│  FLOW STEP 7: DATABASE CHANGE DETECTED                                                                       │
```

```
│  File: services/postgres_wal_monitor.py                               │
└──────────────────────────────────────────────────────────────────────────────────────────────────────────────
─────────────┘

SCENARIO: Someone inserts a new ticket via API

  API Request: POST /tickets
       │
       ▼
  Database: INSERT INTO tickets (title, assigned_to_id) VALUES ('Bug', 5)
       │
       ▼
  PostgreSQL WAL: Records this change
       │
       ▼
  Monitor receives message via consume_stream()
       │
       ▼
  _process_message(msg) is called


  def _process_message(self, msg):
      # Step 7.1: Parse the WAL message (JSON)
      payload = json.loads(msg.payload)

      # payload looks like:
      # {
      #   "change": [{
      #     "kind": "insert",
      #     "schema": "public",
      #     "table": "tickets",
      #     "columnnames": ["id", "title", "assigned_to_id", ...],
      #     "columnvalues": [123, "Bug", 5, ...]
      #   }]
      # }

      # Step 7.2: Decode into RowChange objects
      changes = self.decoder.decode_wal2json(payload)

      # changes = [
      #   RowChange(
      #     schema="public",
      #     table="tickets",
      #     event=EventType.INSERT,
      #     row={"id": 123, "title": "Bug", "assigned_to_id": 5, ...}
      #   )
      # ]

      # Step 7.3: Dispatch to router
      for change in changes:
          self.router.dispatch(change)
```

```
        # Step 7.4: Acknowledge message
        msg.cursor.send_feedback(flush_lsn=msg.data_start)
        _save_offset(msg.data_start)


DESIGN THINKING:
═══════════════════
Q: Why WALDecoder separate class?
A:
  ✓ REMEMBERS: schema_cache
  ✓ GROUPS related operations: decode_wal2json(), decode_test_decoding()
  ✓ Single responsibility: only decodes WAL messages

Q: Why RowChange as dataclass?
A: It's just DATA - schema, table, event, row data.
  Dataclass gives automatic __init__, __repr__, __eq__.
```

FLOW STEP 8: Router Dispatches to Handler

```
┌──────────────────────────────────────────────────────────────────────────────┐
│  FLOW STEP 8: ROUTER DISPATCHES TO HANDLER                                   │
│  File: services/postgres_wal_monitor.py (BinlogRouter class)                 │
└──────────────────────────────────────────────────────────────────────────────┘

    class BinlogRouter:

        def dispatch(self, change: RowChange) -> None:
            # Check all registered rules
            for schema_pat, table_pat, events, handler in self._rules:

                # Does this change match this rule?
                if (change.event in events and
                    fnmatch.fnmatch(change.schema, schema_pat) and
                    fnmatch.fnmatch(change.table, table_pat)):

                    # YES! Submit to thread pool
                    self._pool.submit(self._safe_call, handler, change)

        def _safe_call(self, handler, change):
            try:
                handler(change, self._db_session_factory)
            except Exception as e:
                logger.exception(f"Handler failed: {e}")


EXAMPLE EXECUTION:
═══════════════════
```

```
    change = RowChange(schema="public", table="tickets", event=INSERT, ...)

    Checking rules:

┌──────────────────────────────────────────────────────────────────────────────┬─────────┬──────────┐
│ Rule                                                                         │ Match?  │ Action   │
├──────────────────────────────────────────────────────────────────────────────┼─────────┼──────────┤
│ ("public", "tickets", [INSERT], on_ticket_insert)                            │ YES     │ SUBMIT   │
│ ("public", "tickets", [UPDATE], on_ticket_update)                            │ NO      │ skip     │
│ ("public", "users", [INSERT], on_user_create)                                │ NO      │ skip     │
│ ("public", "tickets", [ALL], on_master_change)                               │ YES     │ SUBMIT   │
└──────────────────────────────────────────────────────────────────────────────┴─────────┴──────────┘

    Two handlers will be called (in parallel via thread pool):
    • on_ticket_insert(change, db_factory)
    • on_master_table_change(change, db_factory)


DESIGN THINKING:
═══════════════
Q: Why thread pool (ThreadPoolExecutor)?
A: Handlers run in parallel - one slow handler doesn't block others.
   Also isolates failures - one handler crashing doesn't crash others.

Q: Why _safe_call wrapper?
A: Error isolation. If handler throws exception, log it but don't crash.

Q: Why fnmatch (pattern matching)?
A: Allows wildcards in future: router.register("public", "ticket*", ...)
```

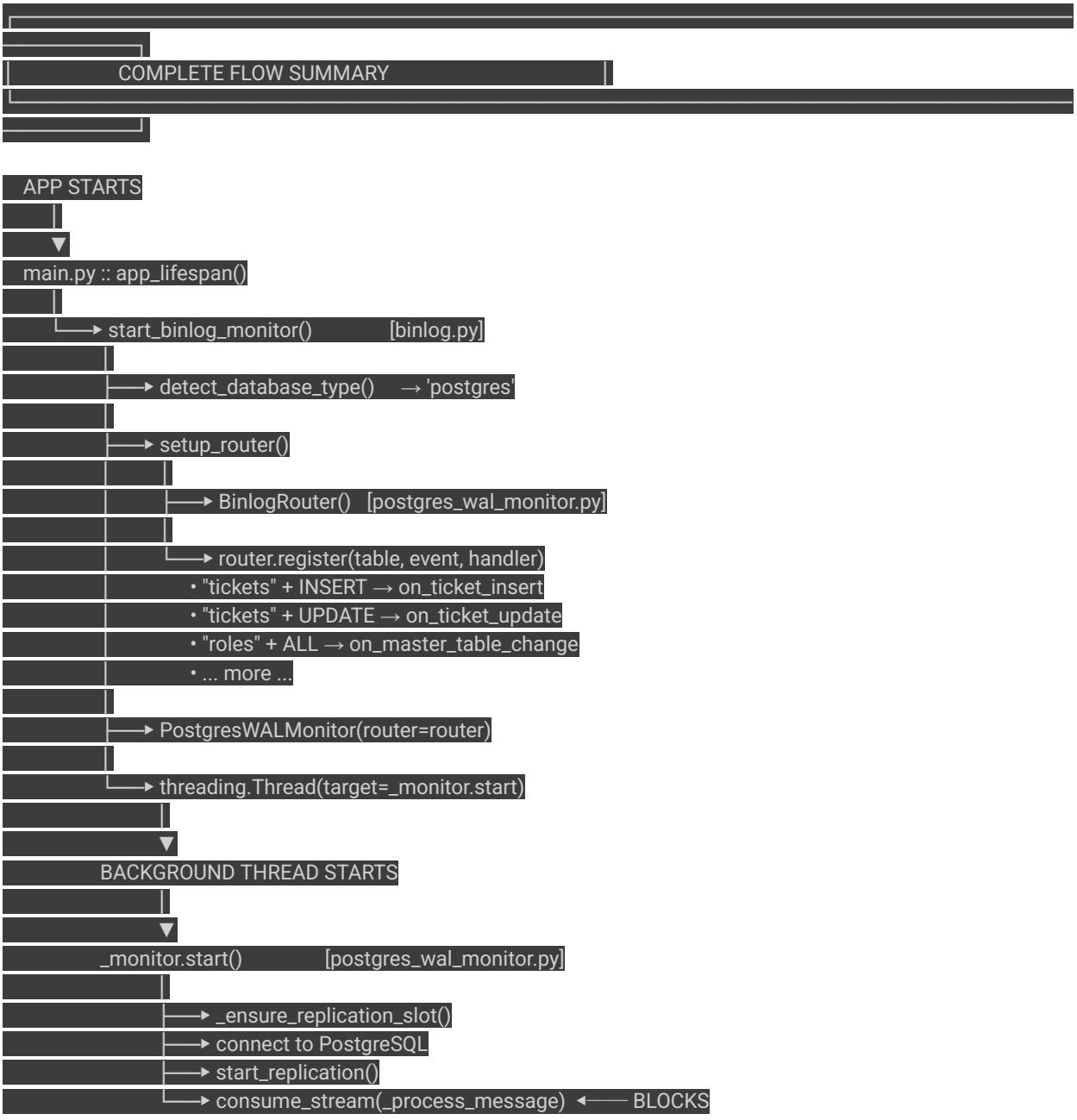
FLOW STEP 9: Handler Executes

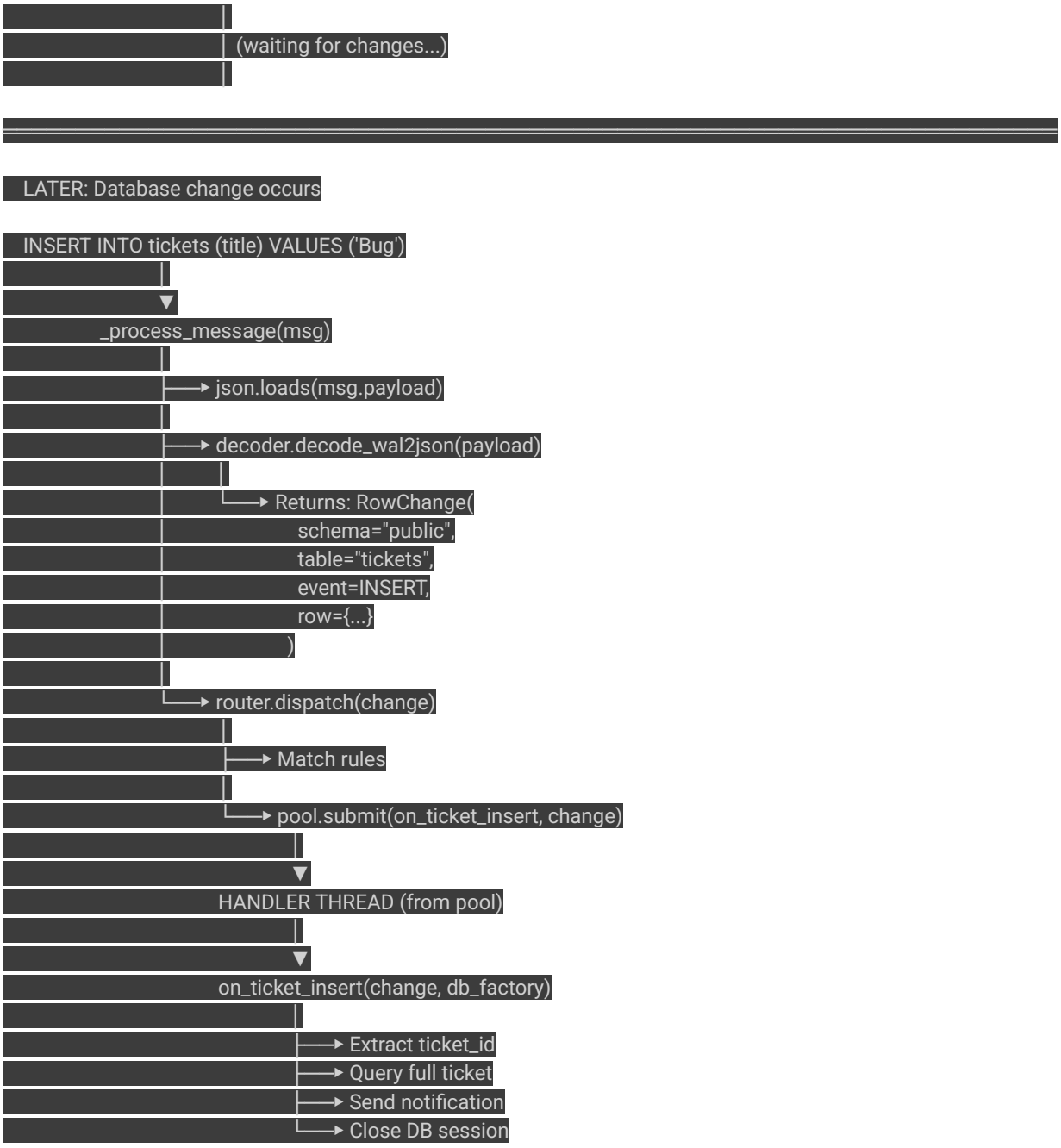
```
┌──────────────────────────────────────────────────────────────────────────────┐
│  FLOW STEP 9: HANDLER EXECUTES                                               │
│  File: services/binlog_handlers/tickets_handler.py                           │
└──────────────────────────────────────────────────────────────────────────────┘

    def on_ticket_insert(change, db_factory: Callable[[], Session]):
        """Handle new ticket creation."""
        db = db_factory()  # Create new DB session
        try:
            # Step 9.1: Extract data from change
```

```
            row = change.row or {}
            ticket_id = row.get("id")
            assigned_to_id = row.get("assigned_to_id")

            if not ticket_id or not assigned_to_id:
                return

            # Step 9.2: Fetch complete ticket from DB (if needed)
            ticket = db.query(Tickets).filter(Tickets.id == ticket_id).first()
            if not ticket:
                return

            # Step 9.3: Build notification data
            ticket_data = extract_ticket_data(ticket, db)

            # Step 9.4: Send notification to assigned user
            notify_users(
                db,
                [assigned_to_id],
                "New Ticket",
                ticket_data,
                "ticket",
                log=True
            )

            # Step 9.5: Notify managers
            manager_ids = get_manager_ids(assigned_to_id, db)
            if manager_ids:
                notify_users(db, manager_ids, "Manager: New Ticket", ticket_data)

        except Exception as e:
            logger.error(f"Error in on_ticket_insert: {e}")
        finally:
            db.close()  # ALWAYS close DB session


DESIGN THINKING:
═══════════════════════
Q: Why handlers are FUNCTIONS, not classes?
A:
  ✗ Don't remember anything between calls
  ✗ No lifecycle
  ✓ One-time operation: receive change → do something
  ✓ Each call is independent

Q: Why db_factory instead of passing db directly?
A: Each handler needs its OWN session.
  If we passed same session, handlers would conflict (running in parallel).

Q: Why try/finally with db.close()?
A: DB sessions are resources that MUST be closed.
  finally ensures close happens even if exception occurs.
```

Q: Why separate handler files?
A: Organization by domain:
  • tickets_handler.py - knows about tickets
  • tasks_handler.py - knows about tasks
  • cache_invalidation_handler.py - knows about cache

Complete Flow Summary





Design Decisions Summary

Component	Type	Why This Design?
start_binlog_monitor()	FUNCTION	Orchestrator, uses global singleton
detect_database_type()	FUNCTION	Simple input→output, no state
setup_router()	FUNCTION	One-time setup, returns router
EventType	ENUM	Fixed values: INSERT, UPDATE, DELETE
RowChange	DATACLASS	Mainly data, few helper methods
BinlogRouter	CLASS	Remembers rules, has dispatch/shutdown
WALDecoder	CLASS	Remembers schema_cache, groups decode
SchemaCache	CLASS	Remembers column info, caches queries
PostgresWALMonitor	CLASS	Lifecycle, lots of state, manages conn
on_ticket_insert()	FUNCTION	One-time action, no state to remember
on_ticket_update()	FUNCTION	One-time action, no state to remember
on_master_table_change()	FUNCTION	One-time action, no state to remember
_monitor (global)	VARIABLE	Singleton - only one monitor runs
_thread (global)	VARIABLE	Reference to background thread

Now you understand the complete flow! The key insight is:

1. **First understand WHAT the code does** (the flow)
2. **Then understand WHY it's designed that way** (the thinking)

Would you like me to trace any specific part in more detail, or explain how to add a new feature to this system?

why we use thread in between and for what purpose ,how we come to know that we shuld use the thread and what things we have to keep in mind to implement or to use the thread ,also in how many ways or types of threads can be implemented as i am confused that why we are using it?

Excellent question! Let me explain threading from the ground up - why, when, and how to use it.

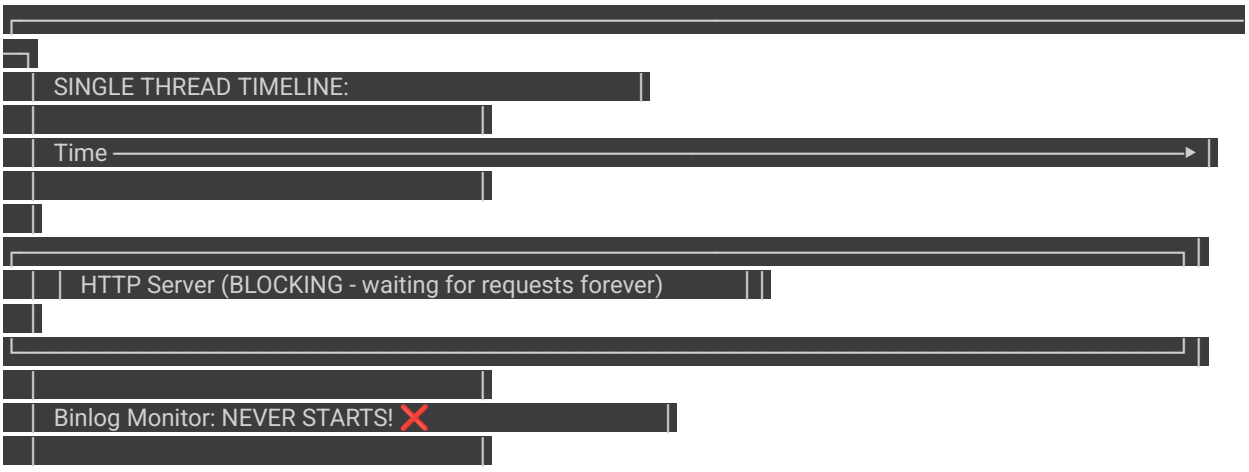
Threading - Complete Understanding

Part 1: Why Do We Need Threads?

SCENARIO: Your app needs to do TWO things:
1. Handle HTTP requests (FastAPI server)
2. Monitor database changes (Binlog monitor)

WITHOUT THREADS (Single Thread):

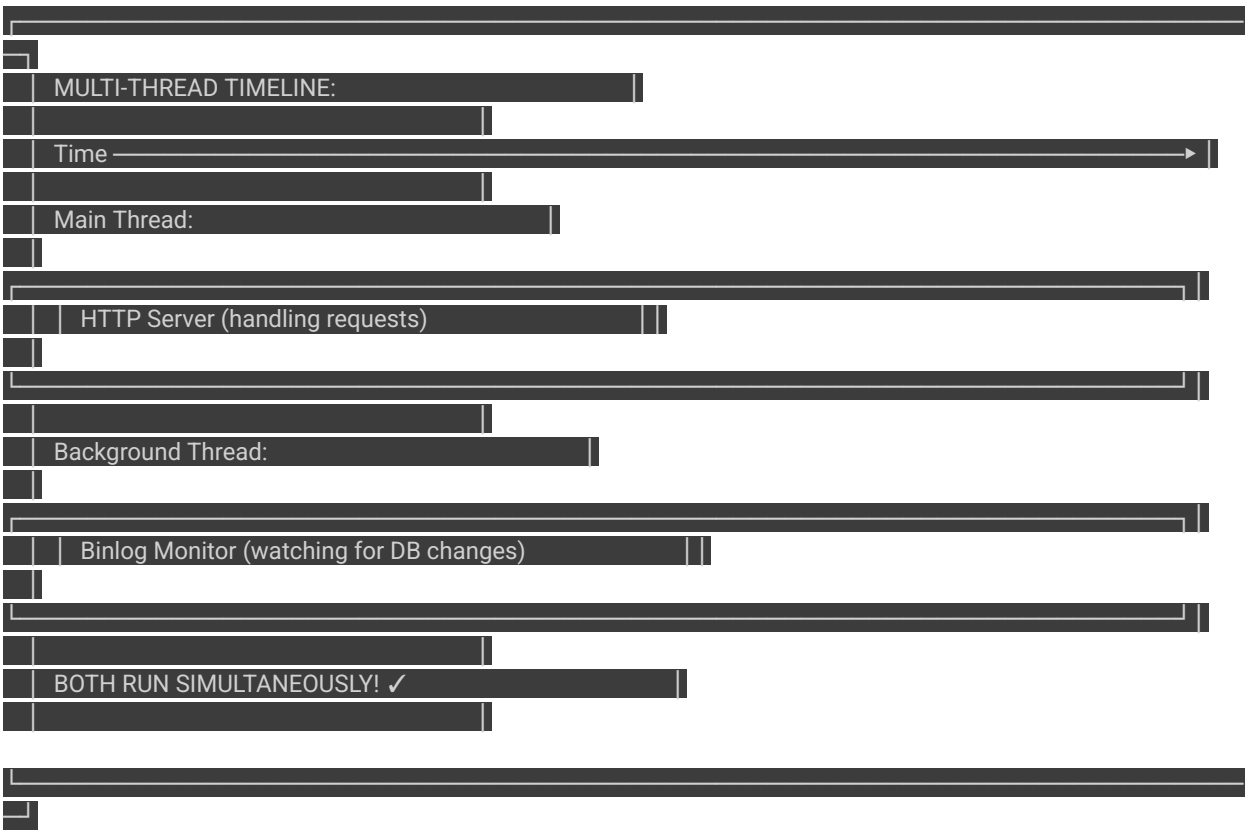
```
def main():
    start_http_server()     # This BLOCKS forever (waiting for requests)
    start_binlog_monitor()  # ❌ NEVER RUNS! (stuck on line above)

OR

def main():
    start_binlog_monitor()  # This BLOCKS forever (waiting for DB changes)
    start_http_server()     # ❌ NEVER RUNS! (stuck on line above)
```



WITH THREADS (Multiple Threads):

```
def main():
    # Start binlog in separate thread
    thread = threading.Thread(target=start_binlog_monitor)
    thread.start()          # Starts running in PARALLEL
```

```
    start_http_server()     # Main thread handles HTTP
```



Part 2: What is "Blocking"?


```
BLOCKING = Code that WAITS for something and doesn't return

EXAMPLES OF BLOCKING OPERATIONS:
═══════════════════════════════

1. WAITING FOR USER INPUT

  name = input("Enter name: ")  # BLOCKS until user types
  print(f"Hello {name}")        # Only runs AFTER user types
```

2. WAITING FOR NETWORK RESPONSE

```
response = requests.get("https://api.example.com")  # BLOCKS until response
print(response.json())        # Only runs AFTER response arrives
```

3. WAITING FOR DATABASE CHANGES (YOUR BINLOG)

```
cursor.consume_stream(handler)  # BLOCKS forever, waiting for changes
print("Done")                   # NEVER RUNS!
```

4. WAITING FOR FILE DOWNLOAD

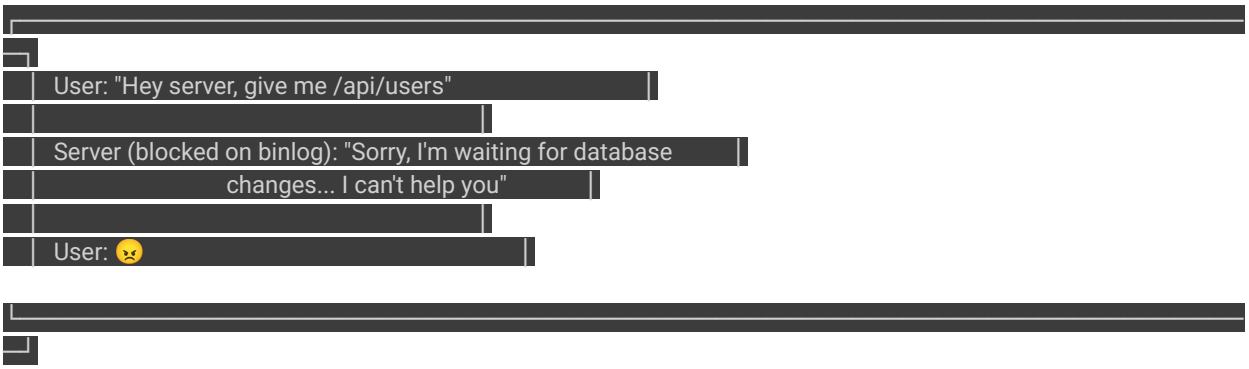
```
download_large_file()  # BLOCKS until download complete (maybe 10 minutes)
process_file()         # Only runs AFTER download
```

5. SLEEP

```
time.sleep(60)     # BLOCKS for 60 seconds
print("Woke up")   # Runs after 60 seconds
```

WHY IS BLOCKING A PROBLEM?

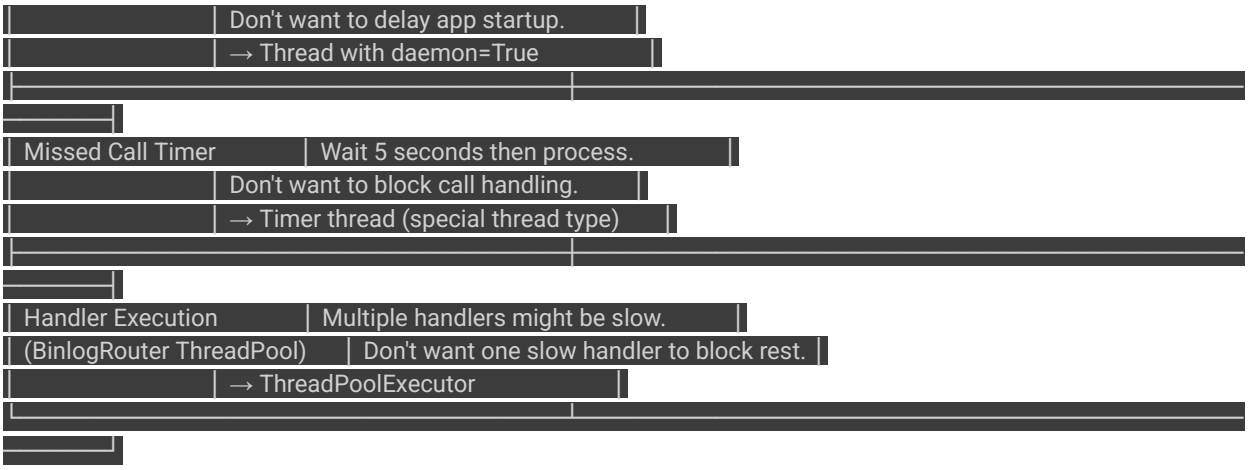
While code is BLOCKED, nothing else can run in that thread.



Part 3: When to Use Threads (Decision Guide)

EXAMPLES FROM YOUR CODEBASE:

Use Case	Why Thread?
Binlog Monitor (postgres_wal_monitor)	BLOCKS forever waiting for DB changes. Main thread needs to handle HTTP requests. → Thread with daemon=True
RabbitMQ Consumer (grandstream_consumer)	BLOCKS forever waiting for messages. Main thread needs to handle HTTP requests. → Thread with daemon=True
SFTP Sync on Startup	Takes time (network operation).



Part 4: Types of Threading in Python

TYPE 1: BASIC THREAD (threading.Thread)

Use when: You have ONE task to run in background

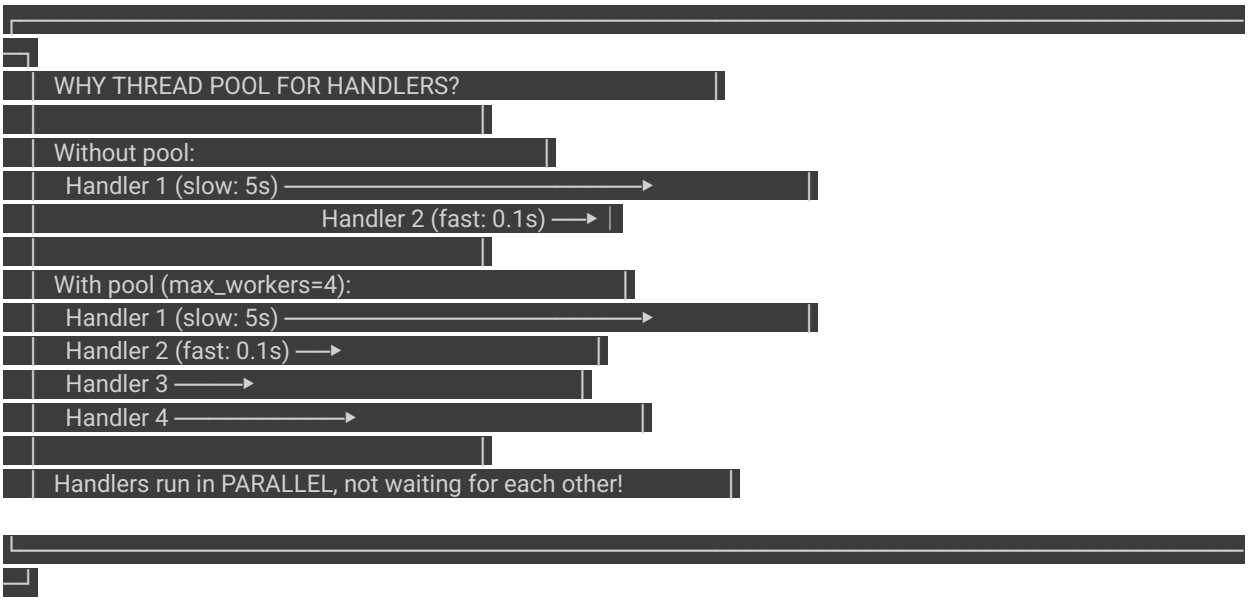
```
import threading

def my_task():
    print("Running in background")
    time.sleep(10)
    print("Done!")

# Create and start thread
thread = threading.Thread(target=my_task)
thread.start()

print("Main continues immediately")
```

Your code example (binlog.py):

```
_thread = threading.Thread(
    target=_monitor.start,    # Function to run
    daemon=True,              # Die with main app
    name="postgres-wal-monitor"
```

```
)
_thread.start()


TYPE 2: DAEMON THREAD (daemon=True)
═══════════════════════════════════

Use when: Thread should die when main app dies

# DAEMON THREAD
thread = threading.Thread(target=my_task, daemon=True)
thread.start()

# If main app exits, this thread is KILLED automatically
# Good for: background monitors, cleanup tasks

# NON-DAEMON THREAD (default)
thread = threading.Thread(target=my_task, daemon=False)
thread.start()

# Main app will WAIT for this thread to finish before exiting
# Good for: important tasks that MUST complete


┌─────────────────────────────────────────────────────────────────────────────┐
│  DAEMON vs NON-DAEMON:                                                      │
│                                                                             │
│  Main app exits...                                                          │
│                                                                             │
│  Daemon thread:     KILLED immediately (might lose work)                    │
│  Non-daemon thread: App WAITS for it to finish                              │
│                                                                             │
│  Your binlog uses daemon=True because:                                      │
│  • Monitor runs forever                                                     │
│  • When app stops, monitor should stop too                                  │
│  • No important work to "finish"                                            │
└─────────────────────────────────────────────────────────────────────────────┘


TYPE 3: TIMER THREAD (threading.Timer)
══════════════════════════════════════

Use when: Run something AFTER a delay

import threading

def delayed_task():
    print("This runs after 5 seconds!")
```

```
    # Start timer - will call delayed_task after 5 seconds
    timer = threading.Timer(5.0, delayed_task)
    timer.start()

    print("Main continues immediately")
    # ... 5 seconds later ...
    # "This runs after 5 seconds!" prints

Your code example (grandstream_consumer.py):
═══════════════════════════════════════════════
    # Wait 5 seconds before processing missed call
    # (in case call gets answered on another device)

    missed_call_timer = threading.Timer(
        delay_seconds + 0.5,        # Wait this long
        process_missed_queue_timer  # Then call this function
    )
    missed_call_timer.start()


TYPE 4: THREAD POOL (ThreadPoolExecutor)
═══════════════════════════════════════

Use when: Many small tasks that can run in parallel

    from concurrent.futures import ThreadPoolExecutor

    def process_item(item):
        print(f"Processing {item}")
        time.sleep(1)
        return f"Done: {item}"

    # Create pool with 4 worker threads
    with ThreadPoolExecutor(max_workers=4) as pool:
        # Submit 10 tasks - only 4 run at a time
        futures = [pool.submit(process_item, i) for i in range(10)]

        # Get results
        for future in futures:
            print(future.result())

Your code example (BinlogRouter):
═════════════════════════════════
    class BinlogRouter:
        def __init__(self, db_session_factory, max_workers=8):
            self._pool = ThreadPoolExecutor(max_workers=max_workers)

        def dispatch(self, change):
            for schema, table, events, handler in self._rules:
                if matches(change):
                    # Submit to pool - runs in background
                    self._pool.submit(self._safe_call, handler, change)
```



TYPE 5: THREAD WITH EVENT (threading.Event)

Use when: Need to signal thread to stop

```
import threading

stop_event = threading.Event()

def worker():
    while not stop_event.is_set():  # Keep running until told to stop
        print("Working...")
        time.sleep(1)
    print("Stopped!")

thread = threading.Thread(target=worker)
thread.start()

time.sleep(5)         # Let it run for 5 seconds
stop_event.set()      # Signal to stop
thread.join()         # Wait for thread to finish
```

Your code example (availability_cleanup.py):

```
_cleanup_stop_event = threading.Event()

def cleanup_worker():
    while not _cleanup_stop_event.is_set():
        # Do cleanup work
        cleanup_stale_sessions()
```

```
        # Wait 60 seconds OR until stop signal
        _cleanup_stop_event.wait(timeout=60)

def stop_cleanup():
    _cleanup_stop_event.set()  # Signal worker to stop


TYPE 6: THREAD WITH LOCK (threading.Lock)
═══════════════════════════════════════════

Use when: Multiple threads access SAME data

import threading

counter = 0
lock = threading.Lock()

def increment():
    global counter
    with lock:  # Only ONE thread can be here at a time
        temp = counter
        time.sleep(0.001)  # Simulate work
        counter = temp + 1

threads = [threading.Thread(target=increment) for _ in range(100)]
for t in threads: t.start()
for t in threads: t.join()

print(f"Counter: {counter}")  # Always 100 with lock

Your code example (rabbitmq.py):
═══════════════════════════════
_connection_lock = threading.RLock()

def get_connection():
    with _connection_lock:  # Only one thread can get/create connection
        if _connection is None:
            _connection = create_connection()
        return _connection
```

Part 5: Thread Types Summary

```
┌──────────────────────────────────────────────────────────────────────────────┐
│                    WHICH THREAD TYPE TO USE?                                 │
└──────────────────────────────────────────────────────────────────────────────┘
```

Situation	Thread Type	Example
Run ONE task in background that runs FOREVER	threading.Thread (daemon=True)	Binlog monitor RabbitMQ consumer
Run ONE task that MUST complete before app exits	threading.Thread (daemon=False)	Save important data before exit
Run something AFTER delay	threading.Timer	Delayed missed call processing
Run MANY tasks in parallel	ThreadPoolExecutor	Handler execution Parallel API calls
Need to STOP thread gracefully	threading.Event	Cleanup service with stop signal
Multiple threads share DATA	threading.Lock	Shared connection Counter updates
Each thread needs OWN copy of some data	threading.local()	DB session per thread

---

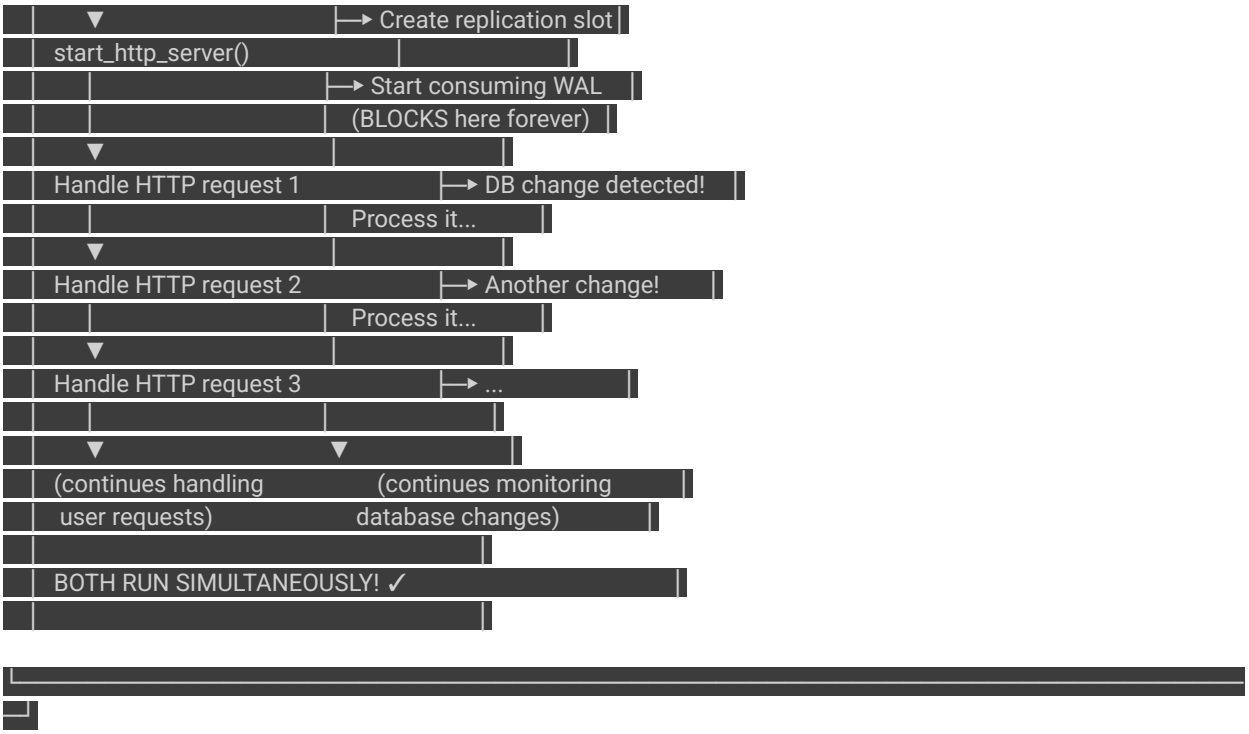
Part 6: Your Binlog Code - Why Thread is Used

YOUR BINLOG CODE - THREADING ANALYSIS

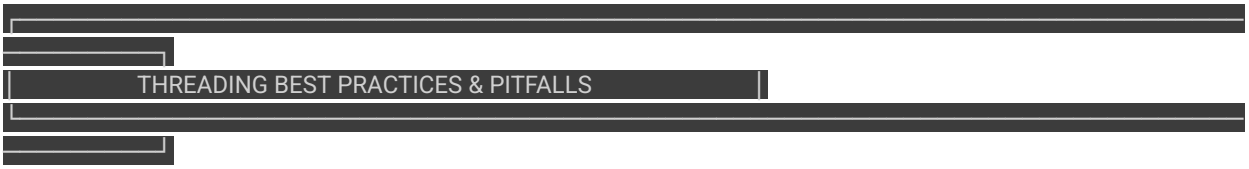
QUESTION: Why does binlog need a thread?

```
# In PostgresWALMonitor.start()
self._cursor.consume_stream(self._process_message)
#          ▲
#          |
```

```
    #           └── THIS LINE BLOCKS FOREVER!
    #               It waits for database changes and NEVER returns.


PROBLEM WITHOUT THREAD:
═══════════════════════

    def main():
        # If we call this directly...
        _monitor.start()      # BLOCKS FOREVER

        # This never runs!
        start_http_server()   # ❌ Users can't access your app!


SOLUTION WITH THREAD:
═════════════════════

    def start_binlog_monitor():
        _monitor = PostgresWALMonitor(...)

        # Start in SEPARATE thread
        _thread = threading.Thread(
            target=_monitor.start,  # This function will block
            daemon=True             # But in its own thread!
        )
        _thread.start()

        # This returns IMMEDIATELY
        # Main thread continues to start HTTP server


VISUAL EXPLANATION:
═══════════════════

┌──────────────────────────────────────────────────────────────────────────────┐
│                                                                              │
│   MAIN THREAD                    BINLOG THREAD                               │
│   ═══════════                    ═════════════                               │
│                                                                              │
│   start_binlog_monitor()                                                     │
│       │                                                                      │
│       ├──► Create PostgresWALMonitor                                         │
│       │                                                                      │
│       ├──► threading.Thread(target=_monitor.start)                           │
│       │                                                                      │
│       ├──► thread.start() ──────────────────────► _monitor.start()           │
│       │    (returns immediately)                      │                      │
│       │                                               ├──► Connect to PostgreSQL
│       │                                               │
```



Part 7: Things to Keep in Mind When Using Threads



RULE 1: DAEMON THREADS FOR "FOREVER" TASKS

```
# GOOD: Daemon thread for monitor
thread = threading.Thread(target=monitor, daemon=True)

# When app exits, thread dies automatically
# No orphan threads left running

# BAD: Non-daemon for forever task
thread = threading.Thread(target=monitor, daemon=False)

# App tries to exit, but waits for thread...
# Thread runs forever...
# App NEVER EXITS! 😱
```

RULE 2: EACH THREAD NEEDS ITS OWN DB SESSION
═══

```
# BAD: Sharing session across threads
db = SessionLocal()

def handler(change):
    db.query(...)  # ❌ Multiple threads use same session = CRASH

# GOOD: Each thread creates own session
def handler(change, db_factory):
    db = db_factory()  # New session for THIS thread
    try:
        db.query(...)
    finally:
        db.close()
```

RULE 3: USE LOCKS FOR SHARED DATA
═══════════════════════════════

```
# BAD: Multiple threads modify same variable
counter = 0

def increment():
    global counter
    counter += 1  # ❌ Race condition! Results will be wrong

# GOOD: Use lock
counter = 0
lock = threading.Lock()

def increment():
    global counter
    with lock:
        counter += 1  # ✓ Only one thread at a time
```

RULE 4: HANDLE EXCEPTIONS IN THREADS
═══════════════════════════════════

```
# BAD: Exception kills thread silently
def worker():
    raise Exception("Oops!")  # Thread dies, no one knows

# GOOD: Catch and log exceptions
def worker():
    try:
        # ... work ...
    except Exception as e:
        logger.exception(f"Thread error: {e}")
```

```
    # Your code does this:
    def _safe_call(self, handler, change):
        try:
            handler(change, self._db_session_factory)
        except Exception as e:
            logger.exception(f"Handler failed: {e}")


RULE 5: CLEAN UP RESOURCES
═══════════════════════════

    # BAD: Thread creates resources, never closes
    def worker():
        conn = connect_to_db()
        while True:
            process(conn)
        # Connection never closed!

    # GOOD: Clean up on exit
    def worker():
        conn = connect_to_db()
        try:
            while running:
                process(conn)
        finally:
            conn.close()  # Always clean up


RULE 6: DON'T START TOO MANY THREADS
═════════════════════════════════════

    # BAD: New thread for each task
    for item in million_items:
        thread = threading.Thread(target=process, args=(item,))
        thread.start()  # 1 million threads! 😱 System crashes

    # GOOD: Use thread pool
    with ThreadPoolExecutor(max_workers=10) as pool:
        for item in million_items:
            pool.submit(process, item)  # Only 10 threads, tasks queue up
```

Part 8: Complete Threading Pattern in Your Binlog

```
┌──────────────────────────────────────────────────────────────────────────────┐
│                    ALL THREADING IN YOUR BINLOG CODE                         │
```

└──┘

THREAD 1: Main Monitor Thread
═══════════════════════════════
File: binlog.py

```
_thread = threading.Thread(
    target=_monitor.start,
    daemon=True,
    name="postgres-wal-monitor"
)
_thread.start()
```

Purpose: Run WAL monitor in background (blocks forever)

THREAD 2: Keepalive Thread
═══════════════════════════
File: services/postgres_wal_monitor.py

```
self._keepalive_thread = threading.Thread(
    target=keepalive_worker,
    daemon=True,
    name="wal-keepalive"
)
self._keepalive_thread.start()
```

Purpose: Send periodic heartbeat to PostgreSQL (prevents timeout)

THREAD 3-10: Handler Pool (ThreadPoolExecutor)
═══
File: services/postgres_wal_monitor.py (BinlogRouter)

```
self._pool = ThreadPoolExecutor(max_workers=max_workers)

# When dispatching:
self._pool.submit(self._safe_call, handler, change)
```

Purpose: Run multiple handlers in parallel (max 8 at a time)

THREAD LOCK: LSN Update Lock
═══════════════════════════
File: services/postgres_wal_monitor.py

```
self._lsn_lock = threading.Lock()

# When updating LSN:
with self._lsn_lock:
    self._last_lsn = msg.data_start
```

```
        self._last_feedback_time = time.time()

Purpose: Prevent race condition when main thread and keepalive thread
        both try to update/read LSN


COMPLETE PICTURE:
═══════════════════
```

Part 9: Quick Decision Guide

```
┌─────────────────────────────────────────────────────────────────┐
│              QUICK DECISION GUIDE: DO I NEED A THREAD?          │
└─────────────────────────────────────────────────────────────────┘
```

ASK YOURSELF:

1. Does my code BLOCK (wait for something)?
   □ Network request?
   □ Database query that takes long?
   □ Waiting for messages (RabbitMQ, WebSocket)?
   □ Monitoring something forever?
   □ Sleep/delay?

2. Do I need to do OTHER things while waiting?
   □ Handle HTTP requests?
   □ Process other events?
   □ Keep UI responsive?

3. If YES to both → USE A THREAD

WHICH THREAD TYPE?
═══════════════════

```
┌─────────────────────────────────────────────────────────────────┐
│                                                                 │
│  "Run forever in background"    → threading.Thread(daemon=True) │
│                                                                 │
│  "Run once after delay"         → threading.Timer               │
│                                                                 │
│  "Run many tasks in parallel"   → ThreadPoolExecutor            │
│                                                                 │
│  "Need to stop gracefully"      → threading.Event + while loop  │
│                                                                 │
│  "Threads share data"           → threading.Lock                │
│                                                                 │
│  "Each thread needs own copy"   → threading.local()             │
│                                                                 │
└─────────────────────────────────────────────────────────────────┘
```

Summary

The key insight is: **Thread = Way to do multiple things at the same time** Your binlog uses threads because:

1. **Monitor BLOCKS forever** (waiting for DB changes)
2. **Main thread needs to handle HTTP requests** (can't be blocked)
3. **Solution: Monitor runs in separate thread**