

NL2SQL Platform – Detailed Architecture Specification

Objective

This architecture transforms NL2SQL from a single pipeline LLM utility into a modular, extensible, enterprise-grade Intelligence Platform capable of deterministic reasoning, cross-database execution, federated query planning, governance, observability, and research-grade evaluation.

High-Level Layered Architecture

The system is structured into layered components: 1) User Interaction Layer (CLI, API, UI) 2) nl2sql-core (Planner, Orchestrator, Validator, Routing, Observability) 3) nl2sql-adapter-sdk defining canonical datasource contract 4) Datasource Adapters (Postgres, MySQL, Snowflake, BigQuery, S3, ADLS, etc.) 5) Inference Layer for LLM orchestration 6) Eval Layer for correctness, determinism, capability, and federated reasoning validation

Core Layer Components

- 1) Orchestrator: Controls execution graph, multi-stage reasoning, and distributed map-reduce execution.
- 2) Planner: Converts natural language into structured execution plans and SQL candidates.
- 3) Deterministic Validator Layer:
 - SqlGlot parse + normalize + transpile
 - Schema-grounded enforcement
 - Safety enforcement (no DROP/UPDATE unless permitted)
 - Candidate ranking and deterministic finalization
- 4) Routing Engine:
 - Chooses appropriate datasource(s)
 - Supports federated decomposition
 - Capability aware target selection
- 5) Observability SDK:
 - Full telemetry
 - Traceability
 - Reasoning visibility
 - Latency and reliability metrics

Adapter SDK (`nl2sql-adapter-sdk`)

Defines official interface contract for all datasource providers. Core Responsibilities:

- Canonical Schema Model
- Capability Negotiation Framework
- Standard Execution Contract
- Structured Error Model
- Compliance & Certification Suite Benefits:
- Prevents fragmentation
- Enables community plugins
- Ensures enterprise trust and compatibility
- Makes NL2SQL an extensible platform

Adapter Responsibilities

Every adapter must:

- Provide deterministic schema metadata
- Advertise capabilities honestly
- Execute SQL safely
- Return normalized results
- Handle pagination
- Emit execution metrics
- Provide explain / cost insight where supported

Plugin Discovery

Adapters register using Python entry points and are auto-discovered at runtime. This enables:

- Pluggable ecosystem
- Separately installable datasource modules
- Private enterprise adapters without modifying core
- Future adapter marketplace potential

Inference Layer Architecture

The inference layer abstracts all LLM reasoning and provides deterministic structured planning.
Capabilities: • Vendor abstraction (OpenAI, Anthropic, Local LLMs, Azure, vLLM) • Model routing rules • Retry and fallback strategies • Structured output enforcement • Determinism controls (temperature, seed, formatting consistency) • Observability hooks Long-Term Opportunities: • Hybrid inference (cloud + on-prem) • Performance tuned caching • Learning-based cost and latency optimization

Evaluation Framework

The evaluation system validates platform reliability across three tiers: Tier 1 – Core Intelligence Evaluation • Semantic correctness • SQL validity • Determinism testing across runs • Schema hallucination detection • Safety constraint adherence Tier 2 – Adapter Certification Suite • Connectivity correctness • Capability truthfulness • Execution normalization correctness • Failure handling discipline • Observability compliance • Performance expectations Tier 3 – Orchestrator/Federated Reasoning Evaluations • Routing correctness • Cross-database accuracy • Execution latency benchmarking • Cost efficiency • Failure robustness

Federated Reasoning & Multi■Datasource Execution

One of NL2SQL's unique advantages is support for multiple heterogeneous databases. Capabilities Enabled:

- Query decomposition with schema awareness
- Per■datasource SQL generation
- Federated execution and merging
- Cost aware routing
- Capability driven execution strategy selection

Research Value:

- First■class research ground for federated AI database reasoning
- Enables deterministic, explainable cross■DB intelligence

Strategic Impact

This architecture evolves NL2SQL from an intelligent tool into a true AI database intelligence platform. It enables enterprise readiness, academic research, community ecosystem development, and long■term product defensibility.