

STB Configuration System — Database Schema, ER Diagram & Implementation (A → Z)

A single-source document that maps the entire database design, table structures, data flows, realtime sync, API design, seeding, and deployment notes for a dynamic STB modules/groups/options configuration system.

1. Project Summary

Goal: Build a dynamic, data-driven STB configuration platform where **Modules → Groups → Options** are stored in a database and the frontend (React dashboard) updates instantly when data is added/changed. The system supports rules/dependencies, project-specific option sets, versioning/auditing, and realtime updates (Socket.IO + DB triggers).

Scope: - Relational DB design (PostgreSQL recommended) - API layer (Node.js + Express) - Realtime sync (Socket.IO + LISTEN/NOTIFY triggers) - Frontend (React) dynamic rendering - Admin seeder / ETL scripts to auto-load JSON configs - Security, monitoring, and scaling guidance

2. High-level ER Diagram (mermaid)

```
erDiagram
    USERS ||--o{ PROJECTS : owns
    PROJECTS ||--o{ PROJECT_OPTIONS : has
    MODULES ||--o{ GROUPS : contains
    GROUPS ||--o{ OPTIONS : contains
    MODULES ||--o{ STATES : has
    STATES ||--o{ TRANSITIONS : has
    OPTIONS ||--o{ RULES : governed_by
    OPTIONS ||--o{ AUDIT_LOGS : audited_by
    MODULES ||--o{ AUDIT_LOGS : audited_by
    PROJECT_OPTIONS }o--|| OPTIONS : references
    PROJECTS }o--|| MODULES : includes
```

Use the mermaid block above in your markdown-capable viewer to visualize the relationships.

3. Table list & purpose

1. `users` — authentication & admin accounts
2. `modules` — top-level containers (Video, Network, Audio)

3. `groups` — sub-containers inside modules (Decoder, Renderer)
 4. `options` — configurable features (H.264, HDR)
 5. `states` — states for state-machine based options (optional)
 6. `transitions` — allowed transitions for state machines
 7. `rules` — dependency rules, requires/forbidden
 8. `projects` — project-specific configuration sets (which options are included)
 9. `project_options` — many-to-many mapping of projects ↔ options (and overrides)
 10. `audit_logs` — record changes for traceability
 11. `events` — realtime events log (optional persistence)
 12. `seeds` — raw uploaded JSON (optional) for auditing imports
-

4. SQL: Example `CREATE TABLE` statements (PostgreSQL)

```
CREATE TABLE users (  
  id SERIAL PRIMARY KEY,  
  username VARCHAR(100) UNIQUE NOT NULL,  
  email VARCHAR(255) UNIQUE,  
  password_hash TEXT NOT NULL,  
  role VARCHAR(50) DEFAULT 'admin',  
  created_at TIMESTAMP WITH TIME ZONE DEFAULT now()  
);  
  
CREATE TABLE modules (  
  id SERIAL PRIMARY KEY,  
  key TEXT UNIQUE NOT NULL,      -- canonical id e.g. video_module  
  name TEXT NOT NULL,  
  description TEXT,  
  active BOOLEAN DEFAULT true,  
  initial_state TEXT,           -- optional  
  meta JSONB DEFAULT '{}',     -- extensible metadata  
  created_at TIMESTAMP WITH TIME ZONE DEFAULT now()  
);  
  
CREATE TABLE groups (  
  id SERIAL PRIMARY KEY,  
  module_id INT REFERENCES modules(id) ON DELETE CASCADE,  
  key TEXT NOT NULL,  
  name TEXT NOT NULL,  
  description TEXT,  
  position INT DEFAULT 0,  
  meta JSONB DEFAULT '{}'  
);  
  
CREATE TABLE options (  
  id SERIAL PRIMARY KEY,
```

```

    group_id INT REFERENCES groups(id) ON DELETE CASCADE,
    key TEXT NOT NULL,
    name TEXT NOT NULL,
    type VARCHAR(50) DEFAULT 'boolean', -- boolean, integer, string, enum
    default_value TEXT,
    editable BOOLEAN DEFAULT true,
    included_by_default BOOLEAN DEFAULT false,
    meta JSONB DEFAULT '{}', -- e.g. constraints, ui hints
    created_at TIMESTAMP WITH TIME ZONE DEFAULT now()
);

CREATE TABLE states (
    id SERIAL PRIMARY KEY,
    module_id INT REFERENCES modules(id) ON DELETE CASCADE,
    name TEXT NOT NULL
);

CREATE TABLE transitions (
    id SERIAL PRIMARY KEY,
    module_id INT REFERENCES modules(id) ON DELETE CASCADE,
    from_state TEXT NOT NULL,
    event TEXT NOT NULL,
    to_state TEXT NOT NULL,
    condition JSONB, -- optional condition expression
    meta JSONB DEFAULT '{}'
);

CREATE TABLE rules (
    id SERIAL PRIMARY KEY,
    option_id INT REFERENCES options(id) ON DELETE CASCADE,
    type VARCHAR(50) NOT NULL, -- 'requires' | 'forbidden' | 'validation'
    payload JSONB NOT NULL,    -- flexible: { requires: ['4k_enabled'] }
    active BOOLEAN DEFAULT true
);

CREATE TABLE projects (
    id SERIAL PRIMARY KEY,
    key TEXT UNIQUE NOT NULL,
    name TEXT NOT NULL,
    description TEXT,
    created_by INT REFERENCES users(id),
    created_at TIMESTAMP WITH TIME ZONE DEFAULT now(),
    meta JSONB DEFAULT '{}'
);

CREATE TABLE project_options (
    id SERIAL PRIMARY KEY,
    project_id INT REFERENCES projects(id) ON DELETE CASCADE,

```

```

option_id INT REFERENCES options(id) ON DELETE CASCADE,
included BOOLEAN DEFAULT true,
value TEXT,                -- override value for editable options
updated_at TIMESTAMP WITH TIME ZONE DEFAULT now()
);

CREATE TABLE audit_logs (
  id SERIAL PRIMARY KEY,
  entity_type VARCHAR(50) NOT NULL, -- 'module', 'group', 'option', 'project'
  entity_id INT,                  -- FK is optional, store referential id
  action VARCHAR(50) NOT NULL,    -- 'create','update','delete','seed'
  payload JSONB,
  actor INT REFERENCES users(id),
  created_at TIMESTAMP WITH TIME ZONE DEFAULT now()
);

CREATE TABLE seeds (
  id SERIAL PRIMARY KEY,
  filename TEXT,
  raw JSONB,
  imported_by INT REFERENCES users(id),
  imported_at TIMESTAMP WITH TIME ZONE DEFAULT now()
);

CREATE TABLE events (
  id SERIAL PRIMARY KEY,
  event_type TEXT NOT NULL,
  payload JSONB,
  created_at TIMESTAMP WITH TIME ZONE DEFAULT now()
);

```

5. Example: How data is stored

- Modules row: `{ id: 1, key: 'video_module', name: 'Video Module', initial_state: 'idle' }`
- Group row: `{ id: 10, module_id: 1, key: 'decoder_group', name: 'Decoder Settings' }`
- Option row: `{ id: 100, group_id: 10, key: 'hdr', name: 'HDR Support', type: 'boolean', default_value: 'false', editable: true }`
- Rule row: `{ id: 5, option_id: 100, type: 'requires', payload: { requires: ['4k_output'] } }`

Project-specific mapping: `project_options` stores whether an option is included and any override value.

6. API Design (REST) — Minimal endpoints

Auth - `POST /api/auth/login` → returns JWT

Modules & structure - `GET /api/config` → returns full assembled config `{ modules: [...] }`
(used by UI) - `GET /api/modules` → list modules - `POST /api/modules` → create module -
`PUT /api/modules/:id` → update module - `DELETE /api/modules/:id` → delete module

Groups/Options - `POST /api/modules/:moduleId/groups` → create group - `POST /api/groups/:groupId/options` → create option - `PUT /api/options/:id` → update option - `DELETE /api/options/:id` → delete option

Projects - `POST /api/projects` → create project (admin adds baseline) - `GET /api/projects/:id/config` → project-specific assembled config (module + option included flags + overridden values) - `PUT /api/projects/:id/options/:optionId` → toggle include / set override value

Realtime - WebSocket / Socket.IO connection to receive events like `configUpdated`, `optionChanged`.

Admin seeding - `POST /api/seed` → upload JSON and seed DB (returns audit log)

7. Backend Implementation Notes (Node.js + Express)

- Use an ORM (TypeORM / Prisma / Sequelize) for migrations + type safety.
- Architectural layers:
 - `controllers` → request handlers
 - `services` → business logic (assemble config, apply rules)
 - `repositories` → DB access
 - `realtime` → Socket.IO emit logic
 - `workers` → background jobs for seeding & ETL
- Use transactions when seeding complex module/group/option inserts.
- Sanitize `meta` and `payload` JSONB before saving.

Sample assemble algorithm for `/api/config` (pseudo): 1. SELECT modules (active) 2. For each module: SELECT groups WHERE module_id 3. For each group: SELECT options WHERE group_id 4. SELECT rules WHERE option_id IN (...) and attach 5. Optionally attach `project_options` if project param passed 6. Return hierarchical JSON

8. Real-time sync (Socket.IO + Postgres LISTEN/NOTIFY)

A. Trigger & Notify in PostgreSQL (example)

```
CREATE OR REPLACE FUNCTION notify_config_change() RETURNS trigger AS $$
DECLARE
    payload JSON;
BEGIN
    payload = json_build_object(
        'table', TG_TABLE_NAME,
        'action', TG_OP,
        'id', NEW.id
    );
    PERFORM pg_notify('config_updates', payload::text);
    RETURN NEW;
END;
$$ LANGUAGE plpgsql;

CREATE TRIGGER options_change AFTER INSERT OR UPDATE OR DELETE ON options
    FOR EACH ROW EXECUTE FUNCTION notify_config_change();

-- create similar triggers for modules, groups, project_options, rules
```

B. Node.js listen + Socket.IO emit

```
// using 'pg' client
pgClient.on('notification', msg => {
    const payload = JSON.parse(msg.payload);
    io.emit('configUpdated', payload);
});

await pgClient.query('LISTEN config_updates');
```

Now, any change to `options`/`modules`/etc triggers a `configUpdated` event to all connected dashboard clients.

9. Seeder / ETL (JSON → DB)

Purpose: auto-import external configs as JSON (raw saved to `seeds` table). Seeder steps: 1. Validate JSON against a schema (AJV) before write 2. Save raw JSON to `seeds` table (for audit) 3. Insert / upsert modules → groups → options in a transaction 4. Insert transitions & rules 5. Insert audit log entries 6. Trigger NOTIFY (or simply rely on DB triggers already defined)

Idempotence: Use upsert (ON CONFLICT) so repeating the seed won't duplicate entries.

10. State Machine Storage & Execution

Options that require state-machine logic use `states` + `transitions` tables. On the backend: - Build an in-memory state graph for the module when `/api/config` is requested. - Use `transitions.condition` (JSON) for additional checks. - For safety, evaluate conditions with a sandboxed expression evaluator (e.g., `jexl` with allowlist) or use `json-logic`.

11. Example: Full assembled JSON response returned by `/api/config`

```
{
  "modules": [
    {
      "id": "video_module",
      "name": "Video Module",
      "initial": "idle",
      "groups": [
        {
          "id": 10,
          "name": "Decoder Settings",
          "options": [
            { "id": 100, "key": "h264", "name": "H.264", "editable": true,
              "included": true },
            { "id": 101, "key": "vp9", "name": "VP9", "editable": false,
              "included": false }
          ]
        }
      ],
      "rules": [ { "option_key": "hdr", "requires": ["4k_output"] } ],
      "states": { "idle": { "ENABLE_4K": "4k_enabled" } }
    }
  ]
}
```

12. Frontend (React) Implementation notes

- Fetch `/api/config` on load and create a normalized state client-side.
- Keep a Socket.IO connection open for `configUpdated` events.

- When event arrives, update the minimal part of state (merge) — do not refetch entire config unless necessary.
- Use virtualization if the UI can render large numbers of modules/options.
- Provide an Admin UI to add/edit modules/groups/options which call API and rely on realtime sync.

13. Sample API flow diagrams (mermaid)

```
sequenceDiagram
    participant A as Admin UI
    participant B as API (Express)
    participant C as Postgres
    participant D as Socket.IO

    A->>B: POST /api/groups (create group)
    B->>C: INSERT group
    C-->>B: OK
    C->>B: NOTIFY config_updates
    B->>D: io.emit('configUpdated')
    D->>A: configUpdated event
```

```
flowchart LR
    subgraph Backend
        API[Express API]
        Worker[Seeder/Worker]
        Socket[Socket.IO]
        PG[Postgres]
    end
    UI[React Dashboard] --> API
    Worker --> PG
    API --> PG
    PG -- NOTIFY --> API
    API --> Socket
    Socket --> UI
```

14. Implementation Plan (A → Z milestones)

1. **Project scaffolding:** repo, CI, linter, env config
2. **DB schema & migrations** (use Prisma/TypeORM/Knex)
3. **Seed scripts** & sample JSON configs
4. **Express API:** config endpoints + auth
5. **Socket.IO integration** & PG LISTEN/NOTIFY wiring
6. **Admin UI:** create/edit modules/groups/options

7. **React Dashboard:** dynamic renderer + realtime merge logic
 8. **Rules & validation engine** (json-logic/jexl) and tests
 9. **Audit logging** & history view
 10. **Integration tests & e2e**
 11. **Deployment:** Docker, K8s manifests, CI pipelines
 12. **Monitoring:** Prometheus, Grafana, Sentry
-

15. Security & Operational Considerations

- Use JWT + role-based access control for the admin APIs
 - Sanitize and validate all JSONB payloads (AJV)
 - Limit meta and rule expression languages to safe allowlists
 - Use DB backups & PITR for Postgres
 - For Socket.IO scale: use Redis adapter (pub/sub) across nodes
 - Use TLS for all client-server comms
-

16. Example queries (useful)

- Get full module config with groups and options:

```
SELECT m.key AS module_key, g.id as group_id, g.name as group_name, o.id
AS option_id, o.key AS option_key, o.name AS option_name
FROM modules m
JOIN groups g ON g.module_id = m.id
JOIN options o ON o.group_id = g.id
WHERE m.active = true
ORDER BY m.id, g.position, o.id;
```

- Upsert module (seed pattern):

```
INSERT INTO modules (key,name,initial_state,meta) VALUES ($1,$2,$3,$4)
ON CONFLICT (key) DO UPDATE SET name=EXCLUDED.name,
initial_state=EXCLUDED.initial_state, meta=EXCLUDED.meta
RETURNING id;
```

17. Testing & QA

- Unit tests for rule evaluation (json-logic fixtures)
- Integration tests for API + DB (use testcontainers or ephemeral DB)

- E2E tests for realtime updates (use headless browser + socket mocks)
 - Load testing for Socket.IO (k6 or Artillery)
-

18. Scaling & Performance

- Use connection pooling for Postgres (pg-pool)
 - Use Redis adapter for Socket.IO across multiple backend instances
 - Cache assembled config per project in Redis and invalidate on DB notify
 - Avoid full-config refetches when small deltas suffice
-

19. Operational Scripts & Maintenance

- `scripts/seed.js` — idempotent seeder from `/configs/*.json`
 - `scripts/sync_remote.js` — ETL job to pull remote configs
 - `scripts/backup.sh` — DB dump and rotate
 - `scripts/migrate.sh` — run migrations in CI/CD
-

20. Next steps / How I can help

- Provide full working **Express + Prisma** starter repo (with migrations and sample seed JSON).
 - Provide a **React** admin + dashboard starter app wired to Socket.IO.
 - Generate exact `CREATE TABLE` migration files for your chosen ORM.
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End of document.