Metro Train Prediction App - Service

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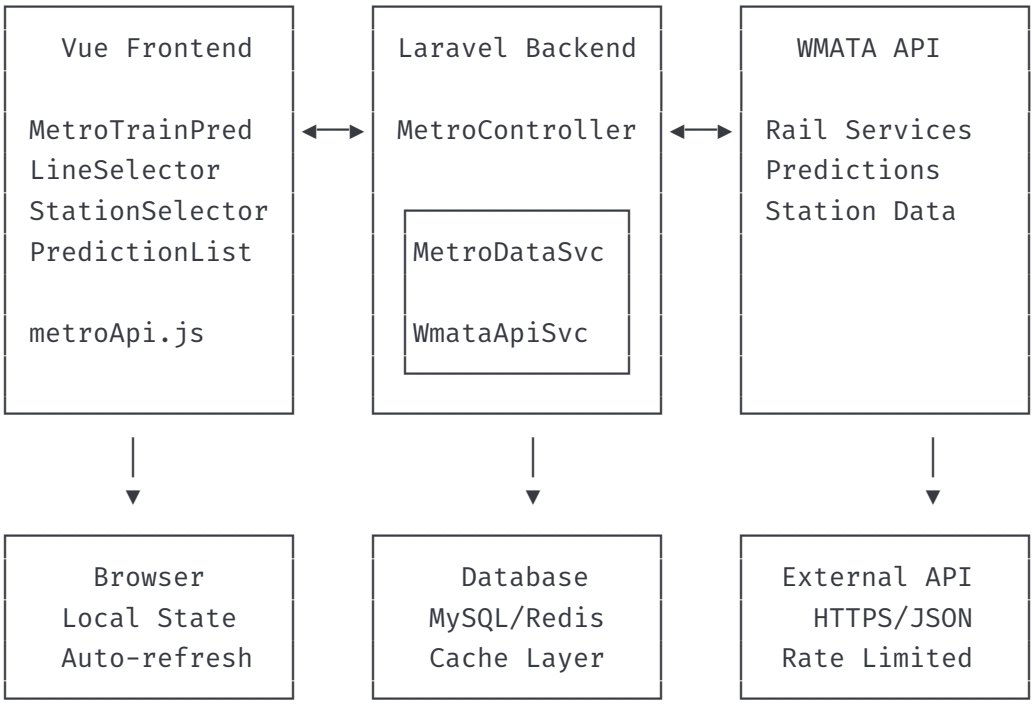
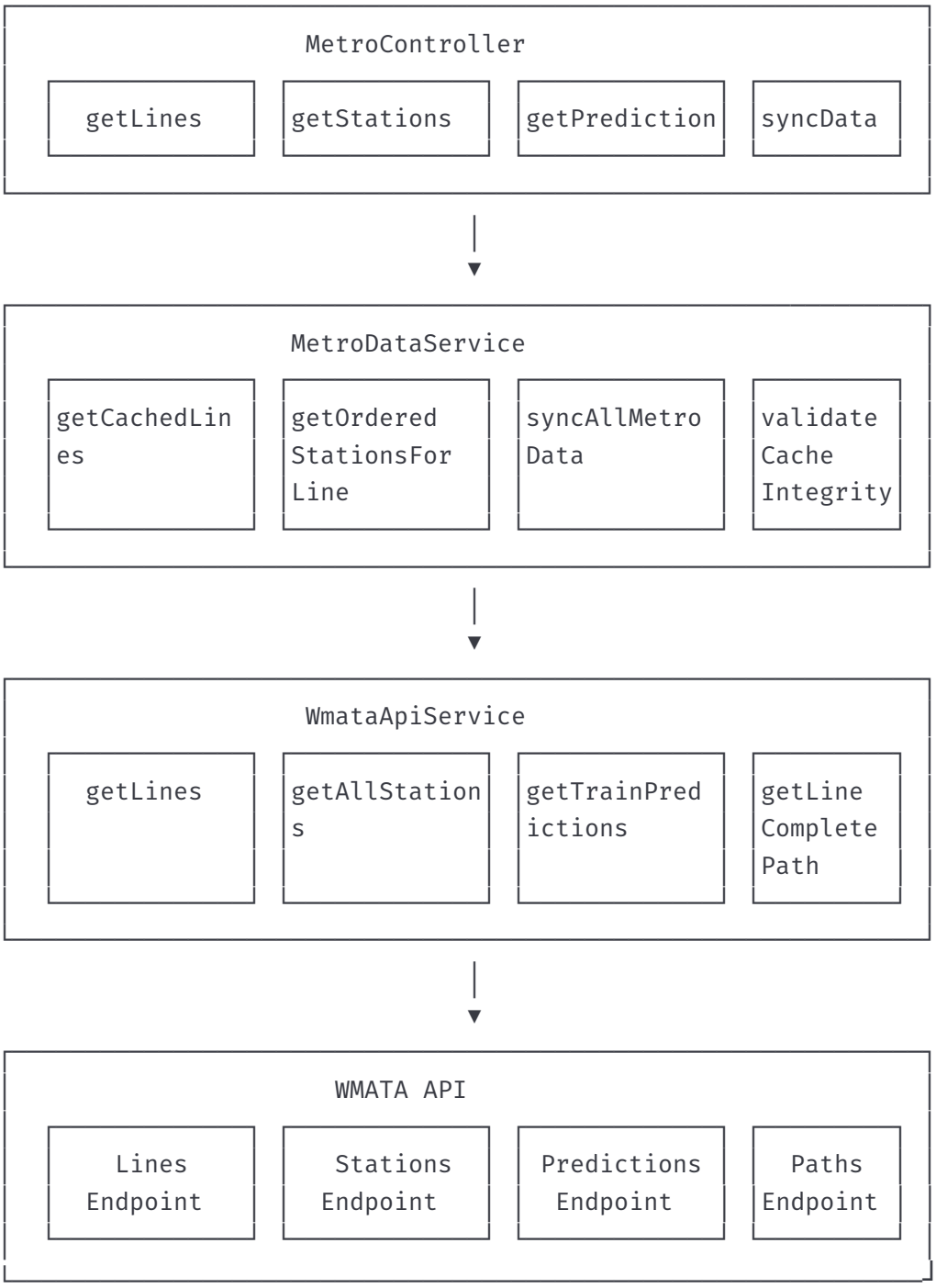
Project Repo: https://github.com/DavMorr/wmata-app

System Architecture

High-Level Architecture Diagram



Service Layer Architecture



Service Interactions

Service Dependency Graph

```
MetroController
    ├── depends on: MetroDataService
    └── depends on: WmataApiService

MetroDataService
    ├── depends on: WmataApiService
    ├── uses: Line Model
    ├── uses: Station Model
    ├── uses: StationAddress Model
    └── uses: StationPath Model

WmataApiService
    ├── depends on: HTTP Client
    ├── uses: LineDto
    ├── uses: StationDto
    ├── uses: TrainPredictionDto
    ├── uses: StationPathDto
    └── uses: AddressDto
```

Service Communication Flow

mermaid

```mermaid
graph TD
    A[Frontend Request] --> B[MetroController]
    B --> C{Request Type}

    C -->|Lines| D[MetroDataService.getCachedLines]
    C -->|Stations| E[MetroDataService.getOrderedStationsForLine]
    C -->|Predictions| F[WmataApiService.getTrainPredictions]
    C -->|Sync| G[MetroDataService.syncAllMetroData]

    D --> H[Cache Check]
    H -->|Miss| I[WmataApiService.getLines]
```

```
    H -->|Hit| J[Return Cached Data]

    E --> K[StationPath Query]
    K -->|Empty| L[Fallback to Stations]
    K -->|Data| M[Return Ordered List]

    F --> N[Cache Check]
    N -->|Miss| O[WMATA API Call]
    N -->|Hit| P[Return Cached Predictions]

    G --> Q[Sync Lines]
    Q --> R[Sync Stations]
    R --> S[Sync Paths]
    S --> T[Return Results]
```

Data Types and Models

Database Models

Line Model

php

```php
// app/Models/Line.php
class Line extends Model
{
    protected $primaryKey = 'line_code';
    public $incrementing = false;
    protected $keyType = 'string';

    protected $fillable = [
        'line_code',              // String(2): RD, BL, GR, OR, SV, YL
        'display_name',           // String(50): Red, Blue, Green, etc.
        'start_station_code',     // String(3): A15, J03, etc.
        'end_station_code',       // String(3): B11, G05, etc.
        'internal_destination_1', // String(3): Optional branch destination
        'internal_destination_2', // String(3): Optional branch destination
    ];
}
```

Station Model

php

```php
// app/Models/Station.php
class Station extends Model
{
    protected $primaryKey = 'code';
    public $incrementing = false;
    protected $keyType = 'string';

    protected $fillable = [
        'code',                // String(3): A01, B02, C03
        'name',                // String(100): Metro Center, Union Station
        'line_code_1',         // String(2): Primary line code
        'line_code_2',         // String(2): Transfer line code
        'line_code_3',         // String(2): Transfer line code
        'line_code_4',         // String(2): Transfer line code
        'station_together_1',  // String(3): Connected platform code
        'station_together_2',  // String(3): Connected platform code
        'lat',                 // Decimal(10,8): Latitude coordinate
        'lon',                 // Decimal(11,8): Longitude coordinate
        'is_active',           // Boolean: Station operational status
    ];
}
```

StationPath Model

php

```php
// app/Models/StationPath.php
class StationPath extends Model
{
    protected $fillable = [
        'line_code',        // String(2): Line identifier
        'station_code',     // String(3): Station identifier
        'station_name',     // String(100): Station display name
        'seq_num',          // Integer: Geographic sequence number
        'distance_to_prev', // Integer: Distance in meters to previous station
    ];
}
```

Data Transfer Objects (DTOs)

LineDto

php

```php
// app/DTOs/LineDto.php
class LineDto
{
    public function __construct(
        public string $displayName,        // "Red"
        public string $lineCode,           // "RD"
        public string $startStationCode,   // "A15"
        public string $endStationCode,     // "B11"
        public ?string $internalDestination1 = null,
        public ?string $internalDestination2 = null,
    ) {}
}
```

StationDto

php

```php
// app/DTOs/StationDto.php
class StationDto
{
    public function __construct(
        public string $code,               // "A01"
        public string $name,               // "Metro Center"
        public ?string $stationTogether1,  // "C01"
        public ?string $stationTogether2,  // null
        public ?string $lineCode1,         // "RD"
        public ?string $lineCode2,         // "BL"
        public ?string $lineCode3,         // "OR"
        public ?string $lineCode4,         // "SV"
        public float $lat,                 // 38.89834567
        public float $lon,                 // -77.02834567
        public AddressDto $address,
    ) {}
}
```

TrainPredictionDto

php

```php
// app/DTOs/TrainPredictionDto.php
class TrainPredictionDto
{
    public function __construct(
        public ?string $car,               // "6" or null for end stations
        public string $destination,        // "Glenmont"
        public ?string $destinationCode,   // "B11"
        public string $destinationName,    // "Glenmont"
        public ?string $group,             // "1" or null
        public string $line,               // "RD"
        public string $locationCode,       // "A01"
        public string $locationName,       // "Metro Center"
        public string $min,                // "3", "BRD", "ARR"
    ) {}
}
```

Frontend Data Structures

Lines Response Format

javascript

```javascript
// Frontend receives from API
[
    { value: "RD", label: "Red" },
    { value: "BL", label: "Blue" },
    { value: "GR", label: "Green" }
]
```

Stations Response Format

javascript

```javascript
// Frontend receives from API
[
    {
        value: "A01",
        label: "Metro Center",
        seq_num: 1,
        distance_to_prev: 0
    },
    {
        value: "A02",
        label: "Farragut North",
        seq_num: 2,
        distance_to_prev: 1250
```

```
    }
]
```

Predictions Response Format

javascript

```javascript
// Frontend receives from API
{
    station: {
        code: "A01",
        name: "Metro Center"
    },
    predictions: [
        {
            line: "RD",
            destination: "Glenmont",
            minutes: "3",
            cars: "6",
            group: "1"
        }
    ],
    updated_at: "2025-06-05T14:30:15.123Z",
    refresh_interval: 30
}
```

Data Flow Pipeline

Data Transformation Pipeline

```
WMATA API Response → DTO → Model → Cache → Controller → Frontend
```

Example: Lines Data Flow

```
1. WMATA API Response:
{
    "Lines": [
        {
            "LineCode": "RD",
            "DisplayName": "Red",
            "StartStationCode": "A15",
            "EndStationCode": "B11"
        }
    ]
```

```
}

2. DTO Transformation (LineDto::fromArray):
LineDto {
    displayName: "Red",
    lineCode: "RD",
    startStationCode: "A15",
    endStationCode: "B11"
}

3. Model Storage (toModel):
Line {
    line_code: "RD",
    display_name: "Red",
    start_station_code: "A15",
    end_station_code: "B11"
}

4. Frontend Format (toSelectOption):
{
    value: "RD",
    label: "Red"
}
```

Example: Predictions Data Flow

```
1. WMATA API Response:
{
    "Trains": [
        {
            "Car": "6",
            "Destination": "Glenmont",
            "Line": "RD",
            "Min": "3"
        }
    ]
}

2. DTO Transformation:
TrainPredictionDto {
    car: "6",
    destination: "Glenmont",
    line: "RD",
    min: "3"
}
```

```
3. Frontend Format (toFrontend):
{
    line: "RD",
    destination: "Glenmont",
    minutes: "3",
    cars: "6",
    group: "1"
}
```

Service Layer Details

WmataApiService

Purpose: Interface with WMATA API and handle caching

Key Methods:

- getLines(): Fetch and cache metro lines
- getAllStations(): Fetch and cache all station data
- getStationsForLine(string $lineCode): Get stations for specific line
- getTrainPredictions(string $stationCode): Get real-time predictions
- getLineCompletePath(string $lineCode): Generate ordered station paths

Caching Strategy:

- Lines: 24 hours (static data)
- Stations: 24 hours (static data)
- Predictions: 15 seconds (real-time data)
- Paths: 24 hours (static data)

Rate Limiting: 1000 requests per hour to WMATA API

MetroDataService

Purpose: Business logic layer and data management

Key Methods:

- getCachedLines(): Frontend-formatted line data

- getOrderedStationsForLine(string $lineCode): Ordered station lists
- syncAllMetroData(): Complete data synchronization
- validateCacheIntegrity(): Cache health check

Data Processing:

- Transforms WMATA data to frontend-friendly formats
- Handles station ordering through StationPath model
- Manages cache invalidation and refresh

MetroController

Purpose: API endpoint handling and response formatting

Endpoints:

- GET /api/metro/lines: Available metro lines
- GET /api/metro/stations/{lineCode}: Stations for line
- GET /api/metro/predictions/{stationCode}: Train predictions
- POST /api/metro/sync: Administrative data sync

Response Format: Consistent JSON structure with success/error handling

Expected Usage Patterns

Typical Frontend Workflow

```
1. Page Load
   ├── fetchLines() → GET /api/metro/lines
   └── Display line selector

2. User Selects Line
   ├── onLineChange()
   ├── fetchStations(lineCode) → GET /api/metro/stations/{lineCode}
   └── Display station selector

3. User Selects Station
   ├── onStationChange()
   ├── fetchPredictions(stationCode) → GET /api/metro/predictions/{stationCode}
```

```
   ├── Display predictions
   └── Start auto-refresh timer (30 seconds)

4. Auto-refresh Loop
   ├── Timer fires every 30 seconds
   ├── fetchPredictions(stationCode) → GET /api/metro/predictions/{stationCode}
   └── Update predictions display

5. User Changes Selection
   ├── Clear timer
   ├── Reset state
   └── Return to appropriate step
```

Administrative Workflow

```
1. Initial Setup
   ├── Run migrations
   ├── Configure .env with WMATA_API_KEY
   └── php artisan metro:sync

2. Regular Maintenance
   ├── php artisan metro:sync (daily/weekly)
   ├── Monitor cache hit rates
   └── Check error logs

3. Cache Management
   ├── php artisan cache:clear (if needed)
   ├── php artisan metro:sync --validate
   └── Monitor memory usage
```

Cache Usage Patterns

```
High Traffic Endpoints:
├── /api/metro/lines (cached 1 hour, hit rate ~95%)
├── /api/metro/stations/{lineCode} (cached 1 hour, hit rate ~90%)
└── /api/metro/predictions/{stationCode} (cached 15 seconds, hit rate ~70%)

Low Traffic Endpoints:
└── /api/metro/sync (administrative, no caching)

Cache Invalidation:
├── Lines/Stations: Manual via metro:sync command
└── Predictions: Automatic TTL expiration
```

Integration Points

Frontend Integration Points

metroApi.js Service

- Handles all backend communication
- Implements consistent error handling
- Manages request/response transformation

Component Integration

- MetroTrainPredictor: Main orchestration component
- LineSelector: Line selection with v-model
- StationSelector: Station selection with conditional rendering
- PredictionList: Real-time data display with auto-refresh

Backend Integration Points

Service Provider Registration

- WmataServiceProvider registers services as singletons
- Ensures proper dependency injection throughout application

Database Integration

- Models provide data persistence and relationships
- Migrations ensure consistent database structure
- Indexes optimize query performance

External API Integration

- HTTP client configuration with retries and timeouts
- Rate limiting to respect WMATA API constraints
- Error handling for network and API failures

Configuration Integration Points

Environment Configuration

- WMATA API credentials and endpoints
- Cache TTL values for different data types
- Rate limiting and timeout configurations

Cache Integration

- Redis for production caching
- Laravel cache facade for consistent interface
- Cache keys organized by data type and identifier

This service overview provides a complete picture of how the Metro Train Prediction App components work together to deliver real-time transit information.