Architecture Documentation

Overview

TechStore is a comprehensive e-commerce platform built using a hybrid micro-frontend architecture that combines Angular and React within an Nx monorepo. The platform provides a complete online shopping experience with AI-powered product recommendations. This document provides detailed information about architectural decisions, component interactions, and design patterns used throughout the application.

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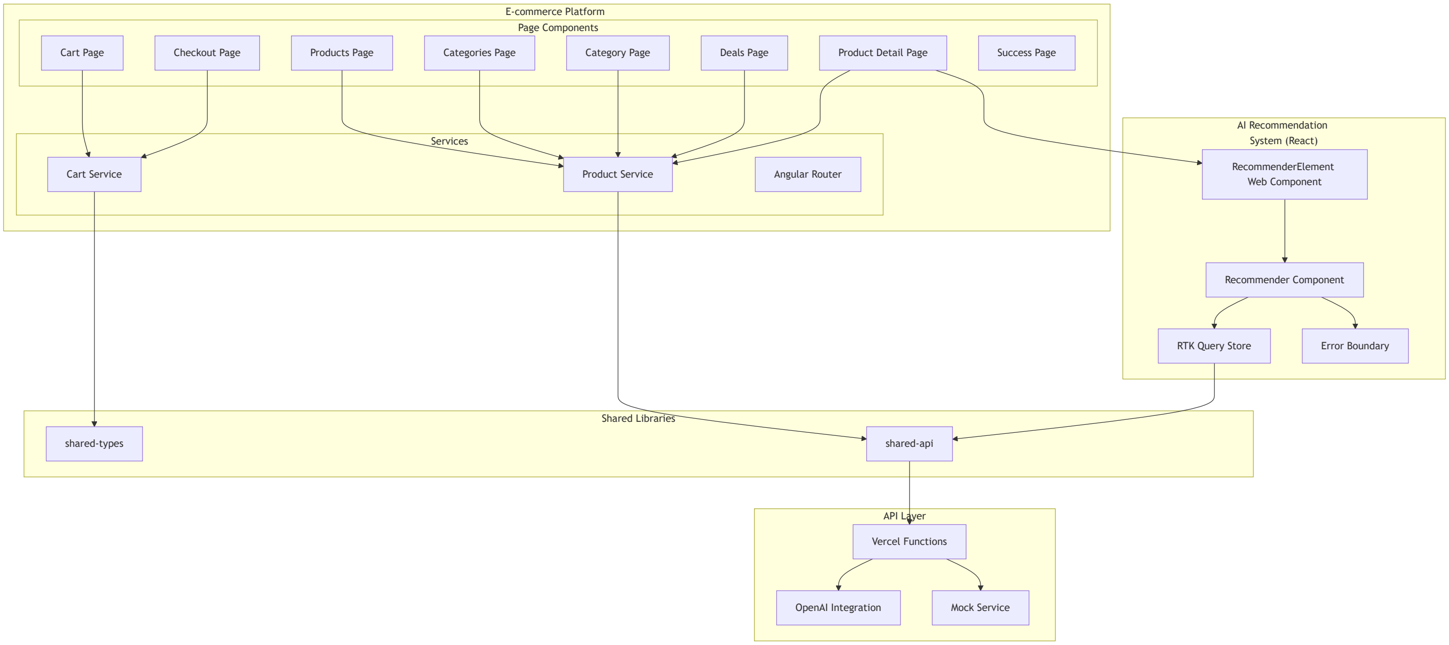
High-Level Architecture

System Overview



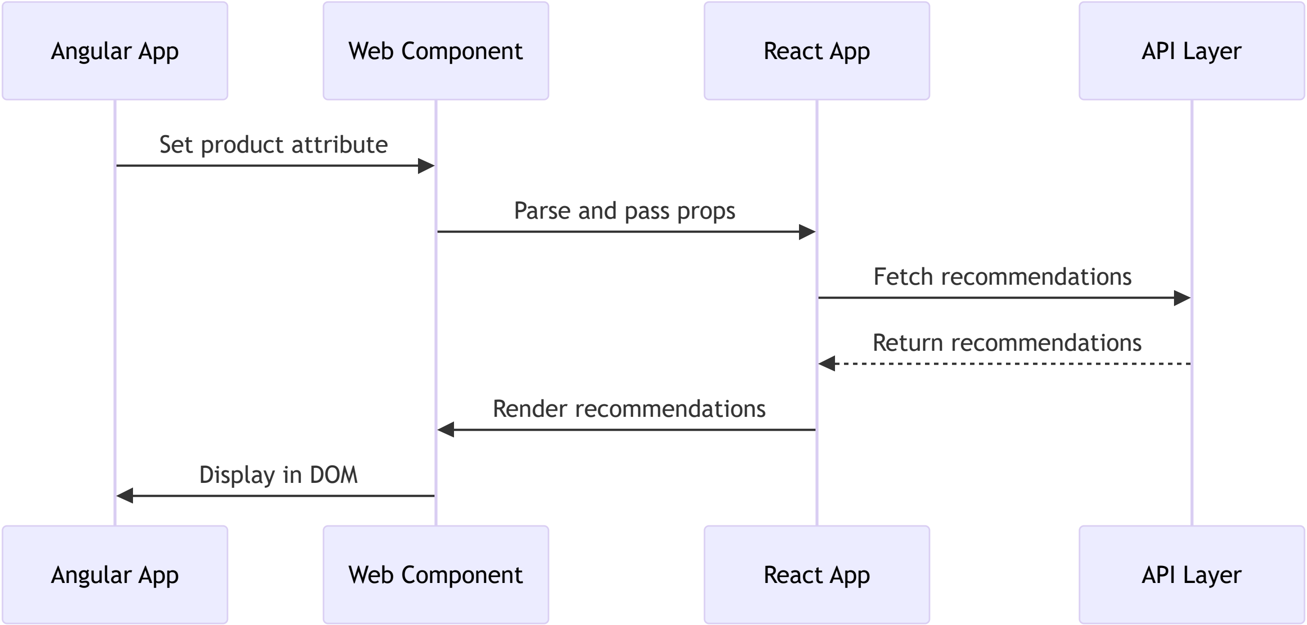
Architecture Principles

1. **Separation of Concerns**: Each framework handles its specific responsibilities
2. **Loose Coupling**: Frameworks communicate through well-defined interfaces
3. **Shared Libraries**: Common functionality is centralized in shared packages
4. **Graceful Degradation**: Multiple fallback layers ensure reliability
5. **Performance First**: Optimized for fast loading and smooth interactions

Framework Integration Strategy

Web Components Bridge

The integration between Angular and React is achieved through Web Components, providing a clean separation while enabling seamless communication.



Benefits of This Approach

1. **Framework Independence**: Each framework can evolve independently
2. **Team Specialization**: Teams can work with their preferred framework
3. **Gradual Migration**: Easy to migrate components between frameworks
4. **Technology Diversity**: Leverage the best features of each framework

Implementation Details

Web Component Registration

```
// react-recommender/src/web-component/index.ts
class RecommenderElement extends HTMLElement {
  private root: Root | null = null;
  private product: Product | null = null;

  connectedCallback() {
    this.root = createRoot(this);
    this.render();
  }

  disconnectedCallback() {
    if (this.root) {
      this.root.unmount();
      this.root = null;
    }
  }

  attributeChangedCallback(name: string, oldValue: string, newValue: string) {
    if (name === 'product' && newValue !== oldValue) {
      try {
        this.product = JSON.parse(newValue);
        this.render();
      } catch (error) {
        console.error('Failed to parse product attribute:', error);
      }
    }
  }

  private render() {
    if (this.root && this.product) {
      this.root.render(
        <Provider store={store}>
          <Recommender product={this.product} />
        </Provider>
      );
    }
  }

  static get observedAttributes() {
    return ['product'];
  }
}

customElements.define('react-recommender', RecommenderElement);
```

Angular Integration

```
// angular-dashboard/src/app/app.ts
@Component({
  template: `
    <div class="grid grid-cols-1 md:grid-cols-3 gap-4">
      <app-product-list
        (productSelected)="onProductSelected($event)"
      ></app-product-list>
      <app-product-detail></app-product-detail>
      <react-recommender
        [attr.product]="selectedProductJson"
      ></react-recommender>
    </div>
  `,
})
export class AppComponent {
  selectedProductJson: string = '';

  onProductSelected(product: Product) {
    this.selectedProductJson = JSON.stringify(product);
  }
}
```

Component Architecture

Angular Components

AppComponent (Shell)

Responsibilities:

- Application layout and routing
- Cross-component communication
- Global state coordination

Key Features:

- Responsive grid layout
- Event handling between child components
- Web Component integration

ProductListComponent

Responsibilities:

- Display product catalog
- Handle product selection
- Provide visual feedback

State Management:

- Subscribes to ProductService for product data
- Emits selection events to parent component

ProductDetailComponent

Responsibilities:

- Show detailed product information
- Handle empty states
- Responsive design implementation

ProductService

Responsibilities:

- Centralized product state management
- Reactive data streams
- Business logic encapsulation

Implementation Pattern:

```
@Injectable({
  providedIn: 'root',
})
export class ProductService {
  private selectedProductSubject = new BehaviorSubject<Product | null>(null);
  public selectedProduct$ = this.selectedProductSubject.asObservable();

  selectProduct(product: Product): void {
    this.selectedProductSubject.next(product);
  }

  getProducts(): Product[] {
    return this.products;
  }
}
```

React Components

Recommender Component

Responsibilities:

- Fetch AI recommendations
- Display loading and error states
- Handle user interactions

State Management:

- Uses RTK Query for API state
- Local state for UI interactions
- Error boundary integration

Error Boundary

Responsibilities:

- Catch JavaScript errors
- Provide fallback UI
- Enable error recovery

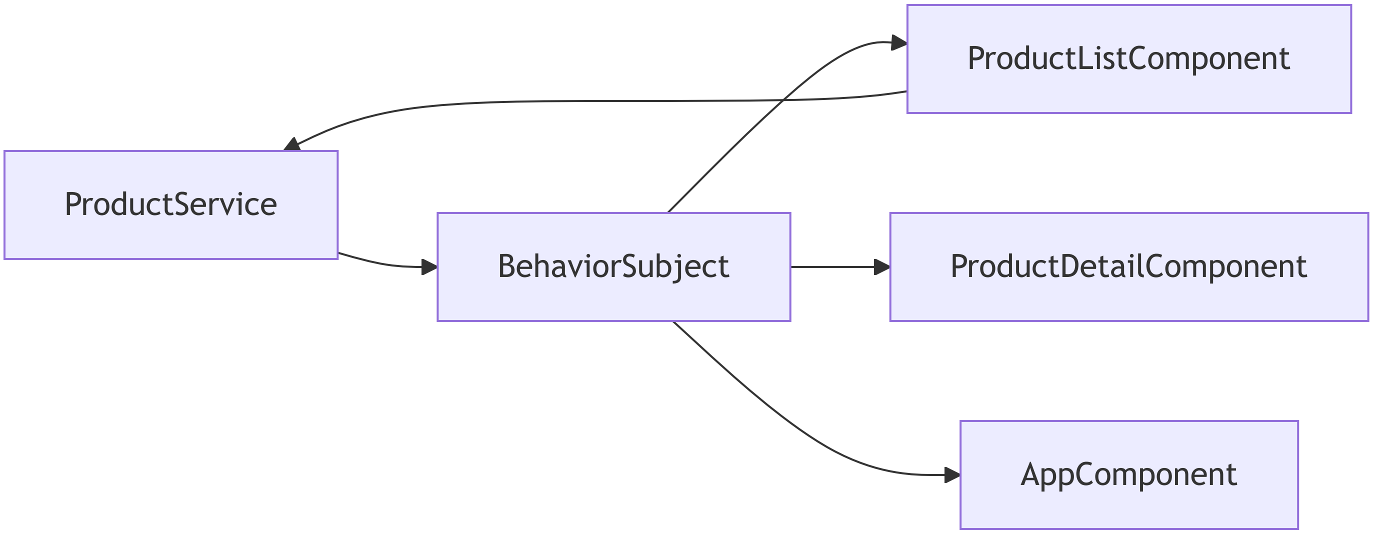
Implementation:

```
class ErrorBoundary extends Component<Props, State> {
  constructor(props: Props) {
    super(props);
    this.state = { hasError: false, error: null };
  }

  static getDerivedStateFromError(error: Error): State {
    return { hasError: true, error };
  }

  componentDidCatch(error: Error, errorInfo: ErrorInfo) {
    console.error('Error caught by boundary:', error, errorInfo);
  }

  render() {
    if (this.state.hasError) {
      return this.props.fallback || <DefaultErrorFallback />;
    }

    return this.props.children;
  }
}
```

State Management

Angular State Management (RxJS)

The Angular application uses the Service Store pattern with RxJS for reactive state management.

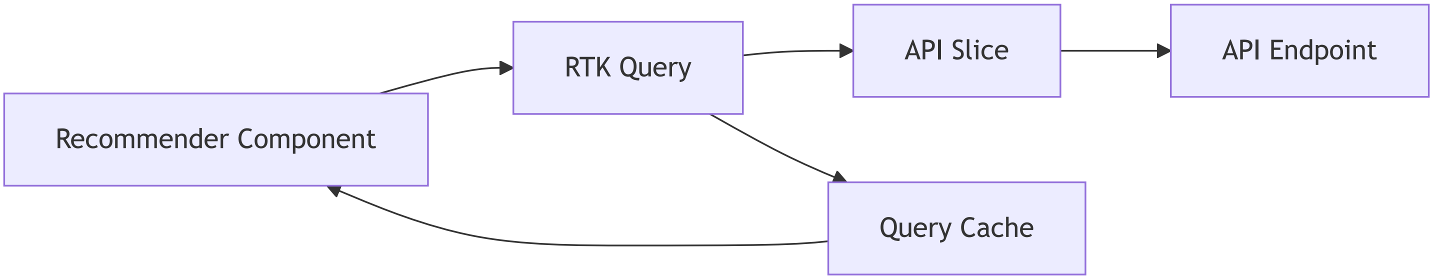


Benefits:

- Reactive updates across components
- Memory efficient
- Angular-native approach
- Easy testing and debugging

React State Management (RTK Query)

The React widget uses Redux Toolkit Query for API state management.



Benefits:

- Automatic caching and invalidation
- Background refetching
- Optimistic updates
- DevTools integration

State Synchronization

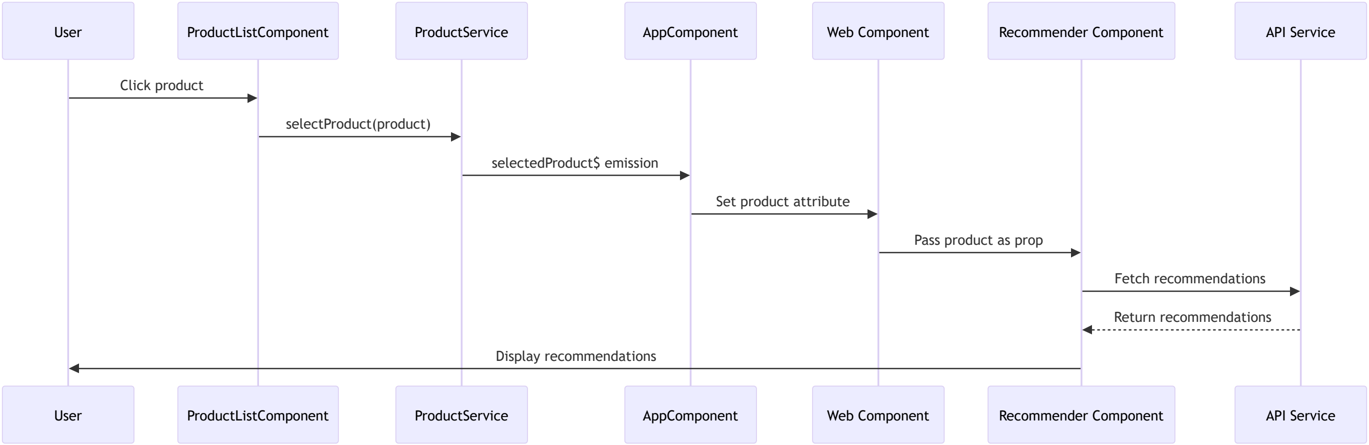
Communication between Angular and React state is handled through:

1. **Props Down**: Angular passes data to React via Web Component attributes

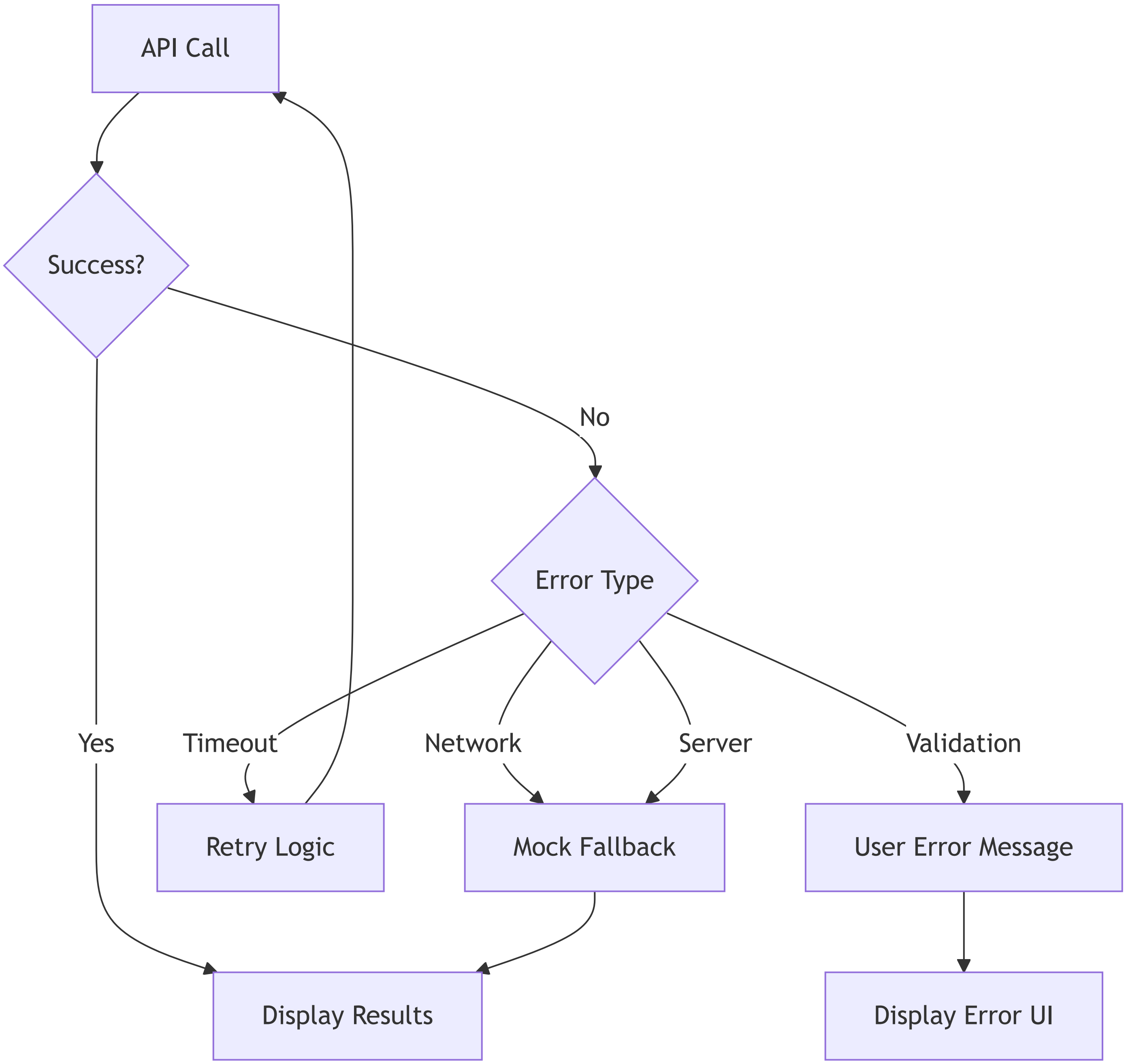
2. **Events Up**: React can emit custom events that Angular listens to
3. **Shared API**: Both frameworks use the same API layer for consistency

Data Flow

Product Selection Flow



Error Handling Flow



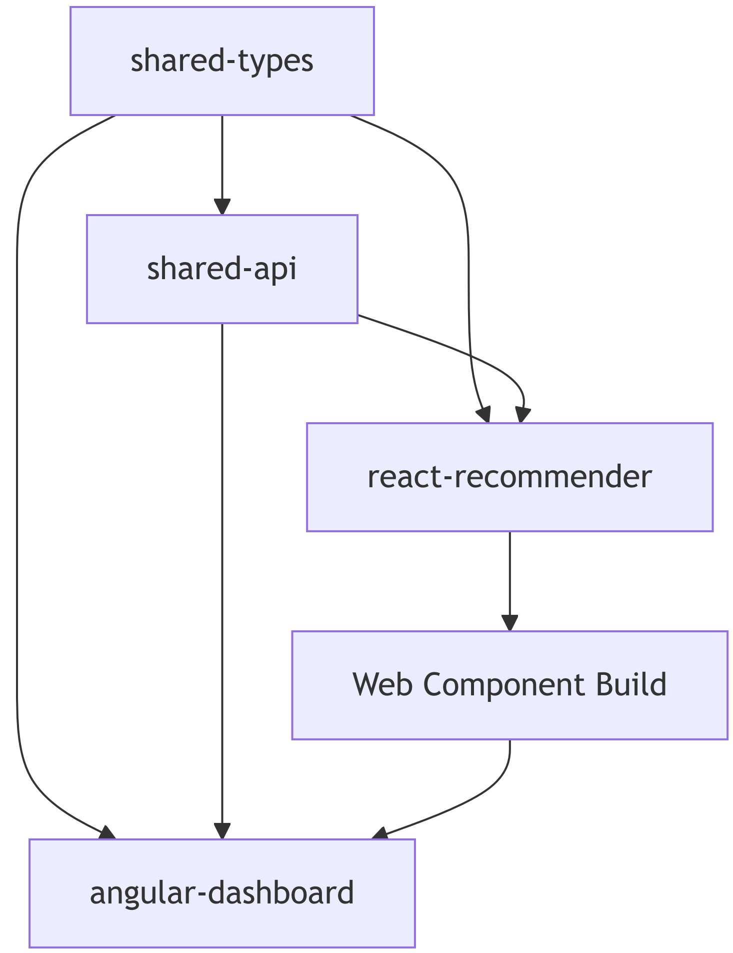
Build System

Nx Monorepo Structure

The project uses Nx for efficient monorepo management with the following structure:

```
ai-product-dashboard/
├── angular-dashboard/          # Angular application
├── react-recommender/         # React application
├── shared-api/                # Shared API functions
├── shared-types/              # TypeScript interfaces
├── integration-tests/         # Cross-framework tests
└── api/                       # Vercel API functions
```

Build Dependencies



Build Process

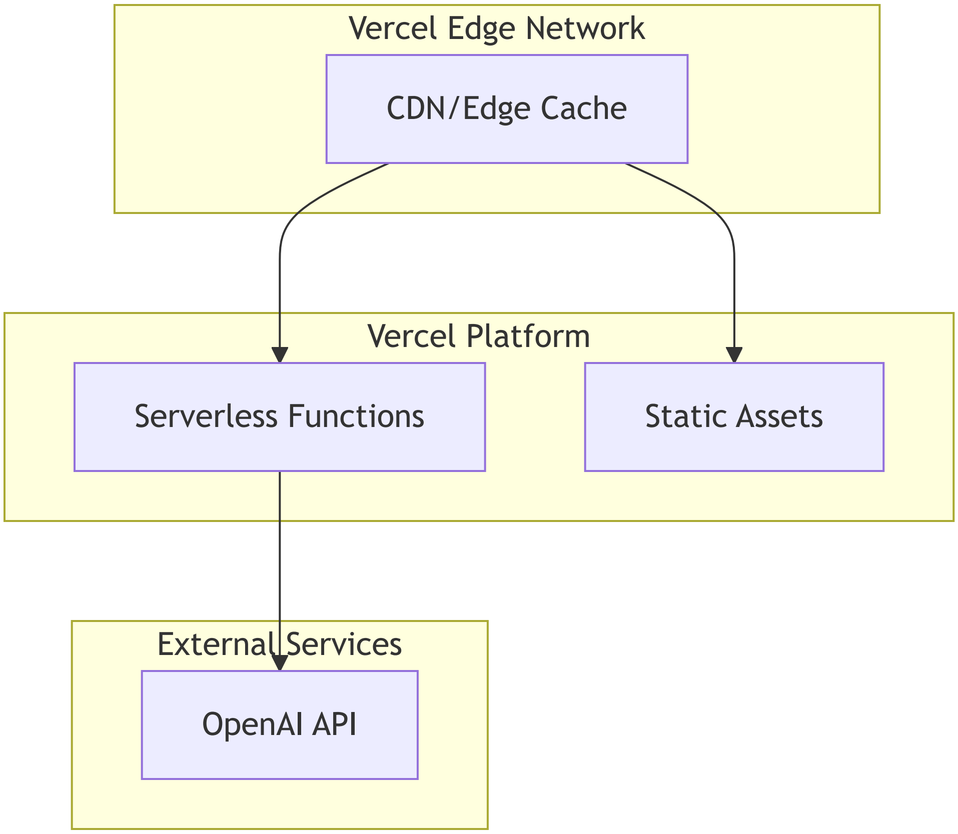
1. **Shared Libraries**: Built first as dependencies
2. **React Web Component**: Built second for Angular integration
3. **Angular Dashboard**: Built last, includes all dependencies
4. **React Standalone**: Built independently for testing

Build Commands

```
# Build all projects in correct order
npm run build:all

# Individual builds
npm run build:react-web-component  # Must be first
npm run build:angular             # Depends on web component
npm run build:react               # Standalone React app
```

Deployment Architecture

Vercel Deployment Strategy



Asset Distribution

- **Angular App**: Served from root path (`/`)
- **React Web Component**: Served from `/react-recommender-web-component/`
- **API Functions**: Served from `/api/*`
- **Static Assets**: Cached at CDN edge locations

Environment Configuration

```
// vercel.json
{
  "builds": [
    {
      "src": "dist/angular-dashboard/browser/**/*",
      "use": "@vercel/static"
    }
  ],
  "rewrites": [
    { "source": "/api/(.*)", "destination": "/api" },
    { "source": "/(.*)", "destination": "/angular" }
  ]
}
```

Design Patterns

Observer Pattern (Angular)

Used in ProductService for reactive state management:

```
// Publisher
class ProductService {
  private selectedProductSubject = new BehaviorSubject<Product | null>(null);
  public selectedProduct$ = this.selectedProductSubject.asObservable();
}

// Subscribers
class AppComponent {
  constructor(private productService: ProductService) {
    this.productService.selectedProduct$.subscribe((product) => {
      this.selectedProductJson = JSON.stringify(product);
    });
  }
}
```

Command Pattern (RTK Query)

Used for API operations with caching and error handling:

```
// Command definition
const api = createApi({
  reducerPath: 'recommendationApi',
  baseQuery: fetchBaseQuery({ baseUrl: '/api' }),
  endpoints: (builder) => ({
    getRecommendations: builder.query<RecommendationResponse, string>({
      query: (productName) => ({
        url: 'recommendations',
        method: 'POST',
        body: { productName },
      }),
    }),
  }),
});

// Command execution
const { data, error, isLoading } = useGetRecommendationsQuery(product.name);
```

Adapter Pattern (Web Components)

Used to adapt React components for Angular consumption:

```
// Adapter
class RecommenderElement extends HTMLElement {
  // Adapts HTML attributes to React props
  attributeChangedCallback(name: string, oldValue: string, newValue: string) {
    if (name === 'product') {
      const product = JSON.parse(newValue);
      this.renderReactComponent(product);
    }
  }
}
```

Strategy Pattern (Error Handling)

Used for different error handling strategies:

```
interface ErrorStrategy {
  handle(error: Error): void;
}

class NetworkErrorStrategy implements ErrorStrategy {
  handle(error: Error): void {
    // Fall back to mock data
  }
}

class ValidationErrorStrategy implements ErrorStrategy {
  handle(error: Error): void {
    // Show user-friendly message
  }
}
```

Performance Considerations

Bundle Optimization

1. **Code Splitting**: Separate bundles for Angular and React
2. **Tree Shaking**: Remove unused code during build
3. **Lazy Loading**: Load React widget only when needed
4. **Asset Optimization**: Compress and optimize static assets

Runtime Performance

1. **Virtual DOM**: React uses virtual DOM for efficient updates
2. **Change Detection**: Angular uses OnPush strategy where possible
3. **Memoization**: React components use React.memo for optimization
4. **Observable Optimization**: RxJS operators for efficient data streams

Caching Strategy

1. **API Caching**: RTK Query provides automatic caching
2. **Static Asset Caching**: Long-term caching for built assets
3. **CDN Caching**: Edge caching for global performance
4. **Browser Caching**: Appropriate cache headers for resources

Memory Management

1. **Subscription Cleanup**: Automatic unsubscription in Angular
2. **Component Unmounting**: Proper cleanup in React components
3. **Web Component Lifecycle**: Cleanup on disconnection
4. **Event Listener Cleanup**: Remove listeners on component destruction

Security Architecture

Input Validation

1. **Client-Side Validation**: TypeScript interfaces and runtime checks
2. **Server-Side Validation**: Comprehensive input sanitization
3. **XSS Prevention**: Framework-level protection in Angular and React
4. **CSRF Protection**: Stateless API design prevents CSRF attacks

API Security

1. **Environment Variables**: Secure storage of API keys
2. **CORS Configuration**: Proper cross-origin resource sharing
3. **Rate Limiting**: Protection against abuse
4. **Error Information**: Sanitized error messages

Content Security Policy

```
// Recommended CSP headers
{
  "Content-Security-Policy": "default-src 'self'; script-src 'self' 'unsafe-inline'; style-src
}
```

Data Privacy

1. **No Personal Data Storage**: Application doesn't store user data
2. **API Key Protection**: Keys stored securely in environment variables
3. **Minimal Data Collection**: Only necessary data is processed
4. **Transparent Fallbacks**: Clear indication when mock data is used

Monitoring and Observability

Error Tracking

1. **Client-Side Errors**: Error boundaries and global error handlers
2. **API Errors**: Comprehensive logging and categorization
3. **Performance Monitoring**: Core Web Vitals tracking
4. **User Experience**: Error impact on user workflows

Logging Strategy

1. **Structured Logging**: Consistent log format across services
2. **Log Levels**: Appropriate levels for different environments
3. **Error Context**: Detailed context for debugging
4. **Performance Metrics**: Response times and success rates

Health Monitoring

1. **API Health Checks**: Regular health endpoint monitoring
2. **Dependency Monitoring**: External service availability
3. **Performance Alerts**: Automated alerts for degraded performance
4. **User Impact Tracking**: Real user monitoring metrics

This architecture provides a solid foundation for a scalable, maintainable, and performant application that leverages the strengths of both Angular and React while maintaining clean separation of concerns and comprehensive error handling.