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The Team

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The idea

Creating a fully wireless smart-home/IOT automation system with a central management controller. We implement an open standard built on plugins and an extensible architecture. The entire Project is fully open source, and contributions from the community are highly welcome. We collect metrics and telemetry from multiple sources and display them in custom configurable dashboards. We also plan to support actor devices that can be controlled via the dashboard in real time or automatically controlled via dynamic workflows.

User Guide

Initial Setup

Devices Integration

Plugin Management

Developer Documentation

This document is intended for developers who want to contribute to the project. It provides an overview of the project's architecture, the technologies used, and the development process.

Required Tools

- .NET 9 SDK
- Dotnet ef tools (For Entity Framework Core)
- Platform IO (For ESP32 development)
- JetBrains Writerside (Documentation)
- Docker
- A modern web browser
- Git
- Make

Optional Tools

- Azd
- Rider
- Visual Studio Code
- cppcheck

GitHub Actions

Automatic Testing

The project uses GitHub Actions to run tests on every push/pr to the master branch. These tests are mandatory and must pass before a PR can be merged. When contributing new code, also try to achieve full test coverage where possible.

Continuous Integration

The server image will be automatically built and published on push to the master branch. The documentation will be published on GitHub pages.

In the future, there will be also plans to automatically publish all the base packages on nuget and build debian packages, including a full raspberry pi image.

Code Quality

The project uses GitHub Actions to run code quality checks on every push/pr to the master branch. These checks are mandatory and must pass before a PR can be merged.

Getting the Code

To get the code, clone the repository:

```
git clone --recursive https://github.com/Team-MPM/MPM-Smart
```

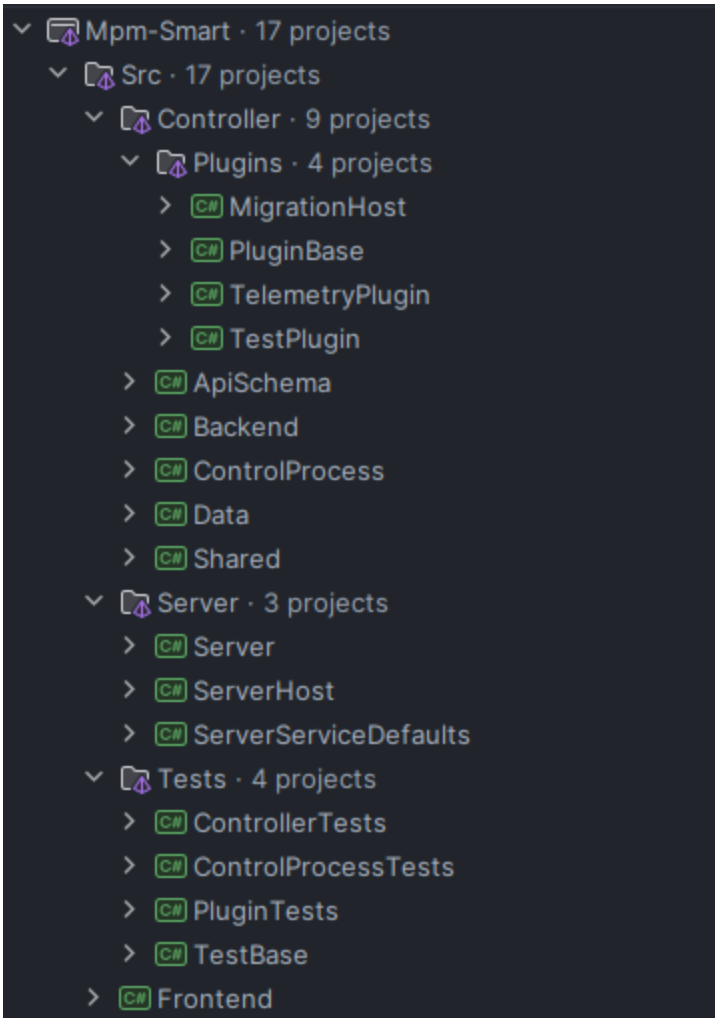
Architecture

Introduction

The solution is generally organized into the following parts:

- Dotnet Solution **.sln/.slnx**
- Cmake Project based on the ESP-IDF

Dotnet Solution Architecture



solution_architecture

Frontend

The frontend is responsible for rendering the user interface and handling user input.

The frontend is a Blazor WebAssembly application. It is written in C# and runs in the browser. It makes use of the PWA (Progressive Web App) features to provide an offline-first experience.

We primarily make use of the following libraries:

- MudBlazor
- FluentValidation

Backend

The backend is the primary application component running on the controller unit. It is responsible for loading all the plugins and managing the communication between them. It handles the communication between devices and acts as a bridge between the frontend and the plugins.

Control Process

Manages the lifetime of the backend process and handles plugin updates and automatic restarts.

Api Schema

Shared class library that contains the data transfer objects (DTOs) used by the frontend and the backend.

Shared

Shared class library that contains the shared code between the backend and the plugin layer.

Plugin Base

Base code and Interfaces for Plugins to reference.

Data

Data Layer of the core Backend Application containing all EF Core Entities and the Database Context configurations.

Server/ServerHost

THe Plugin Server providing Plugins for download via Azure Cloud Storage. It also contains the documentation reference and a List of all Mpm-Smart devices.

Tests

Solution folder containing all the Unit tests separated into the different layers. There is also a **TestBase** class library that provides a unified testing experience. We primarily use XUnit for testing, FluentAssertion for assertions, and Moq for mocking.

ESP-IDF Project Architecture

The ESP-IDF project is organized into the following parts:

- **main** - Application entrypoint
- **shared** - Shared code between the different plugins
- **application** - Contains the primary application layer and base logic handling connections and setup
- **extensions** - Contains the different plugins, for example the dht and sound sensor drivers

Build Instructions

To build the dotnet solution, open the solution file in the IDE of your choice or build it from the command line using the `dotnet build` command. Node: Even when running only a specific project, performing a full dotnet build on the solution first is recommended so that all the plugins and dependencies are built correctly the first time you run them locally.

To build the device firmware, use the esp-idf commandline took to build and flash the image.

To build the documentation as PDF, open the JetBrains Writerside workspace and build the documentation using the included run configuration.

The Makefile in the root of the repository provides shortcuts for mose these commands.

To build the debian packages and controller images from source, consult the `make help` command. Note that this requires you to be on a linux system and have the specified dependencies installed.

To run the frontend in release mode locally, perform a `dotnet publish -c Release` on the frontend, then navigate to the output directory based on `bin/Release/net9.0/publish/wwwroot` and run a local webserver to serve the files in this directory (tested using apache2 and nginx). This can easily be achieved using docker: `docker run -it --rm -p 8080:80 --name mpm-smart-app -v .:/usr/local/apache2/htdocs:ro httpd`

Deployment

Deploying a Controller

To deploy a custom controller instance, make sure you have a linux based machine with supported hardware configuration (see Hardware Requirements (https://harware-requirement)).

You can use the included makefile to build the debian package and controller image. Alternatively you can also build the app from source manually using `dotnet build` and copy over the files manually. To make sure the controller software starts automatically on boot, you can use the included systemd service file.

After following these steps you should be able to connect to your controller in the web ui and undergo the guided setup process.

Deploying the plugin server

The server host project, based on dotnet aspire allows easy deployment no matter what environment you are using. Use `dotnet publish` on the server host to automatically generate the manifest. This manifest can be used for automatic incremental deployments.

For example, to deploy to azure, one can simply use the azd commandline tool with

- `azd init`
- `azd up`
- `azd publish`

Alternatively you can also use other tools like aspirate for custom kubernetes deployments.

Also make sure all the azure based cloud resources are set up accordingly and all connection strings are set via user storage or appsettings.json.

Deploying the Frontend

To deploy the frontend, use the `dotnet publish` command inside `src/frontend`. Then navigate to the build outputs `wwwroot` directory and deploy this to a webserver of your choice. YOu can, for example, run a local docker container: `docker run -it --rm -p 8080:80 --name mpm-smart-app -v .:/usr/local/apache2/htdocs:ro httpd`

Plugins

Overview

Plugins are a way to extend the functionality of the Core Application Layer provided by the Mpm-Smart ecosystem. Plugins are usually provided by a Plugin Server or loaded from a local directory on the controller. Plugins are exclusive to the backend layer. In the UI, all plugins can implement a set of options and views providing user interactivity for plugin-specific settings and exposed data.

How plugins get loaded

Plugins are loaded by the Plugin Manager. The Plugin Manager is responsible for loading, unloading, and managing the lifecycle of plugins. All Plugins are loaded at startup and are initialized in no specific order. Currently, there is no way of reloading plugins while the backend service is running. In deployment, this update workflow is automated by the control process shipping with the backend.

Creating your first Plugin

Introduction

Use the provided template or create an empty C# dotnet 9.0 class library and adapt the **Plugin.csproj** file to the following:

```
<Project Sdk="Microsoft.NET.Sdk">

    <PropertyGroup>
        <TargetFramework>net9.0</TargetFramework>
        <ImplicitUsings>enable</ImplicitUsings>
        <Nullable>enable</Nullable>
    </PropertyGroup>

    <PropertyGroup>
        <OutputPath>your/plugin/output/path</OutputPath>

<AppendTargetFrameworkToOutputPath>false</AppendTargetFrameworkToO
utputPath>
    </PropertyGroup>

    <ItemGroup>
        <ProjectReference
Include="..\plugin_base\PluginBase.csproj" Private="False"/>
        <ProjectReference Include="..\..\Shared\Shared.csproj"
Private="False"/>
    </ItemGroup>

    <ItemGroup>
        <FrameworkReference Include="Microsoft.AspNetCore.App"/>
    </ItemGroup>

    <ItemGroup>
        <None Update="plugin.json">
            <CopyToOutputDirectory>Always</CopyToOutputDirectory>
```

```
        </None>
    </ItemGroup>

</Project>
```

Note: In the future, the PluginBase and Shared references will be replaced by NuGet packages.

The **plugin.json** metadata file is a simple JSON file that contains some general information about the plugin. It should look like this:

```
{
    "name": "Test Plugin",
    "version": "1.0.0",
    "description": "This is a test plugin",
    "author": "Your Name",
    "dependencies": []
}
```

Plugin Class

Create a new class that implements the `IPlugin` interface. Alternatively, one can also make use of the `PluginBase` class that provides some default implementations.

```
public class TestPluginClass : PluginBase<TestPluginClass>
{
    protected override void Initialize()
    {

    }

    protected override void BuildEndpoints(IEndpointRouteBuilder
routeBuilder)
    {

    }
```

```
    protected override void ConfigureServices(IServiceCollection
services)
    {

    }

    protected override void SystemStart()
    {

    }
}
```

Additional Considerations

- Make sure to include all static assets in the output folder of the plugin.
- Make sure there are no overlapping .dll file dependencies with the backend application for shared types.
- Make sure to include all necessary files in the .csproj file.
- Make sure to include all necessary dependencies in the `plugin.json` file.

Developing plugins locally

Building the plugin

To build a plugin, you need to have the following prerequisites:

- .NET 9 SDK
- A source build of the Mpm-Smart Controller
- The current version of the `PluginBase.dll` and `Shared.dll` libraries

Put your plugin dll output in the plugin directory of the controller application. Hot reloads aren't supported, so you have to restart the backend every time you rebuild the plugin. This can be automated using build-hooks. The UI should handle the reconnection logic automatically.

Managing Plugin Services

Introduction

All Services are divided into two parts:

- **Core Services**: These are provided by the backend out of the box and can't be modified from the plugin stage
- **Plugin Services**: These are provided by the plugins and can be modified from the plugin. They also offer a way for plugin to communicate with each other.

Logging

The core application and plugin modules use two separate loggers. For development purposes, all logs are uniformly output to the same console. On disk, you will find a log directory with the following files:

- **backend.log**: Contains all logs from the core application layer
- **error.log**: Contains all errors from the core application layer
- **plugin.log**: Contains all logs from the plugin modules
- **plugin-error.log**: Contains all errors from the plugin modules

These log files use a plain text in UTF-8 format and use the following layout: `Date Time Timezone [LEVEL] Message` For example: `2024-11-04 07:55:17.633 +01:00 [INF] Starting Mpm-Smart`

The logging system uses the default Microsoft.Extensions.Logging base library together with serilog for the backend and plugin modules. To use the logger, inject the `ILogger<T>` interface into your service.

Since there logs can also be exported as structured logs, make use of the message templating instead of using string interpolation and pass down the full exception instance where applicable.

Database Management

The core application layer uses Entity Framework Core to manage its databases. You can also use your own custom database models in your plugins, but using Entity Framework Core with SQLite is the only first party supported option. When registering a Database Context in your plugin service collection, its provided migrations will automatically be picked up by the `DbInitializer` and applied to the database on startup. If the database is not present, it will be created.

> ⚠ **Migrations**
>
> When using migrations, make sure to specify the correct migration assembly in a way that is independent of the hosting environment or the startup project.

> ⚠ **Seeding**
>
> A system to automatically seed plugin databases is not yet implemented. See Project plan for open issue.

Plugins can also access the `SystemDbContext` by using the application service provider provided on initialization of the plugin instance.

Publishing Plugins

Create plugin package

You can use the builtin `dotnet publish` command to create the plugin package file. Make sure the .csproj file is configured to include all additional assets and resources needed in order for the plugin to work.

Register plugin package

Go to the MPM-Smart Plugin Server (https://mpm-smart.g-martin.work) make sure you are signed in and register your plugin package.

Upload plugin package

Use the upload button to upload the built package file. It will be automatically validated to conform to the structure guidelines outlined in the plugin overview.

Presentation

Introduction

Good afternoon, dear teachers, colleagues and classmates. Today, we are proud to present to you, Mpm-Smart. The Smart Home revolution is coming for all of us. I am certain, that we all own a lot of different technology that aims at making our lives easier. But often, we find ourselves in situations where all those different systems just don't work together. This is where Mpm-Smart comes in. Mpm-Smart is a Smart Home solution that aims to bring unify existing system together with new innovation in a single, easy to use, and open-source platform.

Solution

To accomplish this, we have developed a multi-layered architecture that is designed to be modular and extensible. At the core of the system, we have a centralized Controller based on a solid plugin architecture. This controller is responsible for managing all the devices, aggregate their data, and provide a unified interface to the user.

To make the world of extensible plugins more accessible to the every-day user we also ship a fully functional Plugin Registry. This registry allows users to easily discover, install, and manage plugins from a central location. Power-users can also use the registry to publish their own plugins and share them with the community.

To maximize the user experience, we have also developed a modern and responsive web interface. Based on modern technologies we implemented a Progressive Web App (PWA) that can be installed on literally any device and provides an accessible and easy to use interface to the user.

To also comply with modern security standards, we have implemented a full user management system with fine-grained access control. We use modern encryption standards to ensure that all data is secure and private at any time. All first party devices are also secured using mTLS to guarantee that only authorized devices can communicate with the controller.

Technologies

The Mpm-Smart solution is built on a variety of technologies. The core of the system is based on the .NET platform. We use the latest version of the .NET 9 SDK and the Entity Framework Core for our backend. The frontend is built using Blazor WebAssembly, a modern web framework that allows us to write C# code that runs natively in the browser.

For the device firmware, we use the ESP-IDF, a powerful framework for developing IoT devices based on the ESP32 chip.

To ensure the quality of our code, we use a variety of tools and services. We have integrated GitHub Actions into our workflow to automatically run unit and integration tests, build and publish the server image, and publish the documentation. We also use code quality tools like cppcheck to ensure that our code is clean and maintainable.

We also leveraged many cloud servers including not ony Azure Redis Cache, Azure Blob Storage, and Azure SQL Database.

Architecture

Frontend: Blazor WebAssembly WPA using the MudBlazor UI Framework

Controller: ASP.NET Core Web API using EF Core and Identity Framework

Plugin System: Dynamic assembly loading via reflection and inter-process communication

Plugin Registry: Azure Blob Storage and Azure Redis Cache and Azure SQL Database

What is a plugin?

Plugin allow us to extend the core functionality of the system. A plugin is a self-contained piece of code that can be dynamically loaded and executed by the controller. Plugins can be used to add new features, integrate with third-party services, or interact with all sorts of hardware devices.

These plugins can both manage their own resources like static assets, docker and lxc containers or even their own subprocesses and also share/integrate those resources with the core system and other plugins.

You want a plugin to collect data from your smart thermostat and display it in the web interface? No problem. You want a plugin to control your smart lights based on the weather forecast? Easy. You want a plugin to send you a notification when your laundry is done? Done.

Our original Goals and Mockups

Olaf or Jake here you go!

Little Demo

Quickly just show some of the nicer pages, probably no time for a full demo.

Conclusion

You can check out our app right now under https://mpm-smart.g-martin.work or visit our GitHub repository at https://github.com/Team-MPM/MPM-Smart/ and don't forget to leave a star!